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LABORATORY MANUAL FOR ELEMENTARY BOTANY

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LABORATORY MANUAL
FOR
ELEMENTARY BOTANY

BY
EDMUND W. SINNOTT
Professor of Botany, Connecticut Agricultural College

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PREFACE

No written series of directions or manual for the student, however skillfully compiled, can be successfully used as a substitute for good teaching on the part of the instructor himself. The temptation is perhaps to lean too heavily upon text-books and laboratory outlines, especially in large elementary courses where certain of the methods of "mass production" must necessarily be employed, and to regard the instructor, particularly in laboratory courses, rather as an executive whose duty is to make a well-organized machine run smoothly than as a personal guide and stimulus to the individual student. All teaching would be more effective if there were no intermediary between teacher and learner, but where the instructor is responsible for large classes in the laboratory, with the often involved and technical procedure there required, it is essential that a means be found for relieving him of some of the more mechanical details of explanation and direction. To supplement the work of the instructor, but by no means to supplant it, is thus the purpose of any laboratory manual.

The present Manual has been written in response to requests for a series of laboratory exercises to accompany the author's "Botany: Principles and Problems," and is in large part a codification of the laboratory procedure which has been worked out in his own course. Most of the experiments and descriptive exercises will be familiar to teachers of elementary botany, but they are here simplified as much as possible and presented in a form which experience has shown to be most workable and effective. A minimum of expensive apparatus and material is called for, though of course superior equipment will improve the quality of the work. The author has made frequent use of Professor W. F. Ganong's valuable series of normal apparatus.

The exercises in general follow rather closely the presentation of topics in the author's book, but they could well be used to accompany any standard elementary text. They are by no means exhaustive, and exigencies of equipment or material may necessitate omissions, substitutions, or changes in order.

An attempt has been made to avoid the chief danger of most laboratory work—a degeneration into mere mechanical routine—by requiring the student to find answers to a considerable series of questions about his material and to record his experiments in a thorough and critical fashion.

The author wishes to extend thanks to his colleagues, all of whom have been of valuable assistance in the development of the laboratory course on which this Manual is based; and especially to Professor G. S. Torrey for many suggestions and for a critical reading of the manuscript.

E. W. Sinnott.

Connecticut Agricultural College,
July, 1927

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SUGGESTIONS FOR THE STUDENT

Laboratory work is in many respects the most important part of a course in botany, for by its means the student becomes acquainted with plants through direct study of the plants themselves and not from someone else. To help him in taking intelligent advantage of the opportunities offered by laboratory study is the object of a Laboratory Manual. Such a book should by no means tell anyone what to see but should suggest to him some of the important objects for which to look and formulate the problems which he will endeavor to solve. It should also provide directions for a satisfactory procedure whereby to accomplish these ends.

Rightly used, such a Manual may be of great service and is often indispensable; but there is grave danger that any set of suggestions and directions may tend to become a substitute for active thought and that the laboratory work may thus degenerate into a merely mechanical process of grinding out certain required notes and drawings and thus entirely fail of its purpose. To avoid this the student should endeavor to maintain constantly an attitude of thoughtful interrogation. He must "ask the plant," using the Manual or the instructor only for information which cannot be otherwise obtained. In the present book a considerable number of such questions are proposed; but many others will occur to one who approaches his task with real interest, and in finding the answers to these he will gain far more than the mere completion of a required laboratory routine can ever give. When one acquires an automobile, he naturally becomes intensely interested in learning how it is put together and how it "works." If in the same spirit he approaches a study of the structure and operation of the plant as a living machine, he cannot fail to acquire a real understanding of plant morphology and physiology.

Characteristics of Good Laboratory Work.—The important objective of laboratory work is an understanding of plants and their activities, but in order to crystallize and clarify the results and conclusions obtained there and to record them in suitable form for future reference, it is necessary to make somewhat extensive written notes and drawings. Certain desirable qualities in these laboratory records should always be borne in mind.

Neatness.—Neatness in a laboratory report is an indication of care in its execution and is the mark of a certain mental orderliness indispensable for scientific accomplishment. A careless and "sloppy" record is not only unsatisfactory in itself but betokens the lack of a proper attitude toward one's work. Cleanliness of execution, an abstention from soft, smudgy pencils, and a little thought as to arrangement of the notes and drawings will add vastly not only to their appearance but to their value.

Accuracy.—It seems hardly necessary to say that the laboratory records should be as accurate as it is possible to make them, but accuracy seems not to be a natural and easy virtue. One is often tempted to be satisfied with a given observation or result if it is approximately correct. There is also a persistent tendency to be biased in an observation by the thought of what one ought, or expects, to see. The ability to observe and to describe a fact exactly as it is constitutes a valuable scientific accomplishment and should be one of the important by-products of laboratory work.

Completeness.—In every laboratory exercise there is a certain series of objectives, set forth in the Manual or by the instructor, which must be attained; but these represent only the *minimum* results that may be gained. A keen observer will be able to see much more than these, not only as to actual facts but as to the various implications which these facts suggest. There is more to be found in all the exercises than appears at first glance, and the success of a student in the laboratory will be measured very largely by the thoroughness and completeness with which he covers the field.

Laboratory Notes.—Good notes are first of all neat and legible; and when written with pen or medium soft pencil they will be much easier to read than if the drawing pencil is used. If notes are confined to only one side of the paper, and only one laboratory exercise is presented on each page, the danger of confusion is minimized.

Care should also be taken in the composition itself not only to attain correct spelling, punctuation, and grammar, but to present every statement with clarity and conciseness. Many laboratory reports are injured by being excessively "padded" with superfluous and poorly written material.

New technical terms, introduced from time to time in the laboratory work, must be understood and made familiar. A good glossary is useful for this purpose, but perhaps a more effective means is for the student to build up his own glossary, adding thereto each new term as it appears and defining it in his own words. A few pages at the back of the notebook may be reserved for this purpose and will make a valuable addition to the laboratory record.

Laboratory Drawings.—It is not meant that an undue length of time should be spent in making drawings, but a certain amount of effort thus devoted will stimulate one to observe more carefully and exactly than he otherwise might and will tie the facts into his mind more firmly. Good drawings also constitute a valuable record of work for future reference.

Successful scientific drawing is by no means difficult of accomplishment if a few simple rules are observed.

Drawings made with a rather hard pencil, 4H or 6H, are much more satisfactory than those with a softer one, for the latter smudge badly and soon look very untidy. The pencil point must be kept sharp, and every effort exerted to make all the lines of the drawing clear, clean, and firm. If the hand and forearm are rested on the table, and trembling thereby eliminated, such a line is much easier to attain. If the drawing is constantly turned so that the convex side of the curves is always away from the hand, the wrist or elbow may be used as a pivot and a much smoother result secured. It is often useful to sketch in a drawing with a light line until it is satisfactory, then erase almost to invisibility and finish with a smooth dark line.

Irregular and "scratchy" lines often conceal more than they reveal, and frequently give an erroneous impression. Make every line represent an actual fact in the object studied. Shading and other means to produce "artistic" effects are time-consuming and very difficult to use successfully, and they may often be a positive hindrance. Simple line drawings, in many cases even semi-diagrams or diagrams, are far more satisfactory, for by their means the essential facts to be portrayed may be brought out and emphasized and the irrelevant details eliminated. Much of the skill in scientific drawing consists in knowing what *not* to draw.

A common excuse for poor laboratory drawings is that the student has no artistic ability; but training and natural aptitude are by no means essential for satisfactory attainment here. Drawings of this kind are merely the record and measure of what the observer sees; and if he can see an object clearly and understand it thoroughly, he will be able to portray it in an accurate and satisfactory manner. Seeing a thing is really very much harder than drawing it!

Drawings of scientific apparatus should be made with a ruler wherever possible. Sectional views or elevations, such as are used in simple mechanical drawings, which show the internal construction of the apparatus, are not only very much clearer and more useful than external pictures but are far easier to make.

It is very important to plan the size of the drawing and to lay out its proportions on the sheet before any of the actual work upon it is commenced. Drawings that are too small are hard to decipher and very large ones tend to be awkward. In many cases the relative size of parts in a drawing of apparatus may be changed so as to make a more compact and understandable representation without losing any essential fact. Where more than one drawing is placed on a page, care should be exercised to have them well spaced and harmoniously arranged. It is best to use only one side of the paper.

There is much opportunity for the use of good judgment in the amount and character of the labelling. If the words used are written or printed horizontally, at some distance from the drawing itself but connected therewith by straight dotted lines, they serve their purpose well without detracting from the neatness and clarity of the drawing.

The Descriptive Exercise.—Those laboratory exercises which have as their object a study of the structure of plants are necessarily descriptive in character and consist chiefly of a careful observation of the plants themselves, either by the naked eye, the hand-lens or the microscope. At the beginning of such an exercise it is important to study the material very carefully, seeking answers not only to the questions asked in the Manual but to as many others as may come to mind. Certainly before notes or drawings are begun, it is essential that there be a clear perception of just how the particular plant or plant part under observation is constructed. Wherever possible, it is also highly desirable to gain a knowledge of the functions of the various parts observed; for by this means their structures will be much more easily understood and the student will be continually reminded that the plant itself is a living, active organism even though the material which he is studying happens to be dead. An ability to put one's self "inside the plant" is very useful for a comprehension of its construction.

The Use of the Microscope.—For the study of many of the smaller types of plants and of the details of structure of the larger ones, the use of a compound microscope is essential. The instructor will explain the construction of the instrument and the way in which it should be used. A few suggestions, however, may perhaps be emphasized here.

Adequate Light.—In setting up the microscope, be sure that a satisfactory source of light is accessible and that it is properly projected through the instrument by the mirror. Never be satisfied unless the whole field of vision, as seen through the low-power objective, is brilliantly illuminated, even though it may later be necessary to reduce the size of the light opening. With the high-power objective, the concave mirror should almost always be used.

Clean Glass Surfaces.—Unless the lenses of ocular and objective, and the surfaces of slide and cover-glass, are entirely clean, the usefulness of the microscope will be very seriously hampered. Dirt and grease not only reduce the light and blur the image, but may conceal objects of importance. The microscope magnifies dirt as well as it does everything else, and a skilled microscopist is known by the scrupulous care with which he keeps his slides and lenses clean. The lens surfaces should never be polished by anything harsher than lens paper. An old, soft cloth is excellent for cleaning slides and cover-glasses.

Proper Magnification, Aperture, and Focus.—Even with excellent light and clean glass surfaces, full advantage of the microscope cannot be obtained unless its mechanism is used intelligently.

The penalty for the increased magnification which the microscope secures is a much reduced field of view, and the higher the magnification employed, the smaller this field becomes. For this reason, objects should always be located by use of lenses of relatively low power and studied, so far as possible, by the same means.

With these low powers and particularly with bright light, the objects are more sharply defined if the size of the light aperture is reduced, and this should always be regulated so as to give the best results in each case.

When a low magnification is insufficient and a higher one must be used, particular care is required. The most brilliant illumination possible is usually necessary and to this end the diaphragm should be opened widely and the concave mirror employed. Furthermore, the technique of focussing is of very great importance under these conditions. At a given position of the lenses the level at which objects can be seen sharply, or are in focus, is a very narrow one, and objects just below or just above this level are much blurred or quite invisible. Since the lens is so close to the slide, a relatively slight change in the height of the objective alters markedly the level of sharp focus; and thus by a careful manipulation of the micrometer screw, or fine adjustment, the entire depth of the preparation on the slide may readily be explored. It is quite impossible to study an object under the high power of the microscope satisfactorily, particularly if it has any considerable depth, without careful and constant focussing; and the experienced microscopist may always be recognized by the fact that when he uses a high power he is continually turning the micrometer adjustment of his instrument up and down, and thus exploring the various levels of his preparation.

Cautions.—In endeavoring to locate an object under the microscope, particularly when using a high power, one should never focus *downward*, for in so doing he may pass the focal level without discovering it and ruin his preparation by forcing the face of the objective against the cover-glass. This danger may be avoided by setting the objective below the focal level and focussing upward till this is reached.

The eyes will tire much less rapidly in microscopic work if the observer does not squint but keeps both eyes open; and with a little practice it is possible to do this readily, heeding what is seen by the eye looking into the instrument and disregarding the images in the other eye.

The utmost care should be taken of the lenses, particularly those of the objectives. No objective should ever touch a cover-glass. If wetted by liquid in which the material is mounted, it should be carefully dried with lens paper. Objectives are to be removed from the instrument only when it is absolutely necessary to do so, and every precaution should be taken to keep dirt from entering them. When the microscope is not in use it is well to set the low-power objective over the aperture and place the instrument under a dust-proof cover.

The Experiment.—An experiment involves not only careful observation of a given object but the performance of a definite *test* of that object, under controlled conditions, to answer a definite question. We conduct experiments with plants primarily to determine what they *do*. Observation alone will ascertain the facts of a plant's structure, but to discover its activities and functions we must make it perform some of these under experimental conditions. In order to learn the structure of a leaf, for example, one needs only to examine it carefully with the naked eye, hand-lens and microscope. To determine whether starch is manufactured by the leaf, however, or whether water is evaporated from its tissues, or to learn how fast these processes take place, carefully planned and controlled experiments are necessary.

The value of an experiment will depend on a number of factors, such as the character of the material used, the quality of the apparatus, the skill of the experimenter, and the manner in which the experiment is planned.

A good experiment endeavors to answer only a single question, and in as simple a form as possible. To do this, all the conditions except one should be kept constant, and this one carefully controlled. In determining whether light is essential in the production of starch in leaves, for example, a plant may be transferred from the light to a dark chamber, but it is important to see that no other environmental factors, such as temperature, humidity or soil moisture, are changed at the same time. In many cases it is possible to set up, beside the experiment itself, a *control*, in which all the apparatus and conditions of the experiment are duplicated except the particular one under investigation; and to this latter factor, rather than to any uncontrolled conditions, may then safely be ascribed any differences between the results obtained in the experiment and the control.

Ideally, all experiments should be performed by the student himself, but in many instances they must be carried out by the instructor alone. In any case, it is well to follow a rather definite and uniform method in the recording of experiments, for they all have certain features in common. A useful series of subdivisions of the experimental record is as follows:

Object
Apparatus
Procedure
Results
Sources of Error
Conclusion
Significance

In the report of any experiment these headings (or similar ones) should each be written, preferably on ruled paper; and may well be set off in some way, as by paragraphing or underlining. Under each heading is then to be made a concise statement for the particular experiment in question.

A few suggestions may be offered as to the important points to note and record under each of these headings.

Object.—This gives the purpose of the experiment or the question which it is designed to answer. In the present Manual the object is always stated.

Apparatus.—The apparatus used in the conduct of the experiment may sometimes be described simply and completely in words. In most cases, however, drawings, preferably made separately from the notes and on sheets of drawing paper, will also be found necessary. Drawings of the mechanical portion of the apparatus should be as simple and workmanlike as possible, and in every case portray the object as if seen in section, by this means making clear the structure and arrangement of parts which cannot be observed from the outside. Every piece of apparatus used should be enumerated, but certain familiar though complicated items, such as platform balances and electric ovens, may merely be mentioned.

The living plants or plant parts studied, although not apparatus in the strict sense, should be described and drawn here.

Procedure.—Here is to be made a complete statement of the manner in which the experiment is carried out. Reasons should also be given, in every case, for performing the experiment in one way rather than another, when two possible courses are open; and for such precautions as are taken to guard against erroneous results.

Results.—Here are to be stated the actual results of the test or tests which are made in the experiment. They should be recorded promptly at the time they are obtained. Whenever possible, results should be expressed in terms of some unit of measurement, and if thrown into the form of a table or graph they are usually much more clearly presented. In many cases, drawings of the material or apparatus, showing the result of the experiment, must also be made. Care should always be taken not to confuse results with the conclusion to be drawn from the results.

Sources of Error.—Inaccuracy of measurement or lack of skill in manipulation may lead to worthless results; but there are other sources of error, inherent in the experiments themselves, which cannot be overcome by faultless procedure and may seriously vitiate the results. Although he may not be able to overcome these, the careful experimenter will always strive to recognize their existence and will take them into consideration in evaluating his results. In an experiment to determine the rate of evaporation from leaves, for example, by the use of a shoot cut off and placed in water, there is an unavoidable source of possible error in the fact that a shoot may behave very differently under these conditions from the way it would if attached to its own roots. Probably no biological experiment is entirely free from errors of this kind, and they have often led to serious discrepancies in the results of presumably similar experiments. One of the most essential requisites for successful experimentation is to be able to recognize all such possible sources of error and to evaluate them properly when drawing conclusions.

