Laboratory Outlines
for
General Botany

FOR THE ELEMENTARY STUDY
OF PLANT STRUCTURES AND FUNCTIONS
FROM THE STANDPOINT OF
EVOLUTION

THIRD EDITION

BY

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PROFESSOR OF BOTANY, AND HEAD OF THE DEPARTMENT OF BOTANY
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COLUMBUS, OHIO
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PREFACE.

The series of outlines presented in the following pages was first published in the Journal of Applied Microscopy. The outlines as here presented have undergone some additions and alterations in order to bring them up to date and to give a more perfect view of the plant kingdom as a whole. Among other things, an attempt has been made, so far as possible, to use a reasonable terminology.

It is presumed that the course can be covered practically as given in one college year with three laboratory periods of two hours each a week.

The course is intended for the freshman or sophomore year. The student should have a fair knowledge of language, mathematics and drawing as well as the foundations of chemistry, since the pursuit of the biological sciences calls for considerable independent effort, skill of manipulation, and ability to reproduce and describe what is seen.

In case a brief course is necessary a considerable number of types or parts of outlines can be omitted without seriously breaking the continuity of the subject. According to the author's views any thoro course should include at least the following, either complete or in part:

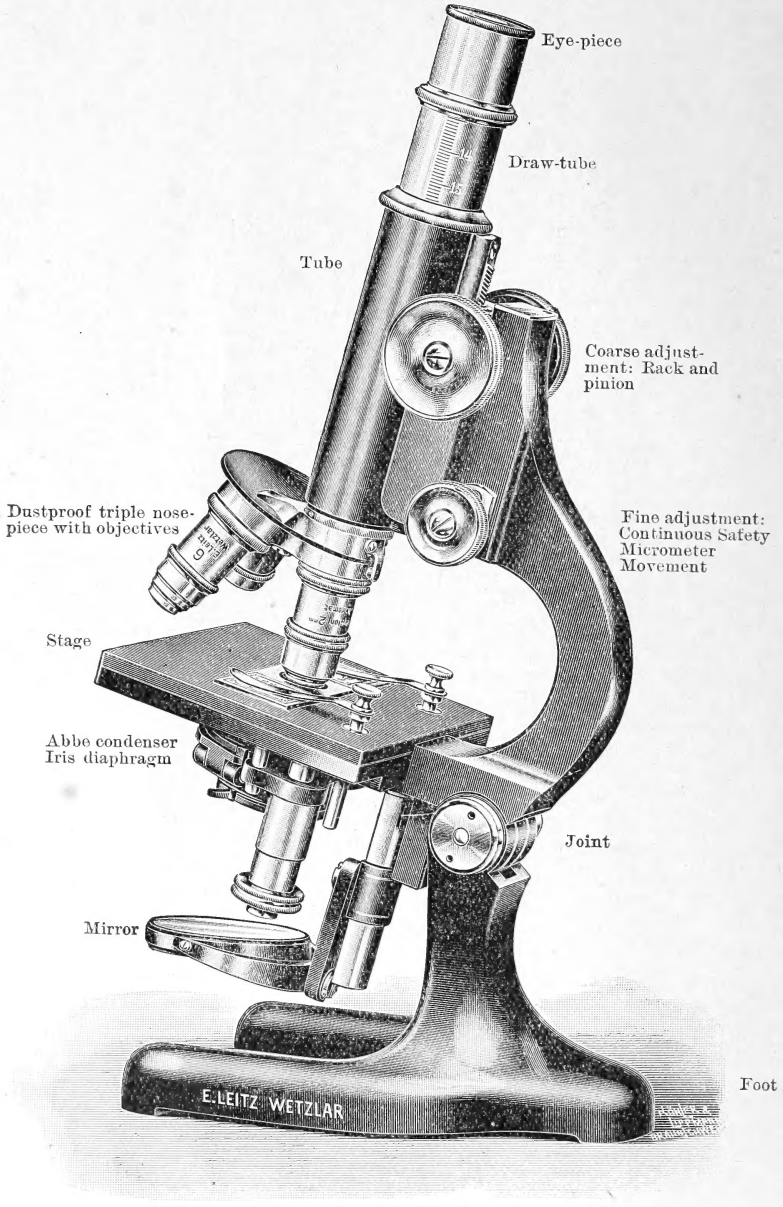
I., IV., VI.-IX. (*b*), X.-XIV., XVIII., XIX., XXII., XXV.-XXVII., XXX., XXXII.-XXXIV., XXXVI., XXXVII.-XXXIX. (*a*), XL.-XLII. (*a*), (*c*), XLIV.-XLVII., XLIX.-LII., LV.-LXI., LXIII.-LXV. (*a*), LXVI.-LXVIII., LXX.-LXXIII. (*a*), (*b*), (*c*), (*d*), (*f*), (*g*), LXXVI., LXXVIII.-LXXX., LXXXII., LXXXV., LXXXVI., XCIII., XCVI.-CI., CIII., CIV., CVII., CX., CXI.

Some of the types which cannot be given in the laboratory period may be used for class demonstrations.

The appendix on microtechnique will be found useful where it is possible to have students prepare some of their own slides. The methods given are for the most part such as have been thoroly tested in the class room by the author himself.

In this third edition a number of corrections and additions have been made in order to include recent discoveries and to permit of a wider selection in mapping out a suitable course. A glossary has been added which will be of considerable value in learning the pronunciation, derivation and meaning of the botanical terms employed.

J. H. S.



Stand II K

PLATE I. COMPOUND MICROSCOPE. LEITZ STAND II K.

INTRODUCTORY SUGGESTIONS.

The following outlines are designed for those who have access to little apparatus outside of a good microscope. The course will probably be more than sufficient for the time usually allotted in most of our colleges and universities.

Whatever may be the opinion in regard to the elementary course of botany, it is the writer's belief that the general college or university course should be largely carried on with the use of the compound microscope; and should cover, in a general way, the whole plant kingdom, so that the idea of the evolution of plants and their natural relationships will be made prominent. The student should have a general grasp of the plant kingdom as a whole, and to accomplish such a result a large number of forms must be studied. Along with this general idea, a considerable knowledge of morphology and physiology may be acquired, since the study should have to do largely with living material. The course should cover a year with at least two laboratory periods of two hours each, a lecture, and a quiz with assignments from a suitable text-book. After such a course the student is well fitted to take up the various departments of advanced work. He will have acquired a sufficient knowledge of biology to carry on intelligently, whatever special studies he may later choose to pursue, as, anatomy, histology, cytology, physiology, ecology, taxonomy, genetics, or advanced work in special groups.

It is often supposed that to accomplish good work it is necessary to have on hand an expensive equipment and all the facilities which our leading universities afford. There is, however, a large amount of work that may be done by those who do not have such an equipment, and substantial progress may be made in the general facts of the science with little besides what is indicated below.

The student should have the following equipment:

1. A good text-book of botany for general reading.
2. A compound microscope, like the Bausch and Lomb FF, having a double nose-piece with 16 and 4 mm objectives, and 7.5x and 12.5x eye-pieces; the Spencer microscope No. 45 with 16 and 4 objectives, and 4x and 9x eye-pieces; or the Leitz microscope Stand II L with objectives 3 and 7 and eye-pieces II. and IV. The same stands with complete substage and triple nose-piece are preferable if one can afford to pay the difference in price.
3. A number of slides and cover-glasses.
4. A good hand-lens or a dissecting microscope.
5. A good note-book with note paper and smooth drawing paper, and also some bristol board drawing paper for the finer drawings. (See "The Laboratory Note Book" in appendix.)
6. Loose writing paper for making temporary records and calculations.
7. Two good lead pencils, a No. 3H and a No. 6H. It is also desirable to have a bottle of India ink and crow-quill or other suitable drawing pen so that the drawings may be finished in India ink.

8. The following instruments are necessary:
   a. A pair of forceps.
   b. Several medicine droppers.
   c. Some needles set in wooden or bone handles.
   d. A scalpel.
   e. A razor.
   f. Dishes, watch glasses, and bottles of various sizes.
   g. Plenty of clean cotton rags and some paper blotters.
9. The following simple reagents will be needed on the table:
   a. A small bottle of 50 per cent. aqueous solution of glycerin.
   b. A bottle of distilled or pure, boiled water.
   c. Iodin solution.
   d. Salt solution, saturated aqueous.
   e. A bottle of ninety-five per cent. alcohol.

If a greenhouse is not near, a window garden and aquarium become indispensable. Water plants kept in glass jars with some small water animals, as water snails and water beetles, will usually grow with little or no attention. In most cases the jars should be covered.

Many of the specimens may be preserved in various preserving fluids, and some may be dried. These will be found very convenient in case fresh material cannot be obtained when desired. Microscopic plants may be preserved in water, in homeopathic vials, provided a drop of carbolic acid is added to each bottle of material. Plants like mosses, liveworts, fleshy fungi, stems, roots, rhizomes etc., may be preserved in 70 per cent. alcohol. The ordinary filamentous algæ are usually well preserved in copper salt solution. (See appendix.) Myxomycetae in the fruiting stage, woody fungi, lichens, some liverworts and many other plants may be kept in a dry condition in ordinary paper boxes.

Useful pamphlets on the use and care of the microscope are furnished by the Bausch and Lomb Optical Co., of Rochester, N. Y., and the Spencer Lens Co., of Buffalo, New York.

The following suggestions are offered especially for the benefit of laboratory students, altho most of the directions will also be useful to the amateur microscopist working at home:

The microscope must always be handled below the stage and never lifted by any part above the stage (unless one has an instrument of the new type with a rigid arm), otherwise the fine adjustment may be injured. The microscope is a very delicate instrument. It must not be inclined for general work, as temporary mounts will not stay in the field unless the stage is horizontal. While working, the observer should keep the side of the microscope with the coarse and fine adjustments toward him. The microscope is not to be moved about to obtain the light. This can be obtained from almost any direction by adjusting the mirror properly. Great care must be taken so as not to run the objective down into the diaphragm or onto the cover-glass and slide. The lenses of the microscope must not be touched with the fingers. They must be wiped only with a very clean, soft, cotton cloth or with lens paper. They must be kept scrupulously clean. The student should learn the different combinations of low and high powers immediately and how to change from one to the other without difficulty.

The wiping rags should always be clean, and the slides and cover-glasses must be kept scrupulously clean. The student should learn at the beginning how to clean the cover-glasses without breaking them. To do this, take the cover-

glass, moistened in water or alcohol, in the rag between the thumb and forefinger and hold it at the edges between the thumb and forefinger of the other hand. In making a mount air bubbles are to be avoided. To accomplish this, after the object has been placed on the slide and covered with a drop of water, hold the cover-glass at the edges between the thumb and forefinger and bring it down obliquely onto a needle held in the other hand, and then withdraw the needle gradually. The cover-glass will then settle down on the object surrounded by water. No water or other reagent must be on top of the cover-glass. If too much water has been put on the slide it may be removed with blotting paper. If the study of a good specimen cannot be finished in the given time, it may be preserved for a number of days by running a little fifty per cent. glycerin under the cover-glass. Reagents cost money, and are not to be poured out like water. The same is true of the material for study. This is often difficult to obtain and should be used with economy, and all good surplus material returned to the receptacle from which it was obtained.

All objects studied are to be carefully figured and described. The drawings may be outlined with the 3H pencil and then finished with the 6H. If time is at hand, the drawing may be finished in India ink with a fine drawing pen. Learn how to keep the pencils sharpened to a fine point. After sharpening with the knife rub the point smooth on a piece of paper. The drawings are to be placed only on the front side of the drawing paper. The notes may be written continuously on both sides of the note paper, but are always to be taken down in ink. The plates containing the drawings should be numbered in Roman figures at the top, and the name of the plant or object written at the bottom. The separate drawings on the plate may be numbered in Arabic figures, and a proper record of them is to be kept in the notes. The notes on each plant may be numbered the same as the plate containing the drawings to illustrate it. The drawings should not be crowded, and the number should always be written below.

The diameter of the field (the white disk visible when looking into the microscope) is usually about eight inches (two decimeters) when projected onto the table. Learn to do this by looking with one eye on the table beside the microscope and with the other into the tube. In this way the magnified image may be directly measured. The actual diameter of the area covered can easily be determined for the low powers by examining a millimeter rule. Learn to keep both eyes open when taking only ordinary observations in the microscope. Be sure to use both eyes, else one will be trained for more acute vision that the other. Make the drawings of small objects of the right proportion, and the actual size magnified. The larger ones may have to be reduced to bring them onto the paper. If the object has a definite relation to environment do not draw it upside down. It must also be remembered that motions are magnified as well as the objects themselves.

Absolute regard for the truth is the first requirement in scientific drawings and descriptions, and the qualities required for good work are accuracy, cleanliness, patience, skill, persistency, good judgment, and logical ways of thinking. The drawings should be exact in all details; the sketches may be more or less diagrammatic. The notes should be written in the best English at the command of the student. The facts should be stated in concise but complete declarative sentences, without rhetorical ornamentation. The observations must always be recorded at the time when they are taken. One's memory should not be trusted very much in recording scientific facts.

Finally, it must be remembered that one of the first things to be accomplished is to educate the hand for delicate manipulations. And it is also well to keep in mind that scalpels and razors are not intended for sharpening lead pencils or cutting the table, that oculars, and objectives are never to be dropped, that stoppers should not be laid down on the bare table, that books and notebooks are not to be soiled by the wet and dirty fingers, that bottles and tumblers of water are not to be overturned, and that one should understand the objects studied before attempting to draw or describe them.

PRELIMINARY STUDY OF THE LIVING CELL.

I. **Philòtria canadénsis** (Mx.). Waterweed.

This is a very common plant growing submerged in ponds, creeks, etc. It will grow well for a long time if simply pulled up and placed in a covered glass jar.

1. Carefully pull off a few young leaves and mount on a slide with a drop of water and a coverglass. Examine under the dissecting microscope. Sketch the entire leaf under low power of the compound microscope. Make the drawing about five inches long. Describe the shape, margin, color, midrib. Are there any other veins?

2. The leaf is composed of cells. How many across the leaf? How many lengthwise? Is the leaf more than one cell in thickness? About how many cells on the upper surface?

3. Cut cross sections with the razor by holding some leaves between pieces or strips of common carrot either fresh or preserved in alcohol. How many cells in thickness, on the average?

4. Suppose the leaf averages three cells in thickness, about how many cells in the entire leaf?

5. Under high power, draw several adjoining cells, carefully showing details. (Draw the walls as represented in Fig. 1). What is the general shape of the cells? The contents of a cell are protoplasm and sap or water. There is usually some dead food material present.

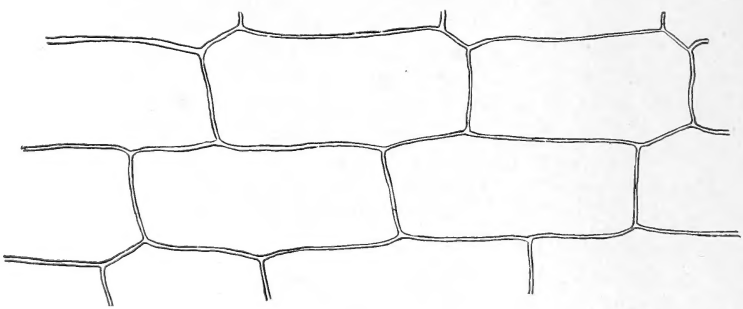


FIG. 1.—CELL WALLS OF PHILOTRIA.

6. Draw a cell showing the nucleus. Notice that the protoplasm is made up of cytoplasm, nucleus, and chloroplasts. Where is the green coloring matter? What is the color of the rest of the leaf? The green coloring matter is chlorophyll. What is its use? Estimate the number of chloroplasts in a single cell.

How many would there be in the entire leaf? How does a green plant get its food?

7. Movement of protoplasm. Describe the motion. Do not be satisfied until the rotation is very striking. The room and water should not be too cold. Does the protoplasm rotate in the same direction in all of the cells? How many seconds does it take for a chloroplast to make the round? Does the nucleus move in the cell? The active agent in the movement is the cytoplasm. The cytoplasm does not move from one cell to another.

8. A cell is a small mass of protoplasm, in typical plants usually differentiated into cytoplasm, nucleus and plastids, and surrounded by a cellulose wall. The cell is the unit of plant structure. In some of the lower plants no nucleus has been discovered, and in many plants the plastids are also absent.

9. Treat a fresh leaf with alcohol. Does the protoplasm still move? What effect does the alcohol have on the chlorophyll? Treat a fresh specimen with salt solution. What takes place? Explain the cause. Ask for an explanation or study the subject of plasmolysis in a text-book. These cells have a vacuole (water chamber) inside of the protoplasm and are normally in a turgid condition. Treat the specimen in alcohol with iodin solution. Notice the nucleus and nucleolus. Notice the large starch grains stained dark blue inside of the chloroplasts.

10. Ecological note. Does this leaf have stomata? How is it adapted to its environment?

II. **Allium cèpa** L. Common Onion.

1. Pull off the inner and the outer epidermis from a living scale of an onion. Mount in water. Compare the cells of the two specimens under low power as to shape, size, and contents. Notice the walls lined with cytoplasm; also the nuclei. Draw a number of adjoining cells from the inner epidermis. Notice the absence of chloroplasts.

2. Under high power, draw a single cell showing the wall, cytoplasm, and nucleus.

3. Study the movement (streaming) of the cytoplasm. This can usually be seen best at the ends of the cells. Notice the fine strands of cytoplasm stretching across the cell or across the corners of the cell thru the large central vacuole. Make a diagram of a cell showing the position of these streams, and indicate the direction of the flow by means of arrows.

4. Treat with a drop of iodin solution after killing the cells in alcohol. Make a careful drawing of the nucleus under high power showing the nucleoli. What is the normal number of nucleoli for each nucleus in these cells? Is the number constant? Are there any starch grains present stained blue by the iodin?

5. Why do the scales of the bulb not have chlorophyll?

III. **Tradescántia** sp. Spiderwort.

The flowers of almost any of the wild or cultivated species of spiderwort will be found suitable. *Rhóeo discolor* Hance, easily grown in greenhouses and window gardens, will also do very well. It blooms almost continuously.

1. Study the stamen hairs. With a scalpel cut off some of the stamen filaments containing the young hairs. Mount in water. Be careful to get the hairs wet, but do not injure them. Under low power, notice that the hair is made up of a chain of cells. Draw.

2. Study a single cell under high power. Observe the position of the nucleus; the cytoplasm, filled with small granules, lining the cell wall; and the large vacuole filled with water thru which granular strands of cytoplasm stretch.

3. Study carefully the streaming motion of the cytoplasm. Are the streams constant or can you see changes going on in their position? Do some of the strands disappear entirely? Watch the position of the nucleus for some time and describe its motion. Select one that is suspended in the central part of the cell. Make a large, careful sketch of a cell showing the streaming to good advantage. Plot all the moving streams visible by focusing up and down, and indicate by means of arrows the direction of the movement.

4. Of what use is the reddish-violet coloring matter in the cells of the hairs, petals, and leaves?

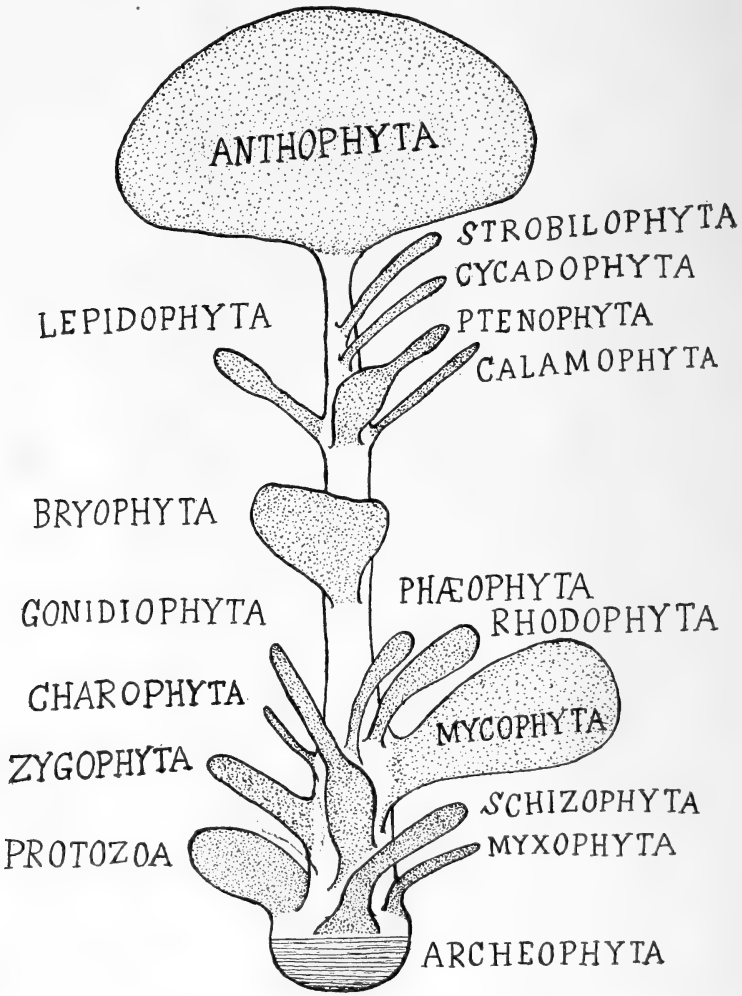


PLATE II. DIAGRAM OF THE PLANT PHYLA.

SERIES I — THALLOPHYTA.

A STUDY OF THE LOWEST, NON-SEXUAL FORMS.

IV. **Pleurocóccus vulgàris** (Menegh.). Phylum, Gonidiophyta. Class. Pleurococceæ. Order, Pleurococcales. Family, Pleurococcaceæ.

This is a unicellular green alga which very commonly forms a green, powdery layer on the bark on the north side of trees, on fences, rocks, etc., and is available at any time of the year.

1. Scrape off some of the green powder from a piece of moist bark and mount in water. Pick out one of the largest single plants and draw under high power, showing the thick cellulose wall and the chloroplasts.

2. Notice that the cells (individuals) have a tendency to hang together for some time after division. Study and draw aggregates or colonies of two, three, four, and eight cells still united. In how many directions do the cells divide? Describe the color, shape, and habitat of the plant. How does it get its food? Notice that it must be exposed to long periods of drouth. Do not forget to look for this plant (and as far as possible all others studied) in its usual habitat out of doors.

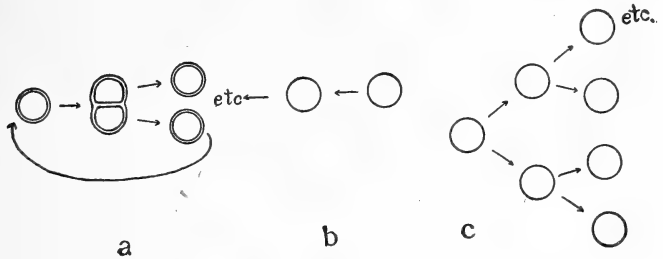


FIG. 2. — LIFE CYCLE OF PLEUROCOCCUS.

3. Its life cycle may be stated as follows: increase in size of the cell, division of the cell into two, separation of the daughter cells. Taking no account of the fact that the cells hang together for some time after division, make a diagram in the notes illustrating this as indicated in Fig. 2, a.

4. Make a diagram showing the ancestors of one individual for ten generations. See Fig. 2, b.

5. Make a diagram showing the descendants of one individual for ten generations. Use an entire page of note paper. See Fig. 2, c.

6. NOTE. All plants and animals, whether high or low (except coenocytic forms) are single cells in the first stage of their life. Therefore, in the higher forms, the egg or spore also passes thru the two, four, etc., celled stages, and in these first stages the cells may also represent a loose aggregate or colony, since in many cases, if the cells are separated from each other by artificial means, two

or more plants or animals may be obtained from the egg, which would otherwise have produced only one individual. Pleurococcus shows how it is possible for a plant to pass from a unicellular condition to a colony, and from the condition of a colony to a multicellular plant. By what means could this be accomplished? The mechanical reason for the division of one of these cells may be dependent on the following facts: All food and waste material must pass thru the wall. Now the surface of a sphere is equal to πD^2 and the volume is equal to $\frac{1}{6} \pi D^3$, therefore, as the sphere increases in size, the surface continues to become less in proportion to the volume. How could a cell increase indefinitely in size and still keep the surface and volume in about the same ratio? What disadvantage or limit would there be to such a process? These plants have potential immortality, i. e., they do not grow old and die, except by accident. Natural death of an organism appears to be an acquired character. This plant, with a number of others to follow, is unicellular and without sexuality. It belongs to the lowest sub-kingdom of plants, which for convenience may be called the *Protophyta.*

V. **Mérismopèdia** sp. Phylum, Schizophyta. Class, Cyanophyceæ. Order, Chroococcales. Family, Chroococcaceæ.

This organism can usually befound in the sediment of creeks, ponds, or lakes, especially in shady places where there is some decaying vegetable matter.

1. Mount some of the sediment and examine under high power. Look for minute, blue-green, more or less rectangular plates of cells. Find colonies of various sizes, select a perfect one and draw, showing the arrangement of the cells.

2. In how many directions does cell division take place? How does the colony break up into smaller pieces? Such a flat layer of cells is called a superficial aggregate. Neither plastids nor nuclei are visible in these cells. The nuclei are very small. The bluish color is due to the presence of a peculiar coloring matter, phycocyan, in addition to the chlorophyll. Notice the gelatinous nature of the cell wall. Write a careful description of the plant.

VI. **Filamentous Blue-green Algae.** (a) **Lýngbya** sp. Class, Cyanophyceæ. Order, Oscillatoriales. Family, Oscillatoriaceæ.

The species known as Lyngbya wollei Farl., which produces large brownish-black masses in rivers and ponds, or any other large species, may be used. A large species, appearing like a brown or black slimy layer, quite common in greenhouses and other moist situations, is also very good for study. This form can be kept indefinitely in a moist jar of earth.

1. Mount a small mass of the slimy material in water, and study under low power. Draw several of the greenish-brown threads or filaments showing how they are interwoven. Notice the disk-like cells which make up the filament. Describe the general character of these plants.

2. Under high power study a single filament. Draw part of a filament, showing the end cell. Why is the end cell more or less hemispherical and the others disk-shaped? Notice the dark granules. Where are they situated? Notice the thick sheath surrounding the cells. Draw a single cell, showing details as accurately as possible.

3. In how many directions do the cells divide? Where and how does cell division take place? A filament like this is called a linear aggregate.

4. Reproduction. In old filaments look for the development of hormogones — short pieces of a number of cells broken loose inside of the sheath. Draw and describe. How do the hormogones escape from the sheath?

(b) **Oscillatòria** sp. Family, Oscillatoriaceæ.

Any of the minute, bluish-green forms which produce slimy, membranous layers in ponds, rivers and creeks may be used. They may be kept for an indefinite time in a covered glass jar of water.

1. Mount a small flake in water, study under high power, and draw several of the slender filaments. There is no definite sheath present. Describe the color, shape of cells, and cell contents so far as they can be seen. Are the two ends alike? Compare as to size, etc., with Lyngbya. Draw a single cell.

2. Study the reproduction. Compare with the method of reproduction in Lyngbya.

3. Make a careful study of the movement of the filaments. To get good results the plants should first be placed for some time in direct sunlight and the water should not be cold. Describe the movement. Why can these plants move more actively than the Lyngbyas?

(c) **Nóstoc commùne** Vauch. Class, Cyanophyceæ. Order, Nostocales. Family, Nostocaceæ.

This plant is common on damp ground in meadows, pastures, hillsides, etc. After a rain it appears as dark green gelatinous wrinkled or lobed masses. It may be kept for an indefinite period and will be in good condition after soaking in water.

1. Describe the colony, noting its size, shape, and color. Draw.

2. Mount and under low power note the general arrangement of the filaments. Look for the limits of the thick gelatinous wall in favorable plants.

3. Under high power note the two kinds of cells composing the filament, ordinary cells and heterocysts. Why are the filaments so crooked? Draw a filament showing both kinds of cells.

VII. **Beggiatòa álba** (Vauch.). Phylum, Schizophyta. Class, Schizomycetæ. Order, Desmobacteriales (Filamentous Bacteria). Family, Beggiatoaceæ.

These plants are usually very abundant in sulfur springs and in shady places in ponds and stagnant water where decaying vegetable matter is present. Beggiatoa may be kept for years in a covered glass jar filled with water, provided there is a layer of decaying vegetable sediment in the bottom.

1. With a medicine dropper take up some of the black sediment containing Beggiatoa, mount, and examine under high power. Study the slender, more or less hyaline filaments, and draw one carefully. Draw a single cell showing the large sulfur granules. No chlorophyll is present. Describe the plant in general.

2. Study and describe the movement. Do the sulfur granules move in the cell? How many seconds does it take for the tip of a filament to travel from one side of the field to the other?

3. How does this plant obtain its food, and upon what does it live? How different in this respect from Pleurococcus? To what physiological group does Beggiatoa belong; holophytes, saprophytes, or parasites?

NOTE — These plants are intermediate between the blue-green algæ and the bacteria. What relation is there between the lack of chlorophyll and the saprophytic habit?

VIII. **Bacteria.** Class, Schizomycetæ. Order, Bacteriales.

There are three families of bacteria:

Coccaceæ, Spherical Bacteria, containing the genus *Microcóccus* and others.
Bacillaceæ, Rod Bacteria, containing the genus *Bacillus* and others.
Spirillaceæ, Spiral Bacteria, containing the genus *Spirillum* and others.

To obtain Bacilli, make a hay infusion by boiling ordinary dry hay for 15 minutes. Keep in a sterilized covered dish for several days. Also boil some beans, and after exposing the broth to the air until cool, cover and set aside for two or three days. Species of Spirillum may be obtained from sewer water, or by letting water plants decay in a jar of water. Micrococci are common in the air, and may be obtained on boiled potatoes, gelatin, moist bread, etc., by letting these culture media remain exposed for a short time and then covering them to keep in the moisture. The bacteria will soon begin to appear in yellow, pink, purple, or red patches.

1. Mount some of the hay infusion and examine under high power. Notice the minute free-swimming hay Bacillus, and draw several individuals. Draw several still hanging together in a filament after division. Describe the shape, color, and movement. Distinguish between the true locomotion of the Bacillus and the Brownian movement of the foreign particles present in the mount.

2. Draw two individuals with spores. The movement is produced by means of flagella or cilia.

3. Mount some of the bean broth and notice the putrid odor. Study the Bacillus present. Estimate the number of bacteria present in the field of the microscope. Counting the number across the diameter of the field and squaring will give approximate results.

4. Supose you had one bacterium to begin with, and that it and its descendants divided once every hour how many bacteria would there be at the end of each hour for 48 hours?

5. Mount some material containing Micrococcus. Draw several individuals and describe.

6. Mount and study some bacteria in the zoöglœa stage (bacteria in gelatinous masses.) Draw and describe.

7. Mount some water containing Spirillum. Study the peculiar movement. Draw several individuals and describe Represent the cell as a real spiral and not simply as a wavy line.

8. *Root-tubercle Bacteria.* Collect fresh roots of white clover (*Trifolium repens* L.) or alfalfa (*Medicago sativa* L.). Sketch a rootlet showing numerous tubercles under dissecting microscope. Crush a large and a small tubercle on the slide, mount in water, and study the bacteria present. Draw a number of individuals, showing the following forms: irregular rods, club-shaped, T-shaped, Y-shaped, and X-shaped. Treat with iodin solution and note the color reaction of the starch and of the bacteria. This symbiosis is a case of Mutualism.

9. Mount some hay Bacilli and some Paramœcia together, and compare them as to size. The Bacillus and the Paramœcium are both single cells. About how much greater in volume is the Paramœcium than the Bacillus? In order to get fairly accurate results, find how many times wider, thicker, and longer the one is than the other. This can be done by projecting the organisms onto the table and measuring them with a millimeter rule. How near would the comparison hold with that of a mouse and an elephant?

10. NOTE. — To obtain Paramœcia, let a mass of Spirogyra or other water plants decay in a jar of water exposed to the air. The Paramœcium is one of the most highly developed and specialized animals belonging to the sub-kingdom *Protozoa.*

IX. **Slime Molds.** Phylum, Myxophyta. Class, Myxomycetæ. Order, Myxogastrales.

The Myxomycetes are a group of organisms which approach very near to the animal kingdom, forming one of the several transition groups from the lower plants to the lower animals. They have developed a very complex life history, altho they are very simple plants. They usually grow on decaying logs and stumps, and may be collected in summer and autumn and kept in the encysted or resting stage for an indefinite length of time, and studied when convenient.

(a) **Lycógala epidéndrum** (Buxb.). Family, Lycogalaceæ.

1. Make a sketch showing the naked eye characters of individuals in the resting stage (æthalia), and how they are situated on the wood. Describe.
2. Moisten some of the downy material (capillitium) and a piece of the outer enveloping layer (peridium) in alcohol, and mount in water. Examine under high power. Is there any cell structure in the capillitium or peridium? Draw a part of the capillitium, showing the peculiar markings.
3. Draw a few of the individuals (scattered thru the capillitium) in the resting stage (spores), and describe.

(b) **Hemitríchia clavàta** (Pers.). Family, Trichiaceæ.

1. Mount one of the sporangia and sketch under low power, showing the stalk of the sporangium, the broken peridium, and the mass of capillitium threads. Describe shape, color, etc.
2. Under high power draw some of the capillitium threads, showing all details carefully.
3. Draw some of the individuals in the spore stage.

(c) **Stemonìtis fúsca** (Roth.). Family, Stemonitaceæ.

1. Mount and draw one of the plume-like sporangia under the dissecting microscope, showing the hypothallus, stalk, columella, and capillitium.
2. Under high power, draw part of the capillitium, showing how it is attached to the columella.
3. Draw some of the spores.

(d) **Plasmodium.**

1. Examine under the dissecting microscope, and describe the plasmodium of a myxomycete in the moist living condition. This can usually be found on decaying logs during the spring, summer, and autumn. If living material is not at hand, examine pieces of plasmodium preserved in alcohol.
2. The flagellate stage of many species of myxomycetes may be obtained by simply making hanging drop cultures with water, or water in which decaying wood has been soaking. Fresh spores of Lycogala will germinate in a day or two, and the preparation can be examined from time to time under the high power.

(c) **Amoèba** sp. Protozoa. Class, Rhizopoda. Order, Amœbida. Family, Amœbidæ.

If the student has not studied the Amœba in a general course in zoölogy, it should be taken up at this point, since the amœboid form probably represents the most primitive type of cell with which we have to deal. Amœbas can generally be found in the ooze at the bottom of ponds and creeks. To obtain Amœbas in large quantities, pack a glass jar rather tightly with Ceratophyllum or with pond lily leaves, and cover with water. The dish should be covered up. After a week or two, when the plants begin to decay, Amœbas will usually be abundant.

1. Scrape off some of the sediment from the Ceratophyllum leaves and mount in water together with some of the brown scum present at this time in the jar. Under high power search for transparent, naked cells of irregular shape, which are slowly changing in outline by thrusting out pseudopodia. Sketch the outline of an individual six times successively, at intervals of ten seconds.

2. Describe the amœboid movement of the animal, and the formation of the pseudopodia.

3. Make a careful diagrammatic drawing of a large Amœba, showing the outer limiting layer (ectosarc), the inner more fluid granular part (endosarc), the nucleus (if distinguishable), the contractile vacuole, and the various ingested foreign bodies, as diatoms, desmids, etc.

4. Note. — In the form following, a return will be made to a typical plant related to Pleurococcus.

X. **Scenedésmus quadricaùda** (Turp.). Phylum, Gonidiophyta. Class, Pleurococceæ. Order, Pleurococcales. Family, Scenedesmaceæ.

Scenedesmus is very widely distributed, and may be found in the sediment in the bottom of ponds, creeks, etc., along with diatoms and other microscopic plants at any season. It usually consist of a colony of four, more or less spindle-shaped, green cells. The two outer cells have four slender, pointed, prong-like projections extending diagonally outward, one at each corner of the colony.

1. Mount some of the sediment containing Scenedesmus, and examine under high power. Draw and describe.

2. Compare a number of colonies as to size, shape of cells, and appearance of the projections.

3. In the sediment with Scenedesmus a simpler and much smaller green alga, *Ankistrodesmus falcatus* (Corda), belonging to the same family will probably be present. This consists of very slender, bent or doubly curved cells either separate or in masses. If present draw and describe.

4. Note. — The thallophytes following are more highly developed forms and possess some type of sexuality or are forms supposed to be descendants from ancestors having a sexual process. They may be called the sub-kingdom *Nematophyta*.

ALGÆ WITH FANTASTIC CELL WALLS OR WITH COMPLICATED CHROMATOPHORES.

XI. **Diatoms.** Phylum, Zygophyta. Class, Diatomeæ. Order, Diatomales.

This order contains a large number of genera and species both living and fossil. Diatoms can always be found forming brown scums or sediments on the bottom of ponds, creeks, ditches, etc.

1. Mount some sediment or water containing diatoms and study the different species present.

2. Under high power, draw six different species, representing them from two to four inches long. They are unicellular plants with two silicified valves or shells which fit together like the lids of a pill-box. Represent carefully the markings on the shell. In some species the ends and central portion of the valves are marked by nodules and these points are connected by a rib or suture called the raphe. These can be seen from the valve view.

3. Notice the greenish, yellow or brown chromatophores, the nucleus, and the cytoplasm. How are the cell organs arranged?

4. Look for chains or filaments of diatoms, also for stalked forms.

5. Study dividing forms. Some species conjugate. Look for such forms.

6. Study the movement. Does it have any relation to the field of the microscope, or the intensity of the light in the field? Describe. What is the cause of the motion? Remember that the motion is magnified under the microscope. How long does it take a diatom to pass across the diameter of the field?

7. *Isthmia* sp. Scrape specimens of Isthmia from dry, red or brown algæ or study from mounted slides. Isthmia can usually be obtained from dry algæ collected on the California coast. Draw a specimen from the girdle view, showing the valves and details of the markings. Notice that the individuals are of very different sizes. Draw one showing the valve view. Draw an individual in process of division. Describe how the valves fit together, how new valves are formed, and what is the character of the valves of the two individuals resulting from a division. Explain the cause of the difference in size.

8. *Fossil diatoms.* Study material from the Tertiary deposit of Richmond, Va. Place a fragment of the diatomaceous earth in a small bottle of HCl, crush gently and mount in water. Draw three different species.

9. Note. — Diatoms, on account of the great number of forms, make a good study in variation. There is a great variety of patterns without very much advance in structure or life cycle — horizontal evolution. Is there any special advantage in the great variety of fantastic markings on the valves?

XII. **Clostèrium** sp. Phylum, Zygophyta. Class, Conjugatæ. Order, Desmidiales. Family, Desmidiaceæ.

Desmids are quite common in ponds and lakes and species of Closterium can usually be found in the sediments at the bottom, on submerged water plants, or in large masses floating on the surface. Sometimes Closterium is very abundant in watering tanks, forming large, green, floating flakes.

1. Mount in water and observe the large bright green, unicellular plants which are more or less curved or crescent-shaped.

2. Draw an individual under high power, showing the cell wall with transverse striations in the central region, the two large chromatophores (chloroplasts) with highly refractive bodies (pyrenoids), the large nucleus with nucleolus in the central, clear space, and the peculiar vacuoles at each end. Notice the dancing, crystalline granules of calcium sulfate in the vacuoles. (Brownian movement). Describe in detail, noting especially the symmetrical halves of the cell.

3. Notice the streaming of the cytoplasm between the large chloroplast and the cell wall. Trace the current around the end of the cell.

4. Look for dividing specimens. Draw and describe.

5. Search for conjugating individuals and for zygospores.

XIII: **Spirogyra** sp. Phylum, Zygophyta. Class, Conjugatæ. Order, Zygnemales. Family, Spirogyraceæ.

Spirogyra grows in stagnant water or slowly flowing streams, forming flocculent, floating masses of a bright green color which are slimy to the touch. It may be collected at any time but more commonly it conjugates in late summer and autumn. Some of the species will conjugate if brought into the laboratory and placed in an open dish of pure water. Metal is very injurious to Spirogyra.

1. Study naked eye characters, noting that the mass is made up of slender free threads or filaments.

2. Mount a few filaments in water and examine under low power. Notice the cells with spiral chromatophores (chloroplasts.) Shape of the filaments and cells? Count the number of cells across the cover-glass ($\frac{3}{4}$ inch across). How many? Measure a long filament and estimate the number of cells it contains.

3. Draw part of a filament under low power showing ends, cells, and chromatophores. Any difference between the two ends? Describe.

4. Under a high power, draw a cell showing the wall with mucilaginous sheath, spiral chloroplasts, pyrenoids, nucleus, and nucleolus. How is the nucleus connected with the other parts?

5. Draw part of a chloroplast showing details of the margin and the pyrenoids.

6. Treat with salt solution. Draw and describe what takes place.

7. Study the conjugation from fresh material, or if this is not at hand, from material preserved in copper salt solution or from mounted slides. Notice two filaments side by side and that all the zygospores are in the cells of one filament, while the cells of the other filament are empty. This indicates a slight differentiation of sex individuals. Draw a piece under low power, showing a number of conjugated cells.

