

POPULAR BOTANY

A. E. KNIGHT AND EDWARD STEP



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THE LIVING PLANT FROM SEED TO FRUIT





[By Sir H. H. Johnston, G.C.M.G.]

A BEAUTIFUL UGANDA FLOWER (*SPATHODEA NILOTICA*).

This *Spathodea* is a tree in the forests of Uganda, and of the equatorial province of the Egyptian Sudan and the northern part of the Congo basin. An allied form is found in Western Equatorial Africa. The flowers, which grow in bunches, are individually shaped like a Roman lamp; and when the tree is in full blossom it looks as though decorated with flaming lamps.

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THE LIVING PLANT FROM SEED TO FRUIT



BY
A. E. KNIGHT
AND
EDWARD STEP, F.L.S.

VOLUME I
WITH
721 BEAUTIFUL ILLUSTRATIONS
AND
18 COLORED PLATES



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[E. Step.

FIG. 1.—JESSAMINE (*Jasminum officinale*).

INTRODUCTION

OUR delightful poet Cowley, in one of the choicest of his essays, tells of the desire he always had to be "master of a small house and garden, with very moderate conveniences joined to them," in order that he might dedicate the remainder of his life "only to the culture of them and the study of Nature."

We can all understand this satisfaction and delight in Nature; yet many, perhaps, while confessing to a sincere admiration for all that is beautiful, would shrink from the study of Botany, and look upon it, maybe, as a dull science, occupied only with desiccations and dissections, and the endless acquisition of names. To such persons a



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FIG. 2.—DOG-ROSE (*Rosa canina*).

A typical representative of a great family which provides us with the most important of our fruit trees, as well as some of our finest flowers.

botanist is a dry-as-dust gentleman, after the pattern of the meagre philomath in Miss Kendall's *Dreams to Sell*, who saw in Nature a soulless something, without beauty and without sentiment:—

He loved peculiar plants and rare
 For *any* plant he did not care
 That he had seen before :
 Primroses by the river's brim
 Dicotyledons were to him,
 And they were nothing more.



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[E. Step.

FIG. 3.—LICHENS ON AN OLD WALL.

Lichens are independent of the soil, and obtain their nutriment entirely from the air. They therefore grow upon bare rocks, tree bark, and walls, drying up in the summer but reviving in the autumn.

Professor Dawson is, we believe, responsible for the saying: "I hate Theology and Botany, but I love religion and flowers"; and if by the term Botany the professor meant only those dry-as-dust expositions of the science which some of us know so well, then we are quite at one with him. But it would seem that the professor's antipathy is to the science itself, as opposed to the more æsthetic study of Nature; and here his laconicism may prove misleading. "You study Nature in the house" (*i.e.* in dried specimens), wrote Professor Agassiz, "and when you go out of doors you cannot find her"—suggestive words, that unlock the secret of many a wearying failure.

Dr. Lindley well observes on this point: "Only to apply their names to



Photo by]

[G. R. Ballance.

FIG. 4.—EDELWEISS (*Leontopodium alpinum*).

A Composite plant whose flowers are not in themselves conspicuous, but are rendered so by the long woolly bracts which set them off. It is now only to be found on points of the European Alps difficult of access. Very slightly enlarged.

a few plants is a poor insipid study, scarcely worth the following; but to know the hidden structure of such curious objects, to be acquainted with the singular manner in which the various actions of their lives are performed, and to learn by what certain signs their relationship—for they have their relations like ourselves—is indicated, is surely among the most rational and pleasing of pursuits." Depend upon it, therefore, if the study of Botany has become to any one a dead letter instead of a living word, it is because it has been pursued apart from Nature, and hence the great purpose of the science has never been truly grasped.



Photo by]

[E. J. Wallis.

FIG. 5.—HUNTSMAN'S HORN PITCHER-PLANT
(*Sarracenia flava*).

The long pitchers contain a liquid in which insects are drowned, their bodies serving for the sustenance of the Plant. NORTH AMERICA.

The truth is there are botanists and botanists. There are some who have an intimate acquaintance with all the plants of their neighbourhood—know them at sight, and can name them correctly when they are in flower. They know them indeed as flowers, but beyond the identification can tell you little about them. They delight in the beauty and fragrance of the blossoms, and probably regard them in the good old-fashioned orthodox way, as created merely to gratify the eye and the æsthetic sense of man. There are others, with the collecting mania strong upon them, whose chief interest in the plants of a new locality is to discover how many blanks in their herbarium they can fill up. This kind of botanist may know all about names and localities and

the comparative rarity of his spoils, but probably little about the living plant. Another type is the botanist of the schools, who knows all the most advanced theories of plant physiology and tissues, but will probably fail in the field to identify correctly the commonest weeds. And then there are the specialists and splitters, the men who have an exhaustive knowledge



Photo by]

[S. L. Bastin.

FIG. 6.—BIRTHWORT (*Aristolochia gigas*).

Insects attracted by the carrion-like odour enter the flower and are kept prisoners for hours in order to effect the fertilization of the incipient seeds. GUATEMALA.

upon this living plant all other life depends entirely; even the entire human race with all its achievements and glorious history has been, and is, indebted for its existence upon the living plant.

The plant provides us with everything we really need, makes the earth habitable, makes the air breathable and the water drinkable; supplies us with food—not merely the food of the vegetarian, but of the flesh-eater also. If there were no other reasons why man should concern himself with an intimate knowledge of the living plant—what it is, what it accomplishes for the world, and how it does it—this one fact should suffice; and it is our justifica-

tion of one group—or even one species, as commonly understood; their knowledge is very deep, but often very narrow. Lastly, there is the all-round botanist of wider sympathies, who, although his knowledge may not go so deeply as that of the specialist's, probably gets more wholesome satisfaction out of it, because he sees vegetation more as a whole, and realizes how it fits in with the general scheme of things on this planet—its connections with soil and climate, with insect, bird, and beast, and with man himself. He may realize what the others are not likely to do, that this living plant has habits, likes and dislikes, and little ways of its own just as surely as every animal has. To him the truth may be patent that



Photo by]

[H. E. Hill.

FIG. 7.—FLOWERS OF BANANA (*Musa paradisiaca*).

The beginnings of the familiar fruit. TROPICS.

tion for placing before readers this elementary and necessarily superficial statement of what the living plant is, what it does for us, and how it accomplishes its good work.

Where does the living plant obtain all the material that feeds and clothes the innumerable forms of animal life, and finally the hundreds of millions of the human race? The answer is, mainly from the atmosphere, partly from the sunbeams, and a little from the earth. Collect a large heap of vegetation, and burn it. You will find that all there is left is a thin layer of fine ash, the mineral portion of the plant's materials. The rest has passed off into the atmosphere from which it was derived.



Photo by

[F. C. White Co.

FIG. 8.—ROOTS OF PINE-TREES.

Denuded of soil by a flood. One of the many exigencies to which the living plant is subject. JAPAN.

Every blade of grass, every tiniest moss, as well as the more noticeable trees and larger herbs, are doing this work for the animal kingdom; and there is scarcely an inch of the natural surface of the globe that is not occupied by one or other of the vast variety of living plants that have adapted themselves for life in all situations and under all conditions. It has been computed that no fewer than two hundred thousand distinct species of the living plant are known to and have been described and named by man, and it may be taken that

all these forms are necessary, in order that full advantage should be taken of all the varying conditions under which life is at all possible. A little warmth, a little moisture, and a little light are the minima of the living plant's demands. At the other end of the scale they may be found in the parched desert, where they must endure extreme heat, extreme light, and almost an absence of moisture. They put in an appearance on the scarcely cooled cinders from the latest volcanic eruption, and thrive in the waters of hot springs having a temperature of 176° F.

For all these varied conditions a corresponding variety of form and habit



Photo by]

FIG. 9.—AMERICAN LAUREL (*Kalmia latifolia*).

[Henry Troth.

Also known as Mountain Laurel and Calico Bush. A beautiful shrub allied to the Rhododendron, with white or rosy flowers an inch across. The stamens are held in little pockets until a bee visits the flower in quest of nectar, when they spring up with force and cover the bee with pollen. NORTH AMERICA.

is necessary, and we find, therefore, the living plant conforming to a number of principal types, and under these principal types almost endless differences in detail. In the waters and on the damp rocks we have the primitive plants of a single cell; where there is the thinnest coating of soil, the moss; where there is a thicker layer of *humus*, formed from the decay of other vegetation, the ferns; and where there are corresponding depths of permeable soil, the flowering herbs, the shrubs, and the majestic trees. Then, to utilize and make further utilizable the decayed and worn-out parts of the green plants, we have the fungus tribe, unable to produce for themselves from the elements, but living as *saprophytes* on dead matter, and some of them as *parasites* upon the living.



Photo by]

[H. J. Shepstone.

FIG. 10.—ELK'S-HORN FERN (*Platyserium grande*).
One of the grandest of the ferns, with fronds five or six feet in length. It grows on the trunks or branches of trees. NORTHERN AUSTRALIA and ASIA.

Now, to an author it is, of course, impossible to take his readers out of doors; but we trust that long before the last page of this work has been reached we shall have fulfilled the humbler task of awakening an interest in the subject that shall compel the reader to go forth and make that closer acquaintance for himself.

It may be added that the study of Botany has special advantages over almost all other sciences, inasmuch as it is concerned with objects which are found in every region of the globe. It is a study which relieves the monotony of town life, and adds interest to every walk in the country. It proposes nothing that could cause distress to a sensitive mind. It quickens the observing powers of the mind; the habits of accuracy and caution, so needful

in every walk of life, grow out of the practice of putting Nature to the question. Best of all, no one is excluded from the study: the poor are as free to pursue it as the rich.



[Photo by]

[F. Steg.]

FIG. 11.—GRAINS OF BARLEY GERMINATING IN THE EAR.

In wet seasons, when harvesting has to be postponed, the ripe corn will germinate in the ear and ruin the crop. Long roots are formed which make towards the earth.

POPULAR BOTANY

THE LIVING PLANT FROM SEED TO FRUIT

CHAPTER I

THE PROTOPLAST

IT is perhaps superfluous to observe that no links have yet been found between living and not living, between organic and inorganic matter, and therefore between plants and minerals. The doctrine of *spontaneous generation*, by which it has been attempted to supply such a link, is based upon assumption and not ascertained facts. The most powerful plea that can be urged for the doctrine is its antiquity. The ancients had their theory of spontaneous generation; though the ancients were not always right. It was Aristotle's belief and teaching that frogs and snakes sprang from mud and slime; and readers of Virgil (*Georg.* IV. 330-65) will recollect the poet's recipe for raising a swarm of bees from the putrefying corpse of a two-year-old bullock, by strewing broken boughs and flowers of thyme and cassia under the corpse. We must



FIG. 12.—BARLEY (*Hordeum*).

Unripe and ripe flower-spikes. To the left are two detached flowers (spikelets) with extended glumes. Below them is a barley-corn, and to the right of it a fully expanded flower showing the male and female parts. Between the spikes are shown barley-corns in process of germination.

confess that our faith in the philosopher's opinion, no less than in the virtue of the poet's recipe, is somewhat weak. Observation teaches that Life, which distinguishes the Mineral from the Vegetable and Animal Kingdoms, does not spring up spontaneously. The *principle* of Life must be there first, under whatever conditions; and hence it is safe to affirm that the doctrine of "Life from Life," or *biogenesis*, is the true doctrine.

"Dead matter," said Lord Kelvin before the British Association some years ago, "cannot become living matter without coming under the influence of matter previously alive. This seems to me as sure a teaching of science as the law of gravitation. I am ready to adopt as an article of scientific faith, true through all space and through all time, that Life proceeds from Life and nothing but Life."

The German botanist Schleiden, taking the crystal as the type of the most perfect form of inorganic body, thus beautifully contrasts it with a living organism, the Barley-plant (see fig. 12). "The crystal does not spring at once a perfect Minerva from the hand of Jupiter; the matter of which it is formed undergoes a constant series of changes, the final result of which is the completed shape of the crystal. The crystal, too, has an individual history, a biography, but only a history of its *becoming*, its origination. . . . Plants and animals form the most distinct contrasts to this, and herein lies



FIG. 13.—A BOGUS PLANT—THE WALKING-LEAF INSECT.

An example of protective resemblance to vegetable forms.

that common nature, which induces us to comprehend them in one conception, as organic or living existence. . . . In spring we commit the barley-corn to its nurse, the earth; the germ begins to move, starts from its envelopes, which fall to decay. One leaf after another appears and unfolds itself; then the flowers display themselves in a thickly crowded spike. Called forth through wonderful metamorphoses, in each originates the germ



Photo by]

[E. Step-

FIG. 14.—BEE ORCHIS (*Ophrys apifera*).

A good example of the way in which some plants mimic animal forms. In this case the reason for the resemblance to a bee is by no means clear. EUROPE and NORTH AFRICA.



FIG. 15.—THE LEAF BUTTERFLY (*Kallima*).
When this butterfly settles upon a twig and closes its wings together, it resembles a leaf.



Photo by]

[S. L. Bastin.

FIG. 16.—A SOUTH AFRICAN PLANT (*Mesembryanthemum truncatum*).

This plant resembles a pebble. It is photographed in the midst of five real pebbles to make the likeness clear.

of a new life; and while this with its envelopes becomes perfected into a seed, constant changes in the plant, from below upwards, are in progress. One leaf after another dies and withers. At last only the dry and naked straw-haulm stands there. Bowed down by the burden of the golden gift of Ceres, it breaks up and rots upon the earth, while within the scattered germ, lightly and snugly covered by protecting snow, a new period of development is preparing, which, beginning in the following spring, continues on the unceasing repetition of these processes. Here there is nothing firm, nothing consistent; an endless becoming and unfolding, and a continual death and destruction, side by side and intergrafted. Such is the Plant! It has a history, not only of its *formation*, but also of its *existence*; not merely of its *origin*, but of its *persistence*. We speak of plants; where are they? When is a plant perfect, complete, so that we may snatch it out of the continual change of matter and form, and examine it as a thing *become*? We speak of shapes and forms; where shall we grasp them, disappearing Proteus-like every moment and transformed beneath our hands? . . . In every moment is the Plant the ruin of the past, and yet, at the same time, the potentially and actually developing germ of the future; still

more, it also appears a perfect, complete, and finished product for the present" (*The Plant*).

Matter, indeed, is too coarse and low a thing to imprison life. Life uses up the virtue out of matter, and when for a space it looks as if the matter lived, it is only for a little time, and the Life passes on to use up fresh material. The former living plant or animal, as we saw it, decays away: but the Life has not decayed: it has changed its place, and has made a step in its mysterious and immeasurable cycle—



Photo by]

FIG. 17.—VEGETABLE SHEEP (*Raoulia eximia*).

[E. J. Wallis.

A Composite plant that grows on exposed hillsides, its tough stems and tiny flowers packed in a compact mass like a great cushion of moss to resist the elements. It is often mistaken at a little distance for a sheep. A native of NEW ZEALAND.

always unseen, unmeasured, and untouched. How different from the inorganic crystal, which knows nothing of this ceaseless change and progression; which has no life-history to offer; which, in fact, has never been alive!

Wide, then, is the chasm, and very definite the line of demarcation, between organic and inorganic bodies—between the Plant, which has Life, and the Mineral, which is lifeless. Biology, indeed, which is the science of life, concerns only the Animal and Vegetable Kingdoms—it has no connection with the Mineral world. Botany and Zoology, the sciences

that deal respectively with plants and animals, are its two main sub-divisions; and Mineralogy is of necessity excluded. Of course it is only with the first of these sub-divisions that we have to do: the subject before us is Botany, not Zoology. The word "Botany," we may remark in passing, is a Greek word, meaning any kind of grass or herb, and *botanike*, in the same language, signifies the art which teaches the nature and uses of plants. The dry look is sometimes taken off a subject when the meaning of its Greek or Latin name is explained.

That any difficulty should be found in distinguishing plants from animals might at first occasion some surprise. A cow is not mistaken for a cucumber, nor an oyster for a water-lily; and even when we take objects externally



Photo by]

[S. L. Bastin.

FIG. 18.—AN AUSTRALIAN PITCHER-PLANT (*Cephalotus follicularis*).

An example of a numerous class of plants that, growing in poor watery soil, are compelled to get their food by trapping and digesting insects. WESTERN AUSTRALIA.

so much alike as a walking-leaf insect or the leaf butterfly and the leaf it mimics (figs. 13 and 15), very little examination is needed to convince us how essentially different they are. Many persons have been deceived by the interesting *Haastias* and *Raoulias* of New Zealand (fig. 17), curious plants allied to *Gnaphalium*, which form masses on the bare mountain tops so closely resembling sheep at a very short distance that the most experienced shepherds are often deceived by their appearance. Some species of *Mesembryanthemum* closely resemble pebbles, as may be seen by our photograph of a plant surrounded by real pebbles (fig. 16). Here also, however, the deception vanishes on a closer inspection; and the same thing may be said of many orchideous flowers, whose remarkable resemblances to objects in the sister kingdom have been often dwelt upon—as, for example, the Bee Orchis (fig. 14). Nevertheless, in other cases real difficulties



Photo by]

[Henry Troth.

FIG. 19.—A PITCHER-PLANT (*Sarracenia purpurea*).

It lives partly on insects, which it traps and kills, and from their bodies it extracts the juices that are necessary for its own growth. NORTH AMERICA.

of distinction exist; and to prepare a definition either of an animal or a plant, which shall be at once sufficiently full and sufficiently exclusive, is in the present state of our knowledge impossible. Probably, indeed, the line of demarcation between the simpler forms of the two kingdoms will never be absolutely determined.

Three important characteristics may, however, be said to distinguish the *higher* animals—viz., the power of locomotion, evident sensitiveness, and the possession of a special digestive cavity for receiving solid food; just as the absence of these characteristics will be found to distinguish the higher plants; though even here exceptions are not wanting. Thus, among

the higher animals the oyster lacks the power of locomotion, and the tape-worm has neither sensitiveness nor a special digestive cavity; while among the higher plants we find a power of locomotion in the spermatozoids of Ferns, extreme sensitiveness in the Mimosas, and "a kind of external stomach which digests solid food" in the Pitcher-plants (figs. 18 and 19). The proposal gravely made by a French savant to define an animal as *un estomac servi par des organes* is, therefore, not to be thought of; and the inadequacy of the definition is more plainly seen when we descend to the lower forms of life. Here, not only are locomotion and apparent sensitiveness common among the simpler water-plants, as *Sphaerella*

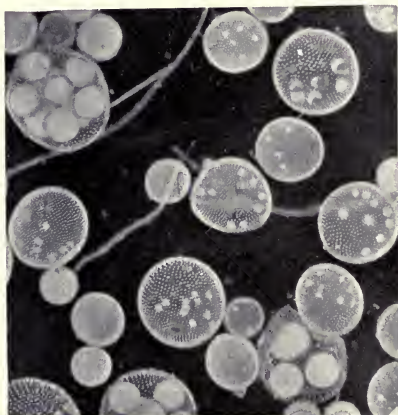


Photo by]

[A. Leal.

FIG. 20.—THE REVOLVING GLOBE
(*Volvox globator*).

Variously regarded as a plant and a simple animal. About fifty of them in a row would measure one inch.

*pluvialis** and *Volvox globator* (fig. 20), but the absence of a digestive cavity is the rule rather than the exception in the lower animalculæ (*Protozoa*), of which the *Amœba* and its immediate allies furnish good illustrations. Indeed, we must ascend the zoonic scale as high as *Vorticella*, the curious little Bell-animalcule (fig. 23), before we meet with even the rudiments of a digestive apparatus.

Now, any one who would understand the complex forms of Life, whether in the Animal or Vegetable world, does well to begin low down in the scale by studying Life in its simplest forms; and *unicellular*, or one-celled, plants supply excellent examples for the purpose. Allusion was made a moment ago to *Sphaerella pluvialis*, one of the simplest forms of vegetable

* *Protococcus viridis* of Thomé; *Hæmatococcus pluvialis* of Flotow, Prantl, and Vines.

life; a microscopic water-plant often to be met with in rain-water cisterns, or as green and reddish incrustations in damp places. *Sphaerella* (fig. 24) is a plant of a single cell; and as we desire to speak a little of the life-history of a single cell, it may be well to take a nearer view of this tiny organism.

If you take some rain-water from a cistern into which the sun has been shining for a few hours, and examine a drop of it under the microscope, you will probably find that it is teeming with life. Minute pear-shaped bodies of a green colour swim rapidly about (fig. 24), propelling themselves along by delicate filaments of a transparent substance, which branch out, two on each individual, from a tiny red spot (termed the *eye-spot*), which might at first be thought to be a head. The movement is due to the alternate shortening and lengthening of these filaments or *flagella*, which are so fine and transparent, and lash the water so rapidly as to be scarcely visible. By-and-by the movement becomes slower, and ceases; the flagella disappear; the green bodies, as though ashamed of swimming about in their nakedness so long, form little jackets for themselves of a substance hereafter to be described, and sink to the bottom of the water, where they enter upon a new stage of existence.

The active, *motile* stage is at an end; the giddy childhood time is passed; an autumnal red has blended with the fresh green hue of youth (for the spent swimmers have partially changed their colour); and the adult or *stationary* stage has commenced. You continue to watch one of these quiescent bodies. It has lost its pear shape now, and has grown larger. Presently a process of rearrangement is seen to be going on inside the little membranous sack.

The contents divide into two portions, each of which again divides: and with that there is a fresh formation of protective membrane, for each of the four bodies must have its own cellulose investment, and—note this well!—each weaves its own. And now we have no

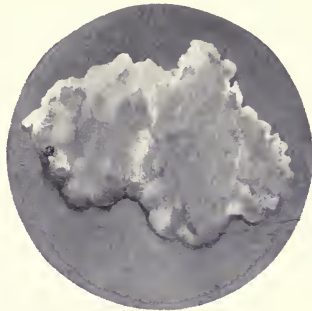


FIG. 21.—PROTOPLASM.
A speck of the simplest form of living matter.
Much magnified.



FIG. 22.—AMOEBA.
A. One of the simplest forms of animal life. B. The same capturing an *Actinophrys*. Magnified about 80 times.

longer one quiescent body, but four; so that when the outer investing sack in which they are all contained gives way, they emerge as perfect individuals. Each will have its own independent history ere long—perhaps a very different history from that of the parent body: for from each may issue, not fully clothed individuals like themselves, but naked, motile bodies, like those from which the parent was evolved, with pear-shaped forms, and scarlet eye-spots, and delicate filaments that possess the power of contraction. Thus the round of life goes on.

But let us pause and ask, What are these changeful little bodies—



FIG. 23.—BELL-ANIMALCULE (*Vorticella*).

A microscopic animal belonging to the Protozoa, but plant-like in appearance. Much magnified.

these minute organisms, so simple and yet so wonderful? To which of the two great realms of living Nature do they belong? Are they animalculæ, or plants? "Surely," it might be urged, "they belong to the Animal Kingdom—the little motile bodies tell us that." Yet the fact is otherwise. Those tiny organisms are plants, true plants, and their names must not be sought for in any zoological catalogue. Their habits are, indeed, strikingly similar in some respects to those of many minute animals (*Vorticella microstoma*, for example); yet are they true plants; and the active little bodies, with red eye-spots and antennæ-like prolongations, are neither more nor less than the motile cells or zoospores of our single-celled plant, *Sphærella phuvialis*.

Yes, plants; and each individual is a single cell, though it is only after it acquires its coat of cellulose that it becomes a cell in the common acceptance of the word. It is an *unicellular* plant, and so is distinguished from the great mass of plants, which are *multicellular*, or made up of many cells. And thus we are brought to a very interesting truth, and one of vast importance to the student of Botany—viz., that *every* plant in the wide world, from the highest to the lowest, consists either of a cell or cells. We shall see farther on that the living matter (or *protoplasm*, as it is called) is the essential part of the cell; indeed, there is evidence of this in the active spores of *Sphærella*, which, prior to the formation

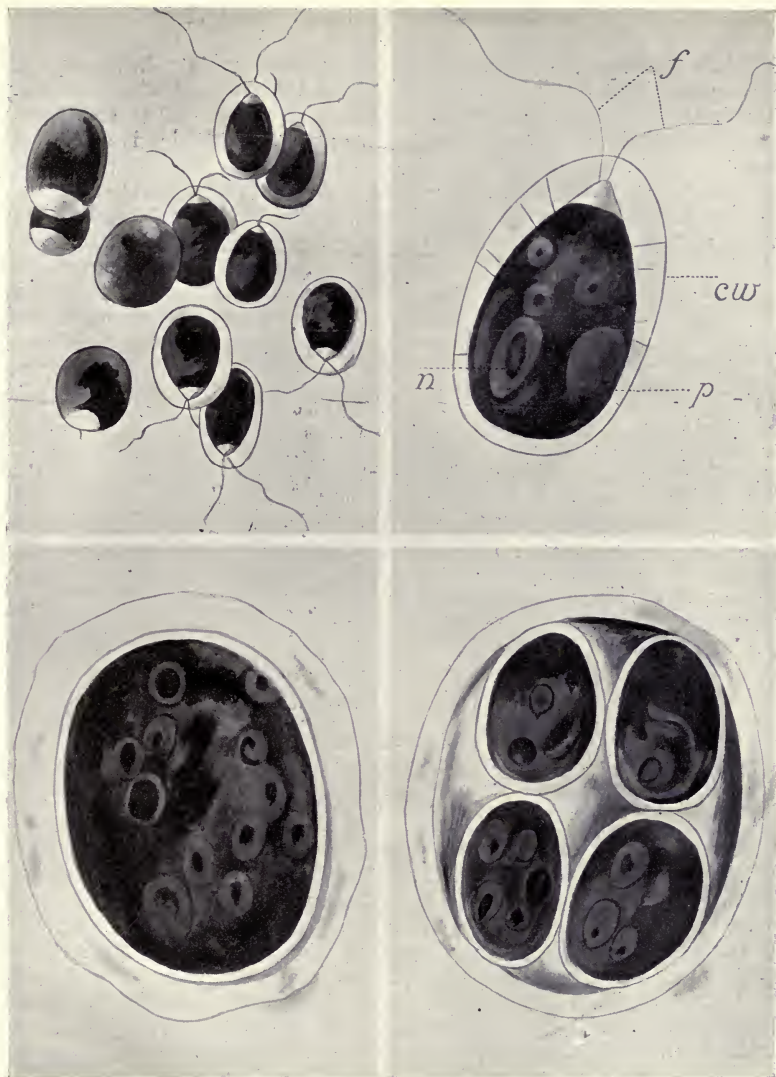


FIG. 24.—A PLANT OF A SINGLE CELL (*Sphaerella pluvialis*).

In the upper left-hand corner are seen the plants in the motile stage. To the right one more highly magnified and showing the cell-wall (*cw*), protoplasm (*p*), nucleus (*n*), and flagella (*f*), arising from the clear part of the protoplasm and piercing the cell-wall. Below to the left is a plant that has passed into the still condition: and beside it one that has divided into four within the cell-wall.

of their coats (properly, *walls*) of cellulose, were simply naked masses of protoplasm. In many-celled plants, where cell-walls are *always* formed, the protoplasm may be used up in the thickening of the wall or transferred to other parts of the plant; but in such cases what remains is still called a *cell*.

The term *cell* appears to have been first used in a botanical connection by the English microscopist, Robert Hooke. Writing in 1665, he says: "Our microscope informs us that the substance of cork is altogether filled with air, and that that air is perfectly enclosed in little boxes or cells, distinct from one another." At that time, and for many years after, the "little boxes" were considered the essential part of the plant; indeed,



FIG. 25. BACILLI: SINGLE-CELLED FUNGI. FIG. 26.



These microscopic plants belong to the division known as Schizomycetes or "Fission" Fungi, from their habit of increasing their numbers by dividing into two. The first is the Comma Bacillus, which produces Asiatic cholera. The second is the Bacillus of Bubonic Plague. Its long appendages are the flagella by which movement is effected. Highly magnified.

it was not till the last century, when Schleiden, Schwann, and Mohl in Germany, and Lionel Beale in our own country, proceeded to *look into the little boxes*, that the maintenance of a contrary view became possible. Then began, indeed, the study of Biology, the greatest though youngest of the sciences, which has grown to such wonderful proportions in recent years, though it must still be regarded as almost in its infancy.

Until the discovery was made that the protoplasm is the essential constituent of the cell, our knowledge in vegetable physiology could make but slow advances, and a great mass of facts connected with the anatomical structure of plants which the microscope had brought to light, though interesting in a general way, could have but little scientific value. There was much, for instance, to gratify one's taste for the marvellous in the statement that the surface of a square inch of cork



FIG. 27.—FRUIT OF THE COTTON-PLANT
(*Gossypium*).

Each of the soft hairs of the cotton is a single cell.

recognise as *suberin* or cork, till the "little box" was almost filled up—when these facts were added, it may be said that our knowledge had indeed made great advances.

As allusion has been made to the wonderful minuteness of the cells of cork (fig. 30), it may not be out of place to add a few remarks on the comparative sizes of cells, before we pass on to the consideration of living matter or protoplasm. All cells, with but few exceptions, are microscopically small; mere specks, indeed, and quite invisible to the naked eye. If the task were proposed to us of counting the honeycomb-like partitions in a thin section of the stem of a lily, or the twig of an apple-tree, or a shred of cucumber, or the petal of a rose—and these delicate partitions are so many cells—we should certainly beg to be excused; for the microscope reveals the fact that they are of such minuteness that many thousands might lie, side by side and end to end, on

contains more than a million cells, and that there are one billion two hundred million in a cubic inch; but the statement by itself has little or no value from a scientific point of view. When, however, we are told (what neither Hooke nor Leuwenhoek, nor any of the older microscopists could have told us) that each of these one billion two hundred million cells originated in a tiny speck of protoplasm, which, after forming for itself—aye, and *from* itself—as our little zoospore had done, a delicate cell-wall, finer a thousand times than the finest gossamer, had proceeded to spread upon the interior of that cell-wall layer after layer of a new substance, which we re-



FIG. 28.—*Vaucheria clavata*.

A plant of a single cell, which is drawn out into a tubular form.

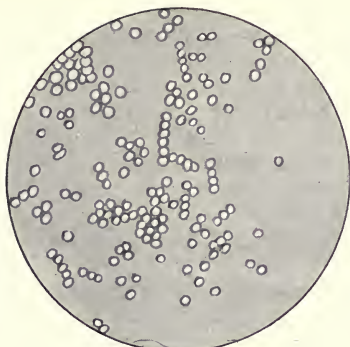


FIG. 29.—“BLOOD PORTENT” (*Micrococcus prodigiosus*).

A microscopic plant of a single cell, which averages about one-16000th of an inch across. One of the Bacteria.

visible under the microscope are the unicellular *Micrococci* (a genus of the Schizomycetes or “fission Fungi”*)—spherical plants whose diameters



FIG 30.—CORK CELLS.

The separate cells may be seen easily in this photo, but they are shown 125 times larger than the natural size.

a surface no larger than one's thumb-nail. As a rule, indeed, the cells of all Flowering Plants are extremely small, though certain organs may offer remarkable exceptions. Thus the loose cells (pollen-grains) contained in what are known as the anther-lobes of flowers are occasionally of an unusual size, some measuring $\frac{1}{16}$ th of an inch in diameter; though it should be added, as a matter of comparatively recent discovery, that the pollen-grains of a large number of plants are now known to be many-celled. In any case, the size given is exceptional, and frequently the grains do not exceed $\frac{1}{200}$ th of an inch.

Some of the tiniest organisms are the *Micrococci* (a genus of the Schizomycetes or “fission Fungi”*)—spherical plants whose diameters vary from $\frac{1}{25000}$ th to $\frac{1}{12500}$ th of an inch (fig. 29); and along with these may be placed those scarlet river-plants (allied, doubtless, to our rain-water *Sphaerella*), many millions of which, as Freycinet and Turrel tell us, might swim without discomfiture in a drop of water! The Schizomycetes form an interesting group, for they include the *Bacteria*, *Bacilli*, and other formidable organisms, to which many of the deadliest diseases are known to be due.† The microscope has revealed no minuter organisms than these. Countless thousands of the dreaded *Kitasato* bacillus (fig. 26), which is parasitic in the human body and

* So called because they multiply by a simple division of the body.

