Botany

A Textbook for College and University Students

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PREFACE

THE material included in the following pages may differ in some respects from the reader's conception of what a beginning course in college Botany should be. It might be advisable, therefore, to state briefly the objects which the authors had in mind in preparing the present volume and to emphasize that it is the outgrowth of the course in General Botany offered at the University of Missouri and its content has been influenced by many other than the authors.

For most students who take it, the elementary course in Botany is the only formal work in biological science they ever do. We have, therefore, attempted to present the fundamental biological principles rather than to lay the foundation for professional botany. This accounts for the inclusion of some material not strictly botanical in nature and the omission of some items which should be included in a course for the preparation of students intending to specialize in Botany.

In addition to presenting the fundamental biological principles we have tried to illustrate by concrete examples the aim of science and the scientific method. The popular conceptions of what science tries to do, of the way in which scientific knowledge accumulates and of the nature of hypothesis and scientific law are frequently erroneous. Science attempts to describe and relate to one another observable facts. Its conclusions are always tentative, subject to revision on the discovery of new facts not in harmony with the generalizations previously made. Scientific knowledge accumulates slowly and is rarely complete and free from error. It does not spring full formed from the mind of any individual. Natural laws are generalizations or summaries of observed facts; not inviolate pronouncements which nature obeys. The results of science have been of incalculable benefit to mankind, but there are limitations to science: both its advantages and limitations should be recognized. The failure to appreciate the true nature of science has caused much misunderstanding which need not be detailed here. A college course in biological science should give the student

a correct idea of the true nature of the aim of science, its methods of work, and the value and limitations of its results.

Finally we have attempted within the limitations of this book to acquaint the student with the variety and extent of the living world as illustrated in the plant kingdom.

The first portion of the book is devoted to the fundamental physiological processes in living things, and the structures which make them possible, as illustrated primarily by the seed plant. This section leads naturally to a general consideration of life and death, and the origin of life, which in turn carries on to the second section which begins with the bacteria and yeasts. The second section of the book is intended to acquaint the student with the variety and extent of the plant kingdom; to offer opportunity to illustrate in other forms the fundamental principles developed by the earlier discussion of the seed plant; to present the process of reproduction with its relation to the life cycle of organisms; and to furnish the material for a discussion of inheritance and evolution. It should be emphasized that the series of plants selected for this portion of the book and the order in which they are arranged are not intended to present any evolutionary sequence. The fungi have been considered first because of the intimate connection between them and the theory of spontaneous generation and because of the new principles of physiology which they illustrate. The fern is considered before the moss because of the clearer demonstration of alternation of generations given by its life history.

A list of reference books, which must necessarily be incomplete, is included in the Appendix.

We have made free use of the many excellent textbooks available on botany and allied subjects and our indebtedness should be expressed individually to the authors if we could locate exactly in all cases the sources of the ideas or special examples drawn from them. Valuable criticisms and suggestions were made by Dr. C. E. Allen, University of Wisconsin; Dr. Donald B. Anderson, North Carolina State College; Dr. Carl Deuber, Yale University; Dr. R. A. Harper, Columbia University; Dr. E. J. Kraus, University of Chicago; Dr. W. E. Maneval, University of Missouri; Dr. L. C. Petry, Cornell University; and Mr. Albert Saeger, Kansas City Junior College.

Acknowledgment for illustrations from various publications or from unpublished photographs generously supplied is made in the

body of the text. Our particular thanks are due Miss Coral Fleenor, Biological Artist at the University of Missouri, who made most of the original illustrations, and Miss Ruth B. Baker, Miss Gertrude J. Bishop, Mr. Francis Drouet, Mr. E. E. Naylor, Mr. R. E. Zirkle and Mr. Neville Todd, students or instructors in the University of Missouri, who are responsible for the balance.

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May, 1929

PREFACE TO THE SECOND EDITION

In preparing a second edition of this book the authors have borne in mind the principles expressed in the preface to the first edition. These principles may be summarized in the statement that the book is intended for general students as part of an education which all should have. It is not intended to lay the foundations for professional botany.