8. Draw two conjugated cells showing all details carefully, especially the zygospore or zygote and the conjugation tube.

9. Draw two cells in which the contents of one cell are passing thru the tube.

10. Draw two cells in which the two rounded processes from the sides have just met.

11. Draw two cells in which the two processes are just beginning to develop.

12. Describe fully the process of conjugation as observed above.

13. Look for cases of parthenogenesis; either with a spore in one cell and a distorted protoplast in the other, or with a spore in each of the conjugated cells.

14. Make a diagram in the notes showing the life sysle by means of diagrammatic figures of the plant, cells and spores.

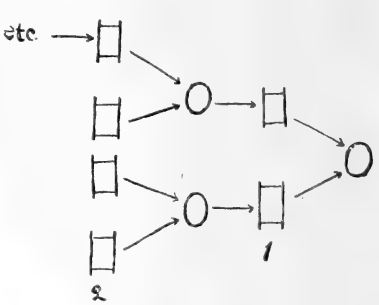


Fig. 3. — Diagram of Ancestry.

15. Make a diagram showing the ancestors of one spore for five generations; take no account of vegetative propagation or of the possible close relationship of conjugating individuals (see Fig. 3). Compare with Pleurococcus. How many ancestors have you yourself had in twenty generations or about 700 years?

A SERIES OF FORMS TO ILLUSTRATE THE EVOLUTION OF SEX.

XVI. **Sphaerélla pluviàlis** (Flotw.). (Hæmatococcus). Phylum, Gonidiophyta. Class, Protococceæ. Order, Volvolcales. Family, Chlamydomonadaceæ.

Sphærella may be found growing in rain water, drain tiles, roof gutters, pools, or ponds. It is unicellular and green in color or sometimes a bright red. If a culture is once obtained, it may be preserved on a limestone rock or a glazed earthen jar. Put the rock into the water containing the alga and after some time take it out and lay it away. Whenever material for study is required the rock need only be placed in fresh rain water, when a new crop will soon appear.

I. With a medicine dropper mount some water containing Sphærella and examine under low power. Under high power study the large, green or red spherical cells in the resting condition. Draw. Notice the green and red coloring matters — chlorophyll and hæmatochrome.

2. Draw an individual divided into two, and one divided into four or eight cells. How does the division take place as regards the cell wall. Compare with

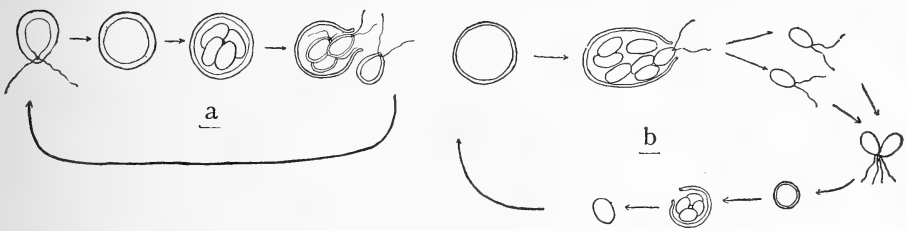


Fig. 4. — Life Cycle of Sphærella.

Pleurococcus. Look for an individual in which the four cells are ready to break thru the old cell wall. The four cells form four free-swimming Sphærellas which have very loose cell walls.

3. Study the active individuals. Describe the shape, color cell contents (especially the chloroplasts and pyrenoids), and the flagella. The flagella branch out from a clear body in the pointed end of the cell and pass out thru two extremely minute openings in the cellulose wall.

4. Study and describe the movement. Which end is directed forward in swimming? How long does it take an individual to pass across the diameter of the field? Suppose the diameter is three-tenths of a millimeter, how long would it take the plant to travel thirty centimeters or one foot? Is the motion rapid or slow? How many times its own diameter does an individual move in one second?

5. The flagella and other parts may be seen more clearly by adding a small drop of iodin solution to the water at the edge of the cover-glass. What happens? How long are the flagella, compared with the size of the body? Look for the nucleus. Notice the protoplasmic strands which pass from the cell-body to the wall.

6. Notice the division of labor in the organism and designate the function of the following organs: *a*, cell wall; *b*, flagella; *c*, chloroplasts.

7. Make a diagram in the notes showing the life cycle of Sphærella when reproduction takes place by the formation of non-sexual zoöspores. (See Fig. 4a.)

8. Sexual stage. Look for individuals divided into eight or more cells. Draw. When these escape they are smaller than the four and at first have no cell walls. These zoöspores are said to conjugate and form zoözygospores. Careful observations should be made in order to discover such a process. In case conjugation takes place the life cycle during this stage may be represented as in Fig. 4b.

XV. **Pandorìna mòrum** (Muell.). Order, Volvocales. Family, Volvocaceæ.

Pandorina occurs in small pools of water, and is often very abundant in summer, coloring such pools a bright green. The individuals consist of a free-swimming colony of sixteen cells, and are more or less globular or oval in outline.

1. Mount some of the colonies in water and examine under low power. Notice the active movement. Draw a colony under high power. If they cannot be followed because of their active movements, add a drop of carbolic acid water.

2. Notice the details of an individual cell of the colony; the two flagella, the red eyespot, the transparent spot in the outer end of the cell, and the chloroplast with a pyrenoid.

3. Study and draw colonies in stages of division. Each of the sixteen cells divides until each forms a group of sixteen new cells, then the gelatinous envelope dissolves and the sixteen daughter colonies are set free. This is the normal method of vegetative propagation.

4. Sexual reproduction. Look for colonies in which the cells are separating as isolated zoöspores. These are the gametes which are very much alike, but are of various sizes.

5. Watch for conjugating forms. Conjugation takes place between two gametes of equal size, or between a larger and a smaller one. The process is complete in a few minutes. Draw stages observed, and also mature zygospores. The difference in size of the conjugating gametes is of special importance, since it is the first step in the evolution of two specialized gametes, the oösphere and spermatozoid.

6. Note. — Pandorina is well preserved in water with carbolic acid, and large quantities may be collected at the proper season, showing the various stages of the life cycle. Cultures can also be obtained in the laboratory from dry zygospores.

XVI. **Eudorìna élegans,** Ehrb. Family, Volvocaceæ.

Eudorina frequently occurs in summer in pools of rain water, in ponds, and in marshes. The colonies are hollow, free-swimming bodies, more or less spherical in shape, usually consisting of thirty-two cells which are considerably separated from each other.

1. Mount a drop of water containing the organism and examine under low power. Under a high power draw a single colony, showing the arrangement of the cells.

2. Draw a single cell, showing the two flagella, the red eyespot, and the chloroplast with a pyrenoid.

3. Vegetative propagation. The individual cells divide into sixteen or thirty-two new cells, and these escape as daughter colonies the same as in Pandorina. Draw a colony showing daughter colonies, and describe.

4. Sexual reproduction. The colonies are either unisexual or hermaphrodite. Draw a colony showing antherida (spermaries), consisting when mature of plates of sixty-four small cells each, which develop into male gametes (spermatozoids). Draw and describe free-swimming spermatozoids.

5. Draw a colony containing female gametes (oöspheres). The colony with oöspheres differs very little from the ordinary vegetative colony. Watch for spermatozoids swarming about the female colonies.

6. Draw and describe the ripe, red colored oöspore.

7. NOTE.—Eudorina shows a considerable advance in sexual development over Pandorina. The female gamete (oösphere) has become stationary, but still retains its flagella at first, and does not divide. The male gametes (spermatozoids) are formed by the repeated division of the cells of the colony. They are very small in comparison with the female cell, swim about freely in the water, and have lost their chlorophyll.

XVII. **Vólvox glòbator** L. Family, Volvocaceæ.

This alga is of such size that its spherical, free-swimming body can easily be seen with the naked eye. In summer and autumn it can frequently be found in fresh water ponds and lakes.

1. Take up some of the spherical colonies with a large-mouthed medicine dropper or a glass tube and, having formed a little chamber on the slide with a xylonite ring or with paraffin, mount and study under low power. Note the rotating movements of the hollow, spherical organism.

2. Draw a colony showing the numerous cells and some daughter colonies, which appear as darker green spherical masses of various sizes.

3. Under high power, study a single colony. About how many cells in a colony of average size? Draw a few cells, showing the cell walls, the protoplasmic strands, connecting the cells (protoplasmic continuity), the chloroplast, the red eyespot, the pulsating vacuole, and the two flagella of each cell. The flagella will be more distinct after staining with iodin.

4. Describe the development of a daughter colony from one of the cells of the mother colony. Look for an opening (the pore) in one side of the young colonies. What advantages may there be in the hollow spherical form?

5. Sexual reproduction. The colonies are hermaphrodite, developing both sexual organs — the ovaries or oögonia and the spermaries or antheridia — in late summer or autumn. Draw an antheridium. This represents an enlarged cell of the colony which has divided into a large number of elongated cells arranged like a bundle of asparagus shoots.

6. Draw an oögonium, projecting into the cavity of the colony, showing the enlarged oösphere. Draw a ripe oöspore, showing the thick wall with peculiar angular spines on the surface.

7. NOTE.—In Volvox complete sexuality has been attained with the normal conditions of the sexual cells (gametes). It will be noticed that the plant is hermaphrodite, and this is the more usual condition in the lower plants.

XVIII. **Vauchèria séssilis** Vauch. Phylum, Gonidiophyta. Class, Siphoneæ. Order, Vaucheriales. Family, Vaucheriaceæ.

This alga grows as a lax, green, felt-like layer on the surface of moist soil, and is especially common on the surface of pots in greenhouses, and may here be in fruit at any time of the year. Other species may be found in ponds.

1. Describe the naked eye characters, noting the coarse cylindrical filaments.

2. Under low power draw an entire filament showing the branches, the tips, and the clear or decaying part of the back end. Note the absence of transverse walls. Such a plant body is called a cenocyte. The protoplasts are not separated by walls. How does the filament grow?

3. Under high power draw a short piece of a young filament, showing details — shape, vacuole, arrangement of protoplasm, chloroplasts, and oil drops. Position of chloroplasts? How can you tell that the filament is cylindrical without seeing a cross section?

4. Draw several chloroplasts. Shape? Draw some in stages of division. Describe. Look for movement of the protoplasm. Numerous nuclei are present in the cytoplasm, but these are not visible without special staining.

5. Study the sexual organs, the antheridium (spermary), and oögonium (ovary). They are usually side by side. Draw carefully and describe. Notice the septa which separate the sexual organs from the main filament. Vaucheria is hermaphrodite, having male and female organs on the same individual.

6. Draw the oösphere (unfertilized egg); also some spermatozoids in the antheridium. Look for free-swimming or escaping spermatozoids; also for spermatozoids entering the oögonium.

7. From the union of the two gametes an oöspore or zygote is formed. Draw a ripe oöspore showing the thick wall and more or less hyaline contents. Describe. Note that fertilization, in this case, is not the stimulus for further development but is followed by a resting stage.

8. Contrast the two sex cells (gametes) as to size, motion, and nutrition. How is an oöspore different from a zygospore? Would there be any advantage in this?

9. Special vegetative propagation by means of volvox-like colonies (compound zoospores), produced in the ends of the filaments, may be obtained as follows: Place a mass of Vaucheria in a porcelain dish, in water, and expose for a few days in the window until small Vaucheria plants are found floating on the surface. Examine very early in the morning and the volvox-like colonies may be seen escaping from the swollen ends of the filaments. In order to observe the colonies later in the morning, cover the dish, the evening before observation is to be made, so that the plants will be in absolute darkness until shortly before the material is to be studied. Study and draw. Describe in detail the formation of the compound zoospores and how they develop into new Vaucheria plants. Might this process indicate some relation of the ancestors of the Vaucheria to the Volvocaceæ?

10. Make a diagram in the notes, showing the life cycle of Vaucheria. (See Fig. 5.)

11. In the notes, make diagrams of the two gametes of Sphærella, Pandorina, Eudorina, and Volvox, and describe how these may indicate stages in the evolution of perfectly developed oöspheres and spermatozoids.

12. Note.— The oösphere and spermatozoid are highly specialized cells, the first representing nutritive qualities, the second the active qualities. A union of the two must result in a very perfect reproductive cell. The development of sexual individuals appears to be along the same lines as indicated in the sexual cells. Maleness or femaleness is not an hereditary character or factor, but a condition and often depends on the environment present during the germination of the spore or the development of the embryo. In some of the intermediate plants the sexual development can be controlled while in the higher groups the sex of the gametophyte is always determined in the spore.

TWO PECULIAR COENOCYTIC COLONIES.

XIX. **Pediástrum pertusum** Kuetz. Phylum, Gonidiophyta. Class, Hydrodictyeæ. Order, Hydrodictyales. Family, Hydrodictyaceæ.

This beautiful alga is found along with other species of the same genus in the sediments at the bottom of ponds and creeks, and is especially abundant in the plankton of fresh water lakes and bays in summer and autumn. It is a flat colony of cells which develop into cenocytes.

1. Mount some of the sediment containing Pediastrum in water and study under high power. Draw two of the plate-shaped colonies — one with sixteen cenocytes and one with thirty-two or more. Notice the difference between the marginal cenocytes and those in the interior. Note also the chloroplast and one or more pyrenoids.

2. Look for colonies in which the cells in each cenocyte have separated, preparatory to the formation of a new colony.

3. Draw a colony in which some of the cenocytes are empty, each empty shell having a slit-like opening thru which the daughter colony escaped.

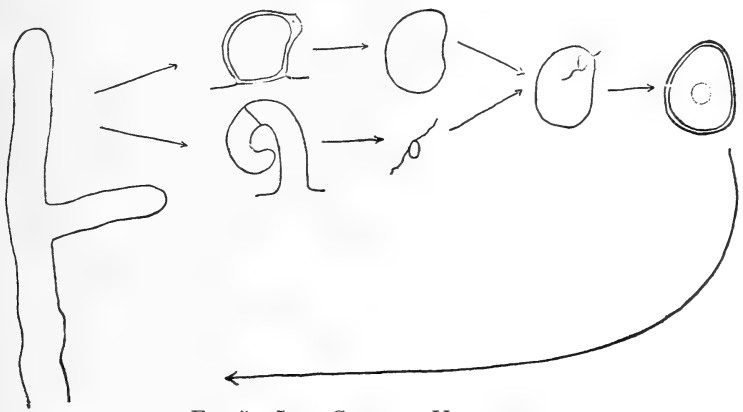


FIG. 5.—LIFE CYCLE OF VAUCHERIA.

XX. **Hydrodictyon reticulàtum** (L.). Water-net. Family, Hydrodictyaceæ.

The water-net forms a large body, which is common in summer and autumn in ponds and canals. It may often be collected in great quantities along the grassy banks of ponds in city parks. The body of the alga is made up of a very great colony of cylindrical cenocytes arranged in the form of a sack-like net.

1. Examine a large plant and describe the naked-eye characters. If fresh material is at hand, place the plant for some time in direct sunlight and note the bubbles of gas collecting in the nets. Of what use? What is the gas.

2. Draw a small portion of a young net under low power, showing how the meshes are formed by the joining of a number of cenocytes. Describe.

3. Under high power draw a single cenocyte, showing the chloroplast and numerous pyrenoids.

4. Vegetative propagation. Study and draw a large cenocyte of an old net in which the cells are developing a daughter net.

A NUMBER OF COMPLEX ATTACHED FORMS.

XXI. (a) **.Caulérpa crassifòlia** (Ag.). Phylum, Gonidiophyta. Class, Siphoneæ. Order, Caulerpales. Family, Caulerpaceæ.

This is a large, much branched, cenocytic plant which reproduces by the branching of the thallus. The creeping, rhizome-like portion develops leaf-like, lobed branches, and continues to grow in front while it dies behind. It grows within the tropics on sandy ocean shores at a depth of several meters. Preserved material will be necessary.

1. Sketch the entire plant showing the creeping "rhizome," the leaf-like lobed branches, and the branching root-like hold-fasts.

2. Mount part of a leaf-like branch and examine under low and high power Note that there are no septa or walls in the plant body. Note the chloroplasts. Draw.

3. Examine a cross section of the cylindrical "rhizome" under low and high power. Note the numerous branched and anastomosing collulose braces stretched across the cavity. Draw.

4. Note.—Caulerpa represents a plant which has developed the extreme type of a cenocytic body. The body takes on a shape suitable to its activities, by its branching habit affording sufficient surface for absorption and photosynthesis. The rigidity of the body is secured thru the complicated system of braces rather than by cell walls. Compare Note 6 on Pleurococcus.

(b) **Botrýdium granulàtum** (L.). Phylum, Gonidiophyta. Class, Siphoneæ. Order, Botrydiales. Family, Botrydiaceæ.

This alga is common in summer and autumn, especially after heavy rains, on wet ground in fields and around ponds, where it forms little green pearshaped bodies with rhizoids extending into the soil.

1. Draw a thallus under dissecting microscope or low power, showing the pear-shaped ærial part and the branching rhizoids. Describe, noting the division of labor in the plant body and that it is a cenocyte.

2. If material is at hand study some plants which are producing zoöspores. Examine under high power and describe. How many flagella?

XXII. **Cladóphora** sp. Class, Siphoneæ. Order, Cladophorales. Family, Cladophoraceæ.

Species of Cladophora are commonly found in flowing water. They appear as large, dark green extensively branched tufts, attached to rocks and pieces of wood. These algæ are also abundant along the shores of lakes, where they may often be found attached to objects which are exposed to the action of waves. They may be obtained at any season.

1. Describe the naked eye characters; size, mode of growth, color, habitat, etc. Note the differentiation of base and apex.

2. Mount a small branch of the thallus in water and study under low power. Draw.

3. Under high power study the stages showing the development of a branch. Make four drawings showing four general stages: (1) a small bulging out of the cell wall on one side below the septum; (2) a short branch with the protoplasm still connected with the parent cenocyte; (3) the branch cut off from the parent cenocyte by a septum; (4) a branch divided by a transverse septum into two cenocytes.

4. Draw a single cenocyte or division between two cross walls, showing the irregular chloroplasts and the pyrenoids. Notice the large central vacuole. Apply salt solution and note the effect. Numerous nuclei are present, but these can probably not be distinguished from the pyrenoids without special staining. Stain with iodin solution and draw. It is a cenocytic plant with numerous transverse walls, but the walls do not represent cell divisions. How and where do the branches always originate?

5. Draw and describe an empty cenocyte or zoösporangium from which zoöspores have escaped. Where is the opening (ostiole) always formed?

6. At certain times zoöspores may be seen forming and escaping into the water. This frequently occurs in material which has been kept in water in a warm room. Draw a cenocyte in which the zoöspores are developing.

7. Draw a cenocyte in which the zoöspores are fully formed. Look for zoöspores in the act of escaping thru the ostiole.

8. Study and draw free-swimming zoöspores, showing the chloroplast and red eyespot. To make the two flagella visible treat with iodin solution by placing a drop on the slide beside the cover-glass and letting it mix slowly with the water of the mount.

9. Draw a zoöspore which has begun to develop into a new filament. The embryo developing from a free spore is called a sporeling.

10. The zoöspores (planogametes) of some species are said to conjugate. Look for such a process.

XXIII. **Ulothrix zonàta** (W. & M.). Phylum, Gonidiophyta. Class, Conferveæ. Order, Confervales. Family, Ulothrichaceæ.

This Ulothrix is a small, unbranched, filamentous, green alga which usually grows in running water, attached to sticks and stones. It may be found in slow-flowing streams, in watering troughs, or in fountains. Collect the material and place it in a shallow dish in about two inches of water, and in a day or two, after the water has evaporated somewhat, large non-sexual zoöspores and sexual gametes will probably be forming. Study the fresh material and preserve some for further use.

1. Mount some of the filaments containing the basal cells (holdfasts) and study under low power. Draw.

2. Under high power draw the holdfast, the terminal cell, and two or three of the central cells; showing the wall, the chloroplast, and the nucleus. Describe these parts.

3. Non-sexual zoöspores. Examine a filament in which the cells are forming either one, two, or four zoöspores each. Observe how they escape by a lateral opening in the cell-wall. Draw and describe. These spores have four flagella and a pulsating vacuole. Draw an empty cell.

4. Sexual reproduction. Study a filament in which the cells have developed a large number (eight, sixteen, or thirty-two) small gametes of equal size (isogametes). Draw part of the filament showing some cells empty and some with gametes. The gametes have only two flagella.

5. Observe the conjugation of the planogametes to form zoözygospores. Draw and describe. In order to bring out the flagella more clearly, stain with iodin solution. If the gametes do not conjugate some may round themselves off and become resting spores. This is a case of parthenogenesis.

6. Note. — When the zygospore germinates it does not develop a new filamentous plant, but gives rise to a number of cells which develop as non-sexual

zoöspores, and these escape and produce the filamentous plant. Ulothrix, therefore, along with many other thallophytes, has what is known as an alternation of generations.

XXIV. **Ectocàrpus confervòides** (Roth.). Phylum, Phæophyta. Class, Phæosporeæ. Order, Ectocarpales. Family, Ectocarpaceæ.

This alga has a branching filamentous frond and grows in summer attached to other algæ or to submerged objects along the seashore.

1. Note the form of the plant and mode of attachment. Draw.
2. Examine under low power. Are the cells in a single row? Draw a branch.
3. Study and draw a plurilocular sporangium; also draw one of the unilocular sporangia which are usually developed somewhat earlier than the plurilocular ones. The unilocular sporangia produce non-sexual zoöspores and the plurilocular sporangia produce planogametes.

XXV. **Fùcus evanéscens** Ag. Phylum, Phæophyta. Class, Cyclosporeæ. Order, Fucales. Family, Fucaceæ.

This brown alga is common along the Atlantic coast. It may be obtained from dealers in botanical supplies, and preserved in alcohol or other solutions, or they may be dried and soaked in water when needed. Various species of Fucus may be found fresh at fish stores in large cities, these plants often being used as packing. The thallus is a large, flat, dichotomously branching frond of a dark brown color, attached to various objects by means of a disk-like holdfast.

1. Place the plant in a plate of water and draw the large thallus. Describe. Note the holdfast, the flattened dichotomous frond, and the thicker central region forming a sort of midrib. Note also the swollen tips of the branches (receptacles), covered with numerous dot-like projections.
2. Find the growing points of the thallus in branches which do not have receptacles. Note the emarginate apices which have a slight groove lying in the plane of the thallus. Draw under low power. The initial cells are at the bottom of this groove. How are the branches formed?
3. Cut thin cross sections of a branch of the thallus with a razor, mount, and examine under low power. Draw. Note the outer, denser, cortical layer, and the loose, inner region, with elongated branched filaments and much mucilage.
4. Cut thin cross sections of a receptacle, mount, and examine under low power. Note the conceptacles, cavities opening by means of ostioles on the exterior. Sketch the entire section.
5. Slect a favorable conceptacle and draw, showing the ostiole, the wall of the conceptacle, the sterile hairs, the large, dark-colored ovaries (oogonia) of oval form, and the small yellowish spermaries (antheridia) situated on branched hairs.
6. Under high power draw and describe a single antheridium showing cells developing into spermatozoids. About how many sperms does an antheridium produce?
7. Draw and describe an oogonium containing the eight ripe oospheres.
8. Compare the egg and sperm cells. About how much larger in volume is one than the other?
9. If fresh material can be obtained, study the spermatozoids and oospheres after their escape from the sexual organs. Take a plant with mature receptacles from sea water and expose it to the air for several hours. Mount some of the exudation, which appears at the ostioles of the conceptacles, in sea water, and

examine under high power. Notice the large spherical oospheres and the small motile spermatozoids. Study the process of fertilization, and describe. Draw an oosphere surrounded by spermatozoids. The discharge of the egg from the ovary into the water is a very unusual phenomenon in the plant kingdom. Compare with Vaucheria and Volvox.

FOUR PHYCOMYCETES SHOWING VARIOUS HABITATS.

XXVI. **Mùcor stolónifer** Ehrenb. Black Bread Mold (Rhizopus nigricans.)

Phylum, Mycophyta. Class, Zygomycetæ. Order, Mucorales. Family, Mucoraceæ.

This fungus can nearly always be obtained by placing a piece of old bread for several days in a moist chamber. An ordinary glass or jar with a cover will do very well for making the culture. Enough water should be added to keep the bread moist without soaking it. The fungus forms a white flocculent mass of cottony filaments (the mycelium made up of hyphae) over the surface of the bread and later also spreads out over the walls of the glass. Some of the hyphæ will be seen to rise vertically into the air and end in rounded black heads. These are the sporangia containing the non-sexual spores.

1. Describe the naked eye characters noted above. Notice habitat and color. Notice also (1) the hyphae passing down into the substance of the bread, (2) the horizontal stolon-like hyphae, and (3) the upright sporangiophores.

2. Cut off a flake of the young mycelium with a pair of scissors and mount in water, taking great care not to injure the delicate hyphae. Study under low power and draw some of the hyphæ showing mode of branching.

3. Mount carefully and under high power draw part of a hypha and describe. Any transverse septa (cross walls)? If not, what kind of a fungus is it? (Compare with Vaucheria.) How does this plant differ from the green algæ in general? Difference in mode of obtaining food? Why is this plant called a saphrophyte?

4. Study and draw a cluster of sporangiophores showing the rhizoids at the base and the sporangia at the tips. The best are those taken from the walls of the dish. Color? Draw a single unbroken sporangium showing the columella on the inside, and the non-sexual spores. Do not mistake the columella of a broken sporangium for the entire body. Describe the structure of the sporangium. What does the columella represent? The sporangia burst readily because of the presence of an intermediate substance which swells readily in water. Of what use is this?

5. Draw and describe the non-sexual spores. Color? About how many in a sporangium?

6. This plant has a partial development of sexuality, and under suitable conditions, if the female and male (or + and —) strains are growing together, produces zygospores. If any of these are at hand or material from another species, study and draw showing the following stages.

a. Two neighboring branches of the mycelium, which are about to conjugate and which are in contact.

b. The stage in which the two branches have fused.

c. The stage in which transverse septa are formed, cutting off the apical part of each conjugating branch. Any difference between the conjugating branches in size or contents?

d. The absorption of the wall separating the conjugating tips and the subsequent mixing of the two cenocytic protoplasmic masses.

e. The mature zygospore suspended between the two branches.

XXVII. **Empùsa múscae** Cohn. Fly-cholera Fungus.

Phylum, Mycophyta. Class, Zygomycetæ. Order, Entomophthorales. Family, Entomophthoraceæ.

This fungus grows on the common house fly (*Musca domestica*). In the autumn dead or dying flies attacked by this fungus may be seen with greatly swollen abdomens of a white color. Specimens may be preserved in alcohol.

1. Study a fly recently killed by this fungus; under low power without a cover-glass. Note the bands of short white hyphæ (conidiophores) protruding from between the black segments of the abdomen. Draw and describe.

2. Tear open the abdomen with needles and mount the white contents and some of the conidiphores in water. Examine under high power. Notice that the mycelium has nearly absorbed the contents of the fly's abdomen.

3. Draw some of the conidiophores with conidia still attached; also draw several of the conidia. Describe. Is the fungus a parasite or a saprohhyte?

XXVIII. **Saprolégnia** sp. Water mold.

Phylum, Mycophyta. Class, Oömycetæ. Order, Saprolegniales. Family, Saprolegniaceæ.

This fungus can usually be obtained by placing dead flies in a dish of spring or pond water. After about five or six days the hyphæ of the fungus may be seen protuding from the body of the fly. On the tips of these hyphæ sporangia are developed which discharge numerous zoospores.

1. Notice the fly in the water, surrounded by a halo produced by the mycelium of the fungus.

2. Mount some of the mycelium in water and examine under low power. Draw a branch under high power, showing the granular protoplasm and a terminal sporangium developing zoospores. Draw a branch showing an empty sporangium.

3. Study and draw free-swimming zoospores. Oospores may also be present.

XXIX. **Plasmòpara vitícola** (B. & C.). Downy Mildew of Grape.

Class, Oömycetae. Order, Peronosporales. Family, Peronosporaceæ.

This mildew causes a destructive disease of the leaves and young shoots of the cultivated grape. The infected leaves may be collected in spring or summer and preserved in 70 per cent. alcohol or dried and kept in paper boxes.

Conidial stage.

1. Examine a leaf carefully under the low power, without cover-glass. On which side do the conidiophores appear?

2. Carefully scrape off some of the conidiophores with a needle or scalpel, mount in water, and examine under low power. Under high power draw one of the much branched conidophores. If dry material is used the conidia will probably all have dropped off. One is developed at the tip of each peg-like branch of the conidiophore.

3. Draw several conidia and describe shape, size, and color.

4. From alcoholic material cut cross sections of a part of a leaf containing the fungus, mount, and under low power note that the conidiophores come out in bunches thru the stomata of the leaf. Draw.

5. To what physiological group does this fungus belong — parasite or saprophyte? Describe its mode of life so far as studied.

EXAMPLES OF THE HIGHER ALGÆ.

XXX. **Chàra** sp.

Phylum, Charophyta Class, Chareæ. Order, Charales. Family, Characeæ. Stoneworts.

The stoneworts are algæ which are found growing in the bottom of ponds, lakes, or slowly flowing creeks and rivers. They are of considerable size and are usually covered with an incrustation of lime. They contain numerous branches arranged in whorls and are firmly fixed in the mud by means of rhizoids. Charas grow very readily in an aquarium and may be kept in a healthy condition all winter by simply placing the plants into a glass jar of water and keeping them near a south window.

1. Sketch an entire plant and describe the naked eye characters. Notice the odor, the nodes and internodes, and the brittleness of the filaments.

2. Mount the base of a plant in water and examine under low power. Draw and describe some of the branching rhizoids. Study the rotation of the protoplasm under high power.

3. Mount the terminal part of a young branch, being careful so as not to crush the brittle lateral branches. Examine under low power and draw the terminal bud. Notice the great internodal cells covered with a cortical layer and the whorls of lateral branches.

4. Draw a cell of one of the branches without a cortical layer, showing the incrustation of lime.

5. Under high power draw a part of a cell, showing the chloroplasts. How are they arranged? Draw several in stages of division. How do they divide?

6. Study the rotation of the cytoplasm in the large cells of the branches and describe. How does it differ from that in the cells of Philotria? Why are the chloroplasts arranged in rows? Note the movements in opposite directions on either side of the neutral line. Is the direction of rotation the same in all the cells?

7. How is the cortical layer developed? In order to determine this, young branches should be observed. Draw a cross section of the main stem. Note the short projecting cells which roughen the surface.

8. The sexual organs are produced during summer and autumn. Study fresh material, or if this is not at hand, material preserved in alcohol or copper solution. The spermaries (antheridia) and ovaries (oogonia) are situated on the lateral branches. Draw. Notice the five spiral branches which cover the ovary. How does this ovary differ from that of Vaucheria? The spermaries are globular organs which are red in color when fresh. Is this plant hermaphrodite or uni-sexual? If the incrustation of lime is too thick remove it with Perenyi's fluid.

9. Crush a ripe spermary under the cover-glass and draw one of the numerous filaments inside. The small cells of these filaments contain the spermatozoids. Draw a single cell showing a mature spermatozoid. How many cells in a single filament? Suppose the spermary contains $8 \times 6 \times 4$ filaments, how many spermao-

zoids would there be produced in each spermary? How many spermatozoids for each oosphere or egg?

10. Draw an ovary containing a ripe oospore. Explain the structure of the entire body. Crush the oospore and note the starch. Treat with iodin.

11. Study the proembryo, from which the normal Chara plant develops as a lateral bud. Draw and describe. Proembryos may be obtained by placing plants with mature spores in a glass jar of water and keeping them over winter. In the spring the embryos will be found at the bottom.

12. Make a diagram showing the life cycle of Chara. Compare with Vaucheria.

XXXI. **Batrachospèrmum monilifórme** Roth.

Phylum, Rhodophyta. Class, Florideæ. Order, Nemalionales. Family, Helminthocladiaceæ.

Batrachospermum is an alga of considerable size which can be found attached to stones in fresh water rivulets and creeks.

1. Spread out the frond of the alga in water in a porcelain plate and sketch the entire plant.

2. Mount some of the branches in water, crushing them considerably under the cover-glass, and sketch under low power.

3. Under high power draw one of the lateral branches coming out from the nodes. Note the oval cells and the bristle-like projections on some of the terminal cells.

4. In a young, main branch study the branches which pass down from the base of the nodal branches and form a loose cortical layer. How does this compare with the cortical layer in Chara?

5. Crush some of the older branches under the cover-glass by pressing and rubbing carefully over the surface with the handle of the needle and study the ovaries. These are situated on the lateral branches, and each consists of a thickened hair-like process (trichogyne) and a bulbous base (trichophore) containing the oösphere. Draw.

6. Study the spermaries, which are single terminal cells, each of which develops a single spherical male gamete (spermatium) without flagella. Draw a spermary and a free floating spermatium.

7. Draw an ovary which has one or more spermatia attached to the trichogyne.

8. Draw a sporocarp under low power. This is a sperical cluster of branches which develops from the fertilized egg.

9. Under high power draw a nonsexual carpospore at the end of one of the branches of the sporocarp.

10. From the foregoing study it will appear that Batrachospermum possesses a sort of an alteration of generations. Besides this, it has another interesting stage. When the carpospore germinates it gives rise to a peculiar filamentous proembryo or protonema, formerly known as the chantransia stage, from which the normal Batrachospermum plant develops as a lateral bud. Protonemal plants should be collected showing various stages in the development of the Batrachospermum bud. The protonemal (chantransia) filament can reproduce itself by means of nonsexual spores developed on the tips of its branches. This is a case of reproduction known as pædogenesis, since the process is accomplished while the plant is in the immature condition. If material is at hand, draw and describe the chantransia filaments and spores.

XXXII. Polysiphònia variegàta (C. Ag.).

Phylum, Rhodophyta. Class, Florideæ. Order, Ceramiales. Family, Rhodomelaceæ.

Polysiphonia grows in abundance on rocky sea coasts. The plants may be found in summer as purplish-brown tufts, a few inches long on other larger water-plants, or on piles and stones. Preserved material may be used by those living away from the seashore.

1. Spread out a frond in a porcelain plate and sketch the entire thallus. Note the holdfast, if present, and the mode of branching.

2. Mount a branch and draw under low power. Note that the body of the thallus consists of successive tiers of cells, each tier consisting of a central cell, surrounded by a layer of cortical cells.

3. Under high power draw a single tier of cells. Crush the thallus a little and note especially the large protoplasmic strands (protoplasmic continuity) which run from the central cell to the several cortical cells of the tier. Note also, the strands connecting the cells of a tier with those of the tiers above and below.

4. Cut cross sections of the thallus, mount, and study under high power. The sections may easily be obtained by chopping up a moist branch on a piece of paper with a sharp scalpel. Draw, showing the arrangement of the central and cortical cells and also the protoplasmic connections.

5. Under high power study the tip of a young branch and draw. Notice the dome-shaped apical cell and a number of cells below. The lower ones are divided by longitudinal walls. How are the tiers and the cortical cells developed? From this it is evident that, altho Polysiphonia appears like a branched filament and continues to develop as such, it finally forms a true solid aggregate.

6. Nonsexual spore reproduction. Mount branches of plants containing tetrasporangia (dark spherical bodies below the cortical cells) and draw under high power. Draw the spore tetrad and one of the mature spores.

7. Sexual reproduction. The spermaries (anthridia) are borne on delicate, colorless dichotomously branched filaments, which form tufts on the younger part of the frond; the ovaries (oögonia) are on short branches in the upper part, or the individuals may be unisexual. Mount branches containing spermaries and draw under high power. Note the slender tip of the branch which extends beyond the oblong spermary. Note also that the sexual plants have no tetraspores.

8. Development of the ovary. Mount branches containing young ovaries and under high power draw: (*a*) a short lateral simple branch showing one of the cells considerably enlarged and more or less spherical; (*b*) one in which this cell has divided by vertical walls into four cells; (*c*) one in which the inner cell of the tier of four has enlarged and divided into three or four cells by transverse walls, the upper one developing into the ovary with a basal trichophore and a slender trichogyne; (*d*) a young cystocarp showing the trichogyne protruding from the mass of cells forming the wall.

9. Draw a mature cystocarp, showing the more or less ovate-globose wall and the carpostome.

10. Crush one of the mature cystocarps and draw several of the dark colored, nonsexual carpospores.

11. Note.—Polysiphonia has an alternation of generations, since the spore-bearing part of the cystocarp and the tetrasporic plant are homologous to the sporophyte of higher plants. Note that the sporophyte is at first nursed by the

gametophyte then produces a number of independent spores. Its life cycle may be stated as follows:

Sexual plant or gametophyte $\left\{ \begin{matrix} \text{spermatium} \\ \text{oosphere} \end{matrix} \right\}$ fertilization—germination of oospore — carpospores — tetrasporic plant or sporophyte (nonsexual) — sporcyte — reduction division — tetraspores — gametophyte, etc.

THE HIGHER FUNGI AND LICHENES.

XXXIII. **Aspergíllus herbariòrum** (Wigg.). Common Green Mold.

Class, Ascomycetæ. Order, Aspergillales. Family, Aspergillaceæ.

This mold is exceedingly common on improperly canned fruit, on cheese and on decaying plants; especially on plants in press for the herbarium when the driers are not frequently changed. The conidial stage is of a greenish color while the ascosporic stage is of a bright yellow-orange to the naked eye.

1. *Conidial stage.* Mount carefully in water and study under low power. Under high power draw a conidiophore with conidia. Describe. How are the conidia developed? Draw a piece of the vegetative mycelium, showing the transverse septa.

2. *Ascus Stage.* Mount some of the white mycelium around the margin of the yellow centre. Under high power draw some of the peculiar coiled hyphal bodies present. These represent the conjugating branches, from which a fruiting body develops.

3. Draw the mature fruiting body (ascocarp) under high power, from a mount of the yellow colored mycelium. Notice the asci containing ascospores.

4. Crush the ascocarps under the cover-glass and draw an ascus with spores. Describe the life history of the plant. The ascocarp may be compared in a general way with the cystocarp of Polysiphonia.

XXXIV. **Morchélla esculénta** (L.). Morel.

Class, Ascomycetæ. Order, Helvellales. Family, Helvellaceæ.

This edible morel is common in spring and summer in moist woods and shady hillsides. Specimens may be preserved in 70 per cent. alcohol.

1. Make a careful sketch of the entire, fleshy, fruiting body, representing the stalk and the deep-pitted pileus on whose surface the asci are borne.

2. Tease out a piece of the stalk and mount in water. Examine under high power and draw some of the mycelial threads. Note that the entire body is a spurious tissue of interwoven septate hyphæ. Compare with Mucor.

3. Tease out a small piece of the pileus, mount, and study the asci. Draw. How many ascospores in an ascus? How do the asci open at the tips?

XXXV. **Uncínula sálicis** (DC.).

Class, Ascomcyetæ. Order, Perisporiales. Family, Erysibaceæ.

This powdery mildew grows as a parasite on the leaves of various species of willow and can usually be found without difficulty in the autumn. It forms a white layer on the surface of the leaf in which minute black bodies are situated. It may be preserved in 70 per cent. alcohol or kept in a paper box.

1. Moisten a leaf with water and scrape off some of the mycelium containing the black bodies (cleistothecia). Mount in water and examine under low

power. Under a high power draw a cleistothecium with appendages. Be careful to have one that it mature.

2. Draw a single appendage. Of what use are the appendages and the coiled tips? Draw a small piece of the mycelium showing the transverse walls in the hyphæ.

3. Crush some of the cleistothecia under the cover-glass by pressing and rubbing carefully over the surface with the handle of the needle. Draw an ascus containing ascospores. How many asci in a cleistothecium? How many spores in an ascus?

XXXVI. **Saccharomyces cerevisiae** Meyen. Beer and Bread Yeast.

Phylum, Mycophyta. Class, Ascomycetæ. Order, Saccharomycetales. Family, Saccharomycetaceæ.

To obtain yeast plants in active, vegetative condition, take a piece of ordinary dry yeast cake and put it in a glass of water containing a small amount of sugar. Keep over night in a warm place.

1. Mount some of the water containing yeast plants and study under high power. Draw several of the large oval cells present; also a short, branched filament of cells.

2. Notice the formation of new cells by process of budding. Draw a number of cells showing the several stages in the formation of a daughter cell.

3. Compare the size of a yeast cell with one of the bacteria present.

4. Stain with iodin solution. Notice, the yellowish-brown color of the yeast plants and the blue of the large starch grains of the yeast cake. Is there any starch in the yeast cells?

5. Draw a large cell carefully, showing granules in the protoplasm and one or more vacuoles.

6. Note. Yeast plants produce alcoholic fermentation in saccharine solutions. Dry bread yeast is usually a form of the beer yeast, and is known as "surface yeast."

XXXVII. **Ustilago zeae** (Beck.). Corn Smut.

Phylum, Mycophyta. Class, Teliosporeæ. Order, Ustilaginales. Family, Ustilaginaceæ.

The corn smut may be collected in summer and autumn and kept in a dry condition in paper boxes.

1. Make a naked eye sketch of one of the large, black, smut nodules. On what parts do the smut nodules develop?

2. Mount some of the black powder and study under high power. Draw a number of the small spores. These are usually known as chlamydospores, or teleutospores. Describe the color, surface and shape.

3. Make a hanging-drop culture of the spores with dilute, boiled, stable-manure water. Smut spores germinate quite readily, but it is best to let them freeze before making the culture. Watch the germination from day to day and note the formation of the small promycelium or basidium which develops a number of byaline basidiospores. Note that the smut plant is a parasite while the promycelium is a saprophyte.

