A HANDBOOK

FOR THE USE OF TEACHERS

TO ACCOMPANY

BERGEN'S FOUNDATIONS OF BOTANY

BY

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This book is intended for use in secondary schools, or for colleges in which botany is not an admission requirement. It will furnish work for a school year, four or five periods per week, or, by suitable omissions, it may readily be adapted to a half-year course.

For *a one-year course* the author would recommend that the chapters be taken in the order in which they occur, as far as the seasons will admit of this. Unless greenhouse material is freely available, Chapter X would have to be postponed until late in the spring. It may also be found necessary to take up Chapters XIV–XVI inclusive after Chapters XXI–XXIII inclusive. Chapter IX, so far as it discusses the forms of leaves, their tips, margins, etc., is for reference only; so is Chapter XIII and much of Chapters XV, XVIII, and XIX. Chapters XXIII and XXX are not so much to be prepared for recitation as to be read for general impressions. It will probably be found that the best way to use such chapters is to assign them for home reading and then call for an abstract, to be written (without referring to the text-book) in school. The author has, indeed, inserted Chapter XXIII only out of deference to the opinion of some teachers who wish to make the evolutionary history of the vegetable kingdom part of their course in botany. There is no doubt that organic evolution can be more easily comprehended by a study of the phylogeny of animals than of plants, and pupils who are to be given instruction both in zoölogy and in botany should get their ideas of evolution in connection with the former subject. Many teachers will no doubt prefer to use the ecological chapters of Part II, from time to time, inserted in suitable places among the topics of Part I.

The *Key and Flora* will probably be much used by some teachers and little or not at all by others. To the author the analysis of flowering plants seems one of the least important of the many topics for study by a class in elementary botany. Whatever work is done in determination of species should be done with extreme thoroughness and supplemented by some such studies of the families of seed-plants as are outlined in Spalding's *Introduction to Botany.*

For *a half-year course* the following options are suggested:

A

Omit about half the laboratory work of Chapter I, all the microscopical laboratory work of Chapters VI and XI, all but the laboratory work and a few definitions of Chapter IX, all of Chapters X, XII, XIII, the last half of Chapter XV, the first half of Chapter XVI, merely read Chapters XVIII, XIX, study one species each from Chapters XX–XXII, omit Chapters XXIII–XXVI and XXX. Determine a very few species by aid of the *Key and Flora,* merely to illustrate the method.

B

Omit as in (A), except that all of the study of cryptogams (Chapters XX–XXII) is to be omitted, and take Chapters XXIV–XXX.

C

Omit as in (A), except that Chapters I–III inclusive are to be entirely left out, except the study of the life-history of a single seedling and a brief account of the storage of plant-food in the seed. Omit Chapters V–XIII inclusive, except a brief statement of the structure and functions of stems and leaves, which may be outlined in a series of topics which the pupil can expand by aid of designated sections in the text-book; omit also Chapters XIV–XVIII inclusive, except sections 205 (or 206 or 207), 208, 214, 221, 226, 227, 229 (or 230), 233. In place of this omitted matter substitute as much of the chapters on cryptogams (XX–XXII inclusive) as the time available will allow.

The author would recommend the half-year course outlined in (A), which does not differ greatly from that which he himself adopts. (B) is more ecological and (C) more cryptogamic than (A).

Teachers who are using the text-book for the first time should be careful not to spend an undue proportion of the time available on the laboratory work of Chapters I and II, VI, or XX–XXII. It would be easy to devote the entire half-year to the study of stem-structure or to laboratory work on the cryptogams discussed in Chapters XX–XXII.

The ecological portion (Part II) may be treated wholly as reading matter, to be read at home and discussed in short talks in the class-room; or it may be studied by aid of laboratory and field work, as described on pages 40–42 of this pamphlet. This latter method should be followed whenever natural plant societies are readily accessible and the pupils are sufficiently advanced to identify plants for themselves.

Whatever course is adopted, the teacher will find it convenient to prepare for his own use an outline of the topics discussed. If the headings of the sections of the text-book are copied into a small blank book, with space enough left under each for brief notes, the use of such an outline will greatly facilitate the work of conducting recitations.

Brief written exercises will save much time that might without them have to be devoted to oral recitations. In many cases such short papers may serve to test the pupil's observing and reasoning powers, *e.g.*, when he is asked to describe a new object somewhat resembling another which he has already studied. For instance, he has become familiar with the onion-bulb, and is then asked to write (with the object in hand) a comparative description of a lily-bulb; or he has studied the histology of sycamore wood and a blue-print photomicrograph is given him or a bromide enlargement is set up before him, representing sections of sassafras wood, similar to the familiar sycamore sections, and he is asked to write about the histological resemblances and differences of the two kinds of wood.

Pupils should be required to study and to recite upon the illustrations of the text-book. Such cuts as those of the magnolia branch (Fig. 35), stem-sections (Figs. 55–58), leaf-sections (Figs. 116, 119), and most of the ecological illustrations furnish abundant material for discussion.

CONDUCTING LABORATORY WORK

Laboratory sections should be small, not over twelve or fifteen pupils to each teacher. The work of the period may be indicated by an outline posted upon the laboratory blackboard. In most cases there is no objection to the use of the text-book in the laboratory, since the laboratory directions of the book do not generally *tell the pupil what he will see,* but rather ask him to look for certain organs, structures, or phenomena of plant-life which are indicated but not described. In the chemical tests given, the pupil is usually asked to discover something for himself. In the same way the teacher will notice that in most instances the illustrations *do not represent the identical objects which the class is studying, but similar objects.* For instance, the germinating castor-bean is figured, but not beans, lupines, peas, or corn; the wood-sections, leaf-sections, and so on given in the illustrations are not those which the class is studying with the microscope. So, too, the cryptogamic genera or species of which cuts are furnished are not usually the ones studied: *e.g.*, the *Saccharomyces* of Fig. 197 is not the commercial species; the mosses, ferns, and *Equisetum* represented in the illustrations are not the ones which will probably be in the hands of the class.

There is some difference of opinion as to whether laboratory work in the physical or biological sciences should precede or follow the discussion of the objects or phenomena studied. In the author's opinion the laboratory work should come first in all cases where the thing studied is moderately easy to see or to understand. It would be a much less interesting and more difficult way to take up the study of seeds by giving a general talk on the origin and homology of the seed than by actually investigating the more obvious features of a bean or a squash seed. Again, the so-called sleep of leaves should be seen first and discussed afterwards. On the other hand, I have found that the best way to teach the histology of the leaf is first to sketch on the board a very simple and highly diagrammatic leaf-section and discuss it at some length, and after this take up the details of an actual section.

The amount of delicate manipulation, such as section-cutting, making permanent mounts for the microscope, micrometer measurement, and so on, which can be demanded of a class, will vary greatly with circumstances. Some experimenting is usually necessary to decide how much of such manipulation had better be done for the class and how much by it. Perhaps the best criterion in every case of the advisability of insisting upon each individual's doing a given piece of work is the educational value of the operation. Since, for instance, the student can get a far better idea of the structure of a grain of corn by cutting his own sections through it than in any other way, he should be asked to do so. On the other hand, it would be folly to have the beginner spend hours in imbedding an object like a hyacinth root-tip and cutting longitudinal sections with a microtome when a good mounted section can be had for a trifling sum, and the pupil can see the general arrangement of parts for himself in a translucent root like that of tradescantia or barley.

It is desirable to make the laboratory work, to some extent, optional. No pupil can master even the rudiments of botany without conducting for himself some elementary researches. But every teacher has discovered that certain pupils soon weary of the laboratory work, while others will gladly undertake extra investigations, to be done outside of the regular hours. The author has frequently adopted the plan of making out lists of optional studies and experiments, for which suitable credit is given on the pupil's record. Plenty of material for such options will be found in the laboratory guides of which the titles are given in the bibliography on pages 46–52.

THE NOTEBOOK

A good deal of the effectiveness of any course in botany which includes some laboratory work will depend on the way in which the notebook is kept.

It is better to have two kinds of paper, one unruled, for drawing, the other ruled, for written notes.[1] All drawings and sketches should be made in such a way as to bring out (as far as the pupil understands them) the characteristic features of the organ or structure which is under investigation. A sketch in which a good deal of detail is omitted will, therefore, often be of more value than one in which the attempt is made to represent everything. Shading is in general to be avoided. The student will need constant admonition not to conventionalize what he sees, or to try to give general impressions. He would, if unguided, very likely represent the cross-section of coniferous wood, magnified 150 or 200 times, by a set of cross-hatchings, with the lines crossing at oblique angles, thus forming a set of very regular, diamond-shaped figures. The best antidote to this tendency is to confront the conventionalizer at every turn with a *camera lucida* drawing of the thing which he has just sketched, or (better still) with a photomicrograph.

The written notes should be kept in an orderly way ; and the book which contains them needs to be indexed, day by

[1] An excellent notebook in which the pages are alternately ruled and blank, as recommended by Prof. W. F. Ganong of Smith College, is furnished by the Cambridge Botanical Supply Company.

day, as the work progresses. The writer feels convinced, as the result of a good many years of experience, that it is a mischievous practice to require pupils of secondary school age to take any notes from rapid dictation. Matter which cannot be furnished in cyclostyle or hektograph copies to every pupil should be dictated very slowly, or else posted on the board, or in a typewritten copy, to which the pupils may have free access during study hours.

Frequent and unexpected examinations of the notebooks by the teacher will do more than anything else to make pupils exact and painstaking in their record of work done. If a binder is used with perforated sheets, to be inserted from day to day, it will be found advisable to collect the sheets with the most important notes and drawings and sign or stamp them before the pupil is allowed to insert them in the book. Unsatisfactory sheets should be destroyed and better ones, without delay, prepared in their stead. Much importance should be given to the valuation of the notebook in judging of the owner's progress in his work.

It is an unpardonable fault in the teacher to allow the notes to become mechanical, and it is therefore, in the writer's opinion, inadmissible to allow any set form of record to be followed throughout the study of any tissue or organ. The observations of the pupil may well be grouped in an orderly fashion during his first studies of leaves, for example, by following in the record some such form as that given in any of the best plant-analysis blanks, but it would be absurd to stretch the learner on such a Procrustes bed more than once. It will go far toward training the pupil into a scientific habit of mind if he is required in his notes and in his recitations to distinguish clearly the sources of his knowledge. He should be able to state whether a given piece of information was derived from his own experiment or personal study of an object or a phenomenon, from an experiment performed by the teacher in the presence of the class, from outside reading, or from study of the text-book. All notebooks should throughout present constant evidence of the care with which their owner has kept account of the source of the subject-matter which he enters in them. Drawings copied from the blackboard or from any book or photograph should be carefully labeled in such a way as to distinguish them from original ones.

The following extract from a notebook will serve to show how much of a record an intelligent and interested student can, comparatively unaided, make of a physiological experiment performed at home. No changes have been made in the record except in the matter of spelling and in substituting the word *stem* for the pupil's *caulicle* (hypocotyl.) Of course the temperatures were not as constant as the pupil seems to have supposed them to be.

EXPERIMENT I

Experiment I was to find out the relation of temperature to germination. I took four cups and put fourteen peas in them which had been soaked in water for twenty-four hours (after I had put a piece of blotting-paper in the bottom of each one of them), and then saturated the blotting-paper with water. I then put one cup in the upper part of the refrigerator, which had a temperature of 40°, and put a second in the lower part, which had a temperature of 50°; a third in the dining-room, which had a temperature of 70°; and the fourth I put in the kitchen, which had a temperature of 80°.

The results I obtained are on the next page, showing the number of seeds sprouted.