Some changes in the order in which the topics are considered have been made, and new material has been added. Much of the text has been rewritten. The introductory chapter is intended to acquaint the student with the main purposes of the book. The discussions of reproduction of the seed plant and of heredity have been shifted to the earlier portion of the book which as now arranged forms a unit dealing with the living plant. The addition of the discussion of reproduction to the first portion of the book makes possible a change to the more conventional order of plant groups in the second part. However, the Pteridophytes may still be taught before the Bryophytes if difficulty is experienced in presenting the subject of alternation of generations, since all necessary concepts are reintroduced and reviewed in the presentation of the Pteridophytes. The section on the origin of life has been placed adjacent to the treatment of biologic evolution.

The book may be used in various ways. For a semester's course the first thirteen chapters with the addition of selected portions of the second part of the book may be found most advisable. Those portions of the second part which may be selected for such a course will depend upon the desires of the instructor. A selection which may be suggested would include Chapters 14, 21, 22, and 23, with forms chosen from the chapters on the plant groups sufficient in number to acquaint the student with the characteristics, diversity, life-cycles and importance of representatives of each group. As pointed out above, the order in which the groups are arranged need not necessarily be followed. If the course extends through the year, a natural division would place the first thirteen chapters in the first semester and the last ten in the second semester.

It is hoped that both student and instructor will realize that an

important function of a course in science is the development of an attitude of mind, the scientific attitude of looking at facts. This of course cannot be accomplished without adequate and accurate acquaintance with the facts themselves, as many would have us believe; but preoccupation with facts may prevent the proper formation of the scientific habit of thinking.

In addition to the acknowledgments made in the first edition, the authors express their thanks to Dr. Lewis Stadler, Miss Ilda McVeigh, Mrs. Theresa B. Rickett, and Mrs. Christine C. Robbins for assistance of various kinds.

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TO THE STUDENT

The questions at the end of the book are designed to help you test for yourself your own mastery of the subject. They afford a means by which you can know whether or not you have assimilated the information given in the text. If you can answer the questions in your own words without referring to the text, you have gained something from your study. The questions do not, however, exhaust the list of possible questions. You should try to formulate questions for yourselves, questions which you think a book on Botany ought to answer.

The majority of the questions are answered in the text. Some require a little reasoning based on the facts presented in the text. A few presuppose some knowledge derived from other sources.

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CHAPTER I

Introduction

1. Botany, Zoology, Biology.—The science of Botany is a part of the subject of Biology in which all of us should be deeply interested since it is concerned with living things, and we ourselves are a part of them. Biology, the study of living things, is divided into Botany, the study of plants; and Zoology, the study of animals. Since we intend to study Botany we might well begin at once to study a plant or one of its parts. However, instead of using this direct procedure, it may be wiser to discuss some of the general concepts which will be used in the pages which follow and to say something of what we hope the reader will secure from the study of Botany in general and from this book in particular. In proceeding in this way we are like the traveler in foreign lands who looks over his equipment and examines a map of his proposed itinerary before he begins his journey.

Botany is the study of plants. What is a plant and how is it distinguished from an animal? Why should we study plants and what are the types of questions which we expect to have answered in a study of plants? Botany is a science. What is a science? These are some of the questions which will be discussed in this chapter even though they might be more completely and more satisfactorily answered after we had studied the subject than before.

2. Plants and Animals.—We divide all living things into two kingdoms, the plant kingdom and the animal kingdom. Everyone knows that a horse is an animal and an oak tree is a plant but not everyone realizes that to characterize plants and animals in such fashion as to enable us to separate all living things into these two groups is difficult, if not impossible; for there are living things which resemble animals in some respects and plants in others. In general, animals have the power of locomotion while plants do not. There are, however, animals which are as fixed and stationary as a tree, and plants which are motile and move from place to place. Plants are frequently thought of as organisms which possess the green pigment, chlorophyll, and have the power of making their own food while animals have not this power. Yet there are many plants

which have no chlorophyll and do not make their own food. It is frequently said that all plants have well defined cell walls (Chapter II) and animals do not; but here again we find organisms without well defined cell walls but with other characteristics which suggest that they should be placed with the plants. In fact, while we have no difficulty in determining for almost all organisms whether they are plants or animals, there is no sharp dividing line separating all plants from all animals; the two kingdoms grade one into the other. Some have suggested that it is preferable to group living organisms into plants, animals, and protista; the last group containing the doubtful and intermediate forms which it is difficult to distinguish as either plants or animals. It should be remembered that the grouping of living things into plants and animals is, as are all such classifications, a man-made grouping. It is not surprising that all living things do not fit the groupings we have made. It is rather a source of gratification that our groupings work as well as they do. This difficulty in separating living things into the groups of plants and animals emphasizes also the fundamental unity of all life.

