REPRESENTATIVE PLANTS

PEPOON

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REPRESENTATIVE PLANTS

A MANUAL FOR THE USE OF STUDENTS OF BOTANY IN SECONDARY SCHOOLS AND COLLEGES

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PREFACE

In the judgment of the author the study of plants ought to begin with the seed plants, as these forms are more or less familiar to the student and, therefore, appeal to him as something not altogether strange. They have a further hold upon him because many of the forms studied have close association with his everyday life.

The first part of the manual, therefore, deals with the general subject of the seed plants, treating of them under the great divisional headings of *Seeds*, *Roots*, *Stems*, *Leaves*, *Flowers*, and *Fruits*. There is undoubtedly more material for study than can be covered in a half year, with a laboratory time of four hours a week, but it is believed the teacher should have abundant subject matter from which to select a course that will be applicable to the conditions prevailing in his school.

There is much diversity of opinion, and consequently of practice, among those teaching botany as to the initial subject for the fall semester. Some begin with leaves, some with seeds, some with fall flowers and fruits, some with the algæ (as pleurococcus). This order of beginning is based upon the assumption that the study of seed plants (Part I of this manual) is taken up during the second or spring semester (the most logical procedure in the opinion of the author). The study of plants, as stated above, ought to begin with these familiar forms, hence an ideal course in botany would start in February and end in January of the following year, the spore plants following the seed plants (*i.e.* from the known to the unknown).

A manual, of course, cannot begin the fall work in all these ways, and so the latter has been chosen as representing a reasonable method of introducing the pupil to the study. Those who differ may easily start at the appropriate part of the manual that to them seems most judicious.

It has impressed itself more and more on the author that a thoroughly logical method of procedure in a well-rounded out course in botany is to occupy ten months or two semesters with the seed plants, spending as much time as possible under each division above named upon the practical application from day to day in the laboratory of facts and principles gathered.

In this daily class work it is possible to produce illustrations from the experience of each pupil — through observation, experiment, and everyday contact — that will lead him to appreciate the intimate relation of botanical science in some of its varied forms to the welfare of men. In this work there are suggestive leadings that may help members of the class to see that along lines of work having foundation in a knowledge of plants and their activities is the possible selection of their life callings. It is believed enough suggestive work has been outlined, if properly elaborated, to easily fulfill this end. This, however, is a matter for the individual teacher to decide for himself, or to adjust to the requirements of boards of education. In any case, practical work should include a considerable experience in the determination of flowers by means of analytical keys and appropriate floras.

To the course as above ideally outlined there may be added a third semester of botanical work on the evolution of spore plants and the study of principles of ecology. This is a course of some difficulty, as it deals so largely with microscopic forms and, therefore, requires for its best acquirement a foundation knowledge gained by the seed plant study, because here the great plant activities may be more easily experimented with and comprehended than in the far less conspicuous and much more unfamiliar spore plants, varied in form and habitat. All the essentials of ecology may be further elucidated — essentials supposedly first hinted at, at the least, under their appropriate seed plant headings.

It is not expected that this manual will please every one, for seldom do two botanists agree on any two things consecutively; but the hope is expressed that there is gathered here work suitable and of sufficient merit to warrant its use by all who, willing to overlook many minor details of disagreement, find the main ideas and scope of the work commendable and worthy of attempt, and that botanical truth may be so presented that the student will be taught to love plants for their own value.

It is to be definitely understood that many forms equally valuable might have been selected as "representative" and some may have been unwisely omitted, but the endeavor has been to select such materials as were most accessible and at the same time reasonably characteristic of the various groups.

The author desires, here, to express his appreciation of the assistance given in the selection and treatment of the subject matter by his colleagues among the teachers of biology in the Chicago high schools, and to Mr. Mason Warner of Chicago for many helpful suggestions in connection with manuscript and proof.

H. S. PEPOON

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REPRESENTATIVE PLANTS

A MANUAL OF BOTANY

PART I

A DETAILED STUDY OF SEED PLANTS, WITH APPLIED OR EXPERIMENTAL BOTANY

SECTION I. A STUDY OF SEEDS AND SEED PROBLEMS

1. The Bean Seed. A Dicotyledon

General statement. Seeds of navy, red, kidney, and lima beans, dry and soaked overnight, are to be carefully compared, and the size, form, color, and external markings of each observed. The difference in size, caused by the soaking in water, is to be particularly considered. How has the seed been increased in volume? What similar familiar facts are of common occurrence in the home kitchen? How does the water gain entrance to the seeds? When a seed is planted, what corresponding occurrence takes place?

External features. Examine the bean for three external markings on the concave margin. The large central one is the scar (*hilum*). Examine its surface with a lens. What caused this scar? Look closely with the lens near either end of the scar. What do you find, and how do the two features differ from each other? One is the pore (*micropyle*), and the other is the blister (*raphe* or *chalaza*). These names are truly descriptive, and pores and blisters are easily distinguished.

Seed coat. With a pin, needle, knife, or even with the finger nail, very carefully cut or tear the skin (*seed coat* or *testa*) the whole length of the convex margin; remove and study. Observe its firmness. Examine the skin, and the part removed from it, and find which one bears the three marks named under "External Features." Pass a pin into the pore and discover in what structure it appears, on the inside. Look at the seed proper and find a structure that "fits" into this depression. Keep this point in mind when you study sprouting seeds.

The seed proper. Examine the seed you have removed from the seed coat. Carefully separate the large halves (*cotyledons* or *seed leaves*) until they break apart. The little structure lying between the cotyledons and fastened to each is the *little plant*. This with a lens may easily be seen to consist of a little stem (*hypocotyl*) and a pair of tiny leaves (*plumule*). Observe that the cotyledons are attached to the larger upper end of the hypocotyl (points where leaves are attached to a stem are *nodes*); with the lens find a small, short, stemlike part connecting this point with the plumule (the embryo stem). The cotyledons and the little plant connecting them (all there is in a bean seed) is the *embryo*.

Drawings. 1. Draw a seed, side, hilum, margin, and end views. 2. Draw the seed with the cotyledons separated and their concave margins next to each other, with the little plant in place. 3. Draw the little plant ($\times$ 4). 4. Draw three cross sections at different points.

Other work. Experiments. Seeds that may be easily separated (on soaking) into similar halves are *Dicotyledons*, (two cotyledons). What is the purpose of the large cotyledons? What other seeds do you know that have the two cotyledons? Try this experiment: Scrape some of the soaked bean and apply weak iodine solution to the scrapings and observe the change of color. This shows what substance in the bean? (Test in the same way some cornstarch with the weak iodine, and you see a deep blue purple color, the characteristic reaction when iodine is added to anything containing starch.) Such a large accumulation of starch is called *food storage*. What is this food stored for? Name ten large seeds that have a similar storage.

2. The Corn — A Monocotyledon

Statement. Kernels of large yellow corn, soaked for twenty-four hours, are to be preferred, although any kind of field corn will answer.

External features. A corn "seed" will be found to have two broad faces, two narrower margins, a blunt and a conical end. Compare the faces and observe that one has an oblong lighter area called the *embryo*, occupying the central part of this face near the conical end.

Seed coat. With a sharp knife, determine whether or not the corn has a seed coat similar to that found in the bean. Break off the conical end and observe the dark oblong *scar* concealed in the grain within this end. This is called the *funiculus*. What purpose has this pointed end and what structure had the same use in the bean?

Internal features. With a sharp knife make four sectional cuts through the corn, viz.: (1) A cross section near the blunt end and outside of the embryo. (2) A cross section through the embryo, near the middle of the kernel. (3) A long section midway between the two margins and perpendicular to the embryo face. (4) A long section parallel to the embryo face and about one-third of the distance through the seed from this face.

Appearance with iodine. After examining each section stain them with weak iodine and study the various parts that now appear much more distinctly. The part unstained in the different sections is the embryo, which may be seen to consist of an outer *scutellum* or cotyledon and a central axis, the *little plant*, having the same parts as in the bean; that part nearest to the pointed end of the seed being the hypocotyl. The stained part is the *endosperm*. What substance does it contain? About how much of the seed does it occupy? What, in purpose or use to the plant, does it correspond to in the bean? Observe in all these operations that the corn seed cannot be split into halves, as can the bean and all other dicotyledonous seeds. All such undividable seeds are *monocotyledonous*. Name other kinds, if possible, having this feature.

Drawings. Make enlarged drawings showing the face views, a marginal view, and all of the above sections, carefully labeled.

3. Pine Seeds

Where procured. The seeds of any available species of pine may be used. Pinon "nuts" may be found in fruit stores in large cities. Other conifer seeds may be substituted, but pine seeds are larger and therefore better.

External features. Soak a number of seeds for several hours. Examine one for any external features. What part is occupied by the seed proper and what part by the broad and thin *wing*? What use has the wing? Throw a seed up into the air and watch closely as it falls. What would happen if a strong wind were blowing on the falling seed?

Sections. With a sharp knife, make some long sections of the soaked seeds. Observe the seed coat on the outside and a thin papery layer next within (the *nucellus* remnant). The mass of the seed is the endosperm. What color is it? Embedded in this is the young plant or embryo. Examine this very carefully (*m*) and find the long stem, hypocotyl, and a cluster of tiny structures near the blunt end (upper) of the seed, the many cotyledons. The plumule is hidden from view.

Drawings. Draw the seed, side and face views, and a long section (*m*) to show the internal parts.

4. Comparative Seed Study

Other work. Make a table showing a number of different seeds, using the following form: —

Name of Seed	Drawings of Seed	Mono or Dicotyledon	External Features: Color, Hardness	Where Obtained	Uses

5. Seed Composition

Tests. The instructor may either demonstrate or give directions to the student so that he may discover for himself the cruder composition of the bean, corn, and other seeds, particularly showing: (1) The amount of water in ordinary dry seeds, by carefully weighing a few ounces, drying thoroughly over furnace or gas, and weighing again. Record your results in per cent. (2) The presence of starch, by the iodine test. (3) The presence of sugar. The Fehling or other test. (See root study, for 4, 5.) (4) The presence of albumen (a proteid matter). The Millon test. (5) The presence of oil. The ether test.

Problems. Of what use, if any, are these various substances to the seed, or when will they be of use? Of what use to man are these substances? Why are seeds normally very dry? What explanation have you to offer for the great variation in the size of seeds? Name the largest and smallest seeds you know. What important groups of manufactured products are made from seeds? See Applied Work on Seeds.

6. Seed Table

Make a list of all the seeds used in your home, in what form used, and for what purpose.

7. Vegetable and Flower Seeds

Write a statement of the seeds used in gardens (the home, market, and florists') and on the farm.

What do you find out about the importance of seeds for these purposes? Examine garden catalogues. Find out, if possible, where garden and flower seeds are grown in great quantities for sale. How do you account for the very great number of kinds of different seeds, for example, of beans, there being originally only about four distinct sorts or species and now the varieties number about 400?

8. Applied Work on Seeds

Practical applications of the facts learned by the study of different seeds, based upon the experience of the pupil.

1. *The Starch Industries.* Soak a number of kernels of white corn, remove the embryos; dry thoroughly, crush, and remove the seed coats. Pulverize the remaining part most thoroughly in a mortar. When very fine, stir thoroughly in cold water and set away in a clean quiet place to settle. When this is accomplished, pour off the water and any loose material. The solidly deposited residue will be found by the iodine test to be almost pure starch. This illustrates in a crude way the immense starch manufacturing of the United States from corn. Many chemical and mechanical means are added to secure a pure product.

Compare your product (*hp*) with cornstarch and laundry starch. Add boiling water and observe the result. Take equal weights of each preparation just named, mix in equal amounts of water, and add one drop of 10 % iodine to each ounce of the mixture. Study carefully the resulting colors for similarity of tints. Read about starch making in the United States. Collect all possible seeds that are used for starch-making purposes.

2. *The Glucose Industry.*
3. *The Oil Industry.*
4. *The Proteid Products.*
5. *The Drug Seeds.*
6. *Perfumes and Spices.*
7. *Beverages.*
8. *Miscellaneous Manufactures.*
9. *The Seed Industry for Farms and Market Gardens and House Gardens.*

Topics 2–9 are largely suggestive. The process of manufacture of glucose, albumen, and oils is generally beyond the facilities of an ordinary laboratory. Seeds, however, may be collected and classified according to use. Some crude results of interest and value may, however, be obtained by the student or instructor in: (*a*) Action of sulphuric acid on starch of corn (a glucose step). (*b*) Oil by expression or extraction by ether (see roots). (*c*) Production of tinctures of seeds by digestion in alcohol.

SECTION II. A STUDY OF SEEDLINGS

Methods of growing. Seedlings of various kinds are to be grown in various ways in quantity. Between folds of heavy felt paper, kept moist, is an excellent method. Wet sawdust, sand, and many other ways may be tried. The student ought to grow seedlings and keep a record of the methods used or record those grown in the laboratory.

Stages. Seedlings for the purpose of study may be conveniently considered in three stages: (*a*) First stage, the first appearance of the sprouting hypocotyl; (*b*) second stage, the first appearance of the plumule; (*c*) third stage, the appearance of roots and foliage leaves.

Detailed study. Study each seedling furnished, and determine what part of the seed first shows growth; also from what part of the seed coat it makes its exit. Study this feature in sprouting seeds, *placed on blotters between glass plates*, and observe direction of growth of the hypocotyl. In the same way study the growing plumule, observing its direction of growth.

Carefully observe the cotyledons in the sprouting seeds of various stages and determine any change of position, form, or color assumed. Study, if possible, seeds of beans and peas planted in earth, and observe the *hypocotyl arch* in the one and its absence in the other, and the effect on the cotyledons in each case.

Drawings. Make drawings showing the several stages in each seedling furnished for study.

Other work. In the growth of the seedlings, what becomes of the seed coats? Study well this feature in as many seedlings as possible. What seems to be the purpose of the cotyledons? What agent do you think causes a change in the color of the cotyledons? What benefit to the seedling may this change bring about? From the various experiments made, what, in your judgment, are the necessary conditions for the *sprouting* (renewal of growth) of the seeds? Look up the word "germination" and find out whether or not it is a correct term to use for the sprouting of seeds. What is the first change in the sprouting of a seed, that the dry seed undergoes, and how is this brought about? (Read the osmosis experiment, under roots.) Try another simple experiment, which consists in placing a few dried raisins in water and observing the results, which are like those occurring in the soaked seed.

Experiments. At this stage in your study make the following test for sugar: Dissolve a little grape sugar in water, and add Fehling's solution (which can be obtained at any drug store). What is the color reaction? Now place the sugar solution in a *test tube* and *boil*. The change of color to orange is a test for grape sugar.

Grind some dry oats in a mortar, add water and Fehling's solution, and boil. Repeat, but use, instead of dry oats, some oats that are well sprouted. How do the two experiments differ, and what is your explanation?

Food of seedlings. What are the sources of all the different foods a seedling uses from the time when the first sprout shows until it may be said to have become a *young plant?* What *really* determines whether a plant is in the seedling stage or not?

Seedlings in trade. Why are some varieties of plants (as vegetables) "raised" from seed, while others (like potatoes, and many fruit shrubs and trees) are raised from *cuttings*, *grafts*, *buds*, etc.? What are "seedlings" commercially and experimentally?

Other experiments. Try as many experiments with seeds and seedlings as time and the materials at hand will permit. Some or all of the following are very instructive, and require but little in the way of apparatus: (The instructor will give explicit directions.) (*a*) Various methods of sprouting seeds. (*b*) The effect of light and darkness on seed sprouting. (*c*) The effect of cold and heat on seed sprouting. (*d*) The effect of lack of moisture or too much moisture. (*e*) The direction naturally assumed by the plumule in seeds sprouted in a pan. (*f*) Oats sprouted in a deep glass jar, and tested in early morning or later daytime with lighted taper for gas production. (*g*) Various forms of cotyledons and amount of development of the same. (*h*) Seedling direction and light. (*i*) Rapidity of sprouting of various seeds, with possible relation to size of seeds and length of time. (*j*) The reason for the change in composition of starchy seeds when they sprout (industries founded on this fact). (*k*) The amount of water absorbed by dry seeds in the soaking process. (*l*) The vitality or "keeping" quality of various seeds may be studied in garden catalogues, farm books, cyclopedias, etc. Remember about seeds of weeds at this point. (*m*) Weight of seeds compared with that of water. Cleaning seeds by flotation of bad seed, impurities, chaff, etc. (*n*) The temperature of sprouting seeds. (*o*) The effect in seedling growth of the removal of the cotyledons. (*p*) Seedlings grown in water, sand, loam, and other conditions. (*q*) Survival test in crowded seedlings (of birdseed, for example). (*r*) Per cent of vitality test (*i.e.*, number of seeds in each 100) to show how many seeds will sprout. Use flannel, felt paper, or blotting paper, kept moist on plates covered with panes of glass. Obtain seeds from as many sources as possible in order to answer the query, "Do cheap seeds pay?" (*s*) Many other experiments may be tried, the above suggesting others along the same lines.

SECTION III. THE ROOT

1. Its Origin, Structure, and Growth

Source of material. The various seedlings of the preceding exercises will furnish much root material. Corn grown in *thistle tubes*, peas and corn on *corks in water bottles*, seedlings between plates of glass, can all be used to good advantage. The grocer's vegetable window furnishes many.

Origin. On examining seedlings well advanced, what part of the growing seed has developed into the root? Observe whether there is but one main root (*primary*) or several (*multiple primary*) proceeding from the lower (*radicle*) end of the hypocotyl.

Observe, further, how soon the roots form branches. In the bean, for example, what effect would the formation of root branches have on the elongating hypocotyl?

Does the pea act in the same manner or not?

In the corn, oats, and some other seeds, observe that some roots arise from other parts of the young plant than the radicle end of the hypocotyl. These are *secondary* or *adventitious* roots.

Draw the various forms of roots mentioned above, not omitting the seed name in your drawings.

Root hairs. Position. Examine young radish, oat, or corn roots of vigorous growth and observe the fine hairs (*root hairs*) covering a portion of the surface. With reference to the *root tips* where are these hairs? What is their form? What is their size and color? Use (*m*)[1] and (*lp*) and study carefully. Offer any explanation you can for their absence from the root tip. To understand this, take a well-grown corn or pea seedling, rule black ink marks at equal distances from the seed to root tip and replace in the growing position. Examine twenty-four and forty-eight hours later and observe the relative position of the marks. Where does the root have its linear growth, or growth in length? What effect on the root hairs would growth in their immediate vicinity have? Examine the varying colors of the corn root and see if any correspondence exists between color and place of growth.

Make drawings showing results of your observations on root hairs and place of growth.

Structure of root tip. Examine (*lp*) the root tips of radish, oats, or onion seedlings. Observe the shape and minute structure of the extreme end (*root cap*). What is the purpose of this part of the root?

Examine the root in the region of the root hairs and

[1] Throughout the Manual (*m*) signifies use the hand lens; (*lp*) the low and (*hp*) the high power of the compound microscope.

observe the outer cells (*epidermis*); the central axis (*stele*); the cell layers between these two (*cortex*).

Draw these features of a root (*lp*).

Root hairs, their use. Read about the subject of "*Root Hairs*" and find the purpose of the hairs. By what process do they accomplish this purpose? Estimate, if you can, how much they increase the root surface. What effect would the "pulling up" of a seedling have on these frail structures? How then should plants, in transplanting, be treated? What damage would be caused by dry air?

2. The Purpose of Roots

Uses. Roots have one or more of the following uses: (1) As holdfasts; (2) as absorbers of moisture and food material in solution; (3) as storehouses of reserve food.

Their forms are, therefore, variously modified to meet these demands made upon them. Roots are, furthermore, markedly influenced by soil conditions, resulting in well-marked peculiarities of shape and extent.

Forms. *The primary tap root.* When the radicle end of the hypocotyl develops a single root, whose direction of growth is directly downward, the branches being much smaller and short, such a root is a *tap root.* Examine the roots of corn, pea, spinach, and any other forms furnished, and determine which answer the requirements of the tap root. Many such roots have naturally, or by cultivation, become very fleshy with reserve food and then are called *storage roots.* Examine the roots of carrots, parsnips, turnips, beets, salsify, horse-radish, and radish.

Draw the various forms of tap roots you have on hand, naming such as are storage.

Examine, at this time, the roots of the onion and observe that, while they are multiple primary roots, each root itself is not fleshy but threadlike or *fibrous.* Examine grass roots, oats, wheat, and other forms showing fibrous character.

Draw examples of fibrous roots.

Soils and form. Examine the roots of plants that have grown, some in dry sand or clay and others in moist ground, others again that have grown in ordinary soil conditions. What influence, if any, do you find the soil conditions to have upon the root form? Why do storage roots have such an excessive amount of reserve food? Seek to discover if this excessive storage is found in cultivated plants, or is found in wild ones also. What effect might a soil very rich in plant food have upon the form of a tap root?

Other root forms. Examine the *aërial roots* of poison ivy, English ivy, or other similar climbers. What purpose have these roots?

If possible, look at some large fig or pandanus trees in the greenhouses of the public parks, and observe the air prop roots. Look at pictures of banyans and other tropical trees, and observe the same features. Examine also, if obtainable, the lower end of a cornstalk for *prop roots.*

In the orchid house, examine, or in books on orchids, read about their air roots and their use.

What differences would you find between the roots of annuals and those of biennial and perennial plants?

Show all such roots by diagrams or drawings.

3. Root and Seed Composition Experiments[1]

Statement. These experiments may be made by the student, but in many cases it will be desirable to have them demonstrated by the instructor, the student taking full notes of apparatus and results.

Tests. Various composition tests are: —

1. The starch test which has been given;
2. The grape sugar test (given in Exp. in Seedlings);
3. The albumen test (proteids).

[1] Have been referred to under the seed study.

Grind up some peas in water, add more water, and place the mixture in a test tube. Add a few drops of Millon's solution and observe that a whitish coagulum forms. Now boil and watch the color of the coagulum as the mixture cools. To verify this experiment use some known albumen compound, observing the final *salmon pink* resulting. (A proteid test.)

There are other good tests,—as nitric acid and ammonia.

4. Oil test.

Grind up flax seed or mustard or yellow corn, place in bottle and add ether and cork tightly. Set aside for some days and then examine for yellow color of solution and for a thin layer of *oil*, shown on the evaporation of the ether.

Test now the various roots furnished, preferably by the pupil, for starch, sugar, albumen, and possibly oil. Let the pupils obtain the results and tabulate. Seeds may be tested in the same way.

5. Water content.

Various roots, particularly vegetables, ought to be obtained and small portions carefully weighed fresh, and after most thorough drying weighed again to obtain the per cent content of water. (See the following table for report on results.) From these results determine which vegetable has the most solid nourishment (composition)

Table of composition and water content

Seed or Root	Starch, Sugar, Oil, Proteid	Weight, Fresh	Weight, Dry	Per Cent of Water	Value as a Food

4. Root Experiments

1. Spinach roots, cut off near the tip and placed in shallow *eosin* (water solution).

After twenty-four hours, cut off and make long. section to find the path of absorbed material in the roots. Shows upward path of absorbed liquid.

2. Oats between glass plates.

As roots grow record direction and rotate plates; wait twenty-four hours and record direction again. Repeat the rotation and observe the repeated effect on the roots and the green shoot direction also.

3. Root osmosis experiment.

Hollow out a fresh carrot from the top, taking care not to pierce the walls, fit in a rubber cork (very tightly) pierced by a long glass tube, fill the cavity, through tube or before its insertion, with syrup water, slightly colored with some anilin stain, place the carrot (with outer skin well scraped), in a vessel of pure water, and securely stay all parts of the apparatus. Observe the results from day to day, apply this experiment to the root in its absorption of water and dissolved food, seeking in the plant for analogues of the experiment parts. An egg osmosis experiment is given in many books, but this is easier to set up, and is more logical.

4. Corn seedling in thistle tube, placed in pure water.

Observe the remarkable root growth and explain also the duration of life in the corn living apparently on water. Through what may other food be taken?

5. Seeds sown in shallow soil on marble slab.

Allowed to grow for some time and then removed. Observe the effect on slab. Seek for explanation and bearing on root work.

6. Seeds in sponge kept moist.

As roots grow, observe their direction with reference to gravity and moisture, and apply to growing plants.

7. Root pressure.

Explained and set up by instructor.

8. Root color, whether exposed to the light or not.

9. Pea seedling supported on netting tied over the mouth of a bottle filled with water. Similar to 4.

5. Experimental Applications of the Root Study

1. **Based on roots as human food.** Bring to the laboratory specimens of all root vegetables used in your home, and from the tests in a previous section determine the food constituents. The home, market garden, and in a few cases the farm growing of these roots should be learned. The history, if possible, ought to be determined, in particular the native country of each, and the character of the wild plant, if existing. The fine quality, size, and productiveness are due to selection of the best seeds, from the best plants, careful cultivation in the best soil, and the crossing of fine plants to secure a combination of their good qualities. Nature makes the wild plant, but man produces the choice cultivated forms. Founded upon these principles are the profitable industries of market gardening and seed production. Certain lines of manufacture, as *dry vegetables, canned vegetables*, and *preserved horse-radish.* Greater than all other features is the saving to the home by the growing of vegetables in the home garden.

2. **Based upon the sugar you find in the beet.** You have found sugar in the garden beet. By selection, as in 1, beets are now grown containing as much as 20 % of cane sugar, and many farmers have become independently rich by the growing of sugar beets. Find out, if possible, the amount of sugar made from beets in 1910 or later.

3. **Based on starchy roots, arrowroot and tapioca.** Florida farmers raise much cassava for the starch or tapioca.

Roots, like licorice and sassafras, used in medicine and for flavoring.

Many miscellaneous roots, for drugs, dyes, and other manufactures.

SECTION IV. STUDY OF STEMS

1. The Winter Twig, External Features

General statement. Twigs of hickory and butternut are particularly good for this purpose, although almost any twig will do, if occasion demands. Twigs may be gathered at any time after the leaves fall and kept in sawdust or sand, in the cold. The student ought to be encouraged to study the twigs on the tree, and at first hand learn their individual characteristics. Simple keys may be made for this purpose.

Surface features. Observe the surface color of the twig in all its length. How does it vary and what may be the explanation? Examine the epidermis and determine whether it is rough or smooth, dull or shining. Some twigs are hairy or downy. Besides these general features you ought to be able to find *four* special features on the twig, viz.: (1) buds; (2) leaf-scars; (3) lenticels; (4) zones.

1. *Buds.* According to their position, buds are *terminal* (*apical*) and *lateral.* What, in the hickory, is the difference in the size of these two kinds? Further, how do the lateral buds vary in different parts of the year's growth? What explanation can you give for these differences in size? Other twigs show similar variation in greater or less degree. Examine a bud and observe the covering of scales. Are these few or many in number? How are they arranged with reference to each other? What is their color? This is often very characteristic of the special kind of tree. What sort of surface has the scale? It may be smooth, downy, hairy, or varnished. What purpose have these special features?

Make a long section through an apical bud and study (*m*). Observe the cut edges of the scales and, in particular, the delicate structures near the center of the bud (tiny leaves and possibly flowers distorted and crowded upon the *growing point* of the stem). What then does the winter bud consist of, and what will it become during the next season's growth? What, again, may be the purpose of the scales with their various coatings? What provision has the plant to insure continued growth if the apical bud is destroyed?