	24 hours	48 hours	72 hours	96 hours	120 hours
At 40°	No seeds burst open or sprouted, but they were swelled a little.	One seed sprout began to show a little.	Seven began to come out a little more, about $\frac{1}{4}$ in.	Nine began to sprout $\frac{1}{2}$ in.	All fourteen appeared; ten being about $\frac{1}{2}$ in. or more.
At 50°	Three seeds showed signs of sprouting a little.	Six seeds began to come out a little, the roots being a trifle longer.	Ten showed themselves very plainly about $\frac{3}{8}$ in.	Twelve could be seen about $\frac{7}{8}$ in. long, but did not grow like the ones in a warmer temperature.	All fourteen came out; ten were $1\frac{1}{2}$ in. long, the rest being about $\frac{3}{4}$ to 1 in.
At 70°	Ten seeds showed signs of sprouting. The roots just beginning to show.	Fourteen began to come out more plainly than before; the roots showing very plainly.	Fourteen long ones came out about 1 in.	All of the roots were about 3 in. long. Eight stems appeared about $\frac{1}{2}$ in. long.	Ten had roots $2\frac{3}{4}$ to $3\frac{1}{2}$ in. long, the rest $2\frac{1}{2}$ in.; ten had stems more than $\frac{3}{4}$ in., the rest $\frac{1}{2}$ in.
At 80°	The whole fourteen seeds began to sprout a little, the roots just beginning to appear.	All of the roots were out about $\frac{1}{4}$ in. to $\frac{1}{2}$ in.	All of the roots were between 1 and 2 in.	All were very long ones, about $3\frac{1}{2}$ in. long, having eleven stems about $\frac{3}{4}$ in. long.	Twelve had roots 3 to $3\frac{1}{2}$ in.; twelve had stems more than 1 in., some were 2 in., the rest were $\frac{3}{4}$ to 1 in.

LABORATORY AND APPARATUS

The laboratory should be a well warmed and lighted room, used for nothing but the practical study of plants. Excellent suggestions in regard to designing and equipping such a laboratory may be found in Ganong's *Teaching Botanist.* It would be well for the inexperienced teacher to visit one or more good biological laboratories before he undertakes to get one ready for his own use.

Requisites for Each Student. — Every member of the class should have:

Two or three mounted needles. (Prepared by forcing fine needles, eye foremost, into round slender sticks, *e.g.*, old penholders.)

A sharp penknife or a scalpel.

A pair of small steel forceps.

A good magnifying glass. The best offered at a moderate price is the achromatic doublet, sold at $8.40 per dozen (duty free) at the American agency of E. Leitz, 411 West 59th Street, New York City. These can be had with a nominal magnifying power of five or of ten diameters (the latter is to be preferred). Their usefulness is greatly increased if they can be mounted in a cheap form of dissecting microscope like that made by the Bausch & Lomb Optical Company and known as Barnes's. This can be had at wholesale for about $1.88, furnished with one fairly good doublet.

A large notebook. This is best made by providing heavy manila-board or other tough flexible covers (often sold as history covers) and perforated paper, some of it ruled and some unruled, to be kept in place by McGill's or other fasteners.

A drawing-pencil.

Pens and holders.

Red ink.

Blue ink.

General Equipment of Apparatus. — Compound microscopes, as described later. It is desirable to have one for the use of each member of the division. Usually it is not possible to secure nearly as many instruments as this. Much good work may be done with only one or two microscopes, but in this case the microscopical work will have to be done partly out of the regular class hour and part of it must be carried along while the class as a whole is doing other than microscopical work.

A set of photomicrographs of some of the most important tissues described in the text, or of similar ones. Blue-prints or silver-prints of twenty-four subjects may be obtained from Miss E. M. Drury, 45 Munroe Street, Roxbury, Mass.

Bromide enlargements of photomicrographs made by Mr. Samuel F. Tower may be had of Ginn & Company. A catalogue of these is given at the end of this *Handbook.* They are large enough to be used for wall charts and are invaluable for histological study.

A clinostat. One of substantially the same construction as that described by Professor Ganong in his *Teaching Botanist* is furnished by the L. E. Knott Apparatus Company, Ashburton Place, Boston.

A small balance.

The hand-scale with five-inch beam and set of weights from .01 gram to 20 grams, furnished by Eimer & Amend of 205–211 Third Avenue, New York, for about $2.00, is good enough.

A trip-scale. The "Harvard trip-scale," furnished by the Fairbanks Scale Company, for about $5.70, is well adapted for weighing potted plants for transpiration experiments, etc.

A cylindrical graduate of 250 to 500 cubic centimeters capacity.

One or two large bell glasses.

Inexpensive one and two-quart battery jars for use in cultivating potted plants, — for transpiration experiments.

(Earthen flower-pots are not so good, because they permit too much evaporation through their sides.)

Six- or eight-quart dishes for germination experiments.

Wide-mouthed bottles.

Glass cylinders of about 300 cubic centimeters capacity for water cultures.

A section-knife, or a razor, flat-ground on one side, hollow-ground on the other, for thin sections.

A heavy section-knife or a flat-ground razor for coarse sectioning.

An Arkansas oilstone.

Watch-glasses.

Glass-stoppered reagent bottles.

Assorted corks and rubber stoppers.

Microscope slides.

Thin glass covers.

Thin sheet rubber, such as is used by dentists, in pieces about twenty-four inches square (this is not needed if the teacher prefers to use sheet lead in the transpiration experiment; see page 161).

The following apparatus will be found extremely convenient, but it is by no means indispensable :

A recording auxanometer, as described in Ganong's *Teaching Botanist*. This is furnished by the Knott Apparatus Company for $8.00.

A horizontal microscope, for study of water-roots, etc. The Bausch & Lomb Optical Company furnish an excellent instrument (Catalogue A, Sixteenth Edition) N 1 for $34.00.

A very simply made support for use with the tube of a Bausch & Lomb or Leitz microscope will be furnished by the Knott Apparatus Company for $16.00.

A still cheaper plan is to support the microscope tube on an iron ring-stand, as shown in *Handbook*, Fig. 1.

A simple section-cutter or microtome. The one sold to schools by the Bausch & Lomb Optical Company at about $20.00, and known as the student's microtome, will answer a good purpose. Their barrel microtome, sold for $6.00, will enable one to cut a better section than can be done free-hand.

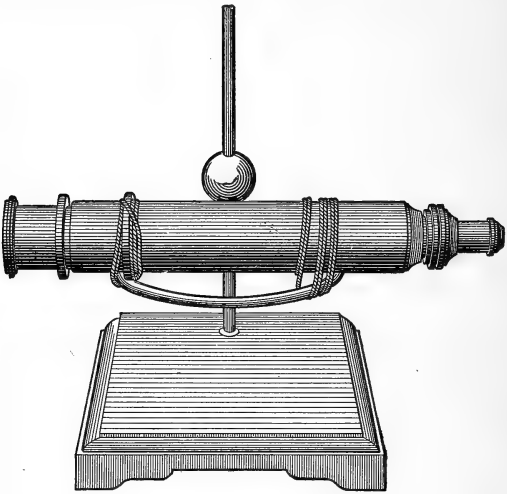

FIG. 1. — Microscope on Ring-stand.

A double-walled thermostat-chamber of sheet copper with self-regulating gas-burner, for use in germination experiments, bacteria cultures, and so on. Such a chamber, 10 × 12 inches, is furnished by the Knott Apparatus Company for $22.00. The place of this can be to some extent supplied by a small incubator. The smallest size sold by Joseph Breck & Sons, North Market Street, Boston, costs $6.00.

A wardian case, as described in Ganong's *Teaching Botanist.* The case (without any provisions for heating) can be had of dimensions 33 × 10 inches and 24 inches high of M. D. Jones & Co., 71 and 73 Portland St., Boston, for $13.50. It consists of glass, set in a steel frame and standing in a galvanized iron pan.

An aquarium or a large goldfish globe. An aquarium large enough to serve well (14 × 24 in.) can be bought of M. D. Jones & Co. for $12.50.

General Reagents and Other Supplies. — Alcohol, commercial, 95 per cent.

Alcohol, absolute, a few ounces only.

Hæmatoxylin solution.[1]

Canada balsam.

Caustic potash solution, 1 part of solid caustic potash in 20 parts distilled water.

Nitric acid, concentrated.

Chromic acid.

Eosin solution.[2]

Potassium chlorate.

Fehling's solution, test for grape sugar. This reagent may be bought of the wholesale druggist or dealer in chemicals. It may be prepared by dissolving 34.64 grams pure crystallized cupric sulphate in 200 cubic centimeters water and mixing the solution with 150 grams neutral potassic tartrate, dissolved in about 500 cubic centimeters of a 10-per cent solution of sodium hydrate. The whole is then to be diluted with water to 1 liter and 100 cubic centimeters glycerine added.

Millon's reagent for proteids. Prepared by dissolving 1 part by weight of mercury in 2 parts of nitric acid of sp. gr. 1.42 and then diluting with twice its volume of water.

Preservative fluid, prepared by adding 1 part of formalin to 40 of water by volume. This does not alter the natural colors of most objects kept in it, and will preserve vegetable tissues indefinitely.

[1] It is cheaper to buy this than to make it.

[2] As considerable quantities of this are to be used (especially if it is issued to the class for home work), if it cannot be bought very cheaply the instructor may make it for himself by dissolving eosin in water. Eosin costs by the pound from $1.65 to $2.00. It may be bought of F. E. Atteaux & Co., 176 Purchase Street, Boston. An ounce will make as much as two quarts of the solution.

Mercury.

Pure glycerine.

Glycerine and distilled water, equal parts.

Carbolic acid crystals.

Carbolic acid, 2-per cent solution.

Iodine solution, prepared by dissolving 4 grams potassium iodide in 40 cubic centimeters distilled water, adding 1 gram iodine, and, when it is entirely dissolved, diluting the solution to 1000 cubic centimeters.

Syrups of various strengths for pollen-tube production, made by dissolving ordinary granulated sugar in boiling-hot distilled water. The water should be weighed cold, then heated in a flask and the weighed amount of sugar added. It will be found less troublesome to weigh out the required amounts in this way than to make a saturated solution and dilute it. Syrups of 2, 5, 10, 15, 25, and 30 per cent sugar will furnish range enough for experiment. If they are kept in glass-stoppered bottles which have been rinsed out with chromic acid solution and then with distilled or thoroughly boiled water, the syrup will keep for years.

Ammonium nitrate, 4-per cent solution. This may be added in small quantities to potted plants as a fertilizer.

Nutrient solution for water cultures made by dissolving in 10 liters of water :

10	grams	calcium nitrate.
2.5	"	potassium chloride.
2.5	"	magnesium sulphate.
2.5	"	mono-potassium phosphate, KH_2PO_4.

A few drops of solution of ferric chloride should be added to each liter of the nutrient solution at the time of using.

Ether, commercial, for extraction of oil from seeds. (Benzine is cheaper and will answer nearly as well.)

Sand, pine sawdust, blotting paper, for germination of seeds.

Grafting wax.

Botanical apparatus and laboratory supplies of every description, including material for study, will be furnished by the Cambridge Botanical Supply Company, 1286 Massachusetts Avenue, Cambridge, Mass. This company has a priced list of articles needed for the *Foundations of Botany*, sent on application.

Apparatus can also be had of Williams, Brown & Earle, Philadelphia, Pa.

Supplies are furnished by the Ithaca Botanical Supply Company, Ithaca, N. Y.

Chemicals and apparatus are furnished by the Bausch & Lomb Optical Company, Rochester, N. Y. Their catalogues are most valuable.