Conclusion.—The conclusion should be drawn by logical inference from the results and should answer the question proposed in the object. A statement of the steps in the reasoning which led to the conclusion may often be desirable and here may sometimes be discussed the probable effect of the sources of error, mentioned above, on the validity of the conclusion drawn.

Significance.—In order that one may recognize what bearing a particular experiment has on the main problems which are being investigated, it is well to state the botanical significance of its conclusion. The fact, for example, that light is essential to the growth of green plants is of the utmost significance, not only for the life of plants but for man himself.

In conclusion, the student is again urged not to let his report of an experiment degenerate into a merely mechanical filling-in of headings, but to preserve a critical and intelligent attitude toward all his work and to let the problem rather than the record hold chief place in his mind.

LABORATORY "DON'TS"

DON'T ask "What am I supposed to see?"

DON'T get all your ideas from your neighbor.

DON'T bring your textbook into the laboratory.

DON'T do any laboratory work outside the laboratory.

DON'T begin to write notes or make drawings till you have studied the material thoroughly.

DON'T be satisfied with merely answering the questions asked you in the Manual.

DON'T try to draw what you don't see.

DON'T use a soft, smudgy pencil.

DON'T try to work with dirty lenses, slides or covers.

DON'T use your microscope or apparatus as a plaything.

THE SOIL

Exercise 1

THE AIR IN SOIL

Experiment

OBJECT: *To determine the amount of air in soil.*

Measure out a sample of rather dry soil which, when shaken or gently pressed together, has a volume of 50 cc. In a measuring cylinder with a capacity of 100 cc. place 50 cc. of water. Slowly pour the soil into the water (why not the water into the soil?) stirring the mixture meanwhile.

Measure the volume of the mixture and calculate therefrom the volume of air in the soil sample, explaining how you do so.

Exercise 2

THE SOLID MATERIALS IN SOIL

Experiment

OBJECT: *To determine the character of the solid materials in soil.*

Fill a test-tube or small, straight-sided glass jar about one-third full of rich soil, add about an equal volume of water, and shake or stir thoroughly. Allow the mixture to settle and to stand quietly for the rest of the laboratory period.

Note the differences in color, shape, size, and specific gravity of the various types of solid material, and the relative quantities of these types.

Exercise 3

THE WATER IN SOIL

Experiment

OBJECT: *To determine the amount of water in soil.*

Weigh a glass or porcelain dish which has a capacity of about one liter. Fill it partly full of moist soil and weigh again. Spread the soil out on blotters or newspapers for two or three days or until it is thoroughly air-dry and dusty. Place it in the dish and weigh again. The water lost by evaporation is the film or *capillary* water.

Now place the soil in an oven at about 100° C. and leave for 24 hours. Weigh it at once on removal from the oven (why?). The difference in weight between the air-dry and the oven-dry soil is due to the fact that the *hygroscopic* water has been driven off under the high temperature. Capillary water is the chief source of water for plants. Hygroscopic water adheres so closely to the soil particles that most plants are unable to absorb it.

Present your results in the form of a table and determine the percentage (by weight) of capillary and of hygroscopic water in the soil sample tested.

Exercise 4

THE WATER-HOLDING CAPACITY OF SOIL

Experiment

OBJECT: *To determine the effect of the texture of the soil on the water-holding capacity of the soil.*

Set up three funnels and place in the throat of each a small cotton plug, loose, but thoroughly wetted (why?). Put into the first funnel 100 cc. of gravel, into the second 100 cc. of sand, and into the third 100 cc. of loam. These soils should all be air-dry. Place a beaker under each funnel.

Now pour over each soil sample a measured quantity of water (100 cc. or 200 cc. is sufficient) taking care to wet the whole soil mass thoroughly. Allow this water to percolate through the soil into the beakers below, and measure carefully the amount in each of the beakers when the flow has ceased. From this data the amount of water held in the soil may be calculated.

Determine the water-holding capacity of each soil type by finding the amount of water which a unit volume of the dry soil will hold. Explain the differences between the three soil types.

Exercise 5

THE MOVEMENT OF WATER IN SOIL

Experiment

OBJECT: *To determine how water moves in the soil.*

Cover the lower opening of a straight-sided glass lamp-chimney, or similar wide glass tube, with several layers of filter paper and fill the chimney with dry soil, well pressed down. Set this in a flat dish and fill the dish with water so that the water can pass through the filter paper and enter the base of the soil column.

Note the movement of water in the soil, and measure its rate at successive 15-minute intervals.

Fill a battery jar or other wide glass vessel with dry soil, and at one spot, next the glass, introduce a few cc. of water into the soil, by a funnel or otherwise.

Observe the movement of water through the soil. What resemblances and what differences are there between the movement here and in the lamp chimney?

On the basis of these results, describe and explain the movement of water in soil.

Exercise 6

THE EVAPORATION OF WATER FROM THE SOIL SURFACE

Experiment

OBJECT: *To determine the effect of the character of the soil surface on the rate at which water is lost from the soil by evaporation.*

Fill three small battery jars of the same size and area of aperture with approximately the same amount of moist soil, shaking it down well. Cover the surface of the soil in one jar with a layer of air-dry soil about one centimeter thick. In another jar, press the soil down very compactly. Leave the third jar untouched, as a control.

Weigh the three jars at the present laboratory period and at intervals of two or three days for two weeks, and present your results in the form of a table. Calculate the daily water loss from each jar during the period.

It will be useful to construct three curves showing the daily water loss from these three surfaces.

Explain the differences observed among the three types of soil surface.

THE ROOT AND ITS FUNCTIONS

Exercise 7

THE POSITION, CHARACTER, AND DEVELOPMENT OF ROOT-HAIRS

In preparation for this exercise, seeds of buckwheat, radish, oats, or other plants should be germinated on black paper, over wet filter paper, in covered glass dishes. Root-hairs in seedling roots can best be studied when the root system is from 2 to 5 cm. long.

Seeds may also be planted in moist sphagnum or sawdust in glass-sided boxes, and the development of larger root systems and their root-hairs observed directly through the glass.

Examine the young seedlings given you, studying them with a hand-lens through the glass without exposing them directly to the air.

The delicate, white, thread-like structures are *root-hairs.*

Just where on the root do they occur?

Are there any regions where the root-hairs are absent? Explain.

About how long are the root-hairs? Are they all of the same length? Explain.

What relation exists between root-hairs and soil particles?

What advantage does the possession of root-hairs bestow?

Where, on a fully grown plant, would you look for root-hairs?

Why do you not see root-hairs on a plant which is pulled up by the roots?

Distinguish carefully between the root-hair and the *lateral roots,* where such occur. Do you think that the lateral roots grow from root-hairs? Explain.

Draw carefully an entire seedling if it is less than 3 cm. long. If it is longer, draw the terminal 3 cm. of a root. In either case, show clearly the root-hairs and the lateral roots. This drawing should be at least 10 cm. long.

Exercise 8

THE PLANT CELL

Before beginning this exercise, read carefully the directions for the use of the microscope on pages 5–8.

All plants are composed of *cells* and an understanding of the fundamental features of cells is essential before one can understand the structures and functions of the plant as a whole.

Examine under the microscope a prepared slide of a section cut lengthwise through the growing tip of an onion root. This section has been stained to make its structures more clearly visible. In life it is almost transparent and colorless.

The rectangular objects are cells, the units of which plants and animals are composed. Remember that you are not looking at entire cells here, but at thin slices cut through them.

Distinguish in each cell the *cell wall*, *cytoplasm*, *nucleus* and one or more *sap cavities*. The nucleus and cytoplasm both consist of living substance or *protoplasm* and are the only parts of the plant body which are truly alive.

What functions can you suggest for the various parts of the cell?

Draw under the high power of the microscope a cell from the region just behind the root tip.

Note and explain the changes in size, shape, and contents of the cells as you move backward from the tip of the root.

Draw one of the elongated cells in the region farthest from the root tip. This, rather than the first cell drawn, is a typical plant cell.

Mount an entire leaf of Elodea in water on a slide and study its cells.

How many cells in thickness is the leaf?

The green bodies in the cells are *chloroplasts* and are found in most cells of green leaves.

Find a cell in which the chloroplasts are moving and follow their movements carefully. Do they go from cell to cell? How can you determine this?

Just where in the cell are they situated? What is their shape? Explain in your notes how you reached your conclusions.

By careful observation you will be able to distinguish the almost transparent cytoplasm and nucleus. Where are they in the cell?

From these observations and the inferences based upon them, describe the shape and the internal structure of a typical leaf cell of Elodea.

Draw a cell as it appears under the high power of the microscope.

Imagine a thin slice cut through the cell at right angles to its long dimension.

Draw such a slice as it would look if seen in face view under the microscope.

Exercise 9

THE STRUCTURE OF A ROOT-HAIR

Mount in water on a slide the terminal portions of a small lateral root, bearing root-hairs, from the seedlings used in Exercise 7. Examine these first under the low power and then under the high power of the microscope.

The oblong units which compose the axis of the root are cells.

Examine carefully a root-hair, tracing it throughout its whole extent by raising and lowering the plane of focus. Give particular attention to the manner in which it is attached to the root.

Of how many cells is a root-hair composed? What connection has it with the cells of the root axis?

Distinguish if possible the cell wall, cytoplasm, nucleus, and sap cavity of the root-hair.

Describe fully the structure of the root-hair.

Draw one or two root-hairs under the high power of the microscope, making each at least 10 cm. long and showing clearly its connection with the cells of the root.

Exercise 10

THE STRUCTURE OF A TAP ROOT

Study the root of the parsnip or carrot.

Examine the markings which you see on its surface. Have they a definite arrangement? What caused them?

Where on the parsnip plant would you look for root-hairs? Are they visible on the root which you have? Explain.

Why is this root tapering in shape?

For what function is a tap root particularly well constructed?

What other plants do you know which have tap roots? Are fleshy tap roots like that of the parsnip commonest in annual, biennial, or perennial plants?

Draw the parsnip root.

Cut the root in two, transversely, and identify the *epidermis*, *cortex*, and *fibro-vascular cylinder*.

Cut one of the halves of the root in two, lengthwise, and identify the same structures. How are the internal structures related to the markings on the outside of the root?

Study a vertical section cut through a parsnip root which has had its cut end placed in stain by the instructor for an hour or more previously. In what tissue of the root has the stain risen most rapidly? Just what would be the path of a drop of water from the soil into the leaf of the parsnip plant?

What are the important functions of the various internal structures of this root?

Make **drawings** of the transverse and longitudinal sections of the tap root.

Exercise 11

THE STRUCTURE OF A FIBROUS ROOT

Examine the root system of a bean or corn plant from which the soil has been washed away, or which is growing in a glass-sided box.

How does it differ from that of the parsnip?

Can you see any definite arrangement in the branching of the roots? Why are so many of the roots irregular in their shape and direction?

Where would you look for root-hairs on this plant?

Is a root system which has a well developed tap root, or one which consists entirely of fibrous roots, the better adapted for (1) anchorage, (2) absorption, (3) storage?

Make a **drawing** of a part or the whole of this fibrous root system.

Exercise 12

DIFFUSION IN A SOLUTION

Experiment

OBJECT: *To determine whether a dissolved substance diffuses in the dissolving liquid.*

Into a test-tube filled with water, drop a crystal of potassium permanganate, copper sulphate, or other soluble colored salt. Place the tube in a rack with a piece of white paper behind it.

At the end of the laboratory period measure the height, in millimeters, at which the dissolved material is visible.

Set the tube away carefully, without shaking or jarring it, and at the next laboratory period measure the height at which the dissolved material is now visible.

This movement is due to the diffusion of the molecules in solution. Explain its cause.

Exercise 13

OSMOSIS

Experiment

OBJECT: *To determine what osmotic interchange occurs between two solutions of unequal concentration.*

Construct an osmoscope or "artificial root-hair" by tightly fitting a rubber cork into a parchment diffusion shell, or bag made of bladder or collodion. This can well be done by soaking in water a parchment shell such as is used for chemical dialysis, slipping into it a test-tube from which the bottom has been broken, and then with wax making tight the joint between these parts. Insert a two-holed rubber stopper tightly into the mouth of the test-tube and fit a long glass tube into one of the holes. The other may be used to fill the tube and should then be closed tightly with a glass stopper. Be sure that all the joints in the apparatus are water-tight.*

Fill the test-tube full of a strong sugar solution so that the liquid rises a little in the glass tube. Suspend the apparatus, to a point above the level of the parchment, in a jar of water.

Note any changes in the level of the liquid in the tube.

Exercise 14

OSMOSIS IN A CELL

Experiment

OBJECT: *To determine the effect of osmosis when the membrane is a closed one.*

Chip off the shell carefully from the large end of a fresh egg, exposing the unbroken membrane over about a fourth or a third of the surface of the egg. The membrane will not be distended but will show one or more "dimples."

* Osmoscopes of other types may readily be made and are quite satisfactory.

Immerse the egg completely in water for a few minutes and note any changes in the membrane.

A similar experiment may be performed by tying up, or otherwise tightly closing, the opening of a bag made of bladder or collodion, which is partly filled with sugar solution, and then placing the bag in water.

In the preceding experiment the membrane was not closed, and the water which entered was forced through the opening and up the tube. The membrane of a cell, however, is a continuous and closed one, and is well imitated by the conditions of this experiment.

Exercise 15

THE TURGIDITY OF PLANT TISSUES

Experiment

OBJECT: *To determine the effect of strong and of weak solutions on the turgidity of plant tissues immersed in them.*

Cut from a potato, preferably one which has become slightly wilted, two slices about 5 mm. thick. Place one in a dish of water and the other in a strong salt solution. Observe and explain the changes which occur in the size and firmness of the two slices after they have been immersed for about half an hour.

Perform the same experiment with two leaves.

Exercise 16

PLASMOLYSIS

Experiment

OBJECT: *To determine the effect of strong and of weak solutions on plant cells immersed in them.*

With a sharp knife or razor blade strip off a bit of epidermis from the lower surface of the petal of a crimson carnation flower, or simply cut off a small piece of the petal.

Mount this in water under a cover-glass and examine with the high power of the microscope.

Study the individual cells, noting the color of the cell wall and of the cell contents. As a part of your results, **draw** two or three of the pink cells, shading the pink portion.

Now draw off the bulk of the water with a bit of filter paper applied to one edge of the cover-glass and run a few drops of a 5 percent salt solution under the cover-glass. Watch the pink cells carefully, and observe what change occurs in them. This change is called *plasmolysis*.

Draw a few of the plasmolyzed cells, showing the distribution and intensity of the color, as compared with conditions before plasmolysis.

From these results draw conclusions as to the structure and contents of the cell, and the relative permeability of its cytoplasm and of its cell wall to water, salt, and the pink coloring matter.

Exercise 17

PERMEABILITY IN LIVING AND IN DEAD CELLS

Experiment

OBJECT: *To determine the effect of the death of the cell on the permeability of its cytoplasmic membranes.*

In the cells of the beet, the red color is due to a pigment dissolved in the cell sap.

Cut three strips from the outer layers of the root of a beet, each several centimeters long, and narrow enough to be slipped easily into a test tube.

Wash each with water (why?) and then place in separate test-tubes and cover with water. Heat one of the test-tubes until the water boils. To another, add a few cc. of a strong poison. Leave the third as a control.

Examine the three tubes at the end of the laboratory period and record and explain such differences as you may observe between them.

Exercise 18

THE ABSORPTION OF WATER BY THE ROOT

Experiment

OBJECT: *To determine whether the root absorbs water from moist soil.*

With a sharp knife cut off, near the level of the soil, a vigorous leafy plant (such as a healthy potted "geranium") the main stem of which is about 5 mm. in diameter. Slip a piece of rubber tubing tightly over the stump, fill the tube full of water and insert a piece of glass tubing into the upper, open end, so that the water level is visible in the tube. Make the joints water-tight by binding with cord or fine wire.

Keep the roots generously watered and observe the water level in the glass tube at the next two laboratory periods.

THE LEAF AND ITS FUNCTIONS

Exercise 19

THE EXTERNAL STRUCTURE OF THE LEAF

Examine the leaves of a "geranium" plant, leaving them attached to the plant.

Identify in each the broad, expanded portion, or *blade;* the leaf stalk or *petiole;* and the two small ear-like structures at the base of the petiole, or *stipules.* What are the functions of each?