XXXVIII. **Puccínia gráminis** Pers. Wheat Rust.

Class, Teliosporeæ. Order, Uredinales. Family, Pucciniaceæ.

The æcidium stage of the wheat rust occurs in the spring on the leaves of *Berberis vulgaris;* the uredo stage, known as red rust, and the teleuto stage, known as black rust, occur on the wheat plant. The infected leaves of the barberry may be preserved in 70 per cent. alcohol and the wheat leaves and stems may be dried or also preserved in alcohol.

Aecidium stage.

1. Study the under side of a barberry leaf containing the rust under dissecting microscope. Sketch an entire leaf, representing the position of the diseased spots.

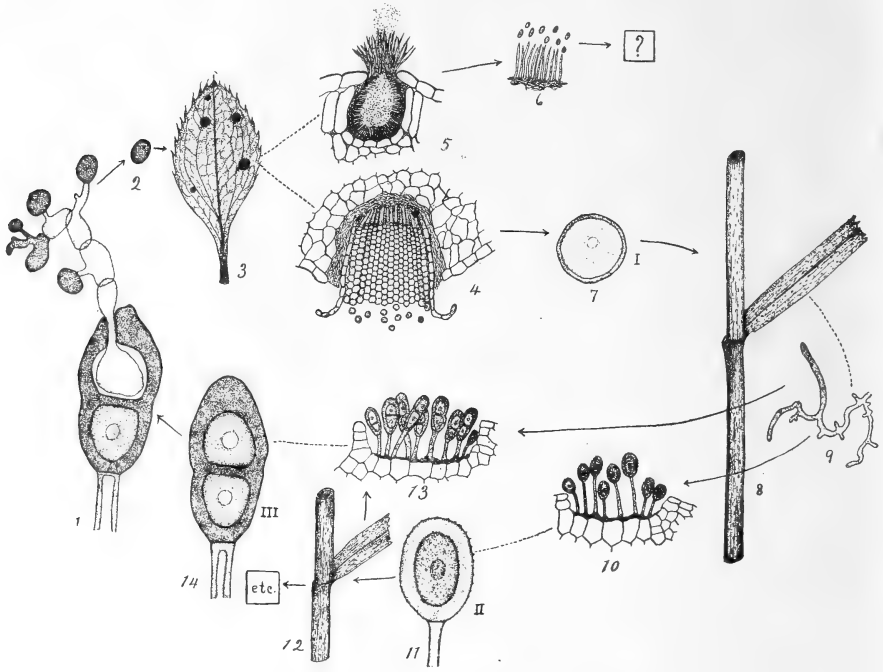


FIG. 6. — LIFE HISTORY OF PUCCINIA GRAMINIS.

1. Teleutospore with basidium (promycelium). 2. Basidiospore (Sporidium,) uninucleate. 3. Barberry leaf with rust spots. 4. Aecidium (clustercup). 5. Pycnidium (spermogonium). 6. Conidia (spermatia) from the spermogonium. 7. Aecidiospore (binucleate). 8. Stalk of wheat showing rust pustules. 9. Mycelium from which the uredo and telento spores are developed. 10. Uredosorus with uredospores. 11. Uredospore. 12. Stalk of wheat showing rust pustules. 13. Teleutosorus with teleutospores. 14. Teleutospore.
The aecidiospore (I.), Uredospore (II.), and teleutospore (III.) drawn on same scale.

2. Under low power draw a spot showing the æcidia — cup-like bodies containing the æcidiospores.

3. Under low power examine a spot on the upper side of the leaf and note the little crater-like openings, which are the necks of sac-like bodies, called "spermogonia" (pycnidia), containing thread-like hyphæ. Draw.

4. By means of strips of carrot and a razor cut cross sections of the leaf, mount, and study under low power. Under high power draw an æcidium, showing the æcidiospores. How are they developed? Draw a spermogonium with conidia.

Uredo stage.

5. Under low power, study the diseased spots on the leaves and stems of wheat (*Tríticum vulgàre* L.). Draw a patch, showing how the spores break thru the epidermis.

6. Pick out some uredospores with a needle, or if fresh material is at hand cut cross sections of the stem, mount, and draw the uredospores under high power.

Teleuto stage.

7. Under low power draw a piece of wheat stem containing the black patches of teleutospores.

8. Pick out some of the teleutospores, or cut cross sections of the stem, mount, and draw a number of spores under high power. Note that the spore is made up of two cells. Study variation in individual spores.

Basidium stage.

9. It is difficult to germinate rust spores in artificial cultures. They germinate most readily in spring when those in the field are germinating. Germinate teleutospores in a drop culture and study the development of the promycelium (basidium) bearing basidiospores. Draw and describe.

10. Describe in detail the mode of growth and life history of this rust, noting especially the presence of heterecism.

XXXIX. (a) **Fòmes applanàtus** (Pers.). (*Elfvìngia megalòma* (Lev.).

Phylum, Mycophyta. Class, Basidiomycetæ. Order, Agaricales. Family, Polyporaceæ.

This fungus is common on logs and stumps, forming semi-circular brackets or shelf-like bodies from a few inches to a foot or more in width. It is of a grayish-brown or white color and may be collected at any season of the year.

1. Draw the entire fruiting body and describe. The vegetative mycelium is in the wood from which the fruiting body projects.

2. Under low power study a patch of the pores on the under side, by simply laying the fungus on the stage of the microscope and focusing properly. Draw.

3. From a fresh specimen cut cross sections of a piece of the pore-bearing layer, mount, and study the basidia projecting into the cavity of the pores. How many spores on each basidium. Draw a single spore.

4. Mount some of the brown, woody mycelium from the upper part of the fruiting body. Draw and describe the structure of the fungus.

5. Is the plant a parasite or a saprophyte? Notice the position of the hymenium (pore-bearing surface) in relation to the surface of the earth. Is the mycelium of the fruiting body irritable to the force of gravity? Is there any advantage in this?

(b) **Polystíctus cinnabarìnus** (Jacq.). Family, Polyporaceæ.

This bracket fungus is very common on dry decaying logs and branches and is easily recognized by its bright red color, especially prominent on the under side.

1. Make a sketch of the entire fruiting body.

2. Under low power draw a patch of the lower surface showing the pores. Note especially the bright red color and compare it with the red color present in many flowers, fruits and roots. How do you explain the presence of the color?

XL. **Psalliòta campéstris** (L.). (Agaricus). Common Meadow Mushroom.

Class, Basidiomycetæ. Order, Agaricales. Family, Agaricaceæ.

This edible toadstool grows in open, grassy places in fields and rich pastures. The so-called "bricks" of "spawn" can be obtained from seedmen and will keep for some time when in a dry condition. It can be cultivated by making beds of the proper character in a cellar or greenhouse, or in the open air in gardens. The fruiting bodies may be preserved in 70 per cent. alcohol.

1. Take some of the white filaments or strands from the ground in which the fungus is growing or from a brick of spawn, tease it out with needles and mount in water. Examine under low and high power. Note the numerous hyphæ of the mycelium and draw. This is part of the vegetative mycelium which takes up the nourishment from decaying substances in the soil.

2. Examine "button mushrooms" of various sizes and make a series of naked eye sketches showing how the button develops into the mature fruiting body or toadstool.

3. Study and sketch the mature fruiting body, showing the cap or pileus with gills on the under side, and the stalk with the annulus. Note the irregular fringe at the margin of the pileus.

4. Find the origin of the annulus and the fringe at the margin of the pileus by studying the veil or vellum of a fruiting body in which the pileus is just beginning to expand.

5. Cut off the pileus of a mature fruiting body and place it gills downward on a piece of white paper. In this way a spore print may be obtained in a few hours. Sketch the spore print.

6. Mount some of the spores and draw under high power. Color and shape?

7. Carefully cut cross sections of the gills of a pileus in which the spores are not quite mature. Mount and study under high power. Draw a part of the hymenial layer (spore-bearing layer), showing the paraphyses and the larger basidia, each of which bears two spores.

XLI. **Bovísta plùmbea** Pers. Class, Basidiomycetæ. Order, Lycoperdales. Family, Lycoperdaceæ.

This puffball of a dark-brown color, when mature, is usually abundant in pastures, where it may be gathered in any season. It has a more or less spherical body, usually from one-half to one inch in diameter.

1. Sketch one of the fruiting bodies, showing the inner peridium with an aperture at the apex for the discharge of the spores.

2. Pick out some of the internal mycelium (capillitium) and after moistening with alcohol mount in water. Under high power draw some of the dichotomously branched mycelium and some of the spores. Describe. How does this plant obtain its nourishment?

XLII. **Lichenes.** The lichen fungi belong to the phylum Mycophyta, the lichen algæ to the Schizophyta and the Gonidiophyta.

Lichens grow on the bark of trees, on wooden fences, on rocks and on the ground. The common forms may be collected at any time and kept indefinitely in a dry condition in wooden or paper boxes. Lichens are associations of fungi and algae. They represent a condition of symbiosis known as helotism, i. e., the lichen fungus is a slaveholder, the algæ are slaves.

(a) **Parmèlia cylísphora** (Ach.). (*P caperàta* (L.)). Subclass, Discolichenes. Order, Cyclocarpales. Family, Parmeliaceæ.

This lichen is of a light green color and is very abundant on trees and fence boards and rails, forming large circular thalli often a number of inches in diameter.

1. Study the naked eye characters of the thallus. Draw a part of the thallus, showing the margin.

2. Soak the thallus in water and tease out a small piece on the slide with needles. Study under high power. Notice two kinds of cells, colorless septate hyphæ, the lichen fungus, and green spherical cells, the lichen algæ. Draw a piece of the mycelium and some of the algæ. To what group do the algæ belong? How are the algæ and the fungus hyphæ arranged in the lichen thallus?

3. Draw two or three algæ, showing the manner in which the fungus grows around the green cell to obtain its food.

4. Vegetative propagation. The alga and the fungus each reproduces itself in the manner peculiar to its species, but the lichen may also propagate itself directly by means of little granular flakes produced on the upper surface of the lichen thallus, known as soredia. Mount some of the granular material in water and examine under low power; notice in favorable specimens that the fungus and algæ are both present in the soredium. Draw and describe.

(b) **Lobària amplíssima** (Scop.). (Sticta). Subclass, Discolichenes. Order, Cyclocarpales. Family, Stictaceæ.

This is a foliaceous lichen of a light gray color which grows on the bark of trees in forests.

1. Soak the thallus in water and note the change in color of the upper surface. Make a sketch showing the position of the brown disk-shaped or cup-shaped apothecia.

2. With a razor, cut free hand cross sections of a piece of the thallus containing an apothecium. Hold the piece between two strips of carrot. Mount the sections in water and under low power draw, showing the green algal layer, the white layer and the position of the apothecium.

3. Under high power study the hymenial layer of the apothecium. Draw one of the asci containing spores. Describe. How many spores? Draw a single spore. Draw one of the paraphyses.

(c) **Dermatocàrpon miniàtum** (L.). (Endocarpon). Subclass, Pyrenolichenes. Order Pyrenulales. Family Dermatocarpaceæ.

This lichen with a rather leathery thallus is common on limestone, where it may be obtained at any time of the year.

1. Lay the thallus on the slide without a cover-glass and examine under low power. Draw a part of the thallus, showing the pores which open into the perithecia below.

2. Cut cross sections of the thallus and mount in water. Sketch under low power, showing the algal and fungal layers and the perithecia.

3. Draw one of the perithecia under high power; also an ascus containing spores.

(d) **Cladònia rangiferìna** (L.). Reindeer Lichen. Subclass, Discolichenes. Order, Cyclocarpales. Family, Cladoniaceæ.

This lichen grows on the ground and is generally present on high wooded hills or slopes where it often forms large masses.

1. Sketch and describe a large specimen.
2. Draw a branch showing the apothecia on the branchlets.

(e) **Collema nigrescens** (Leers). Subclass, Discolichenes. Order, Cyclocarpales. Family, Collemaceæ.

A widely distributed, dark colored lichen growing on the bark of trees and on moss.

1. Sketch the foliaceous body, showing the small circular apothecia.
2. Moisten a small piece of the lichen, tease it out with needles, mount and note the chains of Nostoc cells and the fungus hyphæ. Draw.
3. Tease out some of the asci or cut sections, mount and draw under high power. How many spores in an ascus? How many cells in an ascospore?
4. Tease out a part of a young lobe of the thallus and also cut sections; mount and examine for slender hyphæ which are coiled at the base. These are the so-called carpogonia, the slender projecting part being the trichogyne. In the sections spermogonia, small hollow bodies, may also be found. These bear spermatia on the hyphal branches lining the walls of the cavity. Draw and describe.

THREE INTERESTING GREEN ALGÆ.

XLIII. **Oedogònium crìspum** (Hass.). Phylum, Gonidiophyta. Class, Conferveæ. Order, Oedogoniales. Family, Oedogoniaceæ.

This plant grows either upon or beneath the surface of ponds and pools, usually attached to various solid objects. It fruits most abundantly during May and June, and will grow well in aquaria.

1. Mount some of the filaments in water and examine under low power. Note that the filaments are unbranched and have a definite holdfast at the base. Draw.
2. Draw one of the cells under high power, showing the chloroplast with pyrenoids and the nucleus. Draw the basal cell (holdfast).
3. Nonsexual spore reproduction. If the filaments are in proper condition, any cell may develop into a zoospore and escape from the cell wall. Draw an empty cell. Draw a free-swimming zoöspore. These have a circle of short flagella or cilia. Draw a zoöspore which has settled down and enlarged and is developing a holdfast at the base.
4. Sexual reproduction. Note the ovaries or oogonia, large cells each with an oosphere filled with food material. Draw. Find the opening at the base for the entrance of the spermatozoid. Draw a spermary or antheridium, usually consisting of two or three very short cells each of which give rise to two spermatozoids
5. Look for escaping spermatozoids and for spermatozoids which have entered the oogonium.
6. Draw an oogonium containing a ripe, thick-walled oospore.

7. When the oospore germinates it divides into four cells, each of which develops into a zoospore. The zoospores settle down and develop into new Oedogonium plants. An attempt should be made to have oospores germinate in a dish of water so that the above mentioned process may be studied. If this stage it at hand draw and describe carefully.

8. Write out the life cycle of this plant in the notes, giving the stages in proper order and noting that the plant has two definite stages in its history—the gametophyte and the sporophyte.

XLIV. **Oedogònium borisiànum** (LeCl.). Family, Oedogoniaceæ.

This species grows in stagnant brooks or in ponds and ditches, usually attached to solid objects. The plants are coarse unbranched filaments and they may be grown in an aquarium.

1. Mount in water and study under low power. Note the long unbranched filament and the basal cell expanded into a holdfast. Under high power draw the tip of a filament, several intermediate cells, and the holdfast. At the summit of certain cells broad zones with peculiar ring-like striations may be seen. This is where cell division has taken place. Draw.

2. Draw a single cell, showing a chloroplast with pyrenoids and the nucleus.

3. Study vegetative cells in which the zoospores are developing. These can be seen especially in the morning or in material which has been chilled over night. Draw a single, large zoospore with a circle of short flagella or cilia around the hyaline anterior end.

4. Draw part of a filament, showing ovaries or oogonia, some with an oosphere and an opening in the wall for the entrance of the spermatozoid, and others with thick-walled oospores. Note one or more dwarf males attached to the cell below the ovary.

5. Draw some of the so-called andro-sporangia, which consist of two to five short cells. These cells give rise to zoospores known as androspores, which settle down on the cells below the oogonia and develop into dwarf male plants.

6. Draw part of a filament with ovaries or oögonia and one or more mature dwarf males. Note the large basal cell of the dwarf male and the more slender spermary or antheridium composed of a number of cells.

7. When the oospore germinates after a period of rest the cell breaks out in a delicate sac and divides into a four-celled body (the sporophyte) which gives rise to four nonsexual zoospores. If material is at hand, study and draw.

8. Write out a careful description of the entire life history of this plant, noting especially that it has an alternation of generations.

XLV. **Coleochaete pulvinàta** A. Br. Class, Conferveæ. Order, Coleochætales. Family, Coleochætaceæ.

Several species of Coleochæte are to be round growing attached to the surface of various submerged, fresh water plants. The species mentioned above forms hemispherical masses of closely packed, branched filaments. These masses are large enough to be seen with the naked eye and should be looked for on the petioles or laminæ of water lilies and other hydrophytes.

1. Pick off some of the smaller and larger masses with a scalpel, mount, and examine under low power. Under high power draw a part of the branching filaments, showing the joint-like cells, each with a nuculeus, chloroplast, and pyrenoid, and some with long, narrow, hair-like projections sheathed at the base.

2. Look for nonsexual reproduction by means of zoospores, a single one being produced in a cell. If these are present draw and find how they escape from the cell.

3. Draw the mature ovary or oogonium, showing the oosphere and long slender, open neck. How different from Batrachospermum?

4. Draw one of the spermaries or antheridia, which are terminal or lateral flask-shaped cells of peculiar form easily distinguished from the vegetative cells. Each antheridium produces a single, biflagellate spermatozoid. Compare with Batrachospermum.

5. Draw a mature spermatozoid either free or in the spermary.

6. Draw an oogonium in which the egg has been fertilized, and around which branches are developing from the base.

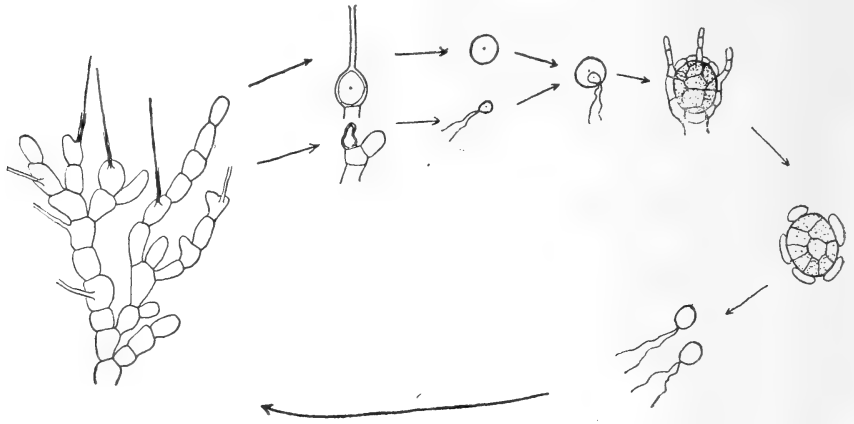


FIG. 7. — LIFE CYCLE OF COLEOCHÆTE.

7. Draw an ovary containing a ripe oospore and cortical layer of close-fitting branches.

8. From material gathered in early spring or from prepared slides, study fruiting bodies in which a small sporophyte has developed by the division of the oospore into a number of cells. Note the advance of the sporophyte over that of Oedogonium. How many cells does it contain?

9. Each cell of the small, oval sporophyte develops a zoospore, which after a period of activity settles down and develops into a new Coleochæte thallus. It is evident from the above that the entire sporophyte of Coleochæte is sporogenous.

10. Make a diagram in the notes, showing the life cycle of Coleochæte. See Fig. 7.

11. If material is at hand study the flat, disk-like thallus of *Coleochæte scutàta* Bréb. Draw under high power and describe.

12. NOTE. — The Coleochætaceæ are the Algæ which are most like the plants of the next higher sub-kingdom. On account of the similarity of the body and the life cycle, the ancestors of the lowest liverworts of the present time are supposed to have been plants which, with the exception of the sexual organs, were something like these Algæ. It must not be supposed, however, that Coleochæte represents an intermediate ancestral stage of the liverworts; for, as will appear from the following study, there are very fundamental differences.

SERIES II — ARCHEGONIATA.

SUB-KINGDOM AND PHYLUM, BRYOPHYTA.

XLVI. (a) **Ríccia flúitans** L. Phylum, Bryophyta. Class, Hepaticæ. Order, Marchantiales. Family, Ricciaceæ.

This liverwort has a small, linear, dichotomously branched thallus which grows floating in ponds and ditches. It also grows in wet places upon the ground, sometimes in cultivated fields. The plant keeps well along with other hydrophytes in a covered, glass jar of water.

1. Mount a small thallus or frond (gametophyte) in water and examine under dissecting microscope. Make a sketch of the plant and describe.

2. Draw a branch of the thallus under low power, showing the air cavities and cellular structure. Note that this thallus is not made up of branching or interwoven filaments, but that it is a true solid aggregate. Most of the thallophytes are either simple or complex linear aggregates.

3. The aquatic form of this plant is usually sterile. In order to study the sexual organs and sporophyte to advantage, examine prepared slides of Ricciocarpus.

(b) **Ricciocàrpus nàtans** (L.). Family, Ricciaceæ.

This plant forms a small, obcordate thallus which floats on the surface of ponds and swamps. The individuals are hermaphrodite and develop the reproductive organs in the spring and summer.

1. Sketch the thallus under dissecting microscope. Describe.

2. Under low power draw part of a section from a prepared slide, showing an anteridium. Draw part of a section, showing the archegonium (ovary) containing the oosphere.

3. Draw an enlarged archegonium (ovary) with the spherical sporophyte, containing a wall one layer of cells in thickness, with the sporocytes lying free in the interior.

4. From older stage draw spore tetrads and mature spores under high power.

5. If prepared slides are not at hand, cut freehand sections of plants (with the aid of strips of fresh carrot roots) with male and female organs and draw an antheridium (spermary) and an archegonium (ovary) under low power. Also cut sections of a plant containing a sporophyte and some free spores.

6. Compare the sporophyte with that of Coleochæte and note the beginning of sterilization of the tissue of the sporophyte. Compare also with Polysiphonia. The antheridium and archegonium may be compared with the plurilocular sporangia of Ectocarpus. They are not at all like the sexual organs of the higher green algæ.

7. Make a diagram in the notes as shown in Fig. 8, which represents the general life cycle for all plants above the thallophytes. Note especially that the diagram represents a life cycle with a true antithetic alternation of generations.

XLVII. **Marchántia polymòrpha** L.

Class, Hepaticæ. Order, Marchantiales. Family, Marchantiaceæ.

This thalloid liverwort is common on moist rocks and earth, especially on cliffs and around springs. Marchatia as well as Conocephalus and Lunularia

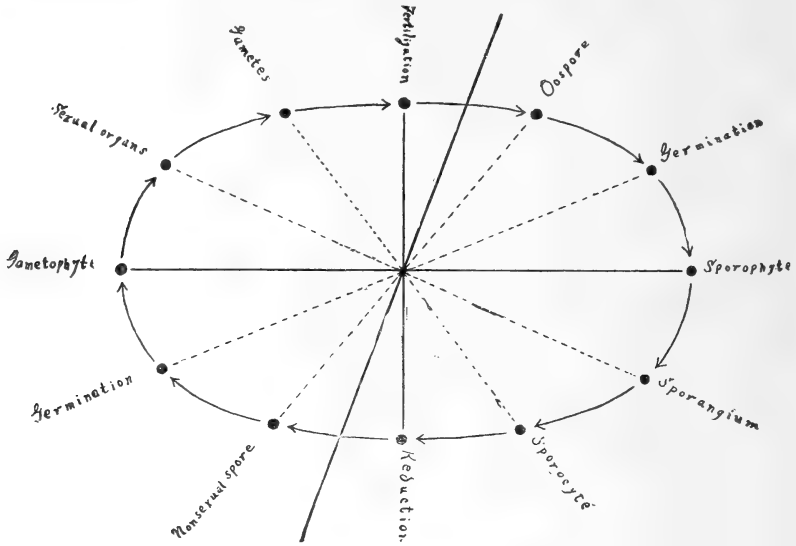


FIG. 8. — DIAGRAM SHOWING PRINCIPAL STAGES IN THE LIFE CYCLE OF THE HIGHER PLANTS.

can be kept without any trouble in a greenhouse or window garden, provided, they are supplied with sufficient moisture and shaded from intense light by a curtain. Material may be preserved in 70 per cent. alcohol or in the copper salt solution.

Gametophyte.

1. Take a thallus (frond) and notice its dorsiventral position on the ground. Make a naked eye sketch, showing the dichotomous branching, the central groove, and the emarginate growing points. Describe. How is it fastened to the ground? How does the thallus continue its development? How is vegetative propagation accomplished?

2. Under dissecting microscope study the upper surface. Notice that it is mapped off into diamond-shaped areas (areolæ), each with a small opening in the center (air passage). Draw a patch of the surface.

3. Study the upper surface under low power without a cover glass, by simply laying the thallus on the slide. Draw several areolæ carefully. The areolæ represent compartments or cavities in the upper surface of the thallus. The thallus should be kept moist on the under surface as it withers very rapidly.

4. Notice the numerous rhizoids on the under surface. Where are they the most numerous? Mount some in water and draw the three types under high power — one with smooth wall, one with scattered peg-like projections in the interior, and one with somewhat spirally-arranged projections. Of how many cells does each rhizoid consist? Of what use are the rhizoids?

5. With a scalpel or knife cut off some of the minute ventral scales arranged in two parallel rows on the under side and forming the central ridge. Mount and draw.

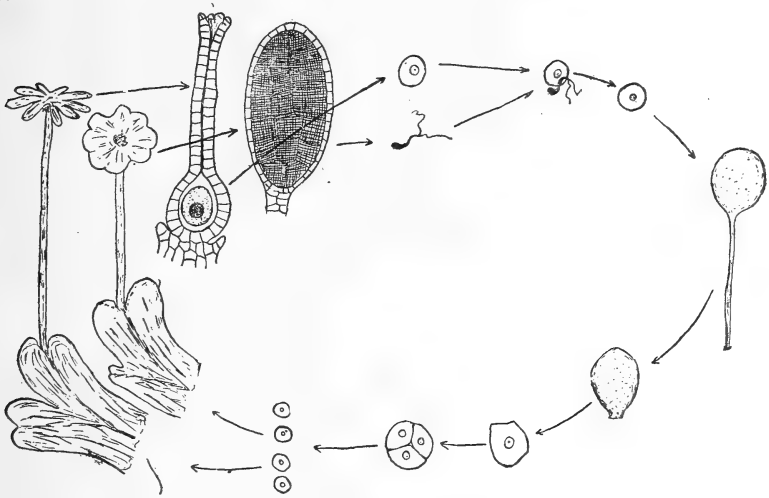


FIG. 9. — LIFE CYCLE OF MARCHANTIA.

6. Some of the thalli will show brood-bud cups. Under dissecting microscope or low power draw one of the cups containing brood-buds (gemmæ). This is a special method of vegetative propagation.

7. Mount some of the brood-buds and draw. Notice the two opposite growing points and the place where the brood-bud was attached to its stalk.

8. Cut cross sections of the thallus thru a cup, with a razor, and under high power study the development of the brood-buds. Describe.

9. Cut cross sections of the thallus and examine under high power. Where is the main part of the chlorophyll? Draw part of a section, showing the walls of the cavities below the areolæ, the peculiar chimney-like air passages, the short filaments containing the chloroplasts, and the cellular tissue below the cavities. These details can be worked out better from prepared slides, which should be studied if available and the free hand sections used merely for comparison.

10. Reproductive branches. Draw a plant with an archegoniophore and one with an antheridiophore. Describe both. Is Marchantia hermaphrodite or unisexual?

11. Under high power study prepared slides of cross sections (cut at right angles to the surface of the disk) of the antheridiophore. Draw an antheridium (spermary), showing the wall, stalk, and the numerous minute cubical mother cells in the interior, each of which will produce two spermatids which develop into spermatozoids. About how many cells in each antheridium? How many antheridia in each disk? Do they all develop at the same time? Notice the openings to the pockets in which the antheridia are situated. About how many spermatozoids are there produced in one antheridiophore?

12. In case no prepared slides are available, cut free-hand sections, mount in water, and study and draw the antheridia under low and high power.

13. From prepared slides study sections of the archegoniophore. Draw an archegonium (ovary), showing the lid cells, the neck, the neck canal, the venter, the oosphere and the incept of the perigynium (incipient perigynium). Draw the venter of an archegonium showing the ventral canal cell and the incipient oosphere.

14. In case no prepared slides are at hand cut sections of the appendaged disk of the archegoniophore, mount in water, and study the archegonia under low and high power.

15. If male Marchantia plants with properly developed antheridiophores are protected for several days in such a manner that no water will come onto the disks containing the antheridia, active spermatozoids may be obtained in the following manner. Place a drop of water on the upper surface of the disk and after a short time take it up with a medicine dropper and mount, or squeeze out several disks on a slide and mount in water. Under high power numerous motile spermatozoids can be seen, each with two flagella. Study their motion for some time, then stain with a small drop of iodin solution and draw.

Sporophyte.

16. Carefully pick out a young light-colored sporophyte inclosed in the perigynium, an older stalked one which appears green, and a nearly mature, yellow-colored one from the under side of the archegoniophore, mount in water and draw under low power, showing the sporangium, stalk, and foot. Describe.

17. If fresh material is available, place a mature sporophyte, which has a ruptured sporangium, on a slide without cover-glass and examine. Breathe gently toward the specimen while making observations. Describe.

18. Under high power draw sporocytes hanging together in chains, and spore tetrads from crushed sporangia, also some mature spores. Draw one of the elaters. What is their function?

19. Make a diagram in the notes showing the life cycle of Marchantia. See Fig. 9.

20. Ecological Note. Describe how the air passages and the character of the nonsexual spores show that Marchantia is adapted to an aerial habitat.

XLVIII. **Other Thalloid Liverworts.**

(a) **Conocéphalus cónicus** (L.). Family, Marchantiaceæ.

1. Study the thallus of Conocephalus and compare in general with Marchantia. Draw.

2. Under dissecting microscope, draw part of the surface showing the areolæ with air passages. How do they compare in size with those of Marchantia?

3. Under low power without cover-glass, draw an areola showing the crater-like air passage. Does Conocephalus have any brood-bud cups?

(b) **Lunulària cruciàta** (L.) Family Marchantiaceæ.

1. Study the thallus of Lunularia and compare with Marchantia and Conocephalus. Notice especially the numerous semilunar brood-bud cups.

2. Draw a plant under the dissecting microscope, showing several cups.

3. Under low power draw several areolæ. How many methods of vegetative propagation has Lunularia? Is there much need for sexual and nonsexual spore reproduction?

XLIX. **Porélla platiphýlla** L. (Bellincinia).

Class, Hepaticæ. Order, Jungermanniales. Family Jungermanniaceæ.

This rather large, scaly liverwort is very abundant on the bark of trees. It may be kept for a long time in good condition in a paper box.

Gametophyte.

1. Moisten a branch of the frond in water and sketch from the upper or dorsal side under the dissecting microscope, showing the arrangement of the lateral scales.

2. Pick off some scales, being careful so as not to tear off the small, lower, ligulate lobe which may be seen under the large upper lobe of the scale. Draw under low power, showing both lobes of the scale. How many cells in thickness is the scale? Is there any midrib? Why is this scale not homologous with the leaf of a fern or one of the higher plants? The scales are partly analogous to leaves.

3. Draw a few cells under high power. Of what advantage are the thick walls?

4. Examine the lower or ventral side of a branch under dissecting microscope and note the semicircular ventral scales. Look for rhizoids. Mount one of the ventral scales and draw under low power.

Sporophyte.

5. Examine a frond containing little yellowish, club-shaped bodies. These are the sporophytes. Carefully pick out one which has the sporangium unbroken and one which shows the wall of the sporangium split into four valves. Mount in water and draw both under low power, showing the sporangium, the foot and the stalk.

6. Draw a spore and an elater under high power.

7. Compare the thallus of Porella with that of Marchantia, noting especially the different ways in which the two thalli have been specialized for the work of photosynthesis.

L. **Sphágnum cymbifòlium** (Ehrb.).

Class, Sphagneæ. Order, Sphagnales. Family, Sphagnaceæ.

The peat or bog mosses grow in and near water in swamps, bogs, and other wet places. The species named above is unisexual, the male plant being more slender than the female. Collect plants with sexual organs in winter and early spring and sporophytes in spring and summer.

Gametophyte.

1. Take a small mass of dry sphagnum, soak it in water and notice the enormous quantity it will absorb.

2. Make a sketch of a female frond. Notice that the frond keeps growing at the top and dying below.

3. Sketch a branch under low power, showing the arrangement of the scales. Draw a single scale. Is there any costa (midrib)?

4. Under high power draw a patch of cells from a scale, some with chlorophyll and some showing the peculiar spiral and ring-shaped thickenings on the inner surface of the wall.

5. Mount a piece of the main stem in water and examine under low power. Draw, showing a central brown cylinder and a cortical layer of clear, large cells with spiral thickenings.

6. Cut off some of the clavate branches at the tip of the male plant, mount, and sketch under low power. Pull off the scales carefully, mount, and examine the antheridia ,spermaries). Draw an antheridium under high power.

7. From a female plant carefully cut out an enlarged archegonium (ovary) containing a young sporophyte. Mount and draw under low power, showing the neck at the summit. Around the base some small archegonia may usually be seen. Draw one of these, showing the stalk, venter, neck and lid cells.

Sporophyte.

8. Pick out a young sporophyte showing the spherical sporangium, the very short stalk and the expanded bulbous foot.

9. Cut off one of the slender pseudopodia containing a nearly mature sporophyte. Sketch under low power showing the sporophyte with sporangium and operculum, and the expansion at the top of the pseudopodium into which the foot fits.

10. Draw some of the non-sexual spores under high power.

11. From prepared slides make a drawing of a longitudinal section of the sporophyte, showing all the details of the structure.

12. Study and draw an apical cell from a branch of the gametophyte, from a prepared slide.

LI. **Mosses, General Study.** Class, Musci. Order, Bryales.

(a) **The juvenile gametophyte.**

When the nonsexual spore of a moss germinates it does not give rise directly to the mature scaly gametophyte, but develops a green filamentous pro-embryo known as the protonema. The protonema can always be found in connection with the very young moss plants which are usually present in greenhouses. The protonema may also be found by examining some of the black earth from a place where mosses are growing. The ripe spores of any common species of moss may be sown on moist soil in a box. In a few days, if the box has been covered with a pane of glass, an abundance of green filaments will begin to appear.

1. Place a little earth with young moss plants into a watch glass and carefully wash off the soil by means of the medicine dropper and needle. Mount the plantlets and any minute masses of filaments present. Examine under low power. Find a good protonema and draw. Notice the branching, the shape of the cells, and the chloroplasts. The similar brown filaments present are rhizoids.

2. Draw a single cell, showing the wall, the cytoplasm, and the chloroplasts. Notice the oblique walls which may be seen in the older filaments. Where and how do the branches originate?

3. Find a protonema which has developed one or more solid green buds from which the mature sexual moss plants will develop. Draw.

4. With what kind of plants previously studied does the protonema compare? What then could you call the protonemal stage? How can this be used to explain the evolution of a moss as to habitat, form, and structure? Explain its evolution on this basis; remembering that the protonema is (1) a single cell, (2) a simple filament. (3) a branched filament; and that (4) it finally develops solid buds. These four stages represent the four successive steps in the evolution of the plant body in going from the lowest unicellular forms to the liver-

worts. Ontogeny is supposed to partly explain phylogeny. Learn the following law: The history of the development of the individual is an abbreviated history of the development of the race to which it belongs.

(b) **The young scaly moss plant.**

Physcomitrium turbinàtum (Mx.) (nearly always abundant in greenhouses, by roadsides, and in old fields) or a species of *Mnium* will be suitable.

1. Mount in water and sketch the entire frond under low power, showing the stem, scales, and rhizoids.

2. Draw a single scale, carefully showing the costa and the margin. How does it differ from the scale of Porella? Under high power draw a cell showing the large chloroplasts and thick wall. As in the liverworts these scales are not homologous with true leaves.

3. Draw a branch of a rhizoid. How do these rhizoids differ from those of Marchantia? What relation is there between the rhizoids and protonema?

LII. **Polýtrichum commúne** L. Common Hair-cap Moss.

Class, Musci. Order, Polytrichales. Family, Polytrichaceæ.

The common hair-cap is a widely distributed moss which grows on the ground in old fields and meadows, on hillsides and in woods. The plants are well preserved in a fruit jar with 70 per cent. alcohol, and collections should be made at various times from winter until early summer when the sporangia are mature. The plants are unisexual and the material for study should include mature male and female plants, female plants with the embryo sporophyte developed just far enough to rupture the calyptra, and female plants with mature or nearly mature sporophytes.

Gametophyte.

1. Draw the male and female plants (fronds) of the gametophyte generation, showing the rhizoids, scales, and tip. If the plants are dry or taken from alcohol, moisten in water. Note the rosette of red scales at the tip of the male branch and also the slender green scales at the tip of the female branch. Why this great difference between male and female?

2. Take the tip of a mature male branch and dissect it with needles in a watch-glass, mount the detached parts and examine under low power. Notice the paraphyses and the white club-shaped antheridia (spermaries). Do not mistake spatulate paraphyses for antheridia. Draw an antheridium under high power. Draw a spermatozoid from a ripe antheridium.

3. Study the living spermatozoids. These may be obtained if suitable male branches are collected after several days of dry weather. Take one of the branches and squeeze out the antheridia onto a slide. Mount in water and observe the motile spermatozoids.

4. If material is at hand, study and draw antheridia from a stained permanent mount.

5. Dissect the tip of a female plant, mount the detached parts from the center, and examine under low power. Draw an archegonium (ovary) under high power, showing lid-cells, venter, and stalk. In good specimens the oosphere may be seen.

6. If convenient, study prepared slides containing archegonia. Draw, showing the stalk, venter, oosphere, neck, neck canal, and lid-cells.

7. Cut cross sections of the scaly stem of a large specimen (using pieces of carrot and razor), mount in water and examine under high power. Draw, representing the epidermal layer, band of peripheral sclerenchyma, inner cortical layer of thinner-walled cells, and central strand.

Sporophyte.

8. Select a female plant with a young sporophyte, pull off the calyptra and then pull out the young sporophyte, being careful not to tear off its foot. Sketch the calyptra under the dissecting microscope. What does the cayptra represent? Sketch the young sporophyte under dissecting microscope, showing three regions—foot, short stem, and tip. Remember that the mature sporophyte of Marchantia has three parts.

9. Draw a mature sporophyte of Polytrichum, showing the foot, the stalk or seta, the hypophysis, and the sporangium or capsule. What important advance has the sporophyte of Polytrichum and other mosses made over those of Marchantia and Sphagnum? Note that the sporophyte is a parasite during its entire life. Does it manufacture any food for itself?

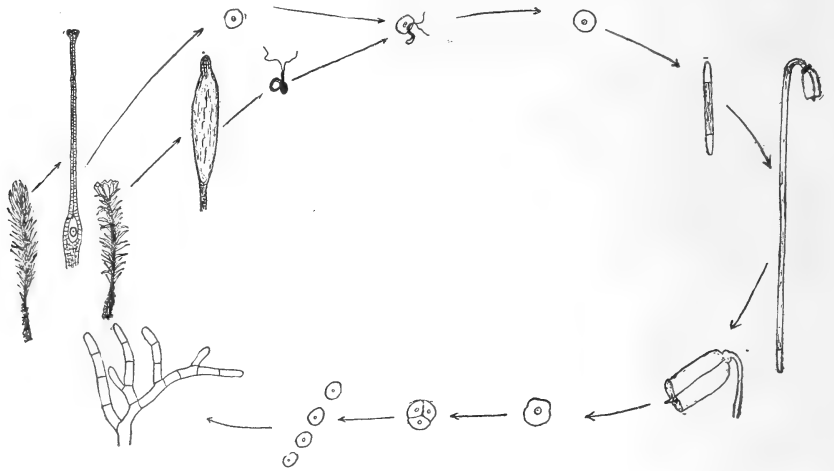


FIG. 10. — LIFE CYCLE OF POLYTRICHUM.

10. Cut cross sections of the seta, mount, and draw under high power, showing the epidermal layer, the band of sclerenchyma, the layer of thin-walled parenchyma, and the central strand. The central strand of the sporophyte may be compared with the vascular bundle system of higher plants.

11. Ecological note. The hair-cap mosses are subject to great extremes of moisture and dryness. Let a gametophyte dry out and then place in water. What occurs? What adaptation has Polytrichum for checking the rapidity of evaporation?

12. Make a diagram in the notes showing the life cycle of Polytrichum (see Fig. 10).

LIII. **Other Mosses.**

(a) **Hýpnum radicàle** Beauv. (*Amblystègium vàrium* (Hedw.).

Order, Hypnales. Family, Hypnaceæ.

This is a common moss on decaying logs, in moist, shady places, and on wet ground. Preserve in 70 per cent. alcohol. The sporophytes are mature in summer and autumn.

Sporophyte.

1. Take a nearly mature sporophyte, lay it on a slide and examine without cover-glass under low power. Pick off the calyptra if still attached and the operculum, being careful so as not to injure the delicate teeth of the peristone. Draw the operculum and the calyptra.

2. Study the hygroscopic movements of the teeth of the peristome by gently breathing on the slide while making observations. Describe the movements. Of what use?

3. Study the true stomata on the hypophysis. Make a sketch of the sporangium, showing the peristome and the hypophysis with stomata. The hypophysis may be compared with a leaf of the higher plants.

4. Cut open a sporangium longitudinally and mount. Examine under high power and draw a stoma, showing the two guard cells and some of the surrounding cells. Draw several of the teeth of the peristome and some of the non-sexual spores. How many teeth are there? Are they in one or two circles?