THE USE OF THE COMPOUND MICROSCOPE

The Instrument. — For elementary class work a low-priced but strong and well-made instrument is needed. Several of the European makers furnish excellent instruments for use in such a course as that here outlined. Among these are the Leitz microscopes, which are furnished by William Krafft, 411 West 59th Street, New York City, or by the Agency of E. Leitz, 659 W. Congress Street, Chicago, Ill., and those of Reichert, sold by Richards & Co., 46 Park Place, New York City. The Leitz stand, No. IV, can be furnished duty free (for schools only), with objectives 1, 3, and 5, eye-pieces I and III, for $24.50. If several instruments are being provided, it would be well to have part of them equipped with objectives 3 and 7, and eye-pieces I and III. The best form of camera lucida for this microscope costs (duty free) $7.80.

The American manufacturers, Bausch & Lomb Optical Company, Rochester, N. Y., and Stewart Building, corner State and Washington Streets, Chicago, Ill., have recently produced a microscope of the Continental type which is especially designed to meet the requirements of the secondary schools for an instrument with rack and pinion coarse adjustment and serviceable fine adjustment, at a low price. They furnish this new stand, "B," to schools and teachers at "duty-free" rates, a really good equipment being the stand with two eye-pieces (any desired power), $\frac{2}{3}$-inch and $\frac{1}{4}$-inch objectives, or with 2-inch, $\frac{2}{3}$-inch, and $\frac{1}{4}$-inch objectives, and two eye-pieces.

A cheaper, but serviceable instrument is stand "A," the same stand as the "B," without joint and with sliding tube coarse adjustment (as in the Leitz stand IV) and with three eye-pieces, and $\frac{2}{3}$-inch and $\frac{1}{4}$-inch objectives. A preferable combination at the same price is stand "A," with two eye-pieces, $\frac{2}{3}$-inch and $\frac{1}{6}$-inch objectives. The prices vary from $20 to $30 according to the equipment chosen and the number of instruments ordered.

Class Use of the Microscope. — If the class works in a special laboratory in small divisions (not more than twelve), the teacher can examine the preparation of the object, the focusing of the instrument, and the sketch which the pupil is making, — all while the work is going on. But if the class unfortunately consists of from twenty-five to forty pupils, in an ordinary recitation room, a good deal of ingenuity will be needed to secure results of any value.

The microscopes with the prepared objects should be placed upon the desks or tables which are best illuminated, that is, with a strong side light, but not in sunlight.

If a ready prepared object (not the pupil's own section) is under examination, it is important to have a card attached to each microscope stating what object is upon the stage and what magnifying power is given by the combination in use. The class may sometimes be divided, and half, or less than half, be allowed to work with the microscope while the rest are engaged in written or oral recitation, or in examining the gross anatomy of the seed, root, stem, etc. Each student should be required to take his notebook to the microscope and draw while at the instrument.

Several of the best sketches may be put on the board toward the end of the hour, and a composite drawing finally made, embodying the best portions of each. A still better plan is to have posted at the last a drawing which the instructor has prepared beforehand (best with the aid of the *camera lucida*, or from a photomicrograph), and if desirable to have this copied by the class. The objects sought should be to allow the pupils to see as much as possible for themselves, but to make sure before leaving the object that they understand its real form and structure.

Magnifying Power. — The lowest magnifying power which will show the desired structure is to be preferred, both because this admits of the best illumination and (when the instruments must be left adjusted for use by several pupils in succession) because an average focusing which will suit most of the eyes in the class can be secured with objectives of $\frac{1}{2}$-inch or longer focus, but not with higher powers. Constant use should be made of the $1\frac{1}{2}$-inch or 2-inch objective to give general views of the object. A double nose-piece with 2-inch and $\frac{1}{2}$-inch, or 1-inch and $\frac{1}{6}$-inch objectives attached will save much time and trouble.

The class may best be made to understand the meaning of the term "magnifying power" by examining the same simple object as seen with several powers. For instance, a letter of ordinary print (*e.g.*, the finest used in this book) may be examined with the naked eye and with the magnifying glass. Then sketches on cardboard may be handed round to show the size of the object, drawn with the camera lucida as seen under the 2-inch objective, with others drawn to scale, to show the effect of all the other magnifying combinations which the microscopes belonging to the school afford.

For further suggestions in regard to the manipulation and use of the microscope the teacher is referred to any of the standard works on the subject. The little book of Charles H. Clark, cited in the bibliography, is compact and usable. See also *The Laboratory Manual of High School Botany*, by Clements and Cutter.

An important adjunct to the microscopical work (or, if need be, a partial substitute for it) consists in the use of photomicrographs of the most important tissues. The mounted silver-prints, or unmounted blue-prints, may be numbered and given out to the division for study at the desk *after the structure in question has been studied with a microscope.* If a bromide enlargement of a photomicrograph of the object under consideration is available, it may be placed before the class near the close of the period assigned for microscopical work. Ample time should be given for careful examination of the pictures thus given out, and then the members of the division may be questioned individually on the photographs, or a written exercise may be given in which all shall write as fully as possible about the photomicrographs examined. The teacher will find that the prints differ just enough from the somewhat diagrammatic or idealized cuts usually given in books to afford an admirable opportunity for the pupil to exercise his powers of observation and discrimination, in making out the exact nature of the several tissue elements to be found in each photograph.

MATERIAL FOR STUDY

Chapter I. — Squash seeds, beans, peas, sunflower seeds, white lupine seeds, horse-chestnuts, or buckeyes, corn, malt. Seedlings may be taken at any desired stage of growth and preserved in formalin for study.

Chapter II. — Sprouted peas, clover seed, four-o'clock seed, Indian corn, boiled green corn in alcohol, bean seedlings three weeks old, ground flaxseed, soaked corn, corn meal, flour, oatmeal, buckwheat flour, rye flour, rice, mustard seed, Bermuda arrowroot, sunflower seeds, peanuts, Brazil nuts. Also elder-pith or sunflower-pith, mounted sections of cotyledons of soaked beans and of bean cotyledons from seedlings just ready to shed them.

Chapter III. — Barley, red clover seed, squash seedlings in all stages of growth, seedlings of four or five kinds preserved in formalin solution for the permanganate test, sprouted peas for Experiment XIV, pine seedlings.

Seeds, bulbs, etc., may be obtained of J. M. Thorburn & Co., 36 Cortlandt St., N. Y., Joseph Breck & Sons, 51–52 North Market St., Boston, or the nearest local dealer.

Chapter IV. — Cuttings of tradescantia, cornstalks with roots, water-hyacinth, microscopic sections of roots,[1] parsnips, dahlia roots or sweet potatoes, begonia leaves, fresh eggs, potted plants of dahlia, *Helianthus*, *Ricinus*, *Begonia*, cucumber, or tomato, for root-pressure experiment, tobacco seedlings, sprouting Windsor beans, sprouting peas, living *Spirogyra*, or other pondscum.

Chapter V. — Twigs of horse-chestnut, hickory, beech, etc., with winter buds, twigs to illustrate alternate and opposite branching, potatoes, onions, rootstocks of iris, sweetflag, or sedges (best in preservative fluid), living cactus plants, sprays of garden asparagus pressed as herbarium specimens (or of the common greenhouse species in a fresh condition), *Myrsiphyllum*.

Chapter VI. — Cornstalk (in preservative fluid), palmetto in large billets, rattan, bamboo, asparagus, sunflower stems (in preservative fluid), billets of coarse-grained hard wood (*e.g.*, red oak) 6–12 in. long, cut off squarely at the ends, split through the pith, planed very smooth, and coated with white shellac; also other billets planed through the bark so as to show the edges of the medullary rays (tangential section),

[1] See list below.

twigs (fresh or in preservative fluid) of cherry or birch, also of one of the following trees or shrubs: alder, box-elder, wahoo, willow; also of elm, leatherwood, pawpaw, or basswood. Prepare or procure microscopical sections of corn-stem or other annual monocotyledonous stem and of the objects described in Sect. 107; also see list below.

Chapter VII. — Fresh shoots of apple or cherry and of oak, ash, or elm, fuchsia growing in a flowerpot, microscopic sections of twigs cut in November, potatoes, onions, tulip bulbs.

Chapter VIII. — Twigs with winter buds of horse-chestnut or buckeye, hickory, beech, tulip tree, lilac. Growing plants of geranium (pelargonium) or *Hydrangea Hortensia*, or *Ficus elastica*, to show naked buds. A cabbage (preferably a red one), a Bryophyllum leaf.

Chapter IX. — Leafy twigs of elm and maple, a variety of netted-veined and some parallel-veined leaves, compound leaves of several kinds.

Chapter X. — Potted plants of oxalis and sensitive plants, sunflower seedlings a foot or more high to show movement of leaves to secure sunlight.

Chapter XI. — Fresh lily leaves, microscopical preparations (see list below), fresh hydrangea or cucumber leaves, potted hydrangeas and rubber plants (Sect. 171), leaves of lettuce, hydrangea, maple, hickory, cucumber or "calla lily" (*Richardia*) to show course of water in bundles (Sect. 173). *Elodea*, *Fontinalis*, *Spirogyra*, etc., growing in water to show oxygen-excretion (Sect. 178). Growing nasturtium plants or leaves prepared as described in Sect. 181. Early summer and late fall leaves of trees in alcohol.

Chapter XII. — Living plasmodia of *Myxomycetes*, if obtainable. Fresh flowers of any species of *tradescantia*, or living *Chara* or *Nitella* in water.

Chapter XIII. — [As this chapter is intended for reference only, no separate material need be provided for illustrating it.]

Chapter XIV. — Flowers of trillium, tulip, buttercup, *Calochortus*, *Fritillaria*, *Erythronium*, *Liriodendron* (or any others, more easily obtainable, which are regular, large, and of simple structure). If this work is to be done in the autumn, simple flowers are more difficult to find. *Gentiana*, *Datura*, and other solanaceous genera, *Pelargonium* and *Gladiolus*, are available.

Chapter XV. — Imperfect flowers, as those of willow, poplar, walnut, birch, hazel, begonia.

It is best to begin practice on floral diagrams with flowers so firm and large that actual sections of them may be cut with ease and the relations of the parts in the section readily made out. Among the many excellent early flowers for practice in constructing diagrams may be mentioned tulip, trillium, bloodroot, dogtooth violet, marsh marigold, buttercup, tulip tree, horse-chestnut, or buckeye, Jeffersonia, May-apple, cherry, apple, crocus, daffodil, primrose, wild ginger, cranesbill, locust, bluebell.

Chapter XVI. — For study of morphology of the flower, flowers of *Nymphæa* or *Nuphar*, *Calycanthus*, any cactus with transitions from bracts to sepals and petals, all in preservative fluid. Fresh pollen of *Cytisus*, sweet pea, or nasturtium, mounted slide of pollen (see list below).

Chapter XVII. — Fruits of tomato, capsicum, lemon, bean, dock, or any convenient substitutes for these, some fleshy and some dry ones; a series of strawberries in formalin to show the progressive enlargement of the receptacle, a similar series to show the production of an aggregate fruit (*e.g.*, mulberry) by the coalescence of the ovaries and other parts of many flowers.

Chapter XX. — Slime moulds in general may be looked for on any kind of rotten wood or bark. Tan bark is often covered with them. *Stemonitis* abounds on decaying basswood and on various kinds of rotten coniferous wood. On laboratory cultivation of slime moulds, see Professor Macbride's article in *Rhodora* for April, 1900. See also *The North American Slime Moulds*, by Thomas H. Macbride, The Macmillan Company.

Bacteria may be procured for study as suggested in the text, or by soaking the green parts of plants in water in a warm place for a few days. The dealers in botanical supplies can usually furnish slides of named species or material for pure cultures. See Bausch & Lomb's catalogue of *Microscopes and Accessories.*

Oscillatoria and related forms may most easily be found in filthy ponds, pools, ditches, or brooks. The outlet by which a sewer discharges into a stream of fresh water is nearly sure to afford an abundant supply of material. It may be collected at almost any time of the year, or may be preserved in formalin solution. The collector can distinguish it from *Spirogyra* and related forms by its darker bluish-green color, by the velvety covering which it forms on sticks, stones, etc., and, in most cases, by the comparative shortness of the filaments.