3. The Plant Kingdom.—The number of different kinds of plants is very great. There are at least 300,000 different species or kinds of plants known and named and this number does not include the numerous varieties of domesticated plants. Thus the botanist considers the wheat plant (*Triticum vulgare*) as a single species but there are several hundred recognizable cultivated varieties of wheat. These numerous species of plants are grouped or classified according to their likenesses. There are several such classifications; one of the commonest and for us the most useful is that which groups the kinds of plants into four large divisions.

The seed plants or Spermatophytes form one such division and in it are placed all plants which form seeds. The Spermatophytes include the most familiar and most useful plants; for example, trees, shrubs, grasses, pines, firs, corn, roses, bamboo. The Spermatophytes will be described in some detail later. It must suffice to say here that they are extremely diverse in size, general appearance and habit of growth. The Spermatophytes have well defined leaves, stems, and roots; they are the most complex in structure; and are the dominant plants in our vegetation.

The ferns and their allies, scientifically known as the Pteridophytes, comprise a second division. In this division are placed the ferns, horsetails, lycopodiums, and the tree ferns. Some of these

kinds of plants are not fern-like in their general appearance and would never be considered by the casual observer to be related to the ferns; less obvious but important characteristics, however, show their relationship. Not many kinds of Pteridophytes are more than a foot or two high, almost all have leaves, stems, and roots—and almost all are land plants. Many hundreds of thousands of years ago there were more kinds of Pteridophytes than there are now and they formed a more important part of the earth's flora: a place now occupied by the Spermatophytes.

The mosses and their relatives form a third division. They are called the Bryophytes. The liverworts, many of which are not at all moss-like in their general appearance, are included with the mosses. The mosses have simple stems and leaves; they are small plants infrequently reaching a length of more than an inch or two; they grow in carpet-like mats. The liverworts rarely have structures which are leaf like or stem like; many kinds are thin, flat and ribbon-like in general form. The Bryophytes are for the most part land plants.

The thallus plants or Thallophytes make up the fourth division. In the Thallophytes are included the seaweeds and their relatives, known as the algae; and the molds, bacteria, mushrooms, toadstools, puff balls, and shelf fungi which together are known as the fungi. Many of the Thallophytes are water plants. The Thallophytes were probably the first plants to live upon the earth.

To give some idea of the representatives of these various divisions of the plant kingdom, their structure, habits of life and importance, is one objective of the second part of this book.

4. Reasons for Studying Botany.—You may naturally inquire why we should study plants. Why do many men and women in all countries of the world devote the major portions of their lives to familiarizing themselves with what is known about plants or spend days, weeks and years of painstaking labor discovering new facts about them while thousands of students in our schools and colleges each year study the subject of Botany? There are several reasons for studying plants—among which may be mentioned the following: First and foremost with many is the economic reason. Plants supply the foods for all living things. This is obvious in the case of herbivorous animals such as cattle and deer but it is true of carnivorous animals also which live on flesh; for this flesh in the last analysis grew from vegetable food. We can safely say that without

plants there would be no food. Furthermore, plants maintain the oxygen content of the air without which life would be impossible and are the chief primary source of those important accessory foods, the vitamins. In addition plants supply us with wood, turpentine and resin; with a variety of important drugs; with perfumes, flavorings, and spices; they furnish huge quantities of oils and fats; they are the source of our paper; their fibers or their hairs are used for cordage and clothing; and from the cellulose of their bodies chemists make artificial silk, powerful explosives, for example nitrocellulose, and many other useful and important products. In addition some kinds of plants (the bacteria) cause diseases, for example pneumonia and typhoid fever, and are responsible for commercially important fermentations such as the souring of milk. You can readily think of many other ways in which plants are a benefit or detriment to man. In view of the great economic importance of plants, it is not difficult to understand why we wish to become acquainted with them as thoroughly as is possible.