Study the *venation* of the blade. This leaf is netted-veined. What functions do the *veins* perform? On which surface of the leaf are they more prominent? Explain.

Study the arrangement of the leaves on the plant and their position with reference to each other, especially when the plant is looked at from above. What seems to determine their arrangement?

Are the petioles all of the same length? Explain. Is the ratio between petiole length and blade length always the same? Explain.

Which surface of the blade is the darker green? Explain.

Draw carefully a leaf, with all its parts, as seen in face view.

Examine a leaf of the bamboo grass (Arundinaria), or some other grass in which the attachment of leaf to stem can be studied. This is a parallel-veined leaf.

Identify the *blade, ligule,* and *sheath.*

What are the functions of each?

In what ways does this leaf differ from that of the geranium?

Draw one of the leaves.

Exercise 20

THE INTERNAL STRUCTURE OF THE LEAF

Examine under the microscope a thin section through the blade of a living leaf which has been freshly cut by the instructor and mounted in water.

That portion of the leaf in which the green coloring matter (*chlorophyll*) occurs is called the *mesophyll* or *chlorenchyma*. How much of the leaf does this occupy?

Identify the upper and lower *epidermis*. How many cells thick is each? How do the epidermal cells differ from those of the mesophyll?

Examine a prepared slide of a thin, stained section cut at right angles to the surface of the leaf blade and thus showing the thickness of the leaf. The chlorophyll has, of course, been removed.

Identify the *cuticle*, *upper epidermis*, *lower epidermis*, *palisade layer* of the mesophyll, *spongy layer* of the mesophyll, *chloroplasts*, *veins*, *air spaces*, and *stomata*. You can tell which is the upper surface of the leaf from the fact that the palisade layer is always next that surface.

The chloroplasts originally contained chlorophyll (see the leaf cell of Elodea, Exercise 8), but it has been dissolved out in the preparation of this section.

Where are the chloroplasts most abundant? Explain.

What important differences are there between the palisade layer and the spongy layer?

On which surface of the leaf is the epidermis thicker? the cuticle thicker? the stomata more abundant? Explain these facts.

State the functions of each of the structures observed.

Under the high power of the microscope make a very careful **drawing** of a portion of the blade, not including a vein. In this drawing the thickness of the blade should be about 15 cm. and the width of the drawing about 10 cm.

This is a very important exercise, since a thorough knowledge of the structures of the leaf is essential if one is to understand the various functions which it performs.

Exercise 21

THE STRUCTURE OF THE STOMA

Trace the outline of a leaf of *Zebrina pendula* (or a similar leaf of simple shape) on cross-section paper and determine roughly its area in square centimeters.

Now mount a portion of it on a slide in water, its lower epidermis uppermost, and examine with the low power of the microscope. The stomata appear as minute pores, each in the center of a small green area.

In three separate portions of the leaf make a count of the total number of stomata visible in the field of the microscope. This field (with 16 mm. objective and no. 10 ocular) is about two square millimeters in area.

Average these three counts and compute the number of stomata on the lower surface of this leaf.

With a sharp knife strip off or slice off a bit of the lower epidermis, mount in water, and examine under the high power of the microscope. Most of the cells visible are ordinary epidermal cells, but scattered among these are the stomata. In a stoma identify the *pore* and the *guard cells*, together with the accessory cells to which the guard cells are attached.

How does the structure of a guard cell differ from that of an ordinary epidermal cell? What are the structures which you see inside the guard cell? What suggestions can you make as to their function?

Draw a single stoma as seen thus in face view.

Examine the prepared slide of a leaf section (preferably of a parallel-veined leaf) and study a stoma under the high power.

Identify the pore and guard cells. State clearly, the relation between this view of the stoma and the face view studied in the first part of this exercise.

Draw a stoma as seen in section.

Make a **diagram** showing a stoma in face view and in section, to the same scale, one above the other, connecting corresponding parts by dotted lines.

As the guard cells become turgid with sap, they tend to pull apart and the stoma opens; and as they become wilted, the stoma tends to close. In view of these facts, what do you think are the conditions, both external and internal, under which the stomata will tend to open? to close?

Exercise 22

THE PRESENCE OF STARCH IN GREEN LEAVES

Experiment

OBJECT: *To determine whether starch is present in a green leaf which has been exposed to the light.*

From a geranium plant (or other vigorous plant) which has been exposed to bright daylight for several hours, remove a leaf, roll it up, and place in a test tube about one-third full of alcohol.* Place the tube in a dish of water over a flame and heat till the alcohol boils. The green pigment, *chlorophyll,* will gradually dissolve into the alcohol and the leaf will become bleached.

Save this extract of chlorophyll for the next experiment.

Remove the bleached leaf, unroll, place in a solution of iodine† and note result. The ordinary test for starch is the development of a dark blue color in the presence of an iodine solution.

Exercise 23

CHARACTERISTICS OF CHLOROPHYLL

Experiment

OBJECT: *To determine the characteristics of chlorophyll.*

Examine the alcoholic extract of chlorophyll obtained in the previous experiment. If it is not dark green, extract into the same solution the chlorophyll from another leaf. If the solution becomes milky, discard it.

* Denatured alcohol is satisfactory.

† See p. 105.

Hold the test tube containing the extract so that light shines through it and note the color. Then place the tube against a dark background and allow a bright light (direct sunlight if possible) to shine on the liquid. How does its color as seen thus by reflected light differ from its color by transmitted light? The property of chlorophyll which is thus demonstrated, and which it shares with certain other pigments, is called *fluorescence*. What significance may there be in this property of chlorophyll?

Now add an excess of carbon tetrachloride (or of benzol), shake the mixture well, and allow it to stand. The carbon tetrachloride will not mix with the alcohol but the two liquids will gradually separate, the former settling to the bottom of the test tube and the latter rising to the top.

What difference is there in color between the two liquids after their separation? In which is the bulk of the chlorophyll dissolved?

The yellow color of the other liquid is due to the pigments *carotin* and *xanthophyll* which are almost always associated with chlorophyll though not concerned with photosynthesis. Explain clearly what makes the chlorophyll and the yellow pigments separate in this experiment.

If time allows, note which solution begins to break down first. What conclusion can you draw from this as to the relative chemical stability of chlorophyll and the yellow pigments?

Exercise 24

THE IMPORTANCE OF CHLOROPHYLL IN PHOTOSYNTHESIS

Experiment

OBJECT: *To determine the importance of chlorophyll in photosynthesis.*

Examine a leaf of a variegated or silver-leaved "geranium" (or other leaf of the same type). **Draw the outline of the leaf and, inside this, draw the line dividing the green, chlorophyll-bearing central portion from the colorless margin.**

Extract the chlorophyll with hot alcohol, as in Exercise 22.

Compare the distribution of starch as shown by this test with the distribution of chlorophyll in the living leaf as recorded in your drawing.

Exercise 25

THE IMPORTANCE OF LIGHT IN PHOTOSYNTHESIS

Experiment

Object: *To determine the importance of light in photosynthesis.*

(*a*) From a geranium plant which has been kept in darkness for two or three days remove a healthy leaf, extract the chlorophyll, and test the leaf with iodine for starch. Do the same with a leaf which has been exposed to normal illumination. Record any differences you may observe in the amount of starch in the two leaves.

(*b*) Place a light-screen upon a healthy leaf of the plant which has been kept in the dark, without removing the leaf from the plant. Any apparatus which will darken a corresponding part of the upper and lower surfaces of the leaf and still leave the lower surface exposed to the air (why?) may be used.*

Place the plant in normal illumination until the next laboratory period, or for from one to three days, and then remove the light-screen. Does the leaf appear different in any way from the other leaves? Can you see the pattern of the light-screen upon its surface?

Remove the leaf, extract its chlorophyll, and test for starch, recording any relations you may observe between the position occupied by the light-screen and the distribution of starch in the leaf.

* A Ganong light-screen is recommended as a simple and satisfactory apparatus.

Exercise 26

THE IMPORTANCE OF THE STOMATA IN PHOTOSYNTHESIS

Experiment

OBJECT: *To determine whether the leaf can manufacture starch if the stomata are closed.*

Place a healthy potted plant in the dark until its leaves have lost all their starch. Cover with vaseline about half of the lower surface of each of several leaves (the corresponding upper surface also, if the species has stomata on both surfaces) thus effectually sealing the stomata, and place the plant again in the sunlight.

After a few hours (or a day or two) remove the vaseline, extract the chlorophyll and test the leaves for starch.

Exercise 27

EVOLUTION OF GAS IN PHOTOSYNTHESIS

Experiment

OBJECT: *To determine whether a gas is given off from a plant during the process of photosynthesis.*

Cut a shoot of Elodea into several pieces about 10 cm. long, tie the cut ends loosely together and place these ends in the throat of a funnel which is inverted and submersed under water in a battery jar. Over the tube of the funnel invert a test tube filled with water, so that if gas escapes from the cut ends of the plants it will rise in the test tube and collect at the top of it. The funnel should be supported by blocks so that it does not rest directly on the bottom of the jar (why?).

Set up another jar as a control, similar to the first except that it is without a plant.

Expose both jars to bright sunlight and observe whether gas is given off from the plant tissues. From time to time shade the jar containing the plant with black paper and observe the effect.

If sufficient gas collects in the test tube, test it for oxygen with a glowing splinter.

Exercise 28

GAS EXCHANGE IN PHOTOSYNTHESIS

Experiment

OBJECT: *To determine what gas exchange takes place during photosynthesis.*

In one of two small museum jars of equal size place a geranium shoot. Leave the other empty as a control. Cover each jar with a glass plate. By means of a lighted candle on a wire, slipped quickly under the plate and into the jar, exhaust most of the oxygen in each jar, replacing it by carbon dioxide. Count the number of seconds the candle burns in each before going out. This will give a rough measure of the relative amount of oxygen in each.

What is now the composition of the gas in the two jars?

Invert each jar in a wide flat-bottomed dish partly filled with water, thus preventing any circulation between the gas in the jar and the outside air. Set both jars in good light but not in strong direct sunlight.

At the next laboratory period slip a glass plate over the mouth of each jar, lift the jars from the water, and test the gas in each with the candle that was used before, counting the number of seconds which it burns.

Exercise 29

MEASUREMENT OF THE GAS EXCHANGE IN PHOTOSYNTHESIS

Experiment

OBJECT: *To measure the gas exchange which takes place during photosynthesis.*

The instructor will demonstrate and explain the use of the Ganong photosynthometer (or a similar apparatus).* The total volume of the chamber in this apparatus is 102 cc. Into this chamber place a small plant shoot (Oxalis is good) the volume of which has been found by displacement to be

* For more detailed directions as to the use of this apparatus, see Ganong's "Laboratory Course in Plant Physiology."

2 cc. Introduce a known amount of carbon dioxide (10 cc.) from a carbon dioxide generator, seal the apparatus, and place it in the light.

The composition of the gas in the chamber is thus known at the start of the experiment (what is it?), and after a few hours of exposure to the light it may be analyzed by dissolving out the carbon dioxide by potassium hydroxide and the oxygen by potassium pyrogallate.*

A comparison of the constitution of the gas at the start and at the close of the experiment will enable one to measure the gas exchanges which have been effected by the photosynthetic activity of the green shoot.

Exercise 30

THE RATE OF PHOTOSYNTHESIS

Experiment

OBJECT: *To determine the rate at which photosynthesis takes place.*

Place a green plant in the dark for two or three days or until the starch has disappeared from its leaves. Then in the morning remove from the plant a measured amount of leaf tissue. This can be done by taking several leaves of about the same thickness and carefully measuring their surface area. A better procedure is to use a punch which cuts out a known area of leaf tissue (the Ganong leaf punch is satisfactory) and to punch out a given number of pieces from one side of most of the larger leaves, avoiding the big veins in doing so, and leaving the leaves attached to the plant.

The leaf tissue thus harvested in the morning should at once (why?) be thoroughly dried in the oven. Its dry weight per unit area of leaf surface may now be determined.

Meanwhile the plant should be placed in the light for a definite number of hours. At the end of this period a given area of leaf tissue should again be harvested. If a punch is

* See page 105.

used, an equal number of pieces should be taken from the same leaves used in the morning, the punches being made on the other half of each leaf and in places symmetrically opposite those made in the morning. For this tissue the dry weight per unit area should also be determined.

By comparison with the morning weights, the net gain in weight per square meter per hour from the photosynthetic activity of the green leaves may be calculated.

Exercise 31

THE IMPORTANCE OF PHOTOSYNTHESIS FOR GROWTH

Experiment

OBJECT: *To determine the importance of photosynthesis for growth.*

From a group of bean seeds out of which all the largest and smallest beans have been removed, so that those remaining are of approximately the same size, select twelve beans, weigh them, and determine their average weight, and then plant six in each of two pots of similar soil.

The instructor will determine the average dry weight for these beans by drying a few beans of this size for a day or more in an oven at 100° C. and weighing. Thus the amount of actual water-free plant material in each of the two sets of beans planted may be estimated rather accurately.

Place one pot in the dark and the other where it is exposed to good illumination. Water both sufficiently to keep the soil moist, and endeavor to maintain the two at about the same temperature.

At the end of three or four weeks, or when the young bean plants have made a good growth, compare the two sets of plants. How do they differ in size? in color? in structure?

Harvest all the plants, taking care to get all the roots and washing the soil cleanly from them. For each of the two sets determine the average fresh weight (weight before the plant wilts) and then the average dry weight per plant.

Compare the weights of the plants grown in the dark with those grown in the light, and both of these with the weights of the seeds planted, explaining such differences as you may observe.

Exercise 32

TRANSPIRATION

Experiment

OBJECT: *To determine whether water is given off through the leaves of the plant.*

Place a vigorous leafy potted plant, with the pot closely wrapped up in oil cloth, on a glass plate under a bell-jar. Set up a similar jar, plate, and pot with soil (but without a plant) as a control.

Place the bell-jars side by side in the sunlight and note any changes on their inner surfaces.

Exercise 33

MEASUREMENT OF TRANSPIRATION

Experiment

OBJECT: *To measure the amount of water given off in transpiration.*

(*a*) Place a potted geranium plant, well watered, in an aluminum shell with a rubber top, or in some other way cover the pot and soil so that no evaporation can take place therefrom.

Weigh the entire apparatus.

Set aside until the next laboratory period and weigh again.

(*b*) Set up a potometer* as explained by the instructor, placing in it a vigorous shoot with several leaves. Be careful that the joints are air-tight.

* An instrument for measuring the rate of absorption of water by the rate of movement of a column of water in a calibrated tube. The potometer in Professor Ganong's apparatus is very satisfactory.

Record the distance traversed in a given time by the retreating end of the water column in the tube or of one end of an air bubble which has been admitted.

In both these experiments the leaf area of the shoots studied may be determined and the transpiration per sq. cm. per hour calculated.

Exercise 34

THE RELATIVE RATE OF TRANSPIRATION FROM UPPER AND LOWER LEAF SURFACES

Experiment

OBJECT: *To determine from which surface of the leaf transpiration takes place more rapidly.*

(*a*) From a rubber plant pick three leaves which are of approximately the same age, size, and vigor. Coat the upper surface of one thickly with vaseline and do the same for the lower surface of another. Leave the third uncoated as a control. Hang up all three leaves freely exposed to the air.

For the next two laboratory periods observe the relative rate at which the leaves wither.

(*b*) The instructor will demonstrate the property of cobalt chloride paper (filter paper soaked in a strong solution of cobalt chloride and then dried) whereby it becomes pink when moist and blue when dry.

To the upper and to the lower surface of a healthy leaf, still attached to the plant, apply a piece of dry (blue) cobalt chloride paper, pressing these pieces rather closely to the leaf by two microscope slides clamped at each end by a spring clothespin or other clamping device. The slides will hold the papers close to the leaf surface and away from the outside air, and will at the same time allow a clear view of the papers.

Observe on which surface of the leaf the paper changes color more rapidly.

Exercise 35

EXTERNAL CONDITIONS AND TRANSPIRATION

Experiment

OBJECT: *To determine the effect of external conditions upon the rate of transpiration.*

(*a*) *Humidity*

Set up a potometer, as in Exercise 33, on the laboratory table and record the rate of transpiration for half an hour (or more if possible).

Place the apparatus under a bell-jar in which the air has become saturated with moisture by evaporation from sheets of wet filter paper, or by other means, and record the rate of transpiration for half an hour.

Compare the rate of transpiration in the air of the room (relatively dry) with that under the bell-jar (relatively humid).

If possible, measure the humidity in these two situations.