† *Bacillus anthracis* is the probable cause of anthrax in cattle, etc.; *B. tuberculosis* of consumption; *Spirochete cholerae asiaticae* of Asiatic cholera (fig. 25); and various other species of bacteria are associated with leprosy, relapsing typhus, footrot, etc.



Photo by]

FIG. 31.—A SLIME-FUNGUS (*Stemonitis fusca*).

[E. Step.

The plasmodium stage, in which thousands of swarm-spores have united into a creamy mass which moves with a rolling motion prior to forming into sporangia. Natural size.



Photo by]

FIG. 32.—A SLIME-FUNGUS (*Comatricha obtusata*).

[E. Step.

The ultimate stage (*sporangia*) of the remarkable organisms which are variously considered to be animals and plants, are shown like pins sticking in the piece of rotten wood. Natural size.

causes bubonic plague, could, it is said, find lodgment on a needle's point; while their rate of multiplication is so extraordinary that *many millions of millions* may be produced from a single individual in a few hours! It is estimated that one cubic inch of good soil will contain something between fifty millions and four hundred millions of Bacteria, and many of them are of the greatest value to the husbandman. Surely we are here approaching the Infinite!

In contrast to the Schizomycetes may be mentioned the *Nitella*, an interesting fresh-water plant, which has cylindrical cells that measure



Photo by]

FIG. 33.—A SLIME-FUNGUS (*Lycogala miniata*).

[E. Step.

This is one of the largest of those members of the group that have separate sporangia (in others many sporangia are combined to form cake- or cushion-like masses called *athalia*). They are pink in colour, and are here shown of the natural size.

nearly two inches in length and $\frac{1}{2}$ th of an inch in breadth; or such one-celled plants as the *Vaucheria** (fig. 28) and *Siphonoclada*, where the individual consists of a remarkable branched cell, greatly in excess of this. Each of the soft hairs which cover the seed of the Cotton-plant (fig. 27), and which are spun into cotton; is in reality a long cell. This may be readily seen by unravelling a thread of reel-cotton and placing it under the microscope.

* *Vaucheria* is a fresh-water alga. Perhaps it is hardly fair to compare the branched multinucleate body of *Vaucheria* with a simple cell.

In commencing the study of cells an excellent object for microscopic examination is the thin skin which covers the inside of the fleshy scales of the common onion. The object depicted in fig. 35 consists of a small fragment of this delicate membrane, mounted in balsam. Observe that it is made up of a number of hexagonal or six-sided figures, on the interior of which is an irregular granular substance. Each of these hexagons represents a perfect cell; its sides are cell-walls, and the granular matter in each is *protoplasm*.

Protoplasm in its natural state is colourless and transparent—so transparent as only to be distinguished with difficulty under the microscope. To make it more apparent the specimen is soaked in iodine solution, which has the effect of staining living protoplasm brown, while it tinges with pale yellow the lifeless walls of cellulose. The pale yellow is hardly noticeable by lamp-light; but if a drop of strong sulphuric acid is run under the cover-glass at the time of preparing the slide, the cell-walls become coloured blue. It is by the use of these and other reagents that the organic elements of cells and tissues are distinguished. The word “protoplasm” appears to have been first used by Purkinje* in 1840, to denote the formative substance of the animal embryo, which he compared with the soft cellular tissue (cambium) between the wood and the bark of trees. Mohl, a few years later (1846), applied the term to the contents of the vegetable cell.

It will be noticed that the protoplasm of each of the onion cells contains a small spherical or oval mass, which takes a darker brown than the surrounding matter when treated with iodine. The darker colour is due to the greater density of the protoplasm at these points; and these denser portions envelope a sort of kernel—the *nucleus* (Lat. *nux*, a nut or kernel),

* The substance itself was first noticed and described by Roesel v. Rosenhof in his account of the Proteus-animalcule, and was named *sarcoda* by Dujardin in 1835.



FIG. 34.—BEADED HAIRS OF VIRGINIAN SPIDERWORT (*Tradescantia*).

Showing the rotation of the protoplasm in their cells. Each swollen part in the stream of protoplasm denotes a nucleus. Greatly magnified.

which consists of a net-work of threads (or *fibrillæ*), embedded in a semi-fluid substance known as *nucleoplasm*. The nucleus is not, however, a necessary element; protoplasm may live, and move, and do work when no nuclei are present.

Once these cells were living cells—not, indeed, alive in every part, for that could be said of nothing that lives; but they were living cells. Each cell was a life-unit, for the mysterious principle of Life was in each; and the protoplasmic contents of the cell, *not the cell-walls*, constituted the life-matter. Out of this apparently structureless matter the cell-walls were formed, much as were the cellulose coats of our self-dividing *Sphaerella*; for in each case the protoplasm was the vital, active, formative element of the cell. Did, then, these cell-walls cease to grow when once they had been formed?

By no means. Yet their growth was due, not to any principle of Life within themselves, but to the introduction of fresh particles of cellulose among those already existing. And these fresh particles were formed and added by the protoplasm.

The history of our fragment of onion-skin is not singular. What was once true of this little cluster of cells, packed together in a space no larger than a Lupin seed, is true of all living organisms whatsoever, whether in the Vegetable or the Animal world. The protoplasm is the essential part of the cell. We would press this, even

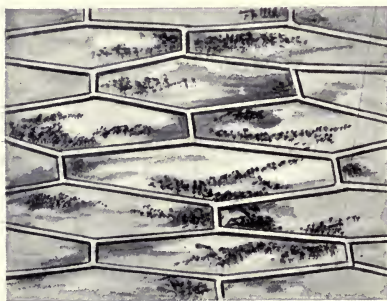


FIG. 35.—CELLS OF ONION SKIN.

A fragment (much enlarged) of the delicate skin between the firm layers of the onion bulb.

at the risk of being tedious. It is a point of all-importance. The granular, structureless contents of the cell, and not the wall of cellulose, constitute the unit, the elementary part or cell. The protoplasm produces from itself the cellulose; the cellulose does not form the protoplasm. Cellulose, indeed, is formed from three of the elements which enter into the composition of protoplasm—namely, carbon, hydrogen, and oxygen. The formula is $C_6H_{10}O_5$. Here, then, is proof from chemical analysis. When our *Sphaerella* was at rest at the bottom of the drop of water, the source of all the vital changes, it will be remembered, was the protoplasm, not the membranous coat that invested it. Through this delicate coat, it is true, was drawn in from the surrounding water the lifeless material which was required for the nourishment and growth of the plant; but the interior substance was the active agent, the protoplasm was the drawing power; indeed, the same work went on when the plant was a naked cell, without any cellulose envelope whatever.



Photo by]

FIG. 36.—SWEET BRIAR (*Rosa rubiginosa*).

[E. Step.

Although so varied in its parts—red stems and thorns, green leaves, and pink flowers—all are alike composed of cells, built up by the protoplasts. EUROPE.

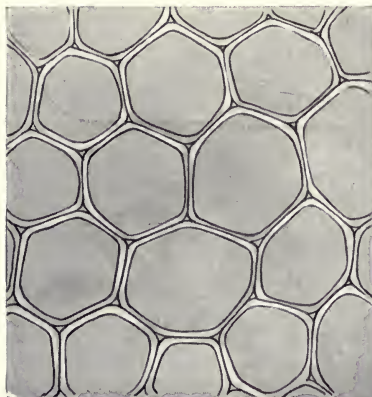


FIG. 37.—TRAVELLERS' JOY (*Clematis vitalba*).
Young cells from the stem, with walls of cellulose.

This leads us to another important phenomenon in cell-building—the conversion of lifeless into living matter. Deeply interesting is the power which the protoplasm possesses, not only of building up formed material from itself, but of transforming the lifeless material which it draws to itself into living matter! There is nothing in the whole range of Nature more wonderful. A tiny speck of matter—viscid, transparent, and, so far as the highest powers of the microscope can inform us, structureless—is able to produce matter like itself—living, formative matter—out of the non-living material by which it is surrounded! Yet the two are quite

distinct. The difference between the minute speck of protoplasm and that which nourishes it is absolute. Nor does the one pass by delicate gradations into the other. The change from the non-living to the living is instantaneous. No less absolute is the distinction which exists between living matter and the formed cellular material which is produced by it. The passage from one state into the other is sudden and abrupt; matter cannot be said to half live or half die. Thus a ceaseless round of change goes on—an endless transformation of the lifeless and inorganic into the living but structureless, and of the latter into formed material.

The wonderful movements of protoplasm have been often observed, and perhaps no plant has been more studied for this purpose than the Common Spiderwort or Flower-of-a-Day (*Tradescantia virginica*). If we remove a single hair from a stamen of this plant by tearing off a portion of the cuticle to which it is attached (thus avoiding injury to the hair itself), and place the object in a drop of water under the microscope, we may watch for ourselves two of the most characteristic movements of protoplasm. Presuming that we have been fortunate in a choice of specimen, we shall find that the hair consists of three or four cells, of which the shortest and broadest is at the base (fig. 34). In this cell the protoplasm will shortly be seen to be moving in several elliptical currents from a common point, the nucleus; while in the other cells it will be seen to travel round the cell-walls, though the nuclei, as before, will be the points of departure and return. The former kind of movement is known as *circulation*, the latter as *rotation*.

Rotary movement may also be well seen in certain cells of the Water-

thyme (fig. 39) and the grass-like leaves of that river wonder, *Vallisneria spiralis*; for here there are no stationary nuclei, but the whole of the protoplasm moves round and round. In some instances this movement is found to take place in opposite directions in contiguous cells, observation of this interesting fact being facilitated by the presence in the transparent protoplasm of minute grains of a green colouring matter (chlorophyll), which are carried round with the stream, and thus discover its course. The layers of living matter in which these corpuscles float are frequently no more than $\frac{1}{200000}$ th of an inch in depth! What, then, must be the dimensions of the green grains themselves?

Probably enough has now been said, at least for the present, about the remarkable properties of protoplasm. We have seen that the little specks of germinal matter—the protoplasts, if you please—are the weavers of the warp and woof of organisms—the builders, may we not say?—of all animal and vegetable structures whatsoever. They constitute, indeed, “the physical basis of life,” and are the fabricators of every object that lives or has lived!

Is it not wonderful to think of our little protoplasts even as the builders of a single plant? Conceive of them, for example, as the fabricators of a Sweet Briar-rose. Here a number of them are busy at work in their self-formed cells, and they throw out material—as what? As incipient hairs. Here are numbers more equally as busy, and they are producing material which will be built up into woody fibre. Others, close at hand, are constructing a wonderful layer of similar cells, each with its own protoplasm, its own walls, its own cell-sap. Thus in one part of the plant we have our root-hairs; in another, our woody fibre; and in a third, some delicate tissue of cells which is to aid in the formation of a petal, a foliage leaf, or perchance a seed. All this, remember, in a single plant! Yet the little workers are chemically alike in each case; and all consist of the same elementary substances.

And as with our sample



Photo by]

[W. Plomer Young.

FIG. 38.—SENSITIVE PLANT (*Mimosa pudica*).

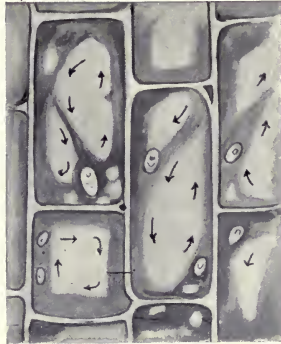


FIG. 39.—CELLS OF WATER-THYME (*Elodea canadensis*).

Showing the directions of the currents of protoplasm in the cells of the leaf.

and others established the fact that the matter was identical in animals and plants, the distinguishing term was dropped, and now, whether we are speaking of animal or vegetable organisms, the one word protoplasm is used to denote its common nature.



FIG. 40.—GREEN MOULD (*Penicillium glaucum*),

Which rapidly grows on stale food. Each branch ends in a chain of spores, which fall away as they ripen.

Briar-rose, so is it with *all* plants. The chemical constituents of protoplasm are the same wherever you find it; in the simple Fungus (*Penicillium glaucum*) (fig. 40), which forms the green mould on stale food, as in the complex organism of a Trumpet-flower or an Orchid.

The foregoing may appear to be a sweeping statement, involving as it does the fundamental unity of all forms of vegetable life; but we may go much further than that and say, with full sanction of modern Science, that the protoplasm of the cells of which we and the entire membership of the Animal Kingdom are built up, is essentially the same as that which we have been considering in the living plant. Formerly, the cell-matter of animals was distinguished from that of plants by the name of *sarcodé*; but when Max Schultze and others established the fact that the matter was identical in animals and plants, the distinguishing term was dropped, and now, whether we are speaking of animal or vegetable organisms, the one word protoplasm is used to denote its common nature. As a consequence of this identity of elemental structure, no one can say with certainty where the Vegetable Kingdom ends and the Animal Kingdom begins. The simplest plants are grouped under the name of Protophyta, and the simplest animals form a corresponding group known as Protozoa; but in consulting a modern natural history of plants and a natural history of animals in turn, you will find a number of species doing double duty and appearing in each. Botanist and zoologist alike claim them as their subjects. The difficulty is increased by the fact that many indubitable single-celled plants are in their younger condition unhampered by the wall of cellulose they secrete later, and without which they are able to move freely, just like similar organisms of undoubted animal nature. The evolutionist, who contends that animal and plant life have had a common origin, gets over this difficulty by merging Photophyta and Protozoa into a single group under Haeckel's name of Protista.



Photo by]

[E. Step.

FIG. 41.—OAK-TREE (*Quercus pedunculata*).

Even the strongest and greatest of trees is built up of minute cells, which constitute its stout trunk with its wood and bark, its leaves, flowers, and acorns. All the potentialities of this massive tree were packed into the cells of the acorn. NORTHERN TEMPERATE REGIONS.

CHAPTER II

THE PROTOPLAST AS HOUSE-BUILDER AND HOUSE-FURNISHER

Moreover, the walls of the cells themselves are the work of the protoplasts, and it is not a mere phrase, but a literal fact, that the protoplasts build their abodes themselves, divide and adapt the interiors according to their requirements, store up necessary supplies within them, and, most important of all, provide the wherewithal needful for nutrition, for maintenance, and for reproduction.—KERNER.

THE subject of our last chapter was protoplasm, that wonderful substance which Beale calls the “vital element” of organic bodies, and which Huxley has well defined as the “physical basis of life.” We now propose to advance a step further, and to speak of some of the wonderful results of protoplasmic activity—in other words, of the cells themselves (Hooke’s “little boxes,” if you please), as well as of the changes which they undergo, and of the various substances elaborated within them.

It will be evident to the least reflective mind that these changes must be considerable, otherwise there would be no accounting for the infinite diversities of form, structure, and properties which the Vegetable World presents. For, since the most complex organisms are only the products of cell formation and transformation, and all cells in their beginnings are so much alike, the changes must be vast indeed that produce those diversities—that give us, for instance, in one case a stalk of Wheat, in another a spreading Oak, and in a third a Mushroom.

It will be remembered that the resting spore of our rain-water plant was almost round, while the cells of the piece of onion-skin were hexagonal, and those of the staminal hair of *Tradescantia* were in two cases oblong, in a third almost spherical, and in a fourth triangular: four distinct shapes in a less number of minute objects—inferential evidence, surely, that the forms of cells may vary greatly.

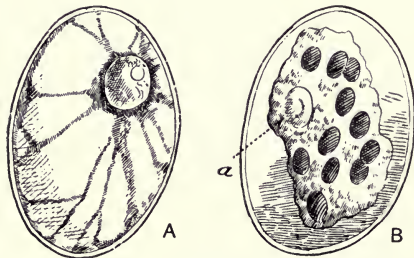


FIG. 42.—A: OVAL CELL FROM FRUIT OF SNOW-BERRY. B: OVAL CELL FROM LEAF OF PINK.
a: NUCLEUS.



Photo by]

[E. Step.

FIG. 43.—SNOWBERRY (*Symphoricarpos racemosus*).

A plant allied to the Honeysuckle, whose tiny pink flowers are succeeded by clusters of pure white berries.
NORTH AMERICA.

The round shape occurs in most cells at a certain stage (*not the earliest stage, when they are contiguous at all points*), but in few cases, comparatively, is this shape retained. The pressure of contiguous cells as growth continues again effects changes, so that we get octagons and twelve-sided forms, and sometimes cells of no definable shape at all. This may be simply illustrated by getting several balls of soft clay and uniting them by gradual and uniform pressure. The fruit of the Snowberry (*Symphoricarpos racemosus*, figs. 42, 43) and the leaf of the Common Pink (*Dianthus caryophyllus*) offer interesting examples of cells retaining the spherical—or more correctly oval—form. The pulp enclosed by the outer membrane of the berry of the first-named plant, even when full grown, consists of a vast number of minute shining white granules, each of which is a perfect and almost spherical cell.

The numberless departures from the rounded shape are not all due to pressure, however. Some cells remain long and narrow through their whole history, as those of the hairy seed-coat of the Cotton-plant, to which reference has been made; and others—to wit, the hairs on the leaves of the Virginia Stock (*Malcolmia maritima*) and the Hop (*Humulus lupulus*) are curiously branched. Stellate or star-shaped cells are also met with, being found in the stems of many aquatic plants; their rays are seldom very regularly placed, and they vary in length on the same individuals. The stellate cells shown in fig. 44, which, however, are not those of an aquatic



FIG. 44.—STAR-SHAPED CELLS OF COMMON BEAN.

some rose-coloured flowers, rising above the surface of the water on a stalk three or four feet high, make it deservedly a favourite with lovers of British water-plants (fig. 51).

Of more than morphological importance are the facts to be next noticed. "Endlessly diversified in the details of their form and structure," says Professor E. B. Wilson in his fine work on the vegetable cells, "these protoplasmic masses nevertheless possess a characteristic type of organism common to them all; hence in a certain sense they may be regarded as elementary organic units out of which the body is compounded. The composite

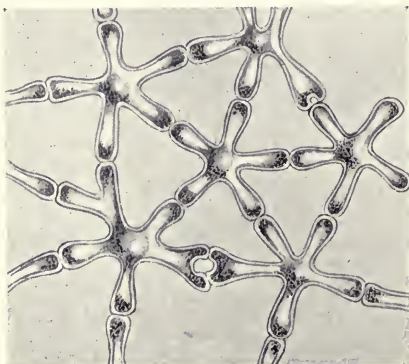


FIG. 46.—STAR-SHAPED CELLS FROM STEM OF COMMON RUSH.

plant, but of the Common Bean (*Vicia faba*), are fairly uniform. The solitary stellate cell in the next figure (fig. 45) is not so regular. It is a *Desmid*—one of a remarkably beautiful family of unicellular *Algae*. Good examples of stellate cells are also afforded by the stems of the Common Rush (*Juncus effusus*, fig. 46), as well as by the Flowering Rush (*Butomus umbellatus*), whose hand-

FIG. 45.—A DESMID.
One of the simplest forms of green plants.

structure is, however, characteristic of only the higher forms of life. Among the lowest forms at the base of the series are an immense number of microscopic plants and animals, familiar examples of which are the *Bacteria*, *Diatoms* (fig. 49), *Rhizopods*, and *Infusoria*, in which the entire body consists of a single cell, of the same general type as those which in the higher multicellular forms are associated to form one organic whole. Structurally, therefore, the multicellular body is in a certain sense comparable with a colony or aggregation of



Photo by]

[C. C. Pierce.

FIG. 47.—FLOWERS OF A CACTUS. (*Cereus*).

The Cacti grow in dry stony places, and have tough skins to prevent loss of moisture by evaporation. To protect them from destruction by thirsty animals, their leaves have been replaced by clusters of sharp spines.



FIG. 48.—SEEDLING OAK.

The store of nutriment packed into the acorn is sufficient to maintain the seedling until it has formed a stem and leaves and the beginnings of its root system.

the lower one-celled forms—a comparison, however, which must be taken with some reservation. The comparison is not less suggestive to the physiologist than to the morphologist. In the lower one-celled forms all the vital functions are performed by a single cell. In the multicellular forms, on the other hand, these functions are not equally performed by all the cells, but are in varying degree distributed among them, the cells thus falling into physiological groups or tissues, each of which is especially devoted to the performance of a specific function." (Of this we shall speak more fully in succeeding chapters.) "Thus arises the physiological 'division of labour' through which alone the highest development of vital activity becomes possible, and thus the cell becomes a unit, not merely of structure, but also of function. Each bodily function, and even the life of the organism as a whole, may thus in one sense be regarded as a resultant arising through the integration of a vast number of cell activities; and it cannot be adequately investigated without the study of the individual cell activities that lie at its root."

On looking at a young seedling—say of an Oak (fig. 48) or Chestnut-tree—the question naturally arises, How is it that so small and tender a plant, which may be bent with the finger, is capable of growing into a mighty forest-tree that shall defy the winter storms of centuries? If the cells of which the young plant is formed were, in their beginnings, only so many little specks of protoplasm, each surrounded by a thin diaphanous wall of cellulose, which the shake of a hand would cause to dissolve away, by what mysterious

process has it attained even its present growth? And, still more, how will it develop into the strong-limbed giant which it is destined in future years to become?

The answer—in part, at least—lies in the wonderful property which the protoplasm possesses, not only of building a primary investing wall for itself, but of spreading on the interior of that wall successively new layers of formed material (woody or otherwise in substance, as the case may require) till the cell is all but filled up. This new material, which is found in all Flowering Plants and in very many Cryptogams or Flowerless Plants, is known as *secondary deposit*. The process which goes on may be likened to the formation of the furred deposit (limestone) on the inside of a kettle. The kettle answers to the cell; the water to the protoplasm; the tin side of the kettle to the primary cell-wall; and the hard limestone accretion to the secondary deposit.

Cellulose itself ($C_6H_{10}O_5$), though it is the material of which the primary cell-wall is formed, is very seldom found as a secondary deposit. The date-stone may be cited as an interesting exception. The thickening which takes place in the interior of the cells of the plum and cherry—we do not speak of the stones of those fruits—and in the pith of certain plants of the Pea family, is a gum; whilst mucilage, a kind of gum, is found in the cells which form the seed-coat of linseed, the apple, pear, etc. A very common and important kind of secondary deposit is *lignin*, which, as might be guessed from the name (Lat. *lignum*, wood), is found in all woody cells. The stones and shells of many fruits are built up of such cells; and woody tissue of course abounds in the stems and branches of trees. Lignin, like all secondary deposits, is derived from the protoplasm, which, as the cell-wall increases in thickness, becomes more and more restricted in its movements, until at last it is crowded out, if one may so say, and dies.

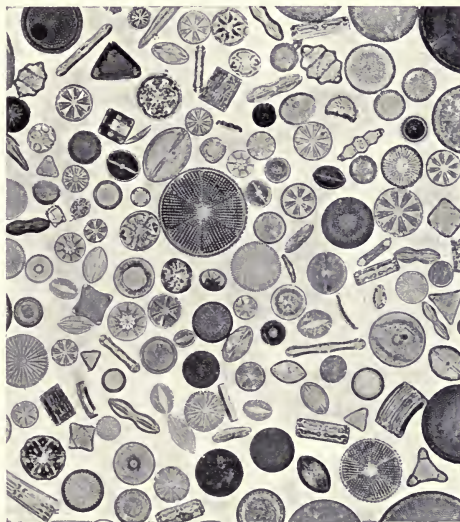


FIG. 49.—DIATOMS.

These are little boxes of pure flint deposited in the interior of microscopic plants. Magnified 60 times.



Photo by]

[E. Step.

FIG. 50.—WILD HOP (*Humulus lupulus*).

A hedgerow plant that climbs by twining round the stems of bushes. The male and female flowers are on separate plants. This is the female plant. The flowers of the male are much smaller. EUROPE.]

Great honour is put upon the cell after death, however; it is dignified with a new name—a name of sixteen letters—as inelegant as it is long. The lifeless structure becomes, in fact, a *sclerenchymatous* cell—the name implying that the cell has had something hard put into it; for the term is derived from two Greek words—*sklēros*, hard, and *enchuma*, anything poured or put in.

Sclerenchymatous cells occur in the gritty centre of the pear, in the stones of the peach, cherry, etc., and in the shell of the common hazel-nut. Lignin takes a deeper yellow than cellulose when treated with iodine, and it becomes brown when treated with iodine and sulphuric acid.

Suberin, or cork substance (Lat. *suber*, cork), is another of the secondary deposits of cells. Like cellulose and lignin, it is coloured yellow by iodine, but it resists the action of sulphuric acid. Cork cells are tough without being woody. Parts of plants the fluids of which require to be protected from evaporation, are usually surrounded by cork cells, as the stems and older branches of trees, in which the sap circulates. In young and quickly growing trees the epidermis (outer skin) of the stem, being unable to stretch fast enough, often gets torn, and then the busy protoplasts cover the wound with a special



Photo by]

[E. Step.

FIG. 51.—FLOWERING RUSH (*Butomus umbellatus*).

A handsome waterside plant, three or four feet in height, with an umbel of crimson flowers. EUROPE, ASIA.

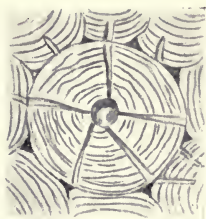


FIG. 52.—CELL from the Bark of a New Zealand Conifer (*Podocarpus dactyloides*).

layer of cork cells. The thick, rough, cleft bark of a Spanish species of Oak (*Quercus suber*) is the cork of commerce, of which the stopples for bottles and casks are made. It is stripped off without injury to the stem—which, indeed, soon gets covered with fresh layers of corky cells, and in eight or ten years the tree is again ready for stripping. The first peeling takes place when the tree is twenty-five or thirty years old, and great care is always taken not to injure the inner bark.

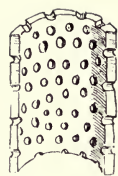


FIG. 53.—SECTION of a Part of a Pitted Cell (diagrammatic).

Earthy or *mineral* substances, found in all plants, abound in some forms of secondary deposit, and may be readily detected when any part of the plant containing them is burned. The ash left after burning is commonly known as "the ash of plants," and consists chiefly of silica, lime, and magnesia. *Silica* (flint) is particularly plentiful in the grasses, canes, etc., the glassy appearance of the stems of such plants being due to the presence of this mineral. Years ago, a melted mass of glassy substance—at first supposed to be a meteoric stone—was discovered in a meadow between Mannheim and Heidelberg in Germany; but when chemically examined it was found to consist of silex combined with potash. Upon inquiry it was ascertained that a stack of hay, which had been recently destroyed by lightning, had stood on the spot. The siliceous mass was simply the ash that remained after the conflagration. One cannot reduce haystack burning to a system for purposes of experiment,



FIG. 54.—PITTED Wood Cells from a *Bigonia*.

but instructive results may be obtained on a small scale by igniting a piece of siliceous tissue on platinum foil, after soaking in nitric acid. If the ash is then treated with the same acid, it will show an insoluble residue, and that residue is flint.

It frequently happens that the protoplasm deposits secondary thickening only in some parts of the cell-wall, the other portions being left bare. For this reason we get some curious varieties of cells. Thus, in what are

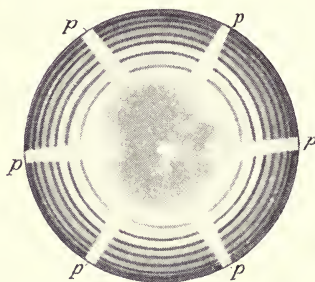


FIG. 55.—DIAGRAM to illustrate the Disposition of Layers of Secondary Deposit in Porous Cells. (*p*) Pores. The Broken Rings represent Successive Layers of Secondary Deposit. The Protoplasm occupies Part of the Central Space.



THE ROSY-LIPPED CATTLEYA (*Cattleya labiata*).

This beautiful Orchid is a native of Brazil, where it grows on the trunks of trees. The magnificent flowers measure six or seven inches across, and there are usually three or four blossoms on a spike. It flowers in late autumn. Under cultivation it has produced several fine varieties.

known as the *pitted* or *dotted* cells, the secondary deposit is spread upon the cell-walls so as to leave little pits, open on the interior side of the cell, and closed at the exterior by the primary cell-wall. These pits have the appearance under the microscope of transparent specks (fig. 53). When several dotted cells come together, it often happens that the pits of their contiguous walls are coincident; and the utility of this very beautiful arrangement is at once evident: for even after the cells have attained a considerable thickness, they are still permeable to the fluid from without, which is taken in through these little pores and used up by the imprisoned but still living and working protoplasts (figs. 53, 54, 55).



Photo by]

FIG. 56.—BOG-MOSS (*Sphagnum acutifolium*).

[E. Step.

The Bog-mosses grow in wet hollows where the soil is sour and too poor to maintain most plants. The decay of the older parts, pressed down by the newer growth, results in the formation of peat. COLDER TEMPERATE REGIONS.

In certain plants of the Cactus order (as *Melocactus*, *Mamillaria*, and *Opuntia*), the wood is entirely composed of short spindle-shaped cells, in which are elegant spiral bands of secondary deposit, looking, as Schleiden neatly expresses it, "like little spiral staircases" (fig. 57). We call these *spiral* cells. The large elongated leaf-cells of the Bog-moss (*Sphagnum*) (fig. 56) and the leaf-cells of many orchideous plants have spiral fibres loosely coiled in their interior; but a better plant than either Orchid or Bog-moss for studying these spirals is the Wild Clary (*Salvia verbenaca*), a portion of the seed-coat of which makes an extremely interesting object under the microscope. If a very thin slice of the outer coat, moistened with a drop of water, be placed between the glass slides, the delicate fibres will

be seen to break through the membranous cell-wall—a proof of their remarkable elasticity. In most spiral cells that have been examined the fibres wind from left to right; and it has been suggested with some show of reason that the direction of the twining stems of plants may have definite relation to the direction of the spirals. This would certainly appear to be the case in the Hop (*Humulus lupulus*), which is a right-handed climber and always has right-handed spirals. *Saccolabium guttatum*, an East Indian species of epiphytal Orchid, has fibres which wind in opposite directions, but this is not a twining plant.

A fair idea of a spiral cell may be obtained by placing a coil of fine wire in a tightly enclosing glass tube of the same length as the coil, and covering up the ends with glass discs. In Nature the fibres are extremely delicate, their diameters being in some cases less than $\frac{1}{12000}$ th of an inch; and as a rule



FIG. 57.—CELLS FROM THE MISTLETOE (*Viscum album*).

1. Spiral cells.

2. Annular cells.

3. Reticulate cells.

they are quite transparent and colourless. Nevertheless, they may—and do—vary considerably in thickness; and in most plants of the Lily order, and also in the Elder (*Sambucus*), the coiled-up threads may be seen with the naked eye. If the stem of a Lily be partly cut across and then gently broken, the chances are that the broken pieces will be held together by some of these delicate threads; and they will probably be found to be strong enough to support the weight of one of the fractured pieces, if the piece in question be not too large. It is wonderful to think that though some of the cells which contain them measure only $\frac{1}{30000}$ th of an inch in diameter, the tiny spirals may consist of several distinct threads; indeed, the contiguous coils in some cases have been found to number more than twenty! How carefully Nature prepares her work even when the objects of her skill are invisible to the unaided human eye!



[Photo op.]

FIG. 58.—THE BUCKBEAN (*Menyanthes trifoliata*).

Also known as Bogbean and Fringed Gentian. The pink-tinted white flowers have their calices fringed with fleshy filaments which give them a very beautiful appearance. The thick leaves are divided into three leaflets, much like those of the bean. It grows in bogs and by the water-side. About one-third the natural size. NORTHERN TEMPERATE REGIONS.

[E. Step.]

The fibrous spirals in the leaf-cells of many Cone-bearing plants (*Coniferae*) have been pressed into the service of man, being found to afford an excellent substitute for wool and cotton. In 1842 a quantity of woven fabric of this material was introduced in place of cotton in the hospital at Vienna, where, after several years' experiment, it was renewed. Similar success attended its introduction into prisons and hospitals at Berlin, Breslau, and other places. When used in mattresses, it is found to last three times longer than wool; while for spinning and weaving purposes it has the strength of hemp,



Photo by]

FIG. 59.—MISTLETOE (*Viscum album*).

[E. Step.

The well-known shrub that grows on various trees, chiefly Apple, parasitically. The possession of leaves, however, shows that it is not wholly a parasite. One-third of natural size. EUROPE, N. ASIA.

and so may be profitably employed in the manufacture of carpets and blankets.