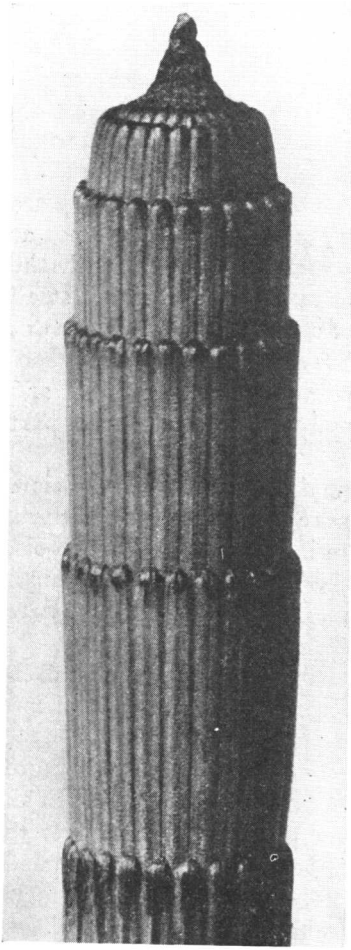

FIG. 1. Modern architectural design in a plant form. End of a shoot of the winter horsetail (*Equisetum hiemale*) enlarged five times. (From Blossfeldt, *Art Forms in Nature*, Ernst Wasmuth, Berlin.)

Another reason which induces many to study plants is their beauty—beauty which exists not only in plants in mass as in a landscape and in their grosser structure, but in their minute make up which is visible only through the aid of an enlarging lens or the microscope. This might be called an aesthetic reason for studying

plants. Few lack an appreciation of the beauty of trees and grass and flowers. Not only are plants beautiful in themselves, but some part of them, frequently their flowers, leaves, or seeds, is often the motif from which some more formal artistic design is developed. Each one of you is familiar with some design in dress goods, wall paper, or architecture, which is based upon the structure of a flower, the shape of a leaf or of some other plant part (Fig. 1, 2 and 3). Familiarity with plants resulting from their study makes it possible to see more beauty in them and to appreciate it more intelligently.

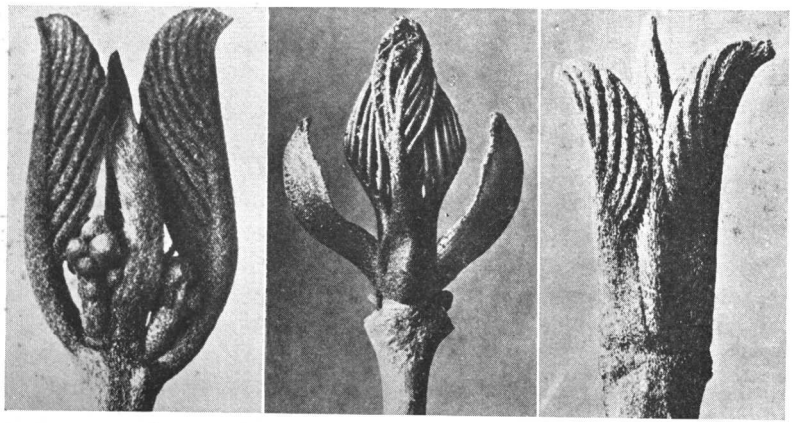

FIG. 2. Classic sculptural design in plants. Expanding buds of California bearberry (*Rhamnus purshiana*), flowering ash (*Fraxinus ornus*), and dogwood (*Cornus pubescens*) enlarged 3 to 12 times. (From Blossfeldt, *Art Forms in Nature*, Ernst Wasmuth, Berlin.)