(*b*) *Movements of air*

Set up a potometer in a glass case or other situation where there are no air currents, and record the rate of transpiration. Then set the same apparatus in an open window or in the current of air from an electric fan, and record. Compare the two rates.

(*c*) *Temperature*

Record the transpiration of a shoot by the potometer at different temperatures, and compare.

In these three experiments care should be taken that a change in the particular environmental factor studied involves as little change as possible in others.

Exercise 36

LEAF STRUCTURE AND TRANSPIRATION

Experiment

OBJECT: *To determine the effect of the structure of the leaf upon the rate of transpiration from the leaf.*

Hang up, freely exposed to the air, a leaf of a rubber plant, or other leathery-leaved species, and also a thin, soft-textured leaf.

At the next laboratory period note the difference in the appearance of these two leaves.

Exercise 37

PROTECTIVE TISSUES AND TRANSPIRATION

Experiment

OBJECT: *To determine the effect of cuticle and corky bark upon the rate of transpiration.*

Choose two apples of approximately the same size (why?) and peel one of them. Weigh both carefully. Do the same thing for two potatoes and weigh.

Set both pairs aside till the next laboratory period and then weigh again, noting the comparative loss of weight in the peeled and unpeeled specimens.

The apple epidermis is covered with a thick cuticle. The "skin" of the potato consists of several layers of corky bark cells.

THE STEM AND ITS FUNCTIONS

Exercise 38

THE EXTERNAL STRUCTURE OF THE STEM*

Examine carefully the twig set before you.

Identify the *nodes* and the *internodes*, by finding the *leaf scars*. What are the leaf scars and what are the small dots on each?

Identify the *buds*, both *terminal* and *lateral*, and state what develops from them.

What relation is there between the position of the buds and the position of the leaves?

What is the function of the buds? Do all the buds develop? Which are the largest, the lateral or the terminal?

Identify the *lenticels*. What is their function?

Are all the internodes of the same length? Explain.

Describe the exact arrangement of the leaves. What advantage does the plant gain from this arrangement?

What morphological relationship can you suggest between the leaves and the bud scales.

Just what part of this twig was produced during the past growing season? During the previous one? During the one before that? State clearly how you can tell this.

On which year's growth of the stem are the leaves always produced?

Just where will this stem grow in length next season? Just where will it grow in thickness? Give reasons for your answers.

Draw the twig carefully, labeling all the parts and labeling each year's growth.

Then make a drawing of this twig as it looked a year ago.

* This exercise is based on three-year-old twigs of Horse-chestnut or Maple.

Cut a cross section of the stem at the base of the twig and see whether you are able to tell its age from what you see within. State at least two ways of telling the age of a small stem. Can you tell the age of a tree in these two ways?

Exercise 39

THE INTERNAL STRUCTURE OF THE STEM

Examine carefully with a hand lens and then with a low power of the microscope the cross section of a Tulip Tree twig* which has been stained and mounted on a slide.

Identify, with the help of the instructor, the following tissues, beginning at the center of the stem: the *pith;* the ring of *wood* (*xylem*) containing the *wood rays*, the *vessels* and the *fibers;* the *cambium;* the ring of *bast* (*phloem*) containing the *sieve tubes* and the *bast fibers;* the *cortex;* the *corky bark;* the *epidermis;* the *cuticle;* and the *lenticels.*

State clearly the function of each of these parts.

Make a **diagram** of the section at least 10 cm. in diameter showing these various regions and paying particular attention to the proportions of the parts. Fill in about one-fourth of the whole section, but do not draw individual cells.

How old was this twig? Is there more than one way in which you can tell its age from this section alone?

Just where and how does the stem grow in thickness?

What makes the annual rings so clearly distinct from each other?

Why are the bast bundles triangular in shape?

Under the high power of the microscope **draw** a small portion of the wood and of the bast, showing the typical structure of each.

* Any other similar dicotyledonous twig, such as that of the Linden, is satisfactory. It should be from three to five years old at the point of section.

Exercise 40

THE GROSS STRUCTURE OF WOOD

(*a*) Examine the log of wood* set before you.

Identify the corky bark, the bast, the cambium, the wood, and the pith.

What are the most notable changes which have taken place since this log was a small twig? Of what tissue is the bulk of the log composed?

Identify the *sap-wood* and the *heart-wood*. How do they differ in position and appearance? What different functions do they perform in the stem?

Which grows more rapidly in thickness as the tree gets older?

Which do you think is more valuable for timber, and why?

Show by two or three diagrammatic outline **drawings** of this log in different positions just what is meant by a *transverse*, a *radial*, and a *tangential* cut of wood, indicating the position of the annual rings on each surface.

(*b*) Examine some boards† which are made of oak wood.

Find a surface which has been cut transversely, one which has been cut radially, and one which has been cut tangentially. How can you identify these?

Draw each of the three surfaces carefully, actual size, showing, in each, the annual rings, the vessels, and the wood rays.

Of the two longitudinal cuts (radial and tangential), which is more commonly exposed in these boards? Why?

* The first portion of this exercise is based on the study of a small log of wood with bark intact, preferably a type in which the annual rings are very distinct and in which sap-wood and heart-wood are conspicuously different. The two ends should be cut straight across, transversely, and two portions near one end should be sawed away to show radial and tangential surfaces. These cut surfaces should all be sandpapered so that the grain is visible.

† The second portion of this exercise is based on a series of oak planks or boards which have been cut and polished (varnished or waxed) so that the grain is clearly visible. If the laboratory tables or other pieces of furniture are made of oak, these may be used.

Explain what it is that causes the marked difference in the appearance of the grain in these two cuts.

Oak cut radially is known as "quartered oak" and is much valued for the beauty of its grain. Show by a **diagram** how you would cut an oak log to get the largest number of boards out of it which showed quartered oak grain.

What makes quartered oak furniture more expensive than plain oak?

Find a board that grew rapidly, and compute the average annual increase in diameter of the log from which it came. Do the same for a board which grew very slowly.

How do you explain the differences in the width of annual rings in the same board or log?

Find a board which was cut from far out in a log; one which was cut from near the center; and (if possible) one which was cut from the very center. How can you determine what the position of the board in a log was?

From the evidence at hand do you think that an oak tree grows more rapidly in diameter when it is young or when it is old? Give reasons for your answer.

Do you think that a board from near the center of the log or from far out in it would be better for cabinet work? Why?

In furniture construction, where a considerable thickness of wood is needed, a single thick board is not used but the piece is built up from several much thinner layers. Why does this give more satisfactory results?

Exercise 41

THE MINUTE STRUCTURE OF WOOD

Examine a slide containing three sections of Pine wood, one transverse, one radial, and one tangential. Identify each and explain how you are able to do so.

The long cells which extend parallel to the axis of the stem and which make up the bulk of the wood, are called wood cells or *tracheids*. The rows of short cells extending through the wood at right angles to the annual rings are the *wood rays*.

In each section identify the spring tracheids and summer tracheids, the end of the year's growth, and the wood rays.

Make a diagrammatic **drawing,** about 10 cm. square, of a part of each section, including (in the transverse and the radial sections) about one full annual ring, showing the various structures mentioned above. Use a ruler to draw the cells if you wish.

From a knowledge of the structure of wood thus gained, reconstruct and **draw** a cube of wood as it would look if seen at the same magnification as your drawings. Point one corner of the cube toward you, thus displaying all three of its faces equally. Show the end of a year's growth extending across the transverse face of the cube. Be sure to have the structures seen in one face connect exactly with those shown on the other faces.

Exercise 42

THE STRUCTURE OF THE STEM OF A MONOCOTYLEDONOUS PLANT

Examine a cross section of the stem of Indian corn under the hand lens and with the low power of the microscope.

Name all the ways in which it differs from the section of the Tulip Tree twig studied in Exercise 39.

The scattered bundles are *fibro-vascular* bundles. Describe their distribution in the stem, and explain its advantage to the plant.

Make a **diagram** of the stem, filling in one-half of it to show the number, arrangement, and relative size of the bundles. Draw simply the outline of each bundle, and not the individual cells.

Draw one bundle as seen under the high power of the microscope.

Find the following tissues or their equivalents: pith, wood, bast, cortex.

Have the bundles any definite orientation? Explain.

How does such a stem as this grow in thickness? Where would you look for the cambium?

Exercise 43

MODIFIED STEMS

(*a*) Examine a plant of Quack Grass (*Agropyron repens*).

Where is its stem? How does this differ from the stems you have already studied? How do you know that it is a stem?

Identify nodes, internodes and leaves on it.

Where do the roots arise?

A stem like this is called a *rootstock*. What advantage does the possession of such a stem bestow? What is it that makes this plant such a bad weed?

Make a **drawing** of the stem and leaves.

(*b*) Examine the *tuber* of a potato plant.

What evidence can you find that this is a stem?

Which end was attached to the parent plant? How do you know this?

Are there nodes and internodes upon the tuber? Where are the leaves? the buds? Is there any relation between them? What are the "eyes"? Have they any definite arrangement?

What advantages does the possession of tubers bestow?

Make a **drawing** of the entire tuber.

Exercise 44

THE PATH OF WATER ASCENT IN THE STEM

Experiment

OBJECT: *To determine in what tissue of the stem the ascent of water takes place.*

Place a freshly cut leaf-bearing stem, preferably a small branch from a tree or shrub, with its cut end in water which has been colored with a little eosin.

After an hour or more cut the stem transversely at various heights and observe where the eosin has risen most rapidly.

If such translucent-stemmed plants as some of the forms of Impatiens and Fuchsia are available, place a freshly cut stem of one of these in the colored water and observe directly the rise of the color in the stem.

METABOLISM

Exercise 45

TYPES OF PLANT FOOD

Experiment

OBJECT: *To determine the character of the food stored in plants.*

The instructor will demonstrate the tests for starch, glucose, fat, and protein; using cornstarch, commercial glucose, olive oil and egg white, or other similar substances. These tests briefly are as follows:

Starch: The appearance of a blue color in the presence of a few drops of iodine solution.* The test is more satisfactory if the starch is boiled and then cooled, before testing.

Glucose: The appearance of a yellow or orange color upon boiling in the presence of a few drops of Fehling's solution.*

Fat: The production of an oily spot when rubbed on paper. The test may also be made by the use of the dyes Sudan III or Sudan IV.

Protein: The appearance of a brick-red color upon boiling in the presence of a few drops of Millon's reagent.*

Grind up separately some beans, some corn, a potato (not including the skin), an onion, and the seeds or storage organs of as many other plants as time allows, and test each for starch, sugar, fat, and protein.

Present your results in the form of a table.

* See page 105.

Exercise 46

THE STRUCTURE OF STARCH GRAINS

Examine under the high power of the microscope some grains of starch, mounted in water. Potato starch, corn starch, bean starch and wheat starch illustrate the main types.

Identify where possible the *hilum* and the *rings* in each. What cause can you suggest for these structures?

Describe briefly the characteristic features of each type of starch grain, telling how you would be able to distinguish it from all the others studied.

Draw a few starch grains of each type.

Exercise 47

DIGESTION OF STARCH

Experiment

OBJECT: *To determine the effect of a starch-digesting enzyme on starch.*

Make a thin starch mixture by stirring a little starch into cold water, boiling it, and then cooling it again.

Make a preparation of a starch-digesting enzyme, either from prepared diastase powder, from malt, or from saliva, by shaking up the enzyme well in water.

Test a little of both the starch and the enzyme with Fehling's solution to make sure that no sugar is present.

To a test-tube three-fourths full of the starch mixture add a few cc. of the enzyme preparation and mix thoroughly. Keep warm (about 30° C.) and at five-minute intervals pour off a small sample and test for sugar.

At the end of the experiment test the remainder of the starch mixture with iodine.

Exercise 48

RESPIRATION IN PLANT TISSUES

Experiment

OBJECT: *To determine whether germinating seeds respire.*

Fill each of two wide-mouthed bottles about one-third full (why not entirely full?) of vigorously sprouting beans or peas, and cork the bottles. Set up two similar but empty bottles as controls.

Keep in a warm place for 24 hours. At the end of this period test the gas in the jars for oxygen and for carbon dioxide. Absorption of oxygen or liberation of carbon dioxide may be used as good indications of respiratory activity.

The test for oxygen may be made by lowering a small burning candle or taper into one of the bottles and one of the controls.

The common test for carbon dioxide, which will be demonstrated by the instructor, is the production of a white precipitate in lime water. The gas in the second bottle and its control may now be tested for carbon dioxide by drawing it out through a bottle of lime water. This may readily be accomplished by the use of an inverted U-tube, one end passing through a hole in the stopper of the germination bottle and down into the seeds, the other end reaching almost to the bottom of the bottle of lime water. Drawing the air from the lime water bottle through a tube, either by the lungs or a pump, produces the vacuum necessary to pull the gas from around the seeds over into the lime water. There should, of course, be a second hole in the cork of the seed-bottle to allow entrance of air.

Exercise 49

THE LOCATION OF RESPIRATORY ACTIVITY

Experiment

OBJECT: *To determine in what parts of the plant respiration takes place.*

Provide each of five cylindrical glass jars with an air-tight glass or rubber stopper. Small museum jars are satisfactory.

Select a healthy and flowering geranium plant. Wash its root system thoroughly, cut it off and place the roots in one of the jars. Cut off the leaves and place in another jar, the stem in another, and the flower in the fourth. Leave the fifth jar empty as a control.

Place the stoppers in the jars securely and put all of the jars in the dark (why?).

At the next laboratory period test the gas in each jar by quickly pouring into it a few cc. of lime water, replacing the cork, and shaking the jar. A comparison of the lime water in the jars containing the plant parts with that in the control will enable you to determine whether these parts, or any of them, have been giving off carbon dioxide.

The presence and relative amount of oxygen may now be determined by lowering a candle on a wire into each jar, quickly replacing the stopper, and noting the number of seconds the candle burns. Why should this test be made after that for carbon dioxide rather than before? The oxygen test had best be made in a second series of jars, if possible, for the removing of the corks twice, even if done carefully, is likely to modify slightly the character of the gas in the jars.

Exercise 50

ENERGY RELATIONS IN RESPIRATION

Experiment

OBJECT: *To determine whether energy is liberated in respiration.*

Fill one Dewar flask or "Thermos" bottle (why not an ordinary bottle?) about one-third full (why not completely full?) of seeds which have been soaked and have begun to sprout, and into another put about the same quantity of seeds which have sprouted but were afterwards killed by soaking in formalin, or by other means.

Cork both bottles, but through a hole in the cork of each lower a thermometer into the seeds, first making sure that the thermometers register the same.

At intervals for several days compare the readings of the two thermometers.

Exercise 51

THE IMPORTANCE OF AEROBIC RESPIRATION FOR GROWTH

Experiment

OBJECT: *To determine whether oxygen is necessary for growth.*

Place in the bulb of a fermentation tube, retort, or similar apparatus, a bit of moist cotton and a few sprouting seeds. Suspend the open end of the tube in a strong solution of potassium pyrogallate, which in a few hours will dissolve the oxygen in the apparatus and will consequently rise for some distance into the tube. The sprouting seeds are now in an atmosphere devoid of oxygen.

As a control set up an apparatus which is similar except that access of air to the seeds is possible through the end of the tube, or other opening.

Set both aside in the dark (why?) and after a few days compare the growth of the two lots of seeds.

Exercise 52

MEASUREMENT OF THE GAS EXCHANGE IN RESPIRATION

Experiment

OBJECT: *To measure the gas exchange which takes place in respiration.*

Place a few vigorously sprouting seeds into some form of respirometer.* This is a glass chamber the capacity of which is definitely known, and a portion of which is calibrated so that its volume may be measured.

The volume of the seeds should first be ascertained, which will make possible a calculation of the volume of gas present in the apparatus. This gas at the start consists of atmospheric air, approximately 80 percent nitrogen and 20 percent oxygen.

Seal the apparatus and set aside for a day or two. At the end of this period analyze the gas in the chamber for the volume of carbon dioxide and oxygen as in the experiment with the photosynthometer, measuring the amount of carbon dioxide by dissolving it in potassium hydroxide and the amount of oxygen by dissolving it in potassium pyrogallate.

Exercise 53

FERMENTATION OF SUGAR BY YEAST

Experiment

OBJECT: *To determine the effect of yeast on a sugar solution.*

Prepare a mixture of about three parts of water to one part of molasses. Stir up a fresh yeast cake in half a glass of water. Fill a wide-mouthed jar two-thirds full of the molasses mixture, add about half the yeast, and stir thoroughly.

