Mast, Samuel Ottomar,

Structure and Physiology of Flowering Plants.

1907.

Compliments of the Author

Structure and Physiology of Flowering Plants

STUDENTS GUIDE

STRUCTURE AND PHYSIOLOGY OF FLOWERING PLANTS

STUDENTS GUIDE

BY

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PREFACE.

The following laboratory directions are intended to serve as the basis for an introductory course in biological science. A student of average adaptibility can complete the laboratory work here outlined in one hundred hours.

The object in view in this course is to familiarize the student with scientific methods of study, to gradually introduce the microscope, and to teach the general structure, the life history and the more important physiological processes in phanerogams.

Unsatisfactory results in beginning the study of plants and animals with such forms as Ameba, Paramecium and Spirogyra, led to the composition of these directions for the use of students in Hope College six years ago. They have been used every year since and have been revised and rewritten several times. In revision especial emphasis was laid on the practical as well as the logical arrangement of experiments and other matter and on the needs and difficulties of students beginning the study of living beings, as observed in personally directing their work in the laboratory.

After completing the laboratory work on any given subject, the student is referred to literature selected from various texts. One or more of each of these texts should be in the laboratory. This feature of the course is considered very important, since the student thus not only gets the best written on any particular subject, within his range of knowledge; but he also necessarily becomes acquainted with a number of authors and consequently gets a broader view of the subject than he would if only a single text were used. A course conducted along these lines should be accompanied by occasional simple descriptive talks and numerous quizzes. Students frequently fail to understand the significance of many plant structures and the meaning of experiments unless they are carefully questioned about them. Undigested laboratory work has but very little value.

While these laboratory directions are intended primarily for college work, they have proved satisfactory in the hands of tenth grade students, and have been used with slight modifications in a course given yearly during the past five years. Judging from results in this work I believe this method would prove both successful and economic in all biological work in high schools. The department library can be well equipped and maintained if each student contributes about half the cost of an ordinary text in these subjects. And after the course is well organized, certain students can be appointed to take charge of the library and thus relieve the instructor of extra work.

S. O. M.

CONTENTS

STRUCTURE AND PHYSIOLOGY OF FLOWERING PLANTS.

GENERAL LABORATORY DIRECTIONS.

Be as quiet as possible while in the laboratory. Keep your table in order; do not write on it, or mar the surface in any way. Thoroly wash all dishes and apparatus immediately after using them, and return them to their proper places.

Notes will be required on all work in the laboratory unless otherwise stated in your laboratory directions. See that your notes are as nearly perfect as you can make them with regard to neatness, diction, spelling, grammar, punctuation, and capitalization. Your notes should contain descriptions of what **you do and see.** Try to make your descriptions clear enough so that by reading them any one who knows nothing at all about your work could get a clear idea of what you are trying to describe. All existing facts should be put in the present tense. Use the third person rather than the first. Occasional quotations are admissible, but if anything is quoted use proper marks to indicate it. All notes must be written in **ink.**

In correcting notes the following abbreviations will be used: Not definite, nd; not clear, nc; description before name, dbn; incorrect with reference to, (1) subject matter, ?; (2) grammar, g; (3) diction, d; (4) punctuation, x; (5) spelling, s; (6) paragraph, p. Before correcting your notes always study the object described again.

SEEDS.

Common White Bean.

In your work in the laboratory always select several apparently perfect specimens for study. Having selected several common white beans, study them carefully, aiding the eye with a hand lens, and describe one **in** detail. Whenever a description of an object is called for, describe it with regard to form as a solid, size, color, surface characteristics (i. e., hard or soft, smooth or rough, glossy or dull), structure, composition, and relation to other objects, or as many of these attributes as possible. In measuring use only the metric system thruout the course.

Note the scar near the middle of the straighter edge of the beans, a small elevation near one end of the scar, and a small hole near the other. The scar is called the **hilum**; the small elevation, the **chalaza**; and the hole, the **micropyle.** Describe each. The hilum marks the place of attachment between the bean and its stalk, the **seed stalk** or **funiculus.**

Near one end of one of your drawing cards draw a bean as seen from the side, and again as seen from the straighter edge, twice natural size (x2.) You may shade your drawing if you understand shading, but if not, draw the outline only.

Label your cards consecutively with Roman numerals, I, II, III, etc., and all the figures on each card consecutively with Arabic numerals. Let your initials appear in one corner of each card. Do not write on the cards with a soft pencil. Read the introductory chapter of Stevens' Botany, pages 1-4, and Leavitt's Botany, pages 244-245. See also Ganong's Teaching Botanist, page 165.

As soon as you have completed your drawings ask the instructor to criticise them. Do this with all future drawings, unless otherwise advised.

Structure—Study several soaked beans. What effect did the water have on their size, form, and surface markings? Remove the seed-coats, two closely united. The outer is called the **testa** and the inner the **endopleura**; describe both. Are the markings seen on the surface of the dry bean, in the testa or the endopleura? What relation does the chalaza, the hilum and the micropyle bear to the testa? All that is left of the bean after the seed-coats are removed is called the **embryo.** It is composed of two large parts, the **cotyledons,** a root-like structure, the **radicle**, and a small bud of leaves, the **plumule.** Describe each in detail. Are both cotyledons attached to the radicle? What is the relation in position between the point of the radicle and the micropyle? Is the testa in any way modified near the distal end of the radicle? How many leaves do you find in the plumule? How are they folded? Demonstrate this to the instructor by cutting and folding pieces of paper to represent the leaves.

Make a drawing (x2) that will show the plumule, radicle, and one cotyledon in their natural position.

From the study of the bean it will be seen that the embryo of a seed is really a small plant which has been arrested in its growth and is now lying dormant. We know from experience that under certain conditions, and certain conditions only, this small plant will develop into a larger one. What these conditions are, and what becomes of the different parts of the embryo, as well as the relation between the plant and its environment, we shall try to ascertain by experiments that are to follow.

Each student will perform all experiments personally, excepting those preceeded by the word class or group, which will be performed by students selected by the instructor. All students will, however, make observations on **all** class and group experiments and write them up, just as tho they had performed them personally.

Exp. 1: *In some moist soil plant three or four of each of the following seeds: bean, castor-bean, four-o'clock, corn, pea, maple, squash, and clover. Cover the seeds with soil, approximately 2 cm. deep, and set them in a warm place. Keep the soil moist. Study the development of these seeds for two or three weeks, noting what becomes of the different parts of each variety; the time it takes each to come up, the development of leaves, the position of the leaves, opposite or alternate, the kind of leaves, simple or compound, netted or parallel veined, the kind of root system, tap or fibrous, etc. The roots are to be studied, at the close of the experiment, by

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* In writing notes on the experiments use the following headings and write a paragraph under each: 1. Description of Experiment. 2. Results. 3. Discussion of results. 4. Conclusions. The descriptions of the experiments should be brief and concise. It can frequently be best given in connection with a sketch of the apparatus used. The results must be recorded *in detail*. The discussion should be clear and logical and the conclusions definitely stated.

pulling up the plants. Record the results of your study by writing a paragraph on each variety of seeds studied.

Four-o'clock. (Mirabilis.)

Thoroly study Four-o'clock seeds externally. Do you find a hilum, micropyle, and chalaza? Carefully remove the hard covering (testa) from a soaked seed. What are its characteristics? Do you find an endopleura? If so, describe. Note the leaf-like structure, a cotyledon forming a partial outer coat of the embryo. Remove it carefully. Do you find other cotyledons, a radicle, a plumule? Occupying the central portion of the seed is a white mass of substance called **endosperm.** After you have carefully worked out the form, size, color, structure, and interrelations of the different parts of the seed, demonstrate the results of your study to the instructor. No notes on the Four-o'clock seed will be required.

Cut an entire seed, which has been soaked, crosswise near the middle, and draw it as seen from the cut surface (x4). Remove the testa from another seed, cut it lengthwise thru the radicle, and draw as seen from the cut surface (x4). Read Gray's Lessons of Botany, pages 22-26.

Indian Corn. (Zea Maize.)

Carefully study several kernels of corn, dry, and describe one. On the material table you will find some corn which has been soaked two or three days. Remove the outer coat from a kernel. This coat is really composed of two coats very closely united. The inner is the testa, the outer is known as the **pericarp.** Describe.

That part of a kernel which remains after removing the coats, consists of a creamy colored embryo, seen on one of the broad flat surfaces, and endosperm, which partially surrounds the embryo. Separate these two parts and describe each.