Then, too, some people are interested in plants for the same reason that one becomes interested in postage stamps or coins or old furniture. These are hobbies which satisfy the desire in each of us intimately to know some one thing, to collect it and to work with it. We may collect plants as a hobby, preserving them as dried and mounted specimens in a herbarium; we may cultivate them, specializing in a certain group, for example the irises or roses, perhaps attempting to develop new and superior varieties; or we may study them, trying to learn how they reproduce, why they grow where they do and answer from first hand observation other questions which may come to our minds. Studying plants as a hobby has the advantage of taking us out of doors and requiring us to walk

about: it is not possible to study plants from a moving automobile. Some amateur botanists—as individuals are known who study plants as a hobby—have become noted authorities on particular groups of plants and have been consulted by interested individuals from various parts of the world. Charles Darwin might be described as an amateur botanist since much of his scientific work was concerned with plants and he was professionally engaged in biological work for but a small part of his life. The same may be said of Gregor Mendel and many others who have become noted for their work with plants.

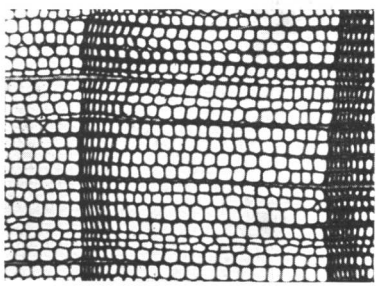

FIG. 3. A thin slice of the wood of the redwood tree (*Sequoia sempervirens*) magnified. ". . . a piece of Nature's Handicraft which far surpasses the most elaborate Woof or needle work in the World." Nehemiah Grew.

Closely connected with the study of plants as a hobby, and sometimes indistinguishable from it, is the study of plants for scientific reasons. There are many important and fundamental questions in biology which can be attacked as satisfactorily (or even more so) with plants for experimental material as with animals. In addition, plants can be grown in large numbers, and we have no sentimental compunctions in destroying them. Many of the most important discoveries which have been found to hold true for both plants and animals were first made by students of plants. Furthermore, the study of Botany should furnish an appreciation of science and the scientific point of view.

5. Science.—What is science? The term science is used in a variety of ways. In the popular mind science means such subjects as chemistry, physics, mathematics or biology, and a scientist is thought of as an individual who is trained in these subjects and who devotes his life to them. Science is to many something mysterious which certain types of minds only can grasp, and the scientist is regarded as a unique individual with peculiar gifts. Such an attitude of mind is illustrated by the characterization of Edison as a wizard and the description of scientific discoveries as miracles.

Wonderful as science is and much as we are indebted to the scientist there is nothing so unusual about it. All of us, whether

we have studied science or not, know some science and often use the same method as that used by the greatest scientists in making their most remarkable discoveries. Science is primarily a collection of answers to questions; answers which have been secured by careful and repeated observations and experiments and by reasoning, limited and corrected by the observed facts. In securing the answers to questions the scientist proceeds as follows: First, he analyzes and defines the question in which he is interested. On the basis of his observations, his experiments and his thinking he proposes an answer. This answer, called a hypothesis or theory, is tentative; it is not, however, a "guess" but an answer justified as possible and probable by the known facts. The tentative answer is tested by experiment and by checking it against known facts and further observations. It is accepted, modified or rejected on the basis of the additional observations and experiments. In this way the hypothesis becomes a better and better answer to the question. It may eventually be called a scientific law. This procedure—question, tentative answer, the testing of the answer and its modification in the light of the results—is the *scientific method.*

The method of science, therefore, depends on observation—the more careful and the more complete the observation the better the results of the method; that is, the better the science. It depends, furthermore, on reasoning; that is, the principles of logic applied to our observations. Both these processes are, of course, used by us every day of our lives. There is, therefore, nothing remarkable or formidable about science—except care and patience. In fact, the great English zoologist, Huxley, has said,

"Science is nothing but trained and organized common sense differing from the latter only as a veteran may differ from a raw recruit." He said further,

"The method of scientific investigation is nothing but the expression of the necessary mode of working of the human mind."

Of course, there are other methods of answering questions than the scientific method and those, too, we are likely to use every day of our lives. We may answer questions on impulse, emotionally, from prejudice, or in the desire to have a wish fulfilled; or we may accept an answer from some one else which has been made on one of these bases. Such answers may be correct but if they are it is by chance only. "The four obstacles to knowledge," said Roger Bacon, "are authority, prejudice, habit and a false conceit of knowledge."