Sometimes the thickening of the cell-walls takes the form of rings, as in the Mistletoe (*Viscum album*) and many grasses; and thus we get *annular* cells—a name derived from the Latin *annulus*, a ring (fig. 57). Three or four indiarubber rings fitted tightly in a short cylindrical lamp-glass give the idea. Not infrequently the rings appear to have their beginning in spiral fibres, which, in consequence of their rapid growth, get broken in places, and so fall together in rings; indeed, the transition from the spiral to the ringed form has been observed in certain plants, notably in the

Opuntias, that well-known genus of the Cactus, order to which the Prickly Pear (*O. vulgaris*) belongs. They are plentiful enough, too, in the leaf-stalk of the Common Ivy (*Hedera helix*). Cells containing these composite fibres are described as *spiro-annular*.

Another modification of the true spiral is found in *reticulated* cells (Lat. *reticulum*, a small net), where the bands of thickening are arranged in a net-like manner on the interior of the primary walls. By this disposition of the secondary deposit, little trenches are left at variable distances, which appear under the microscope like more transparent lines. The Touch-me-Not Balsam (*Impatiens noli-tangere*) and the Mistle-toe (*Viscum album*) furnish interesting examples of reticulated cells (fig. 57).

"It is scarcely possible," says Dr. Carpenter in his *Vegetable Physiology and Botany*, "to observe the number of different forms resulting from the varied combinations of the simple elements, each of them probably having its peculiar function in the Vegetable economy, without being struck with the simplicity of the plan by which Creative Design has effected so many marvels, as well as with the extreme beauty and regularity of the structures which are thus produced. The comparison of such specimens of Nature's workmanship as the meanest plant affords, with the most elaborate results of human skill and ingenuity, serves only to put to shame the boasted superiority of man; for whilst every additional power which is applied to magnify the latter serves but to exaggerate their defects and to display new imperfections, the application of such to organized tissues has only the effect of disclosing new beauties, and of bringing to light the concealed intricacies of their structure."

But it is time to pass from this subject. We trust that we have now treated with sufficient fulness the more important facts connected with the thickening of the primary cell-wall by means of secondary deposit; and that some definite idea has been conveyed of the manner in which cells—though not *all* cells—are made strong and hard and capable of firm resistance. We will now consider some of the other substances produced in vegetable cells as the result of protoplasmic activity.

In treating of the movements of protoplasm in *Vallisneria*, allusion was made to the minute green corpuscles contained in the living matter of the long grass-like leaves, and carried round with it in the cells. These little

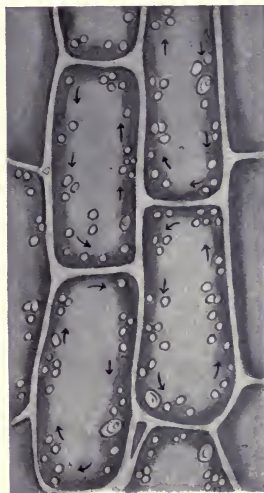


FIG. 60.—CELLS FROM LEAF OF *Vallisneria spiralis*.
Showing chloroplasts (the oval bodies in the protoplasm.)

bodies are known as *chlorophyll corpuscles* or *chloroplasts*, and the green colouring pigment chlorophyll—a name derived from the Greek *chloros*, green, and *phullon*, a leaf. Many millions of such corpuscles exist in every full-grown plant of *Vallisneria*; though that circumstance alone is not our warrant for returning to the subject. If chlorophyll were only distributed in the tissues of a few water-plants, it would call for no special mention here; but the contrary is the case. As a matter of fact, these tiny bodies of coloured matter constitute one of the most widely distributed of vegetable substances, being found in all green plants; while their essential identity with protoplasm gives them an especial interest. Chlorophyll corpuscles



FIG. 61.—SECTION THROUGH
A THALLUS OF LICHEN
(*Sticta fuliginosa*).
Magnified 500 times.

have, indeed, been defined as specialized masses of protoplasm coloured green, and no definition could be more clear, concise, and satisfactory. It is thought that they possess a reticulated structure, and that the colouring matter occupies the meshes of the network in a state of solution. Chloroplasts are not found in animals, save, indeed, in some of the *Flagellata*, *Planarians*, etc., as a foreign product. The latter exception needs to be recorded, since it was long held that the chloroplasts contained in the tissues of the fresh- and salt-water Sponges, and the fresh-water Polyp, belonged to those animals.* Professor Weiss has shown that they are really vegetable cells which may be cultivated outside the animal body. "As," says he, "these green cells can form starch and ultimately sugar, which transfuses out of the *Algae* into the body of the animal, it is evident that they are of real benefit to the animal, while the *Algae* themselves can absorb certain substances out of the animal cells. An analogous example occurs in the Vegetable Kingdom in the case of the Lichens, in which some green *Algae* are associated with a Fungus. Every Lichen consists of the two

different organisms, and the green cells form, under the influence of light, food substances which are made use of by the Fungus. In initial stages the Fungus can be seen capturing, with its threads, the *Algae* cells of which it makes use, and which are the working partners of the concern" † (fig. 61).

Some minute marine-worms (*Turbellaria*), known as *Convoluta*, have established a remarkable partnership with some of these green single-celled

* Chlorophyll corpuscles were found in fresh-water Sponges by Sir E. Ray Lankester, and Mr. MacMunn found them in no less than nine specimens of sea Sponge.

† *Proceedings of the Manchester Microscopical Society*, 1892.



Photo by]

[F. Skeen & Co.

FIG. 62.—JAK-FRUIT (*Artocarpus integrifolia*).

A species of Bread-fruit, and valuable as food to the inhabitants of the districts in which it grows. INDIAN ARCHIPELAGO.

Algæ, which multiply to such an extent in their substance that the entire animal is coloured green. After its larval stage the worm does not need to trouble about food, for the plants manufacture and supply it with starchy products. The plants in turn needing nitrogen, which is a rare commodity in the sea, obtain it from the animal's waste. This partnership is not an occasional or chance affair: both plant and animal have so thoroughly entered into it through many generations that it has become fixed and habitual, like the association of Algæ and Fungus which has resulted in the production of thousands of species of the compound plants we know as Lichens. Professor Keeble has devoted a small volume entirely to telling the story of the relations between these very dissimilar organisms.*

Under the microscope the chloroplasts have usually a globular appearance, but instances occur in which they are quite formless. In the well-known Water-thyme (*Elodea canadensis*), so excreted by bargemen



FIG. 63.—STARCH-GRAINS OF POTATO.

and water-mill owners, they are irregular in shape, some presenting the appearance of circular flattened discs, while others are spherical and oval. Their diameters vary from $\frac{1}{30000}$ th to $\frac{1}{50000}$ th of an inch. Of the colouring matter diffused through the corpuscles, we have as yet no certain knowledge, but the opinion still held by very many that it is composed of two independent colouring substances—a golden-yellow and a blue-green—is now abandoned by the highest authorities. Those substances are,

indeed, the products of the *decomposition* of chlorophyll, but chlorophyll itself is a single pigment.

One eminent analyst (Gautier) regards it as related to the colouring matter of the bile; another (Hoppe-Seyler) as a fatty body allied to lecithin, which is a phosphoretted viscous substance entering into the formation of the brain. But "it is extremely difficult," says Dr. Reynolds Green, "to say what is the chemical composition of chlorophyll, on account of the readiness with which it is decomposed. In all the processes which have been adopted for its extraction it undergoes decomposition, and consequently no definite conclusions as to its chemical nature can at present be arrived at. It can be made to yield definite crystals by appropriate methods of treatment after extraction, but it is probable that these crystals are a derivative of chlorophyll, and not the pure pigment." The statement found in many of the text-books that the chloroplasts are coloured blue by iodine

* Keeble, *Plant-Animals: a Study in Symbiosis*, 1910.

is misleading. Iodine denotes the presence of starch-grains, which often occur—but by no means always—in the corpuscle.

Specially interesting is the fact that light is a necessary condition for the formation of chlorophyll. Grow a plant in the dark, and its leaves will be yellow and sickly; bring it forth to the light, and it will become green and healthy. Hence it will be readily gathered that chlorophyll is seldom found in the roots of plants. The roots of the Common Buckbean or Marsh-trefoil (*Menyanthes trifoliata*) may be cited as a curious and—in so far as underground roots are concerned—perhaps an unique exception; but the green aerial roots of some epiphytal Orchids (fig. 64) contain this important substance. The whiteness of celery is due to the exclusion of light from the stem and leaves, which are banked round with earth as fast as they grow. Hindrance is thus offered to the formation of chlorophyll, and by this mode of cultivation the rank coarse taste of the plant is completely removed, and the mild sweet flavour which we associate with table celery is imparted to it. In its natural state celery is a poisonous plant.

Doubtless the reader will have noticed how quickly the pale unfolding leaves of spring assume their characteristic hue if the weather be bright and sunny; and, on the other hand, how slowly this change is effected during a succession of dark cloudy days. This fact is more remarkable in tropical countries than in England. It frequently happens in America that clouds and rain obscure the atmosphere for several days together, and that during this time the buds of entire forests expand themselves into leaves. These



FIG. 64.—AERIAL ROOTS OF AN EPIPHYTAL ORCHID.

leaves assume a pallid hue until the sun appears, when, within the short period of six hours of a clear sky and bright sunshine, their colour is changed to a beautiful green. Mr. Ellis, an American writer, tells of a forest in one of the northern States, the leaves of which, though fully expanded, were almost white, no sun having shone upon the forest for twenty days. One forenoon, however, the sun began to shine in full brightness, and the colour of the forest absolutely changed so fast that the progress of the transformation could be watched. "By the middle of the afternoon the whole of this extensive forest, many miles in length, presented its usual summer dress."

Often associated with chlorophyll is *starch* ($C_6H_{10}O_5$), which plays so important a part in the nutrition of mankind. "Starch makes the man," said a lady lecturer half a century ago; but she spoke of it in another connection—namely, as the stiffening property in linen articles of male attire.

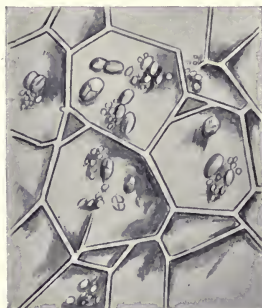


FIG. 65.—STARCH-GRAINS IN
BROKEN CELLS OF A POTATO.

Starch was imported into this country in considerable quantities during the sixteenth and seventeenth centuries, when the enormous ruffs inseparably connected with the Elizabethan and early Stuart periods were in vogue. Gerarde tells us that the best of this starch was obtained from the Cuckoo-pint or Wake-robin (*Arum maculatum*). "The most pure and white starch is made of the roots of the Cuckoo-pint, but most hurtful for the hands of the laundress that hath the handling of it; for it choppeth, blistereth, and maketh the hands rough and rugged, and withal smarting." That dealer in spells and philters, the notorious Mrs. Turner, has the credit of introducing yellow-starched ruffs into Britain, blue and white being the

fashionable colours hitherto. Mrs. Turner literally died in starch. In the presence of many women of fashion she "made her exit on the scaffold at Tyburn, rouged and dressed as if for a ball, and wearing an enormous ruff stiffened with her own yellow starch."

The formation of starch is effected by protoplasmic bodies, which may either be the chloroplasts already spoken of or *leukoplasts* (Greek *leukos*, white, and *plasma*, something formed), which only differ from the former in being colourless. Starch-making chloroplasts are found chiefly in the leaves of plants; leukoplasts in the roots and tubers and certain other parts which are hidden from the light; yet the relationship between the two is shown by the fact that leukoplasts turn green when light is admitted to them for a sufficient time. They take a yellow or yellowish brown stain when treated with iodine, and should be examined under a high power. The starch-grains have the same chemical composition as cellulose ($C_6H_{10}O_5$), but, unlike cellulose, are soluble in water, and will take a blue or violet stain if



FIG. 66.—SUGAR CANE (*Saccharum officinarum*).

A giant grass whose cells are stored with *canose* or cane-sugar. The juices are extracted by pressure, and after passing through purifying processes are crystallized. Cultivated from very early times. TROPICS.



FIG. 67.—HIP OR FRUIT OF DOG-ROSE (*Rosa canina*).

treated with iodine, which cellulose will not. Their formation may be thus described. The cells containing chlorophyll, which are always near the surface of the plant, absorb carbonic acid gas (CO_2) from the atmosphere or water (the latter in the case of submerged plants), and this gaseous compound reacts with water (H_2O) in the chlorophyll corpuscles under the action of light. The first organic product as a result of this process is, in most plants, *glucose* ($\text{C}_6\text{H}_{12}\text{O}_6$), or some other form of sugar. The sugar has to be diffused along certain delicate cells* of the plant, and as the process of diffusion is too slow to keep pace with the process of construction, another agency is brought into play. The chloroplasts, in short, have the power of converting sugar into starch—a power (we quote from Dr. Reynolds Green) which “is quite independent of the colouring matter, being shared by other quite colourless plastids [the leukoplasts already mentioned], which occur in other parts of the plant. The transformation is apparently a process of secretion. Part of the sugar consequently gives rise to numerous minute grains of starch, which the plastid forms within itself, and deposits in its own substance. This formation of a temporary store not only relieves the over-saturation of the sap in the cell, but supplies the need of the protoplasm when the formation of sugar from carbon dioxide and water is interrupted by the failure of the daylight.” It has been estimated that one hundred square yards of green leaves can during five hours of sunlight manufacture one pound of starch.

In this way, then, do green plants assimilate the carbon which they take into their cells by absorption; and as carbon usually forms one-half of the dried plant by weight, the statement will not appear extraordinary that starch (or its physiological equivalent) is really the raw material from which all the other organic substances of the plant are elaborated.



FIG. 68.—RASPBERRY (*Rubus idaeus*).

Starch-grains are found in almost all plants, in every part, but particularly in the roots, tubers, seeds, and fruits, where they are stored up as reserve food material: in fact, they supply the young plant with food till it is in a condition to feed itself. The roots of the Tapioca-plant (*Jatropha manihot*) yield about $13\frac{1}{2}$ per cent. of this important substance; the tubers of the Potato-plant (*Solanum tuberosum*) nearly twice that proportion (figs. 63, 65);

* The bast-tissue (*vide* Chapter III.).

and the seeds of Wheat and Maize about 75 and 85 per cent. respectively. The fruit of *Artocarpus incisa*—

The Bread-tree, which, without the ploughshare, yields
The unreaped harvests of unfurrowed fields ;
And bakes its unadulterated loaves
Without a furnace—

yields about $3\frac{1}{2}$ per cent.

Starch-grains vary considerably in size, according to the plants in which they are found. Some of the largest occur in the tubers of *Canna edulis*, and measure $\frac{1}{300}$ th of an inch in diameter. This is the interesting Tous-les-mois starch of commerce. The grains differ very much in form also, but ovoid and lens shapes are most common. Spherical grains are found in the tuberous roots of plants of the Orchid family, and rod and bone shapes in the milk-sap of many tropical Euphorbias. In the Corncockle (*Agrostemma githago*) they are spindle shaped; and angular starch granules, cemented together to form ellipsoidal grains, are found in the seeds of the Oat (*Avena*) and Rice-plant (*Oryza*).

Closely allied to starch is *inulin* ($C_6H_{10}O_5$), which is found in solution in many roots, tubers, seeds, etc.—

particularly of plants of the Composite order. Thus it occurs in the roots of Elecampane (*Inula helenium*), Dandelion (*Taraxacum officinale*), Chicory (*Cichorium*), and Feverfew (*Matricaria parthenium*); in the tubers of the Potato-plant (*Solanum tuberosum*), Dahlia, and Jerusalem Artichoke (*Helianthus tuberosus*); and in the seeds of the Sunflower (*H. annuus*) and many other plants. The inulin of the chemist, which is a soft, white, tasteless powder, is usually prepared from Elecampane or the Dahlia. In its natural state inulin is distinguished from starch by



Photo by]

[E. Step.

FIG. 69.—CUCKOO-PINT (*Arum maculatum*).

A familiar hedgerow plant whose tubers are rich in starch. About one-third the natural size. EUROPE, N. AFRICA.



FIG. 70.—COMMON BEET (*Beta vulgaris*).

fluid which the roots of plants absorb from the soil, or the leaves from the atmosphere, and which contains in solution the true nutritious principles. Water is the chief constituent of cell-sap, calculations showing that for every two hundred grains of water absorbed and exhaled by a plant, only one grain of inorganic matter is appropriated; and for every two thousand grains of water consumed, one grain of inorganic matter is appropriated.

Young cells are usually well supplied with sap, which fills the spaces (called *vacuoles*) occurring in the protoplasm. It is conveyed into the plant



FIG. 71.—ANTS HELD FAST BY THE MILK-SAP OF THE GARDEN LETTUCE.

by the roots, but not till it reaches the leaves does it undergo any important changes. The proof of this must be left for another chapter, our present purpose being simply to speak of the sap as a substance found in vegetable cells apart from the functions which it discharges. Cell-sap may be sweet or acid, clear or turbid, nutritious or innutritious, so that its value from an economic point of view is often great. The refreshing acid taste of most unripe fruits is due to the sap. *Citric acid*—a familiar form of it—gives sharpness to the juices of lemons, oranges, limes, and many of our commonest fruits, as the cranberry,

giving a yellow or yellowish brown instead of a blue colour with iodine, and by its inalterability under the influence of ferments. It assumes the form of beautiful sphere-crystals on the addition of alcohol, and is coloured an orange-red with alcoholic solution of orcein, after warming with hydrochloric acid.

An earlier occasion should perhaps have been chosen to speak of the *sap* of plants. We propose in the following section to treat of its composition only, reserving a consideration of its functions for future chapters. Cell-sap is the



Photo by]

[W. Rossiter.

FIG. 72.—ACKERMANN'S CACTUS (*Phyllocactus ackermanni*).

This species has beautiful crimson flowers measuring from six to eight inches across. The stems are flat and leaf-like.
A native of Mexico.

cherry, red whortleberry, and the "hip" of the Dog-rose (fig. 67); and it exists, with an equal proportion of another acid—*malic*—in the cells of the red gooseberry, the currant, the bilberry, the black cherry, the wood strawberry, and the raspberry (fig. 68); while the latter is found alone in apples, pears, etc. As these acids are much disliked by birds and mammals, they serve as a protection to the young fruit, which would otherwise get eaten before the seeds are ripe and ready for dispersion. As the seeds

mature, however, a sweetening property is added to the sap, and so the visits of birds and other fruit-eating animals, whose presence is now required, are bountifully encouraged.

The acid juice of *Gymnema sylvestre*, a tropical Aselepiad, destroys or vitiates the taste if the leaves be chewed. Mr. Edgeworth, who was the first to draw attention to this singular fact, states that "after masticating the leaf, powdered sugar was like sand in the mouth; while a sweet orange had the flavour of a sour lime, the sourness of the citric acid being alone distinguishable. Only sweet and bitter flavours are thus destroyed. This indi-



Photo by]

FIG. 73.—CHICORY (*Cichorium intybus*).

[E. Step.

A Composite plant with flowers of a distinctive bright blue. Its thick roots contain *inulin*. EUROPE, N. AFRICA, N.W. INDIA

icates that the action is not due to a complete temporary paralysis of the nerves of taste. After a good dose of the leaf, sulphate of quinine tastes like chalk. The effect usually lasts two or three hours." It has been proposed to call the acid *Gymnaic acid*, after the plant.

The sweet pink cell-sap of the Common Beet (*Beta vulgaris*, fig. 70) owes its sweetness to the presence of *Canose* (cane-sugar) dissolved in it. The Prussian chemist Margraff was the first to discover this fact (about 1747), but it was not till the year 1809, when Napoleon forbade the importation of West Indian cane-sugar into France, that the discovery was turned

to practical account. An Imperial sugar factory was then established at Rambouillet; pupils were regularly instructed in the process; premiums were offered for the best samples of the new sweetener; and, in the course of three or four years, the manufacture of beet-sugar was prosperously set on foot. Canose occurs abundantly in the Sugar-cane (*Saccharum officinarum*) and Sugar-maple (*Acer saccharinum*), and is the substance found in the nectaries of flowers out of which the bees make their honey. It is secreted by the protoplasm of the cells composing the nectaries, and the quantity is at its maximum during the emission of the pollen, but ceases when the fruit is formed. Its purpose is evidently to attract insects or small birds to the plant, and thus to secure pollination—a subject of deep interest, which will be considered more fully farther on.

Canose, or Cane-sugar, must be carefully distinguished from *Glucose*, or Grape-sugar. The formula of the first-named is $C_{12}H_{22}O_{11}$, of the latter $C_6H_{12}O_6$; and glucosé, as we have already seen, is a result of chemical rather than of protoplasmic action (p. 44). It gives a bulky yellow precipitate with the reagent known as Fehling's solution, which Cane-sugar does not.

No account of the peculiar juices of plants would be satisfactory which excluded a reference to the milk-sap, or *latex*. This fluid, though clear



Photo by

[E. Step.

FIG. 74.—CELANDINE (*Chelidonium majus*).

A plant that must not be confused with the Lesser Celandine, which is not related. The Celandine is a member of the Poppy family. Its sap is milky but of a yellow colour. EUROPE and W. ASIA.

while in the uninjured tissues, instantly becomes turbid on exposure to the atmosphere. The colour of the latex is usually milk-white; but yellow, red, and, in rare cases, blue milk-saps are met with. The microscope shows that it consists of a colourless fluid wherein float myriads of minute globules, which give the sap its opaque appearance. The Dandelion (*Taraxacum officinale*) and Celandine (*Chelidonium majus*) are familiar instances of latex-yielding plants. The latter exudes a bright yellow juice if the leaf or stalk be broken. Lettuces, again, when allowed to run up to flower, yield a white

milky fluid; and both caoutchouc (indiarubber) and the opium of commerce are simply the dried juices of two world-known plants; caoutchouc being obtained from *Hevea brasiliensis*, a tall tree of tropical America, and other trees, and opium from the large Opium Poppy (*Papaver somniferum*).

The production of caoutchouc by the various species of rubber trees is not so much that man may wear mackintoshes and tennis shoes, play golf and have rubber tyres to his cycle and motor-car, but that the tree may be protected from boring insects and other afflictions. Mr. Belt makes this clear by telling us* that rubber trees which have been drained of all their milk-sap get into an unhealthy condition, and are soon riddled by boring beetles. If a beetle or a woodpecker begins to bore into a healthy tree, the latex is at once poured



Photo by]

[E. Step.

FIG. 75.—CRUDE RUBBER.

A section through a lump of native rubber from the Niger. In this condition it contains many impurities, being merely the coagulated sap as it has exuded from incisions in the tree.

into the wound, and its poison will drive off the bird, or kill and make a prisoner of the beetle. So freely is this latex poured out to repair any such injury, that it flows in a thin stream down the trunk and, soon coagulating, produces a long, thin, elastic cord, which the natives use for tying up bundles. This, no doubt, first directed man to the valuable nature of indiarubber; and who can properly estimate the importance of that discovery?

* *Naturalist in Nicaragua.*



Photo by]

[E. Step.

FIG. 76.—WOOD-SORREL (*Oxalis acetosella*).

One of the most charming of our native wild flowers. Its pure white flowers are streaked with hair-lines of purple. Its trefoil leaves close down upon the stalk at night and during rain. Natural size. EUROPE, N. AFRICA, N. ASIA, N. AMERICA.

Professor Kerner relates some curious facts to illustrate the protective purposes of the milky juices of plants. These protective juices are not, as in the case of the acid juices already referred to, required to keep off birds and mammals, but to shield the plants, and particularly the floral organs of plants, from the depredations of ants and other insects. Kerner's observations, recorded in his *Flowers and their Unbidden Guests*, were confined



Photo by]

FIG. 77.—POPPY-HEADS.

[E. Step.

The seed-capsules of the Opium-Poppy (*Papaver somniferum*). One to the right is cut open to show the divisions of the interior. The others show the open doors under the roof which regulate the dispersal of the seeds.

to two species of the Lettuce family—*Lactuca angustana* and the Garden Lettuce (*L. sativa*); and he thus describes the effects of the flow of juice on some ants whose little hooked feet had cut through the epidermis of the plants in certain places, and thus induced the flow: "Not only the feet of the ants, but the hinder parts of their bodies, were soon bedrabbled with the white fluid; and if the ants, as was frequently the case, bit into the tissue of the epiderm in self-defence, their organs of mastication also at once became coated over with the milky juice. By this the ants were much impeded in their movements, and in order to rid themselves of the annoyance to which they were subject, drew their

feet through their mouths, and tried also to clear the hinder part of their body from the juice with which it was smeared. The movements, however, which accompanied these efforts simply resulted in the production of new fissures in the epiderm, and fresh discharges of milky juice, so that the position of the ants became each moment worse and worse. Many of them now tried to escape by getting, as best they might, to the edge of the

leaf, and letting themselves fall from thence to the ground. Some succeeded, but others tried this method of escape too late; for the air soon hardened the milky juice into a tough brown substance, and after this all the strugglings of the ants to free themselves from the viscid matter were in vain. Their movements became gradually fewer and weaker, until finally they ceased altogether."

Latex-yielding plants increase in number as we approach the tropics. The milk-sap is in some cases extremely nutritious; but mostly poisonous in the highest degree. The juice of one species of *Euphorbia* (*E. balsamifera*), thickened into a jelly, is eaten as a delicacy by the inhabitants of the Canary Islands;

and the Singhalese use the latex of the Ceylon Cow-tree (*Gymnema lactiferum*) exactly as we do milk—a fact which perhaps accounts for what Miss Gordon Cumming calls their "invincible objection to cow's milk."* The South Americans have their Cow-tree also (*Galactodendron utile*), a native of Venezuela, where it forms large forests. If a tolerably large incision be made in the trunk of one of these trees, it will yield a quantity of rich sweet milk, sufficient to satisfy the hunger of several persons. "What most interested us" (in the virgin forest near Pará), says Dr. Wallace in his *Travels on the Amazon*, "were several large logs of the Milk-tree. On our way through the forest we had seen some trunks much



FIG. 79.—AN OLIVE WITH PART OF THE FLESH REMOVED TO SHOW THE STONY CENTRE.

notched by persons who had been extracting the milk. It is one of the noblest trees of the forest, rising with a straight stem to an enormous height. The timber is very hard, fine grained, and durable; and is valuable for works which are much exposed to the weather. The fruit is eatable and very good, the size of a small apple and full of a rich and very juicy pulp. But strangest of all is the vegetable milk, which exudes in abundance when the bark is cut. It has about the consistence of thick cream, and but for a very slight peculiar taste could scarcely be distinguished from the genuine product of the cow." Some notches

* "This prejudice has been in a measure conquered in the immediate neighbourhood of towns where foreigners require a regular supply; but (like the Chinese) no Singhalese man, woman, or child seems ever to drink cow's milk, though a little is occasionally used in the form of curds and eaten with *ghee*, which is a sort of rancid butter."—*Two Happy Years in Ceylon*, by C. F. Gordon Cumming, vol. i. p. 113.

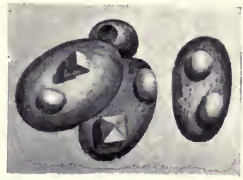


FIG. 78.—CRYSTALLOIDS AND GLOBOIDS IN ALEURONE GRAINS.

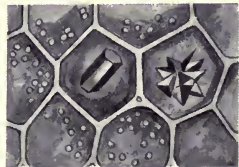


FIG. 80.—CRYSTALS IN CELLS OF ONION (*Allium*).



FIG. 81.—RAPHIDES
OF A SPECIES OF
FUCHSIA.

having been cut in the bark of one of these trees with an axe, "in a minute the rich sap was running out in great quantities. It was collected in a basin, diluted with water, strained, and brought up at tea-time and at breakfast next morning. The peculiar flavour of the milk seemed rather to improve the quality of the tea, and gave it as good a colour as rich cream; in coffee it is equally good."

Travellers would doubtless be thankful if the milk-saps of all plants were as nutritious as the milk-sap of the American Cow-tree; but it has been otherwise ordained. Some, as we have already remarked, are extremely injurious. The latex of the famous Javan Upas-tree (*Antiaris toxicaria*) is a deadly poison, and will produce large blisters and painful ulcers on the person who incautiously touches it. In the juice of the Mandioc-root (*Manihot utilissima*)—from which the tapioca of our shops is prepared—the Indian of Guiana dips his arrows to poison them; and the juice of a South African Spurge (*Euphorbia caput-medusæ*) is used by the natives of Bechuanaland for the same purpose.



FIG. 82.—CYSTOLITH FROM LEAF OF
DIARUBBER-PLANT.

Sugar, inulin, and starch are largely used by the protoplasm in the formation of cellulose for the cell-walls in young plants; as are also the fixed or fatty oils—olive, rape, poppy, palm, etc. (see p. 58)—which swim in the cell-sap in the form of minute, shining yellow globules. These plastic substances—all originating in protoplasm—are stored up as reserve material in the cells of seeds, bulbs, etc., though each has to undergo various changes before the final conversion into cellulose is effected. Chief among these changes is their transformation into the soluble substance *glucose*, or grape-sugar, already mentioned, which is conveyed through certain conducting cells to that part of the plant where new cells are being formed. How admirable is the wisdom directing this complicated process! Had the glucose been deposited in the first instance, it must have undergone fermentation, and thus would have become worthless before the plant was ready to make use of it; but the deposition of starch (or its equivalent), which can remain unchanged for almost any length of time, and which can at any moment be converted into sugar, secures the desired object in the most effectual manner.



FIG. 83.—CYSTOLITH.
Crystals in a cell of Walnut-tree (*Juglans regia*).

The process is known as *metabolism* (Greek *metabolē*, a changing)—a term which is very comprehensive. It includes, indeed, not only all the chemical changes which take place in the protoplasm, but the resulting phenomena



FIG. 84.—BAMBOO (*Bambusa arundinacea*).

The Bamboo is a gigantic grass, growing to a height of 50 or 60 feet. It is a native of the East Indies and China. In the latter country it is also carefully cultivated as one of the most useful of plants from which the Chinaman gets almost everything he requires.



Photo by]

[E. Step.

FIG. 85.—FLOWERS OF SORREL (*Rumex acetosa*).
The Sorrels are not related to the Wood-sorrel, but to the Dock.
The similar names have been bestowed because both contain sharp
juices due to the presence of oxalate of potash in their tissues.
Slightly reduced. NORTHERN TEMPERATE AND ARCTIC REGIONS.

as well. Thus the substances known as *secondary* or *by-products*, such as volatile oils, resin, tannin, pectin, acids, wax, etc., are results of metabolism; so, too, are the substances called *degradation-products*, which are formed by the breaking down and partial dissolving of organized structures. To this class belong the mucilage of quince-seeds and linseed, and many kinds of gum, in some of which—as the Gum Tragacanth—the organization of the cell-walls used in their formation may be detected. The gum named is obtained from the Great Goat's-thorn (*Astragalus tragacantha*), a Levantine shrub, from the bark of which it exudes spontaneously at certain seasons of the year, when it coagulates and hardens and is then ready to be collected.

How marvellous are these changes when considered as the results of protoplasmic activity! What miracle-workers are our little protoplasts! What a box of wonders is every living cell! "They may be regarded," as Dr. Taylor pleasantly remarks, "as so many organic chemical laboratories, in which synthesis is carried on even more vigorously than analysis. Some are starch manufacturers like Colman, as in the potato and other tubers and bulbs; some are perfume distillers like Rimmel, as the cells in the leaves of Sweetbriar (*Rosa rubiginosa*), Lavender (*Lavandula*), and Mints.

(*Mentha*). Every cluster of cells has a work to do—sometimes special kinds of work, but usually generalized kinds.”

We would remark, further, that the reserve materials which we have been considering (not the degradation- and by-products, but the nutritious substances) fall naturally into two great divisions. The first division comprises those substances which, like protoplasm, contain the elements carbon, hydrogen, oxygen, nitrogen, sulphur, and perhaps, in some cases, phosphorus. They are *essentially* the plastic materials out of which the protoplasm produces its wonderful transformations. Hence the name *proteids*



Photo by]

[E. Step.

FIG. 86.—LIME (*Tilia*).