The embryo is composed of a single cotyledon, a radicle, a plumule, and a rudimentary stem, the caulicle. The radicle, caulicle and plumule are imbedded in the flat surface of the cotyledon and can be only faintly seen. Lay these structures bare by removing parts of the cotyledon with your needle. The radicle, surrounded by a thin membrane, the root sheath, points toward the smaller end of the kernel, the plumule toward the larger, and the caulicle lies between these two. Which of these three structures is attached to the cotyledon? Cut thin cross sections of the plumule, cover them with water on a slide, and try to work out the structure with the aid of a hand lens.

Cut an entire kernel lengthwise thru the middle of the embryo perpendicular to its flat surface, and draw it as seen from the cut surface (x2). Make three cross sections of a kernel, one thru the plumule, one thru the caulicle, and one thru the radicle, and draw each (x2).

Making use of your experience in studying the bean, four-o'clock and corn, work out the structure of the following seeds: pea, squash, clover and castor-bean. The enlargement found on one end of the castor-bean is known as the caruncle. On the side of the caruncle next to the flattened side of the bean you will find a small dark projection, the hilum. From the hilum to the opposite end of the bean note a small flat ridge, the raphe, and at the end of this ridge a slight elevation, the chalaza. The castor-bean has two cotyledons which are very thin and leaf-like. They are surrounded by endosperm. No notes will be called for on these seeds, but you will demonstrate the results of your study on each variety to the instructor, and make sufficient drawings on your cards to represent the structure. Put the drawings of the pea on a card by itself.

Outside the laboratory study as many other seeds as you can conveniently get, e. g., apple, pea-nut, cherry, orange, etc. No notes or drawings will be called for on these seeds.

Literature.

Spalding: Introduction to Botany........................13-19
Gray: Lessons and Manual of Botany...........117-125, 125-128
Wood: Botany and Florist..............................58-60

Exp. 2: Plant ten peas in moist sawdust, in a flower pot. Cover the pot with a glass plate, and keep it on your table in a temperature of about 22 degrees C, 70 degrees F. Study the development of the peas from day to day. As soon as the radicle breaks thru the testa, draw one of the peas and the same pea again when the plumule breaks thru. These drawings of the pea and those that follow are to be put on the card which contains a drawing of a soaked pea. When working with seedlings always keep them in water as much as possible and handle them with great care. After the radicle of the pea, which was drawn, is about 1.5 cm. long, select two other peas with radicles also about 1.5 cm. long. From one of these **carefully** remove one cotyledon and from the other both. Ask the instructor for a piece of wood or cork (5 x 5 x 1 cm.) containing three small holes, float it in a liter can nearly full of water, and put the radicles of the three peas selected thru the holes so that they will extend into the water. Put up something for the peas to climb on as they grow. Make two more drawings of the pea with both cotyledons; one when the lateral roots appear, and the other when the leaves appear. What is the effect of removing the cotyledons? After you have arrived at a conclusion, add about 10 c. c. of culture fluid to the water and watch the development of the plants for several weeks longer.

Exp. 3: Plant several peas in perfectly dry sand. Examine them after four days.

Results; conclusions?

Exp. 4, Class: On a piece of slate about 22 x 30 cm. lay a piece of carpet paper just large enough to cover it. Cut two strips of the same paper 3 cm. wide and 25 cm. long; fold them in the middle, lengthwise, and cover the two longer edges of the carpet paper with them. Scatter a dozen or more sunflower seeds with the shells removed, some kernels of oats, and a little clover seed on the paper from end to end, and cover them with a glass plate as large as the slate. Use patent adjustable pinch cocks, test tube holders, or spring clothes pins to hold the plates together, and set one end of the plates into water approximately 2 cm. deep, so that they will be perpendicular to the surface of the water. Study this experiment from time to time for about a week. Results; conclusions?

Exp. 5, Groups of Two: Mix fifty soaked peas with an equal amount of small pieces of moist blotting paper and put them into a 50 c. c. wide mouthed bottle. Close the bottle loosely with a cork containing a hole large enough to pass a thermometer thru, and set the bottle into a 4 liter can. Cover the can loosely with a glass plate or a can cover. When the radicles of the peas are approximately 1 cm. long, partially remove the cover of the can carefully, and take the temperature of the air in it and also of the peas by thrusting the thermometer into them **without** removing the bottle from the can. Likewise take the temperature on each of the three following days. The temperature should be read as late in the afternoon as possible. Results; conclusions?

Exp. 6, Groups of Two: Carefully remove the shells from twelve sunflower seeds. Put six in each of two **clean** bottles which hold 10 to 20 c. c. Partly fill one of these bottles with tap water, but do not cork it. Fill the other bottle **entirely** with water that has been heated to the boiling point and then **cooled without** being shaken, and cork it air tight. (Note that much of the air in solution in the water is driven off by heating). Keep these bottles on your tables several days or longer. Results; conclusions?

Exp. 7: Fill a large test-tube or a 50 to 75 c. c. wide mouthed bottle which is comparatively tall, about half full of water; mark the level of the surface by tying a cord around the tube or bottle and then add 25 dry peas. Be sure to remove all bubbles of air clinging to the peas, and then record the level of the water again. Set the peas aside for 24 hours and then note the level of the water. Pour the water and peas into a dish, return the water without the peas to the tube or bottle, and record the level of the water. What is the relation between the increase in the volume of the peas and the decrease in the volume of water? What causes the peas to become larger?

Exp. 8: Mix the 25 peas used in the preceding experiment with small pieces of wet blotting paper and put them into a 50 c. c. wide mouthed bottle. Close the bottle tight and set it aside until the peas have radicles about 6 mm. long. Carefully open the bottle and insert a burning splinter, also insert a burning splinter into a similar bottle without peas. Results; conclusions? After the splinter has been inserted close the bottle air tight and compare the growth of the peas in this bottle with that of those in the open bottle used in exp. 5.

Exp. 9, Class: Obtain four 50 c. c. wide mouthed bottles, an 8 to 15 liter bottle, a small bell-jar with an opening at the top, and rubber stoppers with two holes each, to fit all the bottles and the jar. Run a glass tube thru each hole in the stoppers; one should extend to the bottom of each bottle, the other only a short distance beyond the lower surface of the stoppers. Set the bell-jar into an open dish containing water several centimeters deep, and connect the glass tubes with pieces of rubber tubing so as to make an air tight series consisting of two of the 50 c. c. wide mouthed bottles, then the bell-jar, then the two remaining small bottles, and finally the large bottle. Fill the large bottle entirely with water and the four small bottles about one-third with clear lime water, $Ca(OH)_2$. Procure a wide mouthed bottle nearly 10 cm. high, containing vigorously growing pea seedlings with radicles about one centimeter long, and place it under the bell-jar. Now siphon the water out of the large bottle by fastening a rubber tube to the glass tube which extends to the bottom of the bottle. After the water has run long enough to replace nearly all the original air in the bell-jar with air which has passed thru lime water in the first two bottles, close the rubber tubes leading from the bell-jar with pinch cocks and change the lime water in the two small bottles nearest the siphon, making sure that it is clear. Now fill the large bottle with water and siphon it off drop by drop so as to force the air thru the apparatus very slowly. The flow of water can be nicely regulated by means of an adjustable pinch cock. After the apparatus has been in operation several hours, note changes in the lime water.

(a) Results with peas under the jar.

1. In strong diffused sunlight?
2. In total darkness?

(b) Results with a frog under the jar?

Conclusions?

Draw the apparatus in outline side view.

Exp. 10, Class: Put 10 or 12 soaked peas mixed with moist pieces of blotting paper into a 50 c. c. wide mouthed bottle. After the radicles have broken thru the testa and are growing rapidly, take another bottle of the same size and fill it nearly full of water. Bend a 3 or 4 mm. glass tube in the form of a U large enough so that one arm can be put into each bottle. Pass one of the arms thru one of two holes in a rubber stopper in the bottle containing the peas, and the other thru a hole in a cork in a small test-tube containing an opening in the bottom. Insert a thermometer into the bottle containing the peas and see that the bottle is air tight. Raise the temperature to 24 degrees C. by firmly grasping the bottle in the hand, and then record the level of the water in the test-tube. Twenty-four hours later raise the temperature to 24 degrees C. again and record the level of the water. Has the volume of the gas in the bottle changed? Conclusion?