Caution. Mistakes are commonly made here. Consult a good reference book (up to date) on the use of the bud covering. Make drawings showing an apical bud and a lateral bud, natural size (*m*), also a bud section (*m*).

2. *Leaf scars.* Examine the surface below the buds for peculiar scars or marks. What are their shape and size compared to the twig diameter? Observe carefully the surface of the scars. What do you find? What may be the causes of the scars and the scar markings?

Draw a scar in relation to the bud above it (*m*).

3. *Lenticels.* On the surface of the twig look for small marks, scattered here and there, varying much in number, size, and shape, in different twigs. These are the *lenticels* or air pores, and are caused by the stretching of the epidermis in growth. Same use in part as the stomates (in leaf study).

4. *Zones.* In a twig of some length or of several years' growth look for peculiar bands of small *scars*, at irregular intervals along the twig. These are the *zones* of *scars.* What explanation have you to offer for their production and irregular distribution? What relation may there be between zone number and age or years' growth? Compare the hickory twig with as many others as possible, for the purpose of shedding light on the zone question. An apple twig is very fine for zone study.

Twig drawing. Make a drawing of the whole twig, natural size, showing buds, scars, lenticels, and zones, and write a clear description of the same.

2. Exercises on Various Twigs from Forest and City Trees

Bud arrangement. Twigs show four possible bud arrangements. (1) One bud at each node, each successive bud on the opposite side of the twig from the preceding. *True alternate.* (2) One bud at each node, with other arrangement than in (1). (See the subject *Phyllotaxy*, in reference books.) *Scattered alternate.* This is the most common arrangement. (3) Two buds at each node. *Opposite.* (4) Three or more buds at each node. *Whorled.*

The bud arrangement is very characteristic of certain trees and tree families, and should be carefully observed.

Twigs to be drawn. Various twigs ought to be drawn carefully and brief characteristics written to familiarize the pupil with our common trees. Among those easily obtained are *elms, maples, basswood, oaks, ash, cherries, poplars, cottonwood, willows, catalpa, box elder*, besides many others of rarer occurrence. The characteristics aside from those shown by the drawing are color, smoothness, odor, of both bark and buds.

Make a table of all the twigs studied, as follows: —

Name	Where Native	Cult. or Not	Buds		
			Arrangement	Size	Color

Bark		Growth	
Color	Surface	Rapid	Slow

Street trees. Determine the trees that are found growing along the streets, and the relative abundance of each kind. Seek an explanation for the abundant planting of a few varieties.

3. Climbing Stems

Material. Material for this study may be found commonly in woodlands, or lacking such sources, the vines of the flower garden and lawn may be drawn upon. If possible, however, *honeysuckle* and *bittersweet*, *Virginia creeper* and *grape*, besides herbaceous climbers, should be studied.

Twiners. Examine the *twining* stems of *honeysuckle* and *bittersweet*. Compare their stem diameters with their length of vine. How does the proportion compare with the similar measurement of upright shrubs? Why do these plants twine?

Holding the entwined stem with its upper end toward you, observe the direction in which the stem twines. Does it twine with (from left to right) or contrary (from right to left) to the hands of a watch or clock? Do both kinds of vines, named above, twine in the same direction?

Draw each vine and designate direction of twining.

Study other forms, if obtainable, in the same manner.

Tendril bearers. Examine grape or Virginia creeper and observe the coiled, slender branches (*tendrils*). Study, if possible, material showing all ages of tendrils. Observe a double effect of the coiling of the tendril. How do the tendrils of the two vines differ? How are the tendrils arranged with reference to buds? Discover, if possible, other vines that have similar tendrils.

Draw the tendril and adjacent stem of such specimens as you have.

What advantage, if any, does either form of climber possess?

Air roots. Study a stem of the poison ivy (inclosed in a bottle). What structure does this vine have to enable it to climb? Is it similar to or different from the forms adopted by twiner or tendril bearer? The structures on the "ivy" are really air roots and might have been considered in the previous study.

Draw a portion of the ivy, showing air roots.

Table. Make a table of all the climbing vines you know, filling out headings as follows:

NAME	WOODY OR HERBACEOUS	CLIMBS HOW	CULTIVATED OR NOT

4. MODIFIED STEMS

Tubers

Potato. Examine the common potato. What is the shape? Find the point of attachment to the plant portion that bears it. In particular, look at the *eyes* sunk here and there in the surface and the markings near them. What structures on an ordinary stem do these *eyes* and markings remind you of? What bears the potato; that is, to what is it attached, a root or a stem? Observe the cluster of eyes opposite the attachment end. What part of the stem may this be considered? The potato tuber is a stem modified for a special purpose. What is this purpose? Try the following test: —

Scrape some potato flesh, mix it with water, and add iodine solution. What does the result show?

Draw a potato tuber, naming all the parts.

Other tubers. Study, if obtainable, other tubers, as artichokes, yams, etc.

Potato continued. To grow potatoes the tuber is cut up into pieces, each bearing one or more *eyes*, and these pieces are planted. Name other plants that are propagated in a similar manner by planting stems. This may be called "artificial vegetative multiplication." What would happen if you planted the seeds of a potato? How are new varieties of potatoes produced? You ought to learn what the schoolboy Burbank did. Why is this tuber called the *Irish* potato? What other plant rightfully might deserve to have the name *potato?* Study the history of the potato and determine its relation to other plants that form a plant family, the Night Shades; also its original home and its characteristics in a wild state. Read about the *Night Shade* family, and find out the vegetables that belong to the same.

Beginning at the bunch of *eyes* at one end, trace a line in ink to the opposite end, following a series of *eyes* that are evidently arranged in a line. Continue until all *eyes* are marked out. What figure do you find marked on the surface?

Experiential application. Scrape several large potatoes until you have a mass of pulpy "scrapings." Place them in a large clean dish, pour on a large amount of water, and stir vigorously for 10 minutes. Cover and allow the mixture to remain for 24 hours. At the end of that period, pour off carefully all the water with its floating débris. A layer of starch will be found in the bottom. With improvement, of course, but practically the same, this is the European method of starch making. Why do the factories of the United States make most of the starch out of corn? Take equal quantities of the potato starch you have made and corn laundry starch. Examine with *hp*, test, and then add boiling water in equal amount to each starch. Compare with each other for consistency, color, stickiness, odor, and any other features you may notice.

Starch is the almost universal food. What per cent of your food is starchy? How often do you eat potatoes? What peoples depend largely on potatoes for food? Ordinary potatoes are $\frac{1}{4}$ starch and $\frac{3}{4}$ water. Could not your experiment above made show this? What benefit would an increase in starch have?

The Rhizome or Horizontal Underground Stem

Kinds of plants with rhizomes. Examine the underground stem of a fern, common sand rush, Solomon's Seal, or false Solomon's Seal; observe the apical bud or buds. Are there any lateral buds? What evidences are there of former attachments of aërial stems? What caused the scars? Observe the roots, as to their number and place of origin.

Make drawings of the various rhizomes furnished.

Purpose. What advantage, if any, is the one apical bud? Why is the stem direction horizontal? What advantage to any plant is the possession of an underground stem of this character?

From a study of these various rhizomes, find some constant character that enables one to decide that these structures are *stems* and not *roots*.

Table. Read under the title "Rhizomes," and in other ways, try to find out a number of useful plant products, furnished by these peculiar forms of stems, and place in a table as follows: —

Name	Where Found	Use
Orris "Root"	Italy	Tooth Powder

Note. Remember that many rhizomes are commonly designated as "roots" in both common and commercial language. Bloodroot, ginger root, etc., are rhizomes.

Field work. Examine, in the proper season, plants that bloom in early spring, with reference to their underground portions. Observe the number that have rhizomes. Explain the presence of such structures in early blooming plants. What advantage may there be that will insure rapid growth?

Applications. Obtain a specimen if possible of each of the following. The drug store keeps them.

a. Ginger	*d.* Geranium
b. Turmeric	*e.* Calamus
c. Orris	*f.* Sarsaparilla

Take three vials for each specimen. Take equal quantities of each, crush in a clean mortar, one at a time, and place in vial, labeling, ginger, 1, 2, and 3, and so on, for the others. Fill vials, No. 1 with hot water; No. 2 with water and glycerine, equal quantities of each; No. 3 with 60 % alcohol. Set all the vials away for one week, and then compare 1, 2, and 3 of each series, by color, odor, taste, and residue. Your experiment illustrates, roughly, how medicines and flavors may be made. Many other solvents besides the ones given are used.

Bulbs. (Bud Type of Stem)

Form and structure. Examine bulbs of onions, narcissus, tulips, gladioli, and other forms convenient to obtain. For purposes of this study, the bulb should be cut into two sections, lengthwise through the middle. A bulb is in its general plan of structure very similar to a bud, and it is well to revert to the bud structure at this time and observe the points of resemblance. The dense portion of the bulb, from the lower end of which the roots grow, the upper end being continued into an *apical bud*, is the *stem* proper. Observe further that all the *fleshy scales* (*modified leaves*) are attached to this stem. A stem may be defined as ordinarily and primarily a *structure*, the *purpose* of *which* is in large part to bear *leaves*. *Keep this in mind.*

Drawings. Make drawings of all the bulbs, external and sectional views, you are able to obtain, carefully naming all parts.

Other work. What advantage to the plant is the bulb form of stem? Obtain a garden catalogue and observe the names of many bulb-bearing plants, common in the garden either as vegetables or flowers.

Why do early spring flowers commonly have some form of underground stem, — bulb, tuber, or rhizome, — or else have fleshy roots? (See rhizomes.)

Experiential applications. *Onions*, *gladioli*, *tulips*, and *lilies* grow into large bulbs. All are grown in immense quantities for food or for flowers. How would you proceed to produce the bulbs themselves of the largest size for purposes of sale?

Onions, shallots, leeks, garlic, chives, are all bulbs. How do they differ? In how many ways may the first be grown? What will an acre of onions yield in bushels and money? What are Bermuda and Spanish onions?

Grind up a large onion, place pulp in strong cotton bag on an inclined board with grooves leading to a common outlet. Cover with another board, on which place as great a weight as possible. Collect all the juice. Allow to stand for 24 hours. You will find *oil* and *water*. Which is on top? Separate by a pipette. You are an oil producer.

5. Miscellaneous Stems

Kinds named. Cacti plants and stems of scouring rushes ought to be obtained to show stems particularly modified to do the work ordinarily done by other plant parts. Grass stems in long section and the compound thorns of honey locust and the simple thorns of hawthorns show other stem modifications of importance.

Study. Study carefully each stem furnished. Observe its peculiarities of form and structure and make drawings showing all peculiar features.

What part of the ordinary plant is green? What color have the cacti and scouring rush stems? Do these stems have leaves as commonly understood? Keep this in mind until leaves are studied, and then insert here the purpose of the green stem.

Look at the hollow stem of the scouring rush and the grasses. Offer, if possible, an explanation. What evidence is there to you to show that thorns are really true stems or rather branches? Compare at this point with the rose or prickly ash stems which are covered with *prickles*. What is the difference between a thorn and a prickle? What may be the purpose of each?

Read in particular about cacti and the reason for their fleshy stems and their leaves reduced to prickles. Consult books that describe deserts and their plant life.

After careful study and reading, seek some explanation for the peculiar stems (like those of the cacti, euphorbias, etc.) of so many desert plants. These plants, in their peculiarities, strongly illustrate the effect of environment or surrounding influences on the form and structure. Ecology is the study of such influences and effects.

Practical application. The government investigators are doing much experimentally to find out what grains, grasses, fruits, and trees will grow well in our dry West. They obtain their new forms from every dry land on the earth. Such forms are Durum and Speltz wheats, milo and Kaffir corns, and alfalfa.

What did Mr. Burbank do for the arid regions when he produced a spineless variety of cacti?

6. Structure of Stems

Material. Various woody stem sections should be collected, both di- and monocotyledons. Sumac and elder are especially good for the former, and greenbrier, cornstalks, and palm-leaf stalks for the latter. Material may be preserved in formaldehyde, if stems are to be studied in winter.

Cross sections of dicotyledons. Make clean-cut cross sections of the various stems. Observe in the ordinary dicotyledonous stem (as the sumac) a central soft part, *pith;* an outer part, *bark* (at first epidermis), and between these a layer of hard material, *wood*, which again may be subdivided by *porous rings* into other layers.

Observe that the larger and therefore the older the stem, the more abundant these latter layers. What is the explanation that you could give? Running from the pith toward the bark are radiating lines (*pith rays*). Compare the elder, sumac, and oak, and measure the proportion of pith in each. Why is the pith smaller in amount as the stem increases in age and size?

Examine (*m*) the bark and find three layers, *white*, *green*, and the *outside brown* or *corky*. Study long sections of stems at the junction of branches and find the layers above named. Make careful drawings, recording all the features of the dicotyledonous stems.

Section of monocotyledons. Examine now a cross section of a monocotyledonous stem and find three features: *pith*, *wood bundles*, and *outer cortex*. Observe the great difference in the arrangements of the parts in the two kinds of stems.

Where in each stem is the hardest portion?

What occupies the position of the true bark in monocotyledonous stems?

What evidence, if any, to indicate age?

Make drawings of cross and long sections of a monocotyledonous stem.

Microscopic structure. Study thin sections of both kinds of stems (*lp*), to learn about the cell structures. Observe the great difference in size, shape, and cell walls of the *pith* and *wood*.

Make drawings of a quadrant of these thin sections, showing the different kinds of cells and cell combinations. Turn to the fern study for the details of vascular bundles (wood).

7. A Study of Lumbers and Cabinet Woods. Experiential Applications

Material. Have prepared specimens of as many commercial woods as possible, sawed radially and tangentially. Collect native woods.

Discover, by reading, the source of each form, and its value as a wood for various special uses.

Methods of study. Study the individual specimens, for: —

(*a*) Color.

(*b*) Grain (learn here the meaning of "quarter-sawed").

(*c*) Hardness; hard and soft woods.

(*d*) Polish.

(*e*) Weight, compared with water.

(*f*) Special markings ("bird's-eye," "burl," "crotch," "curly").

(*g*) Strength (breaking).

(*h*) Durability.

(*i*) Odor.

(*j*) Effect of oil and varnish application.

(*k*) Ease of working with edge tools.

Table of commercial woods

Name	Family	Country	Use	Value

Other work. What are veneers? Why are so many woods used mostly in this form?

How are veneers produced?

What uses have veneers?

What is meant by the terms "treating," "preserving," "doctoring," woods for fence posts, ties, paving, etc.? What substances are used for preservation?

What important home articles are made of wood?

What substitutes may be used instead of wood?

Forestry. What is the definition? The government has many Forest Reserves. What is their object? Who are Forest Rangers, and what are they paid? Where are there Schools of Forestry, and what do they teach young men to do? What is Burbank's walnut? What worth has the eucalyptus?

If you are 18 and planted 10 acres to eucalyptus and Burbank's walnut, 5 of each, 400 trees to the acre, and these in 12 years gave you clear logs that would square 12 in. by 50 ft., worth to-day (1910) $150 a thousand feet, how much would your trees bring you when you were 30 years old?

8. Review Table of Stems

Use each stem that has been studied, and fill out the columns properly.

Name	Ordinary Stems			Modified Stems			Purpose
	Bark color	Bud color	Bud arrangement	Kind	Shape	Where growing	

9. Supplementary Exercise. Purpose of Stems

It ought to be constantly kept in mind that ordinary stems are leaf-bearing structures, and that the arrangement of the buds and branches and the general habits of the plant are very largely an effort to obtain the best possible light relation for the leaves. Stems, of course, have many other purposes, which you are supposed to have stated in the review table.

Particular attention ought to be paid to the influence of environment on the form, structure, and habits of stems.

Read about "Desert Vegetation," "Tropical Forests," "Arctic Plants," and "Water Plants" in this connection.

10. Useful Stems Table

Make a table of useful stems as follows: —

Name	Where Native	Use: Crude, Raw, Cooked	Use Manufactured	In what Industry

11. Further Applications

1. You may make sugar from sorghum, sugar cane, or maples. How would you proceed? How important is cane sugar?

2. You may make dyes from oak and walnut bark.

3. You may make a cough syrup from cherry bark.

4. You may make strong fibers from flax or hemp stem by pounding the cured stems, to break the woody parts, and then separating the tough long strands of fiber? What are these fibers used for?

5. You may make tannin from oak (black) bark or hemlock. Slowly steep some chicken skin in strong decoctions of either for a week, and observe the results.

6. You may make furniture, canes, and other articles from crude limbs and branches.

7. You may learn how to prune trees and shrubs for form, flowers, or fruit, and so learn horticulture and pomology.

12. Physiology of Stems

(Some of the experiments can be made by the students, others will have to be demonstrations by the instructor.)

Exp. 1. The water content of various woods. (Students.)

Weigh blocks of different woods freshly cut and after drying.

Exp. 2. Water content of heart and sap woods from freshly cut trees. (Students.) Conduct experiment as in 1.

Exp. 3. Rapidity of decay; durability. (Students.)

Keep blocks of wood in moist warm earth for one month. Examine for signs of decay.

Exp. 4. Amount of ash. (Students.)

Weigh, burn, and weigh the ash remaining.

Exp. 5. Path of upward sap movement. (Students.)

Place fresh cut elder, lilac, or other twig in eosine solution for 24 hours. Make long sections through pith, wood, and bark, and observe region of discoloration.

Exp. 6. Path of the downward movement of elaborated sap or food in solution. (Instructor.)

Exp. 7. Tensile strength. (Students.)

Weights square rods of equal area and length will support before breaking.

Exp. 8. The "bleeding" of woody plants, particularly maples, grapes, hickory, and birch, in early spring. (Students.)

Exp. 9. Effect of light and direction of exposure on the color and thickness of bark. (Students.)

Bore holes in the different sides of trees for thickness.

Exp. 10. Earthpull or geotropism. (Students.)

Observe the direction of leafy stems, branches, runners.

Exp. 11. Lightpull or heliotropism. (Students.)

As in 10.

Exp. 12. The epidermis coating or protective "varnish." (Instructor.)

Exp. 13. Food storage of stems. (Instructor.)

Exp. 14. The effect of wind pressure and means of resistance. (Instructor.)

Exp. 15. Effect of climatic extremes on bark character. (Instructor.)

Exp. 16. Grafting. (Students or instructor.)

Exp. 17. Budding. (Students or instructor.)

Exp. 18. Cuttings, stolons, layers. (Students or instructor.)

Exp. 19. Pruning. (Instructor.)

The above list is largely suggestive. The experiment details may be stated more fully as the instructor desires. Other experiments not named may be given.

SECTION V. LEAVES

1. Geranium Leaves or other Complete Leaf

General statement. When the study of leaves comes during the "off" season, there is no better form to be easily obtained than the geranium. During the growing season many other leaves may be added to the list, but even at such time it will be difficult to improve on this selection. The pupil should compare all available leaf forms, in order to broaden his comprehension of these most vital parts of the plant.

Surface features. Examine a growing shoot of a geranium and observe the leaves borne here and there. What is their variations in size on different parts of the shoot? Where are they largest and why? A leaf has the following parts: If it is a *complete leaf,* it will have a pair of small, expanded structures, *stipules,* where the leafstalk joins the shoot; a *petiole* or leafstalk, bearing at its outer or distal end the large green expanded *blade.* Are all these parts found in the geranium? Observe that the blade is supported upon a framework of ribs or *veins.* When one main vein runs from end to end of the leaf, giving off small branches, the leaf is *pinnately* veined and the main vein is the *midrib*. If, on the contrary, a number of equal or nearly equal veins radiate from the base to the margin, the leaf is *palmately* veined. What condition is found in the geranium? Examine the margin of the leaf. Is it even, not having any irregularities (*entire*) or is it more or less irregularly lobed and toothed or notched? If the notching is shallow, the leaf is *toothed*; if deep, it is *lobed*; if the division almost reaches the veins, the leaf is *cleft*.

Examine the surface of the leaf, above and below, and observe the color. What difference do you find, and how do you explain it? Observe the presence or absence of *leaf hairs* on the surface. Examine the leaf for odor. Examine the hairs, (*m*) and (*lp*), and find that some have knobs at their ends. What connection may these hairs have with the odor? Brush the leaf with the fingers to test any difference in the odor.

On which side are the veins most prominent? What connection have the veins with the petiole? Compare the veins to blood vessels. Is the comparison justifiable? Compare the veins to floor joists to explain their great prominence on the under side. Draw (1) a portion of the shoot bearing a leaf; (2) the under view of the blade; (3) the leaf hairs (*m*) and (*lp*).

Epidermis. Peel off the thin epidermis from the upper and lower surfaces of the leaf, examine with the *lp* or *hp*, and find the irregular *epidermal cells* and the *stomates* or small openings with their two *guard cells*. Where are the stomates found? Estimate their number in the field of the microscope, and with this as a starting point, figure the number of stomates on a leaf.

What do you infer the stomates and guard cells are for? Why do the epidermal cells have such an outline? Draw the epidermal cells and stomates.

Structure. Examine the sections of the leaf (*lp*) and observe the epidermal layers and the green *mesophyll* between. What color has the epidermis? Are the cells thin or thick? What purpose has this layer? What form have the cells of the mesophyll? Are they alike in shape throughout, or are some elongated perpendicularly to the epidermis (*palisade cells*)? If the section shows them, examine the stomates, and determine what they open into. If a vein is cut across, study its cell structure and compare it with the vascular bundles in ferns or in stems of seed plants. Notice the hairs and discover to what part of the leaf they are attached. Draw the leaf section and any details of cell structure observed.

Description. Write a careful, complete description of the geranium leaf, answering all the questions. Read about "Geranium" and "Pelargonium" in a good encyclopedia, and learn the peculiar features of these plants, and decide which name really belongs to your plant.

2. Venation and Vernation

Statement. A great variety of leaves may be used and ought to be compared by the student with the types given in these exercises. For convenience, the venation study is based on the following leaves, all easily obtainable: *grass leaves, Wandering Jew* (Tradescantia), *hyacinth, evening primrose, elm, oak, maple, violet, ivy, begonia, pine, spruce.*

Forms of venation. The pinnately veined and palmately veined leaves have been defined in the geranium study. Two other forms of venation may be recognized: *parallel-veined, viz.*, when the main veins run from the base to the apex and are more or less parallel, and finally the peculiar *needle leaves* of the spruce and pines, with generally one or two central veins. Examine any of the above-named leaves or any others furnished and determine the method of venation. Make careful drawings showing the character of the veining.

Conclusions. From your knowledge of common tree and plant leaves, which form of venation is the more common? Which form is best adapted to large leaves? What functions do the veins possess as shown by the venation?

Vernation. The unfolding of a leaf from the bud is *vernation.* There are several forms: *rolled, folded, twisted,* and *coiled.* Study and draw some forms of vernation. Cut off twigs of as many different trees as it is possible for you to obtain, place in water, and study carefully as the buds begin to swell and grow. In this manner many examples of vernation may be easily observed. Observe very particularly, in this process, that the bud develops *into a stem* on which the leaves are borne and not into a single leaf.

Some odd forms. Some supplementary statements about venation may be made. Certain leaves, like the common plantain, appear to have a parallel veining, but are really net-veined. Such leaves are *ribbed.*

Trillium leaves are apparently a combination of *parallel* and *net* venation. Another type, a form of parallel venation, is seen in the banana and other monocotyledons. Many leaves have a *marginal* vein into which the netted branch veins terminate.

3. Leaf Division

Statement. Many leaves, instead of consisting of a single entire piece of expanded *blade (a simple leaf),* have this blade variously divided, the lesser amount of division forming teeth and lobes, and the greater separating the leaf into few or many small portions called *leaflets,* all borne on a common stem or *petiole.* These latter forms have been called *compound,* but *divided* is a far better expression. The following leaves are easily obtainable, some from the greenhouse, others when there is no snow on the ground, or in very early spring: Strawberry, five-finger, yellow strawberry (*potentilla sp.*), rose, clover, all divided forms, besides which various toothed and lobed leaves may be used, preferably oaks, which as dry leaves are present all winter.

Special leaves. Examine each leaf furnished, determine the *method* of division (palmate or pinnate), the *amount* of division, and the features of the leaflets. Examine for stipules. Draw each leaf, showing all the features.

A leaf discussion will follow later, but determine at this point, if you can, the value to the plant of divided leaves. Is it a common feature or not? Is it more abundant among herbs or among trees? Some reasons for this may appear later.

General terms. Many terms are in use, especially in the older editions of our botanical textbooks, expressing all degrees of variation in form and amount of division, but the following seem sufficient for the purpose of the average student: (1) Entire margin (lilac); (2) serrate margin (willow); (3) dentate margin (catnip); (4) crenate margin; (5) lobed margin (oak, maple); (6) cleft margin (hemp); (7) trifoliate leaf (clover); (8) quinate leaf (five-finger); (9) odd pinnate leaf (locust); (10) even pinnate leaf; (11) decompound leaf (yarrow); (12) ternately divided leaf (meadow parsnip)

4. Winter and Spring Rosettes and Leaf Mosaics. Leaf Arrangement

Material. Rosettes are very easily obtained in the late fall or early spring, from mullein, shepherd's purse, thistle, evening primrose, and five-fingers. A growing plant of begonia, geranium, or primrose in a window will do well to show the mosaic arrangement on the stem. For many purposes, specimens mounted on bristol board behind glass are admirable for this work, and, in truth, for practically all the study of ordinary leaves.

Study of forms. Examine the rosettes and observe the arrangement and varying size of the leaves. Why do such conditions exist? Why do so many plants have rosettes that persist through the winter? How are they preserved from injury from the winter cold? *Biennials* and *winter annuals* commonly possess rosettes. What are such plants? Examine, in particular, the winter rosettes of the mullein and look at the covering of the leaves. What is it? Examine (*m* and *lp*). What may this covering be for? Make careful drawings of rosettes, showing outline of the whole and details of one leaf. Draw hairs of mullein (*m* and *lp*).

Examine a growing plant that has for some time been in a window. What position do the leaves occupy with reference to the window? What is the cause of this condition? How are the large and small leaves arranged? Why is such an arrangement called a *mosaic?* What benefit does the plant receive from such an arrangement? Recall if you can the appearance of ivy leaves or plants climbing over brick and stone walls. Look in your reference books for pictures showing leaf mosaics. Make a drawing showing leaf mosaics.

Arrangement on stem. Examine growing leafy shoots for the leaf arrangements, comparing them with the bud arrangement already learned, and name in a similar manner. Look down the shoot with the apical portion toward you, and observe the position of the leaves, radiating outward. What agent decides the leaf position? Make a diagram showing the leaf position as a result of the last observation.

5. Leaf Modifications

Material. Thistles, cacti, cobæa, vetch, smilax, pitcher plant, locust, and head cabbage, besides many other plants easily obtained, will furnish leaf modifications in abundance.

Study of each form. Examine each modification furnished, find its peculiar characteristics, decide what leaf part or parts enter into it, and try by careful and thorough investigation to determine what the modification is for. In this connection read about cacti, climbing plants, and insectivorous plants. Draw each modification, naming the parts.