Diatoms nearly free from admixture with foreign substances are found in many polishing powders; *e.g.*, in the "Silver Cream" and the "Red Star Cleaning Powder," manufactured by J. A. Wright & Co., Keene, New Hampshire.

Whenever a brownish slime full of gas-bubbles or a brownish scum is found on the bottoms and margins of ponds and brooks or floating on their surfaces, it may be collected and examined for living diatoms. Great numbers (usually of only a few species at any given time) may often be collected in a small bag of very fine muslin tied tightly over a faucet, which is then allowed to run slowly for some hours. Some should be studied in a living condition and others deprived of all but their siliceous shells.

The author has found it easiest to get rid of the organic matter in a dry mass of diatomaceous material by boiling the substance a few moments in concentrated chemically pure sulphuric acid in a porcelain evaporator and then cautiously adding minute fragments of pure sodium nitrate to the boiling mixture. The white residue obtained after cooling and pouring off the excess of acid may be washed with distilled water and kept for study. *Ordinary pupils should not be trusted to perform these operations*, as the boiling acid is too dangerous for them to handle.

If *Spirogyra* is not easily found, the teacher may advantageously use *Zygnema* or *Mesocarpus*. Any of these organisms may be recognized by their grass-green or paler color, their frequently floating habit, and (with a strong lens) by their structure. It is desirable to pick out the coarser species for study. Live specimens are much more beautiful and interesting than dead ones in preservative fluid, but the latter are better than nothing. If conjugating material cannot be found, it may be obtained of the dealers in botanical supplies. *Spirogyra* may with care be cultivated indoors in ordinary well or spring water, or better in nutrient solution (*Handbook*, p. 16). It should be kept in a cool but somewhat sunny place and aerated by dripping water.

FIG. 2. — Cell from a Thread of Pond-scum (*Spirogyra*). (Magnified about 90 diameters.)

k, nucleus; *ch*, spiral band containing chlorophyll; *p*, *pyrenoids*, little masses of proteid material with starch-grains.

Pleurococcus is so abundant, especially on the north or shaded side of unpainted fences or the bark of trees, that it can usually be collected at any time of year. It will keep in a dormant condition for any desired length of time if left in a dry place in the laboratory, and should then be moistened a day or two before it is to be studied, to insure active growth and cell-division. *Protococcus* is much more profitable to study, particularly in its motile condition, but harder to obtain. Pools in barnyards, containing the leachings of manure heaps, are especially likely in warm weather to afford an abundant supply of this organism.

Vaucheria is most easily found in greenhouses, as suggested in the text. It is, however, often sterile when growing on soil, and should be immersed in plenty of water and allowed to grow there for some six weeks before it is wanted for study. It will then be comparatively clean and may fruit.

Nitella and *Chara* are rather local in their distribution. They usually grow in clear ponds or in streams where the current is not too swift. They may be recognized by the peculiar orange-colored fruit, which is easily seen with a good lens. *Nitella* is much more slender than *Chara*, and is so translucent that the movements of the cell-contents may be more readily made out under the microscope. Either plant will grow readily in a well-lighted aquarium, supplied with plenty of pond, river, spring, or well water.

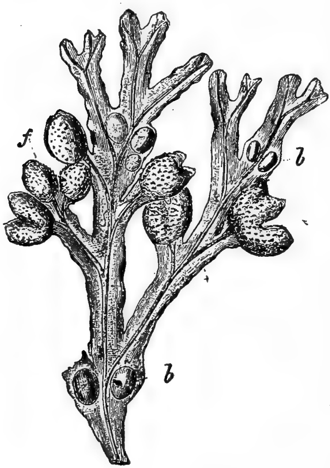

FIG. 3.—Common Bladder-wrack or Rockweed, *Fucus vesiculosus*. (Reduced to about one-third the natural size.)

b, air-bladders ; *f*, conceptacles.

Fucus vesiculosus is the most generally available species of rockweed, but others may be substituted for it. When it can be collected at all it may generally be gathered by the wagon-load. Schools in the interior can most conveniently obtain it from the dealers in botanical supplies or by exchange with teachers of schools near the seaboard. It is best preserved in formalin.

The red algæ (of which *Nemalion* is one of the commonest) have few fresh-water forms. *Batrachospermum*, with a thread-like thallus, fringed at intervals with necklace-like short filaments, is one of these not infrequently found in brooks and springs. Carrageen, or Irish moss, may often be bought in a dried condition of grocers. Inland schools, however, will usually have to depend on dealers in botanical supplies for suitable material for the study of the red algæ. Teachers who have an opportunity to collect sea mosses will find many genera as interesting as *Nemalion*, but some of them are of much less simple structure.

Moulds. — If any difficulty is experienced in procuring material for the study of black mould, *Rhizopus nigricans*, the common sage-green mould, *Penicillium glaucum*, can always be procured and propagated as described in Huxley and Martin's *Biology*.

The quickest and most certain mode of obtaining a good crop of the desired mould is to sow its spores upon the wet bread or other culture medium that is used. Spores may be kept indefinitely, in a dry condition, for this purpose. Exposing the bread to a confined portion of the atmosphere of any place, *e.g.*, a cellar, where the desired mould has previously flourished, will insure a prompt growth of the mould anew.

Wheat Rust. — This may be collected on the leaves or stems of grains or grasses when the host-plant is mature, in summer or autumn. The leaves make better material for sectioning than do stems. The cluster-cup stage is to be looked for as suggested in Sects. 310, 311.

Microsphæra.[1] — Of the host-plants mentioned in the text the lilac is perhaps the most generally found. Leaves of the lilac should be collected in late June or in July for the purpose of showing the development of mycelium and conidia, and

[1] The teacher should be careful to explain, if both *Puccinia* and *Microsphæra* are studied, that though placed side by side in the text their systematic position is otherwise.

another set of leaves in the autumn, when rough black dots show the presence of conceptacles. The leaves are to be dried under pressure between layers of absorbent paper and kept in a dry place until needed for study.

Saccharomyces. — Ordinary compressed yeast is the best source for yeast cultures. Occasionally other species will be found together with the commercial *S. cerevisiæ* in fermenting liquids into which no organism except the ordinary yeast has been intentionally introduced. Fig. 197 represents *S. ellipsoideus.* The subjoined figure, *Handbook,* Fig. 4, is of *S. cerevisiæ.*

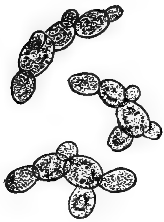

FIG. 4. — Yeast (the commercial species, *Saccharomyces cerevisiæ*) increasing by Budding. (Greatly magnified.)

Lichens. — The encrusting lichens (somewhat like Fig. 198) may be found upon the bark of trees or upon rocks in shaded situations over a considerable portion of the country. Lichens of the general form of Fig. 198 or Fig. 199 are commonest northward, but can easily be obtained of the dealers in botanical material by teachers who cannot collect them for themselves. All specimens should be gathered when the apothecia are well developed, that is (for most genera), in late autumn.

Liverworts. — *Marchantia* is described in the text because it is very widely distributed and grows freely in greenhouses or can be cultivated under bell-glasses in the laboratory. Out of doors it flourishes on rocks or earth which are kept constantly damp, as by the water which percolates from a brook or spring or the spray from a waterfall. *M. polymorpha* is the commonest species. Figs. 201, 202 represent a rare species, *M. disjuncta.* Specimens to show the structure of the thallus and the gemmæ may be collected at any time when the plants are in vigorous condition, but those which are to be studied for the heads of antheridia and of archegonia must be carefully selected in late spring or summer. Archegonial heads to be used for sections must be collected before their stalks have lengthened much; others should be collected and examined when mature. Antheridial heads should be nearly full-grown when put into preservative fluid for study. *Conocephalus* is another large liverwort, which grows in the open air in similar localities to *Marchantia*, but is less generally distributed and not as easily cultivated. It may readily be distinguished from *Marchantia* by having larger diamond-shaped markings on the thallus, by the absence of gemmæ and the sessile condition of the antheridia. Excellent descriptions and figures of many North American liverworts can be found in Gray's *Manual of Botany*.

Mosses. — The true mosses are well represented by the species described in the text.

Polytrichum commune. This is selected as one of the largest and commonest of mosses. If any other tolerably conspicuous genus, such as *Mnium*, *Bryum*, or *Atrichum*, is more readily obtainable, the teacher may as well use it. For an excellent account of the structure and physiology of mosses, consult Bennett and Murray's *Cryptogamic Botany*. For the determination of species, see Lesquereux and James' *Mosses of North America*. All mosses for class study should be collected when the archegonia and antheridia are fully developed, that is (for many genera), in early spring. If the moss is diœcious, pains should be taken to get sufficient numbers both of male and of female plants. The former may usually be recognized by the shallow, bowl-shaped clusters of leaves at the tips of the branches, with minute dark-red antheridia in the bottom of the concavity. The female plants have terminal leaves which stand nearly erect, so as to shut in the antheridia. Plenty of specimens with spore-capsules in various stages of development should be secured, some with the hood in place (as shown in the left-hand

FIG. 5. — A Plant of Pigeon-wheat Moss (*Polytrichum commune*).

rh, root-like portion; *s*, bristle-like stalk of calyptra, or spore-case; *c*, hood-like cover of calyptra; *ap*, knob at base of calyptra; *d*, cover of calyptra. (Natural size.)

calyptra of *Handbook*, Fig. 5), others more mature, for the study of fully ripe spores.

Protonema may often be collected in good condition on the earth beneath and close by patches of full-grown moss.

Ferns. — The outline given in the text-book for the examination of a fern applies exactly only to *Asplenium filix-fœmina.* Any species of *Asplenium* or of *Aspidium* is just as well adapted for study. *Cystopteris* is excellent, but the indusium is hard to find. *Polypodium vulgare* is a simple and generally accessible form, but has no indusium. *Pteris aquilina* is of world-wide distribution, but differs in habit from most of our ferns. The teacher who wishes to go into detail in regard to the gross anatomy or the histology of ferns as exemplified in *Pteris* will find a careful study of it in Huxley and Martin's *Biology*, or a fully illustrated account in Sedgwick and Wilson's *Biology.*

The asexual generation or spore-plant of whatever fern is selected for study should be collected as soon as the sporangia are fully developed. Some plants may be pressed entire between many sheets of absorbent paper and preserved in folded sheets of manila paper for study. Others may have all but the sporangia-bearing portions of the fronds cut away, to save space, and thus be dried, while still other portions of fronds and of rootstocks may be kept for study in preservative fluid.

The prothallia may be collected as described in the text. Unless the teacher has a good deal of time at his disposal, he may find it better economy to buy sections of the antheridia and archegonia than to direct pupils in cutting them or to cut and mount them himself.

Equisetum. — *E. arvense* is the commonest species. It bears a pretty close resemblance to the one represented in Fig. 213. The fertile stems appear in early spring in sandy or wet soil, often along railroad embankments and in similar habitats. These are colorless and (above ground) nearly or quite branchless, as shown in Fig. 213. They should be collected and kept in preservative fluid for use. The branching green, sterile stems, which appear later than the fertile ones, may be dried and thus preserved.

Lycopodium. — This is one of the commonest plants of pine and other evergreen woods of the northern United States, and is generally known as ground pine, ground cedar, or evergreen. In northern cities it can be had in abundance at the Christmas season, when it is sold for decorative purposes. The spikes of spore-cases should be kept for study in preservative fluid, and entire plants should be dried for class use. *Selaginella* may be bought of florists at any season.

RESULTS OF EXPERIMENTS

Experiment I. — Various seeds should be used in different years so as to procure a set of observations for the *optimum* temperature for germination in the case of several seeds.