Exp. 11, Groups of Four: Select a tall wide mouthed bottle and put 25 peas into it after they have been in water 12 to 24 hours. Lay the bottle over and distribute the peas equally along the side from top to bottom. Now cover them with a strip of moist blotting paper and fill the bottle with moist sand, packing it enough to hold the seeds in place as you put it into the bottle, and set it into a depth of about 6 cm. of running hydrant water, or water kept cold with ice. As soon as the peas begin to germinate, insert a thermometer into a hole in the soil near the peas and ascertain the temperature of the lowest peas germinated.

Some students will use soaked corn, others soaked wheat, clover, or beans, in place of peas, but every student will take note of all the experiments. Results; conclusions?

Exp. 12, Class: Procure a thin glass flat bottom dish approximately 2 cm. deep, and a large flat cork to fit it. Fasten the shaft of a clinostat to the center of the larger flat surface of the cork and cover the opposite surface of the cork and the sides of the dish with blotting paper. Select six peas with straight radicles 5 to 10 mm. long and fasten three to the cork near the perifery by thrusting pins thru the cotyledons. The radicles must be parallel with the flat surface of the cork and must point toward its center. Arrange the clinostat so that the surface to which the peas are fastened is vertical. Moisten the blotting paper and cover the peas with the glass dish. Fasten the remaining three peas to a piece of wood, previously soaked in water, so that the radicles point in different directions, and place them in a damp chamber in such a position that the surface on which the peas are found is vertical. Wind the clinostat every day and keep it running a week. The rotation neutralizes the effect of gravitation. Explain how this is done. Results; conclusions?

Exp. 13, Class: Pour mercury into a tumbler to a depth of about 2 cm., then add water about 3 mm. deep. Fasten two peas with straight radicles about 1.5 cm. long to a piece of water-soaked wood tightly wedged in the tumbler in such a position that the radicles form an angle of about 30 degrees with the surface of the mercury and their tips extend to within about 2 mm. of it.

Do the radicles grow into the mercury? Conclusion?

Exp. 14, Class: In a wire basket nearly filled with wet sawdust plant a dozen peas and as many kernels of corn, so that they will lie about 1.5 cm. from the bottom. Now set the basket in a moderately damp place in such a way that the bottom will make an angle of about 45 degrees with the horizontal.

Study the effect of moisture on the direction of growth of the radicles after they extend thru the bottom of the basket. Results; conclusions?

Exp. 15, Groups of Two: As soon as the plants in exp. 1 come up, cover some of them with an opaque jar so as to exclude **all** light. Study these plants from day to day for a week or more. Results; conclusions?

Exp. 16, Class: This experiment is intended to show which chemical elements are necessary in the soil in order to insure normal development in green plants.

Plant a small handful of corn in a flower pot containing sawdust and keep it in a warm place where germination will take place rapidly. Procure nine jars holding one liter each and flat corks large enough to fit them. Put four holes about 2 mm. in diameter thru each cork and pass a glass tube about 10 cm. long thru one. Wash the jars, corks, and tubes in a weak solution of hydrochloric acid, rinse them in water, then sterilize them by immersing in boiling water, and finally wash them in distilled water. Fill the jars nearly full of distilled water and label them 1, 2, 3, etc. To the water in jar No. 1 add the following compounds and label it "All":

Potassium nitrate................	1 gram.
Calcium sulfate..................	0.5 gram.
Magnesium sulfate..............	0.5 gram.
Calcium phosphate (pulverized)..	0.5 gram.
Sodium chlorid....................	0.5 gram.
Chlorid of iron (weak solution)...	0.5 c. c.

Note the elements found in these compounds.

Jar No. 2.—Add to the water in this jar the same compounds as were added to No. 1, but add sodium nitrate in place of potassium nitrate. Label "All minus potassium."

Jar No. 3—Same as No. 1, excepting potassium phosphate in place of calcium phosphate and omit calcium sulfate. Label "All minus calcium."

Jar No. 4—Same as No. 1, excepting magnesium chlorid in place of magnesium sulfate, and omit calcium sulfate. Label "All minus sulfur."

Jar No. 5—Same as No. 1, excepting omit calcium phosphate. Label "All minus phosphorus."

Jar No. 6—Same as No. 1, excepting omit magnesium sulfate. Label "All minus magnesium."

Jar No. 7—Same as No. 6, excepting potassium chlorid in place of potassium nitrate. Label "All minus nitrogen."

Jar No. 8—Same as No. 1, excepting omit iron chlorid. Label "All minus iron."

Jar No. 9—Omit all chemicals. Label "distilled water."

After the corn seedlings planted in sawdust have plumules about 2 cm. long, select 27 vigorous specimens, put them into water as soon as taken from the sawdust, handle them very carefully, remove all particles of substance clinging to the roots, with a camels hair brush, wash them thoroly, and rinse them in distilled water. Push the plumule of a seedling thru each hole in the corks from below, and fasten it by filling the space around it with cotton. Fill all crevices around the corks with cotton and plug the upper end of the glass tubes. Wrap opaque paper around the jars, fasten it so as to exclude all light, and put the labels on the outside. Set these jars where they will be in direct sunlight at least part of the day. Replace the water evaporated by adding distilled water, thru the glass tubes once a week or oftener if necessary, and study the development of the plants until the close of the course.

Results; conclusions?

Literature.

Spalding:	Introduction to Botany	23-28
Leavitt:	Outlines of Botany	15-23
Coulter:	Text-book of Botany	84-97
Stevens:	Introduction to Botany	16-27

Histology of Seeds.

Ask the instructor for a pea that has been in glycerin for some time. With a sharp razor cut thin cross sections of one of the cotyledons, put them on a slide, add a few drops of 50 per cent glycerin and cover them with a cover-glass. Study the sections carefully with the low power and note that they contain numerous holes, many of which are filled with granules. These holes are known as **cell-cavities**, and the substance between the cavities composes what is known as **cell-walls.** A cell cavity with its contents, surrounded by a cell wall, constitutes a cell. All cells, however, do not have a wall. Find a thin place in one of your sections, move it to the center of the field, carefully turn on the high power, and study the cells. You will find granules of various sizes in them. The large ones are **starch granules** and the very small ones **proteid granules.** Turn on the low power, remove the slide from the stage, add a drop of dilute iodin to one edge of the cover glass and apply a piece of blotting paper to the opposite edge until the iodin has been drawn under far enough to reach some of the sections but not all. Now study the sections both under the low and the high power. What is the effect of iodin on starch granules; on proteid granules? Is the proportion between starch and proteid the same in all cells? Study particularly those near the outer surface. Accurately draw three or four typical adjoining cells in outline as seen under the high power and represent the granules in one of them.

Cut sections perpendicular to the cross sections already cut and study them as you did the cross sections. From these two series of sections you should get a clear conception of the form of the cells as solids. Describe the microscopic structure (histology) of a cotyledon of a pea.

Find some starch granules not in the cell-cavities. How can they get out of the cavities? Under the high power study the structure of some not stained with iodin. Make an enlarged drawing of a typical specimen showing the marking in it and describe.

Making use of the experience gained and the laboratory notes used in working out the cell structure of a cotyledon of a pea, study the histology of the following seeds: bean, corn, wheat, oats, soaked in water about 12 hours, and sunflower seed and castor-bean not soaked, and also that of a potato, which is not a seed. Make drawings similar to those made in studying the pea. Note the relative amount of starch and proteid in each seed, form, relative size of the cells and thickness of the cell-walls, etc. In which part of each seed do you find most proteid; most starch? The sunflower seeds and castor-beans contain oil. Mount some sections of these seeds in water and others in glycerin. While studying one of the sections in water under the low power, press the cover-glass lightly with a needle directly over the section, and note that globules of oil ooze out. Do you find any starch or proteid? Crush a small piece of both seeds on glazed paper with your scalpel and note the oil. What is manufactured from castor-beans? Mention several other seeds that contain oil.

Cut sections of a cotyledon of a pea or bean, the stem of which is 20 to 30 cm. long. What changes have taken place in the cells and their contents? Starch granules which are considerably corroded may frequently be found. Draw one.

Ask the instructor for six unknowns, each of which may contain one or more of the different kinds of starch you have studied, and also proteid. Ascertain the contents of each. Record your results and report to the instructor.

Mount a few cotton fibers. Note that each fiber is composed of a thin long cell, containing a very small cavity and a thick cell wall. The wall is composed largely of a substance called **cellulose.** Add strong iodin. What effect does it have on the cells? Remove the iodin with blotting paper and ask the instructor to add a few drops of 75 per cent. sulfuric acid. **Be exceedingly careful not to get acid on the microscope table, cleaning cloth, or hands or instruments. Study under the low power only.** How does the acid affect the color of the cell walls? What is the final effect of the acid on the cells? When a substance takes on the color you obtained in the walls of the cotton fibers after adding iodin and sulfuric acids it contains cellulose.