Table. Make a table embodying the results of your study of leaf modifications, using the following model : —

Name of Plant	Name of Modification	Part of Leaf	Purpose of Modifications

Ecology. Leaves are very greatly modified by the nature of the environment. Desert plants have their leaves so changed in form, structure, external covering, time of production, and other characters, as to show in a very marked way the influence of excessive heat and light on leaves. Similarly, plants of very wet places show such condition by many peculiarities. Such response to environment gives rise to Ecology. This science is rapidly assuming great importance in the study of plants and their activities.

6. Broad and Narrow Leaved Evergreens

Material. Without much difficulty there may be obtained enough specimens of lemon, rubber, and certain fig species from greenhouses and vinca (myrtle) from the open ground, and also pine and spruce, to make a satisfactory study. The pupil should seek further knowledge by looking in reference books and examining pictures of tropical plants, especially trees.

Study of forms. Observe the general form of the leaf. What peculiarities of thickness, leaf margin, and surface do you observe? Determine the fitness of the leaf in all particulars to remain long on the plant and its adaptation to great moisture and heat, or to great cold. Examine a transverse section of a leaf (*lp.*), and compare with that of the geranium. Make drawings showing the various leaves and the details of structure.

How can you explain the presence of such broad, evergreen leaves on the vinca, exposed, as it may be, to great cold, whereas most leaves of this character (broad) are found on trees of warm and moist regions? Are the leaves really evergreen? Compare them with the narrow-leaved evergreens, like the pine of cold countries, and observe the great difference in size and form, and seek carefully for an explanation of the difference.

Make a list of ten forms of each kind, stating where each is found.

7. Leaf Experiments and Determination of Leaf Functions[1]

1. Grow some oats in the dark in a deep narrow glass jar, and at the end of 5 or 6 days observe the color of the leaves. What is the explanation?

2. Place a small vigorous geranium in total darkness, for the same length of time, keeping it well supplied with water. From the two experiments what is necessary for the healthy chlorophyll formation?

3. Place a vigorous leafy shoot in a small bottle of water and seal about the stem with wax. Place under bell jar. What is the result? The process or function illustrated here is called *transpiration*.

[1] Other experiments, other than the ones given, may suggest themselves.

4. Take a vigorous geranium, or better a primula obconica (baby primrose). Water well, wrap the whole pot and top of soil in tin-foil, making a tight joint about the plant stem, then carefully weigh and balance on a pair of scales. Record the results from day to day. What is it that the plant is giving off that affects its weight, and where does this substance come from to the plant? Through what plant structures does it reach the leaves?

Read "Transpiration" and find out its value to the plant, and in particular, how it is regulated. Try experiment 5.

5. Place fresh leaves of mullein and lettuce on the table for one hour and observe the results. Which wilts more rapidly? What explanation is there?

6. Take a vigorous geranium having several healthy leaves. Inclose a young leaf in black French tissue paper. Place the plant in the sunlight, and after three days test this leaf and another similar but uncovered leaf for starch. (Remove the chlorophyll with alcohol.) Which leaf shows a starch reaction? The process of starch making in leaves or other green parts is *photosynthesis*. Read about this in reference books. (See algæ studies.)

7. Take a vigorous leaf from a geranium near the close of a sunny day, take out the chlorophyll, and test for starch. Take another from the same plant in the early morning, before any sunlight has affected it, and treat as before. Explain the results.

8. Experiments on respiration are difficult, and the pupil may read about this function.

Record carefully each experiment performed above, or any other introduced by the instructor or *worked out* by yourself. Where possible, make diagrams to show apparatus.

9. Take a geranium shoot and place cut end in a weak eosin solution. Examine the leaf after a day or two, and observe the location of the color, and explain.

10. Place vigorous plants of various kinds in a window, and allow them to remain for a few days. Turn each half around and determine the varying rapidity of the response of the leaves to the light. Seek for any explanation.

11. Place a number of sprouting salsify, carrots, spinach or other vegetables *flat* in a tray. Keep for 24 hours. What direction have the *youngest* leaves assumed? Split a sprouting onion in halves. Place on the table with cut surfaces up. What happens to the sprouts?

12. As in 4, but place the whole plant in an inverted glass bell jar of great height (16 in. or more) filled with water. Place in bright sunlight. Observe gas; collect and test for oxygen.

13. As in 1, but grow in the light until vigorous. Place in closet at close of day, bring out the next morning, and lower a taper to the bottom. What happens? Breathe repeatedly into a similar deep glass and test as before. Compare the two.

14. Take fresh leaves of fern, lettuce, plantain, beet, maple, mullein, sunflower, water lily, corn, carrot, and onion.

Allow each to remain on the table in dry room for one hour or until well wilted. Record varying time.

Now plunge each into cold water and let it remain for some time. What amount of revived freshness does each show? What caused the wilting and how did the cold bath restore?

8. Ecological Study of Leaves

Field work. Throughout the season, from early spring to fall, find out and observe carefully as many rosette forms of leaves as possible. Rosettes found in early spring, especially, should be noticed, with the locality in which each grows. What do you infer, by studying each, as to the plants' life duration? How did they survive the cold weather? What proportion of the plants having rosettes are annual? Examine shepherd's purse and peppergrass very early in spring. When did these rosettes of annuals start to grow?

Examine plants growing in sandy and very dry places, and find, if possible, any leaf peculiarities. Do you find any number with common features? If so, try to find some explanation.

Examine plants found in dark woods, and compare with the same kind of plants in similar soils growing in bright sunshine.

Study carefully as many water plants as you can obtain, and seek for characters shared in common by all. Examine, if possible, leaves from all sources, under the compound microscope, for any peculiarities of stomates or structure.

Conclusions. From all the examples you have studied, what do you conclude regarding the influence of surroundings on leaf structure?

Table. Tabulate your observations on the forms examined, using the following (Two examples are given as guides to proper use.):

Name of Plant	Location	Leaf Arrangement	Size of Leaf	Leaf Surface	Texture	Position
Mullein	very dry soil	spring rosettes	large	very hairy	dry	horizontal
Pickerel weed	in water	one	large	very smooth	fleshy	vertical

9. Useful Products of Leaves and Application of the Study to the Wants of Man

1. Make a table of useful leaves and their products, using the following form, seeking particularly to have important

samples under each of the following uses: (*a*) for food; (*b*) for medicine; (*c*) for drink; (*d*) for clothing; (*e*) for ropes and cordage; (*f*) for dyes; (*g*) for flavoring.

Name	Where Native	Part of Leaf Used	Product, if Manufactured, or Crude Use

2. Obtain leaves of century plant or other agaves; pound with a heavy club on a very firm wooden block; wash away all the débris; continue until you have a bunch of fibers. The original way of preparing fiber for weaving or cordage making. Sisal, used in harvesting, is an agave. What other leaf fibers are noted?

3. Steep finely divided green tobacco, rose petals, and horehound, catmint, plantain, or onion (all fall leaf forms) in 50% alcohol for one week in tightly closed bottles. Press the leaf masses dry and study resulting liquids for color, odor, and taste. You have made medicinal preparations. By following rules of weight and amount of liquid you would have known strengths of drugs.

4. Crush celery, lettuce, cabbage, beet, spinach, rhubarb, kale, chard, dandelions, endive, or other leaf vegetables, and after mixing with water, test for sugar, starch, etc.

5. Dry quickly vigorous plants of red, white, and alsike clover, alfalfa, various kinds of grasses, corn leaves, and young pea vines. What relation has greenness to rapidity of drying? How has the odor been affected? You have "made hay." What are the elements that bring success in haymaking? Try dipping some of your half-dry hay in water until soaked, then continue drying. If possible, obtain or grow a stalk of tobacco. Hang up to dry in a dark, well-

aired place. Observe change of color, odor, and taste. (A step in tobacco manufacture.)

6. Take four leaves of the same kind and treat as follows: —

No. 1. Place between blotters, weight with a heavy book; examine at the end of six days.

No. 2. Place between sheets of writing paper, and then as in No. 1.

No. 3. Place between leaves of a large book for six days.

No. 4. As in No. 1, but change blotters night and morning. Compare results at the end of the six days. You are making herbarium specimens.

7. Dry very quickly violets, roses, lavender flowers, and sage, spearmint, thyme, marjoram, or other leaves. What effect has drying on the odor? Place one half in open boxes and one half in tight receptacles; test for odor in two weeks. Basis of culinary herbs and sachet preparations.

8. Take five small cabbage, tomato, aster, lettuce, or other plants; transplant each of four into flower pots: For No. 1, leave in condition as transplanted. For No. 2, water thoroughly. For No. 3, cover in No. 1 condition by a glass tumbler. No. 4, cover in No. 2 condition by a glass tumbler. No. 5, use as a check experiment not transplanted.

Compare the results and learn how to transplant.

10. Review Table of Leaves

Name	Leaf Arrangement	Venation	Division	Parts Present	Leaf Surface

11. Exercise (A Written Statement)

Review topic questions on leaves

1. What are leaves? Give a good definition in your own words.
2. What are the functions of leaves? Name all you know.
3. Why do leafy plants need sunlight?
4. Why do biennials generally produce winter rosettes?
5. What do desert plants do to regulate transpiration?
6. Why are parasitic flower plants generally devoid of green leaves?
7. What advantage, if any, are divided leaves?
8. What effect have forests on the moisture of the atmosphere?
9. What are evergreen plants?
10. Name three most useful leaf products.
11. Why do the cacti have their leaves reduced to spines?
12. What explanation do you have for a cabbage head?
13. Explain the *pitcher* of the pitcher plant.
14. Explain leaf arrangement with reference to light.
15. Why do leaves wilt?

SECTION VI. THE STUDY OF FLOWERS

General Preface to the Special Studies

General statement. There are many different methods in vogue for the study of flowers, the most common being, perhaps, to study the trillium, tulip, or some other flower of easily discernible parts.

It has, however, been amply justified in the author's school experience, that a better understanding is to be gained by beginning with such an extremely simple structure as the willow; for by so doing the student learns the subject from the foundation, and appreciates much more certainly that the *essential organs* are all that are absolutely necessary in order that the flower may fulfill its destiny. Then again it is the logical procedure from the simple to the complex, and the procedure is like the addition of one brick to another until the building is complete, and not the demolition of a fully made structure to find its component parts.

The student is expected, in the following pages, to learn first of all the primary features of the normal flower, in all its parts, and then by a study of characteristic flowers of the great type *families* to familiarize himself with not only increasingly complex forms, but to also learn the rudiments of classification, the use of artificial keys for plant determination, and the features that distinguish the most important families of plants, either because they illustrate some great feature of flower structure and adaptation to certain definite ends, or because they are greatly important to man from the economic standpoint.

The student is expected to bring in samples of all flowers possible to be obtained, and gradually to learn to locate them in their natural families. Flower tables posted on the wall, giving credit for first-reported flowers, and for all flowers seen by the classes and definitely identified, add largely to the interest. Herbarium material may be collected, but this is by no means the essential element in successful flower study. As far as may be, the flowers should be gathered by the class, thus adding to the value of the work by the personal interest of those who have assisted in furnishing material.

1. The Willow

Staminate Willow Flowers,[1] *or Yellow Pussies or Catkins*

The shrub and its habitat. You ought to notice the willows as they grow, the places they prefer, especially with

[1] Willow flowers are of two kinds, borne on separate plants.

reference to the presence of water or moist ground. Observe the size of the shrubs and the frequency of the yellow-flowered form now to be studied.

The catkin. Examine the "pussies" as they grow on the willow tree or shrub, and observe that, as stated in the note, there are two forms borne on separate plants. What feature easily distinguishes the one kind from the other? The technical name for the flower clusters is *catkin*. What relation does this bear to the common name "pussies"?

Examine a staminate catkin and observe its form and color. To what is the color due?

The small leaves at the base of the catkin are *bracts*. Observe the catkin in detail and find out what structures make up its bulk. Does the catkin appear with, after, or before the leaves? Draw the catkin, natural size or slightly enlarged, as it is attached to the stem.

The flower. Examine an individual structure or part of this catkin (*flower*) (*m*). It consists of a dark scale, bearing one or two slender, knobbed stalks (*stamens*). What is peculiar about the scale, and what use has this peculiar feature? Draw a staminate flower.

The stamen. Examine a stamen (*m*) and (*lp*) and find the slender stalk (*filament*) and the top enlargement (*anther*). What color is each? Draw a stamen (*m*) and (*lp*).

Pollen. Crush an anther on a slide, mount in water, and examine (*hp*). Observe the *pollen* grains (microspores). What is their form, color, and number. Draw several.

Examine pollen grains that have been in water for a couple of hours and observe that some show sprouts (germination). Remember this, as it will be referred to later.

Count the number of catkins on a well-grown branch, also the number of flowers for an average-sized catkin. From this count form some idea of the amount of pollen produced by a single willow. Why is there such an enormous production? Shake a fully blossomed branch. What effect has it on the pollen? What natural agent might shake the branch? What then would become of the pollen? (Referred to later, so remember.)

Pistillate, or Green Catkins

Catkin. Examine a pistillate flower cluster (inflorescence). What is its form and color?

Observe its general "make-up" and compare with the staminate inflorescence in the matters of bracts, scales, and scale peculiarities. How does it compare in size with the staminate? Draw natural size.

Flower. Examine an individual flower (*m*). Find the scale and observe that it bears a green, oblong, or spindle-shaped structure, the *pistil*. Draw a flower (*m*).

Pistil. Examine a pistil (*m*) and (*lp*). Determine the presence or absence of a short stalk or *pedicel*, attaching it to the axis of the catkin. Observe the enlarged lower part, the *ovary* or *ovulary*, often hairy, and the extreme tip, somewhat enlarged, the *stigma*. When the stigma is connected to the ovary by an intervening part, commonly smaller, this connection is the *style*. Is it found here? Examine the stigma (*lp*). What peculiarities of surface do you find? Draw the pistil (*m*) and (*lp*).

Examine a ripened pistil (pod), and observe the tiny seeds within. What is attached to the seeds and for what purpose? (Seeds in the ovary before the process called *fertilization* takes place are called *ovules*.)

Pollination and fertilization. To produce seed in the willow or any other flower two processes are necessary: *pollination* and *fertilization*. Pollination is the transfer of the pollen from the anther to the stigma. It is a general rule among flowers that the pollen is carried by some agency to the stigmas belonging to flowers of another plant of the same kind, *cross-pollination.* From your observation and reading what different methods or agents are there that can accomplish this? Upon what agent does the willow depend? (See staminate study.)

After pollination comes *fertilization.* The pollen grains are lodged in some manner upon the stigma, germinate and send the growing tube seen in your pollen study through the style into the cavity of the ovary, where it enters one of the tiny *ovules* there contained, fuses with the egg cell, and a seed, after some growth, is the result.

Comparative work. Compare, if possible, cottonwood or poplar flowers with those of the willow and observe the resemblances and differences.

Written work. Write careful description of each catkin, flower, and the pollen.

The willow family. The willow is the type of the *willow family*, consisting of common shrubs and trees, and having, as common examples, all kinds of willows, poplars, cottonwood, and "Carolina poplar." Of what value are any of these?

Applications. (1) Take some poplar wood, cut up into small blocks, and soak for 24 hours in 10% sulphuric acid. Now by means of a heavy hammer crush the blocks until thoroughly pulped. You have crudely accomplished one stage in paper making from wood (poplar and spruce).

(2) Take a number of willow blocks, place in any small iron dish that can be closed tightly, heat red hot for 20 minutes, and allow to cool. Examine the wood. You have made charcoal. Why did not the wood burn up?

(3) In spring place several willow twigs in water or earth. Notice the roots forming on the willows in water; also that the willows in the earth begin growth. These plants may be easily propagated in this manner.

(4) If possible, observe the action of bees around staminate willows. What do they obtain from the flowers?

2. The Hazel

Statement. The Hazel is a member of the Birch family and is an easily obtained shrub growing abundantly in thickets. It is in bloom about the time of the willow. In this shrub the flowers are not borne on separate plants (*diœcious*), but both kinds are found on different parts of the same plant (*monœcious*).

Staminate catkins. Examine the staminate catkin and observe its form, color, and position on the branch; also the separate scales, *sporophylls*, that make up the catkin. Draw a catkin natural size.

Examine a single scale (*m*) and find the stamens. How many are there? How do they compare with the willow stamens in size and parts? Draw a single scale with its stamens (*m*).

Examine the pollen (*hp*) and sketch.

Pistillate flowers. Look along the twig for small red clusters of pistillate flowers. How are they surrounded? Examine (*m*) the pistils and stigmas.

Sketch a pistillate cluster (*m*).

Dissect a cluster and examine a single flower (*m*) or (*lp*). Try to determine its parts. Sketch.

Other work. Recall, if you have seen them, the full-grown hazelnuts in their "shucks" that are the result of the growth, after fertilization, of these pistillate flowers. Oak, chestnuts, and various other trees have similar flower arrangements, and all belong to two closely related families, the Birch and the Beech. What useful trees are found here? How many kinds of oaks do you know? When does the oak blossom? How long does it take an oak acorn to ripen?

Final statement. The willow, hazel, and many related forms belong to some lower orders of dicotyledons, having one or both kinds of flowers in catkins or aments (another term for pussy). All, with one or two exceptions, are spring bloomers; have inconspicuous flowers. What agent for pollination, therefore, do these trees and shrubs require? What advantage is the early date of blooming?

Ten important trees belonging to these orders are: (1) Oaks; (2) Chestnut; (3) Beech; (4) Birch; (5) Cottonwood; (6) Osier; (7) Aspen; (8) Filbert; (9) Hornbeam; (10) She-oak. What economic value has each?

3. The Trillium Species

Species available; habitat. For this study any species of trillium is equally good, but for the reason that T. recurvatum, or the bloody butcher, is not picked for its blossoms, good judgment dictates that it is the *best* one to study, because one is not hastening the extermination of a beautiful plant by so doing. It may be commonly found blooming in all rich woodlands in the northern parts of the United States about May 1. A few complete plants should be procured in addition to the flowering stems.

The plant. Examine the whole plant and observe the thick *rhizome* from which the flower stalk grows. Where do the *roots* grow and what are their peculiarities? Find an *apical bud* immediately at the base of the ascending stem.

Study the erect aërial stem. Observe its varying color from base to summit. How do you explain it? How many leaves does it bear? Examine the leaves for shape, size, color, and venation.

What is the position of the flower with reference to the leaves? Is the flower with a stalk (*peduncle*) or without (*sessile*)?

Study a cross section of the stem (*m*). What is the arrangement of the tissues? Is the stem mono- or dicotyledonous in structure? Draw the whole plant, also the stem section (*m*).

The flower calyx. Examine the flower for its size, color, and position. Study the outer (lower) whorl or circle of parts. What color do the parts have? This whorl is the *calyx* and its parts are *sepals*. How many of these are there? Are they stalked or sessile? What is their shape? Examine their venation. Where are they found in the unopened bud, and what seems to be their function? Draw a sepal.

Corolla. Examine the whorl next within (above) the sepals. What color has this whorl and into how many parts is it divided? This is the *corolla* and the parts are *petals*. Study a petal and its shape, direction of growth, and venation. Draw a petal.

Stamens. Next within (above) the petals are a number of oblong or linear structures. How many are there, and what is their color? These are stamens. Find the two parts named under the willow. Investigate their exact position and discover if they are in *one* or *two* rows. Draw a stamen, two views to show its exact form (face and side view).

Pistil. Study the central structure, pistil, and find its parts. (See willow.) What is its color and shape? Draw a pistil, side and top views.

Details of structure. Examine an anther on the concave face (*m*) and observe two lines of yellow. Examine a cross section of the anther (*lp*) and see that these lines really are *pollen sacs* or *microsporangia*. Make drawings showing both the above features. In the stamen section, look for the cell structure. Compare it to a leaf section. The stamen is really a *sporophyll* or modified leaf.

Study the pollen (*lp*) or (*hp*). What is the color and form? Draw several pollen cells.

Examine the *stigmatic surface* of the pistil (*m*), for any peculiarities observable. Draw, if possible (*i.e.*, not too complex or difficult).

Study a cross section of the ovary. Into how many compartments (cells) is it divided? What do you observe in each cell? These structures are *ovules*. Examine very carefully and determine, if possible, their point of attachment (placenta) to the ovary. It may be on a central axis (axial), or on the ovary wall (parietal).

These ovules are really *megasporangia*, each containing one *megaspore*. The ovules eventually become seeds by a process called fertilization. Look this subject up in your textbook and refer back to the willow. Draw a cross section of the ovary (*m*), naming all the parts. If the ovary walls are, as is usually considered the fact, made up of peculiarly modified leaves (carpels), how many can you decide there are in the trillium? Where are the ovules attached with reference to the leaf margins or midribs?

Lily family. The trillium is an example of the lily family, which contains many showy or useful plants, as the tulip, hyacinth, lilies, onions, etc., and is one of the large families of monocotyledons. Some authors divide the family into several smaller families, in which case the Trillium is placed in either the Lily of the Valley or the Trillium Family.

Practical work. The cultivation of the Bermuda, Spanish, or other onions for the mature bulbs, and the immense amount of green onions grown, show the importance of this family as a vegetable producer. Leeks, garlic, chives, and shallots are other related forms.

Asparagus is largely grown for commercial purposes, to be used fresh or canned.

In certain regions tulips, Bermuda lilies, and hyacinths are grown in immense numbers to supply the demand for the flowering bulbs.

A large number of species are grown by florists and in home gardens. A few are valuable in medicine.

An onion venture. A young man planted one acre of rich land (rent $25 per year) to commercial onions, paying also $15 for seed and $100 for labor. The rows were 16 in. apart, and he harvested three large spherical onions, 3 in. in diameter from every foot of the row. He sold his crop for $1 per bushel. What was his approximate net return for the venture?

4. The Erythronium, Dog-tooth "Violet" or Adder's Tongue, (a Typical "Lily")

Where found. The Dog-tooth "Violets" are common plants in moist woodlands, particularly near streams, and are beautiful types of the great Lily family and are introduced to familiarize the student further with this noted plant group.

The plant. Examine an entire plant and especially the part that grows below the surface. What name do you apply to this? Study the leaves as to their shape, number, color, and venation. *Parallel venation* is one of the characteristics of the monocotyledons.

Observe that the flower is borne on a naked stalk or *scape*. What is the color and what the position of the flower (erect or nodding)?

Draw the entire plant in such a position as to show the leaves and the parts of the flower.

Flower. Examine the flower and determine the four kinds of structures named under the Trillium.

How do these parts compare in number and color with the similar named part of that plant? Observe that in both Trillium and Erythronium the ovary stands *above* the *insertion of the sepals* on the top of the flower stalk or peduncle. (This point is the *receptacle*.) Such a position for the ovary is designated as *ovary superior*. In this flower how can you distinguish the sepals from the petals? Compare with a tulip. Draw a *plan* of the flower, by representing the petals and sepals by curved lines, the stamens by solid round spots, and the pistil by a ring properly divided to show the number of cells in the ovary. Be sure to have each part properly located with reference to the adjacent structures.

This is called a *flower plan* or diagram.

Characters of Lily family. See if your study of these examples of the Lily family agrees with the following characterization: —

The Lily family is monocotyledonous, commonly has bulbs or rhizomes, flowers with three sepals and three petals, usually similarly colored (often called the perianth), six stamens in two rows, a single superior ovary having three stigmas and cells. You ought to consult Gray's "Manual of Botany," and familiarize yourself with the characterizations of the families to which the plants you study belong.

Learn also, by continuous practice, how to analyze a flower, or determine its name by a "key."

The study of other forms of the Lily or other monocotyledonous families may be undertaken, following the same guides as used in Trillium and Erythronium.

5. Demonstration of an Orchid — The Lady Slippers (Cypripedium)[1]

Statement. It is not advisable to use orchids for individual class work because of the increasing scarcity of this beautiful group and the consequent danger of helping on their extermination. As the most specialized of the monocotyledons, however, they ought to receive attention by a demonstration before the class, dwelling in particular on their adaptation to insect pollination.

The plant. The leafy stem crowded from base to flower with large parallel-veined leaves and arising from a peculiar

[1] The Iris is equally good, and may be used with necessary changes in wording.

cluster of fleshy roots and *topped* by the odd flower or flowers.

The flower. The peculiarly arranged and colored flower parts: —

1. The three sepals, two united.
2. The three petals, one very irregular, called the "lip."
3. The two fertile and the one sterile stamens, with pollen masses.
4. The stigmatic surface.
5. The long *inferior* ovary, with myriads of seeds.

Plan for cross-pollination by insects. The special adaptation of the *lip* and the relative position of the pollen masses and stigmatic surface to insure *cross-fertilization* by bees.

Orchid family. The characterization of the Orchid family may be inserted to show the highest type of the monocotyledons: (*a*) root commonly fleshy, or, in many cases, epiphytic, (with air roots); (*b*) leaves typically parallel veined, occasionally leafless, and root parasitic; (*c*) flowers three-parted and very irregular, the third petal often variously modified; (*d*) stamens, one, two, or three; (*e*) pistil, one with inferior ovary containing myriads of small seeds.

Use. Often highly valued for ornament, but with very few useful forms; vanilla is one of the most important. Obtain, if possible, a vanilla bean, break up into small fragments, place in a large bottle, and cover with 50 % alcohol. Stopper and set aside for two weeks. Do the same with some tonka beans. Compare the odor and taste. Cheap vanillas are either very often adulterated, or made from other substances as coniferin and oil of cloves.

6. Apetalous Flowers of the Crowfoot Family

Kinds available with habitats. The *Marsh Marigold*, *Anemones*, and *Hepaticas* are all suitable flowers for this study, and are all good types of those crowfoot representatives that are lacking in petals (*apetalous*). Each grows in a habitat peculiar to itself. Find them where they grow if possible.

The plant. Examine the entire plant, observing the roots, leaves, general habit of the stem, and the arrangement of the flowers, singly or in clusters (*inflorescence*). The arrangement may be solitary, in *racemes, corymbs, panicles, umbels*, not easily explained by word alone, but plainly understood by diagram and actual specimens. Determine for the plant at hand what the inflorescence may be, after consulting diagrams made by the instructor.

Flower. Study the flower. There is but one whorl of leaflike colored parts or sepals, the petals being absent. Determine their color and number. Examine the stamens. How many are there and how are they arranged? Study the central pistils. How many are there? Observe that all the parts named are *borne directly* upon the receptacle. Are the ovaries superior or inferior?

Draw a portion of the plant with leaves and flowers; also make a plan of the flower.

Description. Describe carefully, and do the same for each flower hereafter studied when such description is called for. In flowers without petals, having a well-developed calyx, this circle is usually colored like a corolla. What explanation can you give?

Crowfoot family, value. The Crowfoot family contains many showy or favorite garden flowers, as columbines, anemones, peonies, larkspurs, monkshoods, clematis, Christmas rose, and others, and some very valuable medicinal plants, as aconite (monkshood), larkspur, hydrastis, actæa, etc.