The flowers of the Common Lime are here shown with their remarkable leafy bracts. EUROPE.

has been bestowed upon them, from Proteus, the fabulous old man of the sea, who possessed the remarkable power of changing his form. The substances comprised under the second division are distinguished from proteids by the absence of nitrogen and sulphur, whence they are frequently called the *non-nitrogenous compounds*.

The proteids include such substances as *gluten*, which forms a great part of the corn-grains, and which is identical in its composition with albumen, the basis of animal tissues; *legumin*, which exists largely in the pea and bean; and *aleurone-grains*, which are abundant in oily seeds, and which almost always enclose other bodies—namely, crystalloids and globoids

(fig. 78). The non-nitrogenous compounds, which invariably contain the elements carbon, hydrogen, and oxygen, are starch, sugars, inulin, and fatty oils.

As to the *fixed* or *fatty oils*. One of the most valuable of these is olive oil, which is obtained from the Olive (*Olea europea*), a shrubby tree cultivated with great care in Spain, Italy, Syria, and other countries on the shores of the Mediterranean Sea. The oil is contained in the drupe (fig. 79). The Olive harvest in Italy and Spain produces £9,000,000 or £10,000,000 a year. Palm-oil is obtained from the fruit of various Palms, and approaches to the condition of ordinary fat; so that it is well adapted for the manufacture of candles. It constitutes an important article of food in those countries where Palms abound. The Flax-plant (*Linum*) yields the valuable linseed-oil, which is expressed from the seeds and largely used after distillation in the preparation of paint. The pressed seeds from which the oil has been

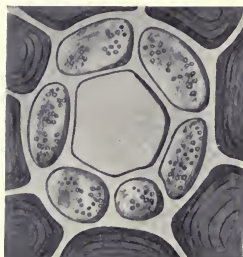


FIG. 87.—SCOTS PINE (*Pinus sylvestris*).

A section of tissue showing the resin passage (in the centre).

partly extracted constitute the oil-cake often given to cattle on account of its fattening properties. Rape-oil is extracted from the seeds of the Rape-plant (*Brassica napus*), and is the oil best adapted for the lubricating of machinery; while the seeds of a species of Poppy (*Papaver somniferum*) supply the oil of that name; and those of the monkey-nut (*Arachis hypogea*) yield the well-known ground-nut-oil, which is largely used in India, Java, and Malacca both for lighting purposes and for food. The fatty oils may be coloured black with osmic acid, or pink by alkanna, and are soluble in ether.

Crystalloids, to which reference was made a paragraph or so back, must not be confounded with true crystals. They resemble them in appearance, but are essentially different, being capable of swelling up when treated with certain reagents, which true crystals are not. They are to be met with in most oily seeds, as the seeds of the Castor-oil-plant (*Ricinus communis*), and are not uncommon in the tuber of the potato. In the latter they take a cubical form, and on being immersed in water split up like a pack of cards, without dissolving (fig. 78).

True *crystals* (fig. 80) are far more plentiful in vegetable tissues than crystalloids; for which reason they call for more extended notice. Plants of the Cactus tribe (*Cactaceae*) usually contain a great quantity of oxalic acid, which would be deadly to the plants were it not that they take up from the soil a proportionate quantity of lime; and this combines with the acids in insoluble crystals. The Old-man Cactus (*Cactus senilis*) is computed to contain as much as 85 per cent. of oxalate of lime; and it often happens with certain species of this tribe that their tissues become so loaded with



[Photo by]

[E. Steg.]

FIG. 88.—WOODLAND OAK-TREES (*Quercus robur*).

Oaks produce an abundance of tannin, of great use in the arts. It imparts a bitter taste to all parts of the tree, especially to its seeds or acorns, and to some of the fungi that are parasitic upon it. EUROPE, S. AMERICA, S. ASIA.

crystals as to render the plants quite brittle. Dr. Carpenter, in his work on the microscope, relates that when some specimens of *Cactus senilis*, said to be a thousand years old, were sent to Kew Gardens from South America some half-century ago, "it was found necessary for their preservation during transit to pack them in cotton like jewellery," so fragile were they from the quantity of crystallized acid in their tissues.



Photo by]

[E. Step.

FIG. 89.—MARJORAM (*Origanum vulgare*).

One of the most fragrant of our herbs, whose masses of purple flowers cover acres of dry chalk-land. It belongs to the family of Labiates, or lipped flowers. One-third of natural size. EUROPE, N. AFRICA, N. ASIA.

Plant crystals are always formed of oxalate of lime or potash. The lime enters the plant as sulphate of lime, and when the sulphur—afterwards used by the protoplasm in the manufacture of new proteids (p. 57)—has been separated by the protoplasts, the lime combines with the oxalic acid already in the plant, and crystallization takes place. The crystallized acid has much the appearance of Epsom salts, but it is highly poisonous.

Never speak of the formation of crystals as "growth." This has sometimes been done, even by writers of considerable reputation, but it is a mistake. Only living matter can be truly said to grow; and crystals are not living matter. The processes of crystal formation are

entirely different from the wonderful and all but miraculous life-processes of protoplasm. The first are purely chemical in their nature, and may be successfully imitated in the laboratory; the second are vital rather than chemical, and defy imitation. A schoolboy may be taught to make crystals; the most skillful chemist cannot make a grain's-weight of living matter. "The processes are absolutely distinct," says Professor Beale, "and the 'growth' of living things implies Life, and such growth never occurs in the absence of Life."

True crystals are found in the epidermal cells of the leaf of the *Iris* and the *Fuchsia*. In the latter, they are disposed in little bundles, and look like so many broken pieces of needle—whence the name *raphides* (Lat. *raphis*, a needle) which is sometimes applied to them (fig. 81). Stellate crystals are met with in the bark of the Lime-tree (*Tilia*); cubical in the Onion (*Allium*); and sphere crystals in one of the Stinkhorn Fungi—viz. *Phallus caninus*. A good slide for showing the cubical crystals of the Onion may be made by soaking a little of the brown skin of the bulb in turpentine till it is quite clear, and then mounting in balsam. In Switzerland, oxalate of potash is



Photo by]

FIG. 90.—WILD THYME (*Thymus serpyllum*).

[E. Step.

A familiar wild plant with trailing stems, neat small leaves, and pale purple flowers. Like Marjoram a Labiate, and aromatic. Slightly reduced. EUROPE and N. ASIA.

prepared from the leaves of the Common Sorrel (*Rumex acetosa*) and Wood Sorrel (*Oxalis acetosella*), so plentiful are the crystals in their tissues.

The cell-walls of the epidermis of some plants of the great Nettle order (*Urticaceae*) and a few others increase in thickness in a very peculiar manner, the deposit taking the form of bladder-like growths containing carbonate of lime. The cells of the Indiarubber-plant (*Ficus elastica*) and Common Walnut-tree (*Juglans regia*) show these remarkable ingrowths very distinctly (figs. 82 and 83). They have been christened *cystoliths* by the learned, a name derived from the Greek *kustis*, a bag or bladder, and *lithos*, a stone. Minute punctiform cystoliths, which reflect the light, are the cause of the

white spots on the downy leaves of those curious shrubby plants, the *Boehmeria*, a tropical genus of the Nettle order.

Closely allied with crystals are certain by-products of a more adventitious kind known as "vegetable stones." A large proportion of these are formed and deposited in the tissues from the siliceous and calcareous substances which circulate with the sap. Thus, in the Bamboo, a round stone is found at the joints of the cane, called "tabasheer"; and in Java and other East India islands, round and pear-shaped stones of carbonate of lime are sometimes found in the endosperm (the edible albuminous part) of the coco-nut.



Photo by]

FIG. 91.—WALNUT-TREE (*Juglans regia*).

[E. Step.

This photo shows the Walnut-tree in its winter condition, with the manner of its trunk divisions, and branch and twig ramifications. From GREECE to the HIMALAYA.

In appearance they are almost lustreless, and not unlike a white pearl. They are often as large as cherries and as hard as felspar. The natives of the Celebes put high value on these vegetable opals, using them as amulets and charms against disease.

Among the other substances which come under the category of by-products may be mentioned the *volatile* and *aromatic oils*, so useful in medicine and perfumery. Of these our naturalized and British plants supply not a few, as every one knows who is acquainted with such old favourites as Lavender and Rosemary, Spearmint and Peppermint, Thyme



Photo by

[E. Step.

FIG. 92.—HEMLOCK WATER-DROPWORT (*Eranthe crocata*).

A beautiful but highly poisonous plant that grows in marshes and by the waterside. About one-third of the natural size. EUROPE (BRITAIN to SPAIN and ITALY).

and Marjoram, which all yield aromatic oils. Yet we must turn to hotter countries for the perfumes most prized and coveted, and especially to the inter-tropical regions. Thus Turkey (chiefly the Roumelian provinces), Persia, and the Rajpootana States supply the fragrant attar-of-roses, which is obtained by distillation from the petals of that flower. The quantity of rose-petals required to furnish a teaspoonful of this princely perfume is almost fabulous, and sufficiently accounts for the high price which the oil commands. The London market is chiefly supplied from Roumelia, whose average annual output is from thirty to forty hundredweight.* About 12,000 persons in this region depend entirely upon this source of income. The Turkish attar is usually adulterated either with the oil of *Geranium* or of the Indian Khus-khus Grass (*Andropogon*). There are two other kinds of attar, both of Indian extraction—namely, the Jasmine and Keova, the former being a production of the Large-flowered Jasmine (*Jasminum grandiflorum*), and the latter of the fragrant flowers of the Screw-pine (*Pandanus odoratissimus*). Then we have oil of cloves and of cinnamon, of cumin and of camphor, of lemons and of bitter almonds, of turpentine and eucalyptus—all aromatic oils of more or less value; while the peculiar scent and great durability of russian leather is attributed to the employ-



Photo by]

[E. Step.

FIG. 93.—ASPEN (*Populus tremula*).

The Aspen is one of the Poplars, but has its smaller, more coarsely toothed leaves on longer flattened leaf-stalks which allow of the constant lateral movements for which the tree is famous. EUROPE, N. AFRICA, N. ASIA.

* It is said that 100,000 roses yield only 189 grains of attar!



GLORY PEA (*Climulbus daupieri*)

A leguminous plant, native of the desert regions of Australia and New South Wales. The pale green foliage is covered with fine white hairs. There are five or six flowers in a cluster, and each measures four or five inches. It is occasionally seen in cultivation in this country, but will succeed only in a hot, dry, sunny situation.



Photo by

FIG. 94.—BIRCH (*Betula alba*).

[F. Step.

A spray showing the delicacy of the twigs, the light character of the foliage, and the short cylindrical cones.
EUROPE, N. ASIA.

ment, during the process of tanning, of a volatile oil obtained by the distillation of Birch bark (*Betula*). The oil has a brown or black colour, and a little of it poured on paper and allowed to dry gives to the paper the scent peculiar to russian leather. On a future occasion, when the odours of flowers in relation to insects will be our subject, allusion will be made to Kerner's helpful classification of the aromatic oils, and some further light will be thrown on this very interesting subject.

Professor Tyndall found that infinitesimal quantities of these essential oils thrown off into the air enormously increased its power of absorbing heat-rays of low tension; and Dr. George Henderson, F.L.S.,* has suggested that in this way these oils may often prevent injury from frost at one of the most critical periods of a plant's life, namely, when it is setting its fruit. He says, "In the low hills of the Punjab Himalaya, from 1,000 to 4,000 feet above the sea and 10 to 20 miles across, in the end of March and in April, when most of the plants are coming into flower, the blossoms are apt to be blighted by late frosts, at least one would expect this; but at that season the air is filled with the odours of essential oils from these blossoms to such an extent as to be at times (and especially on a still night, when frost most often occurs) quite overpowering. My theory is that these essential oils

* *Proceedings of Linnean Society*, 1903.



Photo by]

[E. Step.

FIG. 95.—CONE OF SABINE'S PINE (*Pinus sabiniana*).

One of the finest of the Pine-cones, measuring 8 or 9 inches in length. The tree is a native of California, where it grows to a height of 50 or 60 feet.

help to prevent radiation at night, and thus preserve the blossoms and allow the fruit to set; after all, it is usually only a matter of four or five degrees' fall of temperature just at sunrise that does all the damage."

We may add that the oil of Birch bark mentioned above is simply a form of *tannin*, which is one of the most widely distributed of secondary products. Its characteristic reaction is that of forming insoluble compounds with gelatine, solid muscular fibre, skin, etc., which then acquires the property of resisting putrefaction, as in the tanning of leather. Kerner has pointed out that its extremely bitter taste protects the branches, cortex, and fruits from being eaten. The plants which furnish most of the tannin of commerce are the Oak (chiefly *Quercus sessifolia*, *infectoria*, and *pedunculata*), Hemlock Spruce (*Abies canadensis*),

Red Pine (*Pinus contorta*), and Water-smartweed (*Polygonum amphibium*).

Other by-products of metabolism—and the last that we shall here speak of—are *resins*, *waxes*, and *balsams*, which naturally fall into one group.

Young buds are often coated with a balsam (*i.e.* a solution of resin in an ethereal oil) to protect them from cold and wet during the winter and early spring. The Horse-chestnut (*Æsculus hippocastanum*) and Balsam Poplar (*Populus balsamifera*) offer familiar examples of these varnished buds. Again, the stems of many plants of the Clove order (*Caryophyllaceæ*) are plentifully supplied with a sticky solution formed of resin and gum, which effectually forbids the approach of insects to the flower along that route; while resin-ducts are largely present in trees of the Terebinth and Cone-bearing orders (*Anacardiaceæ* and *Conifereæ*). The resin-producing capabilities



Photo by]

[H. J. Shepstone.

FIG. 96.—GIANT CACTUS (*Echinocactus*).

A native of Mexico. The spines are sufficiently long to be used as toothpicks. A similar plant, about seven feet high and weighing a ton, was once received at Kew, but the injuries to its succulent flesh in transit were such that it did not long survive.



Photo by]

FIG. 97.—WHITE WILLOW (*Salix alba*).

[E. Step.

The upright spikes are the female catkins. At the extremity of the shoot the new leaves are just emerged from the leaf-buds. EUROPE, N. AFRICA, ASIA.

of the Pine family are, indeed, phenomenal, one and a half or even two pounds being frequently obtained from a single tree at each tapping (fig. 87). The Maritime Pine (*Pinus pinaster*) is perhaps the most prolific of all. It begins to yield abundantly when twenty-five or thirty years old, and when the process is well managed will continue to yield for a very long time. There are Pines at La Teste, in France, with as many as sixty scars of places where they have been tapped, evidence that the working of these trees goes back at least three centuries.

The production of resin by the Pines appears to be a protection from the attacks of Fungi. It is most abundant in their trunks just above the roots, from which many of the most deadly of the tree-fungi obtain access. To the fact that roots of trees are often injured by the gnawing of rodent animals many a noble tree falls a victim to fungus, the entire bark being impervious to the attack of the fungus. This broken, a germinating spore—probably brought in the fur of the mouse that gnawed the root—obtains access to the layers of bast-tissue up which its mycelium can extend without limit. Torn limbs offer a similar opening. In the case of the Scots Pine, broken limbs rapidly have the wound closed by an outpouring of resin, which coagulates and closes all the pores. Pine-trees in plantations often have their roots torn by the spades of careless woodmen when cutting drains. The fungus thus gains entrance, for the roots are deficient in resin,

but just above it is so abundant that further progress of the mycelium is stayed. The Spruce and Weymouth Pine are not so rich in resin, and up their trunks the mycelium of the deadly *Fomes annosus* spreads rapidly, causing the condition known as red rot.

Wax is another frequent vegetable production, especially in the torrid zone, where many of the wax-bearing plants supply the natives with light. This substance gives the bloom to the plum, cherry, and grape; and "the raindrops lie on the waxy surface of the Cabbage-leaf like balls of diamond, from the total reflection of light at their points of contact." Wax is secreted in the cuticle for the purpose of getting rid as rapidly as possible of the water which is deposited on the surfaces of the leaves, or to prevent excessive loss of water by transpiration—the latter an invaluable provision in the Aloe, Cactus, and other fleshy leaved plants inhabiting the hot, parched regions of the tropics. A further use is noticed by Kerner. He tells us that the branches of many Willows which bear honey-laden flower catkins are provided with wax-like coverings (combinations of fatty acids with glycerine), so extremely smooth and slippery that would-be visitors to the flowers (unserviceable, honey-thieving ants for the most part) strive in vain to accomplish the ascent.

The delicate waxen bloom of many plants presents some curious forms under the microscope. The bloom on the Rye, familiarised in a once popular



Photo by]

FIG. 98.—PINE FUNGUS (*Fomes annosus*).

[E. Step.

This fungus attacks Pine-trees chiefly through injured roots, and spreads thence up the trunk. The Scots Pine has an abundant store of resin just above the roots which prevents the upward progress of the fungus. It is the cause of "red rot."



Photo by]

[E. Step.

FIG. 99.—COWBANE (*Cicuta virosa*).

An Umbelliferous plant that grows in watery places, and is highly poisonous. About one-fourth the natural size. EUROPE, N. ASIA.

song, consists of dense agglomerations of rods or needles, and is a most interesting object for examination. So, too, is the wax coating of the leaves of the Banana (*Musa*), which consists of little rods that stand erect on the cuticle like so many Lilliputian posts; while the "frosting" of leaves is made up of tiny granules of wax.

It is worthy of remark how much the production of these and other secretions depends upon the intensity of light and heat. Plants that will grow well enough in a climate very different from that to which they have been accustomed, will, nevertheless, frequently cease to form their peculiar secretions, or at least produce them in very diminished quantities. This accounts for the fact that the Tobacco grown in this country is so vastly

inferior to that grown, say, in Cuba or Persia; and to the same cause may be traced the great scarcity in English-grown roses of the fragrant attar already spoken of, which is comparatively abundant in the flowers cultivated for that product in India, Persia, and Roumelia.

Most of the fragrant balsms are the products of warmer countries than our own—in fact, some of those of greatest repute are obtained from places that are hot and dry, such as Arabia and Somaliland. Thus, the Frankincense (*Olibanum*) of the Bible narrative is a resin obtained from species of *Boswellia* which grow in Arabia. It is obtained by making cuts in the bark of the tree, from which the resin is poured out to stop the entrance of parasites. When dried by the sun the resin is scraped off. Other resins coming under the head of Frankincense are Galbanum from *Ferula galbaniflua*, a Persian plant, and Storax from *Styrax officinale* in the Levant. Myrrh is the most ancient of all these aromatic substances: it is obtained from a plant known as *Commiphora myrrha*, a native of Arabia, also found in Eastern Africa. Balm of Gilead is obtained from *Balsamodendron gileadense*, a tree of Palestine; and Ladanum is a sticky



Photo by]

[E. Step.

FIG. 100.—THE LADY FERN (*Athyrium filix-fœmina*).

One of the most delicately graceful of our ferns. Its soft-textured fronds transpire water readily, and therefore it grows where there is an abundance of free moisture in the soil. Here, by the wayside rill, shaded by overhanging trees, is an ideal spot for it, to which it has added a considerable element of beauty. Distribution, world-wide.



Photo by]

[E. Step.

FIG. 101.—THE MALE FERN (*Nephrodium filix-mas*).
One of the most robust of our ferns. In contrast to those of the Lady Fern, its fronds are thick-textured, and it can grow in drier situations.
TEMPERATE REGIONS.

secretion from the leaves of *Cistus creticus*, which is gathered in the island of Crete by dragging leathern straps over the plants. The Ladanum adheres to the straps, and when they are well coated it is scraped off and used in the preparation of a perfume.

The scent of Lavender, remarkably enough, is more powerful in British-grown plants than in those cultivated in the south of Europe, its native habitat, much light and heat being unfavourable to the production of the fragrant oil. Equally curious is the statement—the truth of which is vouched for by Dr. Christison—that the Cowbane (*Cicuta virosa*) and Hemlock Water-dropwort (*Eranthe crocata*), which are poisonous in most districts of England, are innocuous when grown near Edinburgh! The statement seems hardly credible,

and though supported by so high an authority as Dr. Christison, should be received—if received at all—with considerable caution. We do not remember whether the statement has been tested—certainly we should not expect Scottish stock owners to experiment with it upon their cattle, for at intervals one reads in the newspapers that valuable beasts have been killed through eating the plant. Too much care cannot be taken in dealing with plants of this Natural Order—the Umbelliferae—for though it yields us such valuable cultivated plants as Carrot, Parsnip, Parsley, and Celery, it also includes Hemlock and other virulent poisons.

CHAPTER III

CELL COMMUNITIES: A CHAPTER ON TISSUES

Cell joined to cell, mysterious Life passed on
By viscous threads; selecting in its course,
From formless matter, with mysterious touch
That seems a prescience, and that never errs,
Materials diverse, out of which to weave
The warp and woof of tissues.

EVERY plant, as already mentioned, consists either of a cell or cells, or of the products of their formation and transformation. When a Rose-tree begins to grow, its growth is not effected merely—nor chiefly—by the increase in size of already existing cells, but by the formation of cells entirely new; and this is true of all multicellular plants. Of course, *cell multiplication* (as it is called) also takes place in unicellular plants. This we saw to be the case with *Sphaerella pluvialis*; but in such instances the new cells become distinct individuals; they cease to form part of the parent plant, and enter upon an entirely independent existence.

Now, cells may multiply in four ways. *Free cell formation* is one of these; and we take this mode of increase first, because it is the means by which both the resting and zoospores of *Sphaerella* are produced. The pollen-grains of most Flowering Plants are formed in this way, as well as many zoospores besides those of *Sphaerella*. The process has been already described at some length, and there is no need to go over the ground again.

Sometimes, however, the entire protoplasm of the parent cell, instead of dividing off into several individuals, is used up in the formation of a *single* new cell. This mode of cell formation, which is like a renewing of the youth of the individual, is appropriately termed *rejuvenescence*.

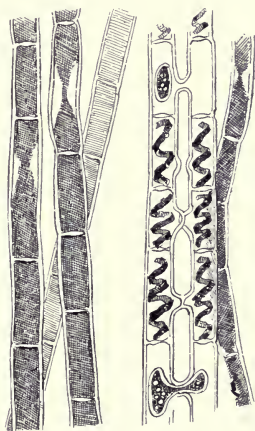


FIG. 102.—SILKWEED OR CROW-SILK.

Portions of the filaments of six separate plants. In the second three filaments ten of the cells are seen to be in various stages of conjugation.

In a few forms of vegetable life the protoplasm of two or more cells coalesces for the purpose of reproduction, and this is known as *conjugation*. Here (fig. 102) are some cells of a little fresh-water weed, *Zygnema quinium*, common enough in our ponds and ditches, and popularly known as Silkweed or Crow-silk. Each of the pale yellow-green filaments represents a separate plant, and is built up of a single row of cells; but when conjugation is about to commence, the cell-walls of two distinct filaments that happen to float in proximity form blunt projections from their sides, and reach out to one another till they meet. Then, at the points of contact, those portions of the walls which hinder communication between contiguous cells dissolve away; the sap at once occupies the passage thus formed; and the protoplasm from one of each pair of united cells, forcing its way through the narrow channel, fuses with the protoplasm in the companion cell, and so conjugation is effected.

But a far more common method of increase than any which we have yet considered is that which is known as *cell division*. Increase *in length* of

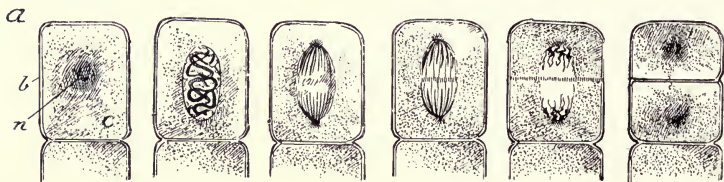


FIG. 103.—INDIRECT NUCLEAR DIVISION (*vide text*).

every filamentary plant of Silkweed was due to cell division: the cells of the fragment of Onion-skin which we were speaking of in the previous chapter multiplied in this way; so did the star-shaped cells of the Common Bean lately mentioned. Indeed, the vegetative organs of most plants (as distinguished from the reproductive organs) are almost always so formed.

But what is cell division? To say that all normal vegetable growth takes place by such means is no explanation of the process; we are only moving in a circle. Will you follow an attempt to illustrate the process by means of a few diagrams? We will suppose that the first sketch (fig. 102) represents a row—or part of a row—of vegetative cells, of which the uppermost is about to divide. Here (fig. 103) is this cell on a larger scale, with its cell-wall (*b*) and its granular protoplasmic contents (*c*), in the midst of which is drawn a circular disc to represent the nucleus (*n*). Changes in the nucleus intimate that the process has commenced. The nucleus elongates, and its delicate *fibrille*—delicate even under the highest powers of the microscope—appear at this stage to interlace in a confusing manner. A little later the tanglement is over, and the *fibrille* are seen to be converging to one or the other of the poles of the nucleus. Between these *fibrille*



Photo by]

[E. Step.

FIG. 104.—REINDEER MOSS (*Cladonia rangiferina*).

One of the Commensal plants known as Lichens. In this country it grows among heather stems, scarcely noticeable in summer, but in winter it greatly increases in size. In the far north it is a plant of considerable importance, and, as its name implies, forms a principal part of the food of the reindeer. Natural size.

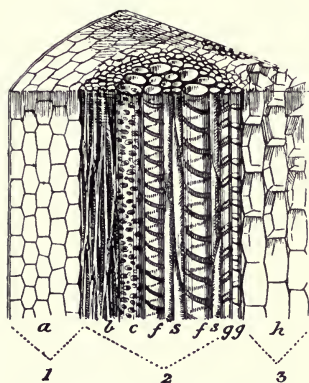


FIG. 105.—PORTION OF STEM OF ITALIAN REED.

1. Outer covering of the stem or integument. 2. Fibro-vascular bundle. 3. Medulla or pith. (a) Tissue of cells (parenchyma); (b) Bast-fibres; (c) Pitted vessel; (f) Spiral vessels; (g) Annular vessels; (h) soft loose cells of pith; (i) Sieve-tubes or bast-vessels.

Such, then, are the principal means of cell multiplication — free-cell formation, rejuvenescence, conjugation, and cell division; and this leads us to another important subject—that of *cell fusion*—with which we may link what little there is to say about vegetable tissues, and then close this division of our subject.

Any set of similar cells, governed by a common law of growth, forms a *tissue*, and two or more cells, coalescing into a single individual by the partial or entire breaking down of their dividing walls, form a *vessel*. The latter process is cell fusion. We have seen an example of tissue already in the stellate cells of the Bean (fig. 44); the fragment of Onion-skin shown in fig. 35 was another example. The diagram now given (fig. 105) offers examples both of vessels and tissues. *c*, *f*, and *g* are vessels, *a* and *h* are tissues of cells. The darkly shaded portion at *b* is woody fibre, of which we shall speak again in a moment. The subject need present no difficulties, as the ground has been already cleared by the remarks upon cell forms and structure; but

new and yet finer threads presently appear, each of which extends from pole to pole, the figure now presented to the eye being that of a miniature spindle in the midst of the protoplasm, and this spindle becomes more and more extended till it stretches across the cell. Meanwhile, along the fibres stream granules of protoplasm, which, gathering where the spindle is widest (*i.e.* exactly midway between the poles), unite to form a plate; while the specks of congested protoplasm which constitute the ends of the spindle become distinct and perfect nuclei. From the plate thus formed is developed in time a wall of cellulose, by which the entire cavity of the mother-cell is divided into two chambers; and then, with the disappearance of the *fibrilla*, the nuclei finally part company, and cell division is accomplished.

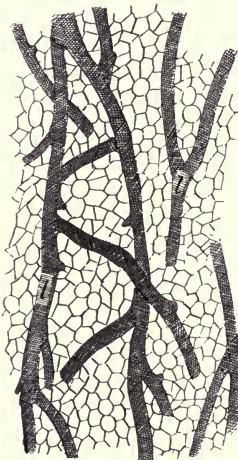


FIG. 106.—LONGITUDINAL SECTION OF A PORTION OF THE CORTICAL PARENCHYMA OF A EUPHORBIA,

Showing laticiferous or branched laticiferous "cell" (l) in the midst of the tissue.

we trust the reader will follow the description closely, as the points to be touched upon are of great importance. We will consider vessels first.

To this end it may be well to take a backward glance for a moment. On pp. 32 and 34 are illustrations of the spiral, annular, reticulated, and pitted cells (figs. 54 and 57). Now, from all of these, vessels may be formed. Place a lot of spiral cells on top of one another, and break away the whole or greater part of each of the partition walls, and you will have a *spiral vessel* (fig. 105, *f*). Do the same with a number of annular cells, or reticulated cells, or pitted cells, and you will have *annular vessels*, or *reticulated vessels*, or *pitted vessels*, as the case may be (fig. 105, *c* and *g*). Of course this could not be done in reality, the vessels being far too small; but we use popular language. Hooke estimated that a cubic inch of oak contains upwards of seven millions of vessels; and another of the old microscopists, Leuwenhoek, computed that the bole of an Oak, only four inches in diameter, contains about two hundred millions! We are not sure whether Damory's Oak in Dorsetshire is still standing; but this tree not many years ago measured eighty-four feet in circumference, and it was then shown by a laborious calculation that more than 240 millions of miles of vessels were packed in a single foot's length of the stem, and that if the vessels contained in the whole tree could be placed end to end in a single line, they would have made a communication backwards and forwards between the sun and every planet in the system! The few thousand miles of piping which underlie London look rather paltry in comparison with this.



Photo by]

[E. Step.

FIG. 107.—CAPER SPURGE (*Euphorbia lathyris*).

A plant frequently grown in gardens, but locally wild in the south of England. Its seed-vessels have been used as a substitute for capers, but they are of a poisonous nature. About one-twelfth of the natural size. S. EUROPE.

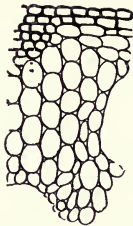


FIG. 108.—PARENCHYMA FROM THE STEM OF THE FIELD HORSE-TAIL (*Equisetum arvense*).

In certain cells of the Ferns and their allies the thickening deposit laid down on the inner surface of the cell-walls takes the form of miniature ladders, on which account the vessels constructed out of these cells (though absorption of transverse septa is rare in Ferns) are called *scalariform*, or ladder-like (Lat. *scala*, a ladder). As a matter of fact, scalariform vessels are only modifications of the reticulated form, from which they differ by the partition-walls of secondary deposit being larger and more regular.

Spiral and annular vessels occur in the stems of most Dicotyledons (plants with two seed-leaves), but only in what is known as the primary wood, which forms the first circle round the pith, and is called on that account the *medullary sheath* (Lat. *medulla*, the marrow of bones); whereas reticulated and pitted vessels are found in the denser internal parts of the woody layers (*vide* Chapter VII.). All of these occur in the leaf-stalks and veins of leaves, and in certain parts of the flower, but never in the bark. They keep the cellular tissue of the leaves stretched and extended, acting like the ribs of an umbrella. In Monocotyledons (plants with only one seed-leaf), they are placed in the interior of the woody bundles of the stem, and sometimes you will meet with them in the root-fibres. In the mature state they contain nothing but air; but occasionally, in the spring, a portion of the sap sucked up by the roots is pressed into them—a process on which depends, for example, the “weeping” of wounded grape-vines (Thomé’s *Lehrbuch*, p. 30).



FIG. 109.—PROSCENCHYMA OF TRAVELLER'S JOY (*Clematis vitalba*).

There is one other kind of elongated cell found in the woody parts (fibro-vascular bundles) of many plants which should not be passed over. We have described it as “woody fibre,” but the scientific name for these vessels is *bast-tubes* or *bast-fibres* (fig. 105, *b*). Bast-tubes must not be confounded with what are known as *sieve-tubes* or *bast-vessels*. The former are long, pointed, and thick-walled, and occasionally, though very seldom, they are branched. The sieve-tubes or bast-vessels, on the other hand, consist of slender flexible tubes, with their walls unmarked by secondary deposit (fig. 105, *s*). The dividing walls of the cells of which the last-named vessels are built are not entirely absorbed, as are the partition-walls in the bast-fibres; but they are perforated in various places so as to resemble a sieve, whence they are called *sieve-plates*, and the vessels, as we have seen, *sieve-tubes*. Not infrequently the side walls of adjoining tubes are also perforated.