With a sharp scalpel (not your razor) cut thin longitudinal sections from the endosperm of a date seed, parallel with the surface opposite the groove in the seed. Mount them in water and note that the cells contain thick walls and small cavities. Draw two or three and test the walls for cellulose.

Literature.

Bergen: Elements of Botany....................................4-28
Bergen: Foundations of Botany...............................8-35
Bergen and Davis: Principles of Botany.....................4-18
Kerner and Oliver: Natural History of Plants.......See index

Distribution of Seeds.

Make a study of the following seeds with a view to discovering the method by which Nature acomplishes their distribution. Illustrate the form of the seeds and their appendages by means of drawings. Describe the method of distribution for each variety and give your judgment as to the efficiency of each method. Milkweed, maple, sand-bur, burdock, catalpa, witch-hazel.

Literature.

Bergen: Foundations of Botany..........................373-395
Bergen: Elements of Botany.............................191-199
Atkinson: Elementary Botany............................458-463
Barnes: Plant Life.....................................361-368
Coulter: Plant Relations...............................113-122
Bailey. Botany 158-163
Beal: Seed Dispersal......................................1-87
Avebury: Flowers, Fruits and Leaves......................52-96

STEMS.

Dicotyledonous Stems.

The stem is that portion of a plant which connects the roots with the leaves. It bears leaves and consequently must contain buds.

Thoroly inspect a horse-chestnut twig about 40 cm. long. The twig has several buds and is consequently a portion of a stem. What is the general character of the bark? How does it differ in different parts of the twig? Note the horse-shoe shaped scars, **leaf-scars.** What are they caused by? Are they alternate or opposite? Note the dots on the leaf-scars? Does the number vary in different scars? The instructor will explain, to the class as a whole, what has caused them. That portion of the stem directly underneath a leaf-scar is called a **node**; the portion between two consecutive scars an **internode.** Are the internodes of different twigs and portions of the same twig grown in different years the same in length?

Rings composed of small narrow scars, **scale-leaf-scars,** will be found on the twigs. Remove the scale leaves which surround a terminal bud one by one. How are they arranged, alternate or opposite? How many are there? What do you find in the bud? What plant structures develop from buds? Can you now ascertain what causes the rings above mentioned? How many terminal buds develop in a twig in a year? How old is the twig studied, at its larger end? How many centimeters has it grown each year? Compare the growth of last year in several twigs. Is it the same?

The smaller buds along the side of the twig are called **lateral buds.** Is there any definite relation in position between buds and leaf-scars? Lateral buds develop into branches. Do they all develop? Are the branches of horse-chestnut opposite or alternate? Does the arrangement of the branches depend upon that of the leaves? Why? Sketch the last two years growth of your twig (XI) and describe it in your notes.

Study the beech twig as you did the twig of the horse-chestnut, using the same outline. Draw and describe the last two years' growth.

The dandelion is a so-called stemless plant. Pull one up by the roots, and remove the leaves one by one, beginning at the bottom. Does the plant have a stem according to the definition of stems? If so, how long is it? How old is the plant studied?

As soon as the pea grown in the culture fluid is large enough, study the stem. Is it cylindrical? How thick is it at the bottom; near the top? Does the plant have lateral buds? Note the terminal bud. Is it protected by scale leaves? If not, why not? The leaves are compound. (See Bergen, Elements of Botany, pages 91-93.) Are they opposite or alternate? Can the stem support itself? Is there anything gained by having the stem so small at the bottom?

Study the stem of a climbing bean or morning glory, following the outline for the study of the pea stem, and ascertain, if possible, how it climbs.

Ask the instructor for alcoholic specimens of Solomon's-seal. Be careful **not to injure** alcoholic material in **any** way. Study it under water, and do not let it get dry. A portion of the stem of this plant grows underground, in a horizontal position. Do you find buds, leaves, scale leaves, or scars on the underground portion? Why call it a stem rather than a root? On the upper surface of the underground stem note several pits. What has caused these pits? How many are there? Is there any relation between the number of pits and the age of the stem?

Describe and draw the last two years' growth of the underground stem (IX), side view.

Procure a medium sized potato. Is it a stem or a root? How is the potato attached to the rest of the plant? Note the pits (eyes) on the surface. How many are there? Where are they most numerous? A very small projection is sometimes found in each eye on the border, nearest the attached end of the potato. This projection is homologous with a leaf. Near the middle find a small elevation (a bud), sometimes several. Study the eyes under a hand lens and draw one. Make an outline drawing of a potato and show the distribution of the eyes. Put a portion of a potato containing several eyes in a damp chamber, set it in a warm place and watch the development of the buds from day to day. Where do the roots come out?

Outside the laboratory study as many other stems and buds as you can—the onion or hyacinth, the cactus, the oak, the pine, the lilac, etc. Nothing need be written about these, but you will be expected to answer questions concerning them.

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Structure of Dicotyledonous Stems.

With a sharp pocket knife or scalpel cut cross sections of a horse-chestnut twig three years old. Place the sections, which should be about 5 mm. thick, on a slide in some water and study them under the dissecting microscope. Observe that the stem is composed of a central portion, the pith, which is surrounded by two layers, one of wood and one of bark. How thick is each of these layers?

The bark is composed of two layers, a brown layer on the outside, and a green layer next to it. What is the relation in thickness between these layers?

Lines radiating from the pith may be seen to extend to the bark. These lines are called **medullary** rays. If they cannot be readily seen in horse-chestnut, look for them in cross sections of a beech twig. About how many do you find? Are they all of the same length and thickness? They are distinctly seen in quarter-sawed oak. Ask the instructor for a specimen.

Wood tissue is composed of concentric layers, arranged around the pith. How many are there in the twig under observation? They are more clearly seen in elm than in horse-chestnut. Cut an elm twig about 1 cm. in diameter, off 3 or 4 cm. above and the same distance below an annular scale-leaf-scar ring. The layers can be seen better if they are cut obliquely. See that the cut ends are smooth. Let them dry a few minutes. How many layers of wood do you find above the annular ring; how many below? What does this fact teach? Numerous small holes may be seen in the layers of wood. In which part of **each** layer are they largest? Can you account for this? Have the instructor explain.

Make an outline drawing of a cross section of a horse-chestnut stem (x2).

Cut cross sections of the following stems, similar to those cut of the horse-chestnut; study these sections as you did those of the horse-chestnut, and make an outline drawing of each: beech, elder, and geranium, or any stem that has grown this year, and butternut or walnut. The central portion of the butternut or walnut stem will be found to consist of dark colored wood. This is called heart wood; it is dead. The light colored wood surrounding it is living and is called sap-wood.

Note the surface character of the bark (brown bark) on all the different trees on the campus. What causes it to become much rougher as a stem becomes thicker? Does any fall off from year to year? How is it replaced? Peel some of the brown bark from a cherry twig. Note the white spots on it, called **lenticells**. Do they vary in form in different parts of the stem? What causes this difference in form?

Exp. 17, Groups of Two: Place three pieces of willow stem about 1.5 cm. in diameter and 15 cm. long into a 2 liter can containing water 2 cm. deep. Carefully take a ring of bark 8 mm. wide from one stem so that the lower edge of the ring will be 5 mm. above the water. See that this stem and one of the remaining are right side up and the third upside down. Cover the can and put it in a warm place (23 degrees C.) Roots will develop on these stems. How long does it take them to start? Where do they come out with reference to the leaf-scars? With reference to the region from which the bark has been removed? After having learned all you can about this experiment have the instructor explain its meaning.

Histology of Dicotyledonous Stems.

As soon as you have finished the following study of the histology of the dicotyledonous stem, describe the cells of each kind of tissue with regard to form as solids, color, relative thickness of cell-walls, character of cells and contents, and also, judging from the structure of the cells and their contents in each kind of tissue, give the function of each.