7. Polypetalous (Choripetalous) Flowers of the Crowfoot Family

Where found. Polypetalous types of the Crowfoot family such as *buttercups* may always be obtained in quantity for study, and it matters not materially which variety is used. They grow in woods and thickets, open damp places, or on dry open knolls and prairies. Many species of this family, such as the buttercup, cowslip, windflower, anemone, and hepatica, are the most common and highly prized wild flowers of early spring. All are similar and show the chief characteristics of the Crowfoot family in a marked degree.

Characters of family. Chiefly herbs with divided leaves: four or usually five parted flowers (that is, sepals and petals of that number); many stamens; several or many pistils; all parts borne on the receptacle; often apetalous.

Plant and flowers. Examine as usual the whole plant and observe its peculiarities. Are the leaves divided or not? How many sepals and petals and what colors are they? Sepals of buttercups often fall away early (fugacious), and the flower then may appear apetalous. Be careful not to make a mistake here. Study the number and arrangement of the stamens and pistils and observe their relation to the receptacle.

Make the following drawings: (*a*) stem-bearing leaf and flowers; (*b*) a single flower, side and face view; (*c*) a stamen and a pistil (*m*); (*d*) plan of the flower.

List. Name all the garden flowers you know that belong to this family; also some medicines made from plants of the same group.

How many kinds of buttercups or crowfoots do you know? What reputation has the buttercup among eastern dairy farmers? What has happened when a buttercup becomes *double?* What is a "double" flower, and are any ever found in a wild state?

8. Polypetalous Flowers of the Mustard Family

Kinds of and where found. *Shepherd's-purse, spring cress, mustard, candytuft*, or other forms may be used. The spring (white or purple) cresses of moist woodlands and bogs are especially good plants for study, as they may commonly be obtained in large quantities in early spring (April 1–May 15).

Mustard family characters. The Mustard family has these characteristics: (*a*) herbs with spicy juice; (*b*) flowers commonly in racemes; (*c*) four sepals and petals; (*d*) six stamens; (*e*) one pistil; (*f*) in fruit a pod, long or short.

The plant and flowers. Study the plant for its roots, leaves, and inflorescence. Examine the flower and determine the number and color of each group of parts. Compare with characterization given above. Examine in particular the stamens. Are the six all of one pattern, or do you find a difference in size and length?

Are the flowers especially attractive to insects on account of their size, color, or odor, or may these plants depend on wind for pollination?

Draw a flowering branch, a single flower, and the flower plan.

Uses of family. Name a number of garden flowers belonging to this family, and also as many *vegetables* you find that belong here. Taste the leaves, and observe that many plants of the Mustard family abound in a hot, spicy juice. Name some that have this quality.

If you know any market gardens, what per cent of their land area is occupied by vegetables of this family?

If cabbages average 6 in. in diameter, and are 2 ft. apart each way, how many would an acre produce? At 5¢ a head, what would they be worth?

Test a cabbage for its food value. Estimate in particular the amount of water it contains. Are they wholesome or not?

Where is the native home of these Mustard family vegetables? What is the life duration of most of them? Where do they store their excess of food material?

Compare cabbage, turnip, and kohl-rabi seed with mustard. Examine radish seed.

Why does grated horse radish lose in strength in standing? What do radishes bring in "returns" to the producer? How are radishes regarded by the Chinese and Japanese?

9. Polypetalous Flowers of the Rose Family

Kinds and place of growth. Various forms of the *potentillas*, often called "yellow strawberries," or five-fingers *strawberries*, *blackberries*, *raspberries*, and the *wild roses* are obtainable at the season, early June, when this study is contemplated. Observe, in every case, if you gather the flowers, where they flourish most luxuriantly?

Plants and flowers. Observe any peculiarities about the plants, as to habit of growth, stem and leaf, and, in particular, the number of petals, stamens, and pistils, and determine whether the different parts are borne on the receptacle (as in buttercups, which these flowers often resemble) or that some different arrangement exists. What relation exists between the calyx and the ovary? Determine the form of the inflorescence. Make a drawing of an individual flower and flower plan and diagram of the inflorescence.

Plants of this family with use. Examine all possible reference books and make a list of plants cultivated for ornament and for use that belong to the Rose family. The number of "small fruits" furnished by this family is very large, and they are the chief source of the commercial value of the "berry" crop supplied to the great city markets.

Compare wild berries with the cultivated kinds and note the improvements brought about by cultivation.

For the student in the northern part of the United States, there is no more appropriate place to study how new or better fruits are produced than in connection with the fruits of this family. Every pupil whose home has a fruit garden, or even vacant land, is able, if he so desires, to do something along these lines.

Grafting is the common method of improving the varieties of apples, pears, plums, cherries, and other fruits. It is now commonly combined with selected seedling production. The method of operation is: first, to plant large numbers of seeds procured from choice, vigorous, and hardy apples (or other fruit), and when old enough, graft the choice seedlings with the desired varieties, the result being a combination of inherited and acquired qualities. (The method of grafting may be given by the instructor.)

Budding, different in operative procedure, has the same ends obtained by similar methods.

Selection of seedlings is a prolific method of producing new varieties. Many plants, apples, pears, plums, peaches, berries, potatoes, etc., do not reproduce "true" from seed. The seedlings will seldom resemble the parent in all points. Hence by careful selections from great numbers of choice seedlings, fine plants may now and then be found, superior in all particulars. In this manner many fine fruit varieties have originated.

The principles of pruning may be learned by demonstration at the hands of the instructor.

10. Flowers of the Apple Family or Subfamily — Pears, Apples, Crabs, and Hawthorns

The trees. Examine, if possible, the trees as they grow in the orchard or occur wild in woodlands and observe in particular their size and form, also the tendency to thorns that most forms show, more especially wild or seedling varieties. Discover the effect that cultivation has on the thorny condition of the trees, also upon the size and condition of the fruit.

Flowers. Examine a flower cluster. What is the inflorescence? What advantage is there in having several flowers near each other in the same cluster? Look at a flower.

In what ways does it resemble and how does it differ from the flowers of the last exercise? What do you find regarding the odor? In general, what may the odor of flowers mean? With reference to the appearance of the leaves, when do apples bloom? After reading the characteristics of the Rose family, how would you characterize *this* family? (It is often combined with the Rose as one of the subfamilies.) Draw a flower, a flower plan, and a diagram of the inflorescence.

Practical uses. Find the various uses of these trees. What is a quince? How do pears differ from apples in bloom and fruit? What are the chief commercial kinds of apples? Why do apples bloom, as a rule, every other year? Where is the native home of each of these fruits? How are apples kept from one season to another? Recall this family when you study fruits, especially the pome.

Why do hawthorns, as a rule, have such disagreeably scented flowers? Do insects frequent the blooming trees, and if so, what kinds? When do these trees bloom with reference to the high tide of bees, butterflies, and flies? What use has the hawthorn in ornamental planting?

What result would come from grafting an apple on a hawthorn or wild crab? What is meant by "stock" for grafting? How may tender fruits be made more hardy?

Learn the characteristics of the best varieties of apples from the actual specimens?

What is evaporated fruit? What is cider? Peaches, pears, etc. are canned. Why not apples?

How long is required for apples to bear fruit from the seed? What returns do apples and kindred fruits give to the grower? Where are the most important apple growing regions of the United States?

11. Flowers of the Prune Family or Subfamily — Plums, Peaches, Apricots, and Cherries (Stone Fruits)

The trees. Which of these trees have you seen growing? How can you tell the fruits from each other? What two main forms of inflorescence have cherries? When with reference to the leaf appearance do cherries and plums bloom? What general name is applied to these fruits? What kinds are wild in the United States and in your own vicinity?

Flowers. Examine the flowers in the same manner that you did the apple. How do these flowers differ from apple flowers and also from other flowers of the Rose family? (They are commonly grouped, along with apples, etc., in that family.) Make drawings as in the last exercise.

Characterize the family by comparison with the characteristics of the Rose and the Pear families.

Uses. What uses have these trees and shrubs? Why are peach and cherry pits unwholesome? How are cherries regarded by the Japanese? How does an almond differ from a peach? Make a list of all the fruits furnished by this family which are useful to man. What are prunes? What are prunelles? Discover the use of the wood of the different kinds.

What has Mr. Burbank done to improve the fruits of this family?

Where are the peach, prune, apricot, and cherry growing centers in the United States?

Which require more room, cherry or apple trees?

Diseases. Apples, and in fact all the fruits named in this lesson and the last, are subject to many insect and fungous diseases. What damage is caused? What means are successful in preventing these troubles? What are some of the principles of "spraying"? Why ought spraying to be practiced by every one owning a fruit garden or orchard?

12. Flowers of the Pea Family (Irregular Polypetalous Forms) — Peas, Clovers, Sweet Clovers, Lupines, Locusts

General statement. The Pea family is an immense one (7000 species), and many kinds may be found in your vicinity, but only a few bloom before the middle of June. Read the family characterization and keep it in mind while studying the flowers obtainable.

Flowers. Observe the form of the inflorescence and the size, color, and odor of the flowers. Examine the flower parts for number and for relationship to each other and to the receptacle. In particular, compare the petals to each other as to shape. What do you find? Flowers in which the parts of the same whorl are unlike in shape are *irregular.* Observe that all the kinds you have access to are similar in general form to a pea flower. The different parts have received special names. The large upper petal is the *banner*, the side petals are *wings*, and the two united lower petals are the *keel.*

Carefully examine the stamens, count them, and find out how they are connected to each other.

Look up the terms *monadelphous* and *diadelphous.* Where are the stamens situated? Look for the pistil. How is it related to the stamens? Are *anthers* and *stigma* in such relative position as to permit pollen to pass readily to the stigma? In fruit, what does the pistil become?

Carefully draw plan of inflorescence and of a single flower, also side and face views of flower and each kind of petal, enlarged.

Pollination. Flowers constructed according to the pea type are especially adapted to *pollination* by *insects.* The color, odor, and inflorescence, as well as the peculiar shape of the flower and the relation of all its parts, adapt these flowers for such a method.

Field observation. If possible, examine blooming clover-plants for insect visitors, and observe how they proceed in order to obtain the *nectar*. Remove the flowers from a fresh red-clover head and draw out the nectar by suction. Compare the bees that frequent the red and white clovers. Are they the same kinds? Recall that the *irregular* flowers of the orchid were also special contrivances for securing insect pollination. What would you infer about irregular flowers in general?

Table. Make a table of flowers of the Pea family which you are able to find from any sources, using the following form: —

Name	Inflorescence	Flower Color	Flower Size	Where Native	Use

Value as soil restorer. The Pea family (*Leguminosæ* is the technical name) is a remarkable one in many ways, but in no way more so than in the peculiar *symbiotic* relation that all members have with nitrogen-fixing bacteria. (See Bacteria study.)

If in season, pull or rather dig up a red clover, sweet clover, alfalfa, or white clover; wash all the dirt from the roots and examine the numerous tubercles caused by the bacteria. A chemical test will show a large amount of nitrogen in these swellings.

Nitrogen is a powerful plant tonic, producing great activity in purely vegetative (growth) work. The soil may obtain this plant food in four ways: —

1. Naturally, by small amounts of atmospheric nitrogen combining in the ground with bases to produce nitrates.

2. Naturally, by the decay of nitrogen-fixing bacteria nodules; often introduced artificially by sowing clover, alfalfa, cowpeas, soy beans, etc.

3. Artificially, by animal waste, as manures.

4. Artificially, by the introduction of nitrate of soda as a commercial fertilizer.

Of these methods the best is by the growth of the legume plants and eventual plowing under. This adds to the soil the nitrogen of the bacteria nodules and *humus* from the decaying plants.

A test that could be easily carried out, if the pupil has land to experiment with, is to take four plots of equal size, side by side, numbered 1, 2, 3, 4.

1	2	3	4

Spade them all, and in July sow on No. 4 crimson clover. Cover No. 3 with ordinary stable manure about Oct. 1. Do not touch 1 and 2. The following spring spade all the plots and plant to some one crop, as sweet corn, beets, or cabbage. Sow carefully and evenly over No. 2 *nitrate of soda* and powdered earth mixed (at the rate of 100 pounds of nitrate to the acre.) Put nothing on No. 1. Compare the harvest on each plot for early maturity, quantity, and quality.

13. Flowers of the Violet Family (Irregular) — Violets and Pansies

Plants and place of growth. Plants ought to be obtained in flower and also when the fruit is well advanced. For flower study any species will do, but for the *cleistogamous* flowers the common blue violets are particularly suitable. They abound in open and moist woodlands.

In many violets all the leaves arise from the short underground stem (radical). Other violets are said to be stemmed; that is, have stems above ground, bearing leaves. In both forms the flowers are on slender peduncles. How many are there to each peduncle?

Flowers. Examine a single flower. Is it regular or not? What is the sepal and the petal number? What is the common petal color? Examine carefully the lowermost petal and find a *spur* at its base. After drawing side and face views of the flower, remove the petals and count the stamens. What is peculiar about all the anthers and the filaments of the two lowermost?

Study the pistil. Draw the flower, flower plan and one of the lowermost stamens.

Examine a plant bearing *cleistogamous* flowers, *i.e.* flowers lacking petals, commonly subterranean. Determine the flower parts and notice the color. Compare the seed number in the *capsules* produced by each kind of flower. What kinds of pollination has the violet?

Some related questions. How do you explain the remarkable variety of color in pansies?

Some other plants have cleistogamous flowers. What explanation can you give for the two methods of reproduction? What seems to be the purpose of the spur in flowers? Recall other flowers with spurs.

14. Flowers of the Highest Polypetalæ. The Carrot Family (Parsley) — Meadow Parsnip, Sweet Cicely, Caraway

The plants. Plants of the Carrot family are common, but only a few bloom early in the season. The characteristics of the family are marked and ought to be easily discovered. Many of the species are poisonous.

Observe the characteristic inflorescence, also the almost universal presence of divided leaves.

Flowers. Are the *umbels* simple or compound?

Observe the presence or absence of small bracts at the base of the primary or secondary rays of umbel. Which flowers of the umbel mature the earliest? Study the individual flower and observe the insignificant calyx and the small petals of the corolla. How many petals are there and what peculiarity of form do they have?

Look at the stamens. How do they correspond in number with the petals? How can the discrepancy be explained? What evidence do you notice for any special form of pollination?

If any fruits are formed, crush, and discover whether any odor is apparent or not.

Draw a diagram of the inflorescence, a single flower (*m*), and the flower plan.

Uses. Look up the uses of plants of this family. What vegetables are found here? What are caraway, dill, anise, and coriander? Why is a wild parsnip poisonous and the garden form harmless? Why will frost kill our garden carrot and yet not hurt the wild carrot (the same species)? How did this plant ever become a weed, or was the vegetable produced from the weed form? Which is the reasonable theory?

Test carrots, parsnips, celery, and celeriac for food value.

15. Shrubs and Trees of the Dogwood Family — Dogwoods (Cornel Species)

Plant habit and habitat. These are common shrubs and small trees of woodland, thicket, and swamp. If you are able to study them as they grow, do so and observe any peculiar feature of form and foliage, and also of bark color. Taste the bark.

The inflorescence is one of the type forms. What is it? What is the size of the separate flowers? (Some kinds have the flowers in *heads*, surrounded by *large colored bracts*, often mistaken for the flower.)

Flower. Study the flower parts. What do you observe about the sepals? How are the petals arranged in the bud? Can you think of any advantages to the plant in having so many small flowers clustered? Make drawings showing a diagram of inflorescence, a flower, and flower plan.

Use. Read about the Black Gum tree or Tupelo; also find out what you can about "Kinnikinik" also the use of these trees as ornamental forms for parks and lawns. What particular value have the Siberian and the native red dogwood as ornamental trees? If possible, look carefully at the common flowering dogwood flower, with its large white or pink bracts looking like petals (petaloid bracts). The true flowers are insignificant. What possible advantage is such a scheme? What use has the wood of this tree?

16. Flowers, with United Petals (Gamopetalous, Sympetalous) of the Primrose Family — the Shooting Star

The plant habitat. This plant is very common in prairie regions, often almost completely taking possession of the ground. In many places it is found on the grassy "brows" of bluffs and cliffs. Study it in its place of growth, if convenient.

What leaf arrangement has this plant? What is the inflorescence? What name do you apply to the common flower stalk? What position have the flowers? What position have the buds?

Flower. Examine flowers as to color, form, and parts.

How many divisions on each whorl? Observe carefully the corolla. How are the petals related to each other? Flowers of this character with the petals more or less in one piece are *gamopetalous* or *sympetalous*. In what direction do the petals point? Look at the stamens. Upon what are they borne? What positions do they occupy with reference to the petal lobes?

Draw a diagram of the inflorescence and the flower plan and a side view of the flower.

Read in reference books the subject, "Primrose," particularly the English forms. What are cowslips?

Prairies. What are prairies? How is their presence explained? What part of the United States is largely prairie? Why did the Indian and the old settler burn the prairie? When was it done, and what effect had this on plant life? Why do prairie flowers differ so markedly from woodland species. If possible, compare the wood phlox and the prairie phlox, or compare other related species of the two localities or environments. What is meant by the latter term?

17. The Peculiar, Highly Specialized Flowers of the Milkweed Family — Milkweed (Asclepias)

Forms. The true milkweeds form a large group of plants having very characteristic features, but most of the species bloom too late to permit them to be in condition for school study. There are a number of June-flowering forms, however, and the genus has such remarkable specialization for insect pollination that an examination of the flowers will be amply repaid. The instructor may have to explain the complicated pollination mechanism, as the flower is very difficult for the student to master.

The plant. Examine the plant and observe the character and arrangement of the leaves. Observe the peculiar sap (*latex*). What is its color and consistency? Touch the tongue to the sap. What is the taste? Of what special use may this latex be? What is the inflorescence?

Flower. Study a single flower. What is the number and color of the sepals and petals? Test the flower for odor. Is it pleasant? Within the petals and attached to them notice a *corona* of five concave *hoods*, each bearing within a *curved horn*. Observe the stamens and determine their number and place of origin and the short filaments and anthers. How are these related to each other and to the stigma? Notice a peculiar inflexed membranous tip to each anther. Seek carefully for the *pollen masses* and observe, if possible, the peculiarity of their attachment.

Draw a flower plan, a flower, and details of the corona and stamens.

Action toward insects. In your reference books read about the relation of these plants and bees. Notice in summer the charm the common milkweed flowers have for butterflies. What attracts them? What do you find, occasionally, has happened to insects? May the flower be said to have become too highly specialized when it catches insects?

Latex. Make a list of all the plants you know that have milky sap or latex.

Collect a lot of milkweed "sap," heat it slowly and carefully over a smoky fire. What happens? Put your heated product aside to cool. Examine and test for odor, color, consistency, and toughness or elastic qualities.

What plants furnish rubber? How is it prepared? Why is it valuable? Burn a piece and observe all the phenomena. Put a small piece of pure soft rubber into a vial of chloroform. What happens? Try another piece in bisulphide of carbon. (Keep both away from flame.)

Make some scars in the fruit capsules of the large garden poppies. Observe the latex and allow it to dry. What color has it? What have you produced? (Read about opium.)

Find out some facts about "spurges," a great family of plants with milky latex.

18. The Salver Form of Gamopetalous Flowers of the Phlox Species (Polemonium Family)

The plants. Common and showy plants of many life habits. Study them as they grow if you are able. What common name is applied to many forms?

Flower. Examine a flowering branch for the character and arrangement of the leaves and the form of the inflorescence. Study a single flower. What do you observe about the calyx and the peculiar form of the corolla? Such a form is said to be *salver form.* The long slender base is the *corolla tube*, and the lobed, expanded part of the flower is the *limb.* Is the flower with petals separate or united? Is there any evidence of odor? Do all the flowers of a corymb open at once or are there some buds and blossoms? Seek for the stamens. Where are they borne and how many are there? Where are the anthers with reference to the stigma? Examine the pistil. Is the ovary superior or inferior? How many styles are there?

Draw a flower on its peduncle to show both calyx and corolla. Make a drawing showing position of stamens. Draw a flower plan. Draw a pistil.

Pollination, etc. What scheme of pollination does the phlox have? Of what importance is the genus as a garden flower? What does "phlox" mean?

Flowers with long tubes. Name as many flowers as you know with long corolla tubes. What insects visit such flowers? What mouth parts would be necessary with such forms? Correlate the sucking tongue of a butterfly, inserted into the tube, with the position of anther and stigma.

19. The Lipped or Labiate Flowers of the Mint Family — Ground Ivy

The plants. The Mint family is one of the most natural plant groups to be found in the temperate portion of the United States. Square stems, odorous leaves, and two-lipped flowers are special features that are very conspicuous, and the student may easily familiarize himself with these prominent characteristics. Nearly all species are late in blooming, and about the only one obtainable in June will be the plant named above. The student may commonly see it growing in deep shade about dwellings, and so learn of its appearance and habits.

Examine the whole flowering stem. What peculiarity of the stem is apparent? How are the leaves arranged? Smell the leaves before and after rubbing them gently. What do you observe?

Flowers. How are the flowers situated? What is their size, color, and peculiar form? In particular, what special features has the corolla? How many petals are there? Flowers of this form are *labiate*, or *lipped*. Look for the stamens. Where do you find them and how many are there? What color have the anthers and what is the situation of these structures with reference to the stigma? Do stigma and anther seem equally mature? Examine the ovary (*m*). What do you find?

Draw, as usual, the flower features. Draw also a flowering stem.

Uses of mints. Make a table of useful and ornamental plants belonging to this family. There are 3000 kinds. What are the mints of commerce? How is peppermint made? (See leaf, Applied Work.)

What are essential oils? Make a list of them, and observe the number furnished by this family. Read about "menthol" in your reference books.

20. The Labiate or Irregular Flowers of the Figwort Family — Figwort

The plants. The Figwort family produces few early flowers, but it happens that the type genus, figwort, blooms in time for study.

Observe the great resemblance of some of the stem and leaf characters to those found in the mint family. Rub the leaves, as in the ground ivy. What result do you have? What is the inflorescence?

Flowers. Examine the separate flowers and observe the odd form and arrangement of sepals and petals. What is the color of each? Find the number and place of attachment of the stamens.

Compare the flower, with its form and parts, with that of the ground ivy.

Examine the pistil. How do its parts differ from those of the ground ivy? How does the number of ovules differ?

Draw inflorescence and flower plan and flower, side view and laid open to show stamens.

What plan, if any, has the flower for pollination? Do all the flowers mature at the same time? Do bees frequent the plant?

Make a list of useful plants belonging to this family; in particular, foxglove, musk plant, mullein. Find some value for each one on your list.

21. Parasitic Plant Demonstration

Forms obtainable. It is possible in most places, either early or late in the season, to procure examples of *broom rape*, *squawroot*, *beechdrops*, *Indian pipe*, or *dodders*. All are equally good to show the profound modifications caused by parasitism.

The plant features. Compare the color of the plant under consideration with ordinary green plants. Examine or learn the place of growth of the plant and explain the peculiarities of color you observe. Upon what food does the plant live and from what source is the food obtained? How do the plants obtain such places in which to grow? What advantage, if any, to the plant, is this parasitic habit?

Examine, if at hand, the inflorescence and flower, and make such notes and drawings as are necessary to show the results of your observation. In particular observe the number and size of the seeds. What evidence, if any, of special pollination schemes?

Table. Make a table of a number of plant parasites of the seed plant group, using the following form: —

Name of Plant	Family of Plant	Where Found	Peculiarities

22. Honeysuckles or Viburnums [1]

Forms. A number of the wild species, notably the smooth red-flowered honeysuckle, and the cultivated bush forms are suitable and easy of access.

If the species studied is one of the climbing forms, examine the method of climbing and the structure of the stem. Observe also the leaf arrangement and any other peculiarities of these organs.

Flowers. Examine the inflorescence. What type is shown? Examine the calyx and find its relation to the ovary. What form has the corolla? Study this structure for color, size, number of lobes or petals, and the arrangement of the latter into regular or irregular flower.

[1] The highest in the rank of flowers except the composites.

What is the shape of the tube? (The viburnums hardly ever have tubes.) Is there any odor or brilliant appearance to attract insects? Look for the stamens. How many are there and where are they borne? Examine the pistil for its parts. Examine the relative position and maturity of the anthers and stigma for pollination devices.

Draw a spray, showing leaves and flowers; also a single flower. Draw a flower plan.

Determine some of the ornamental or useful plants belonging to the honeysuckle family. Why does this family have this name?

Rank in flowers. The more of the following characters any flower possesses the higher in rank it is considered to be: —

1. Ovary inferior.
2. Irregular corolla.
3. Gamopetalous.
4. Various modifications of stamen and pistil to insure insect pollination.
5. Complex inflorescence.

23. The Composite Family (Aster Tribe)

The largest (15,000 species), highest rank, and most difficult for the student to understand. Not many species bloom before June; the dandelion, fleabane, and ragwort being exceptions.

FLEABANES OR RAGWORTS. TUBULAR FLOWERED FORMS

General statement. The "head." Flowers of this family are really a collection of small flowers of fewer or greater numbers, borne on a large receptacle, and inclosed at their outer margin by few or many small greenish or otherwise colored *bracts* forming an *involucre*. The small individual flowers are of one or two kinds: the central tubular forms called *disk flowers*, and flattened marginal forms called *ray flowers*. The latter may be absent (as in thistles) or all the flowers may be flat in form (as in the dandelion). For proper study a lens is a necessity. The collection of flowers surrounded by the involucre is called a "head."

Study the head for size and color of each of the above parts, observing the difference, if any, in color of disk and ray. Determine the number of ray and disk flowers, at least approximately. Look at the bracts of the involucre, and observe the form, number, and arrangement. The student is very apt to consider the involucre a calyx and so designate it. Be careful about this.

The individual disk and ray flowers. Study each form carefully (*m*), particularly the disk flowers. On the latter, find a tiny seedlike *ovary* below, a cluster of fine hairs (*pappus calyx*) just above, and above the latter a tube ending in five teeth (petals). Projecting from the tube is a forked style, closely invested by five anthers.

Drawings. Make the following drawings: side and face views of the compound flower, a single ray and a single disk flower (*m*), and a plan of the compound flower.

Problems. Why are the flowers of this family so numerous in species and individuals? What common devices for pollination have been perfected? For seed distribution? Why is this family considered the highest in the plant scale? (See No. 22.)

Useful applications. Make a table of useful and ornamental plants belonging to the tubular forms of the family, using the form given below as a guide.

Plants for Food with Edible				Plants for Ornament	Plants for Medicine
Roots	Leaves	Stems	Flowers		

24. The Composite Family (Chicory Tribe) — The Dandelion. Flowers all Flat or Strap Form

Statement. The dandelion, owing to its size and extreme abundance, is a flower much more satisfactory to study than the fleabane or ragwort, but, as it shows a different type of head, does not give, alone, a complete idea of the composite types. The dandelion as it grows ought to receive attention. The soil in which it flourishes, its love of sunlight, and its season of bloom are also to be considered. Their great numbers ought to be carefully explained, if you can discover any good reasons.

The head. Examine the *compound flower* and observe the size, color, and appearance, and the arrangement of the involucral bracts. How does the latter feature vary in bud, full bloom, and fruit? Compare the height above the ground of the flower, and the downy head of fruit, succeeding, and explain.