Prepare two control jars, one with the molasses mixture alone and one with yeast and water only.

* The respirometer in Professor Ganong's set of apparatus is very satisfactory.

Cover each jar with a glass plate and set aside in a warm place for twenty-four hours.

Test the bubbles of gas which are given off by the *fermenting* molasses for carbon dioxide. This may be done by pouring some of the solution into a smaller jar and bubbling the gas through lime water.

Test the air in the jars for oxygen by means of a candle flame.

In a few days, after fermentation has stopped, it is possible to test the solution for alcohol, the by-product characteristic of this type by fermentation. Such a test is performed by distilling the solution and testing the distillate with iodine crystals. If alcohol is present the characteristic odor of iodoform will be observed.

Exercise 54

THE STRUCTURE OF THE YEAST PLANT

Mount on a slide a little fermenting molasses mixture and examine with the high power of the microscope.

Identify the minute cells or chains of cells which constitute the yeast plant. It is the physiological activity of these minute plants which produces the fermentation of the molasses.

How do yeast plants grow and multiply?

Draw one of the groups of cells, showing in each cell the cytoplasm and the sap cavity or cavities.

Exercise 55

GAS PRESSURE IN FERMENTATION

Experiment

OBJECT: *To determine whether gas pressure is produced by fermentation.*

Place some vigorously fermenting molasses mixture in a flask and seal with a perforated cork, into the opening of which is tightly inserted a pressure gauge, or a U-shaped glass tube with some mercury in the bottom of the curve. Be sure that all the joints are tight.

Note whether or not pressure is registered by the gauge.

Exercise 56

ENERGY RELATIONS IN FERMENTATION

Experiment

OBJECT: *To determine whether energy is liberated in fermentation.*

Set up two Dewar flasks or "Thermos" bottles as in Exercise 50, but fill one with fermenting molasses and the other with a molasses solution of the same strength but which is not fermenting. Do not insert the corks tightly (why not?).

After an hour compare the readings of the two thermometers.

Exercise 57

GROWING REGIONS OF ROOT AND STEM

Experiment

Object: *To determine where growth in length occurs in the root and the stem.*

Select a vigorous young seedling of bean, squash, or other large-seeded plant growing in wet filter paper or some other medium from which it can readily be removed. The primary root should be about 5 cm. long.

Mark off a series of dots with India ink at millimeter intervals along the root, beginning at the tip and extending back for 2 cm.

Return the seedling to its moist chamber and examine in 24 hours, or at the next laboratory period.

Note the distance which now separates the dots, and from this determine where growth in length has taken place.

In young or fast-growing plants, where the tip of the stem is elongating rapidly, make a similar series of equidistant dots for at least 10 cm. back from the stem tip and note from time to time where growth in length occurs here, comparing it with conditions in the root.

Exercise 58

THE RATE OF GROWTH

Experiment

Object: *To measure the rate of growth in length of a stem.*

Select a rather rapidly growing plant, attach a thread lightly but firmly around the stem near its tip, carry this thread up and attach it to the shorter arm of a pivoting bar or indicator. Beside the tip of the long arm place a ruled measuring scale. The apparatus should be balanced so that the weight of the long arm is sufficient to keep the thread taut but not great enough to exert too strong a pull upon it.

If satisfactorily adjusted, this instrument (or any other type of auxanometer) will enable one to measure with a fair degree of accuracy the growth in length of the stem.

Take readings as often as possible and determine the rate of growth, from day to day, at different times of day, and under as many different conditions as possible.

Exercise 59

CELL DIVISION BY MITOSIS

Examine the prepared slide of a longitudinal section through the growing root-tip of an onion, which was used in Exercise 8.

Under the high power of the microscope study carefully the region near the root-tip, just behind the root cap. Here the cells are small and have not begun to elongate as they do farther back in the root. It is in this region that the cells are dividing, and here can be seen all the steps in mitotic cell division.

Find and **draw** the following stages in this process:

(*a*) *The Resting Cell.*—The nucleus has a well-developed membrane and the nuclear contents are in a granular condition. Some of these granules are more darkly stained than the rest, and constitute the *chromatin.*

(*b*) *The Prophase.*—The chromatin has become aggregated into a thread, which may show signs of breaking up into definite bodies, the *chromosomes.* The nuclear membrane is beginning to disappear.

(*c*) *The Metaphase.*—The nuclear membrane has disappeared, the chromosomes have spread out in a plane across the cell, and each chromosome has split lengthwise into two. Running out from the chromosomes are the *spindle fibers*, which converge at the two poles, one on either side of the equatorial plane.

(*d*) *The Anaphase.*—The chromosomes have separated into two groups, each of which contains one of the halves of each member of the original chromosome set.

(*e*) *The Telophase.*—Each of the two chromosome groups has now become aggregated into a chromatic thread, around which a nuclear membrane is beginning to form. Between these two nuclei a new cell wall is making its appearance. These two new cells soon assume the appearance of the resting cell studied in (*a*), and cell division is complete.

This method of cell division (essentially nuclear division) is known as *mitosis*. What seems to be its most striking characteristic and result?

What does it suggest as to the importance of the chromosomes?

What is the size of the two new cells in comparison to that from which they developed? What ultimately happens to these newly formed cells?

Is the growth of a plant tissue due to an increase in the number of its cells or to an increase in the size of the cells, or to both? Explain.

In what plane, with respect to the axis of the root, do these cell divisions occur? In what direction is the growth which they produce?

How many chromosomes are there in the cells of the onion? In what way could you cut a section of an onion root to determine this number more accurately?

Exercise 60

THE CAMBIUM AND ITS ACTIVITY

Study the transverse section of the twig used in Exercise 39 (or any woody twig a few years old) and examine the cambium under the high power of the microscope.

How many cells thick is it? What is the character of its cells? Explain just how it gives rise to new tissues.

Draw a bit of the cambium and its adjacent cells.

Make three small **diagrammatic drawings,** on the same scale, of this twig as it was when it was one year old; when it was two years old; and when it was three years old, showing pith, wood, cambium, bast, and cortex in their relative positions and sizes. In this way you can show which portions have been added each year and which portions have remained unchanged.

How does this method of growth differ from that common among animals?

If material is available, examine a cross section of a twig cut in the spring just after the cambium has begun its activity. How do the newly produced wood cells differ from the old ones?

Draw a portion of this cambium and the young tissues which it is producing.

THE PLANT AND ITS ENVIRONMENT

Exercise 61

THE EFFECT OF GRAVITY ON GROWTH

Experiment

OBJECT: *To determine the effect of gravity on growth.*

Plant some corn kernels in damp sawdust or sand, preferably in a glass-sided box, with the micropylar end pointing directly downward. When the root and shoot have each grown out a few centimeters and are perfectly straight and vertical, remove the seedlings and replant them in such a position that the root and shoot are now horizontal.

Study the growth of the seedlings from day to day.

Select some straight-stemmed potted plants, of almost any fast-growing herbaceous species, which are from 10 to 30 cm. long. Place one pot on its side so that the plant is in a horizontal position, leave it for a day or two, and study the direction of growth which the stem assumes.

Take another straight-stemmed plant similar to the above and attach it to a clinostat so that the plant is kept in a horizontal position but is slowly rotated by the clinostat mechanism. All sides of the plant are thus exposed equally to the stimulus of gravity.

Study the growth of this plant from day to day, and compare it with the plant which was kept in a constant horizontal position.

Exercise 62

THE EFFECT ON GROWTH OF OTHER FORCES THAN GRAVITY

Experiment

OBJECT: *To determine the effect of centrifugal force on growth.*

Fasten a sprouting corn kernel to each of the wings of a small water-wheel which may be operated by a jet of water from a faucet. Place the kernels in such a position that the young roots are pointing in a different direction in each case.

Revolve the wheel rapidly so that the plants are subjected to the stimulus of a considerable centrifugal force, and observe for a few days the direction of growth of roots and shoots.

Exercise 63

THE EFFECT OF LIGHT ON GROWTH

Experiment

OBJECT: *To determine the effect of light on growth.*

Grow some seedlings of almost any type of plant in a box which is open only on one side, so that all the illumination is lateral. The same result may be obtained, in less extreme form, by growing them in front of a window in an ordinary room, so that the light comes chiefly from one side.

Note the direction of growth of the stem and of the leaves.

If possible, grow some seedlings of Radish or other suitable plant in water culture in a glass jar so that all parts of the plant are visible, and expose them to one-sided illumination. The base of the stem should be kept firmly vertical by being held in a perforated cork, or by other means.

Under these conditions, compare the growth reactions of stem, root, and leaves to light.

Exercise 64

THE EFFECT OF ENVIRONMENTAL CONDITIONS ON PLANT STRUCTURE

Examine a portion of any typical hydrophytic plant or any typical xerophytic one which may be accessible, noting its external characters and then making and studying free-hand sections where possible.

If prepared slides of stems or leaves of these plants are available, study these.

Make **drawings** of the characteristic external and internal structures, and explain the advantages of these structures in the particular environmental conditions under which the plants live.

REPRODUCTION

Exercise 65

THE STRUCTURE OF THE FLOWER

Examine the flower given you.

Identify the *receptacle;* the *calyx,* composed of *sepals;* the *corolla,* composed of *petals;* the circle of *stamens,* each consisting of *filament* and *anther;* and the *pistil,* consisting of *ovary, style,* and *stigma.*

State clearly the function of each of these organs.

Draw the flower in face view and in side view.

Draw a sepal, a petal, a stamen, and the pistil, each by itself.

After the instructor has explained how a floral diagram is made, construct a transverse and a longitudinal **diagram** of this flower.

What is the function of the flower as a whole?

Mount some pollen from an anther in water on a slide and **draw** a few grains under the microscope.

Draw a cross section of the ovary, showing the ovules.

What are the functions of the pollen and the ovules?

Describe what happens in pollination and in fertilization.

Exercise 66

THE STRUCTURE OF THE FRUIT

Examine a ripe (or nearly ripe) but unbroken bean pod.* This is the *fruit* of the bean plant.

From just what part or parts of the flower has it developed? (Examine if possible some flowers of the bean or other member of the Legume family, or a picture of them.)

* This may have been preserved in liquid or merely dried.

Where were the sepals attached? the petals? the stamens? Why should these structures be present in the flower and not in the fruit?

Where was the pollen deposited?

What are the most conspicuous changes which have taken place in this pod since the opening of the flower?

Draw the fruit in side view.

Carefully split the pod open.

The wall of the fruit is called the *pericarp*. From what, in the flower, has it developed?

The beans, now visible inside the pod, are the *seeds* of the plant. From what, in the flower, have they developed?

The specialized portion of the pericarp to which they are attached is known as the *placenta*. What is the position of the placenta in the bean fruit?

A fruit like this, which ripens dry, has a single chamber, and splits open at maturity, is a *pod;* and this particular type of pod is known as a *legume*.

Draw one of the halves of the split pod, showing some of the seeds attached.

Draw the pod as it would look if it were cut transversely, at right angles to its length, and show in this drawing a seed and its attachment.

Study any other typical fruits which may be available, finding examples, if possible, of the *capsule*, the *achene*, the *drupe*, the *berry*, the *pome*, and the *grain*.

Exercise 67

THE STRUCTURE OF THE SEED

Examine some bean seeds which have been soaked in water over night.

Identify on the surface of each a minute opening, the *micropyle*, and a small adjacent elliptical area, the *hilum*. The conspicuous warty structure at the end of the hilum opposite the micropyle is the *caruncle*.

What can you suggest as to the functions, past or present, of hilum and micropyle? (An examination of the beans as they are attached to the pericarp, as seen in the previous exercise, may be suggestive.)

Draw a bean as seen in side view and as seen in face view.

Carefully peel off the seed coat or *integument*, noting whether there is any relation between the position of the hilum and micropyle and the position of structures which you now discover under the seed coat.

That part of the bean remaining after the integument has been removed is the *embryo* or young plant. From what, in the flower, has it developed? Note the two *cotyledons*, and the *hypocotyl* projecting between them.

Draw the embryo in side view.

Carefully separate the two cotyledons and spread them apart. Observe between them the hypocotyl and the *plumule*.

The cotyledons, hypocotyl, and plumule are the parts of the young plant in miniature. What are the functions of each? Into what will each develop when the seed germinates?

Draw the embryo as it is seen in this position.

Now examine and **draw** the soaked seed of the Castor Bean.*

How does it differ externally from the garden bean?

Peel off the integument. What do you discover inside? Dissect the parts carefully and find the embryo. How does this differ from the bean embryo?

The thick white layer deposited around it is the *endosperm*. What is the function of this tissue?

Separate the embryo from the endosperm and **draw** it.

Take another seed and, with a sharp knife, cut it lengthwise at right angles to the broad face. **Draw** the section thus exposed, showing integument, endosperm, and the structures of the embryo.

* Or any seed provided with abundant endosperm.

Examine a kernel of corn, **drawing** it in face and in side view.

Cut it open lengthwise, at right angles to its broad face. Identify the *embryo, plumule, radicle, scutellum* (cotyledon), and *endosperm.* What are the functions of each?

Draw this section.

How does the corn kernel differ from the two seeds you have previously studied?

Is it a seed or a fruit? How can you tell?

Exercise 68

THE STRUCTURE OF THE SEEDLING

Examine some bean seedlings which have just sprouted, some others in which the hypocotyl has lengthened considerably and the seed coat has been cast off, and some others in which the young plumular leaves are fully grown.

Draw a seedling in each of these stages.

Describe fully in your notes just what changes occur as the seed grows into the young plant.

Describe and explain the progressive alterations which take place in the cotyledons. From the evidence before you, what do you think is their morphological nature?

Examine in the same way, if possible, seedlings of the Pea, the Castor Bean*, and the Squash.

State fully the differences as to relative development and character of the various structures in these seedlings, especially the hypocotyl, cotyledons, and plumular leaves, and explain the differences.

* Morning Glory or Buckwheat are very similar to the Castor Bean in most particulars, and are often more available.

HEREDITY

Exercise 69

MENDEL'S LAWS OF SEGREGATION AND INDEPENDENT ASSORTMENT

A. Segregation

In two plant stocks (in corn, peas, or any other suitable material available) which differ in a single Mendelian character, describe carefully the difference involved.

Study some F_1 individuals of a cross between these two races. How do they differ from each parent?

Study an F_2 generation (grown from a self-fertilized F_1 plant or from a cross between two of these).

How many distinguishably different types of plants (as to the character in question) can you find here?

Make a careful count of the numbers of each. How do these numbers differ from those theoretically to be expected under Mendel's law of Segregation? Explain.

What offspring would you expect from each of these F_2 types if it was self-fertilized?

What offspring would you expect from a cross of each parent type with the F_1? of each parent type with each F_2 type?

B. Independent Assortment

In two plant stocks differing on *two* Mendelian characters, study and describe the parents, F_1 and F_2, answering the same questions and working out the same problems as under *A*.

THE THALLOPHYTA

THE CYANOPHYCEAE OR BLUE-GREEN ALGAE

Exercise 70

NOSTOC

Examine a colony of Nostoc. Describe its appearance and consistency. **Draw** it.

Pick out a bit of the colony with forceps, crush it on a slide, mount it in water, and examine under the low power of the microscope. Of what does the colony consist?

Under the high power examine one of the threads or filaments. Of what is this composed? Is it branched or unbranched?

Study the structure of one of its cells. How different in color is this cell from the chlorophyll-bearing cells of the plants which you have previously studied? Where is the pigment distributed? What structures can you distinguish in the cell?

Name all the ways in which this differs from such a typical plant cell as that of the leaf of Elodea, studied in Exercise 8.

The occasional large dead empty cells are called *heterocysts*. What function can you suggest for these?

If material is available, examine and **draw** a spore. How does this differ from an ordinary cell? What is its function?

How does a filament increase in size? How do new filaments arise?

What do you regard as a single, individual plant of Nostoc: a cell, a filament, or the gelatinous mass of filaments? Give reasons for your answer.

How is reproduction effected in this species?

What evidence does a study of this plant present for the belief that these blue-green algae are the most primitive living members of the plant kingdom?

What evolutionary advance has Nostoc made over types which were presumably more primitive?

Draw a part of a filament under high power, making your drawing large enough to show the character of the cell contents.

THE CHLOROPHYCEAE OR GREEN ALGAE

Exercise 71

PLEUROCOCCUS

Study a piece of bark, wood, or other material on which Pleurococcus is growing and describe its appearance as seen with the naked eye.

