A TEXT-BOOK OF BOTANY
For Students

With Directions
For Practical
Work

Amy F. M. Johnson

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FOR STUDENTS

With Directions for Practical Work

BY

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AND OTHERS

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PREFACE

THIS book has been primarily written with the idea of providing a suitable and well-illustrated textbook for my own pupils, but every effort has been made to make it a sufficient guide to anyone working alone, and desirous of obtaining an elementary knowledge of the subject in its more important aspects. No scientific knowledge worth the name can be acquired without practical work as a basis, and it is hoped that the student will use the book in the way suggested, and will, as far as possible, go through the practical work on each chapter before that chapter is read. I would like to add a few words on the method of using the section of the book dealing with the Natural Orders. The general characteristics of the whole Order are given merely as a matter of reference, and are intended for use only after the student has examined as many different members as possible, to enable him to realize how far the points observed are really characteristic of the whole Order, and not of the individual plant.

The subject-matter included is such that the book will be helpful to a student preparing for any of the following examinations: London Intermediate, First Medical, Board of Education (Stages I. and II.), Oxford and Cambridge Joint Board, Cambridge Higher Local, Welsh Central Board.

I am most deeply grateful to the illustrators for their unsparing pains in making the illustrations as perfect as possible. Except for a few explanatory diagrams, all drawings have been made from actual specimens. Many of the microscopic preparations have involved much time and trouble, and we are much indebted to Dr. Burtt, of the British Botanical Supply Association, York, for some most valuable slides. Miss

Boys-Smith, the illustrator of "Elementary Botany," by Miss C. L. Laurie, is responsible for more than half the illustrations. Miss Berridge most kindly undertook 100 of the microscopic drawings. These include Fig. 305 from a beautiful slide lent by Miss Ethel Thomas, Botany lecturer at Bedford College, and well known for her brilliant work on the double fertilization of *Caltha palustris*, and also drawings of *Eurotium*, adapted by kind permission from the paper on "The Morphology of *Aspergillus Herbariorum*," by Dr. Helen Fraser and Miss H. S. Chambers, B.Sc. The remaining figures are the work of three of my pupils—Miss Mabel Barker, B.Sc., Miss Mary Pocock, B.Sc., and Miss Phyllis Palmer.

Miss Thomas was good enough to read through some of the section on Systematic Botany, and my thanks are also due for much valuable and helpful criticism to Miss Berridge, Miss K. Jeffries Davis, B.Sc., Miss M. Pocock, Miss Kilroe, B.Sc., and Miss Laurie.

A full and valuable index has been prepared for me by my former pupil, Miss T. Bosanquet, B.Sc.

LADIES' COLLEGE,
CHELTENHAM,
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INTRODUCTION

BOTANY is one division of Biology—that is, the Science of Life. It is that section which deals with plant life as distinguished from animal life; the study of the latter is known as Zoology. The word "Botany" is derived from a Greek word meaning grass, or herb.

We are far from understanding what life is, what it is that makes things "living," but we know that everything that has life is made of a substance which we call *protoplasm*—*i.e.*, first or fundamental material. This is a most complex substance—indeed, its composition and structure still baffle the most patient investigators.

Distinction between Plants and Animals.

It is not always easy to distinguish a plant from an animal. There are certain living organisms which are claimed by botanists and also by zoologists; this difficulty of discrimination, however, concerns only very lowly forms of life. Though the most essential differences between the animal and vegetable kingdoms are given below, we must bear in mind that there are no sharp lines of demarcation in Nature: one or more of the characteristics of a plant may be missing, and yet the organism be still classed as a plant. It is as well to realize at the outset of our study that the divisions which are made by the student of Nature are merely helps devised for his own benefit.

Observe, first, that in plants minute portions of protoplasm are, as a rule, covered by a delicate skin, or wall, of a substance called cellulose, while in animals the cellulose wall is absent. It is the presence of this skin that causes the great difference between the feeding of a plant and of an animal. The former can take in only such food materials as can be sucked through the membrane; while the latter can take in solid food material.

Secondly, most plants possess a green pigment called chlorophyll, in consequence of which they are able to live on much less complex food substances than animals, in which this particular colouring matter is wanting.