The flower. Study a single flower and observe the inferior, single-seeded ovary, bearing at its summit the hair-like calyx and the flattened corolla. Look at the hairs (*pappus*) (*m*), and observe length and general appearance. Examine the corolla. What are the features of the tube and the limb? How many petals are united to form the corolla? Look at the projecting tube of anthers inclosing the top of the pistil. How many stamens are there and upon what are they borne? Examine the pollen (*m*) for quantity and for form (*hp*). Dissect out the pistil and find all its parts.

Drawings. Make a drawing of the side view of the compound flower, of a single flower, a complete pistil, and some pollen grains.

Problems. What method of pollination has the dandelion? What method of seed distribution? Where are dandelions found? Explain their wide distribution.

Table. Make a table of plants belonging to this tribe, using the following form: —

Name	Native Home	Part Used	For what Used

25. Some Practical Applications of Flowers

1. The *production of honey.* Examine such flowers as white and sweet clovers, heartsease, buckwheat, basswood, and other plants from the nectar of which the bees make honey. Examine, if possible, honey made from any of them. What is honey?

2. The *production of perfumes.* Take any very fragrant flower, as certain roses, collect a quantity of perfectly fresh ones in a clean jar, suspend a small fine sponge saturated with pure olive oil, and close tightly. Press out the oil after twenty-four hours and observe its odor. Try other methods, as saturation with alcohol and heating gently to drive it off, through a tube leading into weak alcohol, or pure oil. Test for odor. The results will be imperfect, but you can make a perfume. Find out what flowers are used in large amounts for this industry.

3. The *production of drugs.* Cover English marigold (*calendula*), chamomile, or dry arnica flowers with 70% alcohol, and allow to remain for a week. Observe the change in color and odor, also taste of the alcohol. You are making drugs in a crude way.

4. Quickly dry rose petals, violets, or other fragrant flowers and observe qualities of the dried products.

5. Gently cook violets in sugar syrup until thoroughly saturated; strain and dry. You have a candied flower.

6. Buy a little crocus saffron, and extract color with dilute alcohol. Some flowers are used for dyes.

7. Cut flowers. Examine a number of florists' show windows, and make a list of the flowers most commonly

exhibited for sale. Obtain their prices and make a table of results.

SECTION VII. STUDY OF FRUITS (VARIOUS FRUITS)

General statement. The various fruits in the Fall Fruits Exercise are to be referred to, but the exercises here given take up the subject more specifically and with greater detail. The fruit definition should be ever before the student, *viz.*: A seed-plant structure, consisting of the ripened ovary alone or with its attached or adjacent flower parts, the purpose of the whole being, first, protection to the seed, and finally seed dissemination. Many fruits also furnish food for the successful seed growth.

Types. There are many types, each characterized by the possession of certain peculiarities of size, form, and structure, but all are separated into *dry* and *fleshy* (or *pulpy*) *fruits*, according to the amount of fluid they contain when *ripe*. Fruits again may open spontaneously (are *dehiscent*) by *valves* or *pores*, discharging the seed, or the latter may only escape by the decay of the fruit (*indehiscent*).

The following types are named with a common example of each. Each of these examples should be carefully studied externally and in section and a set of characteristics formulated.

Drawings should be made to show the result of the study.

	Examples
1. The *grain*.	maize, oats.
2. The akene.	sunflower.
3. The samara.	maple, ash.
4. The nut.	acorn, hazel.
5. The dry drupes.	walnut, hickory.
6. The pod.	bean, pea.
7. The capsule.	figwort.
8. The cone.	pine.
9. The drupe.	cherry, apricot.

10. The berry.	gooseberry, grape, tomato.
11. The hesperidium.	orange, lemon (a modified berry).
12. The pome.	apple.
13. The pepo.	cucumber.
14. The aggregate fruit.	blackberry.
15. The confluent fruit.	pineapple.
16. The accessory.	strawberry.

If time permits, study other fruits and refer them to the proper type. Make necessary drawings.

In each fruit seek to determine the particular scheme adopted on the part of the plant for seed scattering and the external agent that combines with the plant to produce the desired result.

Fruit table. Make a table of fruits as follows: —

Common Name	Fruit Name	Where Native	Juicy or Dry	Dehiscent or Not	Seed-scattering Scheme of Fruit	External Agent in	Use

Uses of fruits. Numberless experiments may be performed by the student under the direction of the teacher obtaining from fruits some of the following useful products: —

1. Evaporated apples.
2. Prunes.
3. Raisins.
4. Dried.
5. Candied.
6. Canned.
7. Jellies.
8. Juices.
9. Ciders.
10. Vinegars.
11. Sugars.
12. Oils.
13. Starches.
14. Rinds.
15. Wines.
16. Alcohols.
17. Perfumes.
18. Proteids.
19. Flavors.
20. Medicines.
21. Relishes.
22. Foods.
23. Drinks.
24. Fibers.
25. Illuminants.
26. Miscellaneous.

PART II

OPTIONAL PRELIMINARY STUDIES

SECTION I. SUGGESTIONS

Order of study. When you examine any object in the laboratory, the proper method of procedure is as follows: —

1. Discover all you can about it with the unaided eye.

2. When small, use a hand lens or magnifying glass. The sign (*m*) in this book refers to such an instrument.

3. If the object is very small, the compound microscope may be required. The signs (*lp*) and (*hp*) refer to low and high powers of this instrument. The parts and use of a compound microscope ought to be familiarized by reference to charts or books furnished by instrument makers.

4. After a thorough study of the object, drawings are to be made showing all that you have discovered.

5. Finally, complete notes, descriptions, or other written work are to be made, showing all that you have discovered. These are to be preserved in connection with the drawings.

Tools for work. The instruments named in Order of Study together with certain others, as the projection lantern and the opaque projector, will enable you to see the object. To assist in handling the object other tools are sometimes used, as needles, scissors, forceps, scalpels, and, at times, apparatus of different kinds.

The projecting lantern, which throws upon the screen images from the lantern or microscope slides, is a very important laboratory help, supplementing the compound microscope, and is often used in well-equipped laboratories. The advantage derived is often very great, saving time and labor, and insuring that all pupils *see* just the important features of structure most essential to a proper understanding of the subject.

Character of work. All drawings ought to be made with well-sharpened and medium-hard pencils, or, preferably, with a fine pen and India ink; the outline should be *clear, distinct*, and *accurate*; every important feature should be properly and neatly labeled; and all written work ought to be in good black ink. In everything the standard should be *accuracy, completeness*, and *neat appearance*.

Preliminary work. Study the compound microscope by the aid of the book furnished. Examine permanent preparations given to you, and make sketches to show each as it appears under the microscope. The preparations may be mounted letters, plant cells of various kinds, fibers of other materials. The object of this work is to familiarize you with the use of the compound microscope, and to practically apply what you have learned.

SECTION II. FALL FLOWERS

(Introductory Work)

1. The Nasturtium or Other Simple Flower

Various species of plants, preferably simple forms, as Bouncing Bet, geranium, or nasturtium, may be used for this study. The nasturtium is particularly good, because of its abundance and the large size of its parts. The entire plant ought to be used.

Place of growth. In the study of a particular plant the first step is to observe its place of growth and the character of the soil; that is, whether it is wild or cultivated, whether the locality is wet or dry, and finally, whether the soil is sandy, clayey, black and loamy, or has other peculiarities. This peculiar place of growth is the *habitat* and is the first subject to be investigated in the study of any plant, as it has much influence on form and structure.

Associations. If flowers are wild, they may grow in little communities by themselves, or they may be more or less intermixed with plants of other kinds. These pure or mixed collections of plants, growing in a given habitat, are called *associations*.

The plant body. Observe the peculiarities of the plant form and growth: habit, unbranched or branched, low or tall; leafiness varying in degree; dry and harsh with scurf, down, hair or bristles, or smooth; color of various shades of green, yellow, brown, or red; the size, form, and division of the root.

The leaf. Observe the size, form, and color of the expanded blade, the degree of division, and the arrangement on the stem. Crush the leaf to discover if there is any odor. Examine carefully with the lens to see whether the surface is smooth or is covered with projections (scurf, hair, or bristles); observe the method of attachment of the blade to the stem by means of a longer or shorter stalk, or directly, without this structure.

Inflorescence. Observe the inflorescence or flower bearing; *i.e.* flowers borne singly or in clusters of various size and shape (each cluster having a special name). Diagrams will enable you to decide which form your plant possesses. These may be drawn by the instructor.

In position the inflorescence is terminal, on stem or branch, thus halting further growth for that year, or it is axillary and does not so affect the plant. Observe the relation between the size of the flower and the size and kind of inflorescence. What forms would favor large flowers?

The flower. (The flower is treated of in detail and relationship in Part I.) Observe the form, size, color, odor, and number; beginning below, or on the outside of a flower, note the different series of parts, each bearing a technical name: (*a*) sepal, (*b*) petal, (*c*) stamen, (*d*) pistil; observe also the difference in form and color between the members of the various series.

Drawings to be made. 1. The whole plant, if small, or a leafy branch, if large.

2. A single leaf, showing all its parts.
3. Diagram of the inflorescence.
4. Side and face views of a flower, natural size or (*m*).
5. Other details as may be called for.

Table of flowers. Make a table of all flowers obtainable at time of study, using form here given.

Name	Where Growing	Inflo-rescence	Color	Size	Use, if Any

2. The Compositæ, or Complex Flowers

General statement. A complete flower study is taken up as a part of the work of the Study of Seed Plants, but it is advisable for the student to become somewhat familiar with the more characteristic flowers of the fall. By far the larger majority of these flowers belong to a great family of plants called the Compositæ, which is the largest of all the plant families, containing some 15,000 species.

What is called a flower really consists of many small flowers of one or of two forms collected together in a *head*, which is surrounded at its base by a number of small, usually green structures (*bracts*) forming an *involucre*.

One of the two forms mentioned above is flat and elongated, colored, often brightly, and narrowed at its base into a white, or otherwise colored part, which usually bears scales, bristles, or fine hairs above, and a single seed below. This form of flower may compose the whole head, but more generally it is arranged around the outside of the head in fewer or larger numbers. From their position these flowers are called *rays* or *ray flowers*. Why is such a name appropriate?

The second form is a tubular, more or less elongated structure, usually five-toothed at its upper end, and bearing below, the structures named in the first form. From its position those flowers are called *disk flowers*, and the whole number combined is called the *disk*. Why are these terms used?

Projecting from the top of the disk flower, or from near the middle of the ray flower, are forked structures, commonly tightly inclosed in a yellowish enlarged part or sheath. These two structures are the reproductive bodies (pistil and stamens) of the flower, and they are considered in detail in another place.

The special flower. Study carefully the particular plant, provided that it bears one or more heads of flowers. Learn all that you can about the flower in its place of growth, whether in a shady or open place, in water or swamp, ordinary dry land or in very dry places, as sand or rock. These several situations give rise to three diverse plant associations: the water-plants (Hydrophytes), ordinary plants (Mesophytes), and very dry land plants (Xerophytes). Observe also whether the plants grow singly or grouped together in numbers.

Compare the flower carefully with the statements made above and determine the particular feature of the flower head.

Drawings. Sketch, natural size, the head, face, and side views, and name all the parts.

Sketch a ray and a disk flower (*m*), one or both, according to the flower.

Sketch a bract of the involucre (*m*).

Description. Describe carefully, noting the size, color, odor, parts, and arrangement on the flower stem; note also the character of the leaves, their number and arrangement. If present, observe and describe the root.

Table. Make a table for comparison of Compositæ flowers studied, using this form: —

Name of Flower	Color of Parts	Rays	Disk	Involucre	Other Features
1.					

Questions. 1. How do composite flowers compare with other flowers in number of individuals? How do you explain?

2. Why are so many of the composite flowers of the summer and autumn yellow in color? (45 out of 100 kinds are yellow.)

3. Why do red and yellow flowers, as a rule, have no fragrance, or at least very little?

4. Why are asters and goldenrods such hardy plants? (Hint: Are they dry and harsh, or soft and full of moisture?)

5. Why are there so many dandelions?

6. Why, on an average, is there one composite flower for every nine of all other kinds combined?

(Study their fruits to help you in answering this question.)

Additional work. 1. Make a table showing the uses of composites, preparing your tablet paper thus: —

Name	Where Found	Part Used	Use	Remarks
Arnica	Europe	Flowers	Medicinal	Liniment for sprains

2. Make a table of wild and cultivated composites thus: —

Name	Color of Flower	Cultivated or Not	Number and Sizes of Seed	Kind of Dispersal

3. A Study of Common Weeds

Statement. Weeds have such a vast influence on the welfare of the farmer, and so indirectly on the people in general, that a knowlege of the more important forms is very desirable; moreover, weeds are so common and show in a marked way so many truths of botanical science that a couple of weeks spent in their study is time well spent.

Collection for study. Bring into the laboratory samples of the common weeds of your neighborhood, and study each to learn its name, characteristics of growth and foliage, root system, number, size, and method of the distribution of the seeds.

When gathering weeds, observe the abundance of each form, place of growth, soil, and presence or absence of damaged foliage (by stock, insects, or other animals).

Successful weeds. Observation has shown that successful plants possess one or more of the following points; compare your weeds with the headings in this list: —

(*a*) Can grow in any soil or very poor soil.*
(*b*) Produces great numbers of seeds.*
(*c*) Special methods of seed or fruit dispersal.*
(*d*) Deep fleshy *taproots*, or,
(*e*) Very many fibrous roots.
(*f*) *Biennials* (living two years).
(*g*) *Annuals* (living one season).*

(*h*) *Perennial* (living three or more seasons).*

(*i*) Few or no animal enemies.*

(*j*) Strong odor or taste.*

(*k*) Harsh or dry in nature of foliage.*

(*l*) Not beautiful or strikingly pleasing.*

(*m*) Seeds hard, and these or the fruits attractive to birds.*

(*n*) Not native to this country.*

(*o*) Native.

The characteristics that are starred are particularly favorable (from the standpoint of the very successful weed).

Definition. From all your observation and study try to express in words a good definition for "a weed."

Table. Make a table of all the weeds you are able to find in the vicinity of your home, using the following form: —

Name	Family	Where Native	Where Growing	Seed Features	Injurious or Not	Use

Field work. 1. In any vacant lot near your home, measure off carefully a square plot of ground of some definite size, five or more feet on each side, that contains a large number of weeds. On a large scale, make a map of the plot, stating the kind of soil, amount of moisture, and shade.

2. Now carefully determine the number and location of each variety of weeds, showing by dots, circles, and other means each different kind; if possible, representing each plant by a mark.

3. By consultation with the teacher determine the name of each kind. Carefully press and mount on your tablet paper, leaf and fruit of each species, or make careful drawings of the same.

4. Try to determine by reference to Successful Weeds what features are found in the more abundant weeds. Seek in this way to find out some, at least, of the reasons for their success, recording your conclusions on the page opposite your map.

Reading. Read in the Government Bulletins how weeds damage the crops, and note what is said of the loss caused by them. (Government Bulletins are to be had free for the asking.)

SECTION III. A STUDY OF FALL FRUITS

Statement. Various burs, preferably the burdock and cocklebur; downy fruits as the thistle and dandelion; winged fruit as the ash, hop tree, or maple; capsules, as the evening primrose, Jimson weed, or others are easily obtainable for purpose of studying fruit and seed dispersal.

The burs. 1. Examine carefully the bur with the naked eye and lens. Observe the general shape and number, size and particular form of the structures that make the fruit a bur.

2. Compare the burs furnished by experimenting on your clothing and find the form that clings most closely. Discover the reason, if possible, in the nature of the bur covering.

3. Count the seeds in each bur studied. Observe, if possible, plants of the same kind growing in vacant lots. Count the number of fruit heads in a good-sized plant, and from these facts estimate the total seed production. (See lesson on Weeds.)

4. Bur plants are very often "weeds." From your observations and what you have previously learned about weeds, how do bur plants fill the requirements of a "good weed"?

5. Record, from observation or reading, various agents that carry burs from place to place. What advantage to the plant is this dispersal of the bur?

6. What enemies, if any, do these burs have? (You may find the fruits with the larvae of insects in them.)

7. How long does it take each bur plant to mature from the seed?

8. Draw each bur, natural size, and the hooks or structures that cling to animals.

The downs. 1. Examine carefully a thistle or other downy structure. Is it the whole fruit or the single seed that bears the down?

2. Observe carefully the number and size of the hairy structures that make the down, also whether they are straight or wavy.

3. Observe in particular where the down is attached to the seed. Why is the attachment generally above the seed?

4. Float a specimen in the air and observe the rapidity of "settling down" to the floor. Blow on the down. Does this action hasten or retard the process of sinking? How would the wind act on the down? What connection do you see between these observed facts and the general distribution of thistles and dandelions?

5. Recall, if possible, the "cotton" seen on June days, where cottonwood trees grow in the neighborhood. Make a list of as many downy fruits as you are acquainted with.

6. Examine the down with (*lp*) and observe the features. Explain, if you find anything worthy of record.

7. Make drawings of complete fruits or seeds, natural size; also of one or more hairs, (*m*) or (*lp*).

8. Describe clearly and accurately each down studied.

9. By reading, discover if any downs are of value to man.

10. Explain, if you can, the results found in the following "living problem" taken from the "prickly lettuce," a "downy" weed introduced from Europe.

(*a*) A square rod of waste ground had 20 large plants of lettuce.

(*b*) Each plant averaged 10,000 seeds.

(*c*) The second year the plot had no more plants than it had the year before.

(*d*) Why was there such an enormous seed production? and

(*e*) Why are there not more plants on the original plot?

NOTE. The Compositæ is the largest family of plants, and, as a rule, the most abundantly represented by species in any locality. The individuals also are numerous. Now, as one half of Compositæ fruits are down-bearing, what influence would this have on the abundance and general distribution? (See study of Compositæ flowers.)

Other fruits. 1. Study the *winged fruits* of ash, maple, hop tree, or Ailanthus, and the *winged seeds* of pine, spruce, catalpa, or birch. Observe the size, form, and adaptation of each sort for dispersal by wind. Make drawings to illustrate the results of your observations.

2. Examine the *dry fruits* of the evening primrose, Jimson weed, poppy, or others of similar nature. How are the seeds distributed? In these fruits what do you discover about the size of the seed? Are the seeds few or many, hard or soft?

Conclusions. Write an essay on the dispersal of seeds, based upon the results of your observations in the foregoing studies. Make your statements clear and specific.

PART III

A SURVEY OF THE PLANT KINGDOM IN DETAIL

SECTION I. THE ALGÆ[1]

TYPE 1. PLEUROCOCCUS (*Pleurococcus vulgaris*)

Habitat. Examine trees, fences, walls, buildings, walks, earth, or other objects for a powdery green coating. In what position with reference to the sun do you find it most abundant? What practical application could be made of this peculiarity?

Examine before and after a rain and observe any difference in appearance, or dampen bark or wood covered with the plant. Compare with a grass lawn under the same conditions.

The green coloring matter observed in this plant and in the grass is called *chlorophyll*, and is the cause of the green color of common plants. What reason can you give for the increased brightness after a rain?

Study in detail. Examine with the lens. What do you discover?

Examine with the (*lp*). Observe the minute, rounded bodies. What color have they? Are they few or many?

Examine a temporary mount[2] with the (*hp*). Observe the following: —

[1] Thallus plants containing chlorophyll.

[2] A temporary mount is made by taking a glass slide, placing on its center a very small portion or a very thin cutting of the object to be examined, covering with clean water, and then, over all, laying a cover glass. See to it that there is always a full supply of water between the two glasses; otherwise air will get in and spoil the view. Refer back to this direction, if necessary, in future studies.

1. The rounded structures (cells) are the individual plants. Are they equal in size? Observe a clear, outside layer (*cell wall*) and the green-stained interior (*cytoplasm* colored with chlorophyll.)

2. Observe that some single cells are oblong in form. What do you conclude from these observations?

3. By moving the slide, discover, if possible, forms with partitions, dividing them into two, three, or four parts.

Observe, further, that these combinations vary much in the completeness of the division into cells. This shows how pleurococcus reproduces and is called *cell division.*

Cell division. Cell division is the simplest manner by which a plant can reproduce itself. It is simply the division of a cell into two parts that may or may not remain temporarily attached. This division may be repeated for a greater or less number of times.

Drawings and description. Make drawings showing all the results of your observations, and remember that all drawings are to stand the test of neatness, accuracy, clear outlines, and proper naming. Write a careful description, embodying in it answers to all the questions asked in the preceding sections.

Green plants. Green plants, *i.e.* those which contain chlorophyll, are able to secure or make their own food from the mineral substances that are in the earth, water, or air. Such plants are independent. Apply this statement to the pleurococcus. Where is the food supply taken from?

An *alga* is a plant of very simple structure containing chlorophyll, usually living in the water. Our plant is an alga. Do its observed habits bear out this statement? In all places that you find the plant growing, what can be said about it? (Refer to habitat.)

3. Algæ have various colors, the color due to chlorophyll being often obscured by other tints. Pleurococcus, however, is true chlorophyll green.

An experiment. Soak some pleurococcus powder in alcohol, in a vial overnight, and study at the next laboratory period. Observe the color of the alcohol, and of the pleurococcus cells (*hp*). What conclusions do you make?

Some final questions. 1. How simple may a plant be and yet do all that is necessary for life and reproduction?

2. What would you say as to whether pleurococcus has any "old age" or not?

3. Why is this plant so universally distributed?

4. How small, actually, is pleurococcus?

Types 2 and 3. Nostoc and Oscillatoria (or Lyngba)

Habitat. These algæ may be found in still water, especially if somewhat impure. Both may be given to you preserved in formaldehyde solution. There are many forms, particularly of oscillatoria.

Nostoc colony. Examine a nostoc colony (the jelly-like mass), and observe its color, form, size, and consistency. What does the naked eye reveal, if anything, in the interior of the mass?

Nostoc structure. Prepare a temporary mount and examine with the (*hp*). Observe, scattered through the jelly film, numerous necklace-like threads (filaments). Examine carefully for color, and shape of cells, and their variation in size and number in the necklace. How does the color compare with that of the pleurococcus? Are the cells larger or smaller than in that algæ? Observe in particular larger cells and their position in the filaments. How do you explain the varying position? How may this alga multiply? What use may the *jelly* have?

Drawings of noctoc. Draw to show the results of your observation.

Oscillatoria. Examine oscillatoria or lyngba with the naked eye. What do you find regarding the general appearance?

Structure. Examine with the (*lp*) or with the (*hp*), according to the kind furnished, using as before a temporary mount. How do the cells compare in shape with those of nostoc? Are they more or less loosely attached to each other? How could you make a filament like oscillatoria from a nostoc necklace? What shape have the free ends of the filament? How do you explain? (Think of a hollow rubber ball.) Observe the color and other features.

Drawings. Make sketches showing all the features discovered.

Comparison of the algæ. Compare pleurococcus, nostoc, and oscillatoria, with reference to the arrangement of cells. Observe the change from single cell to filament.

Table. Record the comparison in a table thus: —

Name	Grows Where	Appearance			Cell Form	Cell Arrangement
		Eye	*m.*	Comp. Mic.		
Pleurococcus						
Nostoc						
Oscillatoria						
Lyngba						

The blue green algæ. 1. Blue green algæ (nostoc, oscillatoria, and many others) have some relationship in structure and habits to fungi (studied later) and are often found in water-supply reservoirs. Discover their importance in such places and the methods necessary for their removal. (Consult for this purpose good reference books.)

2. These algæ are by some placed in a group with the bacteria (to be studied later), called the fission plants, because of their method of reproduction.

Conclusion. Keep in mind all these forms. What really constitutes the individual plant? What observations have you made that form this conclusion?

Type 4. Hydrodiction (Water Net)

Habitat. This alga is found in comparatively stagnant water, and appears at first glance much like the filamentous algæ to be investigated later (*cladophora*, *vaucheria*), but study shows it to be far different. It may be grown with considerable success in aquaria.

Structure. Examine (*lp*) and *m*. Observe the very peculiar attachment of the cells to each other. What is formed by this attachment? What appropriateness has the term *water net?* What is the distribution of the chlorophyll? Compare (in this particular) with the vaucheria. What do you find regarding the size of the nets? Are all alike in size and shape of the "meshes"?

Reproduction. Examine a cell of the largest size with a microscope of comparatively high power. Possibly you may find the contents assuming a netlike appearance. This indeed happens; the old cell wall breaks down, and the tiny net escapes as a glove-fingerlike structure. This is the common method of reproduction. How will this explain, in part, the varying size of the nets? While examining the large cell look for oil globules.

Drawing. Make drawings showing nets of various sizes; also a single cell, the largest you are able to find.

Explanatory note. Water net is a remarkable relative of pleurococcus, each large cell producing myriads of exceedingly small *zoöspores* which never escape from the large *mother cell*, but finally arrange themselves in such relationship to each other that when they begin to grow, tiny nets are the result. Such a close connection of cells, otherwise independent, is called a *colony*.

What advantage can there be in such an arrangement?

Is this condition more or less complex than the simple cell combinations of pleurococcus? How might such colonies be useful to animal life?

Type 5. Spirogyra Species[1]

Habitat. These plants are the common *pond scums*, seen in ponds, slow streams, and ditches. They are also common in springs. They are easily grown in the laboratory and in aquaria.

Appearance. Observe the plant as it grows in the aquarium jar. Find out all you can with the unaided eye. What is its color, habit of massing together, and position with reference to the surface? Observe the presence or absence of gas bubbles. With a forceps take up a very small portion and observe the form of the plant as you slowly remove it from the water. Press between thumb and finger and observe the feeling. Compare some standing in the shade with another specimen on which the sun is shining. What do you notice?

Study with lens. Take a small portion by means of the forceps, place on a slide, cover with water and a cover glass (a temporary mount), and examine with a lens. What do you find with regard to the form of a separate or single plant or *filament*? (Your specimen is probably made up of very many such plants, about the real character of which more will be learned later.)

Experiment. Take a small portion of the aquarium material, place in a small vial, pour alcohol on it, cork, and set aside. Observe at the end of fifteen minutes. What is the color of the alcohol? This is the test for chlorophyll. Keep your vial material for future use.

Structure of filaments and cells. Examine your mount (*lp.*) What now do you observe regarding a single thread

[1] There are many kinds.

(filament) of the plant? Try to follow a single filament from end to end. Look very carefully for markings of any kind along the filament. You ought to be able to distinguish two kinds of these, *viz.*: (1) cross lines at equal distances, really circular partitions between the cells, and (2) what appear to be zigzag lines. What are the colors of the two kinds of lines? What color has the remaining part of each cell?

Demonstration by a student: Let a student take a large open-mouthed cylindrical jar and with a piece of green chalk draw a spiral line on the inner surface. Compare the appearance of this mark with the appearance of the zigzag line of the cell, and from it deduce the true nature and position of the marking.

Effect of iodine. Apply diluted iodine to your preparation and observe the change in appearance. Are the spiral markings more or less distinct than before? What color do they now have? What do you observe scattered along their course? These spiral bands are *chloroplasts* (green substance) and the round or oval bodies are *nodules*.