If two or three hollow cylinders, covered at each end



[Photo by]

FIG. 110.—YEW (*Taxus baccata*).

In this photo the male flowers are shown together with the foliage. These flowers produce pollen in such abundance that it may be seen to fly off from the trees in clouds. NORTH TEXARKANA HERBARIUM.

[P. 87P.]



Photo by]

[E. Step.

FIG. 111.—LARCH (*Larix europæus*).

The Larch, alone among Conifers, sheds its leaves in autumn. Here are shown the new leaves issuing in spring, together with the male flowers. Native of ALPINE EUROPE.

with parchment, be placed together lengthwise, and holes be driven through the parchment covers so that the cylinders freely communicate with each other, a very fair idea will be gained of a sieve-tube: the perforated parchment covers will, of course, answer to the sieve-plates. These vessels retain their protoplasm, which circulates through the sieve-plates, and they evidently play an important part in the life-history of the plant. The German physiologist, Sachs, was of opinion that much of the new protoplasm is produced in the sieve-tube, and this view is shared by Professor Thomé and other eminent botanists. These also are the vessels which play so important a part in the diffusion of the sugar formed by the chloroplasts in the leaves of plants.

In the leaves and outer bark of many plants, thin-walled vessels of various structure may be met with, which usually run parallel with each other and invariably contain bundles of needle-shaped crystals. These are closely related to the sieve-tubes, and are known as *utricular vessels*. A very large number of plants have them.*

The *laticiferous vessels*, which may next engage us, though of much interest from a physiological point of view, need not detain us long. These vessels, as their name implies, convey the milk-sap or latex to the parts of the plants which require, or, at least, seem to require it; for there is some doubt as to the function of latex—whether it is more than a by-product.

* According to Professor Thomé (*Lehrbuch*, p. 32), they occur in most Monocotyledons, and in some Dicotyledons, being found exclusively in the outer cortex or the foliar organs.

Like the vessels last mentioned, the laticiferous vessels are closely allied to the sieve-tubes, consisting of closed tubes, cylindrical or angular in shape, and usually with thin, transparent walls. They are formed by the union of cells, but not necessarily (and here they differ from most vessels) by the union of a single row of cells. They appear to be bound by no rule of growth, so that some very irregular vessels are often seen which branch out in all directions and form a copious network, with free intercommunication. Their presence is limited, however, to a small number of plants; for the milk-sap of many latex-yielding species is not contained in vessels, but in long, branched, simple cells. The Euphorbias (fig. 107), to which the Spurges and South African Tapioca-plant belong, abound in these cells.

We come now to *tissues*. The sections figured (106-114) preclude the necessity of any very detailed descriptions. They show four kinds of tissue; but some courage is needed to declare their names.

The tissue of cells shown in fig. 108 is known as

PARENCHYMA

(Greek *parenchuma*, the spongy substance of the lungs), and this is the general name of tissues the cells of which are arranged in rows, and which are fairly equal in their dimensions, being almost as long as they are broad.

The tissue depicted in fig. 109 is distinguished as

PROSENCHYMA

(Greek *pros*, beside; *enchuma*, some-



Photo by]

[B. Step.

FIG. 112.—LARCH (*Larix europæus*).

The shoots grow downwards, but the cones bearing the seeds stand more or less erectly.

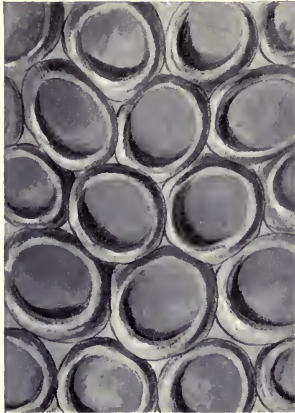


FIG. 113.—COLLENCHYMA OF THE COMMON SOW-THISTLE (*Sonchus asper*).

may be seen to advantage in the leaf-stalks of many Begonias, a transverse section being the best for examination.

The name of the fourth kind of tissue is as tongue-tiring as the others, but we have met with it before—

SCLERENCHYMA.

It will be remembered that the cells from the gritty centre of a pear (p. 31) were sclerenchymatous cells; and it was pointed out that the name is given to thick-walled woody cells in which the protoplasm has been all used up. The section of a plum-stone (fig. 114) shows the same thing. Sclerenchyma comprises, indeed, those tissues the cells of which have become much hardened by secondary deposit, and which contain no protoplasm. It performs the mechanical office of support and strength, and is emphatically *dead* tissue, the very opposite of the tissue to which we next invite attention, namely—

MERISTEM.

Meristem (Greek *meristos*, divided) is the name given to *growing* tissue the cells of which are continually dividing so as to pro-

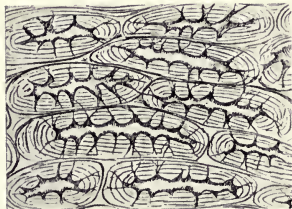


FIG. 114.—SCLERENCHYMA FROM THE STONE OF A PLUM, MADE UP OF LIGNIFIED CELLS.

* The word was formed on the model of "parenchyma" with little regard for derivation (*Text-book of Biology*, p. 409).



[Photo by]

FIG. 115.—CEDARS OF LEBANON (*Cedrus libani*).

[H. J. Shepstone.]



Photo by]

[E. Steg.

FIG. 116.—CONE OF CEDAR-TREE (*Cedrus libani*).

A very hard and solid cone of a purplish-brown tint. The scales are thin, and overlap tightly. The seeds take about three years to ripen. Natural size. MOUNTAINS OF SYRIA.

and flavour of which are derived from minute drops of volatile oil stored up in vast numbers of these little cavities. Glands are frequently external organs, and may be borne upon the ends of hairs, which are then called *glandular hairs*. We find them, for example, in the Chinese Primula. The margins and upper surface of the leaves of our English Sundews (*Drosera rotundifolia* and *D. intermedia*) are provided with delicate glandular tentacles (loosely called "hairs" in many text-books), which are veritable insect-traps. The glands have the appearance of tiny dewdrops, but exude a viscid secretion, by which the thirsty and deluded visitors to the plant are caught and retained—for a purpose which will be explained in the next chapter.

The various kinds of vessels and permanent tissue may be conveniently classed under three heads, which are easily remembered, the arrangement being quite natural. If you take any ordinary leaf—say, the leaf of a Lime—you will perceive that it consists of a thin outer skin, enclosing some tough net-like veins and a lot of soft tissue which fills up the spaces between

duce fresh tissue. These actively dividing cells have thin walls, and no spaces between the cells: they are rich in protoplasm, and always contain a nucleus. From cells of this kind all permanent tissues originate. They are found, therefore, only in the growing parts of plants, as buds, the apex of roots, and in certain parts of the stem. Even sclerenchyma originated in meristem.

Special cells or groups of cells, so disposed as to form cavities in the tissue, are engaged in the formation of the degradation- and by-products (p. 56), and to these the name of *glands* has been given. Thus we have resin-glands, oil-glands, camphor-glands, honey-glands, and others that need not be particularized. They abound, for instance, in the rind of the orange and lemon, the odour

the veins. The outer skin consists of a single layer of cells and is called the *epidermis* (Greek *epi*, upon, and *derma*, skin). The veins are composed in the main of bundles of vessels and long woody cells, and belong to what is called the *fibro-vascular system*; and the soft tissue which constitutes the rest of the leaf is known as *fundamental* or *ground tissue*.

Here, then, we have the three great divisions under which all permanent tissues and vessels naturally fall. Let us go over them again. First, there is the epidermis, a thin cellular covering on the exterior of the plant; secondly, the fibro-vascular system, consisting chiefly of wood-cells and vessels, united in bundles, which extend from the roots to the leaves and really form the skeleton or framework of the plant; and thirdly, the fundamental or ground tissue, which occupies most of the space in the young plant and consists chiefly of parenchyma. The lower plants—that is, the *Fungi*, *Alge*, Liverworts (*Hepaticæ*), and Lichens—have no fibro-vascular bundles, and the Mosses (*Musci*) only contain them in a very rudimentary form. Plants belonging to the Cone-bearing order (*Coniferae*), as the Pines, Larches, Yews, and Cedars (*Pinus*, *Larix*, *Taxus*, *Cedrus*), have wood-cells, but no true vessels, their place being taken by *tracheides*, which are not continuously open. In the higher plants, the wood-cells of the fibro-vascular bundles serve as the channels by which the crude sap, which holds in solution the nutritious principles, is conveyed from the soil to the leaves. The vessels are charged with air.

Before leaving this part of our subject we ought to mention that beneath the single layer of epidermal cells we have in the leaves a layer of elongated cells packed closely side by side in a direction vertical to the surface of the leaf, and these are known as palisade cells, and in the aggregate as



Photo by]

[E. Step.

FIG. 117.—LICHEN ON HOLLY BARK.

This Lichen (*Graphis elegans*) consists of raised dark lines on the smooth bark of the Holly-tree, which look much like the characters of some Oriental alphabet.

palisade-parenchyma. These palisade cells vary in length in different species. Professor Haberlandt suggested that in certain plants the epidermal cells act as ocelli, or primitive eyes, to the plant. The structure of these cells is often lens-shaped, and consequently the rays of light which fall upon them are brought to a focus. He found that by using such cells as lenses he could obtain minute photographs of various objects, the image being focussed upon the basal wall of the cell. When this fact became known in England a few years ago, some of the more sensational newspapers made capital out of it, and explained how plants could see, like animals, and they published drawings that were supposed to be photographs of things "seen through the eyes of plants." Of course, the plant has no nervous mechanism that will enable it to see. For a human being to separate one of these cells

and use it as a lens by which to obtain on the human retina a diminished image of some object is one thing; for plants to be able to see with that lens is quite another matter. But according to Haberlandt's interesting hypothesis, the convergence of the light-rays that pass into these lens-shaped cells causes a differential illumination of the protoplasm on the basal walls of these cells, and sets up a stimulus which results in the leaf being moved into that attitude in which it can obtain the most suitable illumination for its work, in which light plays so important a



Photo by]

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FIG. 118.—*LECANORA PARELLA*.

A Lichen growing on a roofing tile. In such a situation it is evident that the whole of its nourishment must be obtained from the atmosphere. Natural size.

part. Not only is this function being performed by the cells on the upper surface of the leaf, but in a modified degree by those on the lower surface.

It is believed that this convergence or focussing of the light results in the more efficient illumination of the chlorophyll grains. Mr. Harold Wager, F.R.S., who has made many experiments to elucidate the truth of this matter, has shown that under the influence of this convergence the behaviour of the chlorophyll grains is very marked. In a species of *Mesembryanthemum* there are special lens-cells which are equally well developed on both upper and lower surfaces. In *Garrya elliptica*, too, there are special lens-shaped thickenings of the cuticle on both surfaces. It is worthy of note, as supporting the above hypothesis, that, so far as observed at present, epidermal cells of long focus are associated with long palisade cells, and the



Photo by]

[E. Step.

FIG. 119.—SCOTS PINE (*Pinus sylvestris*).

In a pine wood the trunks grow very straight and tapering, due to the fact that a "canopy" of foliage is formed by the upper branches which shuts out light from the lower branches and prevents their growth to any size. In the foreground to the right of the photo will be seen a triplet. Three seedlings started so close together that as they have increased in girth their lower trunks have been squeezed and amalgamated. N. EUROPE, ASIA.

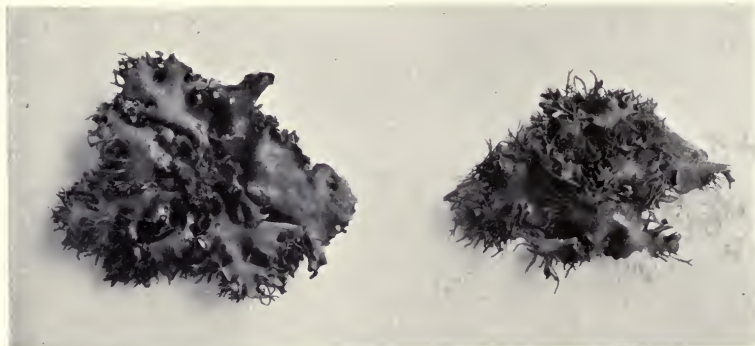


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FIG. 120.—AN ALPINE LICHEN (*Gyrophora cylindrica*).

A dull purplish Lichen with beautifully fringed margins, that grows on Alpine rocks. Slightly enlarged.

surface cells of short focus are connected with short palisade cells. The whole subject, however, is in need of further investigation.

In the leaves of Gymnospermous plants—but not exclusively confined to them—is found a particular form of tissue, known as *transfusion tissue*, which has been the subject of considerable controversy. In the leaves of Conifers and most Cycads it is nearly always found in lateral connection with the vascular bundles, in some genera outside the *phloem*, and in others opposite the *xylem*. The highly developed network of conducting tissue so prominent in the leaves of Dicotyledons is entirely absent from those of the Gymnosperms. "In order to compensate, therefore, for the lack of an efficient conducting system in the leaf, recourse has been had to the development of these peculiar tracheides (often accompanied by bast-cells of similar shape), now known as 'transfusion tissue.' In *Cycas* and many species of *Podocarpus*, in which the broad pinnæ or leaves are traversed by a single bundle, in addition to the normal transfusion tissue, a new and accessory system has been developed, running from the bundle to the margin of the leaf. This, however, . . . is a purely secondary modification of the mesophyll-cells, and bears only a functional relation to the normal transfusion tissue, having therewith no homology whatever. In the pinna of *Stangeria* a dichotomizing system of *closely placed* veins springs from the large central midrib. In the pinnæ of all other Cycads, and in *Podocarpus nageia*, *Dammara*, and *Araucaria*, among Conifers, a system of parallel venation prevails, and here transfusion tissue is markedly developed. The leaves of most Conifers are very narrow, and are traversed by a single bundle, which, in all cases, is provided with well-developed transfusion tissue. *Ginkgo* differs widely from all other Conifers in having a dichotomizing system of bundles traversing its large, fan-shaped leaf,

and has transfusion tissue present in connection with its rather widely separated bundles, though more feebly developed than in most Conifers. . . . It is well known that the bundles of the leaf of Cycads have a structure peculiar to this order and not found in any other living group of plants. Towards the lower surface of the lamina is placed the phloem; next comes the ordinary xylem, which is formed by the cambium in a centrifugal manner; on the inner side of the secondary wood there may or may not be a few elements of primary centrifugal wood, and then follows the protoxylem consisting of narrow, elongated, spirally or reticulately thickened elements. Farther, beyond the protoxylem, *i.e.* between this tissue and the upper surface of the leaf, occurs another strand of xylem, primary in origin, and of much greater development than that of the centrifugal wood; it is *centripetal* in development, *i.e.* its elements are formed successively from the protoxylem towards the upper surface of the leaf; it is characteristic of the Cycadeæ. Typical transfusion tissue occurs at the side of the bundle, and this is seen to be in intimate connection with the centripetal xylem. In the petiole the structure of the bundles is the same, though their orientation is different. In other Gymnosperms and all Angiosperms this tissue is, so far as hitherto observed, absent from the vascular bundle."*

Here we conclude. We have travelled together over a good deal of ground, and the physiological facts which have come before us must

* Mr. W. C. Worsdell, from whom these remarks are quoted, read a paper dealing with this subject at length before the Linnean Society in November, 1897; the paper will be found in vol. v. of the botanical *Transactions* of that Society.



Photo by]

FIG. 121.—CONES OF A CYCAD.

[E. Step.

The Cycads were abundant in Jurassic and Wealden times, but are now very few. They are believed to have been the starting-point from which all our plants with conspicuous flowers (Angiosperms) originated.

have convinced the reader that plants are very wonderful as well as very complex organisms. We claim for them that they are not less wonderful than animals—man alone excepted. Every individual—at least, among the higher plants—is like a little city, athrob with life; in which a pulling down and building up is ever going on; in which there are lanes and alleys, and broadways and aqueducts, and the daintiest of little houses. In one part of the city are the starch factories; in another, the milk-shops; in another, the sugar refineries. Here is the jewellers' quarter, where the crystals are

prepared; here the perfumers', where the most fragrant scents are distilled; here the varnish-makers' and colourmen's. Infinite in variety, marvellous in execution, is the work that goes on; and some of the operations may be watched under the microscope. We may see the little artisans at work—may enter with more or less intelligence into what is being done; though *how* the marvellous results are produced we know not. Here, indeed, we reach the borders of the Unknown Land, which Science has never entered, and where the mysterious facts of Life lie hid. We screw on the highest powers of the microscope; but the secret remains a secret still. The things formed are plain before our eyes, and we may see them forming; we may note effects, and even the processes



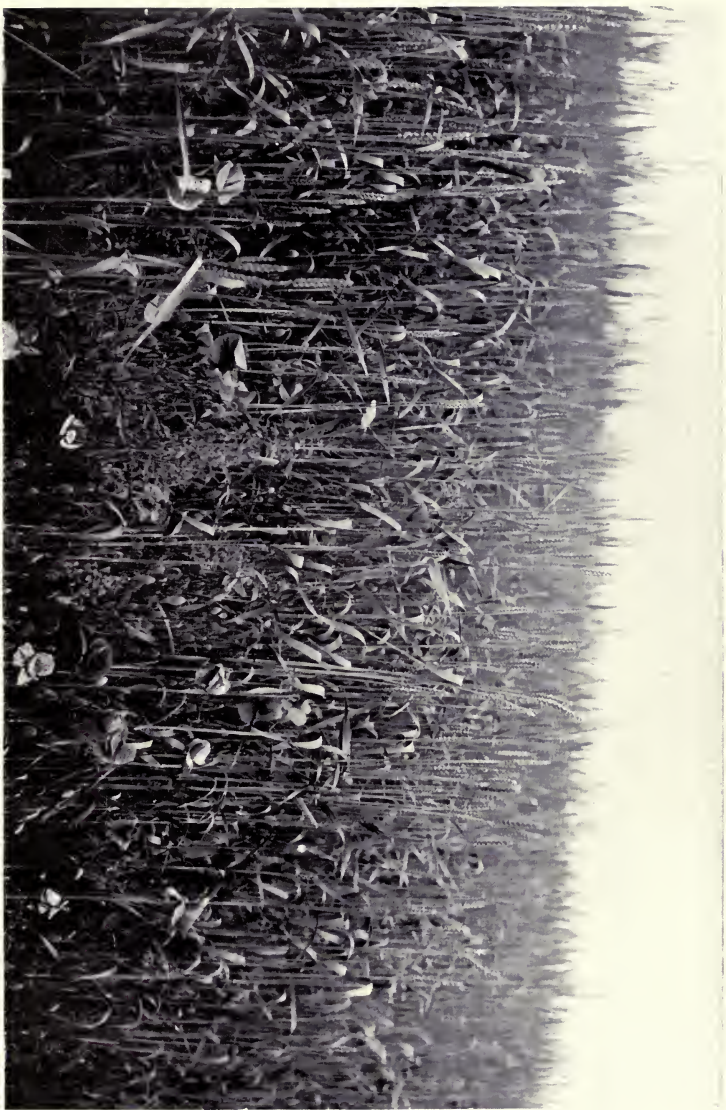
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FIG. 122.—FLOWERS OF GARRYA ELLIPTICA.

The long, pale yellow catkin consists of a series of cups, each containing three flowers. The catkins are five or six inches long, and appear very early in spring. CALIFORNIA, MEXICO, etc.

by which those effects are produced; but behind all is the mysterious principle called Life, and into this we may not enter. Again and again, as we watch those viscid, transparent specks of structureless matter beginning to move—as we see them throwing out their delicate strands, or rotating slowly in their cells—we ask in awe and admiration, How is this? But the question falls in vain. The little protoplasts work on, but will not answer.



[Photo by]

FIG. 123.—WHEAT (*Triticum vulgare*) AND CORN POPPY (*Papaver rhoeas*).

The brilliant Red Poppy shelters among the Wheat-plants, and ripens and sows its seeds before the wheat is ready for cutting.

[E. Step.

CHAPTER IV

THE ASCENDING SAP

Now good digestion wait on appetite.—SHAKESPEARE.

IT has been pleasantly observed by one of our older physiologists that the economy of the plant is analogous to that of a well-regulated household. "The whole structure is composed of a number of different organs or members having different parts to perform in the general scheme; and these parts or functions are so beautifully adjusted together that, in every variety of circumstances in which the being is liable to be placed, they shall still be executed in harmony and with one common



Photo by]

FIG. 124.—HOP TREFOIL OR YELLOW CLOVER (*Trifolium procumbens*).

[E. Step.

Common in pastures and on roadsides. The pale yellow clusters consist of a number of flowers crowded together. The downy stems will be found lying among the grass, etc., and often more than a foot in length. EUROPE, N. AFRICA, N. ASIA.

purpose. One organ pumps up the required water, another carries it, another uses it in cooking, another gets rid of the waste, another obtains the solid food, another carries the cooked provisions to all parts of the structure, another stores up the superfluity, another builds additions to the edifice, while another prepares to send out a colony furnished with supplies of food, and with everything requisite to begin life for themselves" (Carpenter). This is very true; and we propose now to treat a little of some of these interesting functions, on the discharge of which depends not only the life of the plant as a whole, but the permanence of the species.

Now, all the operations carried on in a plant are subordinate to the two great functions of *nutrition* and *reproduction*—nutrition, by means of which the life of each individual is sustained; and reproduction, which secures the continuance of the species. For the present our remarks will be confined to the former.

We may enter upon the subject at once by asking, What is the food of plants?—a question which involves the further inquiry, What are the constituents of protoplasm? For if, as we have seen, all vegetable cells originate in protoplasm, and every plant consists either of a cell or cells, or the products of their formation and transformation, it stands to reason that the elements of protoplasm must constitute a very large proportion of the food of plants. Now, the chief elements of protoplasm have been already enumerated. They are six in number—carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulphur; but in order to complete the list of nutrient substances, we must add the elements iron, calcium, potassium, magnesium, zinc, and, probably, sodium and chlorine.

Of these elements *carbon* is by far the

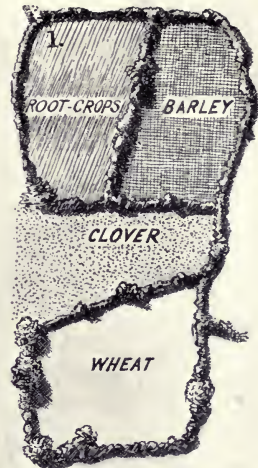


FIG. 125.—FIRST YEAR OF NORFOLK OR FOUR-COURSE ROTATION OF CROPS.

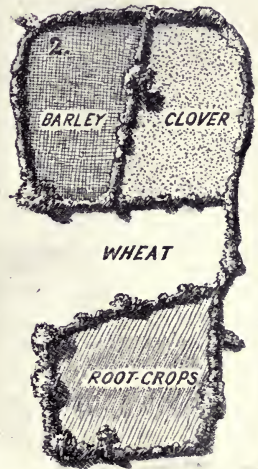


FIG. 126.—SECOND YEAR OF NORFOLK OR FOUR-COURSE ROTATION OF CROPS.

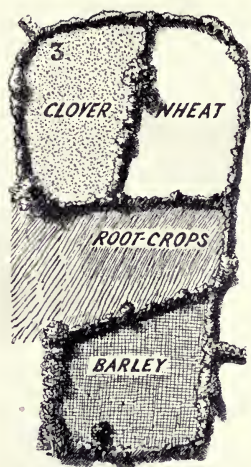


FIG. 127.—THIRD YEAR OF NORFOLK OR FOUR-COURSE ROTATION OF CROPS.

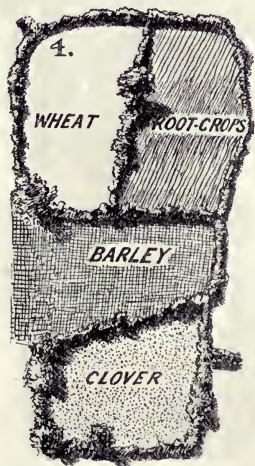


FIG. 128.—FOURTH YEAR OF NORFOLK OR FOUR-COURSE ROTATION OF CROPS.

most abundant. All the plants growing upon the face of the earth absorb it in large quantities. Their leaves take up the carbon from the atmosphere in the form of carbonic acid, and they grow and prosper. Give them air purified from carbon, such as we could thrive in, and they could not live; give them carbon dioxide with other matters, and they flourish. Our floors, our tables, the framework of the chairs on which we sit, have derived all their carbon, as the trees and plants derive theirs, from the atmosphere, which carries away what is bad for us* and at the same time good for them—what is disease to the one being health to the other. “So are we made dependent,” says Faraday, “not merely upon our fellow creatures, but upon our fellow existers, all Nature being tied together by the laws that make one part conduce to the good of another.” †

Carbonic acid, or carbon dioxide as it is now generally called, is present in the atmosphere in the proportion of four parts in ten thousand; so that, in every thousand cubic feet of air, we have not quite half a cubic foot of carbonic acid—a proportion somewhat startling when we remember that this is almost the sole source of supply to the entire vegetable kingdom; yet so great is the volume of atmosphere which surrounds the globe that, according to careful computations, at least three thousand million million pounds of solid carbon must be contained in it—a quantity which is probably far in excess of the weight of all

* Perhaps we should be more exact in saying that it is the *absence* of oxygen, rather than the presence of CO_2 , which vitiates the air from the animal point of view.

† Some interesting experiments by Professor T. D. Macdougall, of Minnesota, U.S.A., on the growth of various plants in an atmosphere devoid of CO_2 , will be found in the *Journal of the Linnean Society* (Botany), vol. xxxi. 1896.



Photo by]

FIG. 129.—THE INTERMEDIATE STAGE (*Drosera intermedia*).

A beautiful little insectivorous plant, growing on bogs and moist heaths. The photograph shows the crowded manner of growth, which makes it difficult for creeping insects to escape contact with some of the leaves. About one-third of the natural size. N. ERIKSSON, N. ASIK, N. AMERICA.

[L. STEV.



Photo by]

[E. Step.

FIG. 130.—ROUND-LEAVED SUNDEW (*Drosera rotundifolia*).

A larger species than the last, growing in similar situations and with the same habits. Reduced about one-third.
N. EUROPE, W. ASIA, N. AMERICA.

the plants which exist upon the earth. Submerged plants, having no direct contact with the atmosphere, derive their carbon from the carbon dioxide dissolved in the water in which they live.

Carbonic acid is a gas consisting of two elements, *oxygen* and *carbon*, combined in the proportion of two atoms of oxygen to one of carbon (CO_2); and as the former is another of our plant elements, it is evident that carbon is not the only nutrient substance taken up by the leaves. Yet by no means all the oxygen required by the plant enters in through these organs. A large proportion is obtained from the water absorbed by the root-hairs, which, indeed, are the organs employed in conveying most of the food substances to the plant; and this taking in of inorganic nutrient matter by the root-hairs is known as *absorption*.

Then there is *hydrogen*. Oxygen combines with hydrogen in a certain proportion (H_2O) to form water; so that when the roots are drinking up water from the ground they are taking in two of the most essential elements of the plant. It is probable, however, that a good deal of the hydrogen supplied to the plant enters it in combination with nitrogen (another of the essential elements of all plants)—in fact, as ammonia (NH_3), that pungent gas which gives strength to hartshorn and smelling-salts, and which is dissolved in the water absorbed from the soil.



A PITCHER PLANT (*Nepenthes ampullaria*).

These pitchers are an outgrowth from the tip of the leaf. They are hollow and provided with a lid to keep out rain. The liquid within is secreted by the walls of the pitcher, and insects which get drowned in it are digested and re-absorbed for the nourishment of the plant.

The supply of nitrogen to plants in an accessible form is not nearly so plentiful as the plant requires, and nitrogen-hunger is frequently experienced by them. "Nor is the origin of this nitrogen deficit far to seek. The nitrogen contained in the soil comes in the plant to form a constituent of the organic nitrogen compounds, such as the proteins. The plant dies and decays, or is eaten and the eater decays. . . . The organic nitrogen compounds of the dead animal or plant are broken down by the bacterial and fungous agents of decay into a series of simpler forms which, acted on by yet other of the ordered army of saprophytic micro-organisms, yield finally ammonia and nitrogen. The nitrogen leaks away into the atmosphere and contributes to the 79 per cent. of nitrogen gas which is contained in the air. The ammonia may leak away also—as every dunghill testifies—or it may be fixed in the soil by the agency of certain nitrifying micro-organisms. These bacteria convert the ammonia into nitrates, and the nitrates so formed become available to the roots of the green plant. On the other hand, the nitrates of the soil may be seized upon by yet other, denitrifying micro-organisms and, becoming converted into ammonia compounds, may be lost to the vital circulation. The constant leakage of nitrogen from combined forms to the free and inert form of nitrogen gas results in a shortage of nitrogen available for the formation of the nitrogenous food of plants. We may thus speak of the problem which besets all living organisms—that of obtaining adequate supplies of organic nitrogen compounds—as the nitrogen problem, and we may well believe that the sum-total of life supported on our planet is determined ultimately by the amount of available nitrogen present in the earth and sea. Occasionally, organisms are met with which have solved the nitrogen problem in a fundamentally satisfactory manner. Among such organisms are nitrogen-fixing bacteria, leguminous plants, and man. Each of these organisms has evolved methods of bringing back into vital circulation the nitrogen which has escaped as nitrogen gas into the air."*

* Keeble, *Plant Animals*, 141.



Photo by]

[E. Step.

FIG. 131.—DROSEREA INTERMEDIA.

A small Dragon-fly (*Agrion puella*) has been caught by the united efforts of several leaves of the Sundew.

The other elemental food substances are also found in the soil, and are either dissolved by the water or by an *acid sap* excreted by the root-hairs. This sap is a very necessary provision, as some of the substances essential to vegetable life and growth are insoluble in water, and but for its timely services the greater number of plants would be literally starved, and in a short time disappear from the face of the earth. The powerful action of this acid excretion may be shown by means of a simple experiment. Let the perfectly smooth surfaces of two slabs of marble be spread with sand to the depth of a quarter of an inch, and in one of the sand layers sow some seeds of mustard and cress. Place both the slabs in a fairly warm place and a good light, and water them occasionally till the plants



FIG. 132.—VENUS' FLY-TRAP (*Dionaea muscipula*).

The action of the leaves as an insect-trap was known as far back as the days of Linnaeus, but regarded only as an extreme example of vegetable irritability. It was not until Darwin had explained the Sundew that attention was drawn to the real purpose of *Dionaea's* movements.

on the seed-sown bed have grown for a short time. On cleaning off the sand from the slabs it will be found that the one which had the sand only will be as smooth as ever, while the other will be covered with minute grooves—a kind of rough etching of the root system. In other words, the root-hairs will have eaten their way in the marble, channeling out passages for themselves by means of the acid sap. This experiment will show how it is that large trees are able to sink their roots deep into the solid rock, which may be literally

split to pieces by the subsequent growth of the tree's embedded roots.

The nutrient substances are never taken up indiscriminately by the plant. Not least among the many marvels of plant life is the mysterious power vested in the root of selecting from the surrounding fluid the substances which it requires and rejecting others. Thus if you plant a pea and a wheat-grain together in the same soil, the former will take care to make the most of whatever of lime and its compounds the water of the soil contains; while the latter, rejecting these, will absorb for itself the silex or flinty matter. How this comes to pass we do not know, and the wisest of savants can assign no reason; but a power of selection undoubtedly exists.

From the fact itself we may learn a good deal. It is evident, for instance, that the soil which is planted year after year with the same



Photo by]

lE. J. Wallis.

FIG. 133.—VENUS' FLY-TRAP (*Dionaea muscipula*).

The first known of these insectivorous plants. Unlike the slow-moving tentacles of *Drosera*, the two lobes of the leaf close with a snap the moment an insect touches one of the three spikes in the centre of a lobe. When the leaf is closed, the spines on the margins interlock like the teeth of a rabbit-gin. NORTH CAROLINA, U.S.A.



Photo by]

[S. L. Bastin.

FIG. 134.—CAPE SUNDEW (*Drosera capensis*).