A third and last distinction which is sometimes drawn is that animals spend a much greater proportion of their energy in movement than do plants. A plant generally remains rooted at one spot, and expends its chief energy in growth. Movements in connection with plant life are, nevertheless, of great importance.

Extent of Vegetable Kingdom. The extent of the vegetable kingdom is not always realized by those who have not studied the subject. The microscopic bodies producing the green appearance of a tree-trunk after rain are as much plants as the stately trees on which they are found. The so-called "germs," which are the cause of most, if not all, infectious diseases, must be reckoned as plants; so, too, must the rusts, mildews, and blights, which cause such havoc among wheat, gooseberry, and potato crops.

Divisions of the Subject. These very varied living organisms are most conveniently studied from the point of view of their external forms. This is what is known as *Morphology*, *i.e.*, the study of form.

Then, again, all living organisms exhibit certain phenomena, they breathe, feed, grow, and move. The consideration of these subjects is dealt with in *Physiology*, *i.e.*, the science of the nature and processes of life. Botanists are realizing more and more that the form of any part of a plant is directly dependent on its function, that is to say, morphology and physiology are intimately associated.

When we come to examine plants microscopically, we find that the simplest consist of a single mass of protoplasm, that is, of a single plant "cell." Through stages of gradually increasing complexity we come to the higher plants, made up of myriads of cells. These cells vary much in many respects, but we find them arranged in groups; such groups constitute the *tissues*. The study of the tissue systems is known as *Histology* (Gk. *histos*, a web), or Minute Anatomy.

Strangely enough, every plant, however complex, originates from a single cell. Each individual to some extent appears to repeat in its own development the history of the race (Recapitulation Theory). The study of the development of the individual from a single cell is known as *Embryology*.

We realize that, though plant forms are very varied, certain forms resemble one another, while they are totally distinct from and unlike other plants. Hence, we arrange plants in groups, and we find that these groups are subject to many subdivisions. This leads to *Classification*, or Systematic Botany.

Within recent years the botanical world has heard much of *Ecology*. This is the study of plants from a physiological point of view in their natural habitats, rather than in the laboratory. Under this heading we shall consider the special adaptations of plants to their environment.

In former geological ages forms differing from our present forms existed on the earth. *Palæobotany*, the study of these fossil plants, is a section of the subject which is also receiving much attention at the present time. New fossils are being found combining the characters of existing groups of plants. Supposing it were possible to obtain all intermediate forms, we might hope to arrange plants in an ascending series, beginning with unicellular organisms and ending with highly complex flowering plants. But the evidence obtained from rocks is most fragmentary. All we can say at present is that the lower groups seem to predominate in the lower rocks, and that they there attained a degree of development quite unparalleled at the present day.

One of the most interesting lines of botanical study is that of *Phylogeny*—that is, the attempt to trace out the line of descent of any plant. In doing so we assume the "Theory of Evolution"—that is, the theory that organic life has gradually developed, in obedience to natural laws, from the simplest to the most complex forms. The theory is no new one: it was accepted by the ancient Greeks, but it is largely due to the work of Charles Darwin that it was revived and established on a more scientific basis.

PRACTICAL WORK.

It is hoped that every student using this book will attempt to carry out carefully and fully the directions and suggestions given for practical work. Botanical knowledge can only be satisfactorily acquired when it is the result of investigations on living plants. To insure accuracy of observation, it is most important that careful annotated sketches be made of all specimens examined. To train the mind to make original and independent observations, it is suggested that as often as possible the practical work on any section should be worked through before that section is read, and revised after the further information has been gained. The illustrations in the text have all been made from actual specimens, except in the few cases of explanatory diagrams. The student should attempt to make his equal to these.

The material required should be, if possible, collected by the student himself. If it cannot be used at the time, it should be preserved in 90 per cent. alcohol until needed. Arrangements have been made which will enable the student to obtain what he cannot find for himself. Particulars as to these arrangements, as well as a full list of materials, apparatus, reagents, etc., are given in an appendix.

PART I.—GENERAL MORPHOLOGY

CHAPTER I

MORPHOLOGY OF THE ROOT AND SHOOT

BEFORE discussing the external form of the highest group of plants known as Flowering Plants, we will very briefly consider the elaboration in form of some of the lower plants, in as far as it will help us to a better understanding of the more complex forms of plant organization.