Nodules. Examine a nodule (*hp*) in an unstained specimen. Examine the same specimen stained with iodine. You observe a change of color, really to a bluish purple, if the spirogyra has been in the sunlight.

Experiment. Take a little starch, mix with water, and add a drop of dilute iodine. What do you observe and what do you now infer concerning nodules? The experiment is the test for starch. Remember it.

Cell structure (*hp*). With an iodine stained specimen and (*hp*) examine the cell very carefully for a brownish body near the center, the *nucleus*. Observe if possible its exact shape, the strands attaching it to the spiral band, and a round spot, the *nucleolus*, within it. Observe any irregularity of the chloroplast and how it terminates at each end of the cell. Does it continue into the next cell or does it stop?

What transparent substance might occupy the seemingly unoccupied parts of the cell? This seemingly unoccupied space in the cell is in reality filled with cell liquid and is often called the *vacuole.*

End of filament. Examine the end of a filament, (*lp*) or (*hp*). What is the shape of the end? Explain, if possible.

Species of spirogyra. Examine different kinds of spirogyra for varying numbers of chloroplasts. How many kinds do you discover? How do they compare with reference to size, color, or cell structures other than the chloroplasts? Such differing kinds are called *species. Spirogyra* is a *genus* name. The two names with the genus first, followed by the species, constitute the *scientific name.* All plants have such names in universal use.

Reproduction. *Conjugating spirogyra.* If specimens are given to you showing *conjugation,* look for the parallel filaments, the short tubes (conjugating tubes) connecting adjacent cells; also any change in the cell contents. These cells which are uniting by the connecting tube are called *gametes* and the process shown is known as sexual reproduction, or the production by cell union of a *spore* (called by various names, zygospore, zygote, and later, oöspore). Plants or cells (in plants consisting of single cells) thus uniting are known as *gametophytes.* In spirogyra, although a filament of many cells constitutes the plant body, in reality, each cell of such a filament can exist independently. If you see dark oval bodies in the cells, the other paired cells being empty, they are the *oöspores,* or reproductive cells, formed by the union of the cell contents of the two connected cells. If possible, note the various stages in the process. Read about the purpose of these cells in the *life history* of spirogyra.

Drawings. Make the following drawings to show the results of your observations: (1) a mass as it appears with hand lens; (2) a filament of at least ten cells (*lp*); (3) a cell with parts of those adjacent (*hp*); (4) same as (3), but stained with iodine; (5) an end cell (*lp*); (6) cells of other species of spirogyra; (7) conjugating spirogyra (*lp*) and oöspores (*hp*); (8) filament after application of salt solution; (9) cell division (if observed) (*lp*).

Cell division. In spirogyra that is fresh and bright green, try to discover in the same filament *long* and *short* cells. How could you obtain the short cells from the long ones? If you find such a condition, it means the reproduction of the filament by vegetation, multiplication, or cell division. In this method how could a single filament, in time, fill a small spring or pool?

Experiments. To fresh living spirogyra, temporarily mounted, add strong solutions of sugar or salt, and observe the effect on the chloroplast band and other cell contents. An action called plasmolysis is taking place; read about this in reference books.

Examine material growing in bright sunlight. Try to perfect some plan for obtaining the gas thrown off. (Instructor may arrange experiment, with the idea of determining the nature.) The plant is making food from the minerals in the water by means of its chlorophyll-stained cytoplasm, the sunlight being the direct stimulus. The gas thrown off is waste matter (to the plant in this process) and is, at least in large part, oxygen. The process is called *photosynthesis*, which is the food-making process of all chlorophyll plants.

Problems. 1. What effect would this alga have on the purity of pond water? What benefits would come to the animals living in such water?

2. Why does it grow in relatively quiet waters?
3. Why does it not grow in the ocean?
4. Why is it not a good plant for the aquaria?
5. Why is it often called "brook silk"?
6. Why does it make starch?

Type 6. Zygnema[1]

Habitat and appearance. The plant grows in localities similar in nature to those where spirogyra is found. It may often be distinguished by its yellow hue. It is easily grown in the laboratory.

Structure. Examine a very small portion of the alga (remember that all the green water plants, or scums, and the pleurococcus, besides many other forms, all containing chlorophyll and living in water, and lowest in the plant scale, bear this name) and treat it as you did spirogyra, (*m*), (*lp*), (*hp*), unstained and iodine-stained. Observe that the cells are shorter relatively than those in spirogyra, and especially observe the very different form of the two chloroplasts found in each cell. Examine very carefully and see if you cannot compare the chloroplast to an irregular, many-pointed star.

By very close observation find an almost transparent connection between the chloroplasts, containing within it the nucleus. This feature is seen more easily in the iodine-stained preparation.

Reproduction. This alga reproduces as spirogyra does. Seek for either form of reproduction found in that plant. Make careful drawings covering the important features you have discovered.

Comparison. Compare spirogyra and zygnema by means of this table: —

Name	Color	Feeling	Cell Ratio, Length of Diameter	Size	Chloroplasts
Spirogyra Zygnema					

[1] A plant allied to spirogyra.

The green algæ. Observe for spirogyra, zygnema, and all other green (as distinguished from the *blue green* forms, as oscillatoria) algæ, that the water in which they grow, however unsightly the floating plants may appear, seems to be very clear and bright, and is, in fact, reasonably pure and well adapted to animal life. How do you explain this by the results of the preceding studies? What relation may these algæ have to animal life? How may the pond scums be injurious to man?

Plants living in water are called *hydrophytes*. How does their environment benefit them? Carefully consider this subject, for it brings to you a new field of work called *Ecology*, or the relation of a living organism to all its surroundings, mineral, plant, and animal. These algæ are the lowest members of the water association.

Type 7. Desmids

Habitat. These very small algæ are more or less common in sluggish streams, ponds, and ditches, where water plants are plentiful. They may be obtained in some abundance by dipping water from such situations, particularly from near the bottom, and straining it through a fine meshed cloth. After straining it through the cloth, put the sediment into bottles with a little water.

Structure. As these plants are practically invisible to the unaided eye, the compound microscope is necessary. Examine the material provided, (*lp*) or (*hp*), and seek for small symmetrical objects, green in color. Study carefully this symmetry of form. How does it manifest itself? Examine the cell wall for any mark or peculiar feature that would cause the symmetry. How is the chlorophyll arranged? Is it in any way covered up or concealed? Try to remove it by repeated treatment with alcohol. If you are able to decolorize it, apply dilute iodine and observe the results in the remaining cell contents.

Movement of cytoplasm. Look in particular for any movement of the cytoplasm, especially near the clear ends of the crescent form, Closterium; this feature is cell circulation. Look for any movement of the entire cell. This is quite often manifest. If observed, watch carefully for some time to see if you can discover the method.

Reproduction. Look for cells in the process of division, the common method of reproduction. Occasionally, conjugation of two individuals occurs. Consult reference books.

Drawings. Make drawings showing different forms you have seen, also any other features observed.

Use of plant. Of what use may these small plants be in the economy of nature? (The economic importance.)

Classification. The three algæ last enumerated, and studies of which are given, are related forms and belong to a group of algæ called the Conjugate. This introduces to your attention the arrangement of all plants in groups, large or small, and this arrangement is called *classification.*

The group names commonly used are, from the highest to the lowest, as follows; kingdom, branch, class, order, family, genus, species, and finally the individual. The scientific name (used the world over for accurate designation) consists of the genus and species names, the latter written after the former. From time to time you will be given appropriate examples to familiarize you with such names, and to learn their value in the description of plants. (See spirogyra.)

Type 8. Cladophora[1]

Habitat. This is one of the most common of all algæ, being abundant in ponds, ditches and on rocks in streams and brooks, and on rocks and piling of the Great Lakes. It is also found in ocean water. It is of the easiest culture in aquaria.

[1] Branch bearing.

Appearance. Examine by feeling and with the naked eye. How do the filaments compare in size and color with those of the algæ already studied? Observe whether it normally floats free, or is attached.

Structure. Examine (*lp*). Observe the color, also the distribution of the chloroplasts, the thick cell walls, and the *oil globules*. Trace a filament for some distance. Is it simple or branched? Would you consider this plant more or less complex than spirogyra? Give some reasons for the answer. Where do the branches always originate with reference to the part of the cell from which they come? What shape has each branch?

Look carefully for cells in the filament that are dividing. Where are they situated? (Cladophora grows in size by the elongation of the cell tips with subsequent division. Branches are formed in the same manner. The plant rapidly increases in size in this manner and by breaking up forms new plants.)

Associated algæ. Commonly attached to the filament are many small brown structures (diatoms) or one-celled brown algæ. Remember this when the diatoms are studied.

Drawings. Make drawings showing the results of your study.

Reproduction. This alga reproduces by *zoöspore* formation, which always occurs at night and hence is seldom seen. Single cells give rise to spores having cilia (called by the above name) which move about for a time; then, after a period of rest, germinate and form new filaments. Under certain conditions these spores, also called *zoögonidia*, unite (conjugate), producing an oöspore (zygospore of many authors), which in time produces a new filament.

What advantage is the double method of reproduction?

Nature of filament. The cells of this alga, while quite similar to each other, do not all do the same work; certain basal ones serving for attachment to rocks, etc., terminal cells elongate and divide, and others produce swimming zoöspores. This alga, therefore, is not a collection of cells, almost or quite independent (as in spirogyra), but is truly a many-celled plant.

Type 9. Vaucheria[1]

A BRANCHED ALGA

Habitat. One species of this alga is a common form about springs, tile drains, in clear ditches, and other similar places. Another form is very common on the ground among carnations and other thickly bedded plants in greenhouses. It is a rare alga in the school aquarium, on account of the great difficulty of growing it in such confined places.

Appearance. Examine material brought from the greenhouse or other source. Observe the color and general appearance of the plant as it grows, and in particular, the matted appearance of the patches, particularly evident in the water form.

Examine mounted specimens, both land and water forms, if they are accessible, (*lp*). Select as bright and fresh green a filament as can be found, and trace it, if possible, from end to end. Observe the form of the growing tips; also seek for branches, and if found, observe the angle they form with the main filament. Carefully observe the distribution of the chlorophyll. Seek for any evidence of cross cell partitions. (The plant is, in theory, many-celled. At least it possesses many nuclei.)

Examine portion of the filament (*hp*) for the chloroplasts and oil globules.

You will find practically the same features in both forms, except that all parts are larger and more vigorous in growth in the water species.

Germinating spores. Among the filaments examined seek

[1] Green Felt.

for oval or globular bodies with green filaments growing from one or both ends. These structures, if found, are *germinating spores*, (probably zoöspores) showing how the plant grows from these reproductive structures.

Rhizoids. In the land material mentioned above, seek for root-like branched structures. If found, what color have they? What might be the use of the same? Recall where the plant grows. Seek for the same in the water material. These structures are *rhizoids*.

Sexual reproduction. On either kind of material, seek for short branches, approximately at right angles to the filament, but differing in arrangement of the two component parts in the two kinds under consideration. In the greenhouse form there are two branches, adjacent, one round or oval, and the other cylindrical and strongly curved, which finally unites its tip with the spherical body. This latter body is the *oögonium* containing the female gamete (uniting cell) or oösphere and the curved body is the *antheridium* containing the male gametes. Observe whether these structures are marked off from the main filament by a cell wall or not. What color has each? In the mature antheridium, find some that have lost their contents. What has become of the same? The result of this reproductive process, by the union of the contents of two cells, is a sexual spore, or oöspore which is a structure that commonly remains dormant for some time (*resting spore*) before germinating. What use could they serve in the plant history? Observe the thickness of the cell wall of the oöspore. Why is the wall so thick? If the form is the one growing in water, both gametes organs are found on the same branch, and there are several oögonia.

Drawings. Make the following drawings if the material will permit: —

1. A complete filament with its branches and growing tips.

2. A portion of a filament (*hp*).
3. Germinating zoöspores (*lp*).
4. Rhizoids (*lp*).
5. Different stages in the formation of antheridia, oögonia, and oöspores (*lp*).

Observations in conclusion. Observe, by feeling, the roughness of this alga as compared to spirogyra, hence its common name, "green felt." Observe the numerous small animals that swim about among the filaments comparable to wild animals in a forest. These are of many kinds, the lowest forms of animal life (infusoria, etc.). Of what advantage to the animals may this growth of algæ be?

Plants with filamentous plant body, many nuclei, but without apparent cross partitions are called cænocytes. Compare with mucor.

Supplementary Observations on Filamentous Algæ. Experiments

1. Observe the bubbles constantly given off by these plants when in the sunshine. Collect the gas by placing vigorous cladophora in an inverted test tube filled with water. Support the tube so that the lower end is below the surface of the water in the aquarium jar. The process will be very slow, but when enough gas is collected, remove, under instructions of your teacher, and test with a glowing wood splinter thrust into the gas. What happens and what gas causes such action? Or fill a test tube with water, invert and insert a short-stemmed glass funnel stem into the tube, and fasten the whole over vigorous algæ. This plan hastens the collection of the gas. These methods, at the best, furnish a very slow accumulation of gas, possibly much mixed with air. In this gas making, the plant is engaged in the very important work of preparing food for its own use. The crude materials are water and carbon

dioxide. Where does the plant obtain these substances? From them starch or oil is made. Observe whether the bubbles are formed when the alga is in a dark corner of the room or early in the morning. From the results of these observations what seems to be necessary for the manufacture of the gas (which is a waste product) and the process of food making which produces the gas?

2. The water and carbon dioxide for the manufacture of starch or carbohydrate food is taken into the cell of the alga through the cell wall according to the laws of absorption or *osmosis*, a physical phenomenon somewhat difficult to understand. A number of experiments tend to illustrate the principle, but all are rather elaborate and may with propriety be demonstrated before the class. You ought to consult the textbooks to find out what experiments they give for this purpose. Some of them you may be able to perform without aid. This simple procedure you certainly can carry out: Soak a well-dried raisin, bean, prune, or currant in water and observe the result. This in a homely way illustrates food absorption by algæ and all other plants. How did the water get into the fruit or seed?

3. In all these experiments you will find that a membrane (fruit or seed coat in the last) separates a thin liquid (of small comparative density) from a much denser, commonly liquid, substance, and that a marked flow of the thin liquid through the membrane into the denser substance is the first phenomenon apparent to the eye.

4. In the algæ we have the dense cell cytoplasm — the cell wall and the surrounding water with the dissolved minerals and other food materials.

Type 10. Rockweed[1]

Habitat. The plants studied in this exercise are common on the rocky shores of New England. In the interior they

[1] Ascophyllum or Fucus.

may be seen in large fish and sea-food stores, having been shipped as packing for lobsters, crabs, and other sea foods.

General appearance. Examine the specimens furnished and observe the peculiar feeling and consistency of the whole plant. Of what does the consistency remind you? The plants grow at tide level, where wave action is very strong. How does the general nature of the plant fit it for such a place of growth? Observe enlargements here and there on the main *axis*. Cut one open. What is it? What can be its purpose? These structures are *bladders*. What is the color of the plants? How does it vary from end to end? Being an alga, it must contain chlorophyll. How do you explain the color observed?

Branching and main axis. Examine the branching. What do you observe on drawing a plan, showing all the branches, properly proportioned? Such a method of branching is called dichotomous. Examine the main axis, and observe whether a holdfast at the large end is present or not. The axis may or may not have a central line or ridge, the *midrib*, and a lateral expansion, *wings*, according to the kind studied.

Branchlets and conceptacles. Examine the final divisions of the axis, which in ascophyllum, in particular, feel like the bladders. Cut one open. Is it hollow? These structures may be called *branchlets*. Examine attentively and observe the minute brown spots or dots scattered over their surface, or collected numerously in some branchlets. These are *conceptacles* and contain the reproductive gametes. In fucus the fertile branchlets (bearing conceptacles) are quite distinct, and commonly in pairs.

Reproduction. Examine (*lp*) or (*hp*) prepared conceptacles, and observe the *antheridia* and *oögonia*. Their full explanation may properly be left to the instructor as special preparations are required in order to see all the reproductive structures plainly.

Consult also your reference books for the reproduction of these seaweeds.

Drawings. Draw the whole plant, or both species, if accessible, naming all the parts; also a branchlet enlarged, showing conceptacles, and these structures from microscopic preparations, charts, or lantern screen.

Economic value of algæ. At this time it will be a valuable piece of work for you to find out all you can about the use of the rockweed in the products made from it and how, in particular, the Japanese use it and kindred seaweeds for a large number of purposes. Consult all the reference books at your command and record the results of your reading in the form of a table, using the following plan: —

NAME OF SEAWEED	WHERE FOUND	NATURE OF THE USE MADE OF IT	NAME OF THE PRODUCT

In this connection investigate further regarding the uses algæ may have in the economy of nature, or their beneficial or injurious effects on associated plant or animal life. Find out what you can about the Sargasso Sea.

TYPE 11. DIATOMS

Where found. These microscopic brown algæ are abundant in ponds,— near the bottom, — in springs, ditches and streams, on all vegetation. Very common on some filamentous algæ, as cladophora. Very abundant as fossils, forming diatomaceous earths. Many may be obtained in the following manner: Fix over a hydrant a fine-meshed cotton cloth and permit the water to run through for some time. Observe the sediment on the cloth and examine (*lp*) and (*hp*) for diatoms. A useless experiment in water systems supplied by wells, but almost certain to yield good results from lake or river sources of supply. From some source obtainable, make a temporary mount and study carefully the profusion of objects that appear under the microscope. Examine as many forms as you are able to find in the mixture. What is the color? Observe that many are transparent (these are dead). Use (*lp*) or (*hp*) as necessary. Observe the similarity of the ends. If possible, study the same diatom on different surfaces. Compare with a box and lid for similarity of form. Find, if possible, many fine lines. Draw the various forms and varying views of the same form. Observe the free brown forms for a slow motion; also that some forms are attached by stalks. Consult the books regarding the cause of this boatlike motion.

Fossil diatoms. Consult all the references to diatoms you can find. What use is made of fossil diatoms? What is the substance in the diatom that makes it thus valuable? What is diatomaceous earth? How do you account for the great accumulations of this material? What reasons can you find for such peculiar cell structure?

Type 12. Red Seaweeds

General statement. These often very beautiful forms of algæ are common along the shores of both oceans, and are often seen mounted on paper as souvenirs of seashore visits. They are often highly complex and exceedingly varied in form. Unless well supplied with fresh material, the question of reproduction will be out of place in the laboratory. Only the more easily observed features will therefore be noted in this exercise.

Appearance. Observe the wonderful variety of forms assumed, flattened, ribbonlike, filamentous, feathery, corallike, and decide what forms your specimens show. Also observe the variety of colors. Observe, in particular, the manner of branching, and compare with that of the rockweed.

Experiment. Wet some dried specimens and note the rapidity of the *freshening-up* process. Also that some forms are *gelatinous*, or very mucilaginous. If at hand, treat Irish moss in the manner suggested and observe the results.

Drawings. Draw portions of several forms and briefly describe, or take notes sufficiently full to characterize each kind drawn.

Reading. Read about the seaweeds in good reference books. Why is it that these algæ do not show any green color? How can you show experimentally that the plants contain chlorophyll? Of what advantage is the red color? Find out any uses to which these plants are put by man.

Type 13. Chara

Habitat. The plant grows abundantly in ponds, slow streams, and lakes. Very common in park ponds and lakes, often causing much damage and necessitating removal. It is found at all depths from six inches to twenty or more feet. It is not easily grown in laboratory aquaria.

Appearance. Examine the plant as it grows (if possible) and observe its color, appearance, and direction of growth, whether floating or erect. Take some between the thumb and finger, rub and observe result. Smell of a fresh mass of the plant. What effect or purpose may this odor have? Place some dried specimens in a vial and add diluted hydrochloric acid. What do you observe? How do you explain? What advantage to the plant may this condition of the stem be?

Parts of the plant. Trace a main axis, often called a stem, throughout its length. Observe at intervals a *whorl* (circle) of branches, and here and there a secondary smaller axis bearing similar whorls. How many branches in a whorl?

How do the whorls compare in the length of branches as you approach the top or tip of the axis? The very tip looks like a bud and is called the *apical bud.* The branches arise from the *nodes* and that part of the axis between two consecutive nodes is called an *internode.* How do these compare in length from end to end?

Structure. Examine a branch (*lp*) and study the nodes and internodes. How many branches at each node? What do you observe on looking at the branch surface? Look now at the surface of the main axis, and observe the similarity of each to the other. You ought to see elongated cells more or less spirally arranged. Examine a branchlet for cell structure. The cells noted above in the main axis and branch are called *cortical cells.*

Reproductive bodies. In material having gamete bodies observe on a branch, at each node, two forms of reproductive structures, the female gamete (oösphere or oögonium) above, and the male gamete (antheridium) below the branchlets. How do these differ from each other in form, size, color, and markings?

Observe the oösphere more attentively, and find, if possible, spiral cells on the outside, and a large central cell within (oöspore), also a lobed margin or mouth. Crush an antheridium and observe the plates composing it, also the strange jointed filaments or *sperms* (those under water move about, some entering into and uniting with the oösphere to produce the oöspore). The oöspore, on germination, produces a new plant.

Section of stem. Study a section of the axis (*lp*) and observe a large central *internodal* cell and a layer of outside *cortical* cells. Compare with the parts of the oögonium.

Drawings. Draw a plant, natural size, with the details, showing a node, branches, branchlets, parts of the adjacent internodes, and a cross section of the axis (*lp*). Also a fertile branch bearing the antheridia and the oögonia, and details of the reproductive structures, plates, sperms, and an enlarged oögonium, all (*lp*).

Marl. Many small lakes support a vast growth of this plant, and it in reality produces from the chemical elements found in the water a carbonate of lime preparation mixed with other elements that form marl. Ascertain the value and use of marl in the manufacture of Portland cement.

SECTION II. THE FUNGI[1]

Type 1. Yeast [2]

Yeast preparations. Examine different forms of yeast preparations furnished by the instructor, as yeast cakes, compressed yeast, and liquid yeast. Observe in each the peculiar odor. Where is yeast obtained? Find out something, if you can, about its preparation on a large scale for the market. Ask your grocer how long he can keep the different kinds of yeasts. Find out how some of your bread-making friends make yeast, and decide, after careful comparison with the following study, if, after all, it is really made, or is something that is grown or prepared.

Home experiments. Mix for yourself, at home, yeast of some sort with water, a little flour, and a small amount of sweetening, and place where the mixture will remain warm. Examine frequently the results.

Note. If possible, put the mixture in a deep, wide-mouthed bottle that can be corked. When freshly mixed, light a taper and insert in the bottle for a moment only. After the yeast begins to foam or bubble freely, cork for some hours; then remove the cork and quickly insert the taper lighted. Compare with the results of the first trial. What gas is being made by the yeast? Compare by breathing into a deep, clean bottle, and then trying the lighted taper for results.

Microscopic structure. Examine some prepared yeast mixture with (*lp*), and particularly with (*hp*), and observe the

[1] Thallus plants without chlorophyll. [2] An imperfect fungus.

size and shape of the yeast cells (really one-celled plants). Do you find chlorophyll? (The lower forms of plants lacking this green color are called *fungi.*) Observe a large round mark in the cell, a *vacuole* or *vescicle*, and surrounding this a more or less granular cytoplasm (all the cell features ordinarily visible).

Effect of iodine. Mixed with the yeast are larger, more irregular cells, with lines on the surface (starch cells). Add dilute iodine, and observe the result to the yeast and starch cells. Examine for cells of different sizes and cells of various sizes placed *end to end* (as in a chain). This is reproduction by *budding.*

CAUTION. Do not mistake accidental contact for real chains.

Drawings. Draw yeast and starch cells and yeast chains, scale of $\frac{1}{4}$ in. for smaller cells.

Bread and yeast. Study bread making in the books, and explain the part that yeast plays in this operation. What effect has baking the bread on the yeast plants? In what great industries does yeast have an important share? In what ways may yeasts be injurious or harmful to man? How may their presence or growth be prevented? Consult the subject of fermentation.

Experiments and problems. Place a small and equal portion of a compressed yeast cake in each of four bottles, *viz.*:

1. Filled with distilled water.

2. Filled with Sach's nutritive solution (for green plants, consult reference books for formula).

3. Filled with distilled water to which a little starch is added.

4. Filled with distilled water to which a little sugar is added.

Observe the results. What does this show regarding the food of this fungus? How would you explain the discovery of the first yeast preparation? What are "wild yeasts"?

What effect has yeast bread in digestion? Which are more wholesome, "light" or "unleavened" breads? What is an enzyme? Why is yeast used in "nonalcoholic" drinks? What is "root beer"? How do you explain the fact that the yeast plants do not *die* in a dry yeast cake? Why are hops often used with yeasts? How may light breads be made without yeast?

Type 2. Bacteria[1]

General statement. Bacteria are very minute, one-celled fungi (by some placed in another group called Fission fungi), and related in some of their habits to molds and yeasts. They are too minute to be observed by most pupils; but with proper manipulation of the (*hp*) (400 d.), it is possible, when studying the yeast plant, to observe the very minute dots, dashes, spirals, light or dark tinted, in more or less constant vibration among the yeast cells. The discolored patches on the bread and odor of decay are easily noted. Many are called germs, and some are frequent cause of serious diseases, not necessarily directly by their presence, but as often indirectly by the poisonous products they produce in their growth (toxins or ptomaines). Cases of poisoning from ice cream and canned meats are examples. Read in good reference books about bacteria, and the various means employed to prevent them from injuring foods or attacking the human body.

Experiments. Try some of the following experiments: —

1. Make some meat broth from beef, chicken, or fish; allow it to cool and then proceed as follows: Take four small bottles, or preferably, test tubes, and number them 1, 2, 3, and 4. Into No. 1 pour a small quantity of the cooled broth; do the same with No. 2, but use some cotton for a stopper. For No. 3, boil the bottle and reboil the broth and while both are very hot, pour the broth into the

[1] Bacilli, Micrococci, Spirilli.

bottle and stopper with a cork; do the same for No. 4, but use cotton for a stopper. Place all in some moderately warm place and watch carefully for any change in appearance and odor. After about three or four days, what do you find, and how do you explain?

2. Boil some pieces of potato until cooked but still firm. Plunge a tumbler and saucer into the boiling water, and with a boiled needle, pick out a piece of potato, place on boiled saucer, under boiled tumbler; surround the base of the tumbler with cotton. Allow the second piece of potato to cool and place on the other saucer without any precautions. Set both away in a warm place for four or five days, and then examine for appearance and odor. What do you find? Explain as before.

The experiments may be varied by placing the tumbler in a cool place.

3. Take two small cubes of fresh meat; dry one quickly and thoroughly over a fire, taking care not to cook it. Place both pieces under tumblers for three days and then examine. Observe the results, and explain them.

Matters to investigate. Read about the various methods of preserving foods from spoiling; *i.e.* plans to prevent the growth of bacteria, molds, and ferments (yeasts).

Discuss, in your paper on bacteria, the economic importance, if possible, of bacteria, and the good as well as the injurious effects that come from their growth.