With a sharp razor cut very small thin cross sections from a beech twig one year old. Mount them in water and study them under low power. Identify the bark (brown and green), wood layers and medullary rays, and pith. Find a **very thin** place near the edge of a section and study it under the high power. Note that the cavities of the cells in the brown bark are filled with brown substance. Draw four or five adjoining cells. Arrange your drawings of the cross sections so that there will be room next to each, for drawing of longitudinal sections of similar tissues. Ask the instructor to correct your drawings on the histology of the stem, while the section drawn is still under the microscope. The cavities of some of the cells in the green bark contain numerous granules called **chloroplasts.** How do the cell walls of these cells compare in thickness with those found in the brown bark? Draw three or four cells and fill in one of them. In the green bark near the wood tissue you will find patches of light colored cells, **bast fibers.** These cells are closely packed together. They are smaller than the green cells, have thick walls, and cavities so small that they appear like mere dots under the microscope. Draw three or four. Between the wood and bark is found a thin layer of tissue composed of thin flat cells. This layer is known as the **cambium region.** It can be most clearly seen in rapidly growing stems because the enlargement of the stems takes place in this region. The instructor will demonstrate how growth takes place, to the class as a whole. Draw a few cambium cells.

The woody tissue is composed of three kinds of cells, **wood-fibers,** which appear in cross-section something like bast fibers; **vessels,** containing large cavities which appear like definite holes thru the section; and **medullary ray cells,** which are much like pith cells, considerably elongated. Draw two adjoining vessels so as to represent the relative thickness of their walls, three or four wood fibers and medullary ray cells, and also a few pith cells. Test the cells in the stem for starch and cellulose. In which do you find starch; in which cellulose?

Select a short piece of stem one year old; split it in half, and cut longitudinal sections from the split surface. Study these sections carefully, with the low and high power and identify all the different kinds of cells seen in the cross sections by referring to their relative position. Many of the vessels have elongated pits running transversely in their walls. Bast fibers and medullary ray cells will not be found in every section. Why not? The medullary ray cells appear somewhat like brick-work. In connection with your longitudinal sections study macerated tissue, which the instructor will prepare for you. In macerated tissue a side view of the fibers and vessels will be seen. This is, of course, much like the view obtained in long. sections. Draw three or four cells of each different kind of tissue found in longitudinal sections excepting fibers and vessels. Make a detailed drawing of a portion of a wood fiber, a bast fiber, and a vessel as seen in macerated tissue, and another outline drawing of a few adjoining cells of each kind showing how they are united.

Exp. 18: Place the cut end of an elder and a beech twig containing several leaves into a weak solution of eosin, also the proximal end of a rather long potato with a little of both ends cut off. After 24 hours make cross and longitudinal sections of the stems with a scalpel. Study these sections, the cut surfaces, and also the leaves. What conclusions can you draw? Do you find any woody tissue in the potato; any vessels; bark; pith? Razor sections may prove advantageous in studying the potato.

Monocotyledonous Stems.

Exp. 19: Place the cut ends of two Trillium or mandrake stems into a weak solution of eosin. After 24 hours make cross and longitudinal sections of the stems with your scalpel. The structures thru which the eosin rose are called **fibro-vascular** bundles. Do you find them equally distributed thruout the stem? How long are they? Beginning at the cut end, trace several single bundles as far up the stem as possible. Do they branch? Where do they end? This can be ascertained by studying a small piece of a leaf under the low power. Describe the distribution of the coloring matter in the leaves. Conclusions?

Monocotyledonous stems are composed of **sclerenchyma** fibres forming a hard rind around the outside, **fibro-vascular** bundles scattered thruout the stem, and pith filling in the spaces between the bundles. Note these tissues under a hand lens in cross sections of a corn stem, and make an outline drawing representing their distribution.

Histology of Monocotyledonous Stems.

Make very thin cross sections of a piece of a corn stem preserved in alcohol. Study them under the high power and draw three or four sclerenchyma fibers and as many pith cells. The fibro-vascular bundles of the monocot stems are homologous with the wood and bark of the dicot stems. They are composed of two kinds of tissue, **xylem** and **phloem.** The xylem is homologous with the wood tissue of the dicot stems, and is composed of fibers and vessels. The three or four large openings are cross sections of vessels; surrounding these there will be seen cross sections of the fibers. Are the walls of the fibers thick? Note their cavities. The phloem is homologous with the bark of the dicot stems. It consists of a group of light colored cells, situated nearly between the two most prominent vessels. Are these cells all of the same size and structure? The larger ones are sievetubes. The cambium region is found only in actively growing stems. It is situated between the xylem and phloem. Surrounding the entire bundle are several layers of small thick walled cells forming the bundle sheath. Select a bundle in which the structure can be clearly seen and make an outline drawing of it about 7 cm. in diameter. Represent the phloem in outline and draw all the larger vessels and a few cells of each of the different kinds of tissue found, including large and small phloem cells. Ask the instructor to criticise your drawing while you still have the sections under the microscope.

Let the instructor give you some macerated fibrovascular bundles and rind. Find isolated cells (fibers and several kinds of vessels) composing these tissues, compare them with their cross sections already studied, and describe them with regard to form as solids, thickness of cell walls, etc. How are they joined to each other? Draw two or three of each of the different kinds of cells. Judging from what you now know about the different kinds of cells in a monocot stem, what do you think the function of each kind is? Is their structure well adapted to their function?

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For a full account of the structure or function of stems see Natural History of Plants. Index Vol. II, Part 2.

ROOTS.

Roots are those organs of plants which are usually found underground.

Recalling the work done on germination of seeds and the results obtained in exp. 17, under stems, give different origins of roots. Those roots which develop directly from stems are called **adventitious** roots. Study those found on a corn stem. Do they have a definite point of origin on the stem? Of what use are they? The cut ends of shoots of a geranium or wandering-jew may be put into jars of water at home and thus the development of roots studied.

Roots may grow in air, water, or soil. Those which grow in air are called **aerial** roots; those in water, **water roots,** and those in soil, **subterranean** roots.

As an example of aerial roots study those of an ivy climbing on a wall. (This study may be carried on most advantageously outside the laboratory.) What is the function of these roots? Do they branch from the stem at any definite place? (See Bergen—Foundations of Botany, page 36.)

Water roots may be found on plants growing in the aquarium in the laboratory. Study these roots. Do they branch? Are they attached to the stems at any definite point? Ask the instructor for a few specimens of **Lemna.** Lay one of the plants onto a slide and cut the roots off near the leaf-like portion of the plant and study them under a hand lens and the low power of the microscope. You will find some of their tips covered by a sort of hood-like sheath, called a **root-cap.** Remove some of the caps with your needles. Draw a root-tip in outline, showing the root-cap, and describe. Root-caps will be more thoroly studied later.

Complete exp. 1 by pulling up some of each of the different kinds of plants and studying their roots. To which class above mentioned do these roots belong? You will find two root systems, known respectively as tap and fibrous systems. What advantage has a tap root system over a fibrous system? Has a fibrous system any advantage over a tap root system? Outside the laboratory study the roots of dandelion, clover, yellow-dock, grasses of various kinds, etc. No notes will be required on the study of roots outside the laboratory, but be prepared to answer questions concerning them. On the clover roots note small enlargements, **tubercles.** Mount one in water and crush it under the cover-glass. Note that it contains numerous **very small** bodies which are in motion. These bodies are **bacteria.** The instructor will discuss their importance.

Exp. 20, Groups of Two: Select four pea or corn seedlings with straight radicles between 1 and 2 cm. long and put a row of dots of India ink 1 mm. apart on the radicles of two of them, beginning at the apex. On the radicles of the two others make heavy continuous lines from end to end. Fasten these seedlings to a support in a damp chamber, with the radicles pointing downward. Study the development of these roots for a day or two. Results; conclusions?

Exp. 21, Class: Select a large sound carrot; bore a hole into the upper end of it about 1.5 cm. in diameter and 5 to 8 cm. deep; make sure that the auger does not break thru the surface. Fill the cavity with molasses or a strong sugar solution and close it with a cork containing a hole about 2 mm. in diameter. Set the carrot into a two liter jar full of water; select a glass tube to fit the hole in the cork and 2 meters or more long, thrust one end of the tube into the hole in the cork and support the other so that it will stand vertical. Short glass tubes may be spliced with rubber tubing if there are no long ones at hand. Record the elevation of the solution in the tube and look for changes during the next 24 hours. What causes the changes? What phenomenon in the physiology of plants does this experiment illustrate?

Exp. 22: Cut 5 to 10 cm. from the lower end of a parsnip or horse-radish and a large sweet-clover root bearing stems and leaves, and place them in a weak solution of eosin. After 24 hours cut the roots longitudinally in half and also cut cross sections with a scalpel. How far did the solution rise? Thru which tissues did it pass? What caused it to rise? The results of exp. 21 should help you to answer the last question.

Root Structure.