5. Cut a cross section of a green sporangium, mount and examine under low power. Sketch the section, noting the following structures: epidermis, hypodermal parenchyma, air space, spore sac, central columella.

(b) **Aulacómnium palùstre** (L.).

Order, Bryales. Family, Aulacomniaceæ.

This moss is common in boggy ground and may be found on charred logs and stumps or on the ground. Collect the material and grow in a moist chamber.

1. Under dissecting microscope make a sketch of a stem, modified in the upper part, the scales of which are easily detached. These scales act as brood buds, and when they fall to the ground are able to develop a protonema.

2. Mount some of the detached scales from near the tip and draw under low power.

(c) **Leptobrỳum pyrifórme** (L.). Long-necked Bryum.

Family, Bryaceæ.

This interesting little moss may be found on moist, shaded cliffs and on rocks near water. It is often very abundant and is easily cultivated in greenhouses, where the gametophyte may be obtained at any season. The rhizoids contain peculiar tuber-like brood buds of a dark-brown color. On the young sterile fronds these tuber-like bodies are often numerous, being produced on short rhizoids which come from the axils of the scales.

1. Crush the enlarged tip of a plant on the slide, mount in water and study under low and under high power. Draw an antheridium (spermary) and an archegonium (ovary); also one of the paraphyses. Note that this gametophyte is hermaphrodite. Compare with Polytrichum.

2. Mount and draw a mature brood-bud under high power, showing the structure. Describe.

3. Draw a rhizoid with an enlarged, light-colored end cell, the incept of the brood-bud.

A STUDY OF FORMS WHICH FORESHADOW SOME OF THE STRUCTURES DEVELOPED IN THE FOLLOWING SUB-KINGDOM.

LIV. **Splàchnum ampullàceum L.**

Class, Musci. Order, Bryales. Family, Splachnaceæ.

Altho this odd looking moss is not very common, an attempt should be made to obtain fresh or preserved material of specimens containing mature or nearly mature sporophytes. The plant grows on decaying animal tissue or excreta and is said to occur in cranberry swamps from Ohio to New Jersey and northward.

1. Sketch the entire moss, showing the gametophyte and the sporophyte with the sporangium and the very large, pyriform, fleshy hypophysis. Describe.

2. Sketch the capsule and hypophysis under low power, carefully representing the shape and surface details.

3. Examine the surface of the hypophysis under low and high power and note the stomata. Draw a small portion of the surface, showing stomata.

4. Note. — The large hypophysis covered with stomata and filled with loose tissue is well fitted for the work of photosynthesis and may be looked upon as foreshadowing the leaf structure found in the ferns and other higher plants.

LV. **Splàchnum lùteum** L. or **S. rùbrum** L.

These remarkable mosses are rather uncommon, and very few will probably be able to collect specimens; nevertheless an effort should be made to obtain fresh or preserved material of plants with nearly mature sporophytes. They are reported mainly from the Rocky Mountain region.

1. Under low power make a careful drawing of the sporophyte, showing the foot, the seta, the large umbrella-like hypophysis and the sporangium (Fig 11).

2. Draw part of the surface of the hypophysis under high power, showing the stomata. Are the stomata both on the upper and lower sides?

3. Compare the hypophyses of *Hypnum radicale, Polytrichum commune, Splachnum ampullaceum,* and *Splachnum luteum* and note the progressive development of the hypophysis as represented by these types. From this comparison it appears that the hypophysis may be regarded as a nascent, transpiratory and food manufacturing organ.

Fig. 11. Sporophyte of Splachnum luteum.

LVI. **Anthóceros laevis** L. or **A. punctàtus** L.

Class, Anthoceroteæ. Order, Anthocerotales. Family Anthocerotaceæ.

The hornworts are common on wet banks and sandstone ledges, especially around springs and shady places. The gametophyte is a small, lobed, more or less

disk-shaped thallus from which the sporophytes extend upward like small vertical horns. Preserve in copper salt solution.

1. Under dissecting microscope, sketch a gametophyte containing nearly mature sporophytes. Note the thick tubular sheath around the base of the sporophyte.

2. Mount a small piece of the thallus and under high power draw a cell showing the single large chloroplast. Compare these cells with those of Coleochæte.

3. Look for endophytic colonies of a blue-green alga (Nostoc) in cavities on the under side of the thallus.

4. Separate a sporophyte, which is just mature at the tip, from the gametophyte, being careful to keep the foot in a perfect condition, and sketch under low power. Represent the slender sporangium, the bulbous foot with wart-like outgrowths, and the short stalk with a growing zone between the foot and sporangium proper. Under high power note the stomata in the green tissue toward the base of the sporangium. Draw.

5. Study a sporophyte in which the tip of the sporangium has split open. Notice the columella.

6. Mount some of the spores and spore tetrads and draw under high power. Describe the spore tetrads.

7. If prepared slides are at hand, the details of the foot, the growing region, and the sporangium should be worked out. Note especially the arrangement of the elaters, which have a tendency to separate the cavity of the sporangium into transverse compartments.

8. Note. — The hornworts come nearer to the lowest ferns than any other Bryophytes and it is probable that the Broyophyte ancestors of the lowest Pteridophytes were something like a horned liverwort with perhaps a chlorophyll-bearing tissue arranged somewhat like the hypophysis of a Splachnum. Anthoceros also points to the Pteridophytes in that it has the sexual organs embedded in the thallus. In Splachnum and Anthoceros together appear five structures which foreshadow or anticipate important structures in the Pteridophytes. These are: (1) the bulbous foot and wart-like outgrowths of Anthoceros; (2) The central strand in the seta of Polytrichum and other mosses; (3) the intermediate growing zone at the base of the Anthoceros sporangium; (4) the large hypophysis of Splachnum with numerous stomata; and (5) the arrangement of the spores and elaters (sterile tissue) in the sporangium of Anthoceros.

SUBKINGDOM, PTERIDOPHYTA HOMOSPORAE.

A SERIES OF FERNS TO ILLUSTRATE THE EVOLUTION OF COMPLEX ORGANS FROM SIMPLE ONES.

LVII. **Ophioglóssum vulgàtum** L. Adder-tongue.

Phylum, Ptenophyta. Class, Filices. Order, Ophioglossales. Family, Ophioglossaceæ.

This simple fern is mature about the middle of June and may be found in moist meadows and thickets. The entire plant should be dug up and care taken so as not to injure any of the roots. Preserve in copper salt solution and press some for herbarium specimens. Altho fresh plants are preferable, preserved or dry herbarium specimens will answer very well.

Sporophyte.

1. Sketch an entire plant, carefully representing the four important regions of the sporophyte — sporangiophore, leaf blade, stem (short upright rhizome), and roots. Do the roots branch? Note the growing point at the summit of the rhizome from which new leaves are developed.

2. These four parts may be compared with the organs of a Splachnum sporophyte in a general way as follows:

a. The sporangiophore with the sporangium.
b. The leaf-blade with the hypophysis.
c. The stem with the seta.
d. The root system with the foot.

Compare also with Anthoceros, noting especially the growing bud in the stem.

3. Study the venation of the leaf under low power. Draw a portion and describe. Study and draw the stomata.

4. Mount a part of the nearly mature sporangiophore. Draw under low power, showing the sporangia. Under high power draw some of the nonsexual spores.

LVIII. (a) **Botrýchium símplex** Hitch. Little Grape-fern.

Class, Filices. Order, Ophioglossales. Family, Ophioglossaceæ.

This fern is to be found in moist woods and meadows and should be gathered about the middle of June.

1. Sketch the entire sporophyte from fresh or herbarium specimen and note the advance in complexity, over Ophioglossum, of the sporangiophore, leaf and roots.

(b) **Botrýchium lunària** (L.). Moonwort.

The moonwort is found in the northern part of the United States and usually grows in fields.

1. Sketch the entire sporophyte, showing the sporangiophore, leaf, roots and rhizome. Describe how this plant differs from the preceding.

(C) **Botrýchium negléctum** Wood. Matricary Grape-fern.

This fern grows in grassy woods and swamps and should be collected about the middle of June.

1. Sketch the entire sporophyte and note the advance in complexity over the moonwort.

LIX. **Botrýchium obliquum** Muhl. Oblique Grape-fern.

This evergreen grape-fern is widely distributed and may be collected in summer and autumn. Good herbarium specimens are satisfactory.

1. Sketch the entire sporophyte and note the advance in complexity over the preceding in the development of the sporangiophore, leaf and roots.

2. Study the venation of the leaf under low power. Is there any relation between the development of lobes and the venation?

3. Mount a branch of the sporangiophore and draw several sporangia under low power. Draw some of the non-sexual spores.

4. Ecological note. Notice the strong root-contraction and draw under dissecting microscope. How does the upright rhizome which continues to grow upward keep in the ground?

LX. **Botrýchium virginiànum** (L.). Virginia Grape-fern.

The Virginia grape-fern is common in rich woods and should be collected in the summer. Good herbarium specimens are satisfactory.

1. Sketch the entire sporophyte, showing especially the extreme complexity of the leaf. What relation is there between the ultimate segments of the leaflets and the venation?

2. Compare the last five plants in regard to the sporangiophore, the leaf-blade and the roots.

3. Cut cross sections of the rhizome, mount and draw a sector under low power, showing the wide cortex, the endodermis, the phloem, the cambium, the xylem (wood) with medullary rays, and the central pith. This type of vascular cylinder is called a siphonostele.

4. Cut longitudinal sections of the fleshy root tips, mount the central sections, and draw a tip showing the apical cell.

5. The gametophytes of the grape-ferns are subterranean and difficult to find. They are destitute of chlorophyll and have the appearance of minute tubers. If fresh or preserved material of the gametophyte of the Virginia grape-fern is at hand, study and sketch under dissecting microscope or low power, showing the general contour of the body and the rhizoids.

6. Note. — The advance from such forms as Splachnum and Anthoceros to Ophioglossum represents a vertical evolution, i. e., evolution upwards. The development indicated in passing thru the series of forms from Ophioglossum vulgatum to Botrychium virginianum represents a horizontal evolution. There is a close relationship among these ferns. It must not be supposed, however, that the latter has necessarily been derived directly from the former, but only that the ancestors of Botrychium were at one time in a condition as simple as Ophioglossum is at the present time.

GENERAL STUDY OF HOMOSPOROUS PTERIDOPHYTES.

LXI. **Ferns.**

(a) **Adiántum capíllus véneris** L. Venus-hair Fern.

Class, Filices. Order, Filicales. Family, Polypodiaceæ.

The venus-hair fern grows in ravines and is widely distributed, but very rare in the North. It grows very readily in greenhouses, and is extensively cultivated. The gametophytes may be found at almost any time on pots in greenhouses. They may be raised in large quantities by sowing spores on any well-prepared, moist ground.

Gametophyte.

1. Mount a fresh, heart-shaped thallus in water and sketch it from the upper side under dissecting microscope.

2. Study the rhizoids under low power and draw a single one under high power. Are they unicellular or multicellular?

3. Under high power draw a single cell of the thallus, showing the chloroplasts.

4. Examine the lower side carefully under low power and note the numerous antheridia (spermaries) and archegonia (ovaries). How are these organs distributed over the thallus? Under high power draw an antheridium and an archegonium (so much as can be seen of them above the surface of the thallus). Compare the thallus of Adiantum with Anthoceros and Marchantia. Note especially the comparatively small size of the gametophyte and that it is hermaphrodite.

5. Look for the large, spirally coiled spermatozoids moving in a ripe antheridium. Study free-swimming spermatozoids and draw. Describe the movement. The spermatozoids can usually be found on gametophytes of proper size and are often present in large number. Iodin will bring out the flagella.

6. If prepared slides are available, draw a section of a nearly mature antheridium, showing spermatozoids in various stages of development; also draw an archegonium, showing the neck, venter and oosphere.

7. Study young gametophytes and recently germinated spores. Note the protonema. Draw. Compare with the Bryophytes.

Sporophyte.

8. Sketch and describe the compound leaf.

9. Mount and draw a single leaflet under dissecting microscope, showing the general outline and the free, dichotomous venation. How does the character of the venation explain the notched and cut margin? Can the origin of the leaflets be explained from the same standpoint? Note that the tips of some of the lobes are bent under so as to cover the sporangia.

10. Under high power study and draw the stomata. Are they on the upper or lower surface or on both? Draw a single cell, showing the chloroplasts.

11. If slides are at hand draw a section of a young sporophyte embryo, showing four definite regions (quadrants).

12. Pick out a young sporophyte from the under side of an old gametophyte, and draw under lower power. Show the four regions, first leaf, root, bud and foot. Note that the young sporophyte is parasitic on the parent gametophyte, and that it acquires its independent life gradually.

13. Cut sections of the rhizome, stain and mount or use prepared slides. Note the general ground tissue and several, scattered, concentric vascular bundles. Draw.

(b) **Pterídium aquilìnum** (L.). (Pteris). Eagle-fern.

Family, Polypodiaceæ.

The eagle-fern grows on hillsides, especially in sunny places. The rhizomes should be preserved in alcohol.

1. Cut cross sections of the rhizome, mount, and sketch under dissecting microscope, representing the following structures: the band of external or cortical sclerenchyma, the pith or ground tissue, internal sclerenchyma (stereome) in two large, brown bands and in smaller patches, and the concentric fibro-vascular bundles —usually three large ones and a number of smaller ones. Note the two lateral ridges. How do you account for the dorsiventral condition of the rhizome? This type of vascular system is known as a polystele.

2. Under high power, make a careful drawing of one of the smaller vascular bundles, showing the bundle sheath, usually brown, the phloem and the central xylem (wood).

3. Test for starch with iodin solution. Draw some of the ground tissue, showing the intercellular spaces, and starch in the cells.

4. Draw a patch of cells from the internal and from the external sclerenchyma, showing the thick cell walls.

5. Cut longitudinal sections of the rhizome, mount and draw, comparing the structures with those seen in the cross section. Also draw a single cell from the external sclerenchyma, the internal sclerenchyma, and the ground tissue. From the vascular bundle, draw a sieve tube and a scalariform tracheid.

6. Describe the mode of growth of the Pteridium rhizome. What advantages in the geophilous habit? Has this rhizome any advantage over the vertical rhizomes of Ophioglossum and Botrychium?

7. Carefully remove the leaves from the apex of a branch of the rhizome and cut cross sections of the growing point. Mount the sections, and in the first two or three look for the apical cell. Draw. Cut longitudinal sections of the apex of another branch, mount and draw the section, showing the apical cell. What is the shape of the apical cell?

8. Under dissecting microscope draw a leaflet of Pteridium from the lower side, showing the membranous false indusium formed of the reflexed margin of the leaflet.

9. If fresh, yŏung leaves are at hand, study the nectar glands with drops of nectar in the axils of the main divisions. Locate them and draw. Of what use are the nectaries?

(c). **Cyrtòmium falcàtum** J. Sm.

Family, Polypodiaceæ.

Cyrtomium grows readily in greenhouses and window gardens, and fresh sporangia may be obtained at almost any time of the year.

1. Examine a sterile leaf and a sporophyll. Draw one of the leaflets showing the circular sori on the under side.

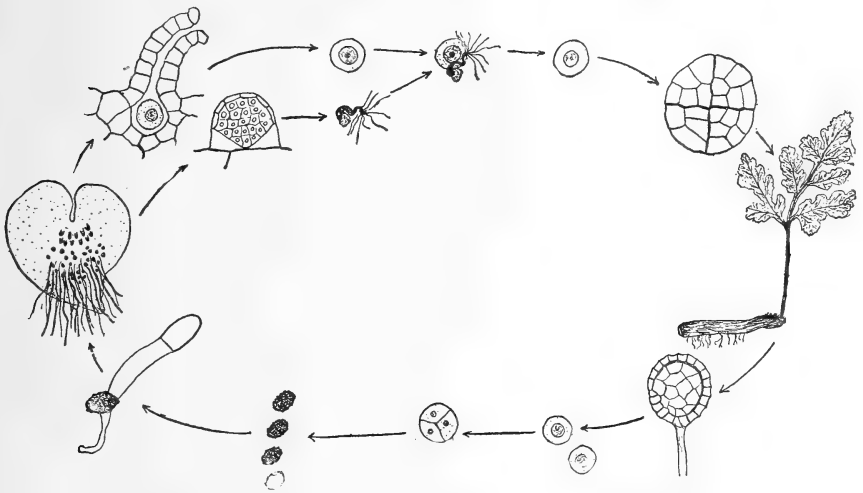


FIG. 12. — LIFE CYCLE OF ORDINARY FERN.

2. Pick off some of the sori which have recently exposed the sporangia, examine without cover-glass and describe how the spores are scattered.

3. Mount an indusium and some opened and unopened sporangia. Draw the indusium under low power.

4. Draw a single sporangium under high power, showing the stalk, annulus, and lip cells. Contrast this sporangium with the one in Botrychium. Draw some of the nonsexual spores. Note shape, color and surface.

5. Make a diagram in the notes showing the life cycle of a fern. See Fig. 12.

LXII. **Other Ferns.**

(a) **Camptosòrus rhizophýllus** (L.). Walking-fern.

Family, Polypodiaceæ.

The walking-fern is common on rocks, especially on limestone. Study fresh or herbarium specimens.

Sporophyte.

1. Sketch a plant with several leaves, some of which have rooted at the long acuminate tips, and show plantlets of various sizes. This is a simple and effective method of vegetative propagation. Leaves are usually highly specialized organs which have to a large extent lost the power of reproducing the individual. There are, however, many cases, like the present one, even in the higher plants, where the leaves retain the power of reproduction to a remarkable degree.

(b) **Fílix bulbífera** (L.). (Cystopteris.) Bulbiferous Bladder-fern.

Family, Polypodiaceæ.

This fern grows on moist rocks, especially limestone, and is easily cultivated in greenhouses, where it propagates itself extensively.

Sporophyte.

1. Sketch a leaf showing a number of fleshy brood-buds (bulblets). On which side of the leaf are they developed?
2. Under dissecting microscope draw a brood-bud which has just fallen off.
3. Draw a young fern plant which is developing from a brood-bud. Is this an efficient method of vegetative propagation? Why?

(c) **Maráttia douglàssii** (Presl.). Order, Marattiales. Family, Marattiaceæ.

This fern may be obtained in large greenhouses and conservatories. Use either fresh or preserved material.

1. Draw a leaflet showing the peculiar sori.
2. Draw a single sorus under low power and describe. This is a eusporangiate fern. How do the sori and sporangia differ from those of Cyrtomium?

LXIII. **Lycopòdium lucídulum** Mx. Shining Club-moss.

Phylum, Lepidophyta. Class, Lycopodieæ. Order, Lycopodiales. Family, Lycopodiaceæ.

This lycopod grows in moist woods and on shady cliffs. Use fresh, alcoholic, or herbarium material.

Sporophyte.

1. Sketch the entire plant. Note the dichotomous branching, the alternating zones of sporophylls and sterile leaves, and the dichotomous roots.
2. Draw a branch, showing very carefully the tip and several zones of sporophylls below. Note that the formation of sporophylls does not stop the growth of the axis on which they are produced. Which are the larger, sporophylls or sterile leaves?
3. Draw a single sporophyll with sporangium under low power.
4. Under high power draw several non-sexual spores.

5. From alcoholic material cut cross sections of the stem, mount, and draw under lower power. Note the epidermis with cuticle, the wide cortical layer, the vascular bundles of the leaf traces, the bundle sheath or endodermis, and the central cylindrical mass of vascular tissue. Inside of the endodermis are a number of more or less parallel strands of xylem and phloem. These structures will be more prominent after staining with iodin solution. This type of vascular system is called a protostele.

6. Cut radial longitudinal sections of the stem and compare in detail with the cross section.

7. Vegetative propagation. Notice the peculiar bulb-like brood-buds near the tips of some branches. Pick off one and draw under dissecting microscope.

LXIV. **Lycopòdium obscùrum** L. Tree Club-moss.

Lycopodium obscurum grows in moist woods, forming long slender rhizomes which creep under the surface of the ground or under leaf mould. From this rhizome upright, ærial branches develop.

Sporophyte.

1. Sketch an entire plant showing the rhizome and upright branch bearing a number of cones.

2. Draw a single cone under dissecting microscope. Note the spiral arrangement of the specialized sporophylls, and that by the development of a cone the further development of the axis is stopped. What is the probable reason for this?

3. Under low power draw a single sporophyll showing the sporangium. Note the advance in specialization of this sporophyll over that of the preceding plant.

4. Under high power draw some of the nonsexual spores; also some of the spore tetrads from younger sporangia.

5. Note. — This cone represents a primitive flower. Compare it with the zone of sporophylls in the preceding species.

LXV. (a) **Equisètum arvénse** L. Field Horsetail.

Phylum, Calamophyta. Class, Equiseteæ. Order, Equisetales. Family, Equisetaceæ.

The field horsetail is common along roadside and railways, on river banks and steep slopes facing the north. The fertile branches come up in April and May, while the sterile ones begin to appear at about the same time, but do not reach their full development until later in the season. Spores may be collected in large quantities and kept in a dry glass bottle. Rhizomes with fertile and sterile branches should be preserved in 70 per cent. alcohol. Good hebarium specimens may also be used.

Sporophyte.

1. Sketch a plant containing the rhizome, fertile shoot with cone, and young sterile shoot. Note the whorls of scale-like leaves at the nodes; also the lack of chlorophyll in the fertile shoot.

2. Sketch a mature sterile shoot.

3. Note and describe the division of labor in the stem of this plant — rhizome for a food storehouse and for vegetative propagation, fertile branch for the production of non-sexual spores, sterile branch with abundant chlorophyll for food manufacture. From whence is the material obtained which goes to form the fertile

shoot? Compare the stems of Lycopodium lucidulum, L. obscurum and Equisetum arvense and note the degree of differentiation in each.

4. Cut off some of the peltate sporophylls, mount and draw from the side under dissecting microscope. Show the stalk, the angular outer expansion and the sack-like sporangia hanging from the under side. How are the sporophylls arranged in the cone? Compare this cone and the sporophylls with those of *Lycopodium obscurum*. Compare also these two sporophylls with a fern sporophyll.

5. Place a small flake of the dry spores on a slide without water or coverglass, breathe on them gently until the glass becomes moist, and examine immediately under low power. Note the spores with appendages coiled about them. In a few moments the spores will be in violent agitation, while the appendages uncoil. Breathe gently on the slide while looking into the microscope. How many appendages on each spore? Draw. Describe in detail the hygroscopic properties of the appendages. Of what advantage to the plant is this peculiar arrangement?

6. Cut cross sections of a young fertile branch from alcoholic material. Mount, stain with iodin solution and draw under low power. Note the epidermis, the wide cortical layer with a circle of lysigenous cavities the endodermis, the circle of vascular bundles, and the pith with a large central lysigenous cavity. The xylem (wood) of each vascular bundle is arranged somewhat in the form of a V, the apex of the V being occupied by a large air-cavity. The two limbs of the V end near the endodermis, and the phloem is situated between these two masses of xylem.

(b) **Equisètum hyemále** L. Scouring Rush.

This plant grows in wet places along the banks of rivers, creeks and lakes.

1. Examine the fresh or dry stems under low power. Notice the parallel grooves and ridges, with lines of tubercles and stomata. Draw and describe.

2. Break some of the dry stems and note their brittleness. Burn one of the stems in a hot flame, mount the outer part of the shell which remains, and examine under low power. Notice that the cell walls and stomata are still distinct. This is because the cell walls are impregnated with silica. Draw a flake showing the stomata.

3. Note. — The cavities often contain water or ice in the winter.

SUB-KINGDOM, PTERIDOPHYTA HETEROSPORÆ.

LXVI. **Marsílea quadrifòlia** L. European Marsilea.

Phylum, Ptenophyta. Class, Hydropterides. Order, Marsileales. Family, Marsileaceæ.

This water fern grows well in artificial ponds, in gardens and greenhouses. The western *Marsilea vestita* H. & G. found in wet places and shallow ditches on the great plains and prairies of the interior may also be used. The sporophytes are mature in autumn.

Sporophyte.

1. Sketch a branch of the creeping rhizome, showing the roots and the leaves with slender upright petioles.

2. Sketch a sporophyll with two sporocarps.

3. Carefully cut off part of the thick inner margin of some sporocarps and place them in a glass of water. In a day or two a gelatinous ring will be ex-

truded on which are situated the sack-like sori in which microsporangia and megasporangia are contained. Draw.

4. Mount some of the microsporangia and megasporangia and draw each under low power. The megasporangium contains a single megaspore; the microsporangium a considerable number of microspores.

5. Under high power draw a single microspore and megaspore, in correct proportion.

Gametophyte.

6. In the meantime the spores will begin to develop the gametophytes. These are very minute, and the spores in the water should be examined every few hours in order to get the proper stages. The male gametophyte develops entirely inside of the microspore wall and the female gametophyte merely protrudes the neck of the archegonium (ovary) from one end of the spore. Draw a male gametophyte with a protrusion on the side of the spore wall for the escape of the spermatozoids and a female gametophyte with archegonium projecting from one end, showing a large number of spermatozoids in the gelatinous substance extending from the neck of the archegonium. Why does the microspore always give rise to a male plant, and the megaspore to a female?

7. If prepared slides are at hand, study and draw sections of mature male and female gametophytes. The male gametophytes correspond to the pollen grain of seed plants, and the female gametophyte to th embryo-sac in the ovule. Both gametophytes of Marsilea must be compared with the hermaphrodite gametophyte of Adiantum. Note especially the great reduction in size; also that after this there will be no more hermaphrodite gametophytes, hence no possibility of self-fertilization.

8. In a week or so the female plants in the glass of water will have embryo sporophytes. Draw under low power and describe.

9. Ecological Note. — Examine a plant at night, or place a flower-pot with a living plant in a dark chamber and note the manner in which the leaflets fold up. How long does it take the leaflets to unfold after being placed in sunlight?

LXVII. **Salvínia nàtans** (L.). Salvinia.

Class, Hydropterides. Order, Salviniales. Family, Salviniaceæ.

This floating water fern grows readily in aquaria in greenhouses.

Sporophyte.

1. Draw an entire plant as it floats on the surface of the water, showing the horizontal stem, the leaves, and the peculiar root-like leaves hanging down from the underside.

2. Take out some of the plants and throw them into the water. Note how they nearly always turn right side up.

3. Place a leaf on the slide and examine without cover-glass under low power. Draw a part of the surface showing the peculiar hairs. What is their use?

4. Mount one of the dissected, root-like leaves and sketch under low power.

5. Ecological Note. — Describe the various ways in which the sporophyte of Salvinia is adapted to its environment.

LXVIII. **Isòetes melanópoda** J. Gay. Black-based Quillwort.

Phylum, Ptenophyta. Class, Isoeteæ. Order, Isoetales. Family, Isoetaceæ.

This quillwort may be found in moist prairies and overflowed fields in the

central states of the Mississippi valley. Fresh or herbarium speciments may be used, and stems preserved in 70 per cent. alcohol.

Sporophyte.

1. Sketch and describe the entire sporophyte, showing leaves, short stem, and roots.

2. Study prepared slides or cut cross sections of stems in alcohol and draw, showing the following structures: the two vertical furrows and two large lateral lobes, the outer cortex and extensive parenchymatous tissue in which the cells are arranged in radial rows, on the inner limits of this layer a zone of meristematic cells, inside of this a layer of clear cells (the phloem, "prismatic layer") and in the center a xylem-cylinder from which bundles pass outward to the leaves.

LXIX. **Sigillària sp.**

Phylum, Lepidophyta. Class, Selaginelleæ. Order, Sigillariales. Family, Sigillariaceæ.

Fossil impressions of the trunks of large, arboreous Sigillarias are common in the formations of the carboniferous period and may be seen in most museums.

1. Sketch the surface of part of a trunk of Sigillaria, showing the leaf scars and the longitudinal fluting.

2. Note. — The heterosporous pteridophytes of the present time are the remnants of a once great group of plants which formed a characteristic vegetation before and during the carboniferous period, which ended millions of years ago.

LXX. **Selaginèlla kraussiàna** (Kunze). Krauss' Selaginella.

Phylum, Lepidophyta. Class, Selaginelleæ. Order, Selaginellales. Family, Selaginellaceæ.

This plant grows very luxuriantly in greenhouses and window gardens, if the soil is provided with proper moisture. Suitable material may be had at any time of the year.

Sporophyte.

1. Sketch an entire plant, showing branches, leaves, and roots. Note that the branches occur only in one plane and that the roots are dichotomous. Describe the character and arrangement of the leaves. How do you account for the arrangement? How does the plant accomplish vegetative propagation?

2. Draw a leaf under low power. Under high power draw a cell, with a single chloroplast and one with several chloroplasts. Draw also one of the stomata. Where are the stomata situated? Look for the ligule on the leaf. Of what use is the ligule?

3. Cut cross sections of a fresh stem or of stems preserved in alcohol, mount, and draw, representing the following structures: epidermis, cortical tissue in which may appear sections of bundles passing to the leaves, two or more large air spaces, and in the center of each space a vascular bundle. The bundle consists of a central strand of xylem (wood) surrounded by a band of phloem which is enclosed in a large-celled bundle sheath. Note the strands of cells passing thru the air space from the cortex to the vascular bundle.

4. Draw one of the short bisporangiate cones (primitive flower) under dissecting microscope, showing microsporophylls above and one or more megasporophylls below.

5. Carefully pick off a microsporophyll and a megasporophyll each with its sporangium, mount and draw under low power. Note the greater specialization

in the arrangement of the sporingia over that of Marsilea. How many megasporophylls in comparison with the microsporophylls on each cone? Note the numerous microspores in the microsporangium. How many spores in the megasporangium?

6. Draw a microspore and a megaspore in exact proportion under low power. How do you explain this difference in size of the nonsexual spores? Determine how many times greater in volume the megaspore is than the microspore. How many megaspores and microspores in one cone?

Gametophyte.

7. From prepared slides draw the male and female gametophytes of Selaginella, the archegonium (ovary) and antheridium (spermary) and the oosphere and

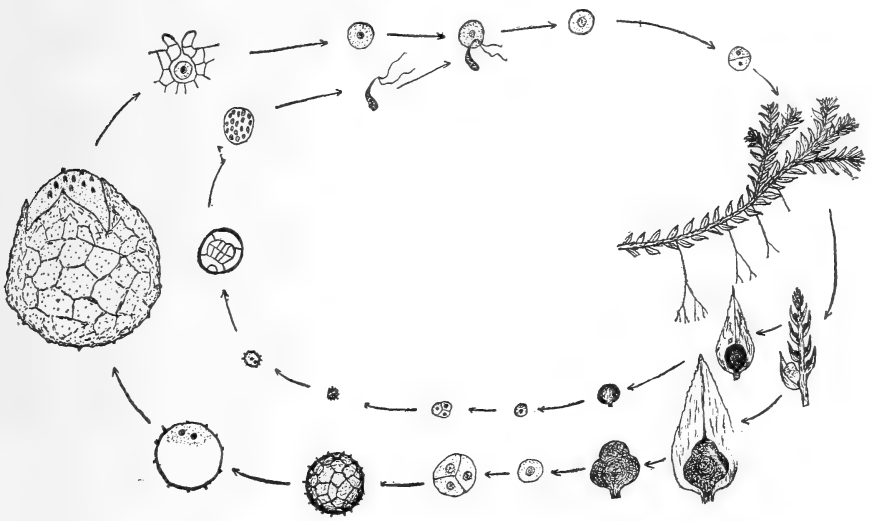


FIG. 13. — LIFE CYCLE OF SELAGINELLA

spermatozoid. Why does the microspore always produce a male and the megaspore a female gametophyte? Compare with Note 12 under Vaucheria. Observe also that the determination of sex in these plants, as well as all other heterosporous groups, has no relation to the reduction division.

8. Draw and describe a young sporling showing root, stem and first leaves with megaspore still attached containing the female gametophyte and foot of the sporophyte.

9. Make a diagram in the notes showing the life cycle of Selaginella. See Fig. 13.

10. NOTE. — It will be remembered that in the lowest archegoniates the gametophyte is the important plant in the life cycle, and that the sporophyte is very small. Now in the highest forms the tables are turned and the sporophyte has become *the* plant. Between such plants as Isoetes and Selaginella on the one hand and the lowest living seed plants on the other, there is a considerable hiatus, nevertheless it is not difficult to trace the transformation which was necessary in passing from the condition of heterosporous pteridophytes to the lowest gymnosperms.

SERIES III — SPERMATOPHYTA.

SUB-KINGDOM GYMNOSPERMÆ.

LXXI. **Cýcas revolùta** L. Cycad.

Phylum, Cycadophyta. Class, Cycadeæ. Order, Cyadales. Family, Cycadaceæ.

This plant is usually grown in greenhouses and conservatories. Herbarium and museum material should also be at hand.

1. Examine a living plant and describe its general character. Sketch the stem, showing the scale leaves and one foliage leaf.

2. Draw a megasporophyll (carpel) from herbarium specimens, showing the megasporangia or ovules. Note the similarity of the carpel to the foliage leaves. The carpels are produced in a whorl like the foliage leaves, and the stem continues to grow thru the whorl. Compare this condition with the ordinary ferns and with *Lycopodium lucidulum.*

3. Make a sketch of the large staminate (microsporangiate) cone. Draw a single microsporophyll (stamen), showing the numerous microsporangia (pollen-sacs) on the under side.

4. From alcoholic material draw a young ovule, properly dissected, showing the integument with micropyle, the inner wall of the ovule (megasporangial wall) with the pollen chamber, and the female gametophyte.

5. Draw half of a large female gametophyte from a mature seed, showing the little depression at the outer end and the dormant sporophyte embryo. The necks of the archegonia open into this depression (called the archegonia chamber) at the time of fertilization.

6. Mount male gametophytes (pollen-grains), and draw under high power.

7. If prepared slides are available study sections of pollen-grains showing the internal structure.

8. Note. — The fundamental difference between the heterosporous pteridophytes and the lower seed plants is that in the latter the microspores and megaspores are not shed, but develop the male and female gametophytes in the microsporangia and megasporangia respectively, while in the former the spores sooner or later drop to the ground. The female gametophyte remains permanently enclosed in the megasporangium, but the male gametophytes are shed from the microsporangia and some fall into the micropyle of the ovule. This is known as pollination. In order that the spermatozoids may fertilize the oospheres in the archegonia a short pollen tube must grow thru the tissue between the pollen chamber and the female gametophyte. It will be observed that the gametophytes are now entirely parasitic, the female in the ovule and the male at first in the pollen-sac, and after pollination, in the wall of the ovule.

LXXII. **Gínkgo bilòba** L. Maiden-hair-tree.

Phylum, Cycadophyta. Class, Ginkgoeæ. Order, Ginkgoales. Family, Ginkgoaceæ.

This beautiful tree, a native of China and Japan, is cultivated quite extensively in the United States. Museum and herbarium material may be used.

Sporophyte.

1. Sketch a leafy branch, showing the leaves developed in clusters on dwarf branches. Note that dwarf branches may give rise to ordinary branches.

2. Sketch a single leaf under dissecting microscope, showing the dichotomous venation. Compare the venation with that of the Adiantum leaf.

3. Sketch a stamen (microsporophyll) under lower power. How many microsporangia or pollen-sacs? Compare with stamen of Cycas.

4. Sketch a mature fleshy seed on its long stalk. Note the collar or cup around the base of the seed and the small undeveloped ovule. On some stalks two seeds develop. Remove the fleshy part of the integument and note the hard, inner layer.

Gametophyte.

5. Draw a male plant (pollen-grain) under high power.

6. From alcoholic material study the mature female gametophyte (kernel of the seed). Sketch, and compare the size of the male and female gametophytes.

7. Carefully cut longitudinal sections from one side of the female gametophyte until the embryo sporophyte comes into view, and sketch the section under dissecting microscope, showing the embryo in position.

LXXIII. **Conifers. General Study.**

Phylum, Strobilophyta. Class, Coniferæ. Order, Pinales.

The conifers called for below are cultivated quite extensively, and material for study can usually be obtained without difficulty.

(a) **Various Conifers.**

Collect branches of the following: Pinaceæ—Norway spruce (*Pícea excélsa* (Lam.), Canadian hemlock (*Tsùga canadénis* (L.), the European larch (*Larix decidua Mill.*), Juniperaceæ — arborvitæ (*Thùja occidentàlis* L.)

1. Sketch a short branch of the Norway spruce and note a slight tendency to bilateral symmetry, and how the leaves are bent from the under side to obtain a proper light relation.

2. Sketch a branch of the Canadian hemlock with carpellate cone at the end. Note bilateral arrangement and the light relation of the leaves, especially the small ones on the upper side.

3. Sketch the larch branch showing the large dwarf branches. Compare with Ginkgo. Note that the foliage leaves are deciduous annually, and that the dwarf branches may develop into ordinary branches. Are the dwarf branches deciduous (self-pruned)?

4. Sketch a small branch of the arborvitæ. Note the flattened condition of the stem and the leaves. Note also that numerous branches of various sizes are self-pruned.

(b) **Pinus.** Family, Pinaceæ.

Collect large branches of white pine (*Pinus stròbus* L.) pitch pine (*P. rígida* Mill.) Austrian pine (*P. laricio* Poir.), and Scotch pine (*P. silvéstris* L.) Also collect the dwarf branches with needle-leaves which have been self-pruned.

1. Study and sketch a branch of the Austrian pine, showing scale leaves, dwarf branches, and foliage leaves (needles). How old is the branch studied? What two ways of telling the age? Are the foliage leaves deciduous? How old are the dwarf branches before they are self-pruned? Where do the ordinary branches originate, and when?

2. Draw a dwarf branch, with scale leaves and foliage leaves, of the white pine, pitch pine, Austrian pine, and Scotch pine. Note the pecularities of each dwarf branch. Compare with Larix and Ginkgo.

3. Under low power, without cover-glass, draw part of the foliage leaf of the Austrian pine, showing the stomata. How are they arranged? Draw a scale leaf from the ordinary branch and one from the dwarf branch. Note the difference between the foliage leaves and the scale leaves.

4. Cut cross sections of a foliage leaf, mount and study under low power. Draw and note the following tissues: epidermis with sections of the stomata, heavy-walled hypodermal tissue, green mesophyll with a number of resin-ducts, a limiting layer of large clear cells, and the light-colored central region with two vascular bundles.

(c) **Structure of White Pine Stem.**

Preserve pieces of branches, one to six years old, in alcohol, and also obtain large, polished cross sections (about two inches thick) of a tree-trunk with bark.

1. With a strong, sharp razor, cut cross, tangential and radial sections of stems in alcohol, mount, and stain with iodin; or study prepared slides.

2. Draw part of a cross section under low power, showing epidermis, cortex, with resin passages, phloem, cambium, xylem in a number of annual rings with medullary rays and resin passages, and central pith.

3. Radial section. Draw under low power, showing cortex, cambium, xylem (composed of the tracheids), and pith. Note the medullary rays passing from the pith to the phloem.

4. Tangential section. Draw under low power, showing part of the xylem with tracheids and cross sections of the medullary rays.

5. Under high power draw part of a tracheid from radial section, showing the peculiar bordered pits.

6. Sketch part of a polished section of an old pine stem, showing bark, cambium, sap wood, heart wood, and pith. Notice the medullary rays. Notice also that each annual ring of wood is double — early wood and late wood. On which side is the early wood? Describe the growth of a pine tree in height and thickness.

(d) **Sporophylls of Pinus larício.**

Use fresh or alcoholic material.

1. Draw a staminate (microsporangiate) cone under dissecting microscope. Describe the arrangement of the stamens (microsporophylls).

2. Draw a stamen under low power, showing the outer (under) side with two microsporangia (pollen-sacs). How different from the microsporophyll of Selaginella in structure and function?

3. Draw a young carpellate (megasporangiate) cone under dissecting microscope. Describe. Note that the parts are smaller at the lower end.

4. Draw a carpel (megasporophyll) from the lower side under low power, showing the bract (true leaf blade of the carpel) and the large ovuliferous scale. This may be an outward growth of the chalazal region of the ovules. Draw the carpel from the inner (upper) side, showing the two ovules(megasporangia) and the ovuliferous scale. Compare the carpel with the megasporophyll of Selaginella.

5. Draw a mature carpellate cone. Note the spiral arrangement and that the carpels at the base are undeveloped and contain no seed. This is an example of rudimentary organs. If a rudimentary organ was formerly more highly developed and functional it is called a vestigial organ or a vestige.

6. Note. — The staminate and carpellate cones of the pine represent primitive flowers. Are these flowers monosporangiate (one kind of spores in the flower) or bisporangiate (both kinds of spores in the same flower)? Compare with the cone in Selaginella. Is the pine tree (sporophyte) monecious or diecious?

(e) Carpellate Cone of Larix decidua.

Collect carpellate cones of the usual type and some which have the tip continued as a leafy branch. Preserve in alcohol.

1. Sketch a normal cone in which terminal growth has been completely checked.

2. Sketch a cone on which a leafy branch has developed at the outer end. Note the gradual transition from carpels to ordinary foliage leaves. Sketch a number under dissecting microscope, showing this transition. This continued growth or prolongation of the floral axis of the larch cone is a good example of reversion to a more primitive condition or atavism. Compare with the ordinary ferns, *Lycopodium lucidulum,* and Cycas.