According to Sachs the temperatures (Centigrade) on the following page were obtained for the seeds named.

TEMPERATURES (CENTIGRADE).

	MINIMUM.	MAXIMUM.	OPTIMUM.
Barley	5°	38°	29°
Wheat	5°	42°	29°
Scarlet runner	9.5°	46°	33°
Indian corn	9.5°	46°	33°
Squash	11°	46°	33°

It will probably be found that for moderate temperatures (say from 40° to 80° F.) a higher temperature insures quick germination. It may not secure an unusually large percentage of seeds finally germinated.

Experiment II. — The student (and perhaps the teacher) will be surprised to find how little water is absolutely essential for the germination of most seeds.

Experiment III. — If this experiment is tried with the seeds in an approximate vacuum, none will germinate. The apparatus must be carefully watched to see whether a minute crack forms on the drawn-out end of the tube (Fig. 3). The trouble arising from the formation of such a crack may sometimes be avoided by thickly painting the drawn-out end of the tube, as soon as it cools, with a melted mixture of beeswax and resin, equal parts.

Experiment IV. — If the seeds used in this experiment are rinsed with five per cent formalin solution and then thoroughly with clear water before germinating, the chance of carbon dioxide being formed by decay due to bacteria on the surfaces of the seeds will be lessened.[1]

Experiment V. — Be careful to select peas of about the same size and with roots of equal length at the outset. If the seedlings do not show marked differences at the end of a

[1] See Barnes' *Plant Life*, Holt, New York, 1898, p. 398.

week, keep them under observation and also start a new set. Usually the one with both cotyledons will in the long run greatly outstrip the others.

Experiment VI. — This experiment is not very valuable but suggests the truth. A small patch of ground at home, planted with grass seed, and a few hills of corn planted by the pupil will teach far more.

Experiment VII. — See notes on V.

Experiment VIII. — Before pronouncing authoritatively on the results reported by the pupils, the teacher should for himself test all seeds that are on the doubtful list, using thin sections and examining them with the dissecting microscope, or the lowest power of the compound microscope. If the seed is oily, removing the oil with ether will make results more definite. Do not let the pupils decide that dry beans and peas contain no starch because the seed is too hard to absorb iodine solution quickly. Boiling the seeds for some time will aid in the application of the test. Ground mustard is usually adulterated with flour, so that tests on mustard must be performed on seeds crushed by the pupil.

Experiment IX. — No special pains are needed to make this experiment succeed.

Experiment X. — The Millon's reagent is troublesome to make and not always satisfactory in its working. The sugar and sulphuric acid test often succeeds, and the nitric acid test is almost always satisfactory. The addition of ammonia water, after rinsing off the nitric acid, improves the color for a time. The xanthoproteic reaction (shown by the yellow color) produced by the nitric acid is in some cases very permanent. The powder left after extracting oil from pulp made of Brazil-nut kernels will remain strongly yellow for years, after treating with nitric acid, if kept in a glass-stoppered bottle. It may be found convenient to keep it so to show to successive classes.

Experiment XI. — The Brazil nut yields a large amount of proteid material, much oil and no starch.

See notes on X.

Experiment XII. — The teacher will probably find that the arch of the hypocotyl is formed to some extent, even when seeds are germinating in moist air without any pressure of soil upon them, but that it is less perfect than when the seed sprouts under normal conditions. It is probably worth while to call the attention of the class to the fact that the plantlet rising from the ground in the usual arched fashion pushes up twice as strongly as it would if only a single column were displacing the bits of earth, pebbles, etc., above it; that is to say, both the root end and the cotyledon end of the hypocotyl are coöperating in the upward push.

Experiment XIII. — The permanganate test is not to be relied upon as affording an exact indication of the boundary between root and hypocotyl. In fact, as has been suggested to me by Mr. I. S. Cutter, there is in some seedlings a considerable intermediate region which is neither root nor stem, but partakes in its histological character of the characteristics of both. The teacher will, however, probably find it worth while to make this test, especially in order to make it clear in the case of such plants as the pea, in which the hypocotyl elongates very little, that the part which rises above ground is the first internode above the cotyledons and that the cotyledons are remaining underground from the fact that the hypocotyl has not elongated enough to push them out.

Experiment XIV. — This experiment is not sure to succeed very satisfactorily, since in a good many cases the young roots wither or decay before much growth takes place, after they have been marked. It is possible to discover (when the experiment is successful) not only the fact that the growth of the root is mainly from the tip, but that a slight amount of increase in length takes place throughout a limited region back of the tip. The marking should never be done with ordinary ink or with any substance which will injure the tissues of the sensitive young root.

Experiment XV. — The egg-osmosis experiment has been selected in preference to the familiar ones with bladders or osmotic cylinders mainly on account of its convenience. A pig's bladder filled with molasses serves very well to illustrate the fact of osmotic exchange, but pains must be taken to tie it very firmly to the glass tube that is employed, and to use a tube which has been somewhat expanded at the lower end to prevent the ligature from slipping off. The osmosis cylinders sold by dealers in apparatus are exceedingly convenient, but the experiment made under such circumstances has an air of artificiality; that is, the pupil is too apt to think that the whole process is an artificial one and to doubt whether under natural conditions it would take place with equal readiness.

Experiment XVI. — This experiment is exceedingly easy to perform, but not very striking. It is much better for individual use than for class demonstration.

Experiment XVII. — It is quite possible that tobacco seedlings are no better for this experiment than some others, but the tobacco is the plant which has been most investigated in this connection. It should be found (according to Pfeffer) that the wilting begins at about 35 to 39° F.

Experiment XVIII. — No particular discussion of this experiment is necessary.

Experiment XIX. — In addition to the discussion in the text, the teacher might impress upon the student the fact that the force with which the tip of a young root lying horizontally presses downward is no criterion of the total force which may be exerted by a more mature root under favorable conditions. In the former case the entire root would be bent upward by any decided resistance applied to the growing tip, while a moderately stout root placed vertically may exert a pressure of many pounds on the earth or other medium through which it penetrates. See Darwin's *Power of Movement in Plants*, London, 1880, pp. 73, 74.

Experiment XX. — It is evident that the slowly revolving clinostat merely removes the plant from the action of gravity, and that under those circumstances the roots will receive no direction from any external force, but grow on in whatever direction they take at the outset. Those shown on the rapidly revolving cylinder in Fig. 27 point outward from the axis of rotation under the influence of the centrifugal tendency caused by the rapid whirling motion. See Vines' *Students' Text-Book of Botany*, pp. 752–754.

Experiment XXI. — If the use of the spectroscope (preferably one of the direct vision, portable spectroscopes) can be had, this experiment may be performed very satisfactorily by watering the roots of thrifty young potted plants, for example, sunflowers, with a solution of lithium nitrate.[1] The concentration of the solution should be about 2 per cent. A few preliminary experiments should be made to get an idea how long it takes for the rise of the water containing lithium to reach the lower part of the stem, and then the subsequent rise may be tested by examining short portions cut from various regions of the stem and comparing them with similarly placed sections of other stems exposed for a little longer time to the action of the solution. The presence of the lithium salt may be detected by the characteristic lines as seen in the spectrum. The greatest pains must be taken not to introduce the lithium compound by accident, *e.g.*, from a soiled scalpel.

Experiment XXII. — This experiment is exceedingly rough, and merely serves to give a general idea of the time required for the rise of water in the kind of stem under observation,

[1] See Detmer's *Practical Plant Physiology*, translated by S. A. Moor, pp. 233, 234, London, 1898.

and to show that the wilting is due wholly to the loss of water.

Experiment XXIII. — Other fleshy parts of plants covered with a layer of cork, as, for example, parsnip roots, carrots, turnips, etc., may be tested side by side with the potatoes, as indicated in the text.

Experiment XXIV. — This experiment may be made with less trouble by heating the water from the boiled onion with an alkaline solution of copper. This solution is made by dissolving copper sulphate in boiling hot potassium hydrate solution.

Experiment XXV. — The onion should yield a decided proteid reaction, much intensified by the treatment with ammonia.

Experiment XXVI. — The results of this experiment are a little uncertain. Not infrequently reasonable success is obtained in inducing the leaves to assume the nocturnal position in artificial darkness.

Experiment XXVII. — If the shoots of ivy are growing freely, it will be found that some of them will point squarely away from the principal source of light, showing strong negative heliotropism. The leaves show equally strong positive heliotropism.

Experiment XXVIII. — In the hydrangea three very well defined leaf-traces occur, and their position is marked by extremely distinct red dots on the scar formed by tearing off the leaf-stalk. Almost any freely transpiring leaf will answer for this experiment, and it may be worth while to study, in this rough fashion, the approximate arrangement of the leaf-traces in several plants.

Experiment XXIX. — The experiment is too simple to require comment.

Experiment XXX. — Other plants than those suggested may be employed in this experiment, but the ones named will be found particularly instructive in their behavior. It would be well worth while to add a prickly pear cactus (*Opuntia*) to the list of plants examined in this manner. The teacher must not assume that a thick and leathery leaf will necessarily transpire slowly. For example, the common oleander is found to have a decidedly rapid rate of transpiration. A large amount of time may profitably be spent in discussing the results of this experiment, which may be protracted for weeks. The pupil may be able to discover for himself that transpiration almost ceases in the *Ficus* leaf unless exposed to sunlight. The attempt should be made not only to discover what is the relative amount of transpiration per unit of area for the two plants under normal circumstances, but what it is under all sorts of abnormal conditions. The student will be especially interested to see how nearly zero the transpiration becomes when the plant is exposed to a cold or nearly saturated atmosphere.

Experiment XXXI. — The leaf covered with vaseline on the upper surface should dry up almost as rapidly as an unprotected leaf, while the one with vaseline on the lower surface may remain green for months.

Experiment XXXII. — This experiment is far from being an exact one and is meant merely to give a general idea of the comparative behavior of xerophytic plants when put under similar circumstances with plants with ordinary powers of transpiration. The teacher should use his own judgment in selecting any species which seem convenient for a comparative experiment.

Experiment XXXIII. — The leaves should be watched continuously, and it may be found worth while to record the progressive rise of the eosin solution by means of a series of rapid sketches at designated intervals of time. Toward the last the experiment will be somewhat unsatisfactory from the fact that the poisoning action of the solution causes the leaves to droop and become flaccid. It may be found desirable to investigate the rate of movement of liquid in a considerable variety of leaves, taking some of comparatively firm structure and relatively low rate of transpiration like the English ivy and others from aquatic or marsh plants, like the *Richardia* "calla."

Experiment XXXIV. — It is hardly worth while to try to collect enough oxygen to establish the nature of the gas absorption, but the manufacture of minute but abundant bubbles is easily secured, if any of the plants suggested are employed and they are in vigorous condition. See to it that the pupil does not mistake air-bubbles set free from the water on warming for oxygen bubbles. *The latter arise only from the surfaces of the plant and at pretty regular intervals.* If convenient, not only the lower limit for oxygen-making should be ascertained, but (by gradual introduction first of warm and then of hot water) the upper limit as well.

Experiment XXXV. — The veins of the leaf will be found comparatively free from starch, while the intermediate portions should show starch in abundance.

Experiment XXXVI. — The covered regions are usually wholly free from blue coloration, owing to the fact that the solution of starch and its transportation to remoter portions of the plant (which goes on in all parts of the leaf where starch is made) is in the covered places not counterbalanced by the manufacture of new starch to make good the loss.

Experiment XXXVII. — As may be gathered from the text, leaves of late autumn should be found nearly or quite free from starch.

Experiment XXXVIII. — No particular difficulty is usually encountered in obtaining pollen tubes from the kinds of pollen suggested; as it is sometimes convenient to have the tubes ready to demonstrate without delay, it is well to have a set of mounted slides in which well-developed tubes are shown. The most striking pollen tubes obtainable are those of the *Asclepias,* which retain their distinctness of outline indefinitely when mounted in glycerine jelly.