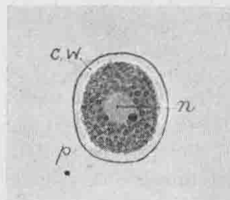

FIG. 1.—PROTOCOCCUS (HÆMATOCOCCUS).

p, protoplasm ; *c.w*, cell wall ; *n*, nucleus.

The simplest form of plant structure is a single spherical mass of protoplasm, bounded by a membrane. If a small quantity of water, from a pond or water-butt, which has become green be examined under a microscope, it will be found to contain a great number of spherical green organisms, similar to that shown in Fig. 1. The external form of the protoplasmic mass may be cylindrical or irregular, sometimes assuming most beautiful and complex shapes. The little plant shown in Fig. 2 is abundant in the damp earth round the edge of ponds. The figures were drawn under a high power of the microscope, and the plants are shown several hundred times their real size.

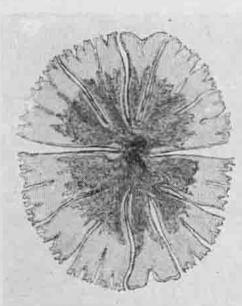

FIG. 2.—A DESMID.

The next in order of simplicity of form of plant body is an elongated cylindrical thread, *e.g.*, Spirogyra (Fig. 3), which is found so commonly in the green scum at the top of stagnant water. This thread of uniform thickness should be compared with that of Ulothrix (Fig. 4), a little plant found in fresh running water, which shows a slight differentiation into base and apex, in that it has a pointed end, by which it attaches itself to stones, etc.

Passing from these filamentous forms, we next come to forms in which the plant body is a flattened expansion. A

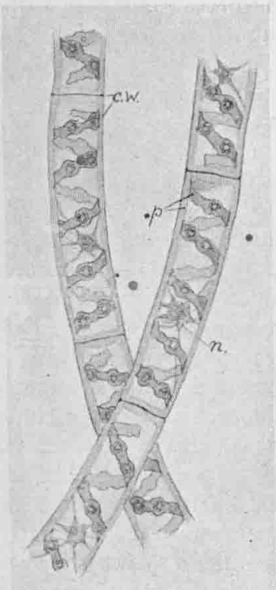

FIG. 3.—SPIROGYRA. (MAGNIFIED.)

p, protoplasm, with spiral chromatophore; *n*, nucleus; *c w*, cell wall.

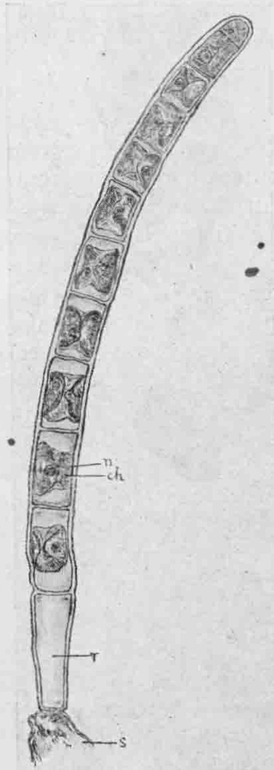

FIG. 4.—YOUNG PLANT OF ULOTHRIX. (MAGNIFIED.)

n, nucleus; *ch*, chromatophore; *r*, rooting cell; *s*, a stone.

well-known example of such a plant is Ulva (Fig. 5), the green seaweed so commonly found adhering to the wooden stakes of a pier about the water-level. This should be compared with the brown bladder-wrack, Fucus (Fig. 6), in which the plant body is branched; but the branches all originate in the same way, and closely resemble one another.

In all these cases the plant body is called a *Thallus*, there being no differentiation into distinct plant members. In many cases among lower plants, *e.g.*, in some Red Seaweeds and in Mosses, we have differentiation of the plant body into parts apparently corresponding to the root, stem, and leaves of higher plants. These structures are, however, not homologous with—*i.e.*, have not the same origin as—the similar structures of higher plants; they are at most merely analogous to them, *i.e.*, they perform the same functions. In higher plants we have differentiation into root and shoot, the latter is composed of stem and leaves. It is with the external morphology of such plants that we will first deal, confining ourselves almost exclusively to the highest division of these plants, namely, ordinary Flowering Plants.

FIG. 5.—ULVA.

Distinction between the Root and Shoot.