3. Observe fresh or dried, young cones and note the presence of a special color. How do you account for the color in this cone?

(f) Gametophytes and seed.

The gametophytes of *Pinus laricio* may be studied from staminate and carpellate cones preserved in alcohol. The seeds may be kept in a dry condition.

1. Draw a male gametophyte (pollen-grain) under high power. Note the two wings. These represent an adaptation for anemophilous pollination.

2. Remove a female gametophyte from a young seed (collected at the time of fertilization about July 1) and draw under dissecting microscope. Note the difference in size between the male and female gametophytes. Compare the two gametophytes with those of Marsilea and Selaginella.

3. Draw a mature seed. Remove the testa and the inner seed coat. What does the inner coat represent? Draw the female gametophyte. Carefully cut out the embryo sporophyte, which is now in a dormant condition. Sketch under dissecting microscope, showing the radicle, suspensor and cotyledons. Pick off the used to advantage.
cotyledons from one side and sketch the plumule. How many cotyledons? Instead of *P. laricio,* the seeds of *Pinus edulis* Engelm, the nut pine of commerce may be

4. If prepared slides are at hand draw a section of a stamen, showing the one-celled microspores.

5. Draw a section of a male gametophyte, showing the large tube cell and nucleus, the generative cell and the two disorganized vegetative cells lying like two thin plates against the wall of the grain back of the generative cell.

6. Draw a section of a young ovule, showing the functional megaspore.

7. Draw a pollen-grain which has formed a short pollen-tube growing down into the nucellus (tip of the megasporangium). Note the tube nucleus in the tube and in the body of the grain the spermatogenous cell, the stalk cell and the remains of the two evanescent vegetative cells. The spermatogenous cell divides latter into two sperm cells which do not have flagella or cilia. From the same section draw the spherical embryonic female gametophyte.

8. Draw a female gametophyte showing archegonia (ovaries) with ospheres.

9. Draw an archegonium (ovary) in which the nucleus of the oosphere has divided into four nuclei.

10. Draw the upper part of a female gametophyte, showing remains of archegonia with an elongated cavity below them in which appear a number of embryos in various stages of development. Only one of these embryos survives, probably the one which has a slight advantage in size, vigor, and food supply. Note the struggle for existence which must go on among these embryos.

11. Sketch a mature seed, showing the wing. Let a winged seed drop to the floor from a height of six or seven feet and note how it falls. Describe the adaptation this seed has for dissemination. Note also the readiness with which the seed is separated from the wing. Of what use is this adaptation?

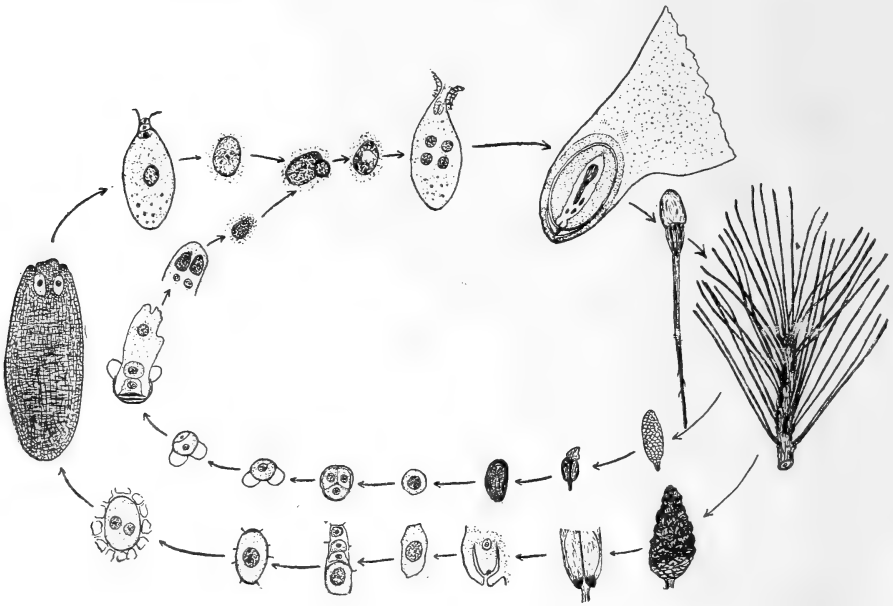


FIG. 14. — LIFE CYCLE OF PINE.

(g) Seedlings and Primitive Leaf Arrangement.

Plant seeds of Pinus and *Thùja occidentàlis* and use fresh plantlets or preserve in alcohol. Also obtain branches of the common juniper (*Juníperus commùnis* L. Family, Juniperaceæ) and cultivated varieties of Thuja known as retinispora forms. In these retinispora or juvenile forms, branches often change suddenly from the form with spreading leaves to the flattened condition, and the flattened branches again revert to the form with spreading leaves.

1. Sketch a pine seedling which has sprouted, showing the seed coat still covering the cotyledons. Sketch a seedling with cotyledons expanded. Describe the important changes which take place in the embryo during the process of sprouting.

2. Sketch a branch of *Juniperus communis* and note that all of the leaves are of the spreading type.

3. Study the sketch the seedings of *Thuja occidentalis* and note that at first the leaves are of the spreading type much like those of Juniperus, and that later the branches have the flattened form characteristic of the adult plant. Apply the recapitulation theory as given in connection with the moss protonema. From

this it would appear that the ancestors of Thuja had the leaves arranged like those of the common juniper.

4. Study and draw a small branch of Thuja (retinispora form), in which the upper part of a flattened branch has changed back to the juvenile form. In such cases there is a second reversion. In other words, the branch takes on first one form and then another successively.

5. Make a diagram showing the life cycle of a pine. See Fig. 14.

6. Note on the development of the carpellate pine cone.

The young carpellate cones of *Pinus laricio* begin to develop in the bud during the summer or fall, and in the following spring the carpels have young ovules with a distinct integument. Later the ovules are pollinated and the megaspore is developed. In the following autumn (October) the megaspore has germinated and the female gametophyte is developing as a hollow spherical body composed of free, naked cells. It passes the winter in this condition, and in the following spring pollination occurs. In June the archegonia with eggs are ready for fertilization and the pollen-tubes have grown down thru the nucellus. About the last week in June or the first in July fertilization occurs, and the embryo is matured and in the resting condition in the following autumn. The seed is usually shed late in the winter or in the early spring of the following year. The whole history thus covers nearly three full years.

LXXIV. **Táxus canadénsis** Marsh. American Yew.

Phylum, Strobilophyta. Class, Coniferæ. Order, Taxales. Family, Taxaceæ.

The yew is a low shrub growing on moist banks and hills, especially in the shade of large conifers. It is common northward. Herbarium and alcoholic material may be used if fresh branches are not available.

1. Sketch a branch, showing arrangement of leaves. Describe.

2. Under dissecting microscope draw a staminate cone. How are the stamens arranged?

3. Draw a single stamen under low power and note the peltate form. How many microsporangia? Compare the shape of this stamen with the sporophyll of Equisetum.

4. Under dissecting microscope draw a small fertile branch with a young ovule at the tip.

5. Cut longitudinal sections of the branch with ovule, mount, and draw under low power, showing the megasporangium in the center surrounded by the long inner integument and a short outer undeveloped aril, with scale-leaves on the stem below.

6. Draw a ripe seed with the thick, fleshy, red aril. Compare the aril with the oviliferous scale of Pruns.

LXXV. **Higher Gymnosperms.**

Phylum, Strobilophyta. Class, Gneteæ.

Study herbarium specimens.

1. Make a sketch of a small plant of *Ephèdra nevadénsis* Wats. (Order, Ephedrales. Family, Ephedraceæ). Note the slender green stems and the dry scale-leaves. In what ways is this plant adapted to a xerophytic environment?

2. Make a sketch of a branch of *Gnètum gnèmon* L. (Order, Gnetales. Family, Gnetceæ). Note the large broad leaves. This is a tropical tree cultivated in India and surrounding regions.

SUB-KINGDOM, ANGIOSPERMÆ.

A NUMBER OF FORMS TO REPRESENT THE GENERAL EVOLUTION OF THE FLOWER IN MONOCOTYLS AND DICOTYLS.

Along with this series of outlines on the Anthophyta, the student should be given work in identification with a key and several peroids can profitably be spent in analyzing and making diagrams of various spring flowers.

LXXVI. **Magnòlia** sp. Magnolia. Phylum, Anthophyta. Class, Dicotylæ. Order, Ranales. Family, Magnoliaceæ.

The magnolias are among the most primitive of the Anthophytes. Any of the native or cultivated species will have suitable flowers in early spring. They may be used fresh or preserved in alcohol.

Sporophyte.

1. Sketch the entire flower; describe size, color, etc. Note the character of the stem. Compare the flower with the cones of Lycopodium, Selaginella, and Pinus.

2. Sketch a sepal, a petal, a stamen and a carpel; describe each organ. The stamen is a microsporophyll and the carpel a megasporophyll.

3. How many sepals in the calyx? How many petals in the corolla? How many stamens in the andrecium (stamen set)? How many carpels in the gynecium (carpel set)? How many cycles in the perianth? Note especially that the stamens and carpels are arranged spirally. Compare several flowers as to the constancy or variability in number of parts. Make a diagram of the flower. See Fig 16a.

LXXVII. (a) **Sagittària latifòlia** Willd. Arrow-head.

Phylum, Anthophyta. Class, Monoctylæ. Order, Alismales. Family, Alismaceæ.

The broad-leaf arrow-head grows in moist ground on the margin of ponds, creeks and canals and blooms in summer. If fresh material is not available, good herbarium specimens may be used. Flowers and other parts may also be preserved in alcohol.

Sporophyte.

1. Sketch and describe the entire plant, noting the character of the leaves, stem, roots, and inflorescence.

2. Sketch the staminate flower, showing sepals, petals and stamens. How many parts in each set? Find the vestigial carpels. Draw one under dissceting microscope.

3. Sketch the carpellate flower and describe the parts present. What parts of the two flowers are cyclic and what parts spiral in arrangement? Is this sporophyte monecious or diecious?

4. Under dissecting microscope draw a sepal, a petal, a stamen (microsporophyll)and a carpel (megasporophyll). Compare the normal carpel with a vestigial carpel. How did this plant attain the monecious condition?

5. Cut cross sections of a young stamen, mount, and draw under low power. How many microsporangia? Note that the stamen is made up of anther and filament.

6. Cut off one side of a carpel so as to expose the ovule (megasporangium). Draw under low power, showing the stigma, short style, and ovulary. Note

that the stigma is a new organ not present in any of the Gymnosperms. Why is the stigma necessary to this carpel?

(b) **Ranúnculus abortìvus** L. Crowfoot.

Phylum, Anthophyta. Class, Dicotylæ. Order, Ranales. Family, Ranunculaceæ.

This plant is common in April and May along brooks, on hillsides, in meadows, and along roads.

Sporophyte.

1. Sketch the entire plant, showing the various organs.
2. Sketch the flower and describe the condition of the four sets of floral organs. Note that the flower is bisporangiate. Compare with the cone of Selaginella.
3. Draw a sepal, a petal, a stamen, and a carpel under dissecting microscope.

LXXVIII. **Alìsma subcordatum** Raf. Water Plantain.

Class Monoctylæ. Order, Alismales. Family, Alismaceæ.

The water plantain is common in wet and muddy places, on the margin of ponds and creeks and blooms in summer. Herbarium specimens and preserved material may be used.

Sporophyte.

1. Sketch a leaf and a part of the inflorescence.
2. Sketch a flower showing the four sets of floral organs — calyx, corolla, andrecium and gynecium. How many sepals, petals, stamens and carpels? Are the parts spiral or cyclic? Free or united? Is the flower monosporangiate or bisporongiate? Note that the flower is hypogynous. What advance does this flower show over that of Sagittaria or Ranunculus?
3. Make a diagram of the flower. See Fig. 16b.
4. Cut cross sections of the stamens and draw under low power. How many microsporangia (pollen-sacs)? Cut open the ovulary and dissect out the ovule (megasporangium). Draw.
5. From prepared slides draw a microsporocyte and a microspore, showing the nucleus, cytoplasm and wall.
6. From prepared slide draw a young ovule, showing the funiculus, the integuments, the megasporangium proper (nucellus), and the single megaspore. Note the absence of a wall around the megaspore. Why not present?

Gametophytes.

7. From prepared slide draw a male gametophyte (pollen-grain), showing the tube nucleus and the two elongated sperm cells.
8. From prepared slide draw an eight-celled female gametophyte (embryo-sac), showing the three anipodal cells, the two polar nuclei, the oosphere, and the two synergids. The oosphere and the two synergids are called the egg-apparatus (ovary).
9. From prepared slide draw a mature, seven-celled female gametophyte, showing the fertilization of the egg and the conjugation of the polar cells to form the definitive cell. Look for the conjugation of the second sperm with the polars (triple fusion).
10. From a prepared slide draw an embryo-sac with endosperm cells, which have come from the division of the definitive cell, and with young embryo, consisting of the embryo proper, the suspensor cells and the large, vesicular, basal,

suspensor cell. Note that the conjugation of the polar cells and the subsequent development of the endosperm are entirely new phenomena, nothing similar being known in plants below the angiosperms. In many other angiosperms the second sperm cell from the pollen-tube comes down and unites with the polar cells producing a triple fusion, as in Alisma.

11. Carefully remove a mature embryo from the seed and sketch under low power, showing the single cotyledon, the lateral plumule and the radicle.

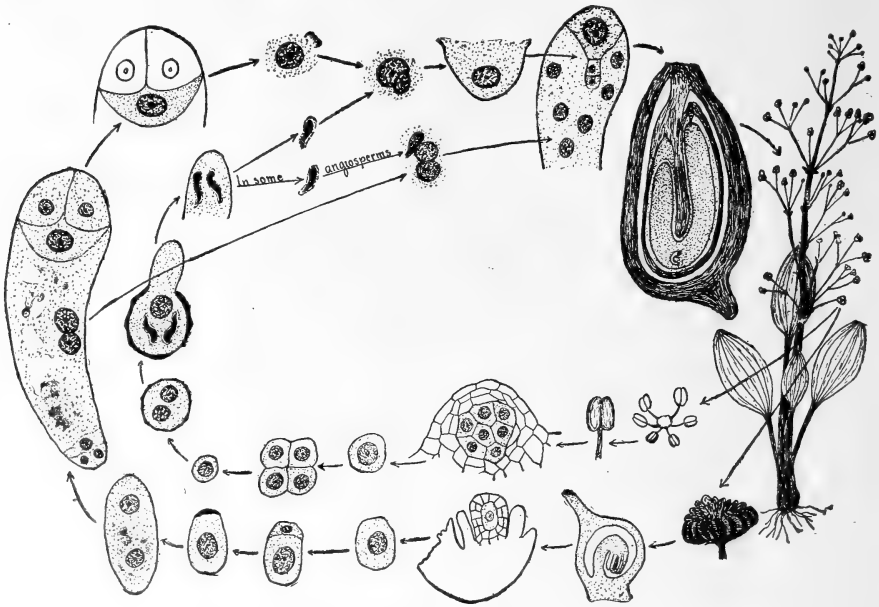


FIG. 15. — LIFE CYCLE OF ANGIOSPERM (ALISMA.)

12. Note that in this plant the seed remains in the ovulary. Make a diagram showing position of the carpel wall, the integuments of the ovule, the endosperm and the embryo. Note also that the ovule is first orthotropous, then anatropous and finally campyllotropous.

13. Sketch a young seedling.

14. Make a diagram in the notes showing the general life cycle of an angiosperm. See Fig. 15.

LXXIX. **Sèdum àcre** L. Wall-pepper.

Class, Dicotylæ. Order, Saxifragales. Family, Crassulaceæ.

Many of the sedums grow well in greenhouses and in window gardens. They usually bloom abundantly in the spring and the above or any other species will be found suitable.

1. Make a careful drawing of the flower and describe the character of the different parts.

2. Make drawings of the calyx, the corolla, the andrecium and the gynecium.

3. Answer the following questions correctly:

Is the flower hypogynous, perigynous, or epigynous?

Is it tetracyclic or pentacyclic?

Are the circles or whorls trimerous, tetramerous or pentamerous?

Are the organs of any whorl or set united or partly united?
Is the flower isocarpic or anisocarpic?
Is it actinomorphic, isobilateral, zygomorphic, or unsymmetrical?

4. Make two diagrams showing the true condition of the flower as learned above. See Fig. 16 c and d.

LXXX. **Trillium grandiflòrum** (Mx.). Large-flowered Trillium.

Class, Monocotylæ. Order, Liliales. Family, Liliaceæ.

The large flowered Trillium grows in rich woods and blooms in April and May.

1. Make a sketch of the entire plant, showing the flower, leaves, and short tuberous rhizome with contractile roots below. How deep was the rhizome under ground? Describe how it descends into the earth. This plant is a geophilous, herbaceous perennial. What are the advantages of the geophilous habit?

2. Cut a cross section of the compound ovulary, mount, and draw under low power, showing the cavities with ovules.

3. Describe the condition of the flower according to the questions asked under *Sedum acre*. Make a diagram of the flower. See Fig. 16e.

LXXXI. **Cypripèdium parviflòrum** Salisb. Yellow Lady's-slipper.

Class, Monocotylæ. Order, Orchidales. Family, Orchidaceæ.

This lady's-slipper grows in wet places and low woods, and blooms in May and June. Any other species will do as well.

1. Sketch part of a plant, showing the flower and part of the leafly stem.

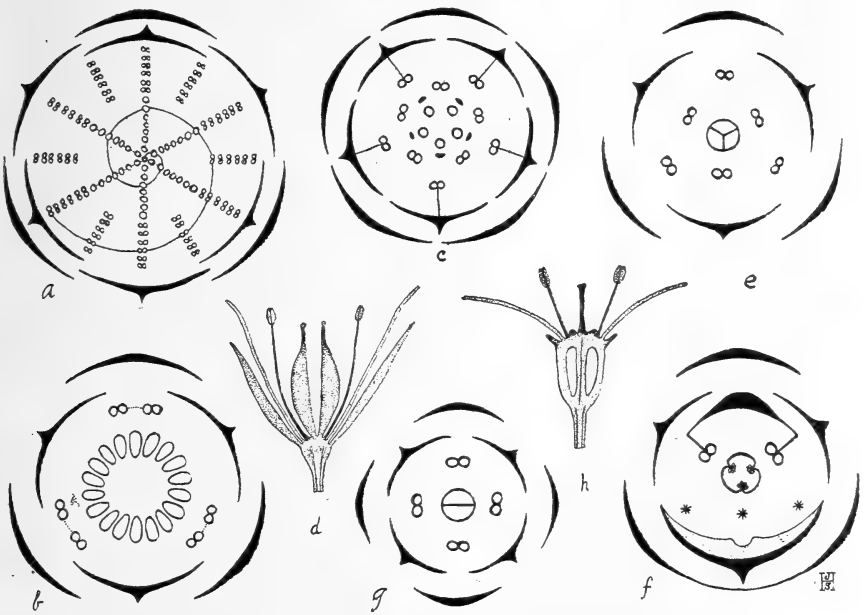


FIG. 16.—DIAGRAMS OF FLOWERS.

2. Cut cross sections of the ovulary, mount and draw. How many carpels? Study the flower with the aid of the diagram, Fig. 16 f.

3. Copy the diagram in the notes and write a general description of the flower, noting especially that it is organized on the same plan as the Trillium flower, that some of the parts have disappeared, that it is epigynous and zygomorphic, that certain parts are united, and that it is highly specialized for insect pollination.

4. Why should this flower be placed higher than any of the monocotyls previously studied? Make a comparison of the flower of Sagittaria, Alisma, Trillium and Cypripedium.

LXXXII. **Catálpa speciòsa** Warder. Hardy Catalpa.

Class, Dicotylæ. Order, Scrophulariales. Family, Bignoniaceæ.

The Catalpa is cultivated extensively and blooms abundantly in May and June.

1. Study the large compound panicle and draw a single flower.

2. Describe the flower carefully, noting the condition of each floral set and whether the flower is hypogynous or epigynous, whether actinomorphic or zygomorphic. What adaptations for insect pollination? Note especially the rudimentary or vestigial stamens. Be careful to distinguish vestigial organs (vestiges) from incipient organs (incepts) and from nascent organs.

3. Cut cross sections of the ovulary, mount, and draw. How many carpels in the gynecium?

4. Make two diagrams of the flower, showing transverse and longitudinal arrangement.

LXXXIII. **Córnus fémina** Mill. Panicled Dogwood.

Class, Dicotylæ. Order, Umbellales. Family, Cornaceæ.

This common shrub usually forms thickets, in forests and on hillsides. It blooms in June, producing an abundance of flowers. Any other species with panicled flowers will do.

1. Sketch the entire infloresence and note the arrangement of the numerous small flowers.

2. Under dissecting microscope draw a single flower. How many cycles? How many stamens, petals and sepals? Note the minute size of the calyx.

3. Cut cross section of the ovulary. Draw under low power. How many carpels? Note that the flower is epigynous.

4. Make a transverse and a longitudinal diagram of the flower. See Fig. 16 g and h.

LXXXIV. **Agerà̀tum conyzòides** L. Ageratum.

Class, Dicotylæ. Order, Compositales. Family, Helianthaceæ.

Ageratums are annuals which bloom all summer and are much used for borders. The flowers may be had in the greenhouse at any time of the year. The plants will live and bloom for a long time.

1. Sketch one of the heads under dissecting microscope, showing the bracts of the involucre and the numerous small tubular flowers.

2. Under dissecting microscope draw a single flower. What is the condition of the pappus? What does the pappus represent?

3. Dissect the flower and draw the corolla and andrecium and the gynecium under dissecting microscope or low power. Describe the flower and its parts in detail.

LXXXV. **Chrysánthemum leucánthemum** L. Ox-eye Daisy.

Family, Helianthaceæ.

This plant grows in fields and meadows and blooms in May and June.

1. Draw one of the heads, showing the bracts of the involucre, the ligulate or ray flowers and the tubular or disk flowers.

2. Under dissecting microscope draw a ray flower and a disk flower. Describe each. What is the condition of the calyx? Why should the outer flowers develop as ray flowers rather than the inner ones? Note that the ray flower is zygomorphic.

LXXXVI. **Leóntodon taráxacum** L. Dandelion.

Order, Compositales. Family, Cichoriaceæ.

The dandelion blooms from early spring to late autumn, so plants may usually be obtained without difficulty.

1. Sketch an entire plant, showing root, short stem, rosette of leaves, and slender stems bearing heads of flowers. Note that the dandelion is geophilous. Why does it not grow up out of the ground? How do you account for the rosette habit?

2. Make a sketch of a single head. Note that all the flowers are ligulate. Also note that the embryonic corollas are tubular, showing five teeth on the limb, and only become strap-shaped when they expand. Make a series of sketches showing this. How does this indicate that Leontodon is a higher type of development or specialization than *Chrysanthemum leucanthemum?*

3. Under dissecting microscope draw a single flower. Describe the pappus, corolla, andrecium, and gynecium.

4. Draw some of the ripe fruit. Note adaptation for suspension in the air. Of what special advantage is this parachute arrangement? Note the action of the involucre while the fruit is ripening.

5. How many seeds are in each dandelion fruit? i. e., how many for each flower? How many seeds are produced on an average-sized head? About how many heads of flowers are matured from a fair-sized dandelion plant in one season?

6. Suppose that you had one mature dandelion plant and that it produced seed normally for ten years and that each seed developed into a mature plant and began to reproduce at the average rate the second year, how many offspring would there be at the end of ten years?

7. The total land surface of the earth is about fifty-three millions of square miles, how many dandelion plants would there be for each square miles of land surface at the end of ten years?

8. Note. — The above problems will indicate to some extent the great possibilities of reproduction present in many plants. It will be remembered that each seed contains a little, dormant embryo; therefore, every seed that perishes means the destruction of a young plant. It is evident that a very large per cent. of young plants must perish each year, and that those which survive for any length of time must usually undergo a severe struggle for existence. In this struggle for life and place the fittest usually survive; i. e., those which are able to grow more vigorously and thus crowd out their weaker neighbors and those which are best adapted to their environment.

OTHER TYPES OF ANGIOSPERMS.

LXXXVII. **Tríticum vulgàre** L. Wheat.

Phylum, Anthophyta. Class, Monocotylæ. Order, Graminales. Family, Graminaceæ.

Material should be collected during and after the flowering period in May and June, and dried or preserved in 70 per cent. alcohol.

1. Study and sketch the spike (head) and describe. Note the character of the stem. What mechanical advantage in the disposition of the tissues of the stem? The axis of the spike is called the rachis.

2. Draw a single spikelet, noting the two empty glumes at the base, and several flowers. How many flowers? What is the condition of the uppermost flowers of the spikelet? The axis of the spikelet is called the rachilla.

3. Draw the two empty glumes noting their peculiarities.

4. Dissect a single flower. It is inclosed in two glumes, the flowering glumes; the one with the awn is the lemma, and the inner one is the palet. Draw both and describe.

5. Just inside of the lemma at the base of the gynecium are minute scales called lodicules. How many? Draw one under low power. What might they represent?

6. There are three stamens in the andrecium, and the gynecium develops into a single grain. Make a diagram showing the positions of the empty glumes, the lemma and palet, the lodicules, the stamens, the ovulary, and the axes of the spike and spikelet.

LXXXVIII. **Fúchsia** sp. Fuchsia.

Class, Dicotylæ. Order, Myrtales. Family, Onagraceæ.

Fuchsias are commonly cultivated in greenhouses and as house plants. The flowers should be studied fresh and any of the common greenhouse species will do.

1. Study and draw the flower.

2. Draw the gynecium with style and stigmas. Cut cross sections of the ovulary noting the number of cavities and ovules.

3. Draw the perianth tube or hypanthium split open, showing the calyx, corolla, and andrecium. How are these parts grown together? Note the color of the calyx and the corolla.

4. Why does the epigynous condition and the peculiar development of the perianth tube indicate a high type of floral development? Describe the entire flower.

5. Make a transverse and longitudinal diagram of the flower, showing the relationships of the parts.

LXXXIX. **Pópulus deltoìdes** Marsh. Cottonwood.

Phylum, Anthophyta. Class, Dicotylæ. Order, Salicales. Family, Salicaceæ.

This is a large tree of rapid growth, common on flood-plains of rivers, and is much planted for ornament. It blooms in April.

1. Collect staminate and carpellate catkins or aments, noting that the trees are diecious—some are staminate trees and some carpellate trees. Note the difference in color between the two kinds of flowers. How do you explain the difference? Draw the two catkins.

2. Draw a single staminate flower and a carpellate flower and describe. Any perianth? Why are the stamens red and not yellow as is commonly the case? Why is it incorrect to say male tree instead of staminate tree and female tree insead of carpellate tree? Or why should you not say male flower and female flower?

3. When the capsules ripen study the seed. How is it distributed? How effective is this method? Why should only staminate trees be planted in a city? How would you make sure that you had staminate trees to plant? Could you plant cuttings? This tree endures city conditions quite well.

4. Note the different kinds of scars on the tree: leaf scars, stipular scars, bundle-scars, self-pruning scars, lenticels. Note also that the pith is 5-angled. Is there anything on the outside of the twig corresponding to this?

5. Note that the leaves have a strong tendency to take a vertical position especially on twigs that grow erect. Draw and describe the flattened condition of the petiole by which this is accomplished. Why are the two sides of the leaf nearly alike? What advantage in the vertical position? Why do you hear a musical rustle of the leaves when the wind is blowing? Note the two glands at the base of the blade. Of what use are the glands?

6. Study and draw self-pruned branches. Fresh material can be obtained in summer and autumn and preserved in alcohol but the dry twigs will do fairly well. Notice that the winter buds are in perfect condition. Draw the base showing the surface of the scar. Draw a self-pruning scar that has healed over. How is the cleavage plane produced in the basal joint? Why are the branches pruned off? How old are the branches when self-pruned?

7. NOTE. This outline may be used as a special exercise to be worked up during the term. A special paper may be written on the subject including the above and many other interesting points connected with the life of this tree.

XC. **Polemònium réptans** L. Greek Valerian.

Class, Dicotylæ. Order, Polemoniales. Family, Polemoniaceæ.

This is a perennial herb growing in woods. It blooms in April and May. Fresh material must be used.

1. Describe the entire plant and sketch a branch showing the leaves and flowers. If young plants are available, note the circinate vernation.

2. Study a single flower. Note the blue color. Is blue a common color of flowers? Note the character of the calyx, the corolla, the andrecium, and the gynecium, and draw and describe each set.

3. Cut cross sections of the ovulary and draw. How many cavities? How many ovules in each cavity?

4. If ripe capsules are present wet the seeds on the slide and examine carefully under low power. What peculiarity becomes evident after a few moments? Crush or break up the seed with a scalpel and observe further.

5. Make a diagram of the flower.

SPECIAL EXERCISES ON ANGIOSPERMS.

XCI. **Comparison of Carpels.**

1. If not previously studied, draw a carpel of *Cỳcas revolùta* L.

2. Draw a carpel of the Kentucky coffee-bean (*Gymnócladus dìòica* (L.).)

3. Sketch a nearly mature fruit of the Velvetleaf (*Abùtilon abù tilon* (L.).) Separate the ovularies and draw a single carpel.

4. Carefully separate the ovularies of the carpels of an orange (*Citrus aurantium* L.) so that they will lie side by side in a row. Draw. Note that some of the divisons are smaller than the normal. There is a struggle for existence among the members of the gynecium so that some are not fully developed.

5. Make a comparison of the four fruits studied above.

XCII. Dicotyl Seed.

Study the fruit and seed of the Olive (*Olea europaèa* L.). Use either fresh or pickled olives.

1. Sketch the entire drupe. Note that the pericarp consists of a fleshy exocarp and a thick, stony endocarp.

2. Break the endocarp and remove the fleshy seed within. Remove the membranous seed coats and sketch the fleshy kernel inside. This is the endosperm.

3. Remove the embryo and draw, showing the short radicle, the two cotyledons, and the plumule. Compare the kernel of Olea with that of the Pine seed and note the differences.

XCIII. Section of Leaf.

(a) 1. Cut cross sections of the lamina of a sunflower (*Helianthus annuus* L.) leaf fresh or preserved in alcohol, mount, and sudy under low and high power.

2. Draw and describe, showing the following tissues: upper epidermis with thick cuticle and multicellular hairs, palisade parenchyma, spongy parenchyma with large intercellular spaces, sections of vascular bundles, and lower epidermis with stomata and multicellular hairs.

3. How do you account for the palisade arrangement of the cells in the upper part of the leaf?

(b) Cut sections of Beech Leaves or use prepared slides. Draw and compare the tissues with those in the sunflower leaf.

XCIV. Leaf Variation.

1. Obtain a series of fresh or pressed leaves of the red mulberry (*Morus rubra* L.) or of the giant ragweed (*Ambrosia trifida* L.) and make outline sketches of ten different forms.

XCV. Section of Winter Bud.

1. From alcoholic material cut longitudinal sections of common lilac buds (*Syringa vulgaris* L.). Mount and sketch under low power. Note the flat apex with outer dermatogen and hypodermal meristematic tissue; and a little farther down the epidermis, cortex (periblem), procambium (formative tissue of vascular bundles), and the central pith.

2. Note the origin of the leaves, beginning at the apex, and also the origin of the lateral buds in the axils of the leaves. Make a sketch showing the entire upper part of the bud, with all the structures mentioned above.

XCVI. Monocotyl Stem.

1. Cut cross sections of young corn stems preserved in alcohol, stain and mount; or use prepared slides. Sketch the entire section under dissecting microscope, showing epidermis, band of sclerenchyma, large pith or ground tissue, and the scattered vascular bundles.

2. Under high power draw one of the bundles. Note the large vessels situated in the xylem arranged like a letter V, the cavity in the tissue at the apex of the V, the bundle of phloem between and beyond the two large vessels, and the sheath of sclerenchyma about the bundle.

XCVII. Herbaceous Dicotyl Stem.

(a) Sunflower Stem.

1. Cut cross sections of a young sunflower stem preserved in alcohol, mount and stain; or study prepared slides.
2. Sketch the entire section under dissecting microscope, showing cortex, circle of vascular bundles, and large central pith. This vascular system is an example of a siphonostele. Compare with Botrychium.
3. Under low power draw part of a section showing the epidermis with epidermal hairs, the layer of collenchyma immediately below this, the parenchyma with resin passages, the vascular bundles with cambium layer, the medullary rays, and the central pith.
4. Under high power draw a single vascular bundle, selecting one of the narrow, oval type. Represent in order the external bundle of sclerenchyma, the phloem, the cambium, and the xylem usually in a double layer.
5. Notice the mechanical principles involved in the structure of the stem and the vascular bundle. Compare with a T railroad rail.

(b) Pumpkin Stem.

1. Cut cross and longitudinal sections of the stem of *Cucúrbita pèpo* L., stain and mount, or study prepared slides. Sketch the cross section under dissecting microscope. Note the epidermis, the cortex, the vascular bundles, the pith, and the large central cavity.
2. Under high power study the longitudinal sections and draw sieve-tubes showing the sieve-plates in the phloem.
3. In the xylem find and draw one of the large reticulate wood vessels; also a spiral wood vessel with a single spiral thickening and one with two spirals; also draw an annular wood vessel in which the thickenings are in the form of rings.

XCVIII. Dicotyl Woody Stem.

1. Cut cross sections of a very young twik of the beech (*Fàgus americàna* Sw.) and one a year old, preserved in alcohol, stain and mount, or use prepared slides. Under low power note the cortical layer, the circle of vascular bundles with medullary rays between, and the central pith. Draw. This is a siphonostele. Compare the younger section with the sunflower. Under high power draw a narrow sector passing thru a vascular bundle, showing epidermis, cork (periderm), cork cambium (phellogen), secondary cortex (phelloderm), primary cortex, sclerenchyma, phloem, stelar cambium, xylem (wood), and pith. Draw a single complete bundle, showing the sclerenchyma, the phloem, the cambium and the xylem.
2. Cut cross sections of twigs of the White Ash (*Fràxinus americàna* L.), preserved in alcohol, one very young, one a few months old, one a year old and one two years old. Study and draw the young sections noting the epidemis, cortex, vascular bundles and pith. Study the one and two year old sections and note the formation of the cork and the secondary development of phloem and xylem. Draw and describe.

3. Cut cross sections of linden twigs (*Tília* sp.) preserved in alcohol. Take one very young branch, one a year old, one two years old, and one three years old. Mount and stain; or use prepared slides. Study under low and under high power. Draw the year old section, noting the following structures: epidermis, cork layer, cortex, phloem and sclerenchyma layer (inner bark), stelar cambium, xylem (wood) with medullary rays, and pith.

4. Make a series of diagrams showing the primary structure and how the secondary structures are developed for the first three years.

5. Under high power draw a small area of the xylem, showing a medullary ray, large empty pitted vessel, small empty wood fibers, narrow empty tracheids, and protoplasmic wood parenchyma. Draw also a small area of cells from the bark, showing a medullary ray, light-colored thin-walled sieve tubes, very thick-walled bast fibers with only a minute lumen, protoplasmic companion cells in and around the sieve tube tissue, and large protoplasmic bast parenchyma.

6. Cut cross sections of a very young and of a year old twig of cottonwood (*Pópulus deltòides Marsh.*); mount and stain. Note the following structures: epidermis, periderm (cork layer) and the five corky ridges, phellogen (cork cambium), phelloderm (secondary cortex), primary cortex, sclerenchyma (fiber bundles), phloem with a narrow band of sclerenchyma, stelar cambium, xylem (wood), and the five angled central pith.

7. Make a sketch of a cross section of a polished tree trunk of black walnut (*Jùglans nìgra* L.), showing these structures: pith, heartwood (duramen), sapwood (alburnum), annual rings with early and late wood, medullary rays, the stelar cambium and phloem (inner bark) separated by irregular strips or arcs of corky tissue from the outer bark. The outer bark has been developed from the cortex and phloem and modified by successive layers of cork cambiums (phellogen). These irregular strips of corky tissue can easily be seen in the outer bark with the naked eye.

8. Compare with the walnut a polished section of the trunk of a bur oak (*Quércus macrocàrpa* Mx.) In this the medullary rays are much more prominent.

9. Study cross section of the trunk of *Catàlpa speciòsa* Warder. Measure the width of the annual rings and draw a curve showing the growth in diameter for the entire life of the tree trunk from which the section was taken.

XCIX. The Root.

(a) Section of Buckeye Root.

1. Cut cross sections of one of the larger fleshy rootlets of *Aesculus* sp. (preserved in alcohol). Mount and draw under low power, representing the following structures: the four or more primary xylem bundles, four or more primary phloem bundles alternating with the xylem, the beginning of the stelar cambium passing between the xylem and phloem, the endodermis or bundle sheath, and the broad cortex, with a superficial layer of cells known as the piliferous layer.

2. Cut cross sections of a somewhat older root which has turned brown, mount, and sketch the entire section under low power. Represent the following structures: the central strand of xylem composed of wood vessels and smaller cells, the stelar cambium, the band of phloem consisting of several kinds of cells, the remains of the endodermis, and the cortex and piliferous layer turned brown.

(b) **Embryonic Root Tip.**

1. Carefully remove the hard parts around the base of the embryo in a grain of corn (*Zèa màys* L.) and with a razor cut longitudinal sections of the radicle of the dormant embryo. The corn may be soaked in water for a while before cutting the sections, tho this is not necessary.

2. Mount the central sections in water and sketch under low power. Note the following embryonic tissues: the outer scutellum, the root-sheath of a dark appearance inside of the scutellum, and the root tip inside of the root-sheath. The root tip is made up of the root-cap (of a light color), the dermatogen (a layer of large cells inside of the cap), the dark layer of periblem, the central light plerome, and the growing point at the tip of the plerome. Outside of the dermatogen, at the apex of the root is the formative tissue of the root-cap, known as the calyptrogen. It will probably not be distinct enough in these sections to trace out, but its position should be noted.

(c) **Root Hairs.**

1. Sprout grains of corn on moist blotting paper in a box or under a bell-jar; after a few days the roots will be covered with root hairs. Sketch under dissecting microscope.

2. With a scalpel cut off some of the epidermis containing root hairs, mount and examine under high power. Draw and describe.

3. Under low power examine roots of young seedlings planted in soil and note the relation of the root hairs to the soil particles.

C. **Lenticels.**

1. Examine and sketch the bark of a green and of a year-old elder stem *Sambucus canadensis* L.) showing the surface covered with lenticels.

2. Cut cross sections of the bark, mount, and examine under low power. Sketch one of the lenticels. How and where do they originate?

CI. **Starch, Cellulose, Lignin, tannin, etc.**

1. Cut a potato and scrape off some of the cells. Mount in water and study under high power. Draw some of the large starch grains present, showing the hilum and the stratified structure.

2. Place a drop of iodin solution beside the cover-glass and watch its effect on the starch. What is the color reaction?

3. Mount some wheat flower in water and treat with iodin. Note the blue colored starch and the yellow colored proteid material.

4. Mount a hair of common cotton (*Gossỳpium herbàceum* L.) It is made up of nearly pure cellulose except the small central cavity in which is a small amount of dry protoplasm. Draw. Treat with Schulze's solution (Chlor-zinc-iodin) and after a while note the color reaction. Care must be taken so as not to get any of this solution on the microscope as it is strongly acid.

5. Treat cross sections of a sunflower stem (from alcoholic material) with Schulze's solution, examine, and note the cellulose reaction in the walls of the cortical and pith cells.

6. Treat a section of a sunflower stem with phloroglucin, mount and study color reaction in the xylem bundle. Care must be taken in its use as it contains an acid.

7. Cut cross sections of a young twig of linden preserved in alcohol, treat with phloroglucin, mount, and note color reaction in the wood.

8. Cut cross and tangential sections of peach pits taken just when they are beginning to harden. Mount and study the cells of this stony tissue. Draw a number of the cells and describe.

9. Tannin, which is the cause of astringency of many fruits, may be readily demonstrated by Vinson's method. Pour some sweet spirits of nitre, or a 20 per cent. alcoholic solution of nitrous ether, into a glass stoppered jar containing broken piece of pottery or glass to prevent the fruit to be treated from falling into the liquid, and then drop in some fruit rich in tannin like green dates or persimmons. Stopper tightly and let remain from 12-24 hours. At the end of that period the tannin bearing cells will be of a dark brown color and will show distinctly when the fruit is cut open. Mount some of the dark cells in water and examine under low and high power. Note the large tannin masses. Crush the masses by pressing on the cover-glass and note how they stretch and finally break. A stained fruit may be preserved in 95 per cent. alcohol. Date fruits are ideal for this experiment and may be obtained in autumn from Arizona.

10. Aleurone grains. Cut sections of the endosperm of a seed of *Ricinus communis* L., castor-oil plant, after soaking in water. Mount in alcohol or dilute glycerin and draw several cells showing the oval aleurone grains. Each grain usually has a crystalloid and a globoid in its interior.

CII. **Crystals.**

The material for sectioning may be preserved in alcohol.

1. Cut cross sections of the rhizome of the large blue-flag (*Iris versicolor* L.) mount, and under high power draw the simple crystals present.

2. Cut sections of a year old twig of the wahoo (*Euonymus atropurpureus* Jacq.), mount, and draw the large compound sphere-crystals in the pith and cortex.