The structure of roots is very much like that of stems. It will be only briefly studied. With a scalpel make cross sections of a young cherry, maple, or beech root about 1 cm. in diameter, and also of the clover root used in exp. 22. Note that the root, like the stem, is composed of three kinds of tissue, bark, wood and pith. There is but very little pith. Make an outline drawing representing the relative amount of the three kinds of tissue and their relative position.

Both fibrous roots and tap roots may become much enlarged as, e. g., the dahlia, sweet potato, parsnip, carrot and turnip. Why not call these underground stems? Make cross sections of the enlarged roots used in exp. 22 and ascertain the cell contents as far as possible. Which tissue (bark, wood, or pith) has become most modified in the enlargement of the roots? What is the function of enlarged roots? This question may be answered by the following experiments:

Exp. 23: With iodin test cross sections of a clover root taken from the soil in the fall after all growth has ceased, and of another taken from the soil in spring, after it has produced a stem 20 to 40 cm. long. Results; conclusions?

Exp. 24, Class: Cut a large carrot in half crosswise, hollow out the cut end of the upper half, hang it in a warm, well-lighted place, and keep the cavity filled with water. Why can the carrot grow without soil?

Root-hairs and Root-caps.

Ask the instructor for kernels of barley, wheat, or oats that have germinated in a damp chamber.* Note that the roots contain numerous hair-like projections, **root-hairs.** In which region of the roots are they largest and most numerous? Are they found on all parts of the roots? Do you find them on roots that grow in water? You should be able to explain the cause of this later.

* Roots to be used for this work can be readily grown by soaking kernels of wheat or oats in water twenty-four hours and then scattering them on mosquito bar suspended about 2 cm. above the surface of water in a damp chamber.

Cut about 1 cm. from the tip of a root containing root-hairs, mount it in water and study it under the low power. Crush the root by lightly pressing on the cover glass. With the high power work out the relation between the root-hairs and the cells of the roots. Note the vessels and fibers in the central portion of the roots. Draw a single root-hair showing its connection with the root in detail. Work out the history of the development of root-hairs by studying those found near the tips of the roots and illustrate by making three outline drawings showing different stages in their development.

Note that the root-hairs and the cells of the root contain a grayish granular substance called **protoplasm.** Put a little 10 per cent. salt or sugar solution on some root-hairs that are still quite short. If the solution is of the proper strength, the protoplasm will draw away from the cell walls. Cells thus affected are said to be **plasmolyzed.** Draw a plasmolyzed root-hair. Remove the salt or sugar solution by replacing it with fresh water. Does the protoplasm again return to its natural position? The instructor will explain the cause of this. What is the chief function of root-hairs? Pull up a plant growing in soil and note the relation between the particles of soil and the root-hairs.

Mount several root-tips in water and study the root-caps. Note the loose cells along the outer surface. Carefully study longitudinal sections of root-tips of onion which have been stained red. Note the root-caps and the growing point immediately back of it. Make an enlarged outline drawing of the root showing the cap and a few cells in the growing point.

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Kerner and Oliver: Natural History of Plants, Vol. I..749-777

PROTOPLASM.

Crush a wheat, oat or barley root-tip under the cover glass and study the loose cells of the root-cap under the high power. Note that they contain a grayish granular substance, **protoplasm.** In some cells you will find a small rounded mass of protoplasm. This rounded mass is called a **nucleus.** Run a few drops of strong iodin under the cover glass and after leaving it a few minutes replace it with water. What effect does iodin have on protoplasm; on the nucleus? Do you find a nucleus in every cell?

Make an enlarged drawing of one of the cells and describe it.

Cut thin cross sections of a young potato sprout, a stem. Do you find any protoplasm in the cells; any nuclei? Stain the sections with iodin as you did the root-caps. Are the cells entirely filled with protoplasm? If not, where is the protoplasm found; the nuclei? Do you find more than one nucleus in any of the cells? Draw a cell and describe.

Take a small leaf of **Elodea** from a terminal bud and mount it in water. Study it under the low and high power and note that the leaf is composed of cells which contain green bodies called **chloroplasts.** Are the cells all the same in form? Compare those at the edge of the leaf with those in the middle, and with those between the middle and the edge, with regard to form, size, thickness of cell walls, and number of chloroplasts they contain. Is the leaf one or more than one cell thick? This can be ascertained by changing the focus of the microscope. Draw three cells in each of the three regions above mentioned and fill in one.

The chloroplasts are imbedded in protoplasm. Some of them will be found to be in motion. In which cells do they move fastest? Do they move thru the protoplasm or are they carried by it? Do they pass thru the walls from one cell into another? Is the direction of motion the same in all cells? Add one drop of 20 per cent. salt or sugar solution to one edge of the cover glass and slowly draw it under by means of a piece of blotting paper held at the opposite edge. After the cells in the leaf are slightly plasmolyzed replace the solution with water. Result; conclusion? Ask the instructor for alcohol containing Elodea leaves. Study one of the leaves under the microscope. What change did the alcohol produce in the leaf; in the chloroplasts? Compare the alcohol with fresh alcohol and note the difference in color. Conclusion? What is the green color in leaves due to?

Literature.

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LEAVES.

Leaves are those organs of plants especially adapted to expose large surface areas to light and the atmosphere. They are borne on stems.

Review the work already done on leaves which grew on the several plants raised in the laboratory under exp. 1, and also the work done on buds. From what plant structure do leaves develop? Into what two large classes may leaves be put? What is the relation between the venation of leaves and the number of cotyledons in the seeds from which they develop?

Leaves are usually composed of two parts, a slender, more or less elongated portion called **petiole**; and an expanded portion called the **blade.** Can you find any leaves without petioles; any without blades? In addition to the two parts above mentioned, leaves often have more or less leaf-like expansions at the base of the petioles, called **stipules.** Note the stipules on geranium leaves, pea leaves, and others. Do you find stipules in very young leaves? What is their function in buds? In some leaves (bean e. g.) the proximal end of the petiole is modified into a sort of cushion, called a **pulvinus.** The pulvini are functional in leaf movements.

Netted veined leaves may be either **palmately** or **pinnately** netted veined. As an example of the former, we will study the maple leaf. What is the general shape of the blade of a maple leaf? Is its border smooth? How many prominent points does it contain? Where do the large veins ending in the points originate?

Make an outline drawing of the under surface of a small maple leaf (1x), represent the large veins of the entire leaf, and **all** the veins of a small portion.

As an example of pinnately netted veined leaves, beech leaves will be studied. In the study of a beech leaf follow the above outline and draw a leaf as directed there.

Following the same outline, study and draw a leaf of wandering-jew (Tradescantia), which is a good example of parallel veined leaves.

All the leaves studied thus far are simple; a petiole bears but a single blade. Many plants have compound leaves in which a petiole may bear several blades or leaflets.

Leaves may be pinnately compound or palmately compound. As an example of the former study a locust leaf. How many leaflets has it? Is the number of leaflets the same in all leaves? Why call it pinnately compound? Answer this question by studying the following leaves and making outline drawings of each (½x) in the order mentioned: elm, oak, dandelion, locust.

As a typical specimen of palmately compound leaves, study a horse-chestnut or woodbine leaf. How many leaflets does a single petiole bear? Why call these leaves palmately compound? Try to answer this question by studying and making outline drawings (½x) of the following in the order mentioned: woodbine, or horse-chestnut, cut leaf maple, cheese-weed, Nasturtium. Make a special study of a **large** number of red raspberry and blackberry leaves out of doors. Do all the leaves have the same number of leaflets? Are the leaves pinnately or palmately compound? Can you work out any relation between these two classes of leaves in this study? Illustrate by means of outline drawings. Report your results and conclusions to the instructor.

Study several horse-radish plants and note that they bear both simple and compound leaves. Where do you find the compound leaves? Is there any advantage in having them thus situated?

Does your study of leaves thus far seem to indicate any relation between leaves of various forms?

Cut a maple twig bearing several leaves from a well shaded portion of a tree. Are the leaves opposite or aternate? Are the petioles of the same age equal in length? Do they all form equal angles with the stem? How do these variations affect the light relations of the leaves? Throw the twig bottom-side up on the table so that the leaves will have nearly the same relative position they had while on the tree. Make an outline drawing of the terminal end of the twig, including **six** leaves (x¼). In accordance with the above outline study a beech twig and make a drawing similar to the one made of the maple twig. Study and describe the light relations of the leaves of the following plants: lilac, horse-chestnut, milkweed, and prickly lettuce.

Leaf Movements.