The most essential difference between the root and the shoot is that, in nearly all cases, the shoot alone is concerned in the reproduction of the plant. Even when the root does, in very exceptional cases, perform this function, it has not specially adapted organs for this purpose.

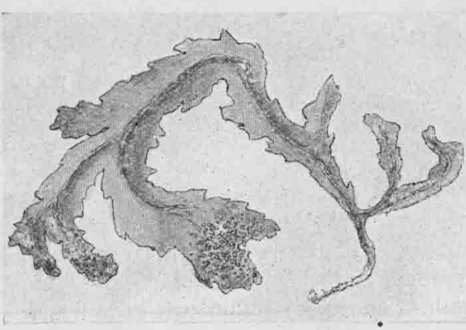

FIG. 6.—FUCUS. (REDUCED.)

In the shoot of the higher plants we find differentiation into stem and leaf. If the following points be borne in mind, there will be little difficulty in distinguishing the stem from the root:

Differences between Roots and Stems.

1. Both root and stem are generally branched—*i.e.*, produce plant members similar to themselves—but the stem bears, in addition, members unlike itself, which are known as leaves. A root never bears leaves.

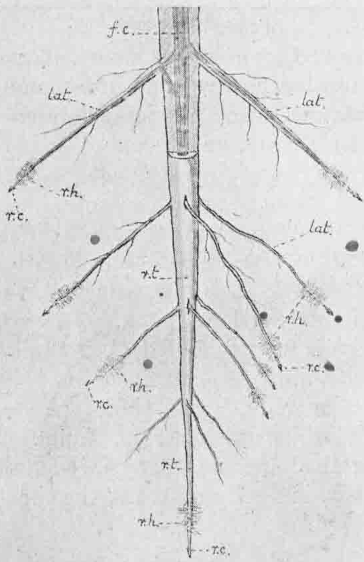

FIG. 7.—A ROOT SHOWING BRANCH ROOTS. (DIAGRAMMATIC.)

r.t, main root; *lat*, lateral roots; *r.h*, root hairs; *r.c*, root cap; *f.c*, firmer tissues.

2. The delicate growing parts of both roots and stems are the tips. In a stem the tip is conveniently protected by the young undeveloped leaves, which are here closely crowded together, forming a bud; in a root the tip has a corky protective covering, known as the "root cap." The root cap is constantly worn away as the root burrows its way into the ground, and is as constantly renewed.

3. The internal structure of the root of an ordinary land plant is generally quite different from that of the stem. The special peculiarities will be better understood after the histology of these structures has been studied, but on cutting the structure across, certain observations may be made with the naked eye. The root has its more rigid part at, or close to, the centre; its work is to keep the plant fixed in the ground, and this mode of construction enables it to resist a pull. The stem has to withstand a swaying movement; its firmer part is therefore nearer the outside, so that it cannot be so easily bent.

4. The branches in a root originate from a deeply-seated

tissue: they are described as arising *endogenously* (Gk. *endon*, within; *ginomai*, to grow). In a stem the branches arise from the superficial layers, that is, they arise *exogenously*.

Hairs and Emergences. Any of the above-mentioned plant members—viz., root, stem, or leaf—may bear outgrowths of lower morphological significance, which are known as "hairs." Hairs are outgrowths of the superficial layer only; outgrowths arising from deeper layers as well, such as prickles and hooks, are known as *emergences*.

These structures are distinguished from true plant members by the fact that they are not developed in regular order, and do not occupy the definite positions which, as we shall presently see, can be assigned to roots, stems, and leaves.

THE ROOT.

It has already been pointed out that every living organism is produced from the development of a single cell. For higher plants this cell is the "egg cell," which is found in the unripe seed. From this is produced the shoot and the root. By the time the seed is ripe, we have an embryo plant formed within it, of which the root portion is known as the *radicle*, and the shoot the *plumule*. On germination of the seed, the radicle grows out into the root of the plant.

FIG. 8.—ORCHID SHOWING AERIAL ROOTS.

Kinds of Roots. A root which is formed from the radicle or its branches is known as a *true* root, as distinguished from roots having any other origin, which are called *adventitious* roots. Adventitious roots are generally developed from stems, *e.g.*, from cuttings or bulbs; but occasionally they may be formed from leaves, *e.g.*, Begonia. They are often formed for special purposes, such as for climbing, *e.g.*, Ivy ; for reproduction, *e.g.*, those which spring from the stems of runners. Plants such as tropical Orchids, which grow seated on the branches of other plants, have special air roots, by the help of which they are able to take in the water vapour of the air (Fig. 8).