3. Cut sections of the rhizome of the lily-of-the-valley (*Convallaria majalis* L.), mount, and draw the bundles of the needle-shaped crystals, raphides.

4. Cut cross sections of the leaves of the India-rubber fig. (*Ficus elastica* Roxb.) mount and draw the large cystoliths which are amorphous masses of mineral substance suspended from a pedicel. The mineral substance of the cystolith is mainly calcium carbonate.

CIII. **Lipochrome.**

1. Cut thin sections of the rind of an orange, mount in water, and examine under high power. Draw a cell showing the chromoplasts.

2. Cut sections of the root of the common cultivated carrot (*Daucus carota* L.). Mount and draw a cell showing the color bodies.

3. Mount pieces of the yellow corolla of the squaw weed (*Senecio aureus* L.) or any other yellow flower, examine under high power and draw a cell with chromoplasts. Describe the cause of the yellow color in these tissues.

CIV. **Anthocyan.**

1. Cut sections of the root of the red garden beet (*Beta vulgaris* L.), mount, and examine under high power. Note that the red coloring matter is in the cell sap.

2. Cut sections of any leaf with red color as the red leaved coleus (*Coleus blumei* Benth.), mount, and study the color under high power.

3. Cut off some of the epidermis of a red apple (*Malus malus* (L.),) mount, and study the cause of the color.

4. Mount part of a petal of a red greenhouse Pelargonium. Study the red coloring matter in the cells.

5 Mount part of a petal of a blue flower (like *Salvia pitcheri* Torr. or *Viòla odoràta* L.) and study the nature of the color.

CV. Solution of Anthocyan.

1. Take a quantity of the corollas of *Maurándia barclaiàna* Lindl. (a common greenhouse vine) or flowers of *Tradescantia virginica* L., place them in a dish and after crushing them cover with a quantity of 95 per cent. alcohol. After a few days or so pour off the alcohol into a bottle and preserve.

2. Take a test-tube about one-third full of the alcohol and add a few drops of aqua ammonia. Note color reaction. Neutralize with hydrochloric acid until the liquid is again clear. Continue to add acid drop by drop. What is the color?

3. Place some red pelargonium (greenhouse geranium) flowers directly in ammonia water. Note that they change to blue. Transfer to acid alcohol and note that they change back to red.

4. How do you account for the change of color in many flowers during the period of blooming and for the many varieties of color produced by cultivation as in the common morning-glory (*Ipomoèa purpùrea* (L.)?

CVI. Temperature Test with Anthocyan.

1. Take two good thermometers which register alike, wrap the bulb of one in a red begonia leaf and the other in a green begonia leaf, put each in a tumbler and place for some time in direct sunlight. Note the difference in temperature. Place the tumblers with thermometers in diffuse light and note the temperature again. Place them in a dark box and after a while read the temperature. Make a second test in the sunlight.

2. Describe one of the uses of anthocyan in roots, stems, leaves, flowers and fruits.

CVII. Chlorophyll Solution.

1. Take a quantity of green leaves, such as the blue grass or greenhouse pelargonium; place them in a porcelain mortar or other suitable dish; cover with 95 per cent. alcohol; and crush the leaves thoroly. After the alcohol is colored a dark green filter into a bottle and keep in a dark place.

2. Take a small quantity in a test-tube and examine by looking thru it toward the window. Note the deep green color produced by the transmitted light. Examine it by reflected light, by standing between the window and the tube, and observe that the color of the solution appears a deep dull red, something like blood.

3. Take a small quantity of the solution in two test-tubes, and place one in the sunlight and the other in a dark box. How long before the one in the sunlight fades out? Compare it with the one in darkness. Thus it will be seen that sunlight when too intense will rapidly change the character of chlorophyll, altho it is generally absolutely necessary for its development.

CVIII. Latex.

1. Take one of the large, red, deciduous stipules which cover the terminal bud of *Fìcus elástica* at the time when it is becoming transparent, a few days

before it is ready to fall. Examine immediately by holding the stipule with the inner side upon the stage of the microscope and examine with low and high power. Note the complex system of lactiferous ducts and the movement of the latex in them caused by its escape from the torn end of the stipule. At times the flow in the ducts appears to be very rapid.

2. Mount some of the latex and examine under high power. Note the spherical granules and draw. These are the rubber globules.

3. Why does the stipule become colored before it drops off from the bud?

CIX. Pollen-tubes in Artificial Cultures.

1. From an opening anther take fresh pollen of Canna, Hyacinth, or Begonia and make cultures in the following solution:

a.	Cane sugar, ...	6 parts
b.	Gelatin, ...	3 parts
c.	Tap water, ...	91 parts

Heat the mixture over a water bath till the gelatin is dissolved.

2. To a cubic cetimeter or two of this solution add an equal quantity of tap water and filter into a small covered dish. Put the pollen into the solution and also make hanging drop cultures, placing the slides into a moist chamber.

3. In 20 to 24 hours examine and draw several tubes representing successive stages of development. Note the rotation of the cytoplasm.

4. Treat with iodin solution and note the position of the nuclei.

CX. Karyokinesis.

Study the nuclear division in specially prepared slides of the root tips of *Allium cèpa* L., the common onion. For a detailed study an oil immersion objective and compensating oculars are necessary, but much may be learned with the ordinary lenses. For staining use the fourth and fifth stains given in the appendix.

1. Resting nucleus. Draw a cell some distance back of the tip where all the nuclei are in the resting condition. Represent the cell wall, the cytoplasm with vacuoles, and the nucleus. In the nucleus observe carefully the chromatin network with chromatin granules and the nucleoli. The nucleus is enclosed in the nuclear membrane. The lightly staining or hyaline substance in the nucleus, seen between the meshes of the chromatin network is called achromatin.

2. Prophase. (a) In the first stage of division the chromatin network is transformed into a continuous thread or spirem wound rather irregularly. At the same time the incept of the achromatic spindle appears forming two dome-shaped projections on opposite sides of the nucleus. This figure is known as the *close mother skein*. Find a suitable figure, draw and describe.

(b) Later the *looped mother skein* is formed by the shortening and thickening of the continuous spirem which is thrown into a definite number of loops, the heads of which in typical cases point toward the two poles of the spindle. The nucleoli and nuclear membrane begin to disappear and the dome-shaped caps of the spindle become more pointed. Draw and describe.

3. Metaphase. (a) After the nuclear membrane disappears the spirem breaks into separate loops which are drawn into the equatorial plane with their heads toward the center. At the same time the spindle continues to elongate. This figure is known as the *broken mother skein*. Draw and describe.

(b) When the chromosomes have come into the equatorial plane, there is a pause resulting from the seeming pull of the spindle fibers in opposite directions and the chromosomes are arranged in a very perfect star-shaped figure known as the *mother star*. Each chromosome has in the meantime commenced to split longitudinally. This may be seen in the more advanced mother stars. Draw and describe.

4. Anaphase. (a) After longitudinal segmentation of the mother chromosomes has taken place, the daughter chromosomes are gradually pulled apart, the separation beginning at the heads of the loops. This stage is called *metakinesis*. In very favorable sections, centrospheres or small round bodies may be seen at the poles of the spindle, also polar radiations, but these can only be studied favorably with an oil immersion lens. Draw and describe.

(b) After the chromosomes have been completely separated they arrange themselves in star-shaped figures around the poles, while a central spindle of threads appears between the two stars. This is the *daughter star* stage. Draw and describe.

5. Telophase. (a) The chromosomes having oriented themselves around the poles, now begin to contract, becoming wavy in outline, and the free ends curve inward. The threads of the central spindle begin to thicken preparatory to the formation of the cell plate. Then the central spindle begins to bulge outward until it reaches the cell wall. Nucleoli begin to appear. In favorable figures the polar radiations are quite prominent and two centrospheres may be seen at the poles under a high objective. This stage is called the *loose daughter skein*. Find a suitable figure, draw, and describe.

(b) After the daughter cells are completely separated by the new cell wall the threads of the central spindle and the radiations around the poles disappear, and nuclear membranes appear around the daughter nuclei. The chromosomes begin to be transformed again into an expanding chromatin network. This is known as the *close daughter skein*. Select a suitable figure, draw and describe.

6. Make a series of diagrams howing the changes in the chromatin from one resting stage to another.

CXI. The Reduction Division.

Study specially prepared slides of the ovularies of *Lilium philadélphicum* L. or the stamens of *Lilium tigrinum* Andr. Delafield's hæmatoxylin stain will bring out the chromatin well. The proper stages are obtained some time before the flower opens. In the ovule of Lilium the archesporial cell is transformed directly into the megasporocyte and this divides to form the first two cells of the embryo-sac, no megaspores being formed. During this karyokinesis the chromosomes are reduced and undergo a qualitative division.

Instead of Lilium the common Hyacinth may be used and will give exceptionally good slides for studying and counting the eight bivalent chromosomes. Plant Hyacinth bulbs about October 22, in sawdust, and kill the flowers about November 1. The root-tips may be used for the vegetative karyokinesis. Stain in Delafield's hæmatoxylin.

1. Under an oil immersion lens, study the early stages during which the chromatin network is being transformed into a spirem. Draw and describe.

2. Draw the stage when the spirem shows a single row of chromatin granules.

3. Study the stage in which the chromatin granules are dividing preparatory to a longitudinal splitting of the linin thread. Draw.

4. Study the stage in which the spirem, after the chromatin granules have divided, is twisting up into loops. There are twelve of these loops which will break apart and form the twelve chromosomes; just half as many as in the previous divisions during the life of the sporophyte. Draw carefully and make a diagram representing a loop and the arrangement of the chomatin granules.

5. Draw a chromosome just after the loops have broken apart, showing the twisted spirem and the closed head end of the loop. These are bivalent chromosomes.

6. Draw a spindle in the mother star stage showing the fully developed chromosomes. Make a diagram illustrating the structure of a chromosome. Count the chromosomes in a favorable cell.

7. Study the metakinesis stage when the chromosomes have partly untwisted and appear like elogated bands on the spindle, just before they break at the center. Draw. Make a diagram showing how the chromosome is attached to the spindle and how it divides.

8. Make a drawing of the early daughter star stage when the division of the chromosomes is complete.

9. Make a series of diagrams showing the changes in the chromatin from the early stage of division to the daughter skein stage. Compare the reduction division with the vegetative division where longitudinal splitting of the chromosomes takes place.

CXII. **Fluctuating Variability.**

One thousand soy beans (Glycine hispida Max.) or other suitable seeds, all taken from successive plants until the number is procured, may be weighed and assorted into glass tubes, each tube containing the beans weighing within 25 milligrams of each other. If small beans are used, a 10 milligram interval may be employed; or if large beans are at hand ,a 50 milligram interval in weighing will give satisfactory results. The tubes may be placed in a box or frame and one or a few sets, if properly managed, will be sufficient for the class. In small classes each student may weigh a thousand beans, if suitable balances are at hand.

1. Count the beans in each tube and make a proper tabulation of the number for each weight.

2. Make a series of slender, contiguous rectangles with equal bases and by shading show diagramatically the difference in number of the various weights of beans.

3. Plot a frequency curve showing the fluctuation of the 1000 beans. Could you state a principle relative to the abundance of the largest and smallest beans as compared with those of intermediate weight? Look up Quetelet's law.

CXIII. **Mendelian Principles of Heredity.**

Take pure white and pure red dent corn or flint corn and cross pollinate them — i. e. put pollen of red dent on the stigmas (silks) of white dent or the same for the flint corn if desired. Keep the silks covered properly to prevent the access of foreign pollen. Keep sampes of the parent type of ears. Plant the hybrid corn and pollinate the hybrid plants among themselves. The hybrid corn will all have grains with red pericarps (sporophyte character). Plant the red grain and in the next season there will be $\frac{1}{4}$ white corn plants and $\frac{3}{4}$ red corn plants. The white if kept separate will remain white pure, but $\frac{1}{3}$ of the red will give pure red and $\frac{2}{3}$ of it will give red and white again in the proportion of 3:1.

It will be seen, therefore, that $\frac{1}{4}$ was pure red, $\frac{1}{4}$ pure white, and $\frac{1}{2}$ hybrid red. The type ears of the original parents and of the three succeeding generations are to be arranged and labeled in proper order in a glass case or glass jars and the student is to note the striking hereditary results.

Also have corn showing first generation hybrid ears with purple and white grains.

1. Note that in the first hybrid generation (F_1) the red color only appears. The red is thus said to be dominant over the white.

2. Note that in the second hybrid generation (F_2) pure white corn is again produced from the red. The white character is said to be recessive to the red. Note that there is no blending of the two characters red and white but that the white is developed as pure from the red. Note the ratio between the red and white. Let R stand for red and w for white and if in the F_1 generation eggs are produced having the R heredity and others having the w heredity and if the same is true for the sperms, make a diagram showing all possible combinations that could occur in fertilization of these two kinds of eggs and two kinds of sperms. Using the letters R and w as symbols, arrange the combinations on a checkerboard of the proper number of squares.

3. Note the results in the third generation (F_3), (a) that the whites produced only whites, (b) that $\frac{1}{3}$ of the reds produced only reds, and (c) $\frac{2}{3}$ of the reds, i. e. $\frac{1}{2}$ of the F_2 generation, produced both reds and whites again in the ratio of 3:1.

4. Make a diagram with braces showing the inheritance from the original pure parents to the third generation of offspring.

5. Note that these generations of corn illustrate the main facts of Mendel's laws of heredity — namely, (a) dominance and recessiveness, (b) the lack of blending of certain hereditary factors or the characters resulting from their activity during development, and (c) the segregation of the factors and characters in definite ratios.

6. If white and purple endosperm characters are hybridized in corn could you explain, by remembering the facts in relation to the female gametophyte of the Anthophyta, why in the F_1 generation of ears there would be both purple and white grains present on the same ear, while in the case of the red and white corn the ears (both in the F_1 and F_2 generations) were always either completely white or red?

APPENDIX.

GENERAL METHODS IN BOTANICAL MICROTECHNIQUE.

GENERAL METHOD WITH PARAFFIN IMBEDDING.

In the following account all details are carefully stated, so that a beginner should be able, with little outside help, to carry the operations thru successfully. The methods employed in preparing plant tissues must be considerably different from those used in zoölogy, since we usually have to deal with a thick cellulose wall and a very delicate protoplasm in which are usually contained large vacuoles filled with cell sap, besides numerous plastids and food contents, all of which tend to make it difficut to preserve and study the finer details of structure in plant cells and tissues.

The object taken for a trial study may be some root tips of the common onion (*Allium cepa*), or pieces of the young ovularies of some species of lily, as *Lilium longiflorum* or *L. philadelphicum*. The root tips may be grown by placing an onion in a flower pot with moist sawdust, and keeping it for a few days where the roots will grow rapidly. The tips should be cut from one-half to three-fourths of a centimeter in length. The lily ovularies may be taken at various stages before and after the flowers open, and cut into transverse pieces from one-fourth to three-fourths of a centimeter long.

1. — Killing and Fixing.

The first thing to do in beginning to prepare any plant tissue for permanent mounting is to kill and fix it in such a way that it will preserve the minute structures as near the living condition as possible. A sharp knife or scalpel should always be used, and great care taken so as not to bruise or injure any of the cells.

Killing Fluid. — The killing fluid is made up as follows:

1.	Chromic Acid, ...	0.8 grams.
2.	Glacial Acetic Acid, ...	0.5 cc.
3.	Water, ...	99.0 cc.

Have the killing fluid in a 4 oz. (120 cc.) bottle with a common cork. Sixty cubic centimeters (2 oz.) of the fluid will be enough to kill one or two dozen objects the size of the root tips. The material must be perfectly fresh and put into the killing fluid as soon as cut. They will usually sink to the bottom after a short time, especially if they are shaken a little from time to time. If much trouble is experienced in having the objects float on the surface of the killing fluid, they may first be immersed for a very brief moment in 95 per cent. alcohol, and immediately after dropped into the killing fluid. This will cause them to sink; or force them

down with a plug of cotton. The objects must be kept in the killing fluid from twelve to twenty-four hours. The onion root tips should be left at least twelve hours; for larger objects, a proportinately longer time.

2. — Washing.

After the tissues have been thorely killed and fixed, the next thing necessary is to wash out the acid. This may be done by pouring off the acid and filling the bottle with water, and changing from time to time. They should be washed in this way from one to four hours, depending on how often the water is changed. A better way, however, is to set up and use the apparatus described as a convenient washing apparatus in this appendix. The water used for washing should be rather pure. If this is not the case, distilled water had better be used.

3. — Dehydrating and Hardening.

The next step is to remove all water from the tissues, and this must be done very gradually or the tissues will shrink and the protoplasmic contents of the cells will be distorted so that the preparations will be worthless. To remove the water successive grades of alcohol are used. During this process the objects may still be kept in the same bottle. The amount of each grade of alcohol should be sufficient to cover the objects well. The various grades of alcohol should be made up and kept in a special set of bottles. It is best not to use the alcohol more than once for this process. Carry them thru in the following order:

1. 10 per cent. Alcohol, ... 4 hours.
2. 25 per cent. Alcohol, ... 4 to 8 hours.
3. 35 per cent. Alcohol, ... 4 to 8 hours.
4. 50 per cent. Alcohol, ... 4 to 8 hours.
5. 70 per cent. Alcohol, ... 48 hours.

The objects should be hardened in the 70 per cent. alcohol at least two days, and a longer period is generally better. They may be kept in 70 per cent. alcohol for several months without injury.

6. 85 per cent Alcohol, ... 12 hours.
7. 95 per cent. Alcohol, ... 4 to 8 hours.
8. 100 per cent. Alcohol, ... 4 to 8 hours.

As a general rule, it is convenient to make three changes a day, morning, noon, and night, except the 70 per cent.

4. — Clearing.

The objects must now be put into some fluid which will dissolve paraffin. The best reagent for this purpose is chloroform.

1. Add one-third chloroform to the absolute alcohol. Let stand from four to eight hours.
2. Add enough chloroform to make a two-thirds solution, and let it remain from four to eight hours.
3. Transfer to pure chloroform and leave from six to twelve hours.

5. — Imbedding in Paraffin.

The objects are now ready for the paraffin. This should be of good quality, with the melting point at 49 degrees or 50 degrees C. The paraffin must be added gradually, in the following manner: add small pieces of cold paraffin to the chlo-

roform in which the objects are, sufficient to form a cold saturated solution. After the cold chloroform has taken up all the paraffin possible, say after about six or eight hours, the objects must be gradually brought into the hot water oven. This may be of various designs and sizes. A square oven with a side door is very convenient and cheap. The oven should be kept at a uniform temperature of about 52 degrees C. The bottle may first be placed on top of the oven, and then inside. When warmed up to the temperature of the oven, melted paraffin, kept in a suitable dish in the oven, may be added from time to time, at intervals of two or three hours. At the same time some of the mixture of chloroform and paraffin is poured off until the objects are in pure melted paraffin, with all traces of chloroform removed. The objects should stay in the oven at least a day, and several days will do no harm if the temperature is uniform. It usually takes two days for the operation. One day, however, is long enough unless the objects are very large and difficult to penetrate.

6. — Making the Cake.

The final imbedding can be easily done in the following manner: use a Petri dish of proper size, 80, 120, or 150 mm. in diameter, depending on the amount of material to be imbedded; or the paraffin imbedding dish described further on in this appendix. Before imbedding, apply a very thin coat of a 50 per cent, equeous solution of glycerine to the parts of the dish with which the paraffin will come in contact, and pour in a suitable amount of melted paraffin to make the cake. The objects being in the bottle with the cork, turn the bottle upside down and allow the objects to settle on the cork. Then remove the cork and let the paraffin in the bottle, with the objects, fall into the dish. The objects may be arranged in the paraffin with hot needles. Put the dish quickly into cold water, but do not let the water flow into the dish until the paraffin is hard enough to bear the weight of the water without being distorted. The paraffin cake must be cooled very rapidly, and this is usually done best in cold flowing water. After the cake is thoroly hardened it is carefully removed from the dish and laid aside until used. When the objects are once properly imbedded they can be preserved for an indefinite period if kept in a cool place. The bottle in which the objects were kept while passing thru the paraffin may be used for the same purpose for subsequent imbeddings thus saving the trouble of cleaning out the paraffin each time. After the objects are in pure chloroform they can be poured into this bottle, which will have some paraffin adhering to its walls.

7. — Cutting Sections.

The sections must be cut on a microtome. Cut one of the objects with a suitabe amount of paraffin out of the cake by means of a sharp scalpel, taking care that the edges of the block will be parallel with the general contour of the object. Trim the block down to a rectangular shape and fasten it to a block of wood, or a special holder which goes with some microtomes. Before attempting to fasten the block to the holder, have the top of this covered with a cushion of paraffin. The paraffin block must be fastened firmly, and the edges especially sealed with a hot needle so that there will be no danger of having it come off. After having cooled off the block in cold water and trimmed the sides to be parallel, fasten it into the clamp of the microtome and adjust the knife and clamp so that the knife will strike the paraffin block perfectly parallel. The block should be arranged with its long axis parallel to the knife edge. The ribbon of sections should be straight and not coiled. If the ribbon coils, no good mounts can be

made even if everything else has been satisfactory so far. The desirable thickness of the sections depends somewhat on the nature of the material and the object to be attained. As a general rule most sections may be cut ten microns (μ) thick. The section knife or razor must be sharp and clean, with not trace of the smallest notches, at least in that part with which the cutting is done. It is well to examine the edge of the knife under the low power of the microscope to see that it is in good condition. After the ribbon has been cut care should be taken to have all the pieces arranged in a continuous series, from left to right, on a clean sheet of paper. The sections may be covered with a wide bell jar. If the sections do not hold together well while cutting, the paraffin may be too cold or there may be other defects. These should be discovered and removed before proceeding further. Ribbons should be cut yards in length, without a single break, when serial sections are cut.

8. — Mounting.

1. Take a clean slide and put a small drop of albumen fixative on it. Spread it out over the surface with the finger into a very thin, even layer, being careful that no part of the finger touches the slide before being covered with a layer of the albumen. The layer must be quite thin so that you can just leave a noticeable impression of your finger on it. Too much albumen will ruin the preparation. The albumen fixative is made as follows:

1. 25 cc. of the white of a fresh hen's egg.
2. 15 cc. of glycerin.
3. 0.5 gram sodium salicylate.

Shake well and filter. This will keep well for a long time.

2. Now lay the slide down on the table and put a few drops of distilled water on it, on top of the albumen film. Care must be taken here that the water will not flow over the edge of the slide.

3. Cut the ribbon into suitable lengths, according to the size of the square or oblong cover-glass, discarding the ends of the ribbon which do not contain sections. With a scalpel lay the pieces of ribbon on the water in the center of the slide in such a manner that one may begin at the upper left-hand corner and follow the sections in lines, as one reads the words on this page. Allowance must always be made for a certain amount of stretching of the ribbons when they are heated, as they are always more or less ruffled. Never press the section down with the finger or by any other means, else the fine structure will be broken and distorted.

4. Warm the slide gently by putting it on the paraffin oven or holding them over a flame until the heat has straightened out the sections on the water, but do not let the sections get so hot as to melt the paraffin. The slides may now be placed on wooden blocks, which may be kept constantly on top of the oven for this purpose. It is best to let them remain for about twelve hours, when the water will all be evaporated and the sections firmly dried to the slide. Four, eight, or more slides can be carried thru at one time just as well as a single one.

9. — Staining.

The sections are now ready for the staining. One must have the following Stender dishes (60 mm. diameter x 90 mm. high):

1. Filled with turpentine.
2. Filled with xylol.

3. Filled with absolute alcohol.
4. Filled with 95 per cent. alcohol.
5. Filled with 85 per cent. alcohol.
6. Filled with 70 per cent. alcohol.
7. Filled with 70 per cent. acid alcohol (1/10 cc. HCl to 100 cc. alcohol.)
8. Filled with 50 per cent. alcohol.
9. Filled with 25 per cent. alcohol.
10. Filled with distilled water.

The various stains used may also be kept in Stender dishes if no special staining dishes are at hand. The following stains are recommended for general purposes:

1. *Anilin safranin,* alcoholic (50 per cent.) solution, made by combining equal parts of anilin water and a saturated alcoholic (95 per cent.) solution of safranin. The anilin water is prepared by shaking up anilin oil in distilled water. About 3.5 per cent. of anilin oil will be taken up by the water.

A good *anilin safranin* may also be made as follows:

Make a 10 per cent. soution of anilin oil in 95 per cent. alcohol. When the anilin oil is dissolved, add enough water to make the whole mixture 20 per cent. alcohol (see paragraph on "Grades of Alcohol"). Add 1 gram of safranin to each 100 cc. of this solution.

The safranin soluble in alcohol is the better one to use altho the safranin soluble in water will also be satisfactory.

2. *Gentian violet,* a 2 per cent. aqueous solution .
3. *Iron alum,* a 2 per cent, aqueous solution of ammonia sulphate of iron.
4. *Haematoxylin,* a 0.5 per cent. solution obtained by dissolving in hot water.
5. *Delafield's Haematoxylin,* to be obtained ready prepared from the dealers, or prepared according to the directions given farther on.

The remaining Stender dishes will therefore be as follows:

11. Filled with anilin safranin.
12. Filled with gentian violet.
13. Filled with iron alum.
14. Filled with haematoxylin.
15. Filled with Delfield's haematoxylin.

Preparation for Staining Bath.

1. Melt the paraffin around the sections of two slides by heating them to 52 degrees C. in the paraffin oven.

2. Wash off the paraffin by putting the two slides back to back into the Stender dish with the turpentine.

3. Transfer to Stender dish of xylol.

4. Next put them in succession into the dishes with absolute alcohol, 95 per cent., 85 per cent., 70 per cent., and 50 per cent., or to whatever grade of alcohol is present in the staining solution. If the stain is an aqueous solution pass down thru 50 per cent. alcohol to 25 per cent. and then to water. Let them remain in each one about ten seconds, more or less. Do not leave the dishes uncovered longer than necessary. In passing the slides thru the solutions it is convenient to take two at once placed back to back.

FIRST STAIN — ANILIN SAFRANIN.

1. Run the slides down thru the grades of alcohol to the 50 per cent.

2. Transfer the slides from the 50 per cent. alcohol to the anilin safranin dish, and let them stain from two to twelve hours or longer.

3. When the sections are stained wash them successively in the 50 per cent. alcohol, 70 per cent., 85 per cent., 95 per cent., and absolute alcohol. Judgment must be used as to how fast the transfer is to be made from one grade of alcohol to the other. They must generally be taken quite rapidly, as the alcohol will take out such stains as safranin.

4. Clear the sections by transferring them to the xylol. The sections must be thoroly cleared. Leave them in xylol until they look transparent.

5. Take one slide out of the xylol at a time; wipe off the xylol with a clean rag, wiping quite close to the sections, but do not touch the sections.

6. Put a drop or so of Canada balsam (dissolved in xylol) on the sections at one side.

7. Put on a clean cover-glass in the following manner: holding the cover-glass with the edges between the thumb and forefinger, bring it down slowly and obliquely upon the drop so that one edge of it is first wetted by the balsam; and supporting the opposite edge with a needle, let the cover gradually settle down and spread out the balsam. There should be no air bubbles and just enough balsam to come to the edge of the cover-glass. Care must be taken to not let the sections become dry at any stage of the foregoing process. The slides may now be laid aside into a convenient place to dry. They may be studied immediately if handled with care for a few weeks until the balsam has thoroly hardened around the cover-glass. If balsam should get on the hands or instruments, it can easily be removed with a little xylol.

SECOND STAIN — ANILIN SAFRANIN, GENTIAN VIOLET.

This makes a good double stain for many purposes. Stain first in the anilin safranin from two to twelve hours; then wash in 25 per cent. alcohol; next in water; and then stain from one to four minutes in the gentian violet. After washing in water, pass thru the grades of alcohol, clear in xylol or clove oil, and mount in balsam.

THIRD STAIN — HEIDENHAIN'S IRON-ALUM-HÆMATOXYLIN STAIN.

Run the slides down to water, and from this transfer to the iron-alum. Keep the sections in this from two to four hours, and after washing well in tap water, stain for twelve hours (or over night) in the hæmatoxylin. After this wash the slides again in water and wipe them clean, and as close to the sections as is safe. The sections are now black and must be cleared. To do this they are placed again in the iron-alum, which gradually takes out the excess of stain. They must be closely watched and examined from time to time under the low power of the microscope. When of a light greyish-blue color they are washed again very thoroly in tap water so that all iron salt is removed, and are then carried thru the grades of alcohol, cleared in xylol, and mounted in balsam. If the iron-alum will not remove enough of the stain use the acid alcohol after taking the slides thru to the 70 per cent.

FOURTH STAIN — ANLIN, SAFRANIN, IRON-ALUM-HÆMATOXYLIN.

After one has become accustomed to use the foregoing combinations successfully, the following is well worth trying: Stain first in anilin safranin or in anilin safranin and gentian violet, as described above; wash in water; and then stain in the iron-alum-hæmatoxylin according to the directions given, just as tho the sections had not been stained at all. After staining, removing excess of stain, and washing in tap water, pass thru the grades of alcohol, clear in xylol, and mount in balsam. This is one of the clearest stains.

FIFTH STAIN — DELAFIELD'S HÆMATOXYLIN.

In staining proceed as follows: Transfer to the stain from 25 per cent. alcohol; stain one to four hours. Wash in tap water until the purple color develops. Pass thru the alcohols to 70 per cent. Dip the slides rapidly into acid alcohol. Run back to water and let remain until the purple color is restored. Pass thru the alcohols, clear in xylol, and mount in balsam.

THE AGAR-AGAR METHOD OF IMBEDDING.

According to Bolton and Harris, "the method consists essentially in placing the fresh tissues in a hot 22 per cent. solution of agar-agar to which 10 per cent. of formalin has been added. The temperature of this fluid should be kept at about 70° C. After remaining in the solution from one to several hours, the tissues are removed and attached to blocks with a 5 per cent. solution of agar-agar containing 10 per cent. of formalin. The heat and the formalin harden and fix the tissues at the same time the agar-agar impregnates it. After fixing the tissues to blocks these are placed in 95 per cent. alcohol and allowed to remain from two to four hours, and the tissues are then ready to be cut into sections which can be stained, cleared, and mounted on slides in the usual way employed for celloidin sections."

The 2 per cent. solution of agar-agar can be made as follows: Take 1 gram of agar-agar to 50 cc. of distilled water and boil for two hours. Then pour the hot solution into a high cylinder and allow it to cool slowly until the cloud has fallen. After the solution has cooled, cut off the clear upper portion and put it in a glass jar. Place the jar in a basin of water and heat it until the agar-agar is melted. Then add formalin in the proportion of 1 part of formalin to 9 parts by volume of the melted agar-agar.

The 5 per cent. solution is made in the same way as the 2 per cent., only 1 gram of agar-agar to 20 cc. of distilled water are taken. Formalin should be added in the same manner and proportions as in the 2 per cent. solution. The 5 per cent. solution when melted is quite fluid, but when cold it is more firm. It becomes much firmer on the blocks after exposure to the action of strong alcohol. Large quantities of the agar-agar solution can be prepared and preserved in air tight vessels to prevent evaporation.

For fixing and imbedding only a small amount of the agar-agar solution need to be taken. The solution should be kept at a temperature of 70° C. The fresh tissues are first placed directly into the hot 2 per cent. solution and left for about two hours and are then transferred to the 5 per cent. solution and left for one hour or more, when they are ready to be imbedded. The tissues are imbedded on wooden blocks. With a small camel's hair brush put a layer of the hot agar-agar on one end of the block, let it cool for a few seconds and then place one of the pieces of material on the block. Cover with more of the agar-agar solution

until properly imbedded. After fixing the tissue to the block, place in 95 per cent. alcohol and let remain for twelve hours. The longer the agar-agar remains in the alcohol the tougher it becomes.

Instead of imbedding directly on the block the objects may be poured into a suitable dish with a proper quantity of thick agar-agar and when sufficiently firm the cake may be cut into suitable cubes. The cubes containing the objects are kept until properly hardened in 95 per cent. alcohol when they may be fastened to the wooden blocks and sectioned.

Leaves or stems containing considerable silicon may be first placed for 12 or more hours in a 5 per cent. aqueous solution of hydrofluoric acid and after washing in water imbedded as described above.

The material is sectioned on a sliding microtome in the same way as with the celloidin method. The knife must be kept wet with 95 per cent. alcohol as well as the blocks during the sectioning. The sections may be stained with safranin and gentian violet, Delafield's hæmatoxylin or other favorable stains.

This method is applicable where a histological study of the plant tissue is desired, but does not seem satisfactory for cytological work.

THE AGAR-AGAR AND PARAFFIN METHOD OF IMBEDDING.

It is often desirable to use the agar-agar method of imbedding and at the same time preserve the sections in series. This can be accomplished very easily by a combination of the agar-agar and paraffin methods. Such objects as fresh leaves and herbaceous stems and fresh or dried leaves with parasitic fungi are favorable objects for trial. The tissues are killed and imbedded in the usual way as described under the agar-agar method, the imbedding being done on a plate of glass. After the agar-agar has cooled for a few minutes the excess is trimmed off and the object incased in the agar-agar block is placed directly into 70 per cent. alcohol, passed up thru the grades of alcohol, and finally imbedded in paraffin in the usual way. The sections will adhere to the slide without the use of albumen fixative.

CELLOIDIN IMBEDDING.

1. Make a solution of equal parts of absolute ether and absolute alcohol.

2. Make a 2 per cent. celloidin solution with the ether-alcohol mixture. Use prepared celloidin like Schering's Celloidin. Also make 4, 6, 8, 10, 12, 14, 16, 18, and 20 per cent. solutions.

For the 2 per cent. solution take 2 grams of celloidin to 100 cc. of the ether-alcohol mixture; for the 4 per cent. solution 4 grams to 100 cc., etc. Keep the stock solution well corked.

1. Treat the fresh material to be imbedded in the same way as for paraffin imbedding until it is in absolute alcohol. Leave in the alcohol long enough to insure complete dehydration.

2. Transfer the objects to the ether-alcohol solution and leave 12 to 24 hours.

3. Next put them into the 2 per cent. celloidin solution for 2 or 3 days.

4. Transfer the objects for 2 days to the 4 per cent. celloidin solution.

5. Put them successively for 1 day each into the 6, 8, 10, 12, 14, 16, 18, and 20 per cent. celloidin solutions.

6. Finally, if desired, a few dry chips of celloidin may be added from time to time until the mixture is quite firm. The bottle with the objects may be kept on a paraffin oven at a temperature of about 40° C. if convenient.

7. The pieces of tissue may now be imbedded and the celloidin hardened in one of three ways:

A. Pour a sufficient quantity of the 20 per cent. celloidin solution into a suitable flat dish; take the objects out of the bottle with a pair of forceps and place them into this dish, arranging them with sufficient space between; cover the dish, but not too tightly; and set aside for about 2 days, when by the evaporation of the ether and alcohol the celloidin will be hard enough to cut into blocks.

Transfer the blocks for about 12 hours into chloroform and then put them into a mixture of equal parts of glycerin and 95 per cent. alcohol, where they may be kept indefinitely.

To fasten the celloidin blocks to the wooden blocks used for clamping to the microtome, trim with a sharp scalpel, place the under side of the celloidin block for a few moments in the ether-alcohol solution, and then fasten it to the wooden block which should have a cushion of thick celloidin solution. Let remain for a little while to allow the celloidin to harden somewhat and then place into the glycerin-alcohol solution until desired for cutting.

B. The pieces of tissue may be taken at once from the 20 per cent. celloidin solution and imbedded on wooden blocks. Place a small quantity of the 20 per cent. solution over one end of the wooden block, and arrange a piece of the tissue on this cushion. In 3 or 4 minutes pour on a layer of the celloidin solution and repeat this until the object is properly covered and imbedded. After about 5 minutes the block with the imbedded object is placed into chloroform and then into the glycerin-alcohol mixture until desired for sectioning.

C. Take the objects out of the bottle with a coat of celloidin adhering and place them for 12 hours in a bottle of chloroform. From this transfer to the glycerin-alcohol mixture and leave for a few days or indefinitely. When ready to section cover the end of a wooden block or object holder with thick celloidin solution, and after trimming the proper end of the block of material and freeing from glycerin, fasten to the moist surface of the object holder.

The sectioning must be done on a sliding microtome. While cutting sections the knife and block should be continually wet with 70 per cent .alcohol or with a higher grade up to 90 per cent. A camel's hair brush is convenient for removing the sections. The sections may be kept in alcohol of from 70 per cent. to 90 per cent. In staining, keep the sections in a small Stender dish or other suitable receptacle and treat in general similar to ordinary sections or paraffin sections passing them up and down thru the grades of alcohol according to the stain used. If desirable the celloidin may be removed, before or after staining, by placing the sections for 15 minutes into ether.

Woody tissues may be softened by the use of hydrofluoric acid. A 5-10 per cent. aqueous solution of the commercial acid should be used. This may be kept in a rubber bottle or in a glass bottle coated on the inside with a thick layer of hard paraffin.

After boiling the blocks of wood place them into the acid for 3 or 4 days, and after washing them thoroly in water pass thru the grades of alcohol. Hard tissues fixed in the ordinary killing fluids may also be softened by placing them for some time into the hydrofluoric acid.

Various stains may be used, but Delafield's hæmatoxylin is a good general stain for celloidin sections, and the following cleaning mixture will be found especially suitable before mounting in Canada balsam:

Turpentine, ...	3 parts.
Carbolic Acid, ...	2 parts.

COMBINATION OF THE PARAFFIN AND CELLOIDIN METHODS OF IMBEDDING.

Infiltrate with celloidin in the usual manner, and when in the thick celloidin place the object in a large quantity of pure chloroform either with or without any quantity of the celloidin adhering to its outer surface. After leaving 24 hours in the chloroform remove the objects to a bath of ½ chloroform and ½ cedar oil. In 24 hours place in the oven in paraffin of the grade used for imbedding. Several changes are necessary and more time must be allowed than for tissues imbedded by the plain paraffin method. Paraffin will penetrate the celloidin itself and the mass cuts with much less vertical compression than in the case of objects in pure paraffin.

IMBEDDING SMALL OBJECTS.

Difficulty is sometimes experienced in imbedding small bodies to be sectioned in large quantities, such as pollen grains, spores, unicellular algæ, etc. The following method will give good results:

The spores are placed in a homeopathic vial and treated in the ordinary way for paraffin imbedding. The objects will sink to the bottom and the different reagents can be easily poured off. When the material is ready the bottle is filled with paraffin and after the spores or other objects have settled to the bottom it is quickly cooled off. When the paraffin is hardened the bottle is broken and with a little trimming the block is ready for the microtome.

DELAFIELD'S HÆMATOXYLIN STAIN.

To 100 cc. of a saturated solution of ammonia alum add, drop by drop, a solution of 1 grain of hæmatoxylin dissolved in 6 cc. of absolute alcohol. Expose to the air and light for 1 week; then filter. Add 25 cc. of glycerin and 25 cc. of methyl alcohol. Let the solution stand until the color is rather dark. Filter and keep in a tightly stoppered bottle. The solution should stand for 2 months before it is ready for use.

SAFRANIN-GENTIAN VIOLET-ORANGE G. STAIN.

Safranin, according to the formula given in the general method for paraffin imbedding.

Gentian violet, a 2 per cent. aqueous solution; orange G., a 1 per cent. aqueous solution. Stain 12 hours in the safranin; wash rapidly in 50 per cent. alcohol, 25 per cent., and water. Stain 2 hours in the gentian violet. Finally stain 1 minute in the orange G. Wash rapidly in 50 per cent. alcohol, 85 per cent., and absolute alcohol. Clear in clove oil about 10 seconds. Replace with cedar oil. If not too dark mount in balsam; if still too dark apply more clove oil.

ACID FUCHSIN STAIN.

Make a 1 per cent. aqueous solution. Stain 15 to 25 minutes, or much longer, according to the material. This stain is good for free hand sections of alcoholic material like the leaves of pine, etc. If sections have been overstained they may be differentiated in a 1 per cent. solution of picric acid in 70 per cent. alcohol; leave about 30 seconds and wash in 70 per cent. alcohol until the red color is replaced, after which pass thru the grades as usual.

A DIFFERENTIAL STAIN FOR CELL STRUCTURES.

Preparations stained in several colors are not always the best to show details of structure. For ordinary class work, however, sections which bring out the various cell organs in distinct colors are very convenient and to a large extent preclude misinterpretations. The following will be found good for ordinary root tips and the material must be killed in chrom-acetic acid:

Stain first two or three hours in anilin-safranin. Next stain for about thirty minutes in an aqueous solution of picro-nigrosin. The picro-nigrosin must be made in the following proportions:

Distilled water, ...	100 cc.
Picric acid, ...	1 gram.
Nigrosin, ...	1 gram.

First dissolve the picric acid completely and then add the nigrosin. After staining, dehydrate and mount in balsam. The stain is permanent, and if properly done the results will be as follows: cell wall well stained and back; cytoplasm of a bluish color; spindle threads bright green; chromatin network and chromosomes brick red; nucleoli bright red; thickened connecting fibers of the central, barrel-shaped spindle dark green and prominent; granules of the cell plate black.

IODIN SOLUTION.