A few questions may assist in the direction of effort to understand these minute forms of life: —

1. What importance are bacteria to the farmer in soil renovation?

2. What plant family is intimately associated with bacteria, receiving much benefit therefrom?

3. What are antitoxins?

4. What life habits have bacteria? How do they multiply, and how rapidly?

5. Why are diseases of the nose, throat, and lungs so common?

6. What agents kill bacteria or hinder their development?

7. Why is country air said to be more pure than that of a large city?

8. What would be the condition of things were there no bacteria?

9. How may bacteria gain entrance to the human body?

10. What are "disinfectants," "antiseptics," "germicides," "food preservatives," and "fungicides"?

Type 3. Common Black Mold of Bread[1]

Home experiments. Take a small piece of bread which is stale, moisten, rub on the floor, and place in a saucer. Over all place an inverted tumbler, and set in a warm place. Watch from day to day, and notice the first appearance of the white "fuzzy" growth, and its further development until the whole has turned dark. Where did the mold come from, and what, from your experiment, seemed to be the conditions requisite for its growth? Try the experiment again without wetting the bread; also again, by keeping in a cold spot. Why would no mold grow on a rock treated in the same manner? As the bit of bread increases in age observe the increasing discoloration by various colored patches; also the increasing offensive odor. These patches are probably caused by bacteria (germs, microbes) and the bread is decaying, or decomposing. Which comes first, the bacteria or the decay?

Vary your experiment by using potatoes, raw or cooked, banana skins, fruits, pieces of meat, chips of wood, or other matter of organic (produced by living things) nature. Ob-

[1] Mucor, Rhizopos.

serve the varying growths on each substance; also that black mold may grow on other substances besides bread.

Appearance. Examine mold under glass, with a lens, and observe its appearance; also the tiny enlargements, light or dark colored, on the ends of some threads. Observe the total absence of true leaf green (chlorophyll); also in a well-grown specimen, observe how the mold seems to *grow out* from the bread along the sides, or even creep over the glass plate on which the saucer containing the bread is placed.

Microscopic structure. Examine a specimen under (*lp*) and observe the white threads that make up most of the plant. This thread is called the *mycelium*, and really composes the body of the mold plant. Observe, here and there, rootlike structures, that attached the mold to the bread, and from which a number of the threads diverge. Of what use would these attaching structures be to the mold plant besides holding it in place? Some of the diverging threads, above mentioned, may end in white or dark knobs, *sporangia* or *spore cases*.

Sporangia. Try to trace all the stages in the formation of these sporangia from the slightly enlarged end of the filament, to the black, spherical body, a ripe sporangium. Find a crushed sporangium. What size and number are the contained spores?

Mycelium. Examine in detail the mycelium of the mold. Is the plant one or more celled as shown by the filament (exclusive of the sporangia which are at last separated from the rest of the plant by wall)? Do you find branches or not? How are the rootlike structures (substratum mycelium) sometimes connected with each other? What benefit would these structures be to the plant?

Drawings. Make drawings showing as many features of this mold as you have been able to find. Be sure to show by a sketch the result of your home experiments.

Problems. What is your explanation of the molding of foods? In what ways can it be prevented? Is mold a fungus or an alga? Read about molds, and find out their economic importance; also the details of their life history not discovered in the preceding work. Are molds poisonous or not? What disease seems to be caused by a moldy grain? Why are molds less injurious than bacteria?

Type 4. Water Molds[1]

General statement. Various kinds of organic material placed in water soon develop moldy growths. Live fish are frequently attacked, causing great loss of life. Let the pupil try to grow these plants by means of various vegetables or bits of meat kept for some time in water.

Structure. Examine the growth in the water by means of the naked eye and with a lens; observe the size of the growth, color, and general appearance. What fungus features, more or less resembling bread mold, do you observe? How do you account for the mold appearing on the articles of food placed in the water?

Examine preparations (*lp*) or (*hp*), and look for mycelium and any reproductive structures.

Drawings. Sketch such structures as you find, and name according to the terms already used in the common bread mold.

Damage from. Find out the amount of damage done by these plants in aquaria, fish hatcheries, and among the fishes. What remedies, if any, are recommended? Look up in any good reference book, and add a summary to your statement about this plant.

Type 5. Mushrooms and Toadstools[2]

General statement. The ordinary forms of "toadstools" and mushrooms are to be found wherever there is decaying

[1] Saprolognia species. [2] Higher fungi.

organic matter of plant origin. "Toadstools" are mushrooms that have the reputation of being poisonous, but, as a matter of fact, many toadstools, so called, are delicious and wholesome, and the deadliest known forms are, as a rule, called "mushrooms."

Form and parts. Examine any "parasol-shaped" form that is furnished, or that you are able to find for yourself. Observe the stalk that attaches the plant to the ground. Often strands of fiber or threads are seen attached to the lower end of the stalk, and these represent a part of the mycelium that is the real plant living in the organic matter, on which the mushroom grows. Break up a stalk and observe its fibrous nature, like a bundle of threads. What is the form, color, and size of the stalk, and is it solid or not? Observe whether or not the stalk is inclosed at the base in a cup, and if near the top, there is a band, or *ring* encircling the stalk. The expanded portion borne on the stalk is the *cap*, or *pileus*. What is its size, shape, color, the nature of the surface, and is the section thick or thin? Observe the absence, or presence, of odor. If your specimen is young, there may be a thin film of skin or membrane stretched from the margin of the cap to the stalk, and covering the under surface of the cap. Such a structure is the *veil*. What purpose has it?

The under surface of the cap may be covered with radiating, narrow ridges (*gills*), small holes (*pores* or *spines*).

Drawings. Draw a side view of the mushroom, a long section through the whole plant, and a view of the under surface of the cap. Draw spores also.

Spore print. Spores. Cut the stalk of a fresh mushroom close to the cap, and place the cap, right side up, on a piece of plain paper. Cover all with a tight glass to exclude any air currents. After three or four hours, remove the glass and lift the cap directly upward, with great care. What do you find on the paper? Compare with the under surface of the cap for similarity of form and color. Make a temporary mount of a small portion of the powder, and examine (*lp*) or (*hp*). What do you see? These small objects are *spores* that reproduce the plant. Where did they come from? Why are they so many and so small? What is the color of the print, and of the spores, under the microscope? Draw some spores.

Decay of mushrooms. Permit a mushroom to decay. Compare it with meat and vegetables; which does it resemble in decay? Is it attacked by larvæ or worms? What odor has it? Will mushrooms keep as long as potatoes or carrots?

Light and mushrooms. Mushrooms are often grown in dark cellars, caves, or in buildings without windows. Why could you not grow green plants in such places? Mushrooms, like all fungi, lack chlorophyll. In food and light requirements how do they resemble animals? From your study of various fungi, state some of the characteristics of this plant group.

Many mushrooms are poisonous. A very few (*amanitas*) are, with certainty, *deadly* in their effect. They may be known by: —

1. White gills, whatever the cap color may be.
2. A cup at the base of the stalk, into which the latter fits.
3. A ring on the stem, more or less like a folded umbrella.
4. Growth on the earth, not on stumps or wood.
5. Grow solitary.

Use. From the nature of the food of most forms, of what value are these plants? Of what use to man are some kinds? (They are nitrogenous in composition.)

Drawings of various species. Draw as many kinds as you can find and have time to work with. Learn their names, if possible, and their edible qualities or dangerous characteristics.

Caution. N. B. Never eat unknown mushrooms, and never trust any rule any one may give, except the exact determination of the kind from some good work on mushrooms.

Type 6. Puffballs[1]

Habitat. These fungi grow in similar situations to those occupied by the mushrooms, often in great numbers and occasionally of enormous size, five to twenty pounds.

Appearance. Examine puffballs of various sorts. Observe the size, appearance, color, surface, and general shape of each; also their attachment to the soil or other object on which the plant grows.

Section. Examine puffballs in long section and observe the base and the colored mealy *sporemass* occupying the upper part of the plant.

Spores. On jarring this sporemass, what do you observe? How do the unripe puffballs differ from the ripe ones? Why do these fungi have such rounded forms? Why do they have so many spores? Examine some of the latter with (*hp*) and compare for size with the mushroom spores.

Some puffballs are raised on stalks. What advantage would this be? Others have an outer skin that splits into valves and recurves (*earth stars*), lifting the ball. Why?

Drawings. Make drawings, external view and sections.

Food value. All puffballs, when white in flesh and solid, are edible, but they are not fit for food when the sporemass is even slightly yellow tinted. Some forms grow to great size and are among the best of mushrooms for the table.

Rules for determination. It may be well here to emphasize again, that there are *no rules* of common acceptance for determining whether forms are poisonous or not, *that are worth anything whatever.* The only safe method is to learn the name of each kind you find from some good descriptive

[1] Higher fungi.

work, dealing with such fungi, and never even taste unknown forms. These plants offer abundant, cheap, and moderately nutritious food, but the greatest care should be taken to learn thoroughly the appearance of wholesome kinds and also, as before given, the characteristics found in the *deadly forms.*

Ten edible mushrooms. Below is a list of ten perfectly wholesome species or groups, most of which have no similarity to poisonous forms, and all perfectly distinct and most easily determined by slight attention to characteristic features: —

1. Morels, brownish, wrinkled, spongy, hollow, on the ground, in May.

2. Puffballs, when white-fleshed and solid, not a single dangerous form.

3. Commercial mushrooms, often wild, ring on the stem, gills pink, ageing to dark brown; plant gray brownish, with short stalk.

4. Fairy ring, small, buff, in grass, forming rings.

5. Coral mushrooms, like branching corals, white, brown, buff, on ground and dead wood.

6. Vermillion Chanterelle, very small, brilliant vermillion, gills blunt, shallow, running down stalk.

7. Sulphur mushroom, on dead logs, stumps, salmon above, sulphur below; a pore form of bracket shape (see next study).

8. Honey mushrooms, stump bases in autumn; in great clusters; buff with whitish gills.

9. Green russula, cap moldgreen, stalk short and with gills white; on ground.

10. Violet cap, whole plant violet tinted.

Type 7. Bracket Fungi

Habitat. These fungi are commonly found on stumps, dead trees, and logs. They are easily preserved. Hunt for them, and if possible, furnish your own specimens for study.

External features. Observe that there is, as a rule, an entire lack of a stalk, the cap or pileus growing directly from the wood. Observe the consistency of the cap as compared to the softness of the ordinary mushrooms. What evidence can you find that these plants live more than one year? Not all, but some do. Compare the under side, or spore-bearing surface, with the same region in the mushroom. What do you find? Study a section of a bracket fungus. Observe the spongy nature of the *cap*. (The Indians make punk from certain forms.) Also the gill, pore, or spiny layer, in which the spores are produced.

Drawings. Draw upper surface and sectional view, also a portion of the under surface (*m*).

Economic importance. These plants often cause serious injury to living trees, their mycelia penetrating into the woody tissues and causing death. They sometimes attain to very large size and are frequently used for ornamental work. Certain forms (notably, one called the sulphur mushroom, on account of the color,) of soft consistency are edible in the young state.

Type 8. Sac Fungi. Cup Fungi. Morels

Habitat. There are many forms of these fungi, some assuming the shape of *cups*, some looking like elongated spongy masses, covered with ridges. The morel is a common form found in open woods in April and May and is highly esteemed as a delicate food fungus.

Appearance. Examine the pileus or cap and observe the form, whether cuplike, club-form, or irregularly covered by ridgelike convolutions. The inner surface of the cups, the outer surface of the clubs and ridges are spore bearing. Draw carefully such forms as you have, both externally and in long section.

Reproduction. Examine (*lp*) thin sections of the spore-bearing surface and observe that the spores are in long *sacs*. To what are the sacs attached? How many spores does a sac contain? Examine the spores and compare them with the spores of common mushrooms. Make drawings showing these reproductive structures.

Lichen features. Find, if you can, these plants growing. Upon what do they live? Refer to these forms when you study the lichens and observe the similar reproductive features.

Type 9. A General Study of Rusts, Mildews, and Smuts

General statement. A very large variety of material may be preserved during the summer for class use during the colder months. This study ought, however, by all means, to be supplemented by out-of-door observations on these forms of plant life during their active growing season. For class or individual work the rusts of grains, barberry leaves in spring, and the blackberry and may-apple cluster-cups, should be studied. The lilac *mildew*, the smut of oats and corn also are easily obtainable and may be preserved dry or as formaldehyde material.

Features of form and structure. Study such material as is presented, with the naked eye and (*m*). Observe the form, color, size, and particular place of growth of each plant. Being without chlorophyll, what class does it belong to? What is its life habit, growing as it does on what living plant? What proportion of the plant part examined is covered with the growth? Where does the fungus obtain its nourishment? What effect would this have on the host plant? Make drawings showing the result of your observations.

Examine preparations (*lp*) and (*hp*), and look for any features of mycelium, sporangia, and spores, characteristic of fungi. How may this plant have gained a foothold on the host? Consult reference books for methods of reproduction.

Reference reading. Read about the damage to growing crops caused by these plants and give the remedies recommended. Consult the government bulletins which give a large amount of information about fungus diseases and spraying for prevention. Many details of reproduction, life history, and other important features must be left to the individual teacher's judgment.

Type 10. Lichens

Habitat. The plants may be found by the pupil, growing on trees, fences, old sheds, stones, often almost completely covering the objects on which they grow.

Appearance. It is well, if possible, to have a plentiful supply of three common forms: *foliose* or leaflike; *crustaceous* or encrusting; and *fruticose* or bushy form. In the specimens presented determine to which of the above groups each belongs, also upon what the plant is found; observe the form assumed by the entire growth (lichens often form, for example, beautiful rosettes). Examine carefully and determine how the plant is attached to the object upon which it grows. Make careful drawings showing the three forms, natural size.

Experiment. Take a dry lichen, observe its color, and then thoroughly soak it. What change in size and color takes place? Recall, if you have seen it, the effect of rain on tree lichens, also on a grass plot after a warm shower.

Structure. Study with (*lp*) or (*hp*) prepared specimens of a lichen to show its real structure. Observe the interwoven mass of white threads. How do they resemble the forms already studied among the algæ and fungi? Observe, in particular, the layer of *green cells* mixed with the white filaments. What plant do they resemble? In fact, these cells are, in all probability, an alga you have studied, and the lichen is really a mutual partnership of a fungus and an alga. What advantage does such a plant have over a fungus? The fungus filaments are attached to the algæ cells by tiny rootlike structures called the *haustoria*. Of what benefit would the partnership be to the alga? This mutual relationship is called *symbiosis*, and often exists among animals. The bacteria have a similar relationship with clovers and related plants.

Reproduction. Observe on some specimens, elongated clubs, cups, or urnlike structures. These are the fruiting bodies or *apothecia*. Study a section of an apothecium (*hp*), and observe the filaments ending in spore cases (*asci*). How many spores in each case? What are the spores for?

Drawings. Draw details of lichen structure and a sectional diagram of an apothecium.

Value of lichens. From any source find out any value to man directly or indirectly which this group of fungi has. Look up, in particular, reindeer moss, Iceland moss, rock tripe, and litmus. What relation have lichens to soil formation?

A Field Study of Algæ and Fungi

Take a limited area, if possible, containing as great diversity of surface features (meadow, wood, pond, creek, sand, gravel banks, bluffs, etc.) as your neighborhood will afford. Make a careful map, drawn to a large scale, of the district, denoting by various tints the various features of topography.

Explore very carefully for any algæ, fungi, or lichens, and designate the location of the same by letter or figure on your map.

Having found as many forms as possible, summarize the whole by a table having the following headlines: —

Kinds of Plants	Number of Kinds of Each	Quantity	Alone or Associated	Shade or Sun	Water Relation	Parasite or Not
Algæ						
Lichens						
Fungi						

From all the observations made try to form a general statement for each class, stating what their environment is, and how each form seems by its structure, color, physical features of dryness, softness, etc., to be adapted to its place of growth.

Draw a few characteristic forms (natural size or *m*) of each class.

Remember definitely that the study of plants and animals in connection with their surroundings or environment is *ecology*, and is perhaps the most valuable and certainly one of the most interesting in which living things can be observed.

SECTION III. THE MOSS PLANTS

Type 1. Water Liverworts (*Riccia fluitans*)

Habitat. Riccia may be found in clear ponds or slow streams having much vegetation, and especially in cold springs of considerable volume. It is most easily grown in the laboratory, where it ought always to be found.

Appearance. Examine a plant in the water with the naked eye. What position with reference to the surface has it? Observe its color, size, shape, and mode of branching. Observe also whether the axis is cylindrical or flattened.

Structure. Examine with (*lp*). Observe the notches at the end of each branch (*vegetative* or *growing notches*) and the mottled appearance of the axis due to *air chambers* within the plant. Examine carefully the lighter areas. If possible, discover the cell network making up the surface.

A higher magnifying power will reveal the small green *chloroplasts* in the cells. Compare for form and size the cells near the margin with those near the center of the axis. What is formed by the latter? Similar features were observed in fucus.

Study a section of the axis (*lp*) and observe the cell structure and air chambers. Explain how the plant floats.

Drawings. Show all the features of plant structure by proper drawings.

Questions. How does the *plant body* of the riccia differ from most of the algæ studied? What effect has the flattened condition on the ability to float? Some of the red seaweeds have a flattened thallus[1] plant body, but they are the exception in algæ. After a study of the next subject observe the gradual change from the algæ to the land liverworts shown by this plant. How is this plant fitted for life on the surface of still waters?

Type 2. A Land Liverwort[2]

Habitat. Marchantia is a very common plant in nearly all regions, growing in deep shade where there is abundant moisture and more or less bare earth or rock. It seems to favor particularly earth that has been burnt over. It is found commonly in greenhouses (being considered an evidence of poor management). It can be grown in a Wardian case in the laboratory. *Lunularia* and *conocephalus*, somewhat similar species, are occasionally found in quantity in somewhat similar situations. If possible, examine these plants where they grow, or placed in dishes in a natural position. With reference to the earth's surface, are they erect

[1] A thallus is a plant having no distinction of stem and leaf.

[2] Marchantia.

or flat? Why do they grow in this manner? How are they attached to the earth? What color and form have the thalli? Do they grow singly or in mats? Take a specimen and place it on the table. Observe the slowness or rapidity of drying.

External features. Place a well-formed thallus in a watch glass. Examine for a midrib, wings, vegetative notches, manner of branches, and hairs that attach it to the soil (rhizoids). Examine the surface for more or less regular areas (*stomata areas*). What do you find in the center of each area? This is a stomate or mouth for the entrance and exit of air and gases.

Cupules. On some thalli, observe the peculiar structure on the upper surface appearing like tiny cups (*cupules*). Upon what are they always situated? If possible, find the different stages from the young to the fully developed. How do they differ? Look inside of a full-grown one. What do you find? Examine the contained structure (*gemmæ*, buds) with (*m*) and (*lp*), and observe the shape, color, and other features, and in particular the notches and shining globules of oil near the margin. Is the gemma a sphere or a flattened disk? How many are there in a cupule? How many cupules are there on a good-sized thallus? These gemmæ are reproductive structures that are prepared for immediate growth and are fine examples of vegetative multiplication. Explain how a gemma becomes a thallus, and how those from one thallus may soon cover a considerable area with plants.

Microscopic structure. Examine the lower surface for any stomates (*m*). Are they present or not? Examine the thin protective layer of cells which may be pulled off from the upper surface of the thallus (*lp*). Study this epidermis for the cells and the stomates. Observe the four *guard cells* of the stomate. What is their use? What color, if any, has the epidermis? Examine, if possible, a section of the thallus and observe, first, the upper and, second, the lower epidermis, and third, the middle mass of cells (mesophyll). What shape have the cells? Where is the chlorophyll located? The mesophyll cells are filled with living protoplasm, hence are the active working cells. Observe that the stomates open into irregular *air chambers.* What structures are found in these chambers? What color have they? Observe the rhizoids projecting from the lower surface, or study them separately and find the variations in form. If no fresh section is available, study a figure in some reference book.

Sexual reproduction. On certain thalli observe two kinds of erect stalks, expansed at the summit, the fruiting or reproductive branches bearing the gamete bodies. How do these two forms differ? The one with the divided top or receptacle is the *archegonial branch.* The other is the *antheridial* branch. What shape has its receptacle? Are both kinds on the same thallus or not? Study prepared sections of each receptacle, or figures of the same in your reference books, and observe the *archegonia* depending below and the antheridia in the upper surface of the respective receptacles. When mature, the sperm and the archegonial oösphere of these plants unite to produce a spore, which grows into a flask-shaped structure, which you can see on the mature receptacle of the archegonial branch, hanging downward (*the sporophyte*). The sporophyte, when mature, contains many spores, mixed with the elastic filaments of peculiar nature, *elaters,* which assist in scattering the spores. These on germination produce the thallus forms studied at first.

Conclusions. What reason can you give, or find in reference books, for the two methods of reproduction? How do these plants get into the greenhouses? What differences are there between the spores and gemmae? Explain the placing of the liverworts with the true mosses in the moss-plant branch? What new structural features are seen in the liverworts for the first time? What is meant by the term *tissue?* What tissues are found in the liverwort? How is the liverwort more complex than the algæ?

Drawings. Make the following drawings from the fresh or mounted material: —

1. Thalli of different sizes and forms, showing cupules, if present.
2. Surface (*m*) to show stomate areas.
3. Epidermis (*lp*) to show stomate structures.
4. Rhizoids (*lp*).
5. Antheridial and archegonial thalli and branches.
6. Gemmæ (*lp*).
   Details of reproduction may be added if observed.
7. Section of thallus (*lp*).

Type 3. The Mosses[1]

General statement about habitat. Mosses are so generally known that the student ought to be able to answer many of the following questions about their place and manner of growth. Recall all the situations in which you have seen mosses growing and enumerate the different forms by some brief descriptive characteristics of stem and leaves. Are they shade or sun lovers? Observe the variation in color. What habit do they all have in regard to their growing together? How do they vary in size and branching? Tabulate the results of your observation on mosses, using the form given below:

No.	Where Grown	Size	Color	Branching	Shade or Sun	Leafiness	With, Without Fruit

[1] True mosses.

Parts and structure. Examine the leafy specimens furnished (naked eye and *m*).

Observe the central stem, bearing the leaves. Are the latter few or many? Are they large or small? Why are you inclined to call them leaves? What, in your own words, is a leaf? Compare leaves of different mosses for size and shape. Mount a stem with some fresh green leaves and study (*lp*). Observe the leaf margin and the presence or absence of veins. Does a leaf appear to you to be thin or thick? Observe the cell structure of the leaf and the cell chloroplasts. Examine the leaf for stomates. Why are they absent? Examine the lower end of a moss stem for the rhizoids. What color have they? Are they branched or not? Carefully observe a large one and find out whether it is a one or more than one-celled structure. What may be the use of the rhizoids? Study a cross section of a moss stem (*lp*) and observe the cell arrangement. Why do we call the structure *a stem?* (This is the first correct use of the term.)

The Gametophyte or leafy plant. Compare the stems and leaves of a number of mosses. Examine leafy moss plants, showing the gamete structures at the summit, and possibly a green algalike filament *Protonema* at the base. These plants are *gametophytes*, and differ from each other in the arrangement of the topmost leaves. In the male gametophyte plant, designated by ♂, they form a complete rosette, in the midst of which the antheridia are borne; in the female gametophyte, designated ♀, the leaves are in a cluster more or less closely inclosing the archegonium. If preparations are furnished, study the archegonia and antheridia, or examine carefully good figures of the same found in your text-books. In either case endeavor to fix in your mind that the flask-shaped antheridium produces *motile sperms*, which in water find their way through the neck of the archegonium into the oösphere, which thus becomes a spore (oöspore).

This, in germinating, becomes the structure studied in the next paragraph.

The sporophyte. Study a complete moss (*i.e.* one with a leafy stem, capped by a naked stalk, bearing an enlargement at its summit) and observe the two structures mentioned. The stalk is the pedicel or *seta* and the enlargement is the *capsule*, often called the fruit. What is the color, size, and length of the seta? If possible, observe a young specimen. In this case what do you observe inclosing the enlarged end? Study now a full-grown seta and capsule. What is the shape, size, color, and appearance of all the visible parts of the latter (*m*)? A pointed or conical sheath or cover, fitting snugly over the end, is the *calyptra*. Remove by the fingers and observe beneath, and covered by it, a conical or hemispherical, pointed lid, the *operculum*, separated from the capsule proper by a seam. Remove the operculum, and some fine teeth, the *peristome*, may often appear, surrounding the mouth of the capsule, and showing in some cases in their midst the protruding *sporangium*. Apply pressure (*lp*) and rupture a capsule, and observe the spores. Are these large or small? Are they few or many? What shape and color have they? What use has each structure mentioned above?

Life history. You have discovered in your study of the moss that there are two different plants, each arising from a spore, but intimately connected. This condition is called the *alternation of generations*. Generation I was the leaf-bearing gametophyte — coming from a spore formed in the capsule. Generation II, consisting of the naked seta and the capsule, is called a sporophyte, and grew from the spore lodged at the summit of the female gametophyte. How do these generations differ in ability to live independent lives? Which one can be considered a parasite? What benefit is it to the moss to have its capsule elevated?

Moss problems. Thoroughly dry freshly gathered moss and then place in water. What happens? Did the changes caused by soaking occur slowly or rapidly? Did it dry rapidly? Apply this, if you can, to the explanation of why mosses are not killed by great drought or Arctic cold. What benefit to the moss is the crowded habit of living? What would you infer to be the food of mosses? Of what use to man are mosses? Read about peat and fuels prepared from this substance. If possible, examine specimens of *sphagnum*, a bog moss, and observe how it differs from the common mosses. The two groups are subgroups of the moss *class*. Find out what you can about sphagnum and sphagnum bogs.

How may mosses be related to algae? What similar features do they have?

What are so-called moss flowers? Why do you not find mosses ordinarily with sporophytes attached?

Drawings. Make careful drawings as follows: —

1. Several mosses (*m*) to show variation in form and size.
2. A complete moss (note size) and (*m*)
3. Leaves of different species (*m*).
4. Leaf (*lp*) to show cell structure.
5. Leaf section (*lp*).
6. Leaf cell chloroplasts (*lp*).
7. Rhizoids (*lp*).
8. Capsule (*lp*) with all the parts.
9. Prepared antheridia and archegonia.

SECTION IV. THE FERN PLANTS

Class 1. Ferns Proper

General statement. Ferns may be obtained fresh from any greenhouse at any time of the year and in sufficient quantities to study the leaves and their vegetative features. For much of the work, dried and carefully mounted material is prefer-able, as it is not subject to wilting and consequent uselessness. Students are often able to furnish some material, fresh or dry, and it is always a distinct benefit to the student whenever even a part of the material which he uses is brought in by himself.

Habitat. Recall where you have seen ferns growing wild. What conditions of moisture and sunlight do they generally need? What forms do you know by name? How large or how small have you seen them? How common are ferns as compared with other plants?