In the cultivation of Begonias, shoots and adventitious roots are induced to grow out of leaves which have been slit and laid on moist earth. Complete new plants are also produced from the fallen succulent leaves of the "Life" plant (*Bryophyllum*, Fig. 9).

The origin of adventitious roots, whether from stem or leaf,

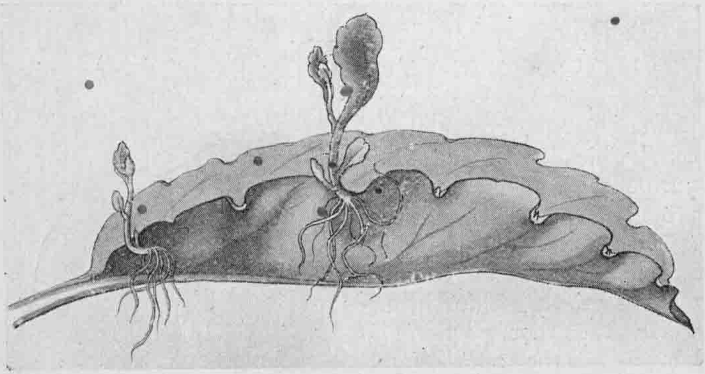

FIG. 9.—LEAF OF BRYOPHYLLUM PRODUCING YOUNG PLANTS.

is endogenous. Branch roots arise in what is known as acropetal, or progressive, succession, *i.e.*, the youngest is nearest the tip. They are arranged in vertical rows. In the figure of the germinating bean (Fig. 10) four such longitudinal rows of branch or lateral roots are seen.

Shapes of Roots. The original true root of a plant is known as the primary root, and in many cases it persists and remains more strongly developed than any of its branches, which are known as secondary, tertiary, etc. The plant is then said to have a *tap* root. The tap root may remain slender and elongated, or it may be short and stout. When it becomes much thickened it is called a *tuberous* root, and may

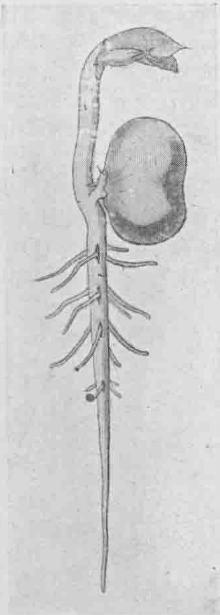

FIG. 10.—BEAN SEEDLING, SHOWING FOUR ROWS OF BRANCH ROOTS.

assume various characteristic shapes, *e.g.*, in carrot, where it is conical; in radish, where it is spindle-shaped, or fusiform. The shape of a turnip root is described as napiform (Lat., *napus*, a turnip).

When the plant has no main root, that is, the primary root is not more clearly marked than the roots of later origin, it is said to have a *fibrous* root. The parts of a fibrous root generally remain thin, but when they become thickened the root is said to be *tubercled* or *tuberculated*, *e.g.*, Dahlia, Lesser Celandine.

Small swellings are often found on the roots of such plants as clover, peas, and beans. By the aid of these the plant is enabled to obtain a very important food substance—nitrogen—more easily than most plants (see p. 158).

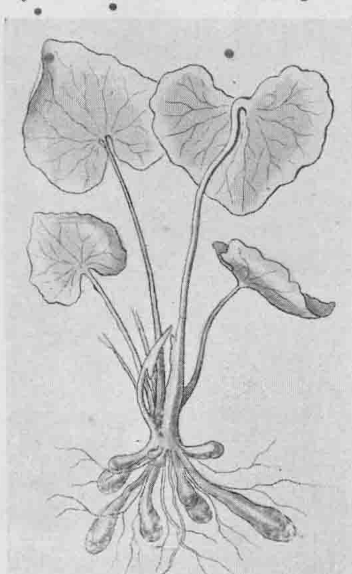

FIG. 11.—PLANT OF LESSER CELANDINE, SHOWING TUBERCLED ROOTS.