If opportunity presents, observe where this plant occurs in nature, and what conditions seem to favor its growth. How different is its environment from that of most algae?

Scrape off a little of the green material, mount in water, and study under the high power of the microscope.

How different is the arrangement of cells from that in the filament of Nostoc?

Examine carefully an individual cell. What structures can you see within it? How do the color and the distribution of the pigment differ from that in a cell of Nostoc? in a cell of the leaf of a seed plant?

What would you regard as a single plant of Pleurococcus?

How do the cells increase in number?

What evolutionary advance has Pleurococcus made over the blue-green algae?

Draw a single cell group.

Exercise 72

SPIROGYRA (GREEN SILK)

Study the living material of this form as it grows in the water. Is it attached to anything or does it float freely?

Lift out a little, and examine the "feel" of it between your fingers.

Mount a little in water and study under the low power of the microscope.

What is the form of the plant body? Are the filaments branched or not? Do they vary in width? How does the terminal cell differ from the others?

Under the low power of the microscope **draw** a portion of a filament, including one end of it, merely outlining the cells of which it is composed.

Examine a cell under the high power.

The one or more green bands are *chromatophores*, and correspond to the chloroplasts of higher plants.

The dense areas in these are the *pyrenoids.*

By careful focusing determine the shape of the cell and the exact position of the chromatophore within it.

Do you see the cytoplasm? the nucleus? Where would you expect to find these structures? What apparently occupies the central portion of the cell?

How does the filament grow in length?

Place a drop of iodine solution at the edge of the cover glass and draw it under by filter paper applied to the opposite side. This should make the protoplasmic structures stand out more clearly. What does it also tell you as to the function of the pyrenoids?

Draw a single cell, making the drawing large enough to show clearly all the details which you have observed.

What evolutionary advance has Spirogyra made over Nostoc? over Pleurococcus?

If material showing sexual reproduction is available, study and **draw** the various stages in the union of two cells. This process is known as *conjugation* and results in the formation of a thick-walled reproductive cell or *zygospore*. For what function is this spore particularly well fitted and why?

Exercise 73

VAUCHERIA (GREEN FELT)

Describe the appearance of this plant to the naked eye, and its feeling to the touch. How does it differ in these respects from Spirogyra?

Examine it under the low power of the microscope. Are the filaments branched or not? Are they divided into cells? Are all portions of the filament alike?

Draw a filament in outline.

Examine it under the high power of the microscope.

Of how many cells is a filament composed?

What would be the shape of a cross section of a filament?

Describe the size, shape, and position of the chromatophores.

Where is the cytoplasm? Watch carefully for movements within the plant.

The glistening droplets inside the filament consist of oily material, the commonest type of stored food in this plant.

Find some of the colorless, root-like branches or *rhizoids*. What is their function?

In what respects does the filament of Vaucheria differ from that of Spirogyra?

Draw a portion of the filament.

If material is available, study the formation of asexual *zoöspores* from the tips of the filaments. What is the function of a zoöspore? Describe and **draw** one.

Study under the high power of the microscope some material in which sexual reproduction is occurring or has taken place.

Identify the sexual organs. The male organs are known as *antheridia* and the female as *oögonia*.

Where are they borne? How are they separated from the rest of the filament? How do they differ from each other in shape and contents? What are the functions of each?

You will probably find a pair of sexual organs in which the antheridium is empty and the contents of the oögonium is a thick-walled *oöspore*. How has this change been brought about?

How different is sexual reproduction in this case from that of a plant like Spirogyra?

Draw a group of sexual organs and the filament on which they are borne.

What evolutionary advances has Vaucheria made over the forms previously studied?

Exercise 74

MINUTE FRESH-WATER ALGAE

Examine under the low and high powers of the microscope the algal flora to be found in the scum floating on stagnant pools, in the ooze in the bed of a brook or pond, or in quiet water generally.

Study and **draw** as many of the different types as you can find, having the instructor identify them for you. Look particularly for diatoms and desmids.

Keep a record of the number of distinguishably different algal species observed.

THE PHAEOPHYCEAE OR BROWN ALGAE

Exercise 75

FUCUS (ROCKWEED)

Examine the plant as a whole and describe its size, its general form, its color, and its method of attachment.

Where does this plant grow?

Such a plant body is called a *thallus*. Describe its method of branching. How does this differ from that of a seed plant?

Describe and explain whatever differences you notice between the basal portion of the plant, near its point of attachment, and the upper portion.

Examine the *bladders* which occur on the thallus. What is their function?

Examine also the swollen tips, or *receptacles*, which occur on some of the branches of the thallus. How different are they from the bladders? The dots on their surface are pores leading into small, sunken pockets which contain the sexual organs.

How different is the color of Fucus from that of the plants you have previously studied? Do you think it contains chlorophyll? Explain.

For just what sort of an environment is this plant well adapted? Explain.

Draw, life size, a portion of the thallus, showing the air bladders, and receptacles.

Cut a thin slice across a receptacle and mount it in water on a slide. Study with the hand-lens or low power of the microscope, and make a diagrammatic **drawing** of the entire section.

The small chambers near the edge, each of which opens to the outside by a pore, are the *conceptacles*, and contain the sexual organs. Each conceptacle usually contains only male or only female sexual structures.

Examine a conceptacle under the high power of the microscope. If your section is thin enough, you can study it directly. If not, dig out some of its contents with a needle.

The female conceptacle is filled with sterile hairs or *paraphyses*. Among the bases of these, and attached to the wall of the conceptacle, are the female organs or *oögonia*, each containing eight *eggs*.

A male conceptacle is filled with a mass of branching hairs on which are borne numerous small male organs or *antheridia*, which are filled with *sperms*.

Draw a male and a female conceptacle, describe them in your notes, and state all the differences which you observe between the two types.

Tease out an oögonium and **draw** it by itself.

Draw one of the branching antheridium-bearing hairs from a male conceptacle.

If freshly gathered plants, both male and female, are exposed to the air for a few hours or wrapped up in paper towelling and placed in a box, a gelatinous substance will usually be found exuding from the openings of the conceptacles. Scrape off some of this and mount in sea water. You should be able to see, under the high power of the microscope, both the sperms and the eggs. The former are small and very active.

Draw one of each on the same scale.

If possible, observe and describe the fertilization of an egg by one of the sperms.

Into what will the fertilized egg, or *zygote*, develop?

What evolutionary advances has Fucus made over the lower members of the Thallophyta?

The Rhodophyceae or Red Algae

Exercise 76

NEMALION AND OTHER TYPES

Study some living plants (or lacking these, some mounted specimens) of various types of red algae.

What is the general character of their vegetative body? Does it more resemble that of the green or that of the brown algae?

For what environmental conditions do the red algae seem to be particularly well fitted?

Do you think that they contain chlorophyll? Explain.

Under the hand lens **draw** a small part of a plant of one or more typical species of this group.

Nemalion.—Study and describe the plant body as a whole as seen by the naked eye.

Crush out a portion and examine under the high power.

Are the cells alike all through the thallus? Describe the manner in which the successive cells in a filament are held together. How does this differ from the condition of other filamentous forms which you have seen?

Describe the chromatophores.

Draw a portion of one of the filaments.

In a prepared slide of a male plant study and **draw** a cluster of antheridia. Each of these at maturity opens and releases a single non-motile male gamete, or *spermatium.*

In a prepared slide of a female plant study the female sexual organ or *carpogonium.* This corresponds to the oögonum of other algae, and contains a single egg.

Note its long extension, the *trichogyne,* to which the sperm has become attached. **Draw** a carpogonium.

Find a large, roundish fructification or *cystocarp* which develops from the fertilized egg in the carpogonium. The remains of the trichogyne may sometimes be seen at its tip.

The cystocarp consists of a group of short filaments, each terminating in a *carpospore.* These spores ultimately slip out and develop into new plants. Thus from one fertilized egg may arise a large number of new individuals instead of only one, a condition which constitutes a very simple example of the alternation of sexual and non-sexual generations so well marked in higher plants.

Draw a cystocarp.

What important evolutionary advance has been made by the red algae over the other Thallophytes studied?

THE BACTERIA

Exercise 77

BACTERIA OF VARIOUS TYPES

Place some hay or other dry plant material in a dish of water and keep for a few days in a warm place. The water will become cloudy and a scum will usually form at its surface.

Examine some of the water and scum under the high power of the microscope. The very minute, colorless organisms are bacteria.

Are they moving? Distinguish between a mere dancing or vibrating movement (Brownian movement) and true locomotion. Do you see any cilia, flagella, or other organs of locomotion?

What shape are the bacteria? Distinguish at least three types, those which are rod-shaped (*Bacillus*), those which are spherical (*Coccus*), and those which are spiral (*Spirillum*).

Are the cells all separate or do they adhere in colonies?

What structures do you see in the cell?

Draw some of each of the types which you can distinguish.

With a match or toothpick scrape one of your teeth and mount the material thus secured on a slide in a drop of water. You will note several types of bacteria here. Describe and **draw** such of these as are markedly different from those growing in the hay infusion.

Why are hay infusions and the mouth favorable situations for the growth of bacteria? How different are these environments from those in which algae occur? Explain.

Examine a prepared slide of various bacterial types which have been killed and stained.

Draw several of these, showing their important characteristics, and particularly the organs of locomotion in the species which possess these.

Bacteria may be grown in culture media of various kinds. Agar-agar, a vegetable jelly, is the base of many of these. This material, mixed with beef bouillon and sterilized by boiling, makes an excellent culture medium for most bacteria. The instructor will describe its preparation. Melt a little of this agar and pour some into each of three Petri dishes which have been sterilized by boiling, taking care to avoid, as far as possible, the danger of admitting bacteria into the dish from the air. Set these dishes aside in a cool place till the agar solidifies. If sterile cultures are desired, these Petri dishes may be placed in a steam sterilizer, but for the present purpose this is unnecessary.

Remove the cover of one of these dishes for three minutes, exposing the culture medium to the air of the laboratory, and then replace the cover.

Remove the cover of another and touch the surface lightly in several places with a pencil point or your finger nail, and replace the cover.

Take the third dish to some place outside the laboratory, expose it to the air for three minutes and replace the cover.

Examine these cultures from day to day and observe the spots which appear on them. These are colonies of bacteria.

From what did each colony arise?

Describe the shape, color, and general appearance of each colony.

Study under the microscope the material from each type, and **draw** and describe any bacteria different from those you have already seen.

How do bacteria reproduce themselves? Is there any evidence of reproduction in the material from these bacterial colonies?

In what ways do bacteria differ from the algae? Which algae do they most resemble?

The Phycomycetes or Alga-like Fungi

Exercise 78

RHIZOPUS NIGRICANS (BREAD MOLD)

Set aside some moistened bread in a closed box for a few days until vigorous growth of bread mold has appeared on it. A thin slice of bread on moistened filter paper in a Petri dish provides a good substratum and one in which the fungus may be easily studied without exposing it to the air. Such bread cultures had best be inoculated with bread mold spores to make sure of the development of this fungus.

What is the general appearance of bread mold to the naked eye? How different are its younger stages from its older ones?

With a hand lens study the vegetative body of the fungus, or *mycelium*, composed of filaments, or *hyphae*.

Describe carefully the manner in which the mycelium spreads over the substratum. Note the spreading hyphae (*stolons*), and the clusters of upright hyphae (*sporangiophores*) each tipped with a black *sporangium*. What stages in the development of these sporangia do you observe?

Draw a portion of the mycelium as seen under the hand lens.

Mount in water on a slide a bit of the mycelium including a cluster of sporangiophores.

Identify the *rhizoids*. What is their function?

Are there cross walls in the hyphae which divide it into cells?

What alga which you have studied does the vegetative part of this fungus most resemble?

Draw under the low power of the microscope a portion of the mycelium, showing stolon, rhizoids, sporangiophores, and sporangia.

Examine with the high power of the microscope a young sporangium, a mature one, and the remains of one which has broken open and liberated its spores.

Observe carefully just where the spores are borne. The central dome-shaped structure is the *columella*.

Draw a mature sporangium as it would look in longitudinal section.

Examine and **draw** a few of the spores. What color are they? What is their function? What advantage has this type of reproduction over that in other Thallophytes which you have studied?

Why is it that moist bread rarely fails to produce bread mold?

Exercise 79

SAPROLEGNIA (WATER MOLD)*

This fungus, or some of its near relatives, will usually develop after a few days on dead flies, bits of meat, or pieces

* Saprolegnia is a somewhat more typical alga-like fungus than Rhizopus, but the latter is more commonly studied and somewhat easier to secure in satisfactory condition for observation. This exercise may be substituted for that on Rhizopus, if desired.

of hard-boiled egg when placed in water from a ditch or pond.

Make a **habit drawing** of the mycelium showing the "halo" of hyphae radiating from the substratum.

What important difference does there seem to be between the food of the water mold and that of the bread mold?

Mount a bit of the mycelium on a slide and study it under the high power of the microscope.

Do the hyphae branch?

Are they divided into cells?

Draw a few vegetative hyphae.

Find a hypha the tip of which is swollen and cut off by a cross wall. This tip is a young *zoösporangium.* Find a later stage in which its contents has divided into a mass of minute *zoöspores* and a still later one where the sporangium wall has broken and the zoöspores are escaping.

Under the high power of the microscope **draw** a zoösporangium and its contained zoöspores. **Draw** a single zoöspore after its escape.

What is the function of the zoöspores?

Have they power of locomotion? Can you see any organs of locomotion?

In what respects do they differ from the spores of bread mold?

In a region of the mycelium nearer the substratum you will usually be able to find the sexual organs.

The *oögonia* are spherical structures. How many eggs does each contain? How is the oögonium attached to the hypha?

Find the delicate *antheridial filaments* attached to the surface of the oögonia. What is their function? Where on the hyphae do they arise? Is there more than one to each oögonium?

Draw in detail an oögonium and an attached antheridial filament, showing their connection with a hypha.

What alga previously studied does Saprolegnia most resemble in its reproductive structures?

THE ASCOMYCETES OR SAC FUNGI

Exercise 80

MICROSPHAERA (LILAC MILDEW)

Study this fungus as it grows on the lilac leaf. On what part of the leaf does it occur?

Examine the mycelium with a hand-lens and describe its appearance. Note the minute dark-colored bodies distributed through it.

Draw a portion of the mycelium under the hand-lens.

Whence does this fungus obtain its food?

From a leaf where the fungus has a distinct powdery appearance, scrape off a little of the mycelium, mount in water—and study under the low and high powers of the microscope. If a portion of the leaf is folded and mounted, the mycelium may often well be seen projecting from the edge.

Do the hyphae branch? Have they cross-walls?

Note the upright filaments or *conidiophores* on the end of each of which develops a chain of air-spores (*conidia* or *conidiospores*). How different is the method of spore production here from that observed in bread mold?

Draw a portion of the mycelium, including some conidiophores and conidia.

Study and **draw** one of the dark bodies or *perithecia.*

What characteristic structures do you observe on the wall of the perithecium? What function can you suggest for these?

Crush a perithecium by pressing gently on the cover-glass with needle or forceps. Observe the sacs or *asci* which escape from it. How many asci are contained in each perithecium?

Examine an ascus and note the *ascospores* within it. How many occur in each ascus? The asci develop as the result of a rather complicated sexual process which cannot be studied here.

Draw an ascus and its associated structures.

If opportunity allows, examine a number of the larger ascomycetes, such as cup fungi, morels, truffles, and black knot, and make a **habit drawing** of each.

Why are ascomycetes regarded as higher than alga-like fungi in the evolutionary scale?

THE BASIDIOMYCETES OR BASIDIA FUNGI

Exercise 81

PUCCINIA (WHEAT RUST)

Examine infected stems and sheaths of wheat and note the spots of red rust spores and of black rust spores breaking through the tissue. The red rust is the common summer stage of this fungus, the black type appearing chiefly late in the season.

Draw a bit of tissue slightly enlarged showing red rust spots and another showing those of black rust. How do they differ as to shape and location?

Where do you think is the mycelium of this fungus? Why does it injure the wheat plant?

Examine prepared slides showing sections through these two types of spots.

Draw a group of red rust spores, or *uredospores*, and a group of black rust spores, or *teleutospores*. How do they differ in size, shape, internal structures, and thickness of wall?

How are the teleutospores particularly well adapted to carry the fungus over the winter?

The teleutospores germinate in the spring, each cell sending out a small *promycelium* on which occur *sporidia* which cannot grow on wheat but infect the leaves of the barberry.