Make a strong solution of potassium iodide in distilled water; to this add crystals of iodin until a saturated solution is obtained. This may be diluted with distilled water until it is of a clear, reddish-brown color.

CHLOR-ZINC-IODIN (SCHULZE'S SOLUTION.)

1. Dissolve 110 grams of zinc in 300 cc. of pure hydrochloric acid and evaporate to 150 cc.

2. Dissolve one gram of potassium iodide in as little water as possible and add 0.15 grams of crystals of iodin.

3. Mix (1) and (2).

A good temporary stain for fresh or alcoholic material.

METHYL-GREEN STAIN.

Make a 2 per cent. aqueous solution of glacial acetic acid and add a little methyl-green. This fixes and stains nuclei of fresh material fairly well. After staining wash in 1 per cent. acetic acid and mount in weak glycerin. The stain fades rapidly.

BISMARK BROWN.

Make a 2 per cent. solution in 70 per cent. alcohol. This is good for cell walls but not for protoplasm. Stain about 30 minutes.

PHLOROGLUCIN.

Dissolve phloroglucin in methyl alcohol (wood alcohol) until a saturated solution is obtained; then add gradually strong hydrochloric acid until precipitation begins.

Use on fresh material or alcoholic material. Lignified walls assume a bright red color. Sclerenchyma is also stained strongly by this solution.

EOSIN, ALCOHOLIC SOLUTION.

Make a saturated solution in 70 per cent. alcohol. This is good for temporary mounts of fungi.

EOSIN, AQUEOUS SOLUTION.

Make a saturated solution in pure water. This is good for temporary mounts of fungi making evident transverse septa, etc.

RAPID STAIN FOR FREE HAND SECTIONS.

It is generally desirable to have students do their own staining so far as time will permit. Most good strains act too slowly to make this possible. An aqueous 1 per cent. solution of gentian violet or of fuchsin will give fair results on sections of rhizomes, stems, roots, and wood. The sections can be stained all together in a dish or one or more may be placed on a slide and covered with a drop of the gentian violet. After staining from 1 to 4 minutes and dehydrating, mount in Canada balsam and study immediately if necessary. A 1 per cent. aqueous solution of equal parts of gentian violet and safranin is very good for some objects.

The process in detail is as follows: Cut sections and place in 70 per cent. alcohol; wash in water; stain; wash in water, in 70 per cent. alcohol, in 95 per cent. alcohol, in absolute alcohol; clear in xylol; mount in balsam.

A RAPID STAIN FOR PARAFFIN SECTIONS.

One per cent. of fuchsin in 95 per cent. alcohol, stain for a few minutes and wash again in 95 per cent. alcohol. This gives a fair stain to root tips with very little manipulation.

A GOOD STAIN FOR STARCH.

A very good and desirable stain for starch may be obtained by the use of anilin-safranin and gentian-violet.

1. Anilin-safranin. Alcoholic fifty per cent. solution, prepared by combining equal parts of anilin water and a saturated alcoholic ninety-five per cent. solution of safranin.

2. Gentian-violet. A two per cent. aqueous solution. Stain from two to four hours or more in the safranin and from two to eight minutes in the gentian-violet. The slides should be taken thru the alcohols quite rapidly, or too much of the stain will be washed out.

FARRANTS' MOUNTING MEDIUM.

This medium modified as follows is good for various objects.

1.	Gum arabic dissolved in cold water (enough to make a thick gum)	20 cc.
2.	Glycerin	4 cc.
3.	Chloral hydrate	1 cc.
4.	Alcohol (95 per cent.)	1 cc.
5.	Glacial acetic acid	1 cc.

Care must be taken in adding the alcohol and acid to avoid coagulation. Various fresh objects, as spores, small gametophytes, fungi, etc., can be mounted in this medium directly from water or 95 per cent. alcohol.

MOUNTING IN GLYCERIN.

The following method will be found satisfactory for making permanent glycerin slides. The objects are taken from water to the pure glycerin by adding the glycerin gradually and permitting the water to evaporate until absolutely pure glycerin alone is left. The objects are then placed in a small drop of glycerin jelly on the slide and a ring of Canada balsam is placed around the drop, after which the whole is covered with a square or round cover-glass. The glycerin adhering to the objects may be drained off by placing them on a clean piece of blotting paper before transferring them to the drop of glycerin jelly. The glycerin jelly and balsam will not mix, and if the two mounting fluids have spread out properly the slide should be perfectly sealed. Such slides need not be sealed in any other way.

This method is suitable for various algæ, molds, powdery mildews, hairs, scales, and many other objects.

TO MOUNT FOSSIL OR DRY DIATOMS.

Place the diatoms or other like objects in 95 per cent. alcohol. Put a drop of the alcohol, with diatoms, on the slide; dry over a flame; cover with xylol; and when clear, mount in balsam.

TO MOUNT SPORES AND OTHER DRY OBJECTS.

To mount spores or funi, ferns, lycopods, etc., also myxocycetes, apply a layer of albumen fixative, sprinkle the spores on this, dehydrate with absolute alcohol, clear with xylol, and mount in balsam.

PERMANENT MOUNTS OF POLLEN.

When only external characters are desired very good mounts can be made in the following manner: Put a drop of albumen fixative on the slide and spread it out in a thin layer, sprinkle the fresh pollen on this, then put the slide into a Stender dish of absolute alcohol to which equal parts of a small amount of safranin and gentian violet have been added. About 0.1 gram of each to 100 cc. of alcohol is the proper amount. After 5-20 minutes transfer to absolute alcohol, clear in xylol, and mount in Canada balsam.

TO PRESERVE A TEMPORARY MOUNT FOR A FEW DAYS.

Place beside the cover glass a drop of 50 per cent. glycerin, letting the drop just touch the water of the mount, when it will be drawn in gradually as the water evaporates. This will of course kill any living organisms.

TO PREPARE DRY WOOD FOR CUTTING.

Boil blocks of a suitable size in water and place in 70 per cent. alcohol. Cut on a hand microtome when desired.

TO PREPARE VARIOUS OBJECTS FOR FREE HAND SECTIONING.

Roots, rhizomes, herbaceous stems, pine leaves, and other herbaceous parts are simply placed in 70 per cent. alcohol and preserved until desired for study.

TO PRESERVE FREE HAND SECTIONS.

Sections of wood, stems, roots, etc., may be preserve indefinitely in 70 per cent. alcohol. If stained they made be kept in xylol for several days and mounted at any time. They should be kept in the dark and carefully corked or stoppered, otherwise they may fade and the xylol evaporate.

DROP CULTURES.

Take a ring of glass made especially for the purpose or build up a chamber on the slide with paraffin. Put a drop of distilled or boiled water in the bottom of the chamber. Apply vaselin to the edge of the ring for sealing. Put a drop of water or other culture medium with spores on the center of the slide and place gently on the ring with the drop hanging down.

KILLING FLUIDS.

(a) FLEMMING'S WEAKER FLUID.

1 per cent. chromic acid,	25 cc.
1 per cent. glacial acetic acid,	10 cc.
Water	55 cc.
1 per cent. osmic acid,	10 cc.

Add the osmic solution from time to time as the reagent is needed for use, since it does not keep well. This fluid is expensive on account of the osmic acid.

The blackening due to the osmic acid may be removed by placing the slides in turpentine exposed to sunlight when they will stain well with a number of reagents. The best stain, however, is the safranin, gentian violet, orange G. combination.

(b) WEAKER CHROM-ACETIC ACID SOLUTION.

Glacial acetic acid,	0.7 cc.
Chromic acid,	0.3 gram.
Water,	99. cc.

This is good for algæ, root tips, and other delicate material. It causes little or no plasmolysis. It is improved by adding for each 10 cc. (as it is used) one drop of a 1 per cent. solution of osmic acid.

(c) ACETIC POTASSIUM-BICHROMATE FLUID.

Glacial acetic acid,	0.4 cc.
Potassium bichromate,	0.6 gram.
Water,	99. cc.

CLEARING MIXTURE AFTER LOW GRADES OF ALCOHOL.

Use phenol, or equal parts of phenol and bergamot oil, phenol will clear after low grades of alcohol, even water. The sections can then be transferred immediately to balsam.

CELLOIDIN FIXATIVE.

5 per cent. solution of celloidin,	1 part.
Clove oil,	3 parts.

PERENYI'S FLUID.

Nitric acid (10 per cent.) solution, . . . 4 parts.
Alcohol (95 per cent.), ... 3 parts.
Chromic acid ($\frac{1}{2}$ per cent. aqueous solution), . 3 parts.

This is good for preparing shell perforating algæ and other lime incrusted forms.

If too slow in action a few drops of nitric acid may be added to the amount used, about 2 drops to 10 cc. of the fluid.

SCHULTZE'S MACERATING FLUID.

This mixture is used to macerate woody tissues.

Potassium chlorate, ... 1 gram.
Nitric acid, ... 50 cc.

The chips or fragments of tissue are boiled in the fluid for a short time in a test tube. When the material is sufficiently macerated, pour off the fluid, wash well in water and after teasing the specimens apart with needles preserve and mount in glycerin.

The boiling should be done out of doors or under a hood as the acid vapors are very corrosive and injure microscopes and other metallic apparatus.

COPPER SALT SOLUTION.

Camphor, 20 grams dissolved in 50 cc. of 95% alcohol.
Glacial acetic acid, ... 100 cc.
Copper acetate, ... 30 grams.
Copper chloride ($Cu.Cl_2$), ... 30 grams.
Distilled water, ... 15 liters.

A larger or smaller quantity may be made in the same proportions. This solution is valuable for preserving green algæ, liverworts and other green plants.

GRADES OF ALCOHOL.

General pharmaceutical rule for making any lower grade or percentage of alcohol from any given grade or percentage.

Take of the grade at hand as many volumes as the number of the per cent. you wish to make; then add to this enough volumes of pure water to make the total number of volumes agree with the number of the per cent. at hand.

For example, suppose you have 95 per cent. alcohol at hand and wish to make 70 per cent. alcohol, take 70 cc. of the 95 per cent. alcohol and add to this 25 cc. of pure water. This will give you 95 cc. of 70 per cent. alcohol.

MARKING SLIDES.

Various methods have been described for labeling slides while they are being stained. Very good results may be obtained by the following method:

The medium used is waterglass, an aqueous solution of sodium- or potassium-silicate. It should be thinned if necessary till it will flow well from a pen. An ordinary steel pen of the stub or ball-pointed sort is used. After the slides are marked they must be heated, either before or after they dry, preferably by holding them for a few seconds in the blue cone of a bunsen flame till the waterglass decomposes giving off strong jets of sodium light, and at the same

time effervescing so as to leave behind a rough sandy surface. This is then rubbed down by a single stroke against the edge of the table or any hard object and leaves a ground glass surface which, if the fixing has been properly done, is permanent and will not be affected by any reagent which does not attack the slide itself. If desired some such dye as carmine may be stirred into the solution to make the marks more conspicuous.

Slides may also be marked with hydrofluoric acid as follows:

Take a clean slide, dip one end into paraffin, and let it cool. With a needle scratch whatever mark or number is desired on the paraffined surface, and then apply a drop of hydrofluoric acid to the mark by means of a wooden toothpick. Let this remain 2-5 minutes; then melt the paraffin and clean the slide. Any number of slides may be marked in a series in this way. Ordinary precautions must be taken in handling the hydrofluoric acid.

A CONVENIENT WASHING APPARATUS.

The apparatus described below will be found convenient for washing material after being killed in an acid or other solution. It consists of a glass or other tube of suitable thickness, ten centimeters long and from two to three centimeters in diameter; an open brass ring with thumbscrew; a funnel of brass or tin about five centimeters wide at the top, four centimeters deep, and ending below in an open tube one centimeter long; and two cotton or linen cloths for strainers. The apparatus is put together as shown in the figure, and may be supported on a tripod.

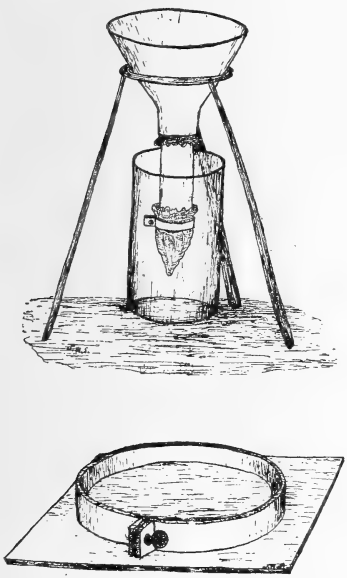


FIG. 17.

When the objects are ready to be washed, remove the ring and cloth and pour the objects, with the solution in which they are contained, into the tube, and then replace the ring and cloth, and let water flow into the funnel. Usually it will be found best to let the lower part dip into a glass dish. When the objects are washed they can easily be transferred to a bottle by taking off the cloth into which they will have settled. In this way small and delicate objects can be handled without injury.

This apparatus can also be used as a filter, or for collecting small water plants and animals. For instance, by having a cloth with a coarser mesh above and a finer one below, organisms of a certain size can be collected in the lower cloth free from foreign matter or larger animals and plants.

THE PARAFFIN IMBEDDING DISH.

When imbedding in paraffin a suitable dish must be used. When only a few objects are to be imbedded a small paper tray may be made. Petri dishes of suitable size may be employed for larger quantities. A dish especially made for this purpose will, however, be found most convenient. (Fig. 17.)

The bottom is a square plate of glass of proper size and thickness, while the box consists of an open brass ring with a thumbscrew. The sides of the ring should be smooth, and should be of sufficient thickness to secure rigidity. It will be found convenient to have rings of several sizes, — 50, 80, 120, and 150 mm. in diameter. Before using apply a very thin coat of 50 per cent. glycerin to the glass and ring, and place the dish on an ordinary plate so that cold water can be run under it.

THE LABORATORY NOTE BOOK.

A good note book is essential to good work in the laboratory, and tho one finds note books of about all shapes, sizes, and qualities, there are few which are really satisfactory for laboratory work. The note book should be 7 x 10 inches in size. This size is not too large to be easily handled, and is still large enough to hold most of the drawings made by the general student. It should be made up of two kinds of paper and two paper covers of stiff cardboard, strengthened with cloth on the back edges; all perforated exactly, with three holes (the outer holes being two inches from the ends), and tied together loosely with a shoestring. The paper should be unruled, and of good quality, so that the notes can be taken in ink; the drawing paper should also be such that a good hard pencil or India ink can be used for drawing. A third kind of paper can be used for the finer work.

This note book will lie absolutely flat on the table and there are no troublesome clamps in the way. It can be folded back to back, can be increased indefinitely in size, and the work can be rearranged in any way desired. Such note books can be made by any local dealer at small expense, and the paper sold to the students in any quantity and quality desired.

Substantial cloth covered backs should also be available for permanent binding.

MICROSCOPE COVERS.

A very convenient and serviceable microscope cover can be made from heavy manilla paper rolled up and glued together in the shape of a slender cone of proper size. A better one can be made in the same way with transparent celluloid.

GLOSSARY.

All important terms and phrases used have been defined and the derivation, when other than Anglo-Saxon, indicated. It was thought advisable to use the Latin alphabet in Greek words since very many college students have no acquaintance with the Greek.

Ab-nor'mal (organ) [Gr. anómalos]—An organ or part which deviates from the usual type in some extraordinary way, as in shape, size, color, or other character.

A-bor'tive (organ) [L. abortivus]—An organ or part normal in the species but which has failed to reach full development in the individual.

Ach-ro-mat'ic spindle [Gr. achrómatos]—The spindle shaped figure of threads formed in the cell during nuclear division. The spindle is usually not stained readily by stains which color the chromatin intensely.

A-chro'ma-tin [Gr. achrôma]—The substance of the nucleus which is not readily colored with basic stains.

Ac'ti-no-mor'phic [Gr. Aktínos+morphé]—Radially symmetrical; a flower or organ which can be cut into similar equal halves by two or more planes.

A-cu'mi-nate [L. acuminatus]—Tapering gradually to the apex.

Æ-cid'i-o-spore' [Gr. Aikía+spóros]—In rusts, one of the nonsexual spores produced in chainlike rows in the Aecidium.

Æ-cid'i-um—A cluster-cup, developed in one stage of the life history of certain rust fungi.

Æ-tha'li-um [Gr. aíthalos]—A compound sporebearing mass, formed in certain slime-molds, by the fusion of many sporangia.

Al-bur'num [L. albus]—The young, usually light-colored, soft wood of a tree next the cambium layer; the sap-wood.

A-leu'rone grains [Gr. áleuron]—Proteid material occurring in the form of minute granules in the seeds of numerous plants.

Al'ga]L.[—A thallophyte with chlorophyll.

Alternation of generations—A condition existing in the life cycle of plants in which a sexual generation alternates with a nonsexual one.

A'ment [L. Amentum]—A slender usually flexible spike of flowers, as in the willows.

An'a-phase [Gr. aná+phásis]—The stage in karyokinesis during which the daughter chromosomes separate and pass to the poles of the spindle.

A-moe'boid [Gr. amoibé]—Like an amoeba, especially in its movements or changes of shape.

A-nal'o-gous [Gr. ana+lógos]—Organs or parts similar in function but not in origin and structure.

A-nas'to-mos'ing [G. anastómosis]—Connecting so as to form a network.

A-nat'ro-pous [Gr. ana+trópos]—An inverted ovule with the micropyle near the hilum, the funiculus being united with the body of the ovule.

An-dre'ci-um [Gr. andrós+oikos]—The whole set of stamens in a flower.

An'dro-spo-ran'gi-um [Gr. andrós+spóros+aggeion]—A spore case containing androspores.

An'dro-spore [Gr. andrós+spóros]—A small spore in certain algae which gives rise to dwarf male individuals.

An'e-moph'i-lous [Gr. a'nemos+philos]—Pollination by the agency of the wind.

An'gi-o-sperm [Gr. aggeion+spérma]—A seed plant which has the seeds enclosed in the carpel, the enclosing case being called an ovulary.

An'i-so-car'pic [Gr. ánisos+karpós.]—Having the carpels of the gynecium fewer in number than the parts in the other floral sets.

An'nu-al [L. annualis]—Yearly; living but one year.

Annual ring—The layer of wood produced each year from the cambium layer in dicotyl and other similar plants.

An'nu-lar wood vessel [L. annulus]—A wood vessel having thickenings in the form of rings.

An'nu-lus [L. annulus]—In the agarics a ring of tissue surrounding the stalk; in ferns, the ring of cells party or completely surrounding the sporangium. A specialized ring of vesicular cells between the mouth of the sporangium and the operculum of a moss.

An'ther [Gr. antherós]—The spore-bearing part of a stamen; the part which finally contains the pollen sacs.

An'ther-id'i-o-phore [Gr. antherós+idion+phorós]—An organ or branch which bears the antheridia.

An'ther-id'i-um [Gr. antherós+idion]—A male organ of reproduction; a spermary.

An-tho-cy'an [Gr. ánthos+kúanos]—A coloring matter in plants of various shades of blue, red, etc.

An-tip'o-dal cells [Gr. anti+poús]—The cells, usually three in number, at the base of the female gametophyte in angiosperms.

Ap'ic-al cell—The cell in the tip of some bryophyte and pteridophyte stems by the division of which the growth in length takes place.

Ap'o-the'ci-um [Gr. apó+théke]—An open cup-like or disk-like body containing asci, in fungi and lichens.

Ar'che-góni-al chamber [Gr. archégonos]—A small depression at the tip of the female gametophyte in the seeds of cycads, into which the necks of the archegonia open.

Ar'che-go'ni-um [Gr. archégonos]—A female organ of reproduction; a special kind of ovary.

Ar'che-go'ni-o-phore [Gr. Archégonos+phérein]—The branch or structure which bears the archegonia.

Ar'che-spo'ri-al cell [Gr. Arché+spóros]—The cell from which sporocytes are finally developed.

Ar'che-spo'ri-um—The cell or group of cells which give rise to sporocytes.

A-re'o-la [L. areola]—A small space as between cracks, grooves, or ridges on various thalli.

Ar'il—An exterior covering or fleshy organ around the hilum of a seed.

As'co-carp [Gr. askós+karpós]—A fruiting body containing asci with ascospores.

As'co-spore [Gr. askós+spóres]—A spore produced in an ascus.

As'cus [Gr. askós]—A sac-like body in which spores are produced, usually definite in number.

As-sim'i-la'tion [L. assimilation]—In plants, the process by which dead, organic food materials are changed into the living protoplasm.

At'a-vism [L. atavus]—A reversion to an ancestral type.

At'a-vis'tic organ—One which shows in the individual a return to some ancestral type.

At'ro-phied organ [Gr. atrophía]—An organ or part normal in the individual but which has become reduced thru pathological conditions or thru disuse.

Ax'il—The point of a stem just above the base of the leaf.

Awn—A slender bristle-like organ.

Bac-te'ri-um [Gr. baktérion]—Any of the organisms belonging to the order Bacteriales or even of the Schizomycetae.

Ba-sid'i-o-spore' [Gr. básis+spóros]—A spore borne on a basidium.

Ba-sid'i-um [Gr. básis]—A special form of sporophore characteristic of the Basidiomycetae and related plants, typically bearing four basidiospores.

Bast—The phloem of the vascular bundle, the inner bark.

Bast fiber—Sclerenchymatous tissue in the bark of various plants.

Bast pa-ren'chy-ma [Gr. parégchuma]—The soft thin-walled cellular tissue in the phloem.

Bi-en'ni-al [L. biennalis]—Lasting for two seasons or two years.

Bi-lat'er-al [L. bi+lateralis]—Having a similarity of parts on the right and left side, or on the two sides of a dividing plane.

Bi-ol'o-gy [Gr. bíos+lógos]—The science of living organisms, including plants and animals.

Bi-spo-ran'gi-ate [bi+spóros+aggeion]—Having both microsporangia and megasporangia; having both stamens and carpels.

Biv'a-lent chromosomes [L. bis+valens]—Chromosomes formed during the reduction division by the synapsis of two simple or univalent chromosomes.

Bordered pits (of gymnosperms)—Peculiar pits in the walls of the tracheids.

Bot'a-ny [Gr. botáne]—The science which treats of plants.

Bract—A small, rudimentary, or imperfectly developed leaf.

Brood bud—A vegetative reproductive bud or structure.

Broken mother skein—A figure in nuclear division after the spirem has broken up into distinct chromosomes.

Brownian movement [Pertaining to Robert Brown]—The peculiar, vibratory movement exhibited by miscroscopic particles when observed in water or other fluids under the microscope.

Bud—A small structure on the end or the sides of a stem, which may develop into flowers or leafy shoots.

Budding—In plants like the yeast, the process by which new cells are developed by the gradual formation of a protubrance from the mother cell.

Bundle scar—A scar in a leaf scar produced by a vascular bundle.

Bundle sheath (of vascular bundle)—A definite layer of cells completely or partially surrounding a vascular bundle.

Ca-lyp'tra [Gr. kalúptra]—The hood or cap covering the sporangium (of a moss) and representing the enlarged archegonium.

Ca-lyp'tro-gen [Gr. kalúptra+gignomai]—The layer of cells at the tip of a root from which the rootcap originates.

Ca'lyx [Gr. kálux]—The outer set of sterile floral leaves; the whole set of sepals.

Cam'bi-um [L. cambire]—The cylinder of growing cells in some stems.

Cam'py-lot'ro-pous [Gr. kampúlos+tropé]—An ovule curved like a horseshoe.

Cap'il-li'tium [L. capillus]—The mass of threads in the sporangium of a slime-mold or puffball.

Cap'sule (of flowering plant) [L. capsula]—A dry fruit of two or more carpels, usually dehiscent by valves or teeth; sometimes applied to the sporangium of a bryophyte.

Car'pel [Gr. karpós]—The megasporophyll of a seed plant; the modified leaf or stem bearing the ovules.

Car'pel-late—Having only carpels or carpellate flowers.

Car-po-go'ni-um [Gr. karpós+gignesthai]—Sometimes applied to the oogonium of the red algae.

Car'po-spore [Gr. karpós+spóros]—A kind of spore produced in the cystocarps or sporocarps of the red algae.

Car'po-stome [Gr. karpós+stóma]—The opening in the tip of a cystocarp.

Cat'kin [Cat+kin]—The same as ament; a slender usually flexible spike of flowers as in the willows; (so called from its resemblance to a cat's tail).

Cell [L. cella]—The unit of plant and animal structure, usually consisting of a small mass of protoplasm, containing a nucleus and with a cell wall.

Cell plate—The central disk or wall formed in the central spindle between the two daughter nuclei in cell division, which finally divides the cell into two daughter cells.

Cel'lu-lose—The carbohydrate which constitutes the essential part of the ordinary cell wall of plants.

Cen'o-cyte [Gr. koinós+kútos]—A mass of cells or protoplasts with a common limiting wall but without walls separating the individual cells, the several or numerous nuclei apparently imbedded indiscriminately in the cytoplasm.

Cen'o-cyt'ic—Having the nature or structure of a cenocyte.

Cen'tral spin'dle—The spindle of threads developed between the two sets of daughter chromosomes in nuclear division.

Cen'tral strand (of mosses)—A strand of narrow, elongated cells in the center of a moss stem.

Cen'tro-some [Gr. kéntron+sóma]—A minute body appearing beside the nucleus or at the poles of the spindle during cell division.

Cen'tro-sphere—Same as centrosome, but including the attraction-sphere around the central granule.

Cha-la'zal [Gr. chálaza]—Pertaining to the base of an ovule.

Chlam'yd-o-sporè [Gr. chlámus+spóros]—A thick-walled, nonsexual spore as in the smuts.

Chlo'ro-phyll [Gr. chlorós+phúllon]—The green coloring matter of plants.

Chlo'ro-plast [Gr. chlorós+plastós]—A minute green, chlorophyll-bearing color body in the cells of ordinary plants.

Chro'ma-tin granules [Gr. chrómatos]—The granules in the chromatin which stain prominently with various dyes.

Chro'ma-tin network—The network of threads with granules in the nucleus.

Chro'ma-to-phore [Gr. chroma+phérein]—A plastid containing some coloring matter.

Chro'mo-plast [Gr. chroma+plastós]—A plastid containing some color other than green.

Chro'mo-some [Gr. chróma+sóma]—One of the group of bodies formed from the chromatin network during karyokinesis. The chromosomes are considered to be the special bearers of hereditary factors.

Cil'i-a [L. cilium]—Slender protoplasmic lashes or projections, having the power of movement, extending from certain cells.

Cir'ci-nate [L. circinatus]—Rolled inward from the apex.

Class (of plants)—A group of plants in one of the seven subkingdoms or subseries having an evident relationship to each other.

Cla'vate [L. clava]—Club-shaped.

Cleav'age plane—A separation layer produced in leaves, stems, and other organs by means of which they are separated from the plant.

Cleis'to-the'ci-um [Gr. kleistós+théke]—An ascocarp in which the asci are completely enclosed, the body having no ostiole.

Close daughter skein—A figure produced by the chromatin during karyokinesis, in which the chromosome loops are more or less joined by connecting strands.

Close mother skein—An early stage in karyokinesis when a continuous spirem is present which has not yet folded into definite loops nor broken apart.

Col-len'chy-ma [Gr. kólla+égchuma]—A tissue of plant cells which have the walls thickened at the angles.

Col'o-ny [L. colonia]—A group of unspecialized unicellular plants loosely connected in the vegetative phase.

Col'u-mel'la [L. columella]—A column-like axis in a sporangium.

Companion cells (in the bast)—Protoplasmic cells in and around the sieve tube tissue of the phloem.

Com'pound leaf—A leaf composed of several divisions or leaflets, the blades of which are not continuous.

Con-cen'tric vascular bundle [L. con+centrum]—A vascular bundle with the xylem in the center surrounded by phlœm, as in certain ferns.

Con-cep'ta-cle [L. conceptaculum]—A cavity, in a fruiting body, opening to the outside by an ostiole and containing either spermaries or ovaries, or both, as in the brown algæ.

Cone—A strobilus, a primitive flower as the carpellate cone of the pine.

Co-nid'i-o-phoré [Gr. kónis+phóros]—A branch or organ which bears conidia.

Co-nid'i-um [Gr. kónis]—A nonsexual spore formed by the cutting off and specialization of cells from the tip of a conidiophore, or by division of fungal hyphæ.

Con'ju-ga'tion [L. conjugatio]—Specifically the union of similar gametes, but generally the union of egg and sperm in fertilization or the union of any two bodies as univalent chromosomes into bivalent ones.

Con-tract'ile vac'u-ole [L. contractus vacuus]—A pulsating cavity in the interior of a protozoan supposed to be excretory in function.

Cork—The suberized tissue produced in the outer bark by the cork cambium or phellogen.

Cork cambium—The tissue of dividing cells in the bark which produces the cork cells.

Co-rol'la [L. corolla]—The inner set of sterile, usually colored, floral leaves; the whole set of petals.

Cor'tex [L. cortex]—The parenchymatous tissue in a young stem between the epidermis and the phloem.

Cor'ti-cal—[L. cortex]—Pertaining to or consisting of the cortex.

Cos'ta [L. costa]—The midrib of a moss scale.

Cot'y-le'don [Gr. kotuledo'n]—A leaf-like organ of the embryo in the seed.

Cross or transverse section—A section cut at right angles to the long axis of an organ as the stem.

Crys'tal-loid (in aleurone grain) [Gr. krústallos]—A minute crystal-like particle present in some aleurone grains.

Cu'ti-cle [L. cuticula]—The outermost tissue of cells, usually one layer thick, in the higher multicellular plants. The cuticle is often destroyed at an early stage as in dicotyl woody stems.

Cy'clic [Gr. kúklos]—Having the floral organs arranged in cycles or whorls.

Cys'to-carp [Gr. kústis+karpós]—A form of sporocarp produced in the red algæ, having the carpospores surrounded by a thickened envelope.

Cys'to-lith [Gr. kústis+líthos]—A concretion of calcium carbonate deposited in certain plant cells, usually on a projection from the cell wall.

Cy-tol'o-gy [Gr. kútos+lógos]—The branch of biology which deals with the structure, functions, and activities of the cell and its various protoplasmic organs.

Cy'to-plasm [Gr. kútos+plásma]—The more fluid part of the protoplasm exclusive of the nucleus and plastids.

Daughter cell—A cell which has been derived from the division of a mother cell.

Daughter stars—The karyokinetic figure in the anaphase when the daughter chromosomes are approaching the poles.

De-cid'u-ous [L. deciduus]—Falling away at the end of the growing period by a separation layer or cleavage-plane.

De-fin'i-tive nucleus (cell) [L. definitivus]—The nucleus which is formed in the female gametophyte of the anthophyta by the conjugation of the polar cells (usually two) and which gives rise to the endosperm, frequently after having conjugated with a sperm nucleus.

Der-mat'o-gen [Gr. dérma+gignomai]—The embryonic tissue from which the epidermis is produced. Incipient epidermis.

Di-chot'o-mous [Gr. dichotómos]—Once or several times two-forked.

Di-cot'ly [Gr. di+kotúle]—A plant belonging to the class of Dicotylæ, or having two cotyledons.

Di-e'cious [Gr. di+oikos]—Having the microsporangiate or staminate flowers and the megasporangiate or carpellate flowers on separate plants.

Disk flower—One of the tubular flowers in such inflorescences as are present in the sunflowers and related plants.

Dis-sem'i-na'tion [L. disseminatio]—The act of scattering seed.

Dom'i-nant character [L. dominans]—A character possessed by one of the parents of a hybrid, which appears in the hybrid and prevents the corresponding recessive character from the other parent from developing so long as their factors are associated.

Dor'sal [L. dorsualis]—Pertaining to the back.

Dor'si-ven'tral [L. dorsum+venter]—Having a distinctly differentiated upper and lower surface or part, usually lying flat on the substratum.

Drupe [Gr. drúppa]—A simple, usually indehiscent fruit with fleshy exocarp and bony endocarp.

Du-ra'men [L. durare]—The heart wood of a tree or shrub.

Dwarf branch—A highly specialized and reduced shoot bearing leaves, as in the pine and larch.

Dwarf male—A very small male plant produced in some algæ like Œdogonium.

Early wood—The first, often porous, wood of the annual ring produced by the cambium in the spring. Sometimes called spring wood.

E-col'o-gy [Gr. oikos+logos]—The study of all the relations of plants associated and grouped together under definite conditions of life, or of the individual and its structures as related to or influenced by the environment.

Egg—The female reproductive cell or gamete.

Egg-apparatus—The two synergids and the egg or oosphere present in the tip of the angiosperm female gametophyte.

E-la'ter [L. elatus]—An organ in the sporangium for opening the wall and aiding in scattering the spores.

E-mar'gi-nate [L. emarginare]—With a notched apex.

Em'bry-o [Gr. émbruon]—An incipient plant. In the seed plants the term is usually restricted to the young sporophyte in the seed. After sprouting it is a seedling or juvenile individual.

Em'bry-o sac (sack) [L. saccus, Gr. sákkos]—The female gametophyte, contained in the ovule of seed plants.

Em-bry-on'ic—Pertaining to an embryo.

Emp'ty glume—One of the two glumes at the base of a grass spikelet.

En'do-carp [Gr. éndon+karpós]—The inner layer of the pericarp.

En-do-der'mis [Gr. éndon+dérma]—A limiting layer of cells inside of the cortical tissue, often separating the parenchymatous from the vascular tissue; in many monocotyls dividing the stem into a central and outer portion.

En-do-phyt'ic [Gr. éndon+phutón]—Applied to a plant growing within another plant on which it may or may not be parasitic.

En'do-sperm [Gr. éndon+spérma]—The nutritive tissue developed around the embryo in the female gametophyte of angiosperms. It is developed from the definitive nucleus and typically has the triploid (3x) number of chromosomes.

En-to-moph'i-lous [Gr. éntomon+philos]—Said of plants in which pollination is accomplished by the agency of insects.

En-vi'ron-ment—The external conditions and influences surrounding the living organism. The influence may be inside of the organism or even inside of the cell.

Ep'i-der'mis [Gr. epi+dérma]—The external layer of cells in plants.

E-pig'y-nous [Gr. epí+guné]—Having the calyx, corolla and andrecium above the ovulary.

E-qua-to'ri-al plane [L. æquator]—The central plane of the cell, cutting the cell at right angles to the direction of the nuclear division.

Eu-spo-ran'gi-ate [Gr. eû+spóros+aggeion]—Having the essential part of the sporangium produced from the sub-epidermal cells.

Ev-a-nes'cent [L. evanescens]—Disappearing early.

Ev-o-lu'tion (organic) [L. evolutio]—The process by which the members of the organic kingdom have developed thru descent from each other. Evolution in general tends from the undifferentiated to the specialized; from the simple to the complex; from the low to the high; but the tendency may also be in the opposite direction, resulting in a simplification of the complex or a degeneration of the functional parts.

Ex'o-carp [Gr. éxo+karpós]—The outer layer of the pericarp.

Eye'spot—A small body containing pigment usually of a reddish color, present in many unicellular plants and animals and especially in zoospores. It is supposed to be sensitive to light.

Fam'i-ly (of plants) [L. familia]—A group of related plants, comprising one or more genera and ranking below the order.

Fe'male—Any plant which produces directly (either following a reduction division or not) eggs or female gametes.

Fe'male gam'ete [Gr. gameté]—The egg cell or oosphere.

Fern—Any plant belonging to the class Filices.

Fer'tile [L. fertilis]—Applied to a plant or part which produces normal spores, pollen, seeds, eggs, or sperms.

Fer'ti-li-za'tion [L. fertilis]—In botany, the union of the two gametes; the conjugation of the egg and sperm.

Fil'a-ment [L. filum]—A thread-like plant body as in the algæ and fungi; in the flowering plants, the slender stalk of the stamen below the anther.

Fla-gel'lum [L. flagellum]—A long whip-like protoplasmic mobile process, projecting from certain cells, especially zoospores and spermatozoids.

Flo'ral organ [L. floralis]—The organs of a flower, mainly sepals, petals, stamens, and carpels.

Flow'er [L. flos]—The modified spore-bearing shoot or branch of the Anthophyta; the various types of strobili or cones of the Calamophyta(Lepidophyta, Cycadophyta and Strobilophyta are primitive flowers to which the term may be applied in a general way.

Flow'er-ing glumes [L. flos, gluma]—The two chaffy bracts enclosing the grass flower.

Fluc-tu-a'tion [L. fluctuatio]—A variation due to the direct effect of the enxironment during the life time of the individual.

Fo-li-a'ceous [L. foliaceus]—Belonging to a leaf; leaf-like.

Foliage leaf—A normal green leaf.

Foot (of sporophyte)—The basal part of the sporophyte of a liverwort or moss; the absorbing organ of a pteridophyte embryo.

Frond [L. frons]—A large or highly developed thallus or gametophyte. Sometimes wrongly applied to fern leaves.

Fruit [L. fructus]—The spore-bearing parts of seedless plants; but especially in the seed plants the ripe carpels or ovulary with the seeds and whatever parts are modified or consolidated with these organs.

Fun'gus [L. fungus]—Any thallophyte without chlorophyll.

Fu-nic'u-lus [L. funiculus]—The little stalk by which the ovule or seed is attached to the placenta.

Gam'e-tan'gi-um [Gr. gameté or gamétes+aggeîon]—An organ which produces gametes.

Gam'ete [Gr. gameîn]—A sexual cell; an egg, sperm, or isogamete.

Ga-me'to-phore [Gr. gameté or gamétes+phérein]—A branch which bears sexual organs.

Ga-me'to-phyte [Gr. gameté or gamétes+phutón]—The sexual generation of plants.

Gem'ma [L. gemma]—A brood-bud capable of reproducing the plant.

Gen'er-a-tive cell [L. generatus]—Sometimes applied to the sperm mother cell in the pollengrain of Anthophyta. This cell by division, either in the pollengrain or in the pollentube, gives rise to two sperms.

Ge'nus [L. genus, Gr. génos]—A group of plants of lower rank than the family. The generic name constitutes the first of the two words in the binomial name of a species.

Ge-oph'i-lous [Gr. ge+phileîn]—Earth-loving; growing under the ground, as underground stems.

Ge-ot'ro-pism [Gr. gê+trépein]—The tendency of roots or other plant organs to assume growth curvatures under the influence of gravity.

Ger'mi-na'tion [L. germinatus]—The division or budding of a spore or reproductive cell; the beginning of the growth of a new individual plant.

Gills [of toadstools]—The spore-bearing plates or lamellæ on the pileus of one of the Agaricaceæ.

Gir'dle view—The side of a diatom where the two valves overlap.

Glo'boid [L. globus]—A small globular body often found in aleurone grains.

Glume [L. gluma]—The scaly bracts of the flowers and spikelets of grasses and sedges.

Grain [L. granum]—Any minute particle; the seed-like fruit of plants belong to the grass family.

Ground tissue—The general pith-like tissue in a stem thru which the vascular bundles and sclerenchyma bundles pass as in the fern stem.

Guard cells—The bordering cells on either side of a stoma.

Gym'no-sperm [Gr. gumnós+spérma]—A plant having naked seeds; a plant belonging to the subkingdom Gymnospermæ.

Gy-ne'ci-um [Gr. guné+oikos]—The whole set of carpels in a flower.

Hab'i-tat [L. habitare]—The place where a plant grows.

Haem'a-to-chromé [Gr. haima+chrôma]—A red coloring matter in some algæ as in Sphaerella.

Haus-to'ri-um [L. haurire]—In parasitic plants, a specialized outgrowth from the stem or mycelium serving as an organ of absorption.

Heart'wood—The hard, central part of a woody stem, usually differing in color from the younger outer sapwood. It is called duramen.

He'li-ot'ro-pism [Gr. helios+trépein]—Same as phototropism.

He'lot-ism [Gr. héilos]—The condition of symbiosis in which one of the symbionts, altho obtaining food from the other and giving none in return, causes no special injury as in the relation between alga and fungus in a lichen.

Her-ba'ceous [L. herbaceus]—Leaf-like in texture and color; having the characteristics of an herb.

Her-ba'ri-um [L. herba]—A collection of dried specimens of plants systematically arranged.

He-red'i-ta-ry [L. hereditarius]—Capable of descending or of being transmitted from parent to offspring.

Hereditary character—Any structure or peculiarity developed in an individual as the result of the normal activity of one or more hereditary factors.

Hereditary factor—The property or ability possessed by a cell thru the activity of which an hereditary character is developed, either independently by its own activity or in connection with other properties or factors.

He-red'i-ty [L. hereditas]—The biological principle or law in accordance with which an organism transmits its qualities and characteristics to its offspring. The ability of an organism to transmit its peculiarities to its offspring.

Her-maph'ro-dite [Gr. hermaphróditos]—An individual having both male and female sex organs.

Hĕt-er-écism [Gr. héteros+oikía]—The condition in which a parasite passes thru different stages of its life history on an alternation of hosts.

Het'er-o-cyst [Gr. héteros+kústis]—A large special type of cell occurring in the filaments of certain blue-green algae.

Het-er-os'por-ous [Gr. héteros+spóros]—Having two kinds of spores; having megaspores and microspores.

Histo-log'ic-al [Gr. histós+lógos]—Pertaining to the cellular structure of the tissues.

Hold'fast—A disk-like or branching body by means of which certain algae are attached to the substratum or support.

Ho'lo-phyte [Gr. hólos+phutón]—A plant which produces all of its food from inorganic substances.

Ho-mol'o-gous organs [Gr. homólogos]—Organs or parts similar in origin and structure.