A native of South Africa, which has green, leaf-like footstalks, indicating that it draws more nourishment from the air than the other species.

system of manuring, they provide against the otherwise inevitable exhaustion of the soil. The well-known Norfolk or four-course rotation is a case in point (figs. 125–128). This consists of root-crops, Barley (*Hordeum*), Clover (*Trifolium*), and Wheat (*Triticum*), which are dealt with in the following manner: “The farm is broken up into four portions. The first undergoes thorough tillage and is planted with Root-crops, which need especially potash and lime, and having short roots, take their food near the surface, or are surface feeders. Division 2 has Barley, which takes up very little lime and potash, but much silica, and is also a surface feeder. Clover, in division 3, takes much the same food as the root-crops, but is a subsoil feeder—that is, sends its roots deeply into the ground. The Wheat, in division 4, is also a subsoil feeder, but, like Barley, takes up much silica.” Next year, and every succeeding year, the position of the crops is changed; and thus, at

* Perhaps this statement needs a note. It has been shown that silica is not absolutely necessary for the growth of cereals; other important constituents would be exhausted long before the silica—*e.g.* nitrogenous matter, *e.g.* phosphates.

crops will soon be impoverished, and at last become permanently unproductive for plants of that description.

A field that is sown with Wheat for a succession of years will at length lose all its flinty matter, and will then be useless, not only as a wheat-producing soil, but also for the growing of all cereal grasses and silica-containing plants.* On the other hand, the very same field may abound in nutrient substances perfectly adapted to vegetation of another kind. Farmers nowadays are well acquainted with these facts, and by a carefully selected succession of different crops—a *rotation of crops*, as it is called—and a scientific

the end of four years, each part of the soil will have had each kind of plant growing on it, and the order for the four years will stand thus:—

YEAR.	DIVISION 1.	DIVISION 2.	DIVISION 3.	DIVISION 4.
First . . .	Root-crops	Barley	Clover	Wheat
Second . . .	Barley	Clover	Wheat	Root-crops
Third . . .	Clover	Wheat	Root-crops	Barley
Fourth . . .	Wheat	Root-crops	Barley	Clover

In former times it was a usual thing to give rest to the land by allowing it to lie fallow at certain intervals, and though our scientific agriculturists have now discovered other means of replenishing the soil, the practice has by no means died out.

The importance of this system of fallowing was known to the ancients, for Virgil in his first *Georgic* mentions it, and suggests as an alternative that the husbandmen should follow the Barley crop by sowing leguminous plants, thus anticipating, or at least foreshadowing, the very modern discovery of the nitrification of the soil by the roots of these plants, or rather by the bacteria that attach themselves thereto. He says: "You shall sow the golden Barley whence formerly you had borne away the luxuriant Pulse in their rattling pods, or the slender produce of the Vetch, or the bitter Lupin's fragile stalks and rattling straw."

It is remarkable that to the present day the Germans grow Lupins on very poor land every third or fourth year, solely for the purpose of ploughing them in for the enrichment of the soil; and



FIG. 135.—PORTUGUESE SUNDEW (*Drosophyllum lusitanicum*).

A sub-shrubby plant of the Peninsula and North Africa. The tentacles do not close over their prey, as in the Sundew. The natives hang these plants in their rooms in lieu of fly-papers.

it is reckoned that no less than 500,000,000 pounds of nitrogen are thus obtained from the air annually by this method of cropping in that country.

Marshy places are usually very deficient in certain of the nutrient elements, as nitrogen, potash, and other salts, and plants which grow in such neighbourhoods, being often hard put to it to obtain a sufficiency of food,



FIG. 136.—MEXICAN BUTTERWORT (*Pinguicula caudata*). The Butterworts catch small insects by means of a viscid secretion from the glands of the leaves. One of these glands, viewed sideways and enlarged, is shown above. The other figure shows the head of the gland.

take to crime for a livelihood. Finding, we know not how, that gnats and flies and other species of the great class of Insects contain in their bodies the aliment which is so deficient in the soil, the plants actually prepare traps for the capture of these winged creatures, which they kill and eat without compunction.

Many have found a difficulty in receiving the statement; nor is a little scepticism surprising. One such plant is the little Round-leaved Sundew (*Drosera rotundifolia*, fig. 130), whose round leaf-blade bears about a couple of hundred red tentacles, each ending in a globular head from which a clear drop of gum exudes and glistens like a drop of dew. These sticky glands close round the insect prisoners, and these movements are accompanied by

the excretion of a digestive ferment comparable with animal pepsin, which dissolves all the nitrogenous constituents of the victim, just as the gastric juice of our bodies would dissolve an oyster.

There are three British species of Sundew, all of which are insectivorous. The round-leaved (*Drosera rotundifolia*) is perhaps the prettiest, and it is to be met with in many places growing amid wet Sphagnum Moss. Equally plentiful is the Intermediate Sundew (*Drosera intermedia*), with



Photo by]

[E. Step.

FIG. 137.—PALE BUTTERWORT (*Pinguicula lusitanica*).

The smallest of our native species, found chiefly in the bogs of the south-west of England and West Scotland. It has pretty lilac-tinted flowers. The leaves are less than an inch in length. Its headquarters are in the PENINSULA and WESTERN FRANCE



Photo by]

[J. J. Ward.

FIG. 138.—SECTION THROUGH LEAF OF BUTTERWORT.

A thin slice from the leaf is here shown highly magnified to make clear the position of the stalked glands. They are seen to arise from special cells of the epidermis.

oval leaf-blades (fig. 128). On another page is a picture of an African species, *Drosera capensis*, the Cape Sundew (fig. 134), which was introduced from the Cape of Good Hope in the year 1875. Its pretty purple flowers are borne on a leafless stem or scape,* which is longer than the leaves but not quite so hairy. In almost every part of the world one or more species of the family may be found. Australia has its twin-leaved Sundew (*D. binata*) and many others; India its *Drosera lunata*, with curious moon-shaped leaves; Africa its few-flowered Sundew (*D. pauciflora*), as well as the Cape species already described; the long-leaved Sundew (*D. longifolia*) is spread over Northern Europe, Canada, and Brazil; while the United States have a pink- and purple-flowered species (*D. filiformis*), which is insectivorous like all the rest.

The margins of the leaf contract so that the leaf-blade is converted into a cup, and into this receptacle the glands pour out a fluid that has the power of digesting the soft parts of the insect, and the enriched fluid is then reabsorbed by the cells of the leaf, and through them distributed to the plant as a whole. This process of digestion and absorption takes about two days, and when it is completed the leaf again expands. A remarkable feature of the plant's behaviour when an insect has been captured is the knowledge of locality shown by the tentacles: from all parts of the leaf the tentacles bend to the particular spot where the captive is, every tentacle co-operating to prevent the possibility of escape. The information must be transmitted from cell to cell in some way not understood.

The *Droseras* are very partial to rump-steak, and devour it greedily when they get the chance—that is to say, when they are under experiment; but cinders, and bits of moss and quill, and tiny balls of paper, they will have nothing of. Drops of milk and dissolved isinglass do not appear to come amiss to them, but tea they determinedly eschew, and will not deign to bend their tentacles even a hair's breadth if you sprinkle a little of the refreshing beverage on their leaves. Insects, however, are

* A leafless stem, springing from the base of a plant and bearing only a flower or flowers, such as is seen in the Primrose, Cowslip, Hyacinth, etc., is a scape.

their special favourites, and the wing of a fly or the leg of an ant will meet with almost instantaneous recognition.

Nearly allied to the *Droseras* is the dainty little Portuguese Sundew (*Drosophyllum lusitanicum*) (fig. 135), which is also a true insect-eater, though the glandular hairs distributed plentifully over its grass-like leaves are not endowed with the motile power of the *Droseras*. In this respect it is more akin to the Catchflies and London Pride, which catch insects by means of the glandular hairs with which their stems are covered. This plant is remarkable as having its habitat, not in marshy places, but on sandy shores and dry rocks; in which respect it resembles many of the Australian Sundews, which grow and thrive in the most arid soil. The villagers in the neighbourhood of Oporto hang the plant in their cottages, using it instead of fly-paper.

More wonderful than either *Drosophyllum* and *Drosera*, and belonging to the same order (*Droseraceæ*), is Venus' Fly-trap (*Dionæa muscipula*), a native of North Carolina (fig. 132). Candour compels us to state that it bears no better character than its unnatural cousins, unless, indeed, its very proficiency in crime may be looked upon as a redeeming feature. Its leaves spread in a circle round the crown of the root, and either lie flat upon the ground or gently elevate themselves above the soil. They consist of two very distinct parts—a stalk and a blade. The stalk is a flat, green, leafy expan-



Photo by]

[E. Step.

FIG. 139.—COMMON BUTTERWORT (*Pinguicula vulgaris*).

A much larger species, common in the mountain districts of the North. Its leaves are two or three inches long, and the flowers violet on purple scapes.

N. EUROPE, N. ASIA, N. AMERICA.

sion, the veins of which are coarsely netted, and it is joined to the blade by a very narrow neck. The blade consists of a roundish, thick, leathery plate, having strong, hidden, parallel veins, which spread nearly at right angles from the central vein or midrib to the margin, and is bordered with a row of strong, stiff, tooth-like hairs. When young, the two sides of the blade are placed face to face, and the teeth cross each other; afterwards, when full grown, the sides spread flat, or nearly so, and the teeth

then form a firm spreading border. On each half of the blade stand three delicate, almost invisible bristles, uniformly arranged in a triangle; and these are the true sensitive organs of the plant. Let but one of the bristles be touched, and the two sides of the blade spring together with considerable force, the marginal teeth crossing each other so as to enclose securely any small object which may have caused the irritation, be it insect, straw, or seductive morsel of steak. Wonderful to relate, no other part of the leaf is sensible to external impressions. In vain is the back of the leaf disturbed, or the smooth glandular surface pricked and tickled; unless you jar one of the bristles, no irritability is excited, and the blades remain immovably open. The moment the shock is communicated through one of the bristles, the collapse is effected, the leaf assuming altogether the appearance of an iron rabbit-trap when it has closed upon its prey; and if, at this time, an attempt is made to open the leaf, it is violently resisted, in consequence of the rigidity of the parallel veins.

Like the Sundews, *Dionaea* feeds upon the insects which it catches, for it possesses, like them, the power of digestion. Dr. Burdon



FIG. 140.—FLOWER OF BLADDERWORT (*Utricularia vulgaris*).

This type of flower is called personate. The lips are closed, as in the flowers of Snapdragon and Calceolaria, only bees being able to force them apart, in order to reach the nectar in the conical spur.

Sanderson, in a lecture delivered at the Royal Institution in 1874, thus referred to the digestive power of this plant:—

“When we call this process digestion, we have a definite meaning. We mean that it is of the same nature as that by which we ourselves, and the higher animals in general, convert the food they have swallowed into a form and condition suitable to be absorbed, and thus available for the maintenance of bodily life. We will compare the digestion of *Dionaea* with that which in man and animals we call digestion proper, the process by which the nitrogenous constituents of food are rendered fit for



Photo by]

FIG. 141.—HYBRID PITCHER-PLANT (*Nepenthes obrienana*).

[E. J. Wallis.

The midrib continues beyond the apex of the blade, as a tendril, but also develops into a pitcher-shaped hollow with a distinct lid, which can be raised or lowered by the plant. The interior walls secrete a fluid, formerly supposed to be pure water, but now known to possess digestive powers.

absorption. This takes place in the stomach. It also is a fermentation—that is, a chemical change effected by the agency of a leaven or ferment which is contained in the stomach juice, and can be, like the ferment of saliva, easily separated and prepared. As so separated, it is called pepsin.

“Between this process and the digestion of the *Dionæa* leaf the resemblance is complete. It digests exactly the same substances in exactly the same way—*i.e.* it digests the albuminous constituents of the bodies of animals just as we digest them. In both instances it is essential that the body to be digested should be steeped in a liquid, which in *Dionæa* is secreted by the red glands on the upper surface of the leaf; in the other case by the glands of the mucous membrane. In both, the act of secretion is excited by the presence of the substance to be digested. In the leaf, just as in the stomach, the secretion is not poured out unless there is something nutritious in it for it to act upon; and, finally, in both cases the secretion is acid. As regards the stomach, we know what the acid is—it is hydrochloric acid. As regards the leaf, we do not know precisely as yet, but Mr. Darwin has been able to arrive at very probable conclusions.”

These ferments are now known as “enzymes,” and those that digest proteids are distinguished as “proteases.” Of the proteases

three kinds are known, under the names of pepsin, trypsin, and erepsin. Pepsin, as Sanderson points out, acts only in an acid solution, but trypsin and erepsin are most active in alkaline liquids. Professor Vines and others have shown the presence of one or other of these enzymes in the germinating seeds of a variety of plants, and demonstrated the probability of a protease of some kind being present in all plants at one stage or another of their development. It appears that the digestive processes are essentially the same in both animals and plants.

The Butterworts (*Pinguicula*) constitute another genus of insectivorous plants. One species, *Pinguicula vulgaris*, better known as the Bog-violet or Large Butterwort, is common



FIG. 142.—COMMON BLADDERWORT
(*Utricularia vulgaris*).

Above, one of the bladders is shown greatly magnified.



Photo by]

[E. Step.

FIG. 143.—SMALL BLADDERWORT (*Utricularia minor*).

A portion of the plant is shown natural size. The pitchers are about one-twelfth of an inch long, and are on short stalks. Widely distributed.

in the North of England, while other species are found in different parts of the United Kingdom. *Pinguicula* is a Latin word, a diminutive of *pinguis* (fat); and the name has been given to the genus because its leaves are greasy to the touch. Like the *Droseras*, *Dionaea*, and *Drosophyllum*, all the Butterworts are fly-catchers and fly-digesters; and the large circular glands, supported upon foot-stalks of varying lengths, which thickly cover the upper surface of the leaves, are the fatal traps. The incurved leaf edges are devoid of glands, and appear to serve the double purpose of preventing insects from being washed away by the rain and of retaining the secretion, which might otherwise flow off the leaf and get wasted. When an insect alights or is blown on the leaf, "it gets entangled in the sticky secretion, and it is killed, and speedily killed, by the secretion adhering to and closing up the spiracles by which the insect breathes" (Sanderson).

Perhaps it is hardly to be wondered at that the *Pinguiculas*, like the *Droseras*, have connections outside their own immediate family. The Butterworts and the Bladderworts are, in fact, first-cousins; and who has not heard of the carnivorous doings of the latter? Our illustration shows the Common or Greater Bladderwort (*Utricularia vulgaris*), an inhabitant of ditches and deep pools (figs. 140, 142). The plant is common enough in this country. Notice carefully the many little bladders attached to the leaves, a characteristic of all the *Utricularias*. These bladders are of curious structure. Each has an aperture closing with an elastic valve, which is of much thinner texture than the vesicle to which it is attached. It opens inwards, and

small aquatic animals, incautiously entering the little door, like the fly in the nursery poem, "ne'er come out again."

"The entrance into the bladder has the appearance of a tunnel net, always open at the large end but closed at the other extremity. The little animals seemed to be attracted into this inviting retreat. They would sometimes dally about the open entrance for a short time, but would sooner or later venture in, and easily open or push apart the closed entrance at the other extremity. As soon as the animal was fairly in, the forced entrance closed, making it a secure prisoner. I was very much amused in watching a



FIG. 144.—PITCHER OF *Nepenthes mixta*.

Note the corrugated rim, and the long spines down the front of the pitcher.

Water-bear (*Tardigrada*) entrapped. It went slowly walking round the bladder, as if reconnoitring, very much like its larger namesake; finally it ventured in at the entrance, and easily opened the inner door and walked in. The bladder was transparent and quite empty, so that I could see the movements of the little animal very distinctly, and it seemed to look around as if surprised to find itself in so elegant a chamber; but it was soon quiet, and on the morning following it was entirely motionless, with its little feet and claws standing out as if stiff and rigid. The wicked plant had killed it very much quicker than it kills the snake-like larva. *Entomostraca*, too, were often captured—*Daphnia*, *Cyclops*, and *Cypris*. These little animals are just visible to the naked eye, but under the microscope are beautiful and interesting objects. The lively little *Cypris* is encased in a bivalve shell, which it opens at pleasure, and thrusts out its feet and two pairs of antennæ, with

tufts of feather-like filaments. This little animal was quite wary, but nevertheless was often caught. Coming to the entrance of a bladder, it would sometimes pause a moment and then dash away; at other times it would come close up, and even venture part of the way into the entrance, and back out as if afraid. Another, more heedless, would open the door and walk in, but it was no sooner in than it manifested alarm, drew in its feet and antennæ, and closed its shell. But after its death the shell unclosed again, displaying its feet and antennæ. I never saw even the smallest animalcule escape after it was once fairly inside the bladder" (Mrs. Treat).



Photo by]

[J. J. Ward.

FIG. 145.—MASTERS' PITCHER-PLANT (*Nepenthes mastersiana*).

A beautiful hybrid with deep claret-coloured pitchers, four and a half inches long, with ribbed margin to the mouth, and sharply toothed wings down the front.

A critical and microscopic examination of the contents of the bladders will show, not only that the habits of the *Utricularia* come nearer to the animal than that of any other of the carnivorous plants, but that the bladders with which they are furnished are, in truth, so many little stomachs, digesting and assimilating animal food.

Besides containing Bladderworts of the British type, the West Indies possesses some of a type not found in this country. During his stay in those islands, Charles Kingsley came upon certain specimens, growing out of the damp clay, which "were more like in habit to a delicate stalk of flax, or even a bent of grass, upright, leafless or all but leafless, with heads of small blue or yellow flowers, and carrying, in one species, a few very minute bladders about the roots, in another none at all. A strange variation from the normal type of the family," continues the eloquent canon, "yet not so strange, after all, as that of another

variety in the high mountain woods, which, finding neither ponds to float in nor swamp to root in, has taken to lodging as a parasite among the wet moss on tree-trunks; not so strange, either, as that of yet another, which floats, but in the most unexpected spots—namely, in the water which lodges between the leaf-sheaths of the wild Pines [*Tillandsia*], perched on the tree-boughs, a parasite on parasites*; and sends out long runners, as it grows, along the boughs, in search of the next wild Pine and its tiny reservoirs."

We must not quit this subject without offering a few remarks on the Pitcher-plants. If the little bladders of *Utricularia*, which measure scarcely an eighth of an inch in length, are so many stomachs, digesting and assimilating animal food, what shall we say of the pitchers of *Nepenthes* and *Sarracenia*, which fulfil a similar purpose, and occasionally measure, in the case of *Nepenthes edwardsiana* twenty inches from lid to leaf attachment, and in that of *Sarracenia flava* upwards of three feet in height? The pitchers really form part of the leaf structure; those in *Nepenthes* and *Sarracenia* are peculiar

* None of these is parasitic in the botanical use of the term.



Photo by]

[S. L. Eastw.

FIG. 146.—PITCHER OF *Nepenthes*.

The first known of these plants was *Nepenthes distillatoria*, from Ceylon, which had much narrower pitchers than the above. The interior of this pitcher is shown in fig. 147.

developments of the petiole, or leaf-stalk, their lids (where lids are formed) probably constituting the blade.

We may begin with the *Sarracenia*s, popularly known as Indian Cups, Side-saddle-flowers, and Trumpet-leaves. In fig. 152 we have the beautiful but treacherous *Sarracenia flava*, which bears a magnificent flower of a rich canary-yellow, sometimes measuring as much as eight inches in diameter. The long trumpet-shaped erections are the leaves, which have been united at their margins to form pitchers (though some regard these pitchers as hollow leaf-stalks), and which usually contain a fluid—not rain-water—of a bland and somewhat mucilaginous taste. In the photograph (fig. 151) is shown a mass of organic matter at the base of the tube, consisting of clotted flies in all stages of digestion and decay.

Professor Asa Gray, the distinguished American botanist, studied these plants closely, and has given an amusing account of what takes place inside the long pitchers when once they have been entered by insect visitors. "After turning back the lids of most of the leaves," he writes, "the flies would enter, a few alighting on the honeyed border of the wing, and walking upward, sipping as they went to the mouth, and entering at the cleft of the lower lips; others would alight on the top of the lid, and then walk under the roof, feeding there; but most, it seemed to me, preferred to alight just at the commissure of the lips, and either enter the tube immediately there, feeding downward upon the honey pastures, or would linger at the trunk, sipping along the whole edge of the lower lip, and eventually near the cleft. After eating (which they generally do with great caution and circumspection), they begin again to feed, but their foothold, for some reason or other, seems insecure, and they occasionally slip, as it appears to me, upon this exquisitely soft and velvety declining substance. The nectar is not exuded or smeared over the whole of this surface, but seems disposed in separate little drops. I have seen them regain their foothold after slipping, and continue to sip, but always slowly and with apparent caution, as if aware that they were treading on dangerous ground. After sipping their fill they frequently remain motionless, as if satiated with delight, and, in the usual self-



Photo by]

[S. L. Bastin.

FIG. 147.—PITCHER OF *Nepenthes*.

The pitcher is here cut through to show what happens to insects when they venture inside.

congratulatory manner of flies, proceed to rub their legs together, but in reality, I suppose, to clean them. It is then they betake themselves to flight, striking themselves against the opposite sides of the prison-house, either upwards or downwards, generally the former. Obtaining no perch or foothold, they rebound off from this velvety microscopic *chevaux de frise*, which lines the inner surface, still lower, until by a series of zigzag but generally downward falling flights, they finally reach the coarser and more bristly pubescence of the lower chamber, where, entangled somewhat, they struggle frantically (but by no means drunk or stupefied), and eventually slide into the pool of death, where, once becoming slimed and



Photo by]

[S. L. Bastin.

FIG. 148.—*Nepenthes*.

A small portion of the inner wall of a pitcher, showing the digestive glands by means of which the plant utilizes the drowned insects. Magnified.

tions of their leaves is—like the tall cups of external stomach which digests solid food. Here is a beautiful hybrid *Nepenthes mastersiana*, which is to be found luxuriating at Kew (fig. 145). Its pitchers measure three or four inches in length, but in most of the *Nepenthes* they are larger. A Bornean species, probably *Nepenthes villosa*, noticed by Dr. Hooker, “has pitchers which, including the lid, measure a foot and a half, and the capacious bowl is large enough to drown a small mammal or bird.” These Nature-made water-vessels (or their contents) have proved, indeed, in more instances than one, the salvation of travellers, in places where streams are few and droughts a common occurrence.

Though the pouches of *Nepenthes distillatoria* are comparatively plain, in

saturated with these Lethean waters, they cease from their labours. After continued asphyxia they die, and after maceration they add to the vigour and sustenance of the plant. This seems to be the true use of the limpid fluid, for it does not seem to be at all necessary to the killing of the insects (although it does possess that power); the conformation of the funnel of the fly-trap is sufficient to destroy them. They only die the sooner, and the sooner become liquid manure.”

In the *Nepenthes* we have another family of irreclaimable insect feeders. Each of the pouch-like prolongations of the *Sarracenias*—a kind of



Photo by]

[E. J. Wallis.

FIG. 149.—*Sarracenia atkinsoni*.

A hybrid between the American Pitcher-plants known as the Trumpet-leaf and the Huntsman's Cup. The green pitchers are covered with a network of red veins.

many species these singular structures are richly marked and show both beauty and variety of form. Observe, for example, the exquisite Nature-painting on the bowl and lid of *Nepenthes mixta*, and the curious corrugated rim with which it is provided (fig. 144). This rim is not merely ornamental. It strengthens the mouth of the pouch and keeps it distended; and moreover, it secretes the honey by means of which insects are attracted to the plant and eventually into the death-pool below.

Another interesting species of pouch-like fly-catcher, though not belonging to the *Nepenthes*, is the diminutive and almost stemless New Holland Pitcher-plant (*Cephalotus follicularis*), a native of Western Australia, where it was discovered by the French naturalist, Labillardière, more than seventy years ago (fig. 154). Dr. Tait has found that the acid secretion of certain glands on the inner surface of the pouches of this plant will digest shreds of albumen and insects, and therefore that the plant is truly carnivorous; and certainly the pitchers are wonderfully adapted for the capture and retention of their living prey. The corrugated rim "ends abruptly on the inner margin in a row of inflexed teeth," and "below the rim is a ledge extending round the inside of the pitcher, with its acute edge projecting downwards into the cavity, forming a kind of contracted neck. This is called the conducting shelf.

Below this, again, the upper two-thirds of the walls are smooth and glandular. At the lower margin of this smooth surface an oblique curved elevation extends on each side, and below all is the bottom of the pitcher, which is smooth and without glands. The surface of the conducting shelf is furnished with hairs projecting downwards."

Dr. Macfarlane found that, by first giving *Nepenthes* insects for the purpose of stimulating the flow of digestive fluid, he could get it to reduce fibrin to the condition of jelly in less than an hour.

A reflective person is apt to inquire, Why were insectivorous plants ever given a place in Creation? and it certainly does seem strange that objects in the Vegetable World should be made the instruments of destruction to objects in the sister kingdom; though we have long been reconciled to the existence and necessity of an opposite condition of things. That ants and aphides should thrive and grow



Photo by]

[S. L. Bastin.

FIG. 150.—CALIFORNIAN PITCHER
(*Darlingtonia californica*).

The entrance to the pitcher is here covered by a hood. Insects crawling along either platform find themselves just under the entrance. Its habits are similar to those of *Sarracenia*.

fat by feeding on the sappy tissues of plants appears to us a natural and even justifiable provision, but that the plants should retaliate by setting traps for their tormentors is not so easily accounted for; and we are immensely shocked when we find that not a few of them actually feed upon their captive enemies. Is not this, we cry—

A sort of retrograding?
 Surely the fare
 Of flowers is air,
 Or sunshine sweet.
 They shouldn't eat
 Or do aught so degrading.

But what these wilful children of Flora *should* do, and what they actually do, are of course two very different things; and when all is told, and poets and moralists have had their say, the stubborn fact remains that certain plants *do* feed on insects: and that nitrogen, potash, etc., may be obtained from other sources than the soil, and be absorbed into the plant by other organs than the root. At the same time it should never be forgotten that the root is the *chief* organ of absorption—that is, of all the nutrient elements save carbon—and, moreover, that insectivorous plants occupy but a small corner of the Vegetable Kingdom. As already remarked, they have apparently taken to this method of obtaining nitrogenous food because there is so little of it in the soil where they grow.

Although the plants in this case have completely turned the tables upon their persistent enemies, the animals, it is interesting to note that the latter again retaliate through some of their members. One of the Lemnaceae is known to raid the larger species of *Nepenthes* for the sake of the dead insects, and even the insects send at least one representative to reduce the spoils of the plant. Mr. F. G. Scott Elliot says: "Near Fort Dauphin, in Madagascar, I found great quantities of *Nepenthes madagascariensis*. Almost every pitcher was one-third to two-



Photo by]

[S. L. Bastin.

FIG. 151.—*Sarracenia*.

A pitcher cut open to show the interior and the black mass of organic matter at the bottom, resulting from the plant's digestion of captured insects.

thirds full of corpses, but in some of them large, fat, white maggots, all of a very unprepossessing appearance, were quite alive and apparently thriving. These must have been the larvæ of a blowfly similar to that which has been mentioned by others as inhabiting *Sarracenia*. At the same place a white spider was very often to be seen. Its web was spun across the mouth of a pitcher, and its body was quite invisible against the bleached remains inside. It had suited its colour to the corpses within, in order that it might steal from the *Nepenthes* the due reward of all its ingenious contrivances!"

We have dealt at some length with these insect-eating plants, but we have not yet exhausted the list. One other that had formerly been regarded merely as a root-parasite has of late years been at least suspected of getting some of its food by predatory courses. We refer to the Toothwort (*Lathraea squamaria*), a rare but interesting plant. During about eleven months of the year it leads

a subterranean existence, fattening upon the sap of the elm and hazel, to whose roots it is attached by suckers. About March it makes its presence known above ground by sending up short, thick, fleshy flowering stems almost white in colour, but usually tinged with violet. The flowers are thickly crowded on the greater part of this stem, but below them are a number of curled fleshy scales—really leaves, but not much like the ordinary forms of leaves. On the underside there are peculiar and complicated chambers which are only accessible near the turned-down tip of the leaf; but though this appears not to be a sufficiently obvious way in, the Toothwort has learnt the weakness of its victims. It is the nature of many of the smallest creatures to look out for hidden retreats in which they can enjoy a moist, cool atmosphere; and so it is stated that many animalculæ and the very smallest forms of insect life explore these labyrinths, and mostly fail to find the way out again. It is not asserted that the Toothwort pours out a digestive fluid, but some observers believe they throw out wisps of protoplasm from the living cells which extract the soft parts



FIG. 152.—TRUMPET-LEAF (*Sarracenia flava*).

Grows to a height of two feet; yellow in colour, the lid netted with purple veins. NORTH AMERICA.



Photo by J

[E. J. Walms.]

FIG. 153.—*Heliophora nutans*.

A Pitcher-plant allied to *Sarracenia*, and of similar habits. It has white or pale—rosy flowers. A native of MOUNT BORAIMA, GUIANA.

of the victims, for they have found only the hard parts of the prisoners remaining after a short period of incarceration.

The accompanying photographs of the Toothwort have peculiar interest, because they were taken in a Surrey lane where John Ray (1628—1705) recorded the plant as growing in his time. The plant photographed is in all probability a direct descendant of the plants he noted. Figs. 155, 157.

It may be asked, How is it that the fluid from the soil is able to force its way through the membranous cell-walls of the root-hairs and to pass upwards into the plant? The question suggests another, namely, How is it that water is drawn up into a piece of loaf-sugar or a sponge? though by fencing the first question in this manner one is only suggesting a solution to the tail-end of the difficulty, nor this, unless something is known of capillary attraction.

But how is it that the fluid of the soil gains entrance into the closed cells? A merely verbal explanation, however clear, would be dry and unenlightening. We might talk about endosmose and exosmose and the power of passing through porous diaphragms for hours, and still fail to convey a definite impression on the subject. An experiment in this case will save a world of laborious explanation. For this experiment nothing more

is required than a bowl of distilled water, some sugar in solution, a small length of glass tubing, and a couple of pieces of bladder to close up the ends.

The experiment is performed in the following manner: Close up one end of the tube with a piece of bladder and pour in the solution of sugar; then close up the other end, and immerse the whole in the bowl of water. It will presently be found that the bladder at both ends has become distended, in consequence of an increase of volume of the fluid in the tube, the increase being due to an inflow of the distilled water in which the tube is immersed. This transmission of fluid through a porous partition from the exterior to the interior is called *endosmose* (Greek *endon*, within; *ōsmos*, impulsion). On applying a little of the distilled water to the lips, it will be found to have acquired a slightly sweet taste, a small portion of the sugary solution having passed out through the bladder. Here, then, is evidence that two currents,



Photo by]

[S. L. Bastin.

FIG. 154.—*Cephalotus follicularis*.

Interior of a pitcher of this little Australian Pitcher-plant. The entire plant is shown in fig. 18. Note the dead insects.



Photo by]

[E. Step.

FIG. 155.—TOOTHWORT (*Lathraea squamaria*).

A parasite upon the roots of Elm and Hazel. The leaves are represented by hollow scales into which minute creatures enter; and it is believed they are digested and absorbed.

of which the inward flow of water is the chief, have been set up. With these results in view, substitute in imagination a root-hair for your glass tube; and for your bladder the exterior cell-walls of the hair, and the experiment will have been made to some purpose.

That there is a slight *outward* flow of sap from the plant, in addition to the more important *inward* passage of water and its concomitants, may be shown in another way. If a plant be grown with its roots in water, the surrounding fluid is soon found to contain some of the peculiar substances contained in the descending sap. Thus a Pea or Bean will disengage a gummy matter, a Poppy will communicate to the water an opiate impregnation, and a Spurge will give it an acrid taste. This passage of the sap through the cell membranes, from within outwards is called *exosmose* (Greek *exo*, outside; *ōsmos*, impulsion).

Once the fluid from without has entered the root-hairs, it diffuses from cell to cell till it reaches the fibro-vascular system—that wonderful arrangement of vessels and woody cells which forms the framework or skeleton of the plant; and so it mounts and mounts, chiefly by way of the wood elements, from root to stem, from stem to branch, from branch to slender twig, till it reaches the leaves—as little changed during its whole

passage as the water which passes through a pump. The wind which rocks the trees and plants to and fro assists in this process, and the leaves also assist, though in quite a different manner. The latter, indeed, are the busiest organs of the plant, as we shall see in the next chapter, when we shall consider their wonderful structure and functions.