External Features of a Root In an ordinary land plant (Fig. 7) we notice at the tip of the main root and at the ends of its branches the root cap, which enables it to burrow its way into the soil. At a short distance from the tip are the *root hairs*, which are very important, as they are concerned in taking up water and food substances for the plant. The degree to which root hairs are developed depends on the difficulty of obtaining water: the drier the soil, the more abundantly will they be produced. The extremities of the root are whitish, but farther back it will be seen that the surface is brownish.

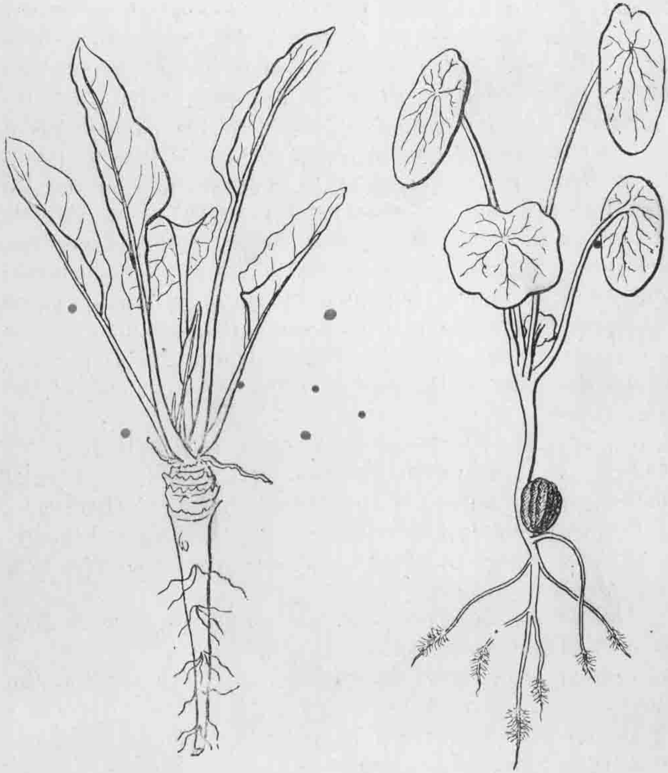

FIG. 12.—YOUNG PLANTS OF BEET AND OF NASTURTIUM, TO SHOW THAT THE LEAVES SLOPE INWARDS IN THE TAP-ROOTED AND OUTWARDS IN THE FIBROUS-ROOTED PLANT.

The darker colour is due to a covering of cork, which is protective, but which prevents the older parts from taking up water. Hence the whole work of absorption has to be performed by the root hairs and the younger parts.

Of great interest are the arrangements exhibited by plants in order that all the water which falls on the plant surface should be poured out on the ground just over the root hairs. In tap-rooted plants the watershed is towards the centre of the plant, and in fibrous-rooted plants towards the outside. In a forest tree the roots will be found to extend under the ground to the same distance as the branches spread out above ground. The leaves are so arranged that water runs from leaf to leaf until the outermost leaves of the crown are reached; thus almost the whole of the water which has fallen on the crown is deposited on the ground just over the root hairs, near the tips of the spreading roots. Almost any plant will be found on examination to exhibit some wonderful device for directing its water supply to the most suitable spots. Leaf-stalks and stems often have a series of grooves, which form a regular system of "water gutters." Sometimes the direction of flow is regulated by ridges of hairs, *e.g.*, in Chickweed. Observations in connection with this point can be easily made by the student. Fig. 12 shows the connection between the form of the root and the arrrangement of the leaves.

Functions of the Root. The functions of the root will be fully discussed in the Physiology section of this book; its internal structure, which adapts it to these functions, in the Histology; and its special adaptations to its environment in the Ecology. The threefold function of this plant member, therefore, will be but briefly stated here.

1. The root is concerned with the taking in of water and food substances from the ground.

2. It is concerned with the attachment of the plant to the ground.

3. In some cases, where it is specially thickened, it is concerned with storage of food reserves.

Duration. In connection with the last point enumerated, we may notice that this thickening takes place remarkably in plants known as "biennials," *e.g.*, carrot, turnip. These, in the first year of their growth, produce a tuft of green leaves, and by their activity make food, which is stored in the thickened root until the next year. Blossoming and seed production, which take place in the second year, depend largely on this food supply. When it is used