Experiment XXXIX. — Yeast grows with the utmost readiness in the molasses and water mixture recommended in the text. It may be found that in a mixture of sugar and distilled water the growth at first is not much less rapid, but that it is somewhat less permanent. Properly distilled water alone should show no growth whatever.

In the student's experiment on the temperature conditions under which yeast will grow (Sect. 320), he will usually have no difficulty in deciding that a freezing temperature reduces growth to a standstill; but he may be misled in regard to the effect of exposure to a boiling temperature by the fact that the gas bubbles in the liquid are expanded and rise rapidly for a time. He should be cautioned to note what occurs after this temporary rise of gas has taken place. On account of the readiness with which growth is manifested by the evolution of gas bubbles, the sensitiveness of the yeast to various toxic substances is more readily tested than that of most low forms of plant life, and the effect of various substances, such as nitric and chromic acid, copper sulphate and sulphuric acid in solutions of known strength, might be given to selected students as a subject for investigation.

CONDUCTING FIELD WORK

In very many high schools field work for entire classes is out of the question. Where it cannot be made to succeed with the entire number of pupils who study botany, even when taken out in small sections, it may be feasible for volunteer divisions of those who are really interested in the subject. The only way to become well acquainted with even the familiar plants of a region is to spend weeks — or, better, months — in the field, studying the flora in its natural environment. Indoor laboratory work at determination of species is desirable as a preparation for the offhand identification of plants, but the latter process is a necessary sequel to the former one, and of far more value to the human being as such than any amount of plant analysis. A little direction suffices to lead the beginner in out-of-door botany to look for the salient characteristics of plants, to pick out *Labiatæ* by their square stems and opposite leaves, and (usually) by their odor to recognize the dotted leaves of *Hypericaceæ*, the characteristic foliage, inflorescence, and fruit of *Umbelliferæ*, and so on. The function of the teacher will be mainly to guide the observations of his class into useful channels, to see that they do not spend too much time on the esthetics of the plants which they encounter, but rather learn to know the plants well and to think of them as more or less thoroughly equipped organisms with a living to make. The best teacher in charge of a botany class out of doors is the one who answers most questions by counter-questions and so gradually leads the pupil to coax the plant's story from the plant itself. A general quiz on the names of the species in sight from a given point and the reasons for their coëxistence there is eminently useful. Collecting is a matter of minor importance and mainly of service in replenishing the botanical museum and herbarium.

Ecology, as above suggested, is one of the principal subjects to be dealt with on botanical excursions. It can only be made valuable by unifying each field lesson as far as may be. The following are but a few of the many topics that might be profitably investigated by pupils who have easy access to considerable areas of land and water which are under fairly natural conditions:

Stems: erect, reclining, climbing, prostrate; effect of shade on development of branches; repair of injuries; rate of growth per year; correlation of stoutness of twigs with size of leaves; winter buds.

Leaves: arrangements for exposure to light; shade-plants and sun-plants; variations of leaves on a single tree due to differences of illumination; exposure to air (free or dissolved in water) of leaves of aquatic species.

Flowers: study and collection of all insect visitors to one or more species; wind-pollination at work.

Fruits and seeds: modes of dispersal as seen in operation; evidences of successful dispersal in previous seasons; study of newly exposed tracts of earth.

Plant-societies: hydrophyte, xerophyte, and mesophyte societies living under natural conditions; sketch-maps of ponds, or small streams and their banks, of sandy knolls and a little of the more fertile land about them, showing the various zones of vegetation present; cryptogamic vegetation on a dry rock, on a tree-trunk, in a brook-bed; weed societies of the dooryard, the barnyard, the pasture, the wheat fields, the fence-row.

The teacher may find it of advantage, in endeavoring to give an idea of the physiognomy of some of the principal plant-societies, to make free use of large photographs. Many excellent photographs for this purpose are to be found in Peabody's *Western Series* and White's *Western Series*, listed in the *Catalogue of American Scenery and Architecture*, published by the Soule Photograph Company, 338 Washington Street, Boston, Mass.

NOTES ON SPECIAL SECTIONS

Sect. 2. *Examination of the Squash Seed.* The pupil may be told that the micropyle represents the opening through which the unformed seed, at the outset, received the minute portion of living matter necessary to set it to growing (Sects. 226, 227). When he comes to the study of fertilization, in Chapter XVI, he may be referred back to Sect. 2.

Sect. 24. *Plant-Cells.* What is here stated about the proportion of protoplasm found in living and growing cells is particularly true of the cells of meristem or formative tissue.

Sect. 66. *Root-Pressure.* For the measurement of pressures of more than a quarter of an atmosphere, it will probably be found more convenient to use a closed pressure-gauge, as recommended in Ganong's *Teaching Botanist.* The Macmillan Company, N. Y., 1899, p. 232.

Sect. 106. *Tissues.*

The following are the most important kinds of tissues found in seed-plants:

1. Formative tissue or meristem.
2. Parenchyma.
3. Collenchyma.
4. Sclerenchyma (including hard bast).
5. Fibrous tissue (of wood fibers).
6. Sieve tissue.
7. Milk tissue, composed of branching tubes which contain milky juice.
8. Tracheal tissue, composed of tracheids or closed cells, the walls of which have some kind of secondary thickening, *e.g.*, spiral vessels and the pitted cells of coniferous wood.

Sect. 109. *Grafting.* The two trunks above the fork in Fig. 70 seem to be united into one. They are covered by a hollow cylinder of bark common to both, but the annual rings of each of the two component trunks could probably be made out on a section taken above the point of union, and each would for some distance retain its own pith.

Sect. 117. *Movement of Water in the Stem.* See Pfeffer's *Physiology of Plants*, Chapter VI, Oxford, 1900.

Sect. 142. *The Maple Leaf.* Any kind of maple will answer the purpose. Palmately veined leaves are less abundant among our forest trees than are pinnately veined ones. The sycamore is one of the commonest species. Among other plants may be suggested the ordinary "geraniums" (pelargoniums), the pumpkin, squash, grape, currant, and hollyhock.

Sect. 164. *Leaf of "India-Rubber Plant."* The spongy parenchyma is not as closely packed as would appear from Fig. 119. There are many air-spaces between the cells.

Sect. 170. *Operation of the Stomata.* It is not certain that the hairs about the mouth of the oleander stoma are solely to keep out dust, but this is a highly probable function. They cannot greatly check transpiration, since this process goes on very freely in the oleander.

Sects. 174, 175. The author has used the terms *potash* and *silica* in preference to potassium oxide and silicon dioxide for the sake of simplicity. For pupils who have learned some chemistry before botany is completed it will of course be desirable to introduce a good many chemical terms and formulæ not here employed.

Sect. 178. On the temperature required for photosynthesis, see Pfeffer (work cited above), pp. 337, 338.

Pfeffer gives as the approximate equation for photosynthesis:

$$6\,CO_2 + 6\,H_2O = 6\,O_2 + C_6H_{12}O_6 \text{ (glucose)}.$$

Sect. 185. *Excretion of Water and Respiration.* The pupil's attention should be called to the fact that respiration in plants is due wholly to diffusion of gases; that plants cannot forcibly inspire and expire air, since they have no mechanism for producing air currents.

Sects. 191–195. *Protoplasm and its Properties.* If the teacher prefers to complete the study of the structure and functions of flowering plants before taking up lower forms, he may omit this chapter until after the flower and the fruit have been studied. It seems better to the author, however, to introduce the morphology and physiology of cells as individuals pretty early, and there are many reasons for taking up these topics immediately after Chapter III.

Sect. 194. *Nature and Occurrence of Irritability in Plants.* In discussing geotropism the teacher should strongly emphasize the fact that the unequal growth of roots and shoots due to the action of gravitation is a highly complex affair and that all that the beginner is concerned with is the result. Gravity acts and the plant is directed, but the internal changes in the plant, due to the stimulus received from gravity, are not explicable in everyday language.

Sect. 205. *Study of Typical Flowers.* Teachers in localities where the flowers mentioned in the text are not obtainable should, of course, substitute the most available material at hand; *e.g.*, on the Pacific Coast *Erythronium* for *Trillium*, and *Calochortus* or *Fritillaria*, for the expensive tulip.

Sect. 370. *The Law of Biogenesis.* It is impossible to put any useful statement of this law into a few lines unless the reader has some knowledge of the amount and kind of evidence on which it is based. Some of the earliest books on the subject are still the best. The teacher should read Haeckel's *History of Creation*, N. Y., Appleton, Fourth Edition, 1899, Vol. I, Chapter XV, and Darwin's *Origin of Species*, Chapter XIV.

Sect. 408. *Enslaved Plants.* On the assimilation of free nitrogen by root-tubercles, see Pfeffer (work cited above), pp. 396–403.

Sect. 409. *Messmates.* On mykorhizas, see Pfeffer (work cited above), pp. 371–373.

REFERENCE BOOKS[1]

Not nearly all of the books which the author regards as useful guides for high school teachers for study and research in the commonly taught departments of botany are here named. Both pupil and teacher will find it desirable to consult some of them frequently throughout the whole course of the botanical work. The starred titles (**) indicate books which will aid the teacher, but which the ordinary high-school pupil could hardly use. Where it is possible to discriminate, the best book, that is, the book which combines accuracy, fullness, newness, and simplicity of statement to the highest degree, is placed first in its own list.

Most teachers will find a good general glossary of much service in reading botanical works. The most recent is Jackson's *Glossary of Botanic Terms*, London, 1900. $2.00. (Imported by the J. B. Lippincott Company.)

General Works

Kerner and Oliver, *Natural History of Plants*. Blackie & Son, London, 1895. Henry Holt & Co., New York, 1895. 4 vols. $15.00.

Strasburger, Noll, Schenk, and Schimper, *A Text-Book of Botany*. Translated by Porter. The Macmillan Company, New York, 1898. $4.50.

Vines, *A Students' Text-Book of Botany*. The Macmillan Company, New York, 1894. $3.75 *net*.

[1] The author has been much aided in the preparation of this list by the one contained in Ganong's *Teaching Botanist*.

Barnes, *Plant Life.* Henry Holt & Co., New York, 1898. $1.12.

Bessey, *Botany for High Schools and Colleges.* Henry Holt & Co., New York, 1885, and later editions. $2.20.

Also Bessey's *Essentials of Botany,* seventh edition.

The Kerner and Oliver is a costly book, but is almost indispensable, since it goes over the greater part of the field of botany in a full and accurate yet thoroughly simple and interesting way. The only criticism that can be urged against it is on the score of occasional fanciful statements in regard to theories as yet unproved. The work of Strasburger and others is perhaps the best recent summary of botany in a moderate-sized octavo volume. All the books above cited are profusely illustrated.

Laboratory Manuals

Detmer, *Practical Plant Physiology.* Translated by Moor. The Macmillan Company, New York, 1898. $3.00.

Darwin and Acton, *Practical Physiology of Plants.* Second Edition. Cambridge, 1897. 4s. 6d.

MacDougal, *Experimental Plant Physiology.* Henry Holt & Co., New York, 1895. $1.00.

Strasburger, *Practical Botany.* Translated by Hillhouse. The Macmillan Company, New York, 1900. $2.60; or, better, *Botanische Practicum.* Fischer, Jena, 1897. 22.50 marks.

Spalding, *Introduction to Botany.* D. C. Heath & Co., Boston, 1895. 90 cents.

Bailey, *Lessons with Plants.* The Macmillan Company, New York, 1898. $1.10.

Clements and Cutter, *Laboratory Manual of High School Botany.* The University Publishing Company, Lincoln, Neb., 1900. 75 cents.

Huxley and Martin, *Elementary Biology* (extended by Howes and Scott). The Macmillan Company, New York, 1892. $2.60.