The Sporophyte

The leaf, external features. Acquaint yourself with the leaf characters of at least the following forms:

The *Boston Fern* (cultivated) and the *Shield, Spleenwort,* and *Brake Ferns* (wild). The characteristics which distinguish will be learned when we study the fruit (spore clusters). Observe the general appearance of the leaf (all that part commonly called the fern), and observe that it has two parts, a stalk below, the *petiole*, and a thin, green, expanded, more or less divided *blade* above. In the Boston fern the blade is once divided into lobes called *pinnæ* (pinna). In the shield fern the blade is divided twice or thrice, the second division forming the *pinnulæ* (pinnula). Observe the amount of division in any of the ferns furnished. Observe whether the stalk is smooth or bears brown scales near its base. Examine a young leaf not yet expanded. What peculiar form has it? (This form is a characteristic of ferns.) The method of leaf unfolding or expansion is *vernation*.

Study the distribution of the veins (*venation*). A characteristic form is the forked or dichotomous, with the vein ends separate.

The rhizome. Examine the fresh *underground stems* (*rhizome*), or the same preserved in some manner. (This stem is commonly called a root.) Observe the direction of growth, the size and color of the terminal growing part (*apical bud*), and the roots; also the place where the roots of the present year were or are attached. The leaves are produced at nodes, and between the nodes are internodes. What evidence do you find that indicates an age of more than one year for the rhizome? Why is the growth horizontal? Why are there not buds at both ends? Do you find any scales (rudimentary leaves) on the stem? Why are the stems of ferns living in cold regions underground structures?

Cross section of rhizome. Examine (*lp*) a cross section of the Pteris (brake) rhizome and observe carefully the four *tissues* (cells similar in form, having the same use). What color and form have the cells of the outside layer? What is the size of the cells? This layer is the *epidermis*. Study the cells next within the epidermis and occupying most of the section. What color, form, and size have these cells? *Parenchyma* or fundamental tissue?

Is the color everywhere the same? Observe two dark brown bands of cells (hard tissue) toward the center of the section. What form has each band and what size, shape, and thickness of wall have the cells? Observe the remaining tissue looking like round or oblong, lacelike areas scattered here and there about the bands of hard tissue. This tissue is the *vascular tissue*, and each area is a *vascular bundle*. Each bundle is inclosed in a necklace of cells (*bundle sheath*, endoderm) within which are wood cells (*xylem*) and *vessels* (phlœm or bast). Study a long section through the same rhizome and try to locate the above tissues. How do the cells differ in shape from the same cell in cross section? Seek to discover the use of each part of the vascular bundles.

Leaf structure. Examine (*lp*) the veins in a leaf, and observe their method of branching, and whether the ends are free from each other or united into a net. Remove a small portion of the epidermis from the upper and the lower surfaces, mount in water, and examine (*lp*). Study the transparent parts for stomates and guard cells. How do the two epidermal layers differ? Which epidermis has the stomates? What reason can you give for their absence in the other epidermis? Study a stomate carefully, and find its shape, and the number, shape, and features of the guard cells (*lp*).

Study a section of the fern pinnula to find the relation of the epidermal layers, stomates, and mesophyll. Where is the chlorophyll?

Reproduction, the sori and contents. Examine fertile leaves of the Boston, shield, spleenwort, and brake ferns for brownish structures on their surface. On which surface do you find them? These structures are *sori* (sorus). What relation to the veins? How are they situated with reference to the midrib of the lobe and to the margin? Compare the sori of as many other ferns as you may have access to, observing the difference in shape and size. The sorus is often covered with a thin skin or flap, or leaf part (*indusium*). What use may this have? How may it have originated? Examine a sorus (*lp*). Of what is it composed? Try to isolate one of the structures (sporangia) and study it carefully. Observe its form, the stalk or pedicel (if present), and a peculiar partial ring of cells (*annulus*). Try to see the sporangium from various points of view. How does the position of the annulus vary? How much of the sporangium wall does it embrace? Do you find any opening in the wall? If the sporangium is only partly grown, observe small irregularly triangular or round objects through the partly transparent wall. Those are the spores. Seek to discover the purpose of the annulus. What would you say, from a study of the spores, sporangia, and sori on a fern leaf, as to the total spore number in a fern plant? Why is such a plenitude of spores produced? What would you judge is produced when a spore from the sporangium germinates?

Sterile leaves and sporophylls. Examine sterile leaves (not having sori) of ferns like the sensitive, ostrich, or cinnamon. Observe the absence of the sori, so common in other fern leaves. Examine now the peculiarly contracted brownish or greenish clustered structures borne on stalks, and found growing from the same underground stems as the naked or sterile leaves you have just looked at. Crush a single division of one of these; mount and examine (*lp*), and observe the similarity to the sporangia studied before. These contracted stalk structures are strangely modified leaves called *sporophylls*, bearing nothing but sporangia.

The Gametophyte

Where found. The spores of the sporangia, when germinating, produce small, inconspicuous plants known as *gametophytes* or *prothalli*. The green coating on the ground of a fern house is largely composed of these minute stages in the fern life history, which, with the fern plants (commonly so called), consisting of leaf and rhizome, constitute the *alternation of generations* of the fern.

Structure. Examine a gametophyte (*vlp*), and observe its color and form. What features remind you of the land liverworts? Observe the cell structure. Discover on the lower surface, near the notch, oblong cells, *archegonia*, and, near the opposite end, more or less mixed with rhizoids, the *antheridia*. What is the actual size of the gametophyte?

Drawings. Make the following drawings:

1. A complete sporophyte (leaf and rhizome).
2. Details of venation (*m* or *lp*).
3. A cross section of a fern rhizome to show the various tissues (*lp*).

4. The several tissues (*lp*) to show cell peculiarities.
5. The upper and lower epidermis of the leaf, with the stomates (*lp* or *hp*).
6. Vernation.
7. Forms of sori (*m*) (round, long, and marginal).
8. Sporangia and spores (*lp*).
9. Sporophyll.
10. The gametophyte (*lp*).
11. Fossil ferns.
12. Several fern species to show leaf variation.

Fossil Ferns

Coal. Examine, if possible, specimens of *fossil ferns* and observe their points of resemblance to the ferns of to-day. What is a fossil plant or animal? Fossil or preserved ferns, with the related horsetails and club mosses, were in part the plants out of which coal was made. Read about this process of coal formation and learn how many steps or stages were necessary from the living ferns and gymnosperms of the ancient swamps to the veins of hard and soft coal as found to-day. (See Coulter, Barnes, and Cowles.)

Fern table. Make a table of all the ferns you are able to study, using the following form: —

Name	Wild or Cultivated	Amount of Leaf Division	Size	Color of Stalk	Sori or Sporophyll	Remarks

Description. Write a *clear, accurate, and general description* of ferns, embodying all the results of your study.

Fern problems. From all your observations, and from what you have found out by reading, what sort of environment furnishes the most luxuriant fern growth? Where, for instance, are tree ferns abundant? How do these ferns differ from ferns of cold regions? What must have been the condition during the coal period for ferns to be so abundant — in Illinois, for example — as to produce, when solidified into coal, from forty to one hundred feet thickness of the same in twenty veins? How do hard coal, soft coal, and lignite differ? Where are the coal fields of the world? There are nearly three thousand kinds of ferns. What uses do you find for this large number of species?

Pteris *aquilina* (the common brake fern) is found in every considerable land area on the earth. What would this show concerning the ancient nature of this species, and of ferns in general?

Class 2. Horsetails and Scouring Rushes

General statement. Material for study may be easily obtained in any region, but for practically all purposes, dried and mounted specimens are as satisfactory as fresh. You may have observed, in your spring walks, the fertile and sterile stems of the common horsetail, in their place of growth and their general appearance. Many students will remember the scouring rushes as objects of use in childhood play, under the names "snake grass" or "pipes." Examine the horsetail, and observe the differences between the *fertile* aërial stem and *sterile;* the former being known by its cone of fruit at the summit. How do the two forms differ in size, color, amount of branching, hardness of stem, and size and appearance of the sheaths of *scale leaves* at the nodes? Examine the branches of the sterile stem for leaves of similar character.

Leaves, in general, are the food-making organs of green plants. What part must do this work in the horsetail? Examine the stem (*m, elp*). What features of the surface do you find? In particular, observe the rows of stomates, or pores. Rub the sterile stems between your fingers, and also on a piece of rusty tin. What do you notice? Examine (*m*) sections of the sterile and fertile stems. What do you find? Explain any advantage of this condition to the plant. Examine the underground stem (rhizome) and find whether each kind of aërial stems is connected to it. How do the appearance, markings, and parts correspond to those of the aërial stems? Where are the roots attached? Are there any evidences of buds?

Scouring rush. Examine now a scouring rush. What structure takes the place of the aërial stems of the horsetail? Observe on this stem the different features found in the horsetail. There may or may not be branches. What, in particular, are the number and arrangement of the stomates (*elp*)? Determine in the same manner as for horsetails the roughness of the stem. What do you find? Is the name appropriate?

Reproduction. Examine fruiting cones (*strobilus*) of the horsetail, or preferably those of the scouring rush. Where are they situated? What is their general appearance? Observe the platelike structures that make up the outer surface (sporophylls). What is the form of each plate? Examine (*m*) a single detached sporophyll, side view, with its stalk and expanded end. Study the saclike structures (sporangia) surrounding the stalk, and attached to the inner face of the plate. How many are there, and how do they correspond to the number of sides in the plate? Crush a sporangium and observe the spores (*lp*). What is their color and shape? What is attached to them? These structures are called *elaters*.

Breathe on some spores, very gently, and observe the results (*lp*). What purpose may be attained by this peculiar action? What use was made of scouring rushes in olden times? Read about "Calamites" and "Silica" in the reference books. What part did the ancient horsetails have in the formation of coal? What are the favorite environments of plants of this class? Are they hydrophytes (water plants) or Xerophytes (dry land plants)?

Drawings. Make the following drawings:

1. A complete horsetail (fertile and sterile stems and rhizomes).
2. Node of each (*m*) to show the scale leaves.
3. Stem section (*m*).
4. Scouring rush, including strobilus.
5. Strobilus (*m*).
6. Sporophyll and spores (*lp*).
7. Stem (*lp*) to show section and stomates.

Class 3. Club Mosses

Habitat. Club mosses, such as *lycopodium*, are common in northern evergreen woods. *Selaginella* is found native in many suitable regions south of the evergreen belt. In all large cities, however, a plentiful supply of selaginella may be found, commonly in park greenhouses. Dried material may be put up during the summer which freshens readily when placed in water. The student will rarely see wild plants, and so it is not a satisfactory field study.

External features. Study selaginella and observe the position of the plant in growth, its method of branching, and the color and arrangement of the leaves. Observe also the form, color, and place of origin of the *aërial roots.* Examine the leaves (*m*) or (*lp*); what are their forms and exact arrangement on the stem? Why are there two sizes of leaves? Are stomates present or not? Study a cross section of the stem and compare it with the section of a fern stem, for any similar tissues. What purpose is fulfilled by the air roots?

Reproduction. Study a strobilus. How do the leaves differ in form and arrangement from those of the stem?

Each strobilus scale is a sporophyll. Examine (*lp*) the sporangia borne in the scale axils. How many kinds do you find, and how do they differ? Observe the *green* sporangium more attentively. What is its form and size when compared with that of the scale? Crush one and observe the large, many-faced spores, *megaspores*. What can you call the sporangium which produces megaspores only? How many spores do you find in each? Examine the other kind of sporangium. What is its color and comparative size? What markings are on its surface? Crush one and observe the spores. Are they few or many, large or small? Name the sporangium. In a strobilus try to determine the number of each kind of sporangia.

Drawings. Make careful drawings of the following: —

1. A spray of selaginella (natural size).
2. A portion of stem with leaves (*m*).
3. A leaf (*lp*).
4. A cone (*m*).
5. Mega- and microsporangia (*lp*).
6. Spores of the two sizes (*lp*).

Description. Write a careful description of selaginella or lycopodium.

Lycopodium is similar to selaginella, but has only one form of sporangium, and there are leaf differences of importance. It may be substituted, but selaginella is the better plant.

Fossil club mosses. Read about "Lepidodendron" and "Sigillaria" in the reference books. What part did these ancient club mosses have in the production of coal? What is lycopodium powder?

Conclusions from fern-plant study. Evolution. You ought to be able to understand and state the new features introduced by the fern-plant classes, *i.e.*, ferns, horsetails, and club mosses. The marked increase in complexity, the interesting life history (alternation of generations), and the value of the same, and the features that lead up to and resemble the cone-bearing trees (the next study). All these features are a part of the *evolution* of plants from lower to higher forms, and more or less clearly point out (what is the belief commonly held among scientific men) that all the complex structures of the highest flower plants have been slowly *evolved* in the long past history of our earth, from lower and simpler forms, and these in like manner from yet simpler, until at length we reach the primordial cell as in pleurococcus, or some similar structure. All the factors entering into these changes of form are not clearly known, but the effect of environment, the survival of useful and beneficial qualities, the influence of heredity, and, above all, the tendency of the *living principle* to variations, small and great, have much to do with the changes wrought. This is a very difficult subject, and it is only hinted at here that you may know a little about the theory that men use to explain the great diversity of plant forms that at the same time are connected by features of structure and reproduction.

SECTION V. THE SEED PLANTS

Class I. Gymnosperms (Conifers, "Evergreens")

A. INTRODUCTORY

We have now finished our examination of the plants of the three branches (Thallus, Moss, and Fern) below the Seed Plants, the last and highest of these great groups. These lower plants have often been called *flowerless* plants, not possessing flowers. Another term commonly applied is *cryptograms*, which signifies a hidden or obscure reproduction. A better understanding of them is, however, given by the use of the three terms above.

The Seed Plants, while in many features very diverse, unite in the production of *seeds*, structures different from anything found among the lower plants. The higher fern plants, however, have numerous points of resemblance to the gymnosperms or lowest seed plants.

This branch offers a study much more familiar to most students, for the types used are, as a rule, known to everyone, and not obscure forms or those of small interest except from the viewpoint of the trained botanist.

B. TYPES

Type 1. *Pines*[1]

Material for study. Good pine material may be obtained anywhere, either from cultivated or wild trees. It is desirable to have as large a variety as possible. White, Scotch, and Austrian pines are generally grown. The pitch or long-leaved pine may often be obtained during the holidays, and in some regions other native species occur. The general form of the trees is to be observed, the arrangement of the branches (compare with chara), and the great prominence of the central axis; the somber green of the "needle" foliage should be noticed, and the brown remains of fallen leaves. Examine the trunk for evidence of the sticky, resinous sap. Are the leaves really evergreen? How long does the leaf remain on the tree? Examine the surface of a pine branch below the leaf-bearing portion and observe the covering of protecting scales. How are they arranged? Examine now the leafy portion for the same structures. What position do they have with reference to the *short dwarfed* branches which bear the leaves. Examine a dwarf branch for its size and covering. How many leaves does it bear? Compare the different species at hand and observe the variations, if any in number.

Leaf details. Examine a leaf and observe its shape and the degree of stiffness or rigidity. Measure for length.

[1] Narrow-leaved evergreens with needlelike leaves.

What shape has it in section? Examine the surface (*m*) for dotlike markings (stomates). Are there few or many of these? Where are they distributed and how are they arranged? What color has the mature leaf? If possible, compare it with the young leaf for form, size, and color. Examine a leaf in cross section (*lp*) and look for the outer *epidermis*, much thickened, the central vascular bundle, and the *mesophyll* containing *resin ducts* or small openings in the outer portion. Carefully study each region and determine the character of the cells and their arrangement. What use has each of these features of the leaf? Observe the *palisade cells* (or the outer layer of mesophyll). How are the cells arranged with reference to the epidermis? What are the advantages of such an arrangement?

Stem in section. Examine a section of a young stem. The layers from outside towards the center are the *bark*, *wood*, and *pith*. Seek for resin ducts in the bark. Observe the sticky cut end of the twig and test its odor. Study, if you have them at hand, thin sections of pine wood, cross and long, observing cells and their peculiar form and markings. Examine pieces of white and yellow pine lumber, and find the difference in *color*, *weight*, *grain*, and *hardness*. Which would be the better lumber for various building purposes? Read about pine lumber and find all the many uses of the different species that time will permit.

Staminate inflorescence "blossoms." Examine the fresh or dried specimen of the staminate inflorescence (sporophylls) of the pine. Where is it located with reference to the old and young leaves, and of what is it composed? Examine a single part (cone of sporophylls) and observe the scales (microsporophylls) composing it. Remove the scale (*m*) and find the receptacles containing the yellow powder (*pollen* or *microspores*). What name would you apply to the receptacles? Examine pollen (*hp*) and observe all its peculiarities. What do you find out about the number of pollen grains? Why do the grains have wings? In the older botanies, these sporophylls are called *stamens*, and the sporangia *anthers*; hence the term used above, "*staminate sporophyll.*"

Pistillate inflorescence. Examine the "pistillate inflorescence." Where is it situated? What is the size and appearance of the small cone? Is it erect or nodding? Study the scale arrangement. What name would you apply to the scale? Examine the scale sporangia (here called *megasporangia*). How many are there? How many spores in each sporangium? Examine a "cone of the first year." What is its size and position? Is it erect or nodding? Why is there a difference in position of the megasporophyll cone and the yearling cone? Examine a mature cone and observe its form and scale arrangement. Where is it situated with reference to the apical bud? Examine an opened cone and find the seeds. Are they freely exposed to the air (naked) or are they entirely inclosed in a *seed* container of some sort? How do the seeds escape from the cone? Remove a seed and notice the peculiarities. Observe the wing. What purpose has it? (Throw a seed up into the air and watch it fall.) How many seeds are there in a scale? How many to a cone?

Drawings. Make drawings of the following:

1. Pine spray to show leaf number.
2. Dwarf branch with leaves (each species).
3. Leaf portion (*m*) to show stomates.
4. Leaf section (*lp*).
5. Stem section (*lp*).
6. Long and cross section of pine wood (*lp*).
7. Staminate sporophyll cone.
8. Pollen (*lp*).
9. Pistillate cones of all stages.
10. Seed.

Other work. Read about the pines. Where do they grow? What agency is necessary to enable pines to carry out their reproduction? (Look up anemophilous.) Of what commercial importance are pines? What are "naval stores"? Make a table of the useful products directly or indirectly depending on pines, thus:

Name of Pine	Where Found	Part Used	How Prepared	Use

Study of woods. Study the varieties of woods used for *cabinet* and *general building* purposes, and observe the *color*, *grain*, *hardness*, *susceptibility to polish*, *weight*, *odor*, and other features. Make a table embodying the results of your study, using the following headings:

Name of Wood	Where Native	Color	Grain	Hardness	Polish	Weight	Odor	Use

Lumber. What are meant by "hard" and "soft" pines? Why are such lumbers so much used by carpenters? Why are pine woods not durable when kept moist? What is lumber? What is pine lumber worth per thousand feet? Why is pine lumber so important? What are timbers? Into what building forms are pine logs sawed? Where does the pine lumber come from that is found in our lumber yards? What is forestry?

Type 2. The Spruces. Short-leaved Evergreens

Where growing. Spruce trees are common evergreens in cultivation, more especially the Blue and Norway. Two other common species are the "black" and "white"; these are the ordinary "Christmas trees" and are very abundant natives of the northeastern United States. The tree as it grows ought to be observed, if possible, — its regularity of form and branching and the marked arrangement of branches. Compare the form with that of a pine.

Sprays. Examine a spray of several years' growth. What arrangement has the branches? How can you tell the end of a year's growth? Examine the apical bud and the lateral buds adjacent to it. How do these help you to explain the branching arrangement and position? How many "years'" growths of the main stem are leaf bearing? Below the leaves observe the bark surface and the similarity to the pines.

Leaves. Examine the leaves. How are they borne on the twigs, like the pines or otherwise? What directions with reference to the twig do they assume? Observe the number. Examine a leaf (*m*). What is its color, shape, and size? How many surfaces has it? Examine (*lp*) for stomates and the nature of the margin and point (apex). Examine a cross section (*lp*) and compare it with a similar section of the pine. In what do they agree and in what do they differ? Make drawings showing spray, single leaf (*m*), and cross section (*lp*).

Reproduction. The process of reproduction is similar to that of the pine. If possible compare the cones of the two types, observing points of resemblance and difference.

Uses. Read about the uses of spruces in paper making. What other uses have they? What is "spruce gum"?

Type 3. Arbor Vitæ (White Cedar)

Place of growth. This tree is native of most parts of northeastern United States and is commonly cultivated as an ornamental tree. As "white cedar," it is universally known in the north as a fine timber and lumber tree, especially in railroad and telegraph construction.

Leafy spray. Examine a spray and observe the color, odor, and general appearance of the leaves. How do they differ from those of pines and spruces? They are said to be *scalelike.* How are they arranged on the twig? Examine (*lp*) and find the exact shape.

Cones. Examine the megasporophyll mature *cones.* Compare them in size, color, and number of scales with those of the pine. Are the cones few or many? Look at the seeds and observe the features.

Drawings. Draw a spray, leaves (*lp*), cone, and seed.

Other work. Read about *white cedar, ties, posts, oil of cedar, cedar knees,* and *arbor vitæ* in medicine. Also the use of the tree in horticulture, and notice the great number of varieties. What qualities make a wood durable? Railroad companies often "doctor" ties. What is meant by this? Why are cedar ties and posts better than white oak, particularly if they have been treated to prevent decay? Creosote is now in general use for this purpose.

Type 4. Balsam Fir and Hemlock

Where growing. These trees are common in the coniferous forests of the north and are occasionally cultivated for ornament. The balsam is infrequently used as a Christmas tree. If possible, examine the standing trees to observe their peculiar characters.

Spray and leaves. Study small twigs or leafy shoots of each tree. What is the arrangement of the leaves on the twig? In how many directions from the twig do the leaves project? What do you notice concerning the odor?

Examine a leaf. What shape has it? Is it flat, round, or angular in section? Examine for a *midrib*. Observe the color of the two surfaces, upper and lower. If the two species are at hand, place side by side for comparison of color, leaf size, odor, and other features.

Cones. Examine mature cones of each tree and observe their peculiarities. Can you tell the trees apart by their cones? Examine the seeds.

Drawings. Draw sprays, single leaves (*m*), leaf sections (*m*), and cones.

Uses of. Read about hemlock and balsam fir, seeking to discover all possible uses for these trees. What connection has balsam with the paper pulp industry? Read about, in particular, the tanning of leather and the connection of hemlock with this important industry. What effect on animal tissues has tannic acid? What sort of lumber does hemlock make? Compare with pine. Is it more or less valuable?

Type 5. Juniper (common) and Red Cedar

Material for study. The trees are not very common in cultivation, and it may not be possible to obtain fresh material except in favored locations, as there are many regions where the trees do not grow wild. Where obtainable, however, they are fine forms for study.

Sprays and leaves. Examine the spray of leaves. Observe the general appearance of the twig. What shape has the individual leaf? What is its size? What do you find regarding size? Are they all of one size? How are the leaves arranged? on the twig? On contact with the skin, what do you notice as to the leaf points?

Cones and fruits. Examine the microsporophyll cones, if·

they are obtainable. Observe their size and any features similar to those of pines.

Examine the juniper "berries" or megasporophyll fruits (hardly possible to call them cones). What color and size do you observe? Taste them and observe the result. Examine carefully for seeds. What do you find?

Drawings. Draw a spray, some leaves (*m*), microsporophyll cones (*m*), and the berries.

Uses. Read about "Juniper" and "Red Cedar" and find out the uses to which they are put. Read the subject "Cedar Apple" and find the connection to a disease of apples.

Examine red cedar wood and discover its peculiarities. What special uses are made of it? Why is it so durable? Where does the red cedar of commerce come from?

Addenda

A table of conifers. Make a table of all the conifers you are able to find by reading or investigating, as follows:

Name	Country Producing	Use and Value for Lumber	Use in Manufacturing	Noteworthy Features

Coniferous forests. Why are coniferous forests largely cold temperate in their distribution? What habits and structural features of pines and spruces, in particular, fit them for cold snowy regions? Why are they not destroyed by animals (herbivorous) in winter, when they are the only green things? What are mixed forests? What peculiarity in this respect do conifers show? Where are the great coniferous forests of America? What conifers are found in the southern hemisphere? What are the agents at work to destroy these forests? What is the prospect of their permanent continuance? How does Germany manage such forests? Make a map of the world on Mercator's projection and show the coniferous forest belt by a green tint. Try to make the distinction as exact as possible.

Class II. Angiosperms (Common Flowering Plants)

The subject title is introduced here to show the student the proper sequence and position of the highest group of plants. Their study has been taken up in Part I of this work.

SECTION VI. SIMPLE CLASSIFICATION OF PLANTS

Branch I. **Thallophytes, or Thallus Plants.**
The lowest and simplest of plants, without true stem and leaf.

Class I. *Fission Plants. Bacteria, Bacilli. Blue-green Algæ.*
The so-called germs. The lowest, simplest, and smallest organisms, in large part without chlorophyll, largely parasites, many injurious, some of great value.

Class II. *Fungi, Molds, Rusts, Yeasts, Mushrooms, Lichens.*
Plants without chlorophyll; many parasites; often saprophytic; many of value.

Class III. *Algæ.* Green, brown, and red forms.
Plants mostly aquatic, with chlorophyll; mostly independent; many useful for food, medicine, etc.

Branch II. **Bryophytes, or Moss Plants.**
Green plants of some complexity with combined parasite and independent generations; the mosses with small leaves.

Class I. *Hepatics, or Liverworts.* Flattened horizontal thallus forms or mosslike.

Class II. *Mosses proper*, with two subclasses.

A. Ordinary mosses, mostly terrestrial or arboreal, some aquatic.

B. Sphagnum forms, aquatic. Peat producers.

BRANCH III. **Pteridophytes, or Fern Plants.**[1]

Green plants, mostly leafy, commonly with underground stems; marked alternation of generations and complicated spore production.

Class I. *Ferns.* Several thousand species of fernlike aspect.

Class II. *Horsetails* and *scouring rushes.*

Green, hollow, jointed stems and scale leaves; conelike spore structures.

Class III. *Club mosses.* Mosslike plants with conelike spore fruits.

BRANCH IV. **Spermatophytes, or Seed Plants.**

Plants with so-called flowers and seed production.

Class I. *Gymnosperms*, or naked seeds; narrow or scale leaves (usually), mostly evergreen; pines, spruces, cedars, yews, — big trees.

Class II. *Angiosperms, or covered seeds;* vastly important.

Ordinary flowering plants of two subclasses;

A. Monocotyledons, or one-seed leaf; grasses, lilies, iris, orchids, etc.

B. Diocotyledons, or two-seed leaves; pinks, crowfoots, mustards, roses, peas, and hosts of others.

[1] Only the more important classes are named.

REVIEW TABLE, NO. I

Make a table below, filling out each column for each plant studied.

Name	Branch	Plant Body	Size	Color	Life Habit	Remarks

REVIEW TABLE, NO. II

Methods of Reproduction

Cell Division	Vegetative Multiplication[1]	Sporangia	Cell Union, Isogamous or Heterogamous	Alteration of Generations	Heterospory or Isospory

REVIEW TABLE, NO. III.

Table of Plant Associations

Name of Plant	Branch and Class	Nature of Environment	Peculiarities	

[1] Other than a single cell.

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