The rate at which the watery sap courses up the stem may be gathered from Kingsley's vivid description of the Liantesse (*Schnella excisa*), a West Indian Water-vine, whose singular stem, hanging in loops twenty feet high,

he likens to a chain-cable between two flexible iron bars. At one of these loops, "about as thick as your arm," writes the Canon, "your companion, if you have a forester with you, will spring joyfully. With a few blows of his cutlass he will sever it as high up as he can reach, and again below, some three feet down; and while you are wondering at this seemingly wanton destruction, he lifts the bar on high, throws his head back, and pours down his thirsty throat a pint or more of pure cold water. This hidden treasure is, strange as it may seem, the ascending sap, or rather the ascending pure rain-water which has been taken up by the roots, and is hurrying aloft to be elaborated into sap, and leaf, and flower, and fruit, and fresh tissue for the very stem up which it originally climbed; and therefore it is that the woodman cuts the Water-vine through first at the top of the piece which he wants, and not at the bottom; for so rapid is the ascent of the sap that if he cut the stem

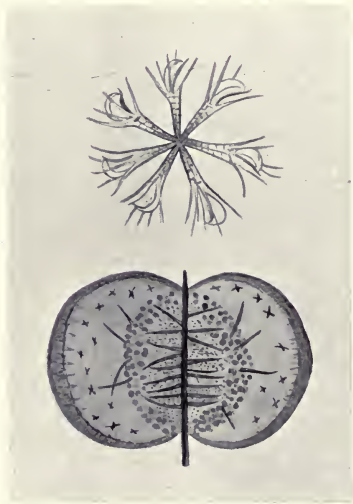


FIG. 156.—AN AQUATIC FLY-TRAP
(*Aldrovanda*).

A small rootless plant that Darwin called "a miniature aquatic *Dionæa*." A single whorl of leaves is here shown, together with an enlargement of a single leaf. EUROPE, INDIA, AUSTRALIA.

below, the water would have all fled upwards before he could have cut it off above" (*At Last*, p. 159).

The "pure rain-water" mentioned by Kingsley is not really pure, for it contains mineral elements from the soil dissolved in it. The plant requires this mineral matter to mix with the gases taken in from the atmosphere, that all may be elaborated into sap in the leaves. But the percentage of mineral constituents is very low, so that a vast volume of water must be given off as vapour through the stomata, and this increases the pulling action which helps the upward flow.

So much for the ascending sap.



Photo by]

[E. Step.

FIG. 157.—TOOTHWORT (*Lathraea squamaria*).

The plant consists of the flower-stems only, which make their appearance in early spring. They are here shown fully extended, but on a scale about one-third less than actual size. EUROPE and ASIA, N. and W.

CHAPTER V

THE DESCENDING SAP

And now returning through the knotty stem
By broader routes, a copious, nutrient stream.

WE saw in Chapter III. that an ordinary foliage leaf consists of three distinct kinds of tissue, which may be popularly described as the veins, the fleshy substance between the veins, and the thin enveloping skin. Here is a microscopic view of the transverse section of part of a Rhododendron leaf (fig. 158). Upwards of twenty layers of cells are packed in the thickness of this single leaf—a fact to arrest attention. The double line of cells lettered *a* belongs to the epidermis of the upper side of the leaf; *b* shows the fibro-vascular bundle of a vein in cross-section: *c* the parenchyma of the ground tissue, easily to be recognised in the actual leaf by the chlorophyll corpuscles contained in the cells; *d* are air cavities between the cells, botanically known as *intercellular spaces*; and the single row of cells at the bottom of the section belongs to the epidermis of the under side of the leaf.

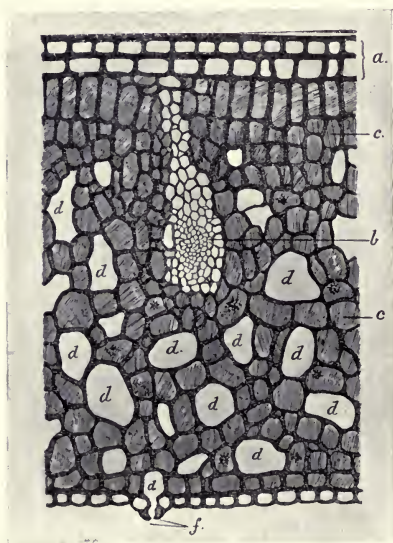


FIG. 158.—SECTION THROUGH PART OF THE LEAF OF A RHODODENDRON.

But some cells have yet to be spoken of which play a most important part in the life of the plant, and to which particular attention should be given. A pair of these cells are lettered *f* in the drawing. They project from the lower line of epidermal cells, and form the two lips of a little mouth, which communicates with one of the intercellular spaces (*d*); moreover, they contain chlorophyll, which the epidermal cells do not. To speak of these projecting cells

as "lips" is not fanciful, for the orifice between them is a veritable mouth, and the name which physiologists apply to such openings is *stomata*, which is simply the Greek word for "mouths" (figs. 160, 162, 163).

The stomata, indeed, are little mouths or crevices in the epidermis, caused by the separation of certain cells in the course of growth; and these cells form the "lips" of the mouth, and are known as *guard-cells*. Each is shaped like a crescent, their points or horns meeting to form the *stoma* or mouth; and it is by means of these peculiar structures that the plant transpires. The tiny openings establish a communication between the atmosphere and the air chambers or inter-cellular spaces in the interior of the plant, the passing in and out of gases being regulated in a beautiful manner by the guard-cells.

Fig. 164 represents a minute piece of the epidermis of the Madder-plant (*Rubia tinctoria*), in which three of the stomata are plainly shown; but far better for examination is a beautiful plant of the Daffodil order—Amaryllidaceæ—known by the very ugly name *Hippeastrum*. It is a variety of *H. ackermanni*, one of the largest flowering species of the genus. As a rule the clefts vary in length from $\frac{1}{300000}$ th to $\frac{1}{123000}$ th of an inch, and so abundant are they on some leaves that a square inch of tissue may contain as many as 250,000 of them. They are met with only in those parts of the plant where they are actually needed, for our protoplasts work on economic principles, never wasting their forces. Hence you will look in vain for the stomata on leaves which grow under water,* or on the under surface of



Photo by]

[E. Step.

FIG. 159.—RHODODENDRON (*R. arboreum*).

This magnificent tree, a native of the Himalaya, is quite hardy in some parts of southern England, and reaches great proportions. The clump photographed is about twenty feet in height.

* *Water stomata*, however, are found in some plants. "These are situated over the ends of small masses of specially modified parenchymatous cells (glandular cells), in which vascular bundles terminate, and which are known as *water glands*." Water stomata give off water and various substances in solution.—*Text-book of Biology*, p. 92.

floating leaves—the very place where they are most plentiful in land plants. Plants of the Cactus tribe (*Cactee*) and some tropical Euphorbias—whose leaves, like those of the Cacti, hereafter to be spoken of, have been metamorphosed into spines and thorns for protective reasons—develop their stomata on the fleshy succulent stems. From roots—if we except the green-celled aerial roots of a few epiphytes, such as the Tree-orchids of the tropics—they are entirely absent. In the interesting Polar-plant (*Silphium laciniatum*) the stomata are about equally distributed on both sides of the broad flat leaves—a very necessary provision, because of the peculiar position of the leaves, both faces of which are in every case equally illuminated by the sun. This is the case with most, if not all, plants with vertical leaves.



FIG. 160.—STOMA OF SCOTS PINE
(*Pinus sylvestris*).

The breathing pores of plants are called stomata or mouths. In this section of a leaf of Scots Pine, the open stoma on the surface is seen to connect with spaces between the cells of the leaf-tissue. Magnified.

ing of the leaf-stalk, and if ever the phenomenon is accounted for it will probably be by one who has studied the plant closely in its native habitat.*

It has been shown that the presence of light is most essential to the development of perfect and vigorously acting stomata. This fact—with other related facts—has been well illustrated in the case of one of the commonest of the Liverworts, *Marchantia polymorpha* (fig. 169). The young plant, when first separated as a kind of bud from its parent, exhibits no stomata or roots.† “It has been ascertained by repeated experiments,” says Dr. Carpenter, “that stomata and roots [really ‘rhizoids’] may be caused

* *Freaks and Marvels of Plant Life*, pp. 196, 197.

† More correctly *rhizoids*. *Rhizoids* corresponds to the root-hairs of Flowering Plants.

A curious fact, not unconnected with our present subject, has been brought to light by Dr. M. C. Cooke, in relation to *Bomarea carderi*, a handsome climbing plant of Colombia. The plant has long lance-shaped leaves, and Dr. Cooke has pointed out that the *under* surfaces of the blades of these leaves are exposed to the light, owing to a twist in the leaf-stalk (fig. 167). To give additional interest to the discovery, a competent physiologist, Mr. W. S. Gilbert, to whom specimens were submitted, ascertained that the entire structure of the leaves is reversed, in order to fulfil the conditions of their reversed position; the under surface being smooth, and presenting the usual characteristic epidermal cells of an *upper* surface; while the true upper surface is fitted to do duty for the former. No satisfactory reason has yet been assigned for the twist-



[Photo by]

FIG. 161.—PRIMROSE (*Primula acutis*).

One of the most beautiful, as it is one of the most plentiful, of our native wild flowers. The long pink foot-stalks of the flowers start from a dwarf scape, hidden among the bases of the leaves. KUMORÉ, N. AFRICA.

[E. Step.

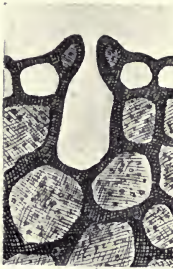


FIG. 162.—RHODODENDRON.
Part of section through leaf, showing a single stoma with its guard-cells. Magnified.

to develop themselves in either of the two sides; the stomata* being always formed on the upper surface, under the influence of light, and the . . . [rhizoids] proceeding from the lower towards darkness. But if the surfaces be reversed *after* the reproductive organs have been developed to a certain point, so that the stomata be directed towards the ground, and the . . . [rhizoids] be made to rise into the air, the little plant will right itself, by twisting itself round, so as to bring its surfaces to their former position. Further, when plants of a higher description are grown in darkness, the stomata are developed very imperfectly, or not at all. Thus we have an example of the very important effects of the stimulus of light upon the vegetable structure, not only in covering its actions, but in influencing its development" (*Vegetable Physiology and Botany*).

We have said that the stomata are the organs through which the plant transpires. The condensation of water on the glass surface of an ordinary fern-case is a familiar instance of *transpiration*; though doubtless some of the vapour is due to evaporation from the soil. By placing a piece of cardboard, through which a small hole has been made for the insertion of a well-developed leaf-shoot, over the mouth of a tumbler of water, and covering the whole (leaf-shoot and tumbler) with a bell-glass, evaporation will be prevented, and the watery deposit forming on the inside of the glass will soon furnish proof that water is transpired from the leaves. Hence the necessity for keeping the roots of plants well supplied with water; for if the loss by transpiration be greater than the quantity supplied by the roots, the conducting parts (as the stem and branches) quickly suffer; and when at length the evaporation from the more delicate organs can no longer be compensated, they lose their stiffness or turgidity, hang down from their own weight, and wither. The flagging of leaves, so often noticed in the potting and bedding-out of plants, is due to the same cause. The delicate root-hairs, by which alone absorption of the soil is effected, get destroyed in the process of transplanting, and thus the upward flow of crude sap to the leaves is temporarily arrested. In cases of this kind, transpiration should be artificially checked by shading the plants from the light till such time as new root-hairs have been found, when absorption will again take place.

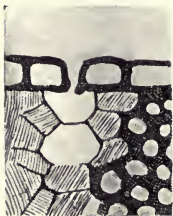


FIG. 163.—FIELD HORSE-TAIL.
Section through part of stem of *Equisetum arvense*, showing a stoma and its connections. Magnified.

* Or, rather, *stomata-pores*. They are really pores in the outermost layer of tissues (for the thallus has no true epidermis), and each pore leads into an air chamber much larger than itself, in which is contained the assimilating tissue of the thallus.



WESTERN BANKSIA (*Banksia occidentalis*).

A representative of the Order Proteaceae. There are numerous species, confined to Australasia. The Western Banksia is found only in South-West Australia. The flowers are without petals, and great numbers of them unite to form heads as shown. But the shrubs are chiefly valued in cultivation on account of their ornamental foliage, which is dark-green above but covered with white or red down on the underside.

Thus we see how important a part the leaves play in connection with the upward flow of sap. Transpiration, which is carried on chiefly through the stomata, not only gets rid of the superfluous water, but sets up a rapid movement of the crude sap from the root to the leaves, drawing it upwards, somewhat as the oil is drawn upwards in the wick of a burning lamp. This giving-off of water by plants is often of considerable benefit to the regions in which the plants are found. "It is a well-known fact," says Dr. Nathaniel Ward, the inventor of the Wardian case, "that many hilly countries have been rendered quite sterile, in consequence of the indiscriminate destruction of their trees, the roots of which, taking up more water from the deep-seated springs than the plants require for their own use, distil the surplus through the leaves upon the ground, forming so many centres of fertility. 'Spare the forests, especially those which contain the sources of your streams, for your own sakes, but more especially for that of your children and grandchildren.'" * Needless to add, the quantity of water given off in the manner described renders the solutions denser in the leaves than in the stems—a point that will come before us again presently.

Before leaving this subject of stomata we should call attention to the analogous structures in the bark, known as *lenticels*. As the stem or branch of a woody plant grows, the epidermis with its stomata gets too small for the increasing diameter of the part. It cracks longitudinally and dies, becoming dead bark, but connection between the air outside and the intercellular spaces of the *cambium* within is maintained by means of the lenticels, through which carbonic acid gas passes outwards and oxygen inwards. These lenticels may be noticed on the twigs of trees as little prominences, differing in tint from the surrounding bark. In the Birch and Cherry they are especially noticeable as transverse lines.

Much more devolves upon the leaves than the giving off of superfluous moisture. We have seen that the crude sap, which contains in solution the nutritious principles, undergoes but little change during its passage from the root to the leaves; and also that the substances thus introduced into the plant are, without exception, *inorganic compounds*. Yet these compounds, if they are to be of any service to the plant, must be converted into organic matter, in order that this, in turn, may form the plastic material or protoplasm out of which new vegetable structures, such as cells, vessels, etc., may be built up. In other words, the food must be *assimilated* by the plant; and this necessity pertains not merely to the nutrient substances absorbed from the soil, but also to the carbon dioxide derived from the atmosphere.

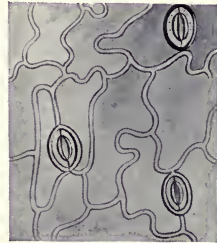


FIG. 164.—STOMATA.
Cells in epidermis of the leaf of
Madder (*Rubia tinctoria*), with
three stomata.

* *On the Growth of Plants in Closed Cases*, etc., pp. 10, 11.

Assimilation, indeed, is found to consist essentially in the decomposition of carbon dioxide and the formation of some kind of sugar—possibly *glucose* ($C_6H_{12}O_6$), possibly *canose* ($C_{12}H_{22}O_{11}$)—in the chlorophyll corpuscles. Allusion was made to this some pages back, where it was pointed out that the cells containing chlorophyll—which are always near the surface of the plant—absorb carbon dioxide from the atmosphere or water (the latter in the case of submerged plants), and that this gaseous compound is decomposed in the chlorophyll corpuscles under the action of light. It was also stated that the first organic compound as a result of the process is, in most plants, a form of

sugar.* The importance of the leaves in the economy of Vegetable Life will be seen at once, when it is added that these are the organs chiefly concerned in the work in question.

You may illustrate the process by a simple experiment. Let the stem of any pond-weed of convenient size be placed in water which holds carbon dioxide in solution (a little spring water will be pretty sure to contain a sufficiency for the purpose), and exposed to sunshine. What follows? From the cut surface of the stem, bubbles of gas are given off at regular intervals. The liberated bubbles consist of oxygen. Probably you now perceive what has taken place. Some of the carbon dioxide has been absorbed by the leaves of the plant, and there decomposed, under the influence of light, the oxygen having been given back to the water as useless. This setting-free or evolution of oxygen from plants is popularly known as “breathing” or respiration, but the term, in this



FIG. 165.—HORIZONTAL SECTION THROUGH THE EPIDERMIS OF A YUCCA LEAF, Showing stomata.

application of it, is altogether erroneous, the process being one of exhalation and simple evaporation. Plants *do* respire, just as animals respire,† but

* It has been proposed to apply the term *photosynthesis* instead of *assimilation* to this process. “As the activity of the chlorophyll apparatus is so essentially dependent upon light,” says Dr. Reynolds Green, “the process of construction of carbo-hydrate substances from carbon dioxide and water, which is its primary object, may appropriately be called *photosynthesis*. This term has certain advantages over the older expression, the *assimilation of carbon dioxide*, as the term ‘assimilation’ may preferably be reserved for the process of the incorporation of the food materials into the substance of the protoplasm” (*Introd. to Veg. Phys.* 1900).

† That is, by giving out carbon dioxide and watery vapour and inhaling oxygen. A plant placed in *pure* carbon dioxide would soon be suffocated, just as would an animal.



Photo by J]

FIG. 166.—CUCKOO-PINT (*Arum maculatum*).

Also commonly known as Lords and Ladies. The large spear-shaped leaves (often spotted with purple) are familiar spring features of the hedge-bank. The so-called 'flowers' consist of a yellow-green hood (or spathe) and a thin, greenish or white spadix. The hood is very minute, and will be found obscured round the spadix in the swollen lower part of the spathe. HURDIN, N. SPEDON.

[E. Steg-

the giving off of oxygen in the manner described is not respiration. We have been watching one of the consequences of assimilation.

Mark, we say, "consequences." The true act of assimilation—in this case the appropriation of carbon—has taken place out of sight in the leaves, which, as already stated, are the organs chiefly concerned in this important function. The process itself is only imperfectly understood, though enough has been discovered to stimulate inquiry. Undoubtedly the first stage in the building-up process is the union of CO_2 and H_2O to form the starting-point for a carbo-hydrate; and the first carbo-hydrate which can be detected in the leaves is, as we have been pointing out, some form of sugar. The leaves

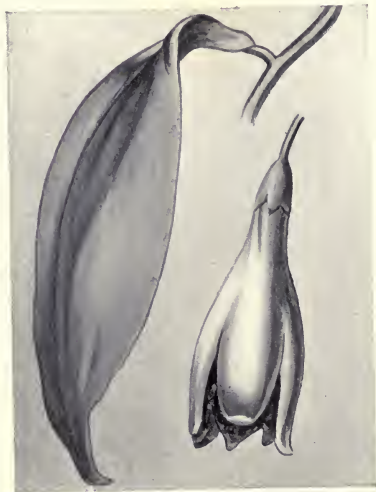


FIG. 167.—*Bomarea carderi*.

Owing to a twisting of the leaf-stalk the lower surface of the leaf is brought above, and the whole of the structural arrangements are altered to correspond with this change of position.

agents or circumstances producing this suspension of function are stated by him to be "dry heat, moist heat, cold, desiccation, partial asphyxiation, etherization, treatment with acids, alkalies, and antipyrin, accumulation of the carbo-hydrate products of assimilation, immersed in very strong plasmolytic solution, and prolonged insolation. The inability to assimilate is, if the cell remain living, only temporary, being followed sooner or later by a more or less complete recovery of the power of assimilation."

are chemical laboratories, wherein the little green corpuscles of protoplasmic matter produce results that have baffled our Kölligers and Faradays, though every year the Plant World is yielding up fresh secrets to the patient workers of to-day. The exceeding difficulty of the investigation may be gathered from a remark by Mrs. Somerville, that "although it may be inferred that chemical action is the same within the vegetable as it is in the inorganic world, yet it is accomplished within the plant under the control of the occult principle of plant life."*

Under certain conditions cells and tissues containing chlorophyll have their power of assimilation arrested for a time, though the cells continue to respire. Dr. A. J. Ewart has made an extensive series of experiments on various plants bearing upon this point (see *Journal of the Linnean Society*, vol. xxxi. pp. 364-461). The

* *Molecular and Microscopic Science*, vol. i. p. 168.

In the leaves are manufactured the starch-grains, proteids, etc., of which some account has been already given, and which are required, not only for the present growth of the plant, but also as reserve food material. But these substances are solid and insoluble in water, a circumstance which prevents their passage from cell to cell; and they have therefore to undergo further changes before they are dismissed from the leaves. Starch, for example ($C_6H_{10}O_5$), is converted, by means of a ferment called *diastase*, into the soluble substance sugar* ($C_6H_{12}O_6$), which, becoming part of the assimilated nutrient sap, is distributed through the plant, to be again fixed in the form of starch at particular places, as in the grains of cereals, the tubers of the Potato, etc. The proteids are also changed, the agents in their transformation (known as *proteolytic enzymes*) being pepsin and the various trypsins.

But we spoke of *respiration*. What is it? If the term is a misnomer as applied to the evolution of oxygen from plants, in what does true respiration consist? The question may be answered by a simple experiment. Soak in water for twenty-four hours, to induce germination, a quantity of peas, then place them in a jar, disposed in single layers between pieces of moist blotting-paper. The mouth of the jar is closed by a tightly fitting cork, which is withdrawn after an interval of a few hours. Now take a lighted taper and plunge it into the vessel. Instantly the flame is extinguished. You guess the cause? While confined in the jar the peas have been evolving carbon dioxide, and in carbon dioxide



Photo by]

[E. Step.

FIG. 168.—*Monstera deliciosa*.

The fruit-spike of this Mexican plant. The seeds are embedded in a luscious pulp, which has a flavour similar to that of pine-apple. The leaves have large perforations in their tissues.

* *I.e.* glucose or grape-sugar. The formula for canose or cane-sugar, sometimes called sucrose, is $C_{12}H_{22}O_{11}$.



FIG. 169.—LIVERWORT (*Marchantia polymorpha*).
Showing the stalked antheridial receptacles.

oxygen nearly equal to the volume of carbon dioxide given out; indeed, the absorption has really preceded the evolution of the latter, and is the cause of it. In other words, the oxygen has found its way into the living cells of the peas, and by decomposing, with the active assistance of the protoplasm, some of the complex carbon-containing compounds, has liberated the carbon dioxide. What is known as *oxidation*, a burning of organic material, has taken place—the very process which goes on in animal bodies, and which is called respiration. The germinating peas have, in fact, been breathing, not through any special respiratory organs, as is the case in animals, but breathing nevertheless; and what is true of the subjects of our experiment is true of the living parts of almost all plants. Respiration is as necessary to vegetable as it is to animal life, and in both the great kingdoms breathing and living may be taken as synonymous terms. True, in certain of the lower forms of vegetation, such as the Yeast-plant (*Saccharomyces cerevisiae*) and Bacteria (*Schizomycetes*), a process of fermentation goes on which appears to obviate the necessity for respiration; but the exceptions only give emphasis to the rule. In the *Algae* and Mosses (*Musci*), again, respiration is comparatively feeble; still, *they breathe*, and whenever a free supply of atmospheric oxygen is denied, they are suffocated and die.

As we ascend the scale of Life, respiration becomes more and more vigorous, and is often attended by a sensible *liberation of heat*, particularly in certain parts of the plant and at certain periods. For this reason the *Soldanellas*, a small genus of pretty Alpine plants, are able to melt a way through the hardest crust of snow, their slender flower-stalks pushing upwards to the light and air as effectually as if they were so many fire-heated awls.

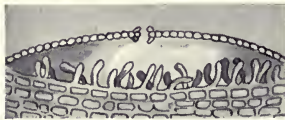


FIG. 170.—SECTION THROUGH PART OF THE THALLUS OF LIVERWORT, Showing a stomate and air chamber.

no flame will live. That the vessel is charged with this gas may be proved in a simple manner. Into another jar pour some lime-water. When carbon dioxide and lime-water are brought together, the former combines with the lime and forms an insoluble carbonate of lime, which imparts a white cloudy appearance to the liquid. If, then, we next tilt the jar containing the peas over the other vessel, the carbon dioxide, which is heavier than the air, will be poured into the lime-water, and the result just described will be witnessed.

It would be easy to demonstrate further that the germinating peas have absorbed a volume of

We may add, before passing from this subject, that in many—probably in *all*—



FIG. 171.—FRUIT OF THE DATE PALM (*Phoenix dactylifera*).

A native of Africa and Tropical Asia. One of the most valuable of trees, as whole tribes practically live upon its fruit, which is borne by the female trees only. Some idea of the abundance of fruit may be gathered from this photograph, which shows only a small portion of the tree.

flowers there is a distinct rise of temperature at the period of opening, a fact the truth of which may be demonstrated by a thermometer in the case of inverted tubular and bell-shaped flowers, the air in which is not only warmed, but, being little disturbed by the surrounding atmosphere, retains its warmth. Kerner (*Natural History of Plants*) has recorded the results of some experiments in this direction which are very interesting. The temperature inside the spathe of one of the Brazilian Aroids, the handsome large-leaved *Monstera deliciosa*, was found to be 38° centigrade, when the temperature of the outer air was only 25° ; the spathe of another Aroid,



Photo by

[E. Step.

FIG. 172.—SWAN'S-NECK THREAD-MOSS (*Mnium hornum*).

One of the most beautiful of our mosses, forming deep and extensive carpets of golden green, above which nod the spore-capsules on their arched thread-like stalks. It may be found on sandy woodland banks, fruiting in the spring.

Arum cordifolium, was $35-39^{\circ}$ at the same air temperature; while *Arum italicum*, a plant extremely common in the region of the Mediterranean, closely resembling our common Cuckoo-pint, actually exhibited a temperature of 44° when the thermometer in the external air only registered 15° . This was at the period of the opening of the spathe, which was noticed at the time to give forth a peculiar fragrance, like wine. Here, then, we have a plant the temperature of whose respiring flowers exceeds that of blood-heat!

The evolution of light from plants is also thought to be connected more

or less remotely with respiration—*i.e.* with the combustion of carbon compounds in living cells. Many theories, however, have been advanced to account for the phenomena of luminosity, and the paucity of our knowledge on the subject may be gathered from the fact that the very existence of the phenomena—at least, in the higher plants—is to this day gravely questioned by many botanists. In our opinion the evidence in favour of the alleged occurrences is too accumulative to be resisted; though doubtless they are due to other causes than those which produce the phosphorescence in plants of lower organization, as we hope presently to show.

The great naturalist Linnæus was the first—at least in modern times—to record an observation on the subject, his attention having been drawn to it by his daughter, Christina Linné. Walking in her father's garden one hot June evening, she observed the flowers of *Tropæolum majus* (the Garden Nasturtium) give forth sparks or flashes. The phenomenon was repeated on successive evenings, and also in the mornings before sunrise, when not only her father, but other men of science were present. One of these gentlemen, a well-known electrician named Wilcke, believed the flashes to be electric; and this appears to be the opinion of most writers who have investigated the subject since; though some believe that the scintillations are only apparent, and class them among optical illusions. The fact that the flashes are invariably observed at times when the air is dry and charged with electricity, is, however, an argument—and a pretty strong one—in favour of the former view.

Perhaps no flowers exhibit this phenomenon in a more remarkable degree than those of the plant noticed by Linnæus; though the common



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[E. Step.

FIG. 173.—MARTAGON LILY (*Lilium martagon*).

One of the plants whose flowers are said to be luminous. EUROPE, ASIA

Marigold (*Calendula vulgaris*), African Marigold (*Tagetes erecta*), Martagon Lily (*Lilium martagon*), and Sunflower (*Helianthus*) are also highly luminous.

The remarkable scintillations first observed by Christina Linné have now been witnessed by so many credible and competent observers, that it is singular their reality should be longer doubted. M. Haggren, a Swedish naturalist, observed them frequently, and when at work in his garden employed a man to watch the flowers and to make signals whenever



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[S. L. Bastin.

FIG. 174.—THE SOLDANELLA (*Soldanella alpina*).

This pretty alpine plant is shown under the snow, which by its own evolution of heat it is able to melt, and so make its way to the light.
EUROPEAN ALPS.

the flashes occurred. They both saw the light constantly, and at the same moment, playing round the flowerheads of the Marigold. This was in the months of July and August, the phosphorescence being only seen at sunset or for half an hour after, and never on rainy days or when the air was loaded with vapour. A microscopic examination of some of the flowers, to discover whether some small insects or phosphoric worms might not be the cause of the light, soon convinced our naturalist that such a theory was untenable. Nothing of the kind was found, and he came to the conclusion that the flashes were electric. His own theory, however, that the electric light was caused by the pollen of the florets, which in flying off was scattered upon the petals, is hardly to be taken seriously.

In the year 1835 Mr. J. R. Trimmer, of Brentford, was an eye-witness of the phenomenon, of which he sent an account to the *Magazine of Botany*. In this case, also, everything points to electricity as the exciting cause. The writer was walking in his garden in the evening, where many Nasturtiums were in bloom, his thoughts far away from the subject of phosphorescence, when vivid flashes from those flowers attracted his notice. The flashes were the most brilliant he had ever observed, and at the



FIG. 175.—NIGHT IN THE GARDEN.

An attempt to show the luminosity of the Nasturtium (*Tropaeolum majus*), which many observers have vouched for as appearing in certain conditions of the atmosphere.

same time—a fact to be specially remarked—the sky was overcast with a thunder-cloud.

Seven years later (August 4th, 1842) the phenomenon was observed by a Mr. Dowden and three others, at nearly the same time of the day and under similar climatic conditions. In other words, the flashes were seen at about eight o'clock in the evening, after a week of dry weather. "By shading off the declining daylight, a gold-coloured lambent light appeared to play from petal to petal of the flowers, so as to make a more or less interrupted corona round the disc." The flowers examined were a double variety of the Common Marigold.

In quite recent years more than one naturalist has recorded his personal observations of the phenomenon. Thus Canon Russell, writing to *Science Gossip* in September, 1891, says: "On the evening of June 16th, 1889,



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[E. Step.

FIG. 176.—DRAGON (*Arum dracunculus*).

This South European species differs from the Cuckoo-pint in producing a stem above ground, which is spotted with purple. The leaves, too, are broken up into large lobes in a pedate manner. The spathe and spadix are purple, and give out a fetid odour.

I happened to be taking a stroll round the rectory garden, and passing by a fine plant of the Common Double Marigold, of a deep orange colour, I was struck by a peculiar brightness in the appearance of the flowers. After watching for a few seconds, I observed, to my great surprise, that coruscations of light, like mimic lightning, were playing over the petals. Thinking that I might be only the victim of an ocular illusion, I brought out other members of the household, and asked them to report exactly what they saw. Some perceived the flashes readily enough, but others only slowly and after patient observation, all eyes not being equally sensitive to such rapid vibrations of light. These performances commenced about 8.30 p.m., and continued for perhaps an hour. I afterwards ascertained that much later on,

when it was almost dark, the whole plant seemed to glow with a sort of pulsing phosphorescence."

The Common Nasturtium was also luminous in a less degree, the luminosity in this case extending to the leaves, which, it is further stated, gave off "a blue vapour of extreme tenuity." "I put a leaf of Nasturtium on the stage of a microscope," continues the canon, "and, having focussed it for the central spot from which the nerves branch off, under an inch and a half objective, I brought it into a room nearly dark. Looking at it then through the microscope, I found that the leaf could be distinctly seen almost by its own light. The appearance of the luminous vapour floating over its surface (like moonlight over rippling water) was strikingly beautiful. The whole leaf seemed to twinkle with points of light—the main ribs radiating from the common centre shining out like a silver star. These effects are best witnessed after a day of hot sunshine."

Canon Russell's discovery of phosphorescence in the leaves of *Tropæolum* introduces a new feature into the inquiry, and is of much interest. Moreover, the fact that the luminosity remained in or on a leaf which had been detached from the plant and removed to quite a different spot, and that it was visible alike in daylight, dusk, and lamplight, might be held to dispose once and for ever of the optical illusion theory; for how could such a theory be sustained in view of the *persistence* of the phenomenon? And yet it is strange that so few have beheld this manifestation.

So far the references have all been to orange-coloured flowers; and it will be remembered that Coleridge wrote:

'Tis said at Summer's evening hour,
Flashes the golden-coloured flower,
A fair electric flame.

The False Dittany (*Dictamnus fraxinella*)—of which there are several garden varieties, white, red, and purple—may be said to occupy an unique



FIG. 177.—FALSE DITTANY (*Dictamnus fraxinella*).