Clark, *Practical Methods in Microscopy.* Third Edition. D. C. Heath & Co., Boston, 1896. $1.60.

Ganong, *The Teaching Botanist.* The Macmillan Company, New York, 1899. $1.10.

Newell, *Outlines of Lessons in Botany.* Part I and Part II, 2 vols. Ginn & Company, Boston, 1892. 90 cents each.

The first three of the books above mentioned are devoted to experiments in vegetable physiology. Detmer's is the best. Strasburger's book is devoted to vegetable histology and is excellent, though the translation by Hillhouse is less satisfactory than the *Botanische Practicum.* Spalding's *Introduction* is not wholly a laboratory manual, though largely so. It supplies admirable directions for getting acquainted with plant life and structure at first hand. Huxley's *Biology* is partly devoted to animals, partly to plants. It gives excellent directions for the laboratory study of some of the lower forms of plant life. Ganong's book is indispensable for all but the most experienced teachers.

Structural and Physiological

Pfeffer, *The Physiology of Plants.* Translated by Ewart. Clarendon Press, Oxford, 1900. $7.00.

Sachs, *Lectures on the Physiology of Plants.* Clarendon Press, Oxford, 1887. (Out of print.)

Gray, *Structural Botany.* American Book Company, New York, 1880. $2.00.

De Bary, *Comparative Anatomy of the Phanerogams and Ferns.*** Translated by Bower and Scott. Clarendon Press, Oxford, 1884. $5.50.

Haberlandt, *Physiologische Pflanzenanatomie.*** Engelmann, Leipzig, 1896. 18 marks.

Gray's *Structural Botany* is written in an exceedingly clear and readable style. It is not brought down to date, and it gives little histology; it is well supplemented by De Bary's work, and these two books, with the masterly lectures by Sachs, furnish a very full account of vegetable structure and life. Vines, *Physiology of Plants,* University Press, Cambridge, 1886, is more to be depended on in its chemical statements than the work of Sachs. Pfeffer's work is authoritative on the subjects of assimilation and metabolism and supersedes all preceding treatises on those topics.

Morphological

Goebel, *Outlines of Classification and Special Morphology of Plants.*** Translated by Garnsey and Balfour. Clarendon Press, Oxford, 1887. $5.25.

Pax, *Morphologie der Pflanzen.*** Enke, Stuttgart, 1890.

Systematic

Warming and Potter, *Handbook of Systematic Botany.*** The Macmillan Company, New York, 1895. $3.75.

Engler and Prantl, *Die Natürlichen Pflanzenfamilien.*** Engelmann, Leipzig.

Engler, *Syllabus der Pflanzenfamilien.*** Borntraeger, Berlin, 1898.

Le Maout and Decaisne, *Traité Général de Botanique.* Firmin Didot Frères, Fils & Cie, Paris.

Strasburger, Noll, Schenk, and Schimper, *Text-Book* (see above).

Campbell, *Lectures on the Evolution of Plants.* The Macmillan Company, New York, 1899. $1.25.

Campbell, *Structural and Systematic Botany,* Ginn & Company, Boston, 1890.

The first-named book in the list is clear, ably written, and sufficient for all ordinary purposes. Engler and Prantl's work in several volumes is a very large and elaborate one, not yet completed, with a wealth of illustrations. Engler's little *Syllabus* forms the best inexpensive thoroughly modern summary of systematic botany. Le Maout and Decaisne's treatise is not modern, but is abundantly illustrated and will be found useful.

Cryptogamic Botany

Bennett and Murray, *Handbook of Cryptogamic Botany.* Longmans, Green & Co., London and New York, 1889. $5.00.

Eaton, *Ferns of North America.*** Whidden, Boston, 1893. 2 vols. $20.00 per volume.

Underwood, *Our Native Ferns and their Allies.* Henry Holt & Co., New York, 1899. $1.00.

Campbell, *The Structure and Development of the Mosses and Ferns.* The Macmillan Company, New York, 1895. $4.50.

Macdonald, *Microscopical Examination of Drinking Water.* Lindsay & Blakiston, Philadelphia, 1875.

De Bary, *Comparative Morphology and Biology of the Fungi, Mycetozoa, and Bacteria.*** Clarendon Press, Oxford, 1887.

Goebel, *Outlines of Classification,* etc.** (See above.)

Warming and Potter, *Handbook,* etc.** (See above.)

The number of monographs on special topics in cryptogamic botany is too great to admit, in an elementary book, of even the mere mention of the most important titles. In the list above given, the works of Bennett and Murray and of

Goebel are the only general ones, and in the former mention is made of a good many of the best special treatises on cryptogamic botany.

Floras, etc.

Gray, *Field, Forest, and Garden Botany.* New edition by L. H. Bailey. American Book Company, New York, 1895. $1.44.

Gray, *Manual of Botany.* Sixth edition, revised. American Book Company, New York, 1890. $1.62.

A new and greatly improved edition of the *Manual* is in course of preparation.

Gray, *Synoptical Flora of North America.* American Book Company, New York.

Britton and Brown, *Illustrated Flora of the Northern United States, Canada,* etc. Charles Scribner's Sons, New York, 1896–98. 3 vols. $3.00 per volume.

Chapman, *Flora of the Southern United States.* American Book Company, 1897. $3.60.

Coulter, *Manual of the Botany of the Rocky Mountain Region.* American Book Company, New York, 1885. $1.62.

Miller and Whiting, *Wild Flowers of the Northeastern States.* G. P. Putnam's Sons, 1895. (Fully illustrated.) $4.00.

Sargent, *The Silva of North America.*** Houghton, Mifflin & Co., Boston, 1892–99. (In 12 vols., very fully illustrated.) $25.00 a volume.

Keeler, *Our Native Trees.* Charles Scribner's Sons, New York, 1900. (Fully illustrated.) $2.00.

Ecology

Kerner, *Natural History of Plants.* (See above.)

Müller, *The Fertilization of Flowers.* Translated by Thompson. The Macmillan Company, London, 1893. 21s.

Darwin, *Insectivorous Plants.* D. Appleton & Co., New York. $2.00.

Darwin, *The Power of Movement in Plants.* D. Appleton & Co., New York. $2.00.

Geddes, *Chapters in Modern Botany.* Charles Scribner's Sons, New York, 1893. $1.25.

Lubbock, *Flowers, Fruits, and Leaves.* Nature Series. The Macmillan Company, London, 1884. 4s. 6d.

Wiesner, *Biologie der Pflanzen.*** Wien, 1889.

Ludwig, *Lehrbuch der Pflanzenbiologie.*** Enke, Stuttgart, 1895. Unbound, 14 marks.

Weed, *Ten New England Blossoms and their Insect Visitors.* Houghton, Mifflin & Co., Boston, 1895.

Beal, *Seed Dispersal.* Ginn & Company, Boston, 1898.

Coulter, *Plant Relations.* D. Appleton & Co., New York, 1899. $1.10.

Schimper, *Pflanzengeographie,*** etc. Fischer, Jena, 1899. Unbound, 27 marks.

Warming, *Oekologische Pflanzengeographie.*** Translated into German by Knoblauch. Borntraeger, Berlin, 1896. 8 marks.

Pound and Clements. *Phytogeography of Nebraska.* Second edition. Botanical Seminar, Lincoln, Nebraska.

Kerner and Oliver's *Natural History of Plants* contains the fullest account of ecology in English of any book yet published. The best three books in the list above given (irrespective of the language in which they are written) are those of Ludwig, Schimper, and Warming. Warming's work is possibly rather theoretical, but it is a most fascinating little treatise by the hand of a master.

The work by Pound and Clements is the best account in book form of the phytogeography of any part of the United States.

EXAMINATIONS

The following examination papers may serve to suggest the lines along which examinations may profitably be set for pupils who are using the *Foundations of Botany.* The first two were given by Professor L. Murbach of the Detroit, Michigan, High School; the remaining ones are from the Boston English High School.

I

1. Describe roots, stems, leaves. Give the functions of each.

2. Give the history of each of the following plant structures, showing the relation they bear to each other: flower, fruit, seed, seedling, root, stem, leaf, bud.

3. Name five plant organs in which food may be stored, and tell in each case of what use the stored food is to the plant storing it.

4. Explain in what ways plants and animals may be of use to each other.

5. Tell the sources of plant-food. Follow it from its entrance into the plant, through its preparation, to its final use or storage.

6. Explain the principle underlying the modification of a plant organ. (Examples.)

7. (*a*) What substance distinguishes the organic from the inorganic? What are its characteristics? (*b*) Name the smallest divisions of it making up the plant.

8. Draw ground plan of a dicotyledonous flower and explain number, form, arrangement, and insertion of parts. Do the same with a monocotyledonous flower.

9. How do flowers produce seeds? Explain all the steps and the agencies employed.

10. Tell the most important fact you have learned from the chapter on "Struggle for Existence."

II

EXAMINATION IN BOTANY

DECEMBER 6, 1900. (ONE-HALF TERM)

1. Explain the make-up of any flowering plant: (*a*) as to its substance and the divisions of this substance (units); (*b*) as to its organs. What is protoplasm? Where is it found? What can it do? Of what importance is it? Name the two groups of organs, indicating their functions with the name.

2. Name the different kingdoms into which natural objects are divided. Discuss their relation to one another. Give examples.

3. Discuss flowers under the following heads: (*a*) structure, (*b*) functions, (*c*) means and devices made use of in performing their functions, (*d*) final products, (*e*) origin of the flower, (*f*) types of flowers.

4. Give your definition of a fruit. Of what use is it to the plant? Name the kinds of fruits as to composition or texture. Explain how each kind does its work, giving details. When the fruit has no devices for scattering the seeds how is this accomplished?

5. Give two points about the leaf, showing its fitness for its work. What are the three chief uses of the leaf? Explain how it performs each of these and illustrate with experiments.

SUPPLEMENTARY QUESTIONS

Discuss (*a*) plant-societies; (*b*) relations between plants and animals.

III

JANUARY 24, 1899

Take questions 1, 2, 3, 4, *and three others.*

1. State where you would find the cotyledons of three of the following plants three weeks after germination began, and tell what work the cotyledons of each plant have been doing, and what changes they have undergone in the mean time: bean, pea, squash, corn.

2. Trace the course of water from the soil to the extremities of the leaves of a dicotyledonous plant; explain how you would find out how fast it rises.

3. Name the layers from the center to the outside of a dicotyledonous tree. Tell what purpose each layer serves.

4. What are the principal uses of leaves? Sketch a cross-section of a leaf and label its parts; explain how each part helps in the work of the leaf.

5. Explain, as far as you can, the peculiar forms and uses of the roots of these plants: dahlia or sweet potato, ivy, duckweed, dodder, tropical air-plants.

6. Write fully upon how plants adapt themselves to different climates, etc., by leaves of various sizes, shapes, and covering.

7. Describe three ways in which plants catch insects. What becomes of the insects thus caught?

8. Describe each of the following plants or parts of plants; tell whether it is root, stem, bud, or other part of the plant, and tell how it comes to have the shape and structure that it does have: an onion, a potato, a melon cactus, a cabbage, a sweet potato.

9. (*a*) Why is some pollen dry and some sticky? (*b*) Why do not the anthers generally lie closely around the stigma? (*c*) Why are so many night-blooming flowers sweet-scented? (*d*) Explain some of the things that adapted one of the flowers that you have studied to be cross-pollinated.

IV

June, 1899

Take any six questions.

1. Write as fully as possible on plant-food found in seeds: (*a*) kinds; (*b*) mode of detecting each; (*c*) how distributed in the seed; (*d*) proof of usefulness to seedling; (*e*) proofs of disappearance from seed after germination.