Examine a barberry leaf which shows the cluster-cups or *aecidia* produced by this fungus. Where on the leaf do these occur? How different is their appearance from that of the rust spots on wheat?

Draw a leaf, slightly enlarged, showing the aecidia.

Examine a prepared slide of a section of the leaf blade of barberry cut through an aecidium.

Note the *aecidiospores* and describe how they are produced. How do they differ from the uredospores and the teleutospores? Note the wall or *peridium* which encloses the spore mass. These spores infect the wheat plant again.

Sunken in the upper surface of the leaf but breaking through the epidermis are small flask-shaped structures, the *spermagonia*, which produce minute bodies, the *spermatia*. These apparently have no function in the life history of the species. What explanation can you offer for their presence?

Draw an aecidium and its contents as seen in section.

This fungus and its related species are serious parasites of wheat and other grains. What relatively simple measure for its eradication would you suggest?

Exercise 82

A GILL FUNGUS: AGARICUS (FIELD MUSHROOM)

The mushroom is the fruiting body of a fungus, the mycelium of which extends through the substratum on which the mushroom is growing.

Study this fruiting body, identifying the stalk or *stipe*, the cap or *pileus*, and the gills or *lamellae*.

In some forms a cup or *volva* is present at the base of the stipe, and a ring of tissue, the *annulus*, around the stipe.

Describe the color of the pileus and of the gills.

About how many gills are there? Do they all extend from the center to the edge of the pileus?

Draw the fruiting body as seen from the side. Then cut it in two lengthwise and **draw** it in section.

Draw a portion of the pileus as seen from beneath, showing the gills.

Study a young mushroom. Cut it in two, lengthwise, and **draw** a sectional view of it. From a comparison of this with the mature condition, describe the development of the fruiting body.

Examine a paper upon which a pileus has been resting for a few hours, gill-side down and covered by a box or jar to prevent air currents. Note the powdery *spores* and their distribution.

Mount a few on a slide and study and **draw** them under the high power of the microscope.

Examine under the high power a section cut across a gill or a portion of a gill teased out and mounted. Note the central tissue and the outer spore-bearing layer or *hymenium.* Of what are these tissues composed? How does their structure differ from that of ordinary cellular tissue as seen in the seed plants?

In the hymenium, identify the squarish, sterile cells, or *paraphyses,* and the longer *basidia.* On the latter are born the spores (*basidiospores*) each on a stalk or *sterigma* (plural *sterigmata*).

Draw a portion of the hymenium showing these structures.

How differently are these spores produced from those of an ascomycete?

Why is this "toadstool" type of fruiting body particularly well adapted for the production and dissemination of spores?

If opportunity allows, examine and **draw** fruiting bodies of other types of fleshy basidiomycetes, such as pore fungi, tooth fungi, and bracket fungi. Where is the spore-producing layer in each?

THE BRYOPHYTA

THE HEPATICAE OR LIVERWORTS

Exercise 83

MARCHANTIA

Vegetative Structures

Examine the thallus of this plant, noting particularly its size, shape, and method of branching.

Where and how does the thallus grow in length?

Describe the appearance of its upper surface and of its lower surface as seen under the hand lens. What is the function of each?

How different is this plant body in structure from that of any of the thallophytes? For what type of environment is it well suited?

What important evolutionary advances has this plant made over the algae in its vegetative structures?

Draw a portion of the thallus.

Male Sex Organs

You will note two kinds of stalked appendages rising from the thallus. Do they both occur on the same plant? The flat-topped discs with scalloped margins are the *male receptacles.*

Draw one of these, considerably enlarged. Describe its upper surface.

Study a longitudinal section cut through the receptacle. Note the air chambers. What is their function? Are stomata present?

Find the male sexual organs, or antheridia, sunken in pits below the surface.

Describe the shape and method of attachment of an antheridium. How many cells thick is its wall? Are the antheridia all of the same age and size? Explain.

What do the antheridia produce?

Make a rather diagrammatic **drawing** of the entire section of the receptacle, and a detailed **drawing** of a single antheridium.

Female Sex Organs

The stalked appendages with long finger-like lobes are the *female receptacles.*

Draw one of them, considerably enlarged.

Draw the receptacle as seen from below, still more enlarged, showing the lobes and the female sexual organs in lines. In older receptacles, after fertilization has taken place, the latter are surrounded by a conspicuous fringed membrane, or *perichaetium.*

Examine a longitudinal section through a rather young receptacle. Study and describe the structure of the tissue just below the upper surface. What is its function?

Study the female sexual organs or *archegonia* (singular *archegonium*) which hang from the lower surface of the receptacle. You should be able to see several stages in the development of these structures and perhaps some in which fertilization has taken place.

Find a mature archegonium and note the swollen basal portion, or *venter,* containing a single large *egg,* the female gamete; and the long *neck,* containing a line of *neck canal cells.* These cells break down, and a sperm enters the neck and passes down to the egg, which it fertilizes.

Draw an archegonium as seen in section.

How do the sperms (which are motile) get from the antheridium to the archegonium?

How different are the sexual organs of Marchantia from those of the Thallophytes?

After fertilization, the fertilized egg begins to divide into a group of cells. In what lower plants have you seen this occur? Look for an archegonium in which this has begun to take place and, if you find one, **draw** it.

Sporophyte

Examine an old female receptacle. Between the fringed membranes you will observe rows of *spore-cases* discharging *spores.* Carefully dissect out one of these and draw it under a hand-lens.

This structure has grown from the fertilized egg. Note the basal portion or *stalk*, and the terminal *sporangium* or *sporogonium.* The stalk is attached to the receptacle by a foot, at the base of the old archegonium, and the sporogonium is surmounted by the *calyptra,* or remains of the archegonium wall. In the sporogonium are produced a group of spores, each of which may give rise to a new Marchantia plant.

This entire structure—foot, stalk, and sporogonium—is known as the *sporophyte;* and the rest of the plant, which bears gametes instead of spores, as the *gametophyte.*

The fertilized egg thus produces not merely one new plant but a new kind of structure, which, in turn, bears a large number of non-sexual spores. Thus a single fertilization may give rise to many new plants, instead of one.

This process, whereby a gametophyte gives rise to gametes, which produce sporophytes; and the sporophytes give rise to spores which, in turn, produce gametophytes, is known as the *Alternation of Generations.* What are its advantages?

Draw a single sporophyte under the hand lens.

Pick out some of the contents of the sporogonium, mount on a slide, and study. Note the long cells or *elaters* among the spores. What is their function?

Draw a few of the spores and elaters.

What evolutionary advances have the liverworts made over the algae?

The Musci or Mosses

Exercise 84

POLYTRICHUM (HAIR-CAP MOSS)

Vegetative Structures

Examine a moss plant, identifying stem and leaves. In what ways does it differ from an ordinary seed plant such as you studied in the first part of the course?

Examine the leaves with a hand lens. How are they arranged? Have they petioles? Do they seem to be thicker or thinner than the leaves in various parts of the stem? How long do the leaves stay on the stem?

How can you estimate roughly the age of this moss plant?

Wash the soil carefully from the base of the plant and observe the slender brownish *rhizoids*. How do these differ from true roots?

You may also observe a mass of delicate, branching, green filaments, the *protonema*. This grows directly from a moss spore and on it appear buds from which arise the moss plants you are studying.

If you find some of the protonema, mount a bit of it and examine under the microscope. Of what does it remind you? What suggestion does its presence offer as to the evolutionary ancestry of the mosses?

What great evolutionary advance in its vegetative structure has a plant of this sort made over one like Marchantia?

Mosses are always small and insignificant as compared to the seed plants. How do you explain this fact?

Draw an entire moss plant.

Sex Organs

Examine the tips of such plants as do not bear the long, stalked spore-cases. Some of these tips you will find to be broad and flattened, bearing a rosette of leaves; while others have their leaves closely rolled together. The former are the male branches, the latter the female.

Draw one of each.

With needle and forceps loosen up the leaves on a male tip and with a hand lens find the cluster of antheridia. Pick them out and mount them.

Draw a single antheridium and one of the green filaments, or *paraphyses*, which occur among them.

If the antheridia are mature, crush one and study and **draw** one of the male gametes or sperms which are liberated.

Examine a prepared slide of a longitudinal section cut through a male tip. How many cells thick is the wall of the antheridium? How does this antheridium differ from that of Marchantia?

Draw an antheridium in section.

Tease apart the leaves at the tip of a female branch and find the group of archegonia. Pick one out, mount it, and **draw** it.

Examine a prepared slide of a longitudinal section cut through a female tip. Find and **draw** a young archegonium which has not opened and an older one which has, labeling their various parts.

What becomes of the canal cells when the archegonium is ready for fertilization?

What is the gametophyte of the moss?

Sporophyte

Examine a plant from the tip of which a long, stalked structure is growing. This is the sporophyte, which has developed from the fertilized egg.

Draw it as it appears to the naked eye, showing the stalk or *seta* and the protecting hood, or *calyptra*, which covers the spore case.

Carefully dissect the stalk out of the gametophyte and note the swollen base or *foot* by which it is attached. What is the function of the foot? of the seta?

From what do you think that the calyptra has developed? Does it belong to the sporophyte or to the gametophyte?

Remove it and find the spore-case (capsule or sporogonium) beneath. Describe its color and shape. Note the lid or *operculum* at its tip and the swollen *apophysis* at its base.

Draw the capsule as seen under the hand-lens.

Lift off the operculum and look at the capsule from the top, noting the membrane or *epiphragm* and the *peristome* or circle of teeth.

Draw it in this view.

Examine a prepared slide of a longitudinal section cut through a mature capsule.

Note the sterile central axis or *columella;* the wall, on the outside; and the loose tissue between the two, in the middle of which is the mass of spores.

What is the form of this spore mass?

What evidence have you as to the function of the loose tissue?

Make a diagrammatic **drawing** of the entire capsule section and a **drawing** under high power of a portion of the tissue from the columella to the outside.

Make a diagrammatic **drawing** of the capsule as it would look in transverse section.

What differences are there between the sporophyte of a moss and that of a liverwort, such as Marchantia?

What important evolutionary advances have the mosses made over the liverworts?

THE PTERIDOPHYTA

The Filicineae or Ferns

Exercise 85

A FERN*

Vegetative Structures

Examine a fern plant as a whole, after it has been carefully freed from the soil. Identify roots, stems, and leaves.

What type of root system has this plant? Where are the roots attached?

What is the chief function of the stem?

Of what shape is a typical fern leaf? What evidence can you see of the presence of reproductive structures?

Where does the stem of the fern grow in length? Does the fern stem grow in thickness with age?

If young developing leaves are present, describe their manner of growth.

What obvious differences do you note in root, leaf, and stem between this plant and a moss? between this plant and a typical seed plant?

For what type of environment does it seem well adapted?

Draw a portion of the fern plant, showing roots, stem, and at least one leaf.

Study a prepared slide of a cross section of a fern stem.

Identify the pith, the cortex, and the circle of fibrovascular bundles. These bundles in some species may be united into a solid ring.

* A species with a fast-growing root-stock, such as *Pteris aquilina*, *Dicksonia punctilobula*, or *Polypodium vulgare*, is better to show the general growth habit of a fern than species with tufted leaves and very slow-growing stems. This exercise is based on the use of such a fern for the vegetative structures and on a species of the Aspidium type for reproductive structures.

What points of resemblance and difference do you notice between this and the cross section of the twig of a seed plant, such as that studied in Exercise 39?

Examine particularly the fibrovascular bundles. Identify the wood (xylem) and the bast (phloem). What is their position with reference to one another? How does this differ from corresponding tissues in the seed plants?

Is there a cambium? How can you determine this?

Make a low-power diagrammatic **drawing** of the entire fern stem as seen in section.

If sections through a node are available, study and describe the way in which fibrovascular tissue from the stem enters the leaf. What is the course by which water passes from the soil into the leaf of a fern?

Spore-bearing Structures

Identify on the leaf the small fruiting-dots or *sori* (singular, *sorus*). Are they found on all the leaves? On which surface of the leaf do they occur? What relation do they have to the veins of the leaf?

Leaves or leaf-like structures bearing sporangia are known as *sporophylls*.

Study under the hand-lens some young sori and some mature ones. The membrane which covers the sorus is known as the *indusium*. What happens to the indusium as the sorus matures? What is its function? The brown structures which project from under its edge in the older sori are the spore-cases or sporangia.

Draw a young and an old sorus as seen under the hand-lens.

Study a prepared slide of a section cut through a sorus at right angles to the surface of the leaf blade.

Draw it under the low power of the microscope, showing the indusium and sporangia of various ages.

Pick off an indusium and mount on a slide some sporangia which are mature but have not yet opened. Study them under the microscope.

Note the stalk of the sporangium. What is its function? What is the shape of the sporangium?

Note the *annulus* or ring of cells with peculiarly thickened walls, which extends part way around the spore case. Describe exactly the thickening of their walls. Note the two thin-walled *lip cells* in that portion of the sporangium wall not surrounded by the annulus.

Study and describe some sporangia which have opened; and if possible place some ripe sporangia on a slide and, under the microscope, watch them open. From these observations explain the functions of the annulus and the lip cells, and the manner in which these structures aid in the opening of the sporangium. **Draw** a sporangium under the high power of the microscope.

Crush a ripe sporangium and study the spores which are liberated. How many are there in each sporangium?

Draw a spore.

Gametophyte

A spore develops into a gametophyte (*prothallus* or *prothallium*) of the fern.

Examine the surface of the soil in a pot in which fern spores have been sown for about three weeks and which has been kept moist. The minute green structures which you can see with a hand-lens are young prothallia. Mount some of them and study under the microscope. Find, if possible, some of the very small ones in which the ruptured spore wall is still present.

How do the prothallia obtain their food?

Draw several stages in the development of the prothallus.

With a hand lens study a mature prothallus.

What is its shape and color? How is it attached to the soil? **Draw** it as seen from above.

Wash the soil thoroughly from the prothallus and mount it on a slide, with the lower or ventral surface uppermost. Examine with the low power of the microscope.

Note the absorbing structures or rhizoids. Where are they attached?

Among the rhizoids you will find small, round antheridia, the male sexual organs. Some of these may have shed their sperms and have turned brown.

Near the notch, or deep angle in the prothallus, you will find the archegonia, or female sexual organs, the venter of each embedded in the tissue of the prothallus and the neck protruding.

Draw an entire prothallus, making your drawing about 10 cm. wide. Fill in the cells over only a small portion. Show the rhizoids, antheridia, and archegonia.

Study and **draw** an antheridium under the high power. This will show best if you can find one on the edge of the prothallus where it can be seen in profile.

Note the *basal cell*, the *cap cell*, and the *ring cell*, the latter forming the side wall of the antheridium.

Watch carefully for escaped sperms, which will be found swimming through the water. Describe the manner in which they move. You can make out their structure better if you add a little iodine solution to the water.

Under the high power of the microscope study and **draw** an archegonium, if possible from a prepared slide. Note the venter and the single egg cell within it; and the neck, protruding from the surface, with two or three canal cells inside it.

How, and under what conditions, is fertilization accomplished in the fern?

Young Sporophyte

In old cultures of fern prothallia, or on the soil around ferns in a greenhouse, or sometimes in the field, prothallia may be found from which young fern plants are growing. Study one of these young plants carefully with a hand-lens. Note its root and its one or more leaves. What is the shape of these leaves and how do their veins branch? Where is the young plant attached to the gametophyte? From what has it developed?

Draw a prothallus and its attached young fern plant as seen with a hand-lens. This young plant grows into the fern plant with which we are familiar and constitutes the sporophyte of the fern. It is a sex-less structure which produces the non-sexual spores. The prothallus is the sexual generation or gametophyte.

To what, in a moss, does the sporophyte of the fern correspond? To what does the sporangium correspond? the spore? the fern leaf? the fern stem? the prothallus? the archegonium? the antheridium? the rhizoids?

Describe briefly the important evolutionary advances which the fern has made over the liverwort and the moss.

With what change in habitat were these advances probably associated?

THE LYCOPODINEAE OR CLUB MOSSES

Exercise 86

A HOMOSPOROUS LYCOPOD: LYCOPODIUM

Vegetative Structures

Examine an entire plant of Lycopodium and describe its roots, stems, and leaves.

How do these structures differ from those of a fern?

What is the method of branching of the stem? How are the leaves arranged on the stem?

Are the stems all alike?

What are the functions of the underground portions?

Where does the stem grow in length? in thickness?

For what sort of environment is a plant of this sort particularly well fitted? Why?