Exp. 25: On a bright, clear day note the position of the leaflets of the compound leaves on a locust tree and a clover or Oxalis plant, about 6 A. M., 9 A. M., 12 M., 3 P. M., and 8 P. M. By means of diagrams represent the position of the leaflets at each observation and describe. What causes the leaflets to change their position? Is this of any importance to plants? Note the difference in the position of leaflets in strong sunlight and that of those in the shade. Cover a clover plant early in the day so that it will be in total darkness. Study the leaflets an hour later. Results; conclusions?

Exp. 26: Pick a young Nasturtium leaf with a long petiole, insert the petiole thru a hole in a cork into water in a bottle, and set the bottle onto a large sheet of white paper in the dark room, in such a position that the blade will receive light from only one direction. On the following day note the change in position of the leaf, turn the bottle thru an angle of 90 degrees, rest your head against some fixed object about 50 cm. above the leaf, close one eye, and trace the outline of the leaf and the petiole on the paper. An hour later and again 24 hours later make similar tracings with the eye in the same position in which it was in making the first. Results; conclusions?

Exp. 27: Select a sunflower plant growing in the open, where the sun will shine all day. At 7 or 8 A. M. on a clear day make a diagram showing the position of the stem and two opposite leaves near the top as seen from the north. At 12 M., viewed from the same place, make another diagram over the first so that it will show the change in position of the leaves and stem. About 6 P. M. make another diagram, over the first two, again showing the change in position of leaves and stem. Conclusion?

Exp. 28: Slightly touch a leaf of a sensitive plant.

Do all the leaves on the plant respond when only one is touched? Try to learn if all parts of a leaf are equally sensitive, by touching different parts **very** lightly with a small splinter. Cover a plant whose leaves are in their normal position very carefully, so as to shut out all light. After the plant has been in the dark half an hour note the position of the leaflets and leaves, and again half an hour later.

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Bergen: Foundations of Botany.........................119-149

Photosynthesis.

Exp. 29, Groups of Two: With a sharp knife cut two slices about 1 cm. thick, from a cork 1.5 cm. in diameter; put the smooth surface of one of the corks against the upper surface of a healthy green Nasturtium or cheese-weed (Malva) leaf and that of the other piece directly opposite against the lower surface of the leaf; stick two pins thru the corks so as to hold them closely against the leaf. Now select a second green leaf on the same plant and without injuring it in any way put the blade into a wide mouthed bottle containing 1 c. c. of 75 per cent. potassium hydrate (KOH), which the instructor will give you. Be very careful not to get this to the leaf. It is used to absorb the carbon dioxid in the bottle. Put a hole, slightly larger than the petiole, thru a cork which fits the bottle; cut the cork in half thru the hole and close the bottle with it; put a little vaseline on the cork around the petiole, so as to make the bottle practically air tight. Set the plant in a well lighted place so that the leaves selected will be exposed to strong light. Late in the afternoon of a bright day, after the pieces of cork have been on the leaf two or three days, pick (1) the leaf to which the pieces of cork were fastened; (2) the leaf in the bottle; (3) a leaf which is partly white, a variegated geranium leaf; and (4) in the morning before daylight pick a third leaf from the plant to which the pieces of cork were fastened. Label these leaves 1, 2, 3 and 4 by slipping their petioles thru small pieces of paper containing these numbers. Boil all the leaves two minutes as soon as they are picked and put them into a wide mouthed bottle containing 15 c. c. 80 per cent. alcohol. As soon as the leaves are no longer green (one or two days) take them out, wash them and lay them on a white plate containing a weak solution of iodin, about 5 mm. deep. Result; conclusion?

Exp. 30, Class: Invert a funnel over some aquatic plants in water (e. g. Elodea), lower the funnel until it is entirely under water, and fasten it. Fill a test tube and invert it under water, then raise it and slip it over the smaller end of the funnel. After several cubic centimeters of gas have collected in the tube, test it with a glowing (not flaming) splinter. Results; conclusions?

Exp. 31, Groups of Two: Break off two branches of Elodea 5 cm. long, fasten them to a glass rod and submerge them in a jar of water, about the temperature of the room. Place the jar containing the branches in direct sunlight. Note that bubbles of gas pass from the cut ends of the branches. After the jar has been in sunlight 10 minutes ascertain the number of bubbles given off per minute. Put the jar into strong diffused sunlight and 10 minutes later ascertain the rate of the bubbles per minute. Then put the jar into total darkness and 10 to 20 minutes later again ascertain the rate. Results; conclusions?

What is the gas given off largely composed of? Is there any gas given off by these green plants in darkness? If so, what becomes of it?

Respiration.

Exp. 32, Class: Early in the forenoon put a green plant in place of the peas in the apparatus used in exp. 9. Set the apparatus into strong diffused sunlight and keep it running very slowly all day and the following night. Results, (1) in the light, (2) in darkness? Conclusions?

Transpiration.

Exp. 33, Groups of Two: Pass the cut end of a twig bearing several leaves thru a small hole in a cork into some water in a small bottle. See that the cork fits the bottle so as to make it practically air tight. Put the bottle with the twig, whose leaves must be dry, into a dry fruit jar, close the jar tight, and set it in a well lighted place, but not in direct sunlight. Make observations late in the afternoon of the following day. Do you find any moisture condensed on the inner surface of the jar? Conclusions?

Exp. 34, Class: Pour mercury into a "U" tube until it is about one-half full and then water until it is entirely full. Pass the cut end of a maple twig bearing about a dozen leaves thru a hole in a cork which fits the tube, so that it will project nearly 1 cm. into the water. Cover the cork with melted paraffin so that it will be **air tight.** After 24 hours measure the difference in the height of the mercury in the two arms of the tube and calculate the pressure. Conclusion?

Exp. 35: Fasten two dry watch glasses to a large begonia leaf that is connected with a plant, so that one will have its concave surface against the upper surface of the leaf and the other its concave surface directly opposite against the lower surface. The glasses may be held in place by means of a wooden test-tube holder, or small sticks held with rubber bands. After 24 hours do you find any moisture condensed on either watch glass? Strip a little epidermis from both surfaces of an old leaf. Do you find stomata in both? Conclusions?

Exp. 36, Class: Procure three leaves, two that have but comparatively few stomata (none on the upper surface) and a **thick** epidermis (e. g., oleander, begonia or India rubber) and one that has many stomata and a rather thin epidermis (iris or lily or any other plant that grows in a moist place). Cover the lower surface and the cut end of one of the two leaves with vaseline so as to close the stomata and hang the three leaves side by side. Which dries first? Conclusions? Strip a bit of lower and upper epidermis from leaves similar to those used and study it under the low and high power. Results; conclusions?

Histology of Leaves.

Place a small piece of a lily leaf between pieces of pith and cut **thin** cross sections. (Pliable tissue like that in the blade of a beech or lily leaf can be cut much more satisfactorily by folding it so as to have several thicknesses and then placing it between pieces of pith). Mount the sections in a little water, then add a drop of 50 per cent. glycerin. Study the sections under the low power until you know which is the upper and which is the lower surface. Find a thin place where the cells appear definite and turn on the high power. A layer of light colored cells will be found both on the upper and the lower surface, called the upper and lower **epidermis** respectively. How many cells thick are each of these layers? What do the cells contain? Are the cell walls equally thick on the outside and the inside? Is this of any importance to the plant? Green colored cells will be found between the upper and the lower epidermis. Near the upper epidermis these cells will be found to be arranged in a more or less definite layer, the **palisade parenchyma.** What is the form of the cells in this layer? How many cells thick is it? Are there any spaces between the cells? The cells between the palisade parenchyma and the lower epidermis form a layer known as the **spongy parenchyma.** What is the relation in thickness between this layer and the palisade parenchyma? What is the form of the cells found in it? Compare the intercellular spaces with those found in the palisade parenchyma. Compare the cells of the two layers mentioned with regard to color. What is the green color due to? Masses of grayish colored cells will be found here and there in cross sections of the leaf. These are cross sections of **fibro-vascular bundles.** Are the bundles in the leaf continuous with those in the stem and root? What is their function? Lay your sections aside. Do not destroy them. Strip a bit of epidermis from both the upper and lower surface of a leaf. In the lower epidermis look for groups of cells forming elliptical rings, called **stomata.** How many cells do you find in a stoma? Draw one with the cells surrounding it. Do you find any stomata in the upper epidermis ? Look for them in your cross sections. Note that each stoma contains an opening thru the epidermis. Into what do these openings lead? What is the function of stomata? Why does Elodea need none? Make an **enlarged** drawing accurately showing all the tissues of a leaf except the bundles. By means of iodin determine the cell contents as far as possible.