Ho-mos'por-ous [Gr. homós+sporos]—Having only one kind of spores on the sporophyte generation.

Hor'mo-gone [Gr. hórmos+goneía]—A chain of cells in certain algæ separated from the parent body and by which the plant is propagated.

Host [L. hostis]—The plant or animal on which a parasite lives.

Hy'a-line [Gr. huálinos]—Clear and translucent.

Hy'brid [L. hybrida]—The offspring of two parents which differ in one or more hereditary factors or characters, especially the offspring of parents from different races, varieties or species.

Hy'dro-phyte [Gr. húdor+phutón]—A water plant, or one growing in very wet conditions.

Hy'gro-scop'ic [Gr. hugrós+skopeîn]—Readily absorbing and giving off water, by which movements are produced.

Hy-me'ni-um [Gr. humén]—The spore-bearing surface of certain fungi.

Hy-pan'thi-um [Gr. hupó+ánthos]—Any enlargement or special development of the torus, in a flower, on which the sepals, petals, and stamens are borne; a perigynous disk.

Hy'pha [Gr. huphé]—A branch or part of a filament of a fungus mycelium.

Hy'po-cot'yl [Gr. hupó+kotúle]—That portion of the stem below the cotyledons in the embryo of a seed plant.

Hyp'o-der'mal [Gr. hupó+dérma]—Pertaining to the tissue or parts beneath the epidermis.

Hy-pog'y-nous [Gr. hupó+guné]—Having the calyx, corolla, and andrecium below the gynecium.

Hy-poph'y-sis [Gr. hupó+phúsis]—The expansion or part just below the sporangium of a moss, often with stomata.

Hy-po-thal'lus [Gr. hupo+thallós]—A fleshy or membranous base bearing sporangia.

Im-bi-bi'tion [L. imbibere]—That phase in absorption which involves swelling and a limited alteration in the dimensions of the absorbing body.

In'cept, in-cip'i-ent [L. incipere]—An organ or part in its first stages of development in the individual, or in its embryonic condition.

In-du'si-um [L. indusium]—The membranous covering of the sori in many species of ferns.

In-flo-res'cence [L. inflorescens]—The flower cluster of a plant and its mode of arrangement.

In-her'it-ance [L. inhereditare]—The act or state of transmitting hereditary factors from one generation to another. The set of hereditary factors possessed by an organism which is or may be transmitted.

In-i'tial cell [L. initialis]—The original cell from which a tissue is developed.

In'ner bark—The tissue between the stelar cambium and the cork cambium.

In-teg'u-ment (of ovule) [L. integumentum]—One or two covering envelopes which invest the ovule and later become seed coats.

In'ter-cel'lu-lar spaces—The cavities between adjoining cells.

In'ter-nodé [L. internodium]—Part of a stem between two successive nodes.

In'vo-lu'cre [L. involucrum]—A whorl of bracts subtending a flower or flower cluster.

I'so-bi-lat'er-al [Gr. ísos+L. bilateralis]—A flower or organ which can be cut into equal halves by two planes, the halves of the one being unlike those of the other.

I'so-carp'ic [Gr. isos+karpós]—Having as many carpels in a set as there are petals, or sepals.

I-sog'am-ous [Gr. ísos+gámos]—Having gametes of equal size and appearance.

I-so-gam'ete [Gr. ísos+gameté]—One of a pair of equal gametes.

Ju've-nile organ [L. juvenilis]—An organ which is normal and functional in the early stages of the individual but which later disappears, as the juvenile leaves of certain seedlings.

Kar'y-o-ki--ne'sis [Gr. káruon+kinein]—The process of indirect nuclear division.

Lac-tif'er-ous duct [L. lac+ferre]—Ducts present in some plants containing a milky sap or latex.

La-mel'la [L. lamella]—One of the gills of a toadstool; a thin plate or layer as the middle lamella of certain thick cell walls.

Lam'i-na [L. lamina]—The blade of a leaf.

Late wood—The part of the annual ring of wood produced at the latter end of the growing season.

Látex [L. latex]—The milky sap of certain plants.

Leaf—An expansion arising from the axis or branch of a sporophyte, usually specialized to carry on the functions of photosynthesis and transpiration.

Leaf'let—One of the divisions of a compound leaf.

Leaf scar—The scar or cicatrix formed where the petiole of a leaf separates from the stem or twig.

Leaf trace—One or more vascular bundles which may be traced down from the base of the leaf into the stem, continuing distinct for some time before uniting with the stele.

Lem'ma [Gr. lémma]—The outer of the two flowering glumes inclosing a grass flower.

Len'ti-cel [L. lens, lentis]—A small, usually oval or round spot on the bark of a twig or stem, produced by a special tissue of cells under a stoma and breaking thru the epidermis.

Lep'to-spo-ran'gi-ate [Gr. leptos'+spóros+aggeion]—Having the sporangia developed from superficial cells.

Leu'co-plast [Gr. leukós+plastós]—A colorless plastid.

Li'chen [Gr. leichén]—A lichen is a plant structure formed by the association of a fungus and numerous algæ, forming a rather definite appearance which simulates an individual. The lichen fungus is a slave-holder, living symbotically with the algæ as slaves. By some the word "lichen" is restricted to the fungus part alone, but as here defined, the lichen fungus is regarded as a true fungus and the peculiar appearance or body, which is readily recognized in typical forms,—caused by the symbiosis of the two organisms,—is called the "lichen."

Lid cells (of archegonium)—The cells at the tip of the neck of an archegonium which open up to permit of the entrance of the sperms.

Life cy'cle—The succession of stages in the life history of an organism from its beginning in the fertilized egg or spore until it reproduces cells of a corresponding nature.

Life history—The succession of stages in the life of an organism from its beginning until it disappears thru natural death or by division gives rise to a new organism similar to itself.

Lig'nin [L. lignum]—The chemical substance composing the walls of woody cells.

Lig'u-late [L. ligula]—Provided with or resembling a ligule; as a ligulate flower.

Lig'ule—A strap-shaped organ; a triangular or somewhat elongated stipule-like organ on the leaves of Isoetes and Selaginella.

Limb—The expanded part of a petal, sepal, or sympetalous corolla.

Li'nin [L. linum]—The substance of the achromatic network or spirem on which the chromatin granules are held.

Lip cells (of fern sporangium)—Specialized cells where the sporangium will break open.

Lip'o-chrome [Gr. lípos+chroma]—Any of several pigments usually yellow, orange, or yellowish-red, nonsoluble in water, found in various plants.

Liv'er-wort—Any plant belonging to the class Hepaticæ.

Lod'i-cule [L. lodicula]—One of the two or three minute hyaline scales in the flowers of grasses, representing a vestigial perianth.

Lon'gi-tu'di-nal [L. longitudo]—Extending in the direction of the length.

Looped mother skein—The stage in karyokinesis in which the spirem is arranged in definite loops just before it breaks in pieces.

Loose daughter skein—The stage in karyokinesis in which the separate daughter chromosomes are beginning to unite, after the daughter star.

Lu'men [L. lumen]—The cavity of a tubular cell; a passage within the walls.

Ly-si'ge-nous cavity [Gr. lúsis+génesis]—An intercellular space formed by the breaking down or dissolution of adjoining cells.

Male—An individual that produces spermatozoids but not oospheres directly from the cells of its own body.

Male gamete—The spermatozoid or sperm.

Mal'for-ma'tion [L. malus+formatio]—Such organs or parts as show abnormal growths due directly to some external condition in the life of the individual, as a bud developed into an insect gall.

Med'ul-la'ry ray [L. medullaris]—A strip of cells passing radially thru the wood from the pith or the various annual rings to the bark.

Meg'a-spo-ran'gi-um [Gr. mégas+spóros+aggeion]—A sparangium which produces megaspores; the ovule in seed plants.

Meg'a-spore [Gr. mégas+spóros]—The larger of the two kinds of nonsexual spores produced in heterosporous plants. The megaspore develops into the female gametophyte.

Meg'a-spo'ro-cyte [Gr. mégas+spóros+kútos]—One of the cells in the megasporangium in which the reduction division takes place and which normally gives rise to four megaspores.

Meg'a-spo'ro-phyll [megas+spóros+phúllon]—The modified leaf which bears the megasporangia. In seed plants usually called a carpel.

Mer'i-stem [Gr. merízein]—A tissue of dividing cells; embryonic tissue.

Mer'i-ste-mat'ic [Gr. merizein]—Pertaining to the meristem or dividing tissue.

Mes'o-phyll [Gr. mésos+phúllon]—The parenchymatous tissue in a leaf between the upper and lower epidermis.

Mes'o-phyte [Gr. mésos+phutón]—A land plant growing in ordinary conditions of moisture.

Met'a-ki-ne'sis [Gr. metá+kínesis]—The stage innuclear division after the formation of the mother star.

Met'a-phase [Gr. metá+phásis]—The second general stage in karyokinesis in which the individual chromosomes pass from a scattered condition in the nuclear cavity to a definitely arranged mother star in the equatorial plane.

Mi'cro-pyle [Gr. mikros+pule]—The small opening or pore at the outer end of the ovule where the integuments come together over the nucellus.

Mi'cro-spo-ran'gi-um [Gr. mikrós+spóros+aggeion]—A sporangium which produces microspores; the pollensacks in seed plants.

Mi'cro-spore [Gr. mikrós+spóros]—The smaller of the two kinds of nonsexual spores produced in heterosporous plants. The miscospore develops into the male gametophyte, called a pollen grain in seed plants.

Micro-spo'ro-cyte [Gr. mikrós+spóros+kútos]—One of the cells in the microsporangium in which the reduction takes place and which usually gives rise to four microspores.

Mi'cro-spo'ro-phyll [Gr. mikrós+spóros+phúllon]—The modified leaf which bears the microsporangia. In seed plants usually called a stamen.

Mid'rib—The central rib of a leaf or other organ.

Mil'dew—Any of the mold-like parasitic fungi, as the downy mildews and powdery mildews.

Mi-to'sis [Gr. mi'tos]—Indirect nuclear division. Same as karyokinesis.

Mold—Any of the saprophytic fungi consisting of loose hyphæ, as the common bread mold and the common blue mold.

Mo-ne'cious [Gr. mónos+oikía]—Having staminate and carpellate flowers on the same plant.

Mon'o-cot'yl [Gr. mo'nos+kotúle]—A plant having one cotyledon.

Mon'o-po'di-al [Gr. mónos+poús]—having a single and continuous axis, as a twig which grows from a persistent terminal bud.

Mon'o-spo-ran'gi-ate [Gr. mónos+spóros+aggeion]—Having only one kind of spores in the flower; a flower with only stamens or carpels.

Mor-pho-log'ic-al [Gr. morphé + lógos]—Of or pertaining to the form and structure of an organ.

Moss—Any of the byrophytes except the liverworts and hornworts, as the bog-mosses, granite-mosses and true mosses.

Mother cell—A cell which divides into two daughter cells; or the parent cell of two cells.

Mother star—The star-like figure appearing in karyokinesis when the chromosomes are in the equatorial plane.

Mul'ti-cel'lu-lar [L. multus+cella]—Composed of more than one cell.

Mush'room—Any large fungus belonging to the Ascomycetæ or Basidiomycetæ, whether edible or poisonous, fleshy or otherwise.

Mu-ta'tion [L. mutatio]—A variation due to the presence of a specific hereditary factor or set of factors in the organism inherited in a definite way. A sudden variation as distinguished from a gradual variation, the offspring differing from the parents in some well-marked hereditary character or characters.

Mu'tu-al-ism [L. mutuus]—The condition of symbiosis in which each of the symbionts is of benefit in obtaining the food supply.

My-ce'li-um [Gr. múkes]—The entire mass of hyphae or threads which make up the body of a fungus.

My-co-rhi'za [Gr. múkes+hriza]—The mutualistic, symbiotic association of a fungus mycelium with the roots or other underground parts of a plant.

Nas'cent organ [L. nascens]—An organ or part at the beginning of its evolution or at the beginning of its development in the race; or in its first stages of evolution as compared with other homologous organs.

Neck (of archegonium)—The upper part of an archegonium thru which the sperms enter to unite with the egg.

Neck canal (of archegonium)—The passage, or row of central cells in the neck of an archegonium.

Nec'tar gland [Gr. néktar]—A gland which secretes nectar.

Nec'tary—A nectar-secreting organ.

Node [L. nodus]—The place where two internodes join, normally with a single leaf or more.

Non-sex'u-al [L. non+sexus]—Being without sex; not producing gametes but spores which develop without conjugation.

Nu-cel'lus [L. dim. of nux]—The incipient ovule, or the outer end of the ovule exclusive of the integuments.

Nu'cle-ar membrane [L. nucleus]—The layer of protoplasmic material surrounding the nucleus.

Nu'cle-us [L. dim. from nux]—The dense, more or less spherical, complex, protoplasmic body present in the cell.

Nu-cle'o-lus [L. dim. of nucleus]—A small rounded body contained in the nucleus; one or more may be present.

On-tog'e-ny [Gr. óntos+gígnomai]—The history of the development of the individual organism; the development of the individual.

O'o-go'ni-um [Gr. oón+gónos]—A simple ovary, usually consisting of a single cell containing one or more eggs.

O'o-sphere [Gr. oón+sphaira]—The unfertilized egg; the female gamete.

O'o-spore [Gr. oón+spóros]—The fertilized egg.

O-per'cu-lum [L. operculum]—The lid at the tip of the sporangium of a moss or other plant.

Or'der [L. ordo]—A group of plants consisting of one or more families; the first general group of lower rank than the class.

Or'gan [Gr. órganon]—A part or structure of a plant fitted for the performance of a definite function or set of functions.

Or-thot'ro-pous [Gr. orthós+trépein]—A straight ovule, having the hilum and micropyle at opposite ends.

Os-mo'sis [Gr. osmós]—Diffusion thru membranes or partitions. The specific relation which exists between solutions and the material of the separating membrane, determining variable selection and permeability.

Os'ti-ole [L. ostiolum]—The orifice opening into the cavity of a conceptacle, perithecium, or similar structure.

Outer bark—The rough corky tissue developed from the cork cambiums outside of the inner bark which is developed from the stelar cambium.

O'va-ry [L. ovum]—The female organ of reproduction; an egg-producing organ.

O'vu-la'ry [L. ovum]—The ovule-bearing part of a closed carpel or set of carpels.

O'vule [L. ovum]—The megasporangium of a seed plant which later develops into a seed.

O'vu-lif'er-ous scale [L. ovum+ferre]—The peculiar outgrowth from the carpels of some conifers at the base of which the ovules are borne.

Pa'let [L. palea]—The inner of the two glumes inclosing the flower of a grass.

Pal'i-sade pa-ren'chy-ma [L. palus. Gr. parégchuma]—The tissue of vertically elongated cells in the upper side of a leaf below the epidermis.

Pan'i-cle [L. panicula]—A compound inflorescence of the racemose type usually of pyramidal form.

Pap'pus [Gr. páppos]—The bristles, awns, teeth, etc., on the top of an achene, representing a calyx, or having the position of a superior calyx.

Par'a-site [Gr. parásitos]—An organism growing upon other living plants or animals and absorbing their juices and tissues as food and thus causing them injury.

Pa-raph'y-sis [Gr. pará+phúsis]—A hair or hair-like scale growing among the reproductive organs.

Pa-ren'chy-ma [Gr. parégchuma]—A fundamental plant tissue usually composed of thin-walled cubical or polygonal cells rich in protoplasmic contents.

Par'the-no-gen'e-sis [Gr. parthénos+gignomai]—The germination and development of an egg or other gamete without being fertilized or uniting with another gamete.

Pel'tate [Gr. pélte]—Shield-shaped, as a leaf with the petiole attached at or near the center of the blade.

Pen'ta-cy'clic [Gr. pénte+kúklos]—Having five cycles.

Pen-tam'er-ous [Gr. pénte+méros]—Five-parted.

Per-en'ni-al [L. perennis]—Growing for more than two years or for many years.

Per'i-anth [Gr. peri+ánthos]—The calyx and corolla taken collectively; the floral leaves taken collectively when not differentiated into calyx and corolla.

Per'i-blem [Gr. periblema]—The layer of meristematic tissue lying between the dermatogen and the plerome.

Per'i-carp [Gr. perí+karpós]—The wall of a fruit; the ovulary wall.

Per'i-derm [Gr. peri+dérma]—The corky tissue of the outer bark derived from growth of the phellogen.

Pe-rid'i-um [Gr. perídion]—The wall of a spore case in various fungi, or the wall of the fruiting body as in a puffball.

Per'i-gyn'i-um [Gr. perí+guné]—The sack-like envelope surrounding the archegonia in liverworts. The sack-like envelope around the ovulary of a Carex flower.

Pe-rig'y-nous [Gr. perí+guné]—Having the sepals, petals, and stamens borne on a disk or hypanthium surrounding the gynecium.

Per'i-stome (of a moss) [Gr. perí+stóma]—The fringe of teeth surrounding the mouth of a moss sporangium when the operculum is removed.

Per-i-thé-ci-um[Gr. perí+théke]—A flask-shaped body with an ostiole containing asci; a certain kind of ascocarp.

Pet'al [Gr. pétalon]—One of the leaves or segments of the corolla.

Pet'i-ole [L. petiolus]—The stalk of a leaf.

Phag'o-phyte [Gr. phagêin+phutón]—A plant which is able to take up organic food either as a parasite or saprophyte.

Phel'lo-derm [Gr. phellós+dérma]—A secondary cortical tissue developed on the inside of and from the phellogen.

Phel'lo-gen [Gr. phellós+genés]—The cork cambium; a secondary meristem giving rise externally to cork tissue, and internally to secondary cortex or phelloderm.

Phlo'em [Gr. phlóos]—The part of the vascular bundle containing the sievetubes and their companion cells; in a dicotyl the phloem forms part of the inner bark.

Pho-to-syn'the-sis [Gr. phôs+súnthesis]—The process of constructive metabolism by which carbohydrates are formed from water and carbon dioxide in the chlorophyll-containing cells of plants exposed to the action of light.

Pho-tot'ro-pism [Gr. phôs+trepein]—The response of plants to light, leading to changes in growth and position (heleotropism).

Phy-co-cy'an [Gr. phûkos+kúanos]—A blue coloring matter found in the blue-green algae.

Phy-log'e-ny [Gr. phûlon+gignesthai]—The history of the development of the race or phylum to which an organism belongs, in distinction from onthogeny.

Phy'lum (of plants) [Gr. phûlon]—One of the great or fundamental natural groups of plants. The plant kingdom can be divided into fifteen phyla.

Phys'i-o-log'ic-al [Gr. phúsis+lógos]—Pertaining to the functions and activities of organisms.

Pi'le-us [L. pileus]—The expanded upper portion or cap of many of the fungi.

Pi-lif'er-ous layer [L. pilus+ferre]—The external layer of cells in a young root. giving rise to the root hairs; the epidermis of a root from which root hairs develop.

Pith—The soft parenchymatous tissue in the center of a stem; the general ground tissue thru which scattered vascular bundles pass.

Plank'ton [Gr. plagktón]—The minute free floating or swimming plants and animals of a body of water; the secondary plankton includes the larger surface floating plants and also such as are commonly torn loose and float in the water.

Plan'o-gam'ete [Gr. plános+gamein]—A motile gamete.

Plas-mo'di-um [Gr. plásma]—A jelly-like mass of fused naked, ameboid cells, as the plasmodium of a myxomcete.

Plas-mol'y-sis [Gr. plásma+lúsis]—The contraction or shrinkage of the protoplasm in a living cell due to the rapid loss of water by exosmosis.

Plas'tid [Gr. plástis]—One of the small granules or color bodies found in the cytoplasm of plant cell. They are divided into chloroplasts, chromoplasts and leucoplasts.

Ple'rome [Gr. pleroma]—The central cylinder or column of tissue in an embryonic plant.

Plu'mule [L. plumula]—The bud or growing point of an embryo plant in the seed.

Plu'ri-loc'u-lar [L. plus, pluris+loculus]—Having several cavities or loculi; in algæ, having many cells separated by walls = multicellular, as plurilocular sporangia.

Po'lar nu'cle-i—The two free nuclei present in most female gametophytes of the Anthophyta which together with a spermatozoid conjugate to form the definitive nucleus which gives rise to the endosperm of the seed.

Po'lar ra'di-a'tions—The radiations which surround the poles of the spindle during karyokinesis and later, near the end of nunclear division, the daughter nuclei.

Poles of spin'dle—The two points in the karyokinetic figure to which the spindle fibers converge, and often surrounded by radiations.

Pol'len [L. pollen]—The mass of male gametophytes of seed plants.

Pol'len cham'ber—The cavity in the tip of the ovule of certain lower gymnosperms. into which the pollen is received after passing thru the micropyle.

Pol'len grain—The male gametophyte of seed plants.

Pol'len sac (sack)—A cavity in an anther containing pollen; the microsporangium of a seed plant after the microspores have germinated.

Pol'len tube—The tubular outgrowth which develops from the pollengrain and penetrates into the ovule. The male gametes or sperms pass thru this tube and enter the female gametophyte.

Pol'li-na'tion—The transfer of the pollen, or male gametophytes, to the stigma or to the micropyle of the ovule.

Pol'y-stélic—[Gr. polús+stéle]—Having several steles.

Pri'ma-ry cor'tex—The periblem or the tissue derived directly from it; the tissue in the stem between the vascular bundles and the epidermis.

Pri-mor'di-um [L. primordius]—A nascent organ; an organ in its first stages of evolution as compared with other similar organs.

Pro-cam'bi-um [L. pro+cambire]—The young tissue of a vascular bundle before its cells have begun to be differentiated, or the tissue from which the original vascular bundles are developed.

Pro-em'bry-o [Gr. pro'+émbruon]—The early embryo before its differentiation. It is usually differentiated into a suspensor and the embryo proper.

Pro-my-ce'li-um— [Gr. pró+múkes]—The short hyphal filament or basidium produced by a germinating chlamydospore, as in the rusts and smuts.

Pro'phase [Gr. pro'+phásis]—The first general stage in karyokinesis in which the chromatn network is transformed into a spirem and thrown into loops.

Pro'to-ne'ma [Gr. prôtos+nêma]—The filamentous green alga-like body or embryonic thread, which develops from the spores of certain ferns and bryophytes or from some part of a moss plant.

Pro'to-plasm [Gr. prôtos+plásma]—The living substance found in the cells of plants and animals.

Pro'to-plas'mic con'ti-nu'i-ty—Having the protoplasts connected by protoplasmic strands which pass thru the cell wall.

Pro'to-plast [Gr. prôtos+plástis]—The protoplasmic cell contents, exclusive of the cellulose wall.

Pro'to-stéle [Gr. prôtos+stéle]—The solid stele characteristic of most roots, of the earliest portions of stems and in some petridophytes of the whole of the axis.

Pseu'do-po'di-um [Gr. pseudés+poús]—A scaleless branch of a moss bearing gemmae or a sessile sporangium.

Puff'ball—Any fungus belonging to the Lycoperdaceæ or similar related forms.

Pul'sa-ting vac'u-ole—A contractile cavity or cell organ present in some lower organisms.

Pyc-nid'i-um [Gr. puknós]—A perithecum-like body bearing conidiospores, present in certain fungi.

Py-re'noid [Gr. purenoeidés]—A transparent refractive proteid body found in the chromotophores of certain algæ. The pyrenoids serve as centers for the deposition of starch.

Pyr'i-form [L. pyrum+forma]—Shaped like a pear.

Qual'i-ta-tive di-vi'sion—Nuclear division in which there is a segregation of chromatin material of distinct kind or a segregation of entire chromosomes, and not merely daughter parts.

Quan'ti-ta-tive di-vi'sion—Nuclear division in which daughter chromosomes, derived from mother chromosomes, are segregated.

Ra-chil'la [Gr. hráchis]—The axis of a spikelet on which the flowers are arranged.

Ra'chis [Gr. hráchis]—The axis of a spike, or raceme, on which flowers or spikelets are arranged; also the axis of a compound leaf.

Ra'di-al section [L. radius]—A section cut longitudinally thru the center of the stem.

Rad'i-cle [L. radicula, dim. of radix]—The incipient stem and root in an embryonic plant.

Ra'phe [Gr. hraphé]—A ridge or seam along the side of a seed.

Raph'i-des [Gr. hraphís]—Minute, usually needle-shaped crystals often occurring in bundles in the cells of certain plants.

Ray flower—One of the marginal or ligulate flowers in the head of a composite.

Re-cep'ta-cle [L. receptaculum]—The stem or axis which bears the floral organs; a special branch which bears the reproductive organs in certain algæ.

Re-ces'sive character [L. recessio]—A character possessed by one of the parents of a hybrid which may not appear in the hybrid but is nevertheless transmitted to the following or a later generation.

Re-duc'tion division—The division in a sporocyte, oocyte, or spermatocyte in which the bivalent chromosomes are segregated into univalents, and in which the reduction number appears during the development of the bivalents.

Re-flexed' [L. reflexus]—Bent backward abruptly.

Re-pro-duc'tion [L. re+producere]—The process by which organisms give rise to offspring.

Res'in duct [L. resina, ductus]—A passage or tube containing resin.

Res'pi-ra'tion [L. respiratio]—The chemical changes taking place in all living cells whereby food constituents are decomposed largely as a result of the action of enzymes, liberating energy, water, and carbon dioxide. In ordinary respiration, the external manifestations are the taking into the cell of the free oxygen of the air and the giving off of carbon dioxide.

Resting nucleus—A nucleus not in the stage of division.

Re-tic'u-late [L. reticulatus]—Arranged as a network.

Re'tro-gres'sive organ [L. retrogressus]—An organ which is passing from a higher to a lower or less perfectly developed condition or state of organization.

Rhi'zoid [Gr. hriza]—A filamentous outgrowth from the thallus or gametophyte, usually functioning as an organ of attachment.

Rhi'zome [Gr. hrizoma]—An underground stem.

Root—An absorptive and supporting organ of the sporophyte usually underground.

Root-cap—A special tissue covering the root tip, developed from the calyptrogen.

Root hairs—Slender thread-like epidermal absorbing cells or filaments developing on roots just back of the growing point, from the piliferous layer.

Ro-sette' [L. rosa]—A closely crowded and symmetrically arranged cluster of leaves at the end of a branch or stem, usually close to the ground.

Ru'di-ment—A rudimentary organ.

Ru'di-men'ta-ry (organ) [L. rudimentum]—An organ or part in the initial, incipient, or incomplete stage of development; or one that has become reduced either in the history of the race or of the individual.

Rust (plant rust)—Any parasitic fungus belonging to the order Uredinales.

Sap'ro-phyte [Gr. saprós+phutón]—A plant which grows on dead organic matter.

Sap'wood—The part of the wood, next to the cambium, thru which the water mainly passes up the stem; the alburnum.

Sca-lar'i-form [L. scalaris]—Resembling a ladder; having transverse bars or markings like the rounds of a ladder.

Scale—A highly modified dry leaf as in a winter bud; a flat more or less membranous outgrowth from a leaf or stem. The leaf like expansions on the gametophytes of mosses and liverworts.

Schi-zog'en-ous (cavity) [Gr. schizein+génesis]—Produced by the splitting of the cell walls as contrasted with lysigenous.

Scle-ren'chy-ma [Gr. sklerós+égchuma]Any tissue outside of the xylen having thickened cell walls, as the fiber cells in the bark.

Scu-tel'-lum [L. Scutum]—A shield-like outgrowth at the side of the embryo as in the embryo of Zea.

Sec'ond-a-ry cor'tex [L. secundarius]—The tissue developed on the inner side of the cork cambium, the phelloderm.

Seed—The ripened ovule with the sporophyte embryo and remains of the female gametophyte in the anthophytes often with abundant endosperm. The seed is not to be compared with a spore. In the anthophytes it contains parts of three generations—the parent sporophyte, the parent female gametophyte and the embryonic sporophyte together with more or less endosperm.

Seed plant—Any plant belonging to the series Spermatophyta.

Self-fertilization—The union of a sperm with an egg produced by the same hermaphrodite individual.

Self-pollination—The pollination of a stigma or ovule by male gametophytes produced on the same sporophyte as the stigma.

Self-pru'ning—The process by which living buds and twigs are separated from a plant.

Sep'al [NL. sepalum]—One of the leaves or divisions of a calyx.

Sep'tum [L. septum]—A partition or separating wall.

Se'ta [L. seta]—The stem or stalk of a moss sporophyte.

Sex'u-al'i-ty [L. sexus]—The quality or state of being distinguished by sex.

Sex'u-al organs [L. sexus]—The organs which produce the gametes or eggs and sperms.

Sex'u-al re-pro-duc'tion—Reproduction by means of eggs and sperms or by isogametes.

Sex'u-al spore—A spore formed by the union of two gametes.

Sheath (of a filament) (of a leaf)—A thickened outer wall as in some blue-green algæ; the base of a leaf below the blade investing the stem as in grasses.

Shoot—A stem with its leaves as distinguished from the root.

Sieve-plate—The thin perforated wall between the adjacent cells of sieve tubes.

Sieve-tube—A tube of sieve cells placed end to end in rows and separated by sieve plates.

Si-lic'i-fied [L. silex]—Impregnated with silica.

Si'pho-no-ste'le [Gr. síphon+stéle]—A hollow cylindrical stele with or without pith.

Slime-mold—A plant belonging to the Myxophyta.

Smut—A plant belonging to the orders Ustilaginales and Tilletiales.

So-re'di-um [Gr. sorós]—A small granular body produced on the surface of a lichen thallus.

So'rus [Gr. sorós]—A cluster of sporangia in the ferns.

Spat'u-late [L. spatula]—Widened at the top like a spatula.

Spe'cies (of plants) [L. species]—A group of more or less similar individuals having a common ancestry and interbreeding readily, with production of fertile offspring.

Sperm [Gr. spérma]—A male gamete; the spermatozoid.

Spermary [Gr. spérma]—An organ which produces spermatozoids; the male reproductive organ.

Sper-ma'ti-um [Gr. spérma]—A non-motile spermatozoid, as in red alga, lichens and fungi.

Sper'ma-tog'e-nous [Gr. spérma+gígnomai]—Sperm-producing.

Sperma-to-zo'id [Gr. spérma+zôon+eidos]—The male gamete.

Sper'mo-go'ni-um [Gr. spérma+goné]—An organ which produces spermatia.

Spike—An elongated rigid inflorescence with sessile or nearly sessile flowers.

Spike'let—A small spike; especially the ultimate flower-cluster of the inflorescence of grasses and sedges.

Spin'dle—The spindle-shaped figure of fibers of achromatic substance, formed during karyokinesis,, to which the chromosomes are attached.

Spi'ral wood vess'el—An elongated wood cell containing one or more spiral thickenings of lignin in the wall.

Spi'rem [Gr. speirema]—The thread of chromatin formed in the nucleus from the chromatin network during nuclear division.

Spon'gy pa-ren'chy-ma—The layer of loosely arranged parenchyma cells in the under side of the leaf.

Spo-ran'gi-o-phore [G. spóros+aggeion+phérein]—An organ bearing sporangia.

Spo-ran'gi-um [Gr. spóros+aggeîon]—A spore-producing organ.

Spore [Gr. spóros]—a modified reproductive cell.

Spore-ling [Gr. spóros+A. S. ling]—A young plant or embryo developing from a spore on the ground, not in a seed.

Spore tetrad—The four spores resulting from the two reduction divisions, before their separation.

Spo-rid'i-um [L. Sporidium from Gr. sporá]—A small spore produced on the promycelium or basidium coming from a teleutospore of one of the Teliosporeæ; probably a type of basidiospore.

Spo'ro-carp [Gr. spóros+karpós]—A carpel-like, or enclosed, spore-bearing organ.

Spo'ro-cyte [Gr. spóros+kútos]—In plants, any cell which undergoes the reduction division in producing non-sexual spores.

Spo'ro-phore [Gr. spóros+phérein]—An organ or structure which bears spores.

Spo'ro-phyll [Gr. spóros+phúllon]—A spore-bearing leaf.

Spo'ro-phyte [Gr. spóros+phutón]—The nonsexual generation of plants.

Sprout (to)—To continue growth, as the sprouting of a bud; to break out of the seed and continue growth, as the sprouting of a seed—to be distinguished from germination, which see.

Stalk—The stem or main axis of a plant; the petiole or peduncle, or any similar part.

Stalk cell (of pollengrain)—The cell at the back of the spermatogenous cell and a sister cell to it.

Sta'men [Gr. stémon, L. stamen]—The organ of a flower which produces microsporangia, which contain the microspores which later develop into pollen grains; the microsporophyll of seed plants.

Stam'i-nate [L. staminatus]—Containing or producing stamens; having stamens only or staminate flowers only.

Starch—A carbohydrate produced in plants and usually found in the form of minute grains in the cells.

Ste'lar [Gr. stéle]—Pertaining to or resembling a stele.

Ste'le [Gr. stéle]—The central cylinder in the stems and roots of vascular plants. It develops from the plerome.

Stem—Any axis which develops buds and shoots, and having definite nodes; also a main axis of a nonvascular plant.

Ster'e-ome [Gr. steréoma]—The mechanical or strengthening tissue in plants, like sclerenchyma.

Ster'ile [L. sterilis]—Not producing spores, seeds, or gametes.

Stig'ma [Gr. stigma]—The upper part of a carpel; a special organ of the Anthophyta to catch the pollen grains.

Stip'u-lar scar [L. stipula]—The mark made on the bark by some deciduous stipules.

Stip'ule [L. stipula]—A bract-like appendage at the base of the petiole of many leaves.

Stipe [L. stipes]—The stalk of a toadstool or similar structure.

Sto'lon [L. stolo]—A basal branch rooting at the nodes.

Sto'ma [Gr. stóma, stomata]—The transpiring pores in the epidermis of the higher plants.

Stro'bil-us [Gr. stróbilos]—A primitive flower or cone, as in a horsetail or pine.

Style [L. stilus, Gr. stûlos]—The narrow elongated part of the carpel or of the united carpels, between the ovulary and stigma.

Sub-merged' [L. submergere]—Growing under water.

Sub'ter-ra'ne-an [L. sub+terra]—Being or growing under the surface of the ground.

Sug'ar—A sweet, transparent, soluble, crystallizable carbohydrate produced in plants thru photosynthesis.

Sus-pen'sor cells [L. sub+pendere]—The row of cells which attach the young embryo, at the radicle, to the inner wall of the ovule.

Sym'bi-ont [Gr. sumbiôn]—One of the two individuals or species which live together in the symbiotic relation or condition.

Sym-bi-o'sis [Gr. sumbiôsis]—The living together of two or more dissimilar organisms in more or less intimate association, including mutualism, helotism, and parasitism.

Sym-met'ric-al [Gr. sún+métron]—Applied to an organ or part which can be divided into equal halves by one or more planes.

Sym-po'di-al branching [Gr. sún+poús, podós]—A system of branching in which the main axis is made up of a series of lateral branches because of the self-pruning or withering of the terminal bud.

Syn-er'gid [Gr. sunergós]—One of the two cells lying above the egg in the female gametophyte of Anthophyta. The two synergids and the egg constitute the egg apparatus.

Tan-gen'tial (section) [L. tangens]—A section cut near the surface of a stem or other structure.

Tan'nin, Tannic acid—An astringent chemical substance widely diffused thru the cells of plants, as in oak bark, oak galls and various leaves and fruits.

Te-leu'to-spore [Gr. teleuté+spóros]—A resting spore, produced in the Teliosporeæ, which gives rise to a promycelium or basidium.

Tel'o-phase [Gr. télos+phásis]—The last general stage of karyokinesis during which the daughter chromosomes are transformed into a resting network.

Tet'ra-cy'clic [Gr. téssares+kúklos]—Having four cycles, as in certain flowers.

Tet'rad [Gr. tetrás]—A collection of four things, as four spores produced from one grandmother cell.

Te-tram'er-ous [Gr. téssares+méros]—Four-parted.

Tet'ra-spo-ran'gi-um [Gr. téssares+spóros+aggeion]—A sporangium which produces tetraspores, as in the red algæ.

Tet'ra-spore [Gr. téssares+spóros]—A nonsexual spore, one of a group of four spores resulting from a reduction division as in the red algæ.

Thal'lus [Gr. thallós]—The plant body of a thallophyte, or of the gametophyte of the archegoniates.

Toad-stool—Any fungus in which basidiospores are produced on plates or gills, usually umbrella-shaped with a central stalk and terminal cap.

Tra'che-id [L. trachia, Gr. tracheia]—One of the strongly lignified cells in woody tissue in which the end walls are not absorbed. Tracheids commonly have bordered pits and are very characteristic of conifer wood.

Trans-formed organ—One which shows a distinct change in the individual from one type of normal structure to another; as a stamen developing into a petal.

Tran'spi-ra'tion [L. trans+spirare]—The process of giving off water vapor thru the stomata.

Trans-verse'septum [L. transversus, septum]—A crosswall or partition.

Trans-verse' sec'tion—A section cut at right angles to the long axis; a cross section.

Trich'o-gyne [Gr. thrix, trichós+guné]—The slender, hair-like process at the tip of the oogonium, as in red algæ.

Trich'o-phore [Gr. thrix, trichós+phérein]—The base of the type of oogonium which bears the trichogyne, as in the red algæ. It contains the egg.

Tri-cy'clic [Gr. tri+kúklos]—Having three cycles.

Tri'mer-ous [Gr. tri+méros]—Three parted.

Tri'ple fu'sion [L. triplus, fusio]—The union of the two polar nuclei and a sperm to form the definitive nucleus from which the endosperm is developed.

Tube cell, tube nucleus—The cell in a pollengrain which develops into the pollentube.

Tu'ber-ous [L. tuberosus]—Consisting of or bearing tubers, or thickened underground stems.

Tu'bu-lar flowers [L. tubulus]—The central disk flowers in a composite as distinguished from the ray flowers.

U'ni-cel'lu-lar [L. unus+cella]—Consisting of but one cell or protoplast.

U'ni-loc'u-lar [L. unus+loculus]—With one cavity.

U-ni-sex'u-al [L. unus+sexus]—Having only ovaries or spermaries on one individual; being purely male or female.

U-niv'a-lent (chromosome) [L. unus+valens]—One of the double number of chromosomes before their union into bivalents in the reduction division.

Un'sym-met'ric-al [Un (Gr. án)+Gr. sún+métron]—Applied to an organ or part which cannot be divided into equal halves by one or more planes.

U-re'do-spore [L. uredo+spora]—A kind of spore produced by certain rusts. They are developed nonsexually and produce a new mycelium directly.

Vac'u-ole [L. vacuus]—A small cavity in the protoplasm containing water or some chemical secretion.

Valve—One of the two parts of a diatom shell; one of the pieces or segments into which a capsule separates at maturity.

Valve view (of diatom)—The side of the shell which presents the end view of one of the valves, contrasted with girdle view.

Vas'cu-lar bun'dle [L. vasculum]—A bundle of tissue in the higher plants containing the xylem and phloem, or the wood cells and bast cells.

Vas'cu-lar plant—Any plant having true vascular tissue in the sporophyte.

Veg'e-ta-tive prop'a-ga'tion [L. vegetatio, propagatio]—Reproduction by means of organs or cells derived directly from the parent individual.

Vien [L. vena]—One of the branches of the vascular portion of leaves or other organs.

Ve-na'tion [L. vena]—The arrangement of the veins.

Ven'ter [L. venter]—The base of an archegonium containing the egg.

Ven'tral [L. ventralis]—Pertaining to the venter, or to the lower surface in a dorsiventral organ.

Ver-na'tion [L. vernatio]—The arrangement of the leaves in the bud.

Ve-sic'u-lar [L. vesicula]—Having the form or structure of a vesicle, or bladder-like body.

Ves'sel (xylem) [L. vas]A long tube in the xylem formed of superposed cells which have lossed their end walls and are usually marked with dots, pits, rings, or spirals. These vessels are often called tracheæ.

Ves'tige [L. vestigium]—An organ or part which was normally developed in the past history of the race, but which has become rudimentary.

Wood—The xylem; the lignified part of a stem.

Wood fi'ber—A slender cylindrical or prismatic cell in the xylem usually with the ends tapering to points.

Wood pa-ren'chy-ma—A thick-walled paranchyma in the secondary xylem.

Xe'ro-phyte [Gr. xerós+phutón]—A plant growing in dry or desert conditions.

Xy'lem [Gr. xúlon]—The part of the vascular bundle which contains the wood cells, as distinguished from the phloem.

Yeast—A plant belonging to the Saccharomycetales.

Zo'o-gloe'a [Gr. zôon+gloios]—A mass of bacteria imbedded in a gelatinous substance.

Zo'o-spo-ran'gi-um [Gr. zôon+spóros+aggeion]—A sporangium which produces zoospores.

Zo'o-spore [Gr. zôon+spóros]—A motile spore provided with one or more cilia or flagella.

Zo'o-zyg'o-spore [Gr. zôon+zugón+spóros]—A zygospore produced by the union of two similar zoospores.

Zyg'o-mor'phic [Gr. zugón+morphé]—Applied to a flower or organ which can be cut into similar halves by only one plane.

Zyg'o-spore [Gr. zugón+spóros]—A spore formed by the union of similar or nearly similar gametes.

Zy'gote [Gr. zugotós]—A spore formed by the conjugation of two gametes; any sexually formed spore.