Draw a portion of the plant, showing roots, stem, and leaves.

Study a prepared slide of a cross section of the stem of Lycopodium. Note that a pith is absent and that the fibrovascular tissue is in a solid, rod-like central cylinder.

How are the wood and the bast distributed in this?

How many fibrovascular bundles occur in each leaf?

How is the fibrovascular supply of the leaf attached to the central cylinder?

Make a low-power diagrammatic **drawing** of this stem section.

Spore-bearing Structures

Study the cones or *strobili* (singular, *strobilus*).

Where are they borne? Of what advantage to the plant is this position?

The units of which they are composed are the cone scales or *sporophylls.* What is the morphological relationship, between these sporophylls and the vegetative leaves? Explain.*

Draw a strobilus, preferably as a part of your drawing of the entire plant.

From a strobilus which has not yet shed its spores dissect out a single sporophyll and study with the hand-lens.

Note the large, roundish sporangium. On which surface of the sporophyll does it occur?

Draw a sporophyll and its sporangium.

Break open the latter and study the ripe spores. Are they numerous or few in a single sporangium? Examine a strobilus which is shedding its spores and note how they are liberated.

Study the spores under the high power of the microscope. What is their shape?

Note the three-angled or tri-radiate ridge on the spore surface. Explain the spore shape and the occurrence of this ridge. (If younger sporangia are available, the adhesion of the spores in sets of four may be observed, which will throw light on these problems.)

Describe the surface of the spore. Of what advantage to the plant may be such a surface?

Draw a single spore.

Examine spores from sporangia at various levels on the strobilus, and determine whether or not they are all alike.

What advantage does the production of spores in strobili have over their production on vegetative leaves, as in the fern?

The lycopod plant is the sporophyte generation and the spores which it produces germinate, under favorable conditions, and develop into peculiar, tuberous gametophytes which are rare and hard to find. If prepared slides through

* This problem may readily be solved if a species like *Lycopodium lucidulum* can be studied.

such a gametophyte are available, describe the character of the gametophyte and the distribution and structure of its sex organs by means of notes and **drawings.**

Enumerate the important differences in structure and reproduction between a lycopod and a fern.

Exercise 87

A HETEROSPOROUS LYCOPOD: SELAGINELLA

Study and draw a plant of Selaginella. How does it differ from Lycopodium?

Examine a strobilus, dissecting out sporophylls from various points along its axis and noting the differences between them.

Identify the *microsporophylls*, bearing *microsporangia*, and the *megasporophylls*, bearing *megasporangia*. How do these differ in appearance? In what portion of the cone is each borne?

Draw one of each of the two types of sporophylls as seen in face view, showing its sporangium.

Open each type of sporangium with a needle. How many *megaspores* are there in a megasporangium and about how many *microspores* in a microsporangium?

Draw a megaspore and a microspore side by side, on the same scale, as seen under the low power of the microscope.

The megaspore develops into a female gametophyte which bears archegonia only, and the microspore into a male gametophyte, consisting chiefly of a single antheridium. The fertilized egg grows into the young sporophyte.

Plants in which the spores are differentiated into megaspores and microspores are called *heterosporous*. Of what advantage is this characteristic to the plant?

What evolutionary advance has Selaginella made over Lycopodium?

The Equisetineae or Horsetails

Exercise 88

EQUISETUM (HORSETAIL)

Vegetative Structures

Examine a plant of *Equisetum arvense*, including its subterranean rhizome.

Describe the method of branching of the stem. Find the leaves and describe their character and arrangement.

Where in this plant is the bulk of the photosynthetic activity carried on?

Describe the external appearance of the aerial stem and of the rhizome.

Draw a portion of the aerial stem, showing branches and leaves.

Examine and draw under the hand-lens a bit of the stem, including a node. Are the ridges of one internode continuous with those of the next or do they alternate?

Study a prepared slide of a cross section of the stem of Equisetum.

Note the large central air space and the two series of smaller ones. What position do these hold in relation to the ridges and furrows of the stem?

Where is the photosynthetic tissue chiefly developed? How can you identify it?

Under the high power of the microscope you can identify the fibrovascular bundles as small groups of xylem and phloem cells, each just outside one of the circles of smaller air spaces.

Make a low power **diagram** of the entire section, showing the position and relative size of the various structures mentioned above, but not drawing cells.

Spore-bearing Structures

Study some material, either fresh or preserved, of the specialized spore-bearing stem of this species, which develops early in the spring.

Where is the strobilus borne? How does it differ in appearance from that of a lycopod?

Draw a strobilus.

Dissect a portion of the strobilus away, studying the structure of the shield-shaped *sporangiophores*. How are they arranged? Do you think that they are sporophylls? Explain. How do they differ from the sporophylls of Lycopodium?

Note the circle of sporangia borne on the inner edge of the sporangiophore. How many are there on each sporangiophore?

Draw a sporangiophore in face view and in side view.

Open a sporangium and study some of the spores under the microscope.

Are the spores all alike?

The filaments attached to each spore constitute the *perinium*. How many such filaments are there? What is their shape? What is their function? Study some spores mounted in water and some others in a dry condition, as they come from a strobilus which is shedding its spores. Breathe on the dry spores and note the change which takes place in the perinium.

THE SPERMATOPHYTA

THE GYMNOSPERMAE OR GYMNOSPERMS

Exercise 89

THE PINE

The vegetative structures of seed plants have been studied in the earlier portions of this course and it will not be necessary to review them here. The plant body in this group is very diverse in character but agrees in general with that of the pteridophytes in being differentiated into root, stem, and leaf systems. The reproductive structures have undergone a considerable evolutionary change, however, and it is with these that the present and the following exercise will chiefly deal.

Study a small branch of a pine tree (the sporophyte) and enumerate the various ways in which the young stem and leaves differ from those of the seed plants previously studied.

The pine, like all seed plants, is heterosporous. It bears its two types of spores in two types of cones or strobili: the microsporangiate, staminate, or "male" ones, and the megasporangiate, pistillate, or "female" (seed-bearing) ones.

Staminate Cone

Study a group of fresh staminate cones or some which have been preserved in liquid.

Where on the branch do they occur? Of what advantage is this position?

How long do they remain on the tree?

Draw a cone, showing the arrangement of its cone scales.

Dissect away a part of a staminate cone and pick out and study one of the cone scales, or microsporophylls.

Note the two large pollen sacs or microsporangia borne on the lower (dorsal or abaxial) surface of the scale.

To what, morphologically, does this microsporophyll correspond in Selaginella? in an ordinary flower?

Draw a microsporophyll as seen in side view and in end view.

Pollen and Male Gametophyte

Mount in water some mature pollen grains taken from a microsporangium. These are *microspores* which have begun to develop very much reduced male gametophytes.

Examine them under the microscope and note the two inflated, wing-like expansions on each, produced by the separation, at two regions, of the inner and outer walls of the grain. What is the function of these two structures?

Examine under the high power of the microscope a prepared slide showing stained sections through some pollen grains. Within a grain identify the *tube nucleus*, near the center, and the *generative cell*, near the wall on the side of the grain away from the "wings." You may also be able to see one or more very much reduced *prothallial cells* between the generative cell and the wall.

Draw a pollen grain showing these structures.

The pollen grain is carried by the wind to a pistillate cone, where it lights directly on the ovule. Here it germinates and sends out a *pollen tube* which penetrates the tissues of the ovule to the female sex organs.

If prepared slides are available to show the development of the male gametophyte, study them and make **drawings** of:

(1) the microspore, still within the microsporangium and containing only one nucleus.

(2) a mature pollen grain.

(3) a germinating pollen grain which has burst and is sending out a pollen tube, down which the tube nucleus is passing, followed by the generative cell.

(4) the division of this generative cell into the two male cells or male gametes, one of which will effect fertilization with the egg.

Pistillate Cone

Examine and **draw** a pistillate cone about one year old. How does it differ externally from a staminate cone?

From a study of larger pine branches, determine when these cones appear and how old they are when they contain ripe seeds.

Dissect away a part of the cone and study a cone scale or megasporophyll. Note the small *sterile bract* at its base. This is thought to represent a modified leaf, and the scale a much reduced branch in the axil of this leaf.

Ovule and Female Gametophyte

On the upper surface of the scale note the two *ovules*.

Draw a scale as seen from the side and as seen from above, showing the ovules.

Each ovule represents, morphologically, a megasporangium surrounded by a coat or integument. At this stage the bulk of the ovule is occupied by the *embryo sac* or female gametophyte, which has developed from a megaspore in a megasporangium borne on the young cone scale. This female gametophyte bears the female sex organs or archegonia, each containing a single large egg. The egg is fertilized by a male gamete which has come down the pollen tube from a germinated pollen grain; and this fertilized egg, the first cell of the new sporophyte, develops into the embryo of the seed.

Slice an ovule lengthwise with a sharp knife and **draw** it as seen under the hand lens, showing the embryo sac and integument.

If prepared slides are available to show the development of the female gametophyte, study them and make **drawings** of:

(1) the single megaspore in the young ovule or megasporangium.

(2) the young embryo sac which is developing from the megaspore.

(3) the mature embryo sac, bearing at one end the ripe archegonia.

(4) a single archegonium.

(5) fertilization of the egg by a male cell brought down by the pollen tube, which has penetrated through the tissues of the end of the megasporangium.

(6) stages in the development of the embryo from the fertilized egg.

(7) the young seed.

Seed

Study and **draw** a ripe seed showing its wing. What is the function of the wing?

Cut a soaked pine seed lengthwise with a sharp knife, and study and **draw** the section, showing the seed coat or integument; the *endosperm*, a mass of stored food developed from the tissue of the embryo sac; and embedded in this the *embryo*, or young sporophyte, developed from the fertilized egg. The embryo consists of a short *hypocotyl* and a circle of *cotyledons*.

Upon the germination of the seed, the embryo will grow into a young pine tree, thus completing the life cycle.

Describe the important evolutionary advances which the gymnosperms have made over the heterosporous pteridophytes. What important advantages does the seed habit confer?

THE ANGIOSPERMAE OR ANGIOSPERMS

Exercise 90

THE LILY

The vegetative structure of angiospermous plants has been studied earlier in this course, and the gross structure of the flower was taken up in Exercise 65.

Stamen, Pollen and Male Gametophyte

Examine a stamen of the lily. To what does it correspond, morphologically, in the pine? in a pteridophyte?

Study a prepared slide of a section across the anther. Note the four anther sacs or microsporangia.

What structures in the wall of the anther do you observe which may assist in the breaking of the sporangium wall and the liberation of the pollen grains?

Make a low-power **diagram** of this section of the anther.

Using this same slide, study and draw a pollen grain under the high power, showing the tube nucleus and the generative cell.

If preparations of earlier stages are available, the development of the microspores may be studied. The pollen grains are not carried directly to the ovules, as in gymnosperms, but to the stigma, where they germinate and send pollen tubes down through the style to the ovules in the ovary. The generative cell divides into two male gametes, and the male gametophyte is thus reduced to these two cells and the tube nucleus.

Ovule and Female Gametophyte

The development of the female gametophyte may be studied from prepared slides of sections cut transversely across the ovary in lily buds.

Examine one of these sections and note the wall of the ovary, and the three chambers or cells, each with a pair of ovules within it. Where are the ovules attached?

To what does the ovary correspond, morphologically, in a gymnosperm?

Make a low power **diagram** of the entire section.

Study carefully, under the high power of the microscope, the individual ovules, noting the occurrence of two integuments. Find and **draw** the following stages:

(1) a single large megaspore.

(2) two nuclei in the megaspore, resulting from the division of the original nucleus.

(3) four nuclei, resulting from the division of each of the first two.

(4) eight nuclei, a group of four at one end of the young embryo sac and a group of four at the other.

(5) the mature embryo sac, consisting of three cells at the end of the sac away from the opening or micropyle of the ovule; three at the end next the micropyle, consisting of an egg and two other cells; and the endosperm nucleus in the center of the sac, formed from the union of two nuclei, one from each of the two earlier groups of four.

Note that the embryo sac, or female gametophyte, is very much reduced and no longer has a definite sexual organ or archegonium.

The ovule is now mature and ready for fertilization. The pollen tube discharges into it two male cells, formed by the division of the generative cell of the pollen grain. One of these fertilizes the egg, from which develops the embryo of the seed; and the other fertilizes the endosperm nucleus, from which develops the endosperm of the seed. If prepared slides are available, **draw** the embryo sac at the time of fertilization.

The structures of the angiosperm seed have already been studied in Exercise 66.

What important evolutionary advances have the angiosperms made over the gymnosperms?

What advantages do these differences confer?

Exercise 91

FAMILY, GENUS, AND SPECIES

Examine a large number of plants in flower (living, if possible; herbarium specimens, if necessary) all of which belong to the same family and which represent a considerable number of genera within that family.

Endeavor to discover a trait or series of traits which is common to all the plants and which may therefore be regarded as distinctive for the *family* as a whole.

Study the members of the various genera represented and determine what are the traits which distinguish each *genus* from the others of the same family.

In one or more of these genera study, if possible, a large number of *species*. In the light of this more extensive material revise, if necessary, your list of traits characteristic of this genus. Determine for each species its own distinctive traits.

Which, of all the traits studied, are the most ancient? How do you know this?

Exercise 92

PLANT IDENTIFICATION

Examine some flowering material of a seed-plant species and write a concise description, so far as the facts are available, of its stem, leaf, flower, and fruit, laying particular emphasis on the floral characters and making transverse and longitudinal **diagrams** of the flower.

You are now in a position to identify the plant by the study of a "Flora," "Manual," or other descriptive plant list of your region, finding therein a description which agrees completely with yours and to which is attached the technical name (genus and species) of the plant in question. This identification is usually accomplished by the use of a *key,* the operation of which will be explained by the instructor. A key is a short-cut to identification and saves going through a long list of descriptions. It is simply a series of choices whereby alternatives are progressively eliminated until the name of the plant or plant group is reached. The usual procedure is to determine the family of your plant by a key to families, usually at the front of the book. It is then possible to turn to this family in the text, identify the genus through a key to the genera, and finally identify the species itself under the genus.

Proficiency in the use of keys and in plant identification in general is not difficult but can be mastered only by a considerable amount of practice. It is a useful accomplishment for anyone and a necessary tool in botanical study of all kinds.

A FEW USEFUL FORMULAS

Iodine Solution.—To a 2 percent solution of potassium iodide add sufficient metallic iodine to color it a deep yellowish-brown.

Fehling's Solution.—Make up two solutions as follows:

A: 35 gms. of copper sulphate in 500 cc. of water.

B: 125 gms. of potassium hydroxide and 173 gms. of Rochelle salt in 500 cc. of water.

Keep A and B separate and in rubber-stoppered bottles, if possible; and mix them in equal volumes when needed for use.

Millon's Reagent.—Dissolve 1 part, by weight, of mercury in 2 parts, by weight, of concentrated nitric acid and dilute the resulting solution with 2 volumes of water.

Potassium Pyrogallate Solution.—Dissolve 1 part, by weight, of pyrogallic acid and 5 parts of potassium hydroxide in 30 parts of water.

THE METRIC SYSTEM

1 meter	= 10 decimeters
	= 100 centimeters
	= 1000 millimeters
1 liter	= 1000 cubic centimeters
1 kilogram	= 1000 grams

1 cubic centimeter of water (under standard conditions) weighs 1 gram.

APPROXIMATE CONVERSION TABLE

Metric to English and English to Metric

1 meter	= 39 inches
1 decimeter	= 4 inches
1 centimeter	= $\frac{2}{5}$ of an inch
1 millimeter	= $\frac{1}{25}$ of an inch
1 liter	= 1 quart
1 kilogram	= $2\frac{1}{5}$ pounds
1 gram	= $\frac{1}{28}$ of an ounce

1 yard	= .9 meters or 91 centimeters
1 foot	= 30 centimeters
1 inch	= $2\frac{1}{2}$ centimeters or 25 millimeters
1 pound	= 453 grams
1 ounce	= 28 grams

CENTIGRADE AND FAHRENHEIT TEMPERATURE SCALES

Water freezes at 0° Centigrade and at 32° Fahrenheit.

Water boils at 100° Centigrade and at 212° Fahrenheit.

1 degree Centigrade = $\frac{9}{5}$ of a degree Fahrenheit.

To convert Centigrade to Fahrenheit, multiply by $\frac{9}{5}$ and add 32.

To convert Fahrenheit to Centigrade, subtract 32 and multiply by $\frac{5}{9}$.

10 centimeters: 100 millimeters.