Following the above outline, study a beech and begonia leaf and compare their histology with that of a lily leaf.

Literature.

Bergen and Davis: Principles of Botany................102-122
Stevens: Introduction to Botany........................81-134
Coulter: Text Book of Botany...........................16-40
Atkinson: Botany...................................35-80
Spalding: Introduction to Botany.......................61-73
Bergen: Foundations of Botany.........................150-177
Bergen: Elements of Botany...........................111-142
Geddes. Chapters in Modern Botany....................161-189
Coulter: Plant Relations...............................35-52
Strasburger: Practical Botany..........................189-203
Strasburger: Text Book of Botany.....................185-223
Barnes: Plant Life.............................See index
Bessey: Botany................................See index
Kerner and Oliver: Natural History of Plants.......See index

MODIFIED PLANT STRUCTURE.

Stems or Shoots.—The modified underground stems of Solomon's-seal and Irish potato have already been studied. Review the work done on these. As examples of others, study tendrils of grape vine, woodbine and Japanese ivy, the so-called leaves of green-house smilax and stems of cacti, the thorns of honey locust and thorn apple. Why call these structures stems or shoots? What is the function of each? Draw a specimen of each.

Leaves.—As examples of modified leaves or portions of leaves, study the leaves of a pitcher plant and onion; the spines of barberry, common locust and common thistle; the tendrils of wild smilax and pea; and the petioles of poplar, Nasturtium and Solanum jasminoides. What has been modified in each case to form these structures? What is the function of each? Draw a typical specimen of each.

Modified organs found in flowers will be studied later.

Roots.—Roots become much less modified than stems and leaves. Can you see any reason for this? As examples of modified roots we have studied enlarged roots and aerial roots. Review the work done on them.

Literature.

Strasburger: Text Book of Botany...........22-27, 34-36, 42-43
Stevens: Introduction to Botany...................134, 136-146
Geddes: Chapters in Modern Botany.......................1-57

FLOWERS.

Flowers are in general reproductive organs of plants. Review the work done on buds. What kind of buds did you find with regard to contents? Considering origin, is there any relation between a flower and a shoot (a stem with its leaves)?

Select for study some typical flowers, e. g., Trillium, tulip, or butter-cup.

Exp. 37: Cut a Trillium, or any other light colored flower so that its stem, **peduncle,** will be about 5 cm. long, place the cut end into a weak solution of eosin. After 24 hours study the petals and sepals. Results; conclusions? Draw a petal and a sepal (x1), showing the principal veins.

Note that a flower has three sets of organs: (1) The outer set, composed of more or less leaf-like structures, is called the **perianth:** (2) the uppermost set is composed of several parts, **pistils,** more or less closely united. It is called the **gynoecium:** (3) The set between the perianth and the gynoecium, composed of several slender projections (stamens), this is called the **androecium.**

Perianth.—The perianth may be composed of one or more than one whorl. If there is more than one whorl and the whorls differ, the outer is called the **calyx** and the rest the **corolla.** The divisions of the calyx are called **sepals** and those of the carolla **petals.** Does the flower studied have a calyx; a corolla? How many divisions in each? What is the relation in position between the petals and sepals? Draw a petal and a sepal (x1). If either the petals or sepals differ in form, draw one of each kind, showing the difference.

Androecium.—How many stamens does the androecium contain? The distal end of the peduncle to which the floral organs are attached is called the **receptacle.** Are the stamens attached to the receptacle or to the petals? If not to the petals, are they attached directly above or between the petals? A stamen is composed of two parts, a rather slender stalk-like part, called the **filament,** and a more or less enlarged part called the **anther.** Draw a stamen, side view (x2). Examine several flowers, some just open and some much older. In what respect do the anthers differ? Do you find a yellowish powder-like substance, **pollen,** on any? If not, let the instructor give you some. Mount a little dry and study. Pollen is composed of numerous small bodies called **pollen grains.** Each pollen grain usually consists of a single cell. Put some water on your specimen. Make an enlarged drawing of a typical grain.

Exp. 38: Mount a little pollen of sweet pea, begonia, common locust, mandrake or sweet-strawberry bush in 10 per cent. sugar solution. Draw one of the pollen grains and then put the slide into a damp chamber. Examine the grains thoroly every day, especially near the edge of the cover glass. As soon as there is any marked change in form, draw a single grain showing the change. Twenty-four hours later make drawings again showing further changes. Conclusions?

Make cross and longitudinal sections of some large anther taken from a bud; study these sections and note that the anther contains chambers **(pollen sacs).** How many pollen sacs are there in the anther studied? Describe them with regard to form as solids, size and relation in position. Do you find any pollen grains in the sacs? Are they attached? Draw a cross section of an anther **in outline.**

Select several anthers, some with pollen clinging to the outside and others much younger. Try to learn how the pollen gets out of the sacs by studying these anthers under the hand lens and attempting to open them with your needles.

Gynoecium.—Of how many pistils is the gynoecium of the flower studied, composed? Each pistil is composed of three parts, an enlarged basel part called the **ovary**; a more or less enlarged part found at the distal end, called the **stigma**; and a part connecting the stigma with the ovary, called the **style.** In some flowers the style is very short or absent. If there is more than one pistil in the gynoecium, they may be more or less completely united, i. e., the ovaries of the several pistils may be united and the styles and stigmas free. Describe, and draw the gynoecium of the flower studied, side view (x4).

Examine in water under the miscroscope, several stigmas, both of flowers just opened and of flowers much older. Is the surface rough or smooth? Do you find any pollen grains attached to it? Have any of the grains germinated? If so, in which direction do the pollen grain tubes extend? If the stigmas are too thick to study under the high power, split them. The instructor will demonstrate the function of the pollen tubes after you have completed the study of the ovary.

Make cross sections of a young ovary and study them under the low power. How many chambers does the ovary contain? If it contains more than one it is a compound ovary and each chamber represents a simple ovary. Note the approximately spherical bodies **(ovules)** in the chambers. To which part of the chambers are they attached? How many are there in each chamber? In order to ascertain this and the form of the chambers, break open some of the oldest ovaries you can get. The stem-like structures by means of which an ovule is attached is called the **funiculus**, and the point of attachment between the ovule and the funiculus, the **chalaza.** Draw in outline a cross section of an ovary showing the ovules. Into what do the ovules develop?

An ovule is composed of a central mass, the **nucellus**, which is nearly surrounded by an integument composed of one or more layers of cells. Cut very thin cross-sections of an ovary taken from an unopened bud of Trillium, lily, or Canna, also ask the instructor for paraffin sections, which you will mount as directed. Carefully work out the structure of an ovule. Of how many layers is the integument composed? Note the opening into it, the **micropyle.** Try to work out the cell structure of the nucellus. Draw an ovule as seen under the high power as nearly accurate as possible.

By means of two diagrams show the relation in position between the floral organs. Refer to Ganong's Teaching Botanist, page 229, for a model of such diagrams.

Study the perianth, androecium, and gynoecium of a white water lily or Canna, following the above outline, omitting the experiments and sections of anthers and ovaries. Do you find any apparent relation in structure between the floral organs in these flowers? Draw all organs necessary to make this interrelation clear. Is there any apparent relation between leaves and sepals in any flowers you have worked on. Study various flowers you may find outside of the laboratory in order to answer this question. Morphologically, what do sepals, petals, stamens and pistils appear to be? Entire flowers? Give reasons for your answers.

Pollination.—The transfer of pollen from anther to stigma is called pollination; if from an anther to a stigma in the same flower, **close-pollination**; if from an anther of a flower to a stigma of a different flower, **cross-pollination.** Outside the laboratory study at least six flowers which are fertilized by cross-pollination, and describe with regard to color, structure and odor. In what way do these characteristics facilitate cross-pollination? By means of what agents is pollen transferred?

Study and describe two flowers which are fertilized by close pollination.

Note the arrangement of various flowers on stems after reading Bergen's Foundations of Botany, pp. 186-191, or Bergen's Elements of Botany, pp. 131-136.

Literature.

Stevens: Introduction to Botany........................162-206
Avebury: Flowers, Fruits and Leaves....................1-44
Bergen and Davis: Principles of Botany..............123-146
Coulter: Plant Relations 123-137
Atkinson: Botany............................443-449; 318-338
Coulter: Plant Structures....................218-231; 181-217
All other works on Botany.........................See index