2. Describe some of the main things necessary to fit a plant: (*a*) for desert life; (*b*) for life in the arctic regions; (*c*) for life on a lawn; (*d*) for life in a dense forest.

3. The yeast plant.

4. Compare two of the flowers that you have studied, so as to show which is best adapted for visits from selected insects.

5. Explain carefully the process of producing seeds, from the time the flower opens.

6. What is a fruit? Show how five very different kinds secure dispersal of seeds. Show how two kinds of plants protect their ripening seeds.

7. Explain in detail the process by which an ordinary plant takes, digests, and uses its food.

8. (*a*) How are plants concerned in the production of these articles: hemp, alcohol, flour, sugar, cotton? (*b*) In what other ways do plants make themselves useful to man?

9. Describe the development of a branch, beginning with the unopened bud.

10. Describe the growth of one of the following seedlings from germination till the seedling has its first regular leaf: bean, pea, squash.

V

January, 1900

Take any six questions.

1. Describe fully an experiment that illustrates osmosis. What has osmosis to do with plant life?

2. Name the chief uses of roots, stems, leaves, flowers, thorns, hairs.

3. Starch: where it is made, from what, by what, under what circumstances.

4. Where would the following be found and of what use are they? — epidermis, cork, wood cells, ducts, stomata, chlorophyll grains, lenticels?

5. Describe the structure of a flower that you have studied. Sketch its essential organs and label their parts.

6. Give the life history of a grain of pollen, telling where it is formed, how it is carried to its destination, what becomes of it there, what its use is, and how it accomplishes this.

7. Sketch a cross-section of a stem of a dicotyledonous plant and label each layer.

8. Compare the method of life of a mushroom or toadstool with that of an ordinary plant.

9. Describe some of the movements of roots, stems, and leaves, explaining the usefulness of each kind of movement.

LIST OF SLIDES[1]

I. Phanerogams

1. Starch in cotyledon of bean.
2. Same three weeks after germination.
3. Chinese lily root, longitudinal section.
4. Corn stem, transverse section.
5. Same, longitudinal section.
6. Macerated bast and wood fibers.
7. *Ricinus* stem, longitudinal section (spiral vessels).
8. *Pteris* rootstock, longitudinal section (scalariform vessels, wood fibers).
9. Cork, epidermis of ailanthus stem.
10. Squash or cucumber stem, longitudinal section (sieve tubes).
11. Clematis stem one year old, transverse and longitudinal section.
12. Golden-rod stem, transverse section.
13. Sycamore stem one year old, transverse section and longitudinal radial section.
14. Sycamore stem three to five years old, transverse section.
15. Sycamore wood, transverse section and two kinds of longitudinal section.
16.[2] Ash twig or beech twig, transverse section in early winter condition (starch).
17. Leaf of English ivy, transverse section.

[1] These slides will be furnished by Miss E. M. Drury, 45 Munroe Street, Roxbury, Mass., directly to teachers or schools and not through dealers. The price for Set I is $5.00 and for Set II $7.00 *net*, with 25 cents additional for each set if sent by mail.

[2] Also fifty sections in alcohol for use with iodine solution.

18. Leaf of lily, upper and lower epidermis.

19. Leaf of *Ficus elastica*, transverse section and lower epidermis.

20. Pollen tubes.

II. Cryptogams

1. Bacteria, stained.
2. *Spirogyra*, conjugating.
3. *Vaucheria*, fruiting.
4. *Nitella*, fruiting.
5. *Fucus*, antheridial conceptacles.
6. *Fucus*, oögonial conceptacles.
7. *Nemalion*, fruiting tips.
8. *Puccinia*, cluster cups on barberry leaves, section.
9. *Puccinia*, wheat rust spores.
10. Mushroom (*Agaricus*), section through gills.
11. Lichen (*Physcia*), section through thallus.
12. *Marchantia*, section through male receptacle.
13. *Marchantia*, vertical section through an air-chamber of thallus.
14. Moss (*Funaria*), antheridium.
15. Moss, longitudinal section through tip of a fertile plant.
16. Moss, section through spore-capsule, showing spores in place.
17. Fern spore, germinating.
18. Fern prothallium, with young plant.
19. *Equisetum*, cross-section of stem.
20. *Equisetum*, epidermis macerated to show stomata.

Extra Slides, 50 cents each

Physcia, section through apothecium. Prothallium of fern, section showing antheridia. Same, showing archegonia. Ovary of *Pyrola*, section showing egg apparatus. Ovules of *Capsella*, showing development of embryo. Twig of *Euonymus alatus*, cross-section of twig, showing cuticle and cork.

Other extra slides will be furnished to order as desired; prices given on application.

BOTANICAL PHOTOMICROGRAPHS [1]

The following subjects are ready; others are in preparation.

Stem sections.

No. 1. *Platanus occidentalis* (Sycamore): complete transverse section × about 135.

No. 2. *Sassafras officinale* (Sassafras): complete transverse section × about 140.

Nos. 1 and 2 show clearly in transverse section all the elements of a woody "exogenous" stem at the close of its first year of growth. No. 1 is particularly good for showing the elements of the woody layer, the bast cells, wood cells, ducts, medullary rays, etc., standing out with great distinctness.

[1] By SAMUEL F. TOWER, Instructor in Botany in the Boston English High School. Printed on heavy "Bromide" paper about 16 × 20 inches. Prices: unmounted, $2.50 each; mounted on heavy cardboard, $2.75 each; sent postage free if unmounted, or by express at purchaser's expense if mounted. *Photographs of this series can be ordered from the publishers.*

This is a series of photographs of plant sections printed from the original negatives by the "Bromide Enlargement" process. The negatives have not been retouched in any particular, so that the prints are in no sense diagrams, but are exact representations of what existed in the plants. The magnification is sufficient to make all the more obvious points of structure and, in many cases, fine details visible across an ordinary recitation or lecture room. The advantage of photographs over such diagrammatic and conventionalized illustrations as are given in many of the best text-books will be appreciated by every teacher of science. The photographs will be found useful for illustrating lectures or class-room talks, or as a basis for review quizzes; they can be used to advantage in the laboratory either to show the young student what to look for in his work with the microscope or to correct his faults of observation after he has sketched the original section; while for giving the sense of proportion and relation that is always wanting in the work of young students they are invaluable. The sections have been chosen with care, so that teachers can get for their classes fresh material like that represented in the photographs. It will be recognized at once that no method of commendation or criticism could be more effective than to confront the student with a photograph of the material which he has just sketched.

No. 3. *Zea Mays* (corn): transverse section of part of stem × over 400; shows a field large enough to give the arrangement of fibrovascular bundles in the monocotyledonous stem, and is magnified sufficiently to show the structure of the individual bundles.

No. 4. *Zea Mays:* longitudinal section of small part of stem × about 350; shows two fibrovascular bundles with the adjacent parenchyma tissue. The annular ducts in the bundles show particularly well.

Nos. 3 and 4 studied together will give a clear idea of the most important points in the structure of the monocotyledonous stem.

No. 5. *Smilax rotundifolia* (Cat-brier): complete transverse section × about 145; shows the structure of the individual bundles and their arrangement in the stem, the thickened walls of the fundamental tissue and the stomata in the epidermis with the thin-walled cells immediately underlying them.

An instructive comparison may be made of No. 3 and No. 5, an herbaceous and a woody stem, both monocotyledonous. It will be profitable also to study No. 5 in connection with No. 1, a monocotyledonous and a dicotyledonous stem, both woody.

No. 6. *Thrinax sp.* or *Sabal sp.* (?): transverse section of part of petiole × about 170. This is a section of a bit of the handle of a "palm-leaf" fan and shows fibrovascular bundles and surrounding tissue of a somewhat different type from the two foregoing; an exceptionally clear photograph.

Root sections.

No. 7. *Prunus serotina* (Wild Cherry): complete transverse section × about 85; shows clearly all the elements of a woody "exogenous" root.

A comparison of No. 1 and No. 7 will be found a very instructive class exercise.

No. 8. *Narcissus Tazetta,* var. *Orientalis* (Chinese Lily): longitudinal section of root tip × somewhat over 400; shows the cells of the rootcap, the point of growth, and the incipient corky layer and central cylinder.

Leaf sections.

No. 9. *Hydrangea Hortensia* (Hydrangea): transverse section × about 600; shows the upper epidermis, the palisade parenchyma, the loose parenchyma, and the lower epidermis. A small vein is also seen in cross-section.

No. 10. *Ficus elastica* (Rubber Plant): transverse section × about 650; shows the same elements as No. 9, and also several stomata, in section, in the lower epidermis.

A comparison of No. 9 and No. 10 will be found very advantageous in connection with transpiration experiments on the *Ficus* and the *Hydrangea.* (See Bergen's *Foundations of Botany*, pp. 159–162.)

No. 11. *Rhododendron sp.:* transverse section × about 1000; shows the same elements as the two foregoing and is in character intermediate between them. The differentiation between the palisade parenchyma and the loose parenchyma is particularly good.

No. 12. Epidermis of leaf of *Cyclamen sp.* × about 780. This photograph represents $\frac{1}{4}$ square millimeter of epidermis, and shows the typical epidermal cells of a netted-veined leaf and the form, number, and arrangement of the stomata. Many cells show nuclei clearly.

As this view shows a definite portion ($\frac{1}{4}$ sq. mm.) of epidermis, the student can easily compute the number on a given leaf of the same sort and thus get a good idea of the immense number of stomata even on a leaf that is relatively poorly supplied with them.

Sections showing ducts.

No. 13. *Ricinus communis* (Castor-oil Plant): longitudinal section of petiole × about 360; shows a group of spiral ducts with the adjacent parenchyma tissue.

No. 14. *Pteris aquilina* (Common Brake): longitudinal section of rootstock × about 300; shows two groups of scalariform ducts and, less distinctly, other parts of the bundles in which they occur with the adjacent parenchyma tissue.

See also No. 4 for annular ducts.

Wood sections.

No. 15. *Sassafras officinale* (Sassafras): transverse section × about 300; shows three annual layers of wood with their ducts, wood cells, medullary rays, etc.

No. 16. Radial section of same wood with like magnification; shows clearly most of the elements of which this wood is composed. Through the middle of the picture runs a duct with its wall nearly intact partially overlaid by the cells of a medullary ray. On the extreme right and left are the remains of other ducts whose walls were torn in cutting. Wood cells, wood parenchyma, and medullary ray cells show very clearly. The picture includes two annual layers.

No. 17. Tangential section of same wood with like magnification; shows in tangential section the same elements as are shown in Nos. 15 and 16.

No. 18. *Pinus Strobus* (White Pine): transverse section × about 300; shows one annual layer of wood with its wood cells, medullary rays, and one resin passage, whose walls are somewhat crumpled.

No. 19. Tangential section of same wood with like magnification; shows medullary rays and wood cells. In many places the "pits" in the walls of tracheids show more or less clearly in section.

No. 20. Radial section of same wood × about 900; shows the same elements as appear in No. 19. The tracheids are relatively too short to be typical of the wood of *Pinus Strobus* (compare No. 19); but the section was chosen particularly to show the discoid pits, which appear in great number and with remarkable distinctness.

NOTE. — For the benefit of those teachers who live at too great a distance to make their selections by personal examination and who have not sufficient laboratory funds at their command to purchase the whole set at once, it may not be out of place to say that, if the author could have only one of the fifty or more that he uses in his own teaching, he would choose No. 1. As the five which, if any, are more useful than the others, he would recommend Nos. 1, 3 or 5, 7, 8, and 9; and as the second five, Nos. 15, 16, 17, 13, and 10. The order would, however, depend greatly on the particular points that the individual teacher emphasizes in his teaching.

A large variety of photomicrographs can also be had of W. H. Walmsley, 4248 Pine Street, Philadelphia. Mr. Walmsley can furnish moderately amplified bromide enlargements of these if desired.