From glands on the flower-stalk this plant exudes an etheric oil which is volatilized in warm weather, and if a light is applied beneath the flower the vapour takes fire. Many modern experimenters, however, have failed to get such a demonstration.



FIG. 178.—LUMINOUS MOSS
(*Schistostegia osmundacea*).

The so-called luminosity is a false appearance due to the reflection of light from certain cells.

place among luminous plants (fig. 177). To quote from Erasmus Darwin :

What time the eve her gauze pellucid spreads
O'er the dim flowers, and veils the misty meads,
Slow o'er the twilight sands or leaty walks,
With gloomy dignity *Dictanna* stalks ;
In sulphurous eddies round the weird dame
Plays the light gas, or kindles into flame.

In plain prose, the plant secretes a fragrant essential oil in great abundance : and in warm weather this exudes and volatilizes, so that the air becomes impregnated with it, and is rendered not only very fragrant, but also highly inflammable ; insomuch that, if a naked flame be brought near the plant, the oily vapour takes fire. This discovery, like that of the luminosity of *Tropaecolum*, was made by the gifted daughter of Linnæus, and has been verified since by Dr. Hahn, the result of whose investigations is given in the *Journal of Botany* for 1863. His first experiments were unsuccessful, but on bringing a lighted match to a nearly faded blossom, he saw "a reddish, crackling, strongly shooting flame, which left a powerful aromatic smell, and did not injure the peduncle." Since then he has repeated the experiment several times, and a careful microscopic examination of the plant has shown that the inflammable etheric oil is contained in numerous minute reddish brown glands, located in the flower-stalks.

Other instances of luminosity in Flowering Plants—which, however,

must be more quickly passed over—are afforded by the latex or milk-sap of a species of *Euphorbia* (*E. phosphorea*), which is said to shine with a phosphorescent light on warm nights in the ancient forests of Brazil, and by the roots of certain plants, as the fragrant *Khus-khus* (*Andropogon*) and other grasses. A luminous rootstock referred to in the *Proceedings of the Royal Asiatic Society* for April, 1845, is perhaps that of the *Khus-khus* grass. After a wet cloth had been applied to its surface for an hour or two it gleamed in the dark "with all the vividness of a glow-worm" ; and though the lustre faded away as the specimen dried, it was revived on the application of fresh moisture, nor did it appear to lose its luminous property after frequent applications. The sap of the *Cipo*, a South American Vine, is said to be so highly luminous that, when injured, it seems to bleed streams of



FIG. 179.—THREAD-LIKE
GROWTH (PROTONEMA) OF
LUMINOUS MOSS.

Greatly magnified.



FIG. 180.—NIGHT SCENE IN A BRAZILIAN FOREST.

A Mushroom (*Agaricus Gardneri*), like some others of its tribe, here gives out a soft but brilliant light. The light is of pale greenish hue, and equal in brilliancy to that of the larger fire-flies.

living fire. "Large animals have been noticed standing among its crushed and broken tendrils, dripping with the gleaming fluid, and surrounded by a seeming network of fire."

Passing now from the Flowering Plants, we come to the non-flowering or Cryptogamic, to which the Mosses, Seaweeds, Fungi, etc., belong. Here we meet with some very striking and unmistakable instances of luminosity, though in some of these, doubtless, the phenomenon is connected rather with the process of assimilation or decomposition than with electrical conditions of the atmosphere. We have seen that assimilation commences with the decomposition of carbon dioxide in the chlorophyll corpuscles, and that this takes place under the action of light. Light is therefore absolutely essential to the successful discharge of the functions which are carried on in green tissues; and hence the very interesting adaptations for increasing light intensity in plants which grow in caverns and grottoes and in the twilight depths of the sea.

Certain caves of Central Europe have long been celebrated for their luminous Mosses. On entering one of these caves, the eye is at once attracted to the floor of the chamber, which gleams and sparkles with minute points of golden-green light. The ignorant beholder might imagine that he had stumbled upon a store of hidden emeralds, but any hopes of sudden enrichment fostered by such a thought will be quickly dissipated; for the treasure is only gnome's treasure at best. On bringing the supposed prize to the light, it is found to consist



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[E. Step.

FIG. 181.—RHIZOMORPH.

Strands of mycelia of the Honey-coloured Mushroom (*Armillaria mellea*), which has often been observed to give out light.



Photo by]

[E. Step.

FIG. 182.—TREE-DESTROYING MUSHROOMS.

Their rhizomorphs or mycelia ascend the tree beneath the bark and cause destruction of its tissues. The species represented are the Sulphur-tuft (*Hypoholoma fasciculare*) and the Honey-coloured Mushroom (*Armillaria mellea*).

of nothing but lustreless earth and yellowish grey fragments of stone, dotted over with tiny, dull green, feather-like Moss-plants (fig. 178), as well as with multitudes of delicate branching threads, which are simply more Moss-plants, but in an earlier stage of development. It is from these slender filaments—or, rather, from the spherical and microscopic cells at the ends of their branches—that these deceptive and beautiful scintillations arise. In fact, the little semi-transparent globes, each of which contains a few grains of chlorophyll, act like the lenses of a cat's eye, refracting the scanty incident light where it strikes the globes, and producing a bright disc on each as the result (fig. 179). By this means the light is concentrated on those places where the chlorophyll is situated, and, in spite of the surrounding gloom, the granules are able to discharge their special functions in an entirely efficient manner. The name of this very curious luminous Moss is *Schistostega osmundacea*.

There are other Mosses (e.g. *Hookeria splendens*) which exhibit the same phenomenon, though in a less marked degree; nor are these special organizations confined to the *Musci*. They are to be found in many of the Sea-wracks and other submarine plants; though the deep-sea Algæ are more often distinguished by an optical phenomenon of another kind. The popular

idea that as you descend deeper and deeper into the ocean, and the light of day vanishes, a fiery yellow first succeeds, then a flaming red (the "watery sea-hell" of Schleiden), then dark crimsons and purples, and finally an impenetrable black, is partially, though not entirely, correct; and the circumstance has an important bearing on our present inquiry. Strictly speaking, the colour of sea-water—in reflected as well as in direct light, and at all depths where the light can reach it—is blue, a fact which is scientifically accounted for by the high refrangibility of blue rays, which



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[E. Step.

FIG. 183.—HONEY-COLOURED MUSHROOM.

A couple of examples of this fungus from the group shown in fig. 182, but here photographed natural size.

enables them to pass easily through the water, while the red, orange, and yellow rays, which are far less refrangible, are absorbed. Yet red and yellow rays are absolutely essential to plants containing chlorophyll if carbohydrates are to be formed and life and growth maintained*; and the question naturally arises, How do the deep-sea *Algae*, which are deprived of all but the blue rays, compensate themselves for this deprivation? The answer to the question affords a striking instance of the resourcefulness of Nature.

No marine plants inhabit a deeper zone than the *Florideæ* or Red Seaweeds, and it is by means of the pigment which gives them that colour that the deficiency is remedied. This pigment, which is known as *phyco-erythrin* (Greek *phukos*, seaweed; *erythros*, red), is fluorescent in a high degree, and has the remarkable property of changing the blue rays which visit the plant into yellow, orange, and red ones; so that the chlorophyll granules contained in the underlying tissues are enabled to carry on their functions in a regular manner, decomposing carbon dioxide and forming organic substances just as do the green *Algae* which float upon the surface of the water. In fact, the arrangement is quite as perfect and efficient as is the lens arrangement in luminous Mosses.

* The blue rays are said to be actually destructive of vegetable protoplasm.



FIG. 184.—LUMINOUS MUSHROOMS.

Several species—among them the European *Agaricus olearius*—have long been known to give out light in the darkness.

We come now to the *Fungi*. Here we meet at once with examples of luminosity which are undoubtedly due to phosphorescence. Phosphorescent Fungi are abundant, for instance, in the coal-mines of Dresden, where they are even said to be dazzling to the eye. Hanging in festoons and pendants from the uneven roofs, twisting root-like round the pillars and covering the walls, they give to these otherwise dreary excavations the semblance of fairy palaces. "I saw the luminous plants here in wonderful beauty," says Mr. Erdman, a Commissioner of Mines, "and the impression produced by the spectacle I shall never forget. It appeared, on descending into the mine, as if we were entering an enchanted castle. The abundance of those plants was so great, that the roof and the walls and pillars were entirely covered with them, and the beautiful light they cast around almost dazzled the eye. The light they give out is like faint moonshine, so that two persons near each other could readily distinguish their bodies."

These spreading masses of luminous vegetable matter were formerly looked upon as a distinct species of Fungus, and were classed with a few others of similar root-like form in the group *Rhizomorpha*; but they



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[E. Step.

FIG. 185.—THE CHANNELLED WRACK (*Pelvetia canaliculata*).

A brown seaweed that grows profusely on the rocks between tide-marks, and twice a day is left dry by the receding tide. On many of the higher rocks it is completely dried up by the sun during the period of low water, but fully recovers on the return of the tide.

are now known to be simply the *mycelia* of various species of Agaric, the large fungi to which our common edible Mushroom belongs. A small portion of one of these rhizomorphs, with the mushroom which is its fruit, or spore-



[Photo by]

[E. Steg.]

FIG. 186 —A MYXOGASTER.

One of these little-known but wonderful organisms (*Brefeldia maxima*) is here shown in the plasmodium stage, when it has the appearance and consistency of cream. At a later stage it gathers into cushion-like masses with a purple-brown crust, under which the plasmodium breaks up into dust-like spores.

bearing body (*sporophore*), is shown in figs. 181 and 183. The phosphorescence of the rhizomorph is said to be due to slow decay and oxidation, either in the mycelia or fructification of the Fungi; and Sir Joseph Hooker found that alcohol, heat, and dryness soon dissipate it. That eminent botanist frequently saw the luminous mycelia in the dead wood used for fuel by the natives of Northern India, and has furnished some remarks on the subject in his interesting and informing *Himalayan Journals*.

Agaricus olearius, a Fungus common in the South of France, is also highly luminous. It grows in the dark crevices of the Olive-stems in November and December, when the gills under the pileus or cap are said to shine as brightly as a glow-worm. It has been proved to emit light only when alive. Under experiment it has been found to cease to do so at once when deprived of oxygen. Equally remarkable is the Brazilian species of phosphorescent *Agaricus* (*A. gardneri*)—a parasite on the Pintado Palm—the light of which is of a pale greenish hue, and equals in brilliancy that of the larger fire-flies; while Borneo can boast a closely allied species, also parasitical on trees, the greenish luminous glow of which has been likened to the glow of the electric discharge. Australia appears to be exceptionally

rich in these fairy lamps, most of which belong to the same great genus, *Agaricus*, though the prevailing colour of their light is white. One species, found by Drummond in the valley of the Swan River, deserves particular mention, if only on account of its size and weight. It measured sixteen inches in diameter and a foot in height, and weighed about five pounds. Even these statements, however, are eclipsed by the account of the Spruce log which the Rev. M. J. Berkeley saw, and which was literally ablaze on the inside with the white plasmodium of some unidentified species of *Myxogaster*.* When some of the luminous matter was "wrapped in five folds of paper, the light penetrated through all the folds on either side as brightly as if the specimen was exposed," albeit the luminosity had been already going on for three days!



FIG. 187.—MISTLETOE (*Viscum album*).
Leaves, buds and fruit are here shown. A photograph
of a larger portion of the plant will be found on page
36 (fig. 59).

M. Tulasne, who made some careful experiments in vegetable phosphorescence, found that the light from luminous Fungi was extinguished in vacuo or non-respirable gases, and from this he inferred that "it is due to a slow combustion without heat, arising from a chemical combination of the oxygen of the atmosphere, inhaled by the Fungus, with a substance peculiar to the plant."

Whether this is the true explanation of the phenomenon, we do not pretend to say, and those who may desire to pursue their inquiries on the subject will do well to consult the learned paper by M. Tulasne in *Ann. des Sci. Nat.* (1848), or Dr. Phipson's little book on *Phosphorescence*, in which been brought together. Neverthe-

less, we think it has been pretty clearly demonstrated that luminosity in the *lower* plants is connected almost exclusively with one or other of those two important functions, assimilation and respiration—the former in the case of cave-growing Mosses and deep-sea *Algae*; the latter in the case of certain Fungi which lodge their spores in decaying wood; whereas the luminosity which has been observed in the *higher* plants, and which appears to be confined to white, yellow, orange, and scarlet

* The Myxogasters appear as small incrustations on dead leaves and twigs, and vary in colour from black to bright orange. They form an anomalous group of Fungi, or as some say of Protozoa, low forms of animal life.



Photo by]

[E. Step.

FIG. 188.—TALL BROOMRAPE (*Orobanche elatior*).

The Broomrapes are a remarkable genus of plants that are parasitic upon the roots of other plants, from which they obtain all their nourishment. Having no use for leaves, these are reduced to thin dry scales. This is our tallest species, and about three feet in height. It is parasitic upon the roots of Hardheads (*Centaurea scabiosa*). EUROPE, S. ASIA.

flowers, is presumably due to electrical conditions of the atmosphere, and, in that case, it ought perhaps to be classed among abnormal phenomena.

But it is time to conclude this long digression, and to return to our more immediate subject—the sap of plants.

The true sap, which conveys the elaborated food material from the leaves to the root, etc., is very different from the crude, thin, watery sap

which ascends from the root to the leaves. A curious fact, illustrative of this difference, is, that the latter is nearly or quite harmless in those plants whose proper juices have the most virulent properties. Thus, according to Carpenter, “the inhabitants of the Canary Islands draw off the ascending sap, which serves as a refreshing drink, from the interior of the stem of *Euphorbia canariensis*, a tree of which the descending sap is of a very acrid nature, resembling that of the Common Spurge (*E. peplus*) of this country, but much more powerful.” It is important to bear this distinction clearly in mind. The crude sap ascends, as we had seen, chiefly by way of the wood elements of the vascular system; while the elaborated sap, avoiding the wood elements, passes down the sieve-tubes, the cellular tissues of the bark,* and, possibly, the laticiferous vessels, though it is now a question whether the latter play an important part as distributors.

Thus we have an ascending and a descending, a crude and an elaborated sap, and each pursuing independent routes through quite distinct parts of the plant. When the experiment has been tried of removing a ring of bark from a tree—

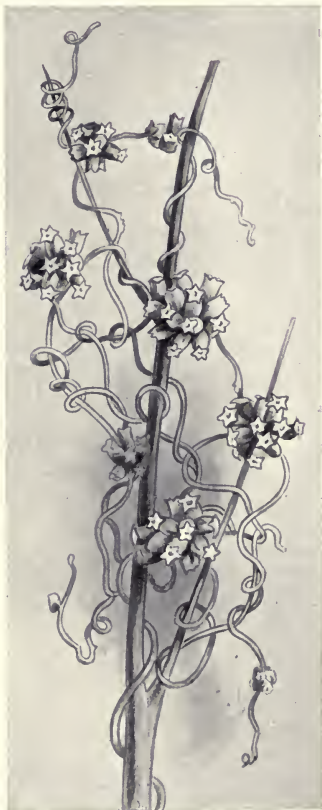


FIG. 189.—GREATER DODDER
(*Cuscuta europea*).

A twining leafless parasite that commences growth in the earth, but soon attaches itself to its victim by suckers, and then gives up its roots.

* The elaborated sap containing the *nitrogenous* organic substances (*i.e.* the soluble results of proteid conversion) descends by way of the sieve-tubes, and, *perhaps*, the laticiferous vessels, while that containing the *non-nitrogenous* organic substances (sugar, etc.) passes downwards through the parenchyma.

say, an Oak or Elm—growth *below* the ring has almost immediately ceased, conclusively showing that the flow of assimilated nutrient sap to that part of the stem has also ceased, and therefore that the way of the sap's descent is the bark. A branch of an ordinary fruit-tree may be made to bear specially fine fruit simply by binding it tightly with a ring of stout wire; for by this means the downward flow of elaborated sap is checked, and the fruit gets the benefit of all the food produced by the leaves of the branch. The fact is well known to gardeners, and much of the prize fruit shown at exhibitions is produced in this way. The upward flow of crude sap of course goes on without interruption through the uninjured wood-vessels; and thus the leaves above the ring are duly supplied with raw material from the soil, out of which to elaborate new descending sap.

Plants which have neither leaves nor roots are of course unable either to draw up a supply of crude sap or to elaborate the juices required to sustain life. They therefore resort to nefarious practices, and live, like the feudal barons in the days of King Stephen, by plundering their neighbours. Of this sort are the Dodders (*Cuscuta*), the Broomrapes (*Orobanche*), the Balanophorales, the Rafflesiales, and a great many more of the plants so well named *parasites*. We will say nothing of the Mistletoe (*Viscum album*), which is, comparatively speaking, a mild offender, and, moreover, possesses true leaves (fig. 187). The germination of the Dodder (fig. 189) is effected, like that of plants in general, in the earth, and without requiring the presence of other plants. The embryo—which, unlike the embryos of most Flowering Plants, has no *external* reserve of food material to feed upon—is nourished, in its first development, at the expense of the albuminous matter *within itself*. The slender and elementary root pushes its way into the earth, and the young, red, thread-like stem rises above it. If it finds no other living plant near it, it dies;



Photo by]

[E. Step.

FIG. 190.—LARGE BROOMRAPE
(*Orobanche major*).

Parasitic chiefly on roots of Furze and Broom.
Grows to a height of two feet. EUROPE,
N. AFRICA.

but should it succeed in finding one, it surrounds the stem, and from the points of contact proceed suckers which contain conducting tissue, and this tissue attaches itself to the conducting tissue of the host, and sucks the juices which the host has elaborated. Then the root of the Dodder becomes obliterated, and dies, and henceforth the plant lives by its suckers alone. "Whilst it was not a parasite," says the eminent French botanist, De Candolle, "it rose vertically; as soon as it became one, it was no longer tempted to direct itself either vertically or towards the light. Its shoots dart from one plant to another, and thus are conveyed to new victims when the old ones are exhausted. Often the seeds germinate before they

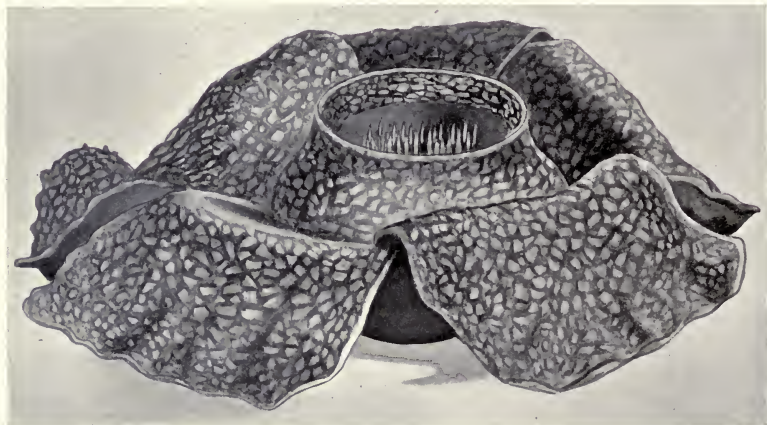


FIG. 191.—*Rafflesia arnoldii*.

Except for its hidden roots which permeate its victim, there is nothing but this enormous flower—three feet across, and the largest blossom known. It is found in the forests of SUMATRA.

quit the capsules, and the new plant immediately becomes a parasite; this is particularly observed in the *Cuscuta monogyna*, which attacks the Vines in Languedoc.*

Fig. 189 shows the Greater Dodder (*C. europæa*), which Gerarde describes as "a strange herbe, altogether without leaves or roote, like unto threds, very much snarled or wrapped together confusedly, winding itself about bushes and hedges, and sundrie kinds of herbes." This species is very partial to the Hop-plant (*Humulus*). Other species attack the Flax-plant (*Linum usitatissimum*), Clover (*Trifolium*), Thyme (*Thymus*), and Furze or Gorse (*Ulex europæus*).

* *Cyclopaedia of Natural History*, vol. ii. p. 262.



Photo by]

[E. Step.

FIG. 192.—LESSER BROOMRAPE (*Orobanche minor*).

Parasitic on the roots of various plants, especially Clovers. The stems are more slender and the flowers less crowded than in the other species.

In the meek garb of modest worth disguised,
 The eye averted and the smile chastised,
 With sly approach they spread their dangerous charms,
 And round their victim wind their wiry arms.

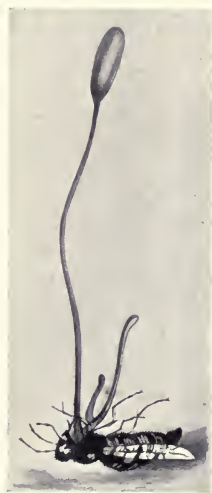


FIG. 193.—*Cordyceps sphecocephala*.

A West Indian fungus that attacks insects, especially a large species of wasp (*Polistes*) here shown to have succumbed to the attack.

The Broom-rapes (*Orobanche*), which are marked by the absence of chlorophyll, carry on their thievish practices underground by fastening on the roots of trees and shrubs, so that when they rise above the soil, and put forth their spikes of dingy flowers, only the instructed botanist would suspect them of the crimes which lie at their door. The Balanophorales and Rafflesiales, which embrace some seven or eight families, are also destitute of chlorophyll, and support themselves in much the same way as the Broom-rapes, by becoming parasitic on the roots of green-leaved woody plants. They belong chiefly to the tropical parts of Asia and America; but a few species are found in South Africa, and two or three belong to Australia and the Mediterranean area. The last-named group (the Rafflesiales) includes that vegetable wonder, *Rafflesia arnoldi*, the largest flower in the world, of which we must give some account (fig. 191).

The plant was discovered about ninety years ago by Dr. Arnold, a botanist of some note, while exploring with Sir Stamford Raffles' party in the interior of the island of Sumatra. The news of the discovery was conveyed by Dr. Arnold in a letter to a friend, and it will be better to quote

from his account than to give the facts in words of our own. The doctor says: "Here [at Pulo Lebbas, on the Manna River, two days' journey inland of Manna], I rejoice to tell you, I happened to meet with what I regard as the greatest prodigy of the vegetable world. I had ventured some way from the party, when one of the Malay servants came running to me with wonder in his eyes, and said: 'Come with me, sir, come! A flower—very large—beautiful—wonderful!' I immediately went with the man about a hundred yards into the jungle, and he pointed to a flower growing close to the ground, under the bushes, which was truly astonishing. My first impulse was to cut it up and carry it to the hut. I therefore seized the Malay's parang (a sort of instrument like a woodman's chopping hook), and finding that the flower sprang from a small root which ran horizontally (about as large as two fingers or a little more), I soon detached it, and removed it to our hut. To tell you the truth, had I been alone, and had there been no witnesses, I should, I think, have been

fearful of mentioning the dimensions of this flower, so much does it exceed every flower I have ever seen or heard of; but I had Sir Stamford and Lady Raffles with me, and a Mr. Palsgrave, a respectable man, resident at Manna, who, though all of them equally astonished with myself, yet are able to testify as to the truth.

"The whole flower was of a very thick substance, the petals and nectary being in but few places less than a quarter of an inch thick, and in some places three-quarters of an inch; the substance of it was very succulent. When I first saw it, swarms of flies were hovering over the mouth of the nectary, and apparently laying their eggs in the substance of it. It had precisely the smell of tainted beef. The calyx consisted of several roundish, dark brown, concave leaves, which seemed to be indefinite in number, and were unequal in size. There were five petals attached to the nectary, which were thick, and covered with protuberances of a yellowish white, varying in size, the interstices being of a brick-red colour. . . . Now for the dimensions, which are the most astonishing part of the flower. It measures a full yard across, the petals being twelve inches from the base to the apex, and the space between the insertion of one petal and the opposite one being about a foot. Sir Stamford, Lady Raffles, and myself took immediate measures to be accurate in this respect, by pinning four large sheets of paper together, and cutting them to the precise size of the flower. The nectarium [or hollow central bowl of the flower] would, in the opinion of all of us, hold twelve pints, and the weight of this prodigy we calculated to be fifteen pounds." The plant grows parasitically on the roots of a species of Vine (*Cissus*), and consists, besides this remarkable flower, of a mycelium-like tissue.

The Cuscutas and the Orobanches, the Balanophorales and the Rafflesiales, by no means exhaust the list of vegetable parasites. There are the Fungi, that comprehensive group in which are included not only most of the mildews, rusts, smuts, blights, etc., whose pernicious ways are unpleasantly familiar to farmers, nurserymen, and



Photo by]

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FIG. 194. — "VEGETABLE CATERPILLAR" (*Cordyceps robertsii*).

A New Zealand fungus that kills the caterpillar of *Hepialus virescens*. The fungus is shown growing from behind the caterpillar's head.

fruit-growers, but also that singular genus the *Cordyceps*, several species of which are parasitical upon insects, spiders, and their allies. Fig. 193 shows a West Indian *Cordyceps* (*C. sphecocephala*), which attacks a species of *Polistes* or wasp. The wasps may frequently be seen flying about with plants of their own length projecting from their bodies. Other well-known species of the same family are *Cordyceps entomorrhiza* and *militaris*, which sow themselves in—and derive their nourishment from—the bodies of larvæ or pupæ buried in the soil or among dead leaves. A New Zealand species, *C. robertsii*, popularly known as the "Vegetable Caterpillar," sometimes reaches a height of eight inches (fig. 194).

In reviewing the ground traversed in this and the preceding chapter,



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FIG. 195.—SNAKE'S-TONGUE FUNGUS (*Cordyceps ophioglossoides*).

This *Cordyceps* attacks another fungus—the Hart Truffle (*Elaphomyces variegatus*)—in our pine-woods.

we think it will be conceded that the analogy between the economy of the Vegetable and a well-regulated household has been sufficiently established. We have observed the admirable manner in which the multitudinous cells and vessels perform their allotted functions in the general scheme, and the harmony of action which exists between the several parts. We have seen how certain organs pump up the required water, and others carry it; how some are employed in getting rid of the waste, while others elaborate the nutrient material, and others, again, distribute the elaborated food through the plant, or store up the superfluity for future use.

Such, in brief, is the economy of the Plant. We have but touched the fringe of the subject; but what a subject it is! How vast and inexhaustible! How incomprehensible and fathomless!



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FIG. 196.—THE CLUBBED CORDYCEPS (*Cordyceps capitata*).

This is a much larger species with stouter head (spore masses). Like the Snake's-tongue, it is a parasite upon another species of Hart Truffle (*Elaphomyces granulatus*), a subterranean fungus of spherical form that would be difficult to find but for the presence of the Cordyceps above ground.

CHAPTER VI

SEED AND ROOT

Then rise the tender germs, upstarting quick
And spreading wide their spongy lobes, at first
Pale, wan, and livid; but assuming soon,
If fanned by balmy and nutritious air,*
A vivid green.

COWPER.

“THE nature of everything,” says Lord Bacon, “is best considered in the seed”—an aphorism which contains a truth of very wide application, though it is only quoted here because the first part of our subject is the seeds of plants. That the nature of the *Plant* is best seen in the seed is a truism which perhaps every physiologist would be willing to admit, and we shall probably be as ready to make a similar admission after weighing a few of the facts with which it is proposed immediately to deal.

When the reign of the Frost-spirit is over, and the earth is brought once more under the mild and vivifying influence of the spring, a large proportion of the seeds confided to the ground, either recently or at the end of the preceding autumn, swell, and release from their envelopes the precious germs which they have held in ward during the intervening months, and which, endowed with a life of their own, soon imbibe freely their nutriment from the atmosphere and the soil. Such is, in essence, the phenomenon of germination, the simplicity of which is perhaps not less wonderful than the results achieved are manifold and surprising. We say “in essence,” for when we come to consider the phenomenon in detail, a surprising variety confronts us. Let us consider a few examples.

The majority of Fungi are propagated by minute dust-like *spores*, which differ from seeds in containing no embryo or young plant, but simply a tiny mass of living matter. Kick a ripe puff-ball—the dusty powder that flies out consists of thousands of these spores. Or if we select as our type the Common Mushroom (*Agaricus cam-*



FIG. 197.—MOREL (*Morchella esculenta*).
A spore of this edible fungus, and another in process
of germination.

* The poet might have added, “And fostered by the light-dispensing sun.”



VARIEGATED ADAMIA (*Adamia variegata*)

The Adamias are shrubs, members of the Saxifrage family, and near allies of the Hydrangeas. The species figured is perhaps the most beautiful of the genus. At first the unopened buds are nearly white, then become bluish, while the fully-opened flower is purple and violet. It is a native of China.



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FIG. 198.—COMMON MUSHROOM (*Agaricus campestris*).

The mushroom is not the fungus but its fructification, the plates or gills under the cap (*pileus*) producing millions of microscopic spores which have the power under suitable conditions of reproducing the thread-like *mycelium* which is the working stage of the fungus. About one-fourth of the natural size.

pestris, fig. 198), the spores are borne on the under side of the frail umbrella-like cap (the *pileus*) on minute stalks. A powerful microscope is needed to examine them, as individually they are quite invisible to the naked eye. When these spores fall to the ground they begin to swell, and presently put out cellular threads of wonderful tenuity, which grow and branch, and continue growing and branching, till they form a beautiful white flocculent mass—the “Mushroom spawn” of our markets—from which new Mushrooms may be raised. Thus the spore does not develop at once into a perfect Mushroom, with thick stem and spreading disc-shaped fructification; there are two distinct stages of development. The close pile of whitish threads—botanically known as the *mycelium*—appears first; and then, out of the mycelium, arises the fructification or Mushroom, consisting of stalk and cap. It is important to bear these successive stages of development in mind.

When demolishing old houses, one frequently finds on the damp rafters or underneath the planks the mycelia of other Fungi, spreading from a centre nearly equally in all directions, and so delicate that a breath might dissipate them; but even in quite new houses one may meet with the terrible “dry rot” that will soon make havoc with the timber, and reduce it to tinder. In the species common in woods and meadows, it is the fructification alone which attracts our notice. In the latter case, indeed,

the mycelia are for the most part hidden, either in the soil or in the bark of trees; while the fruit-bearing organs assume the brightest colours, and flaunt themselves with gay effrontery. They appear in all conceivable forms (figs. 199-201), graceful and grotesque, elaborate and simple, geometrical and irregular. You may meet with them as cups and bottles, as horns and trumpets, as umbrellas and canopies, as finger-rings and strings of beads, as eggs and egg-cups, as globes and discs, as solid leathery lumps

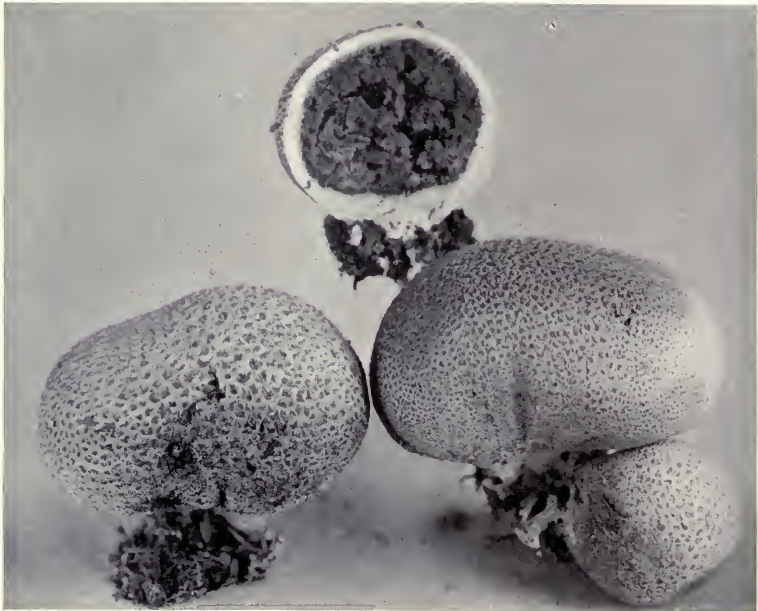


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FIG. 199.—EARTH-BALL FUNGUS (*Scleroderma vulgare*).

Often mistaken for a Puff-ball or even Truffle. The skin is thick and the contents at first a hard blue-black mass, which ultimately breaks up into minute spores, which are set free by the rupture of the corky shell. In this condition it is known as the Devil's Snuff-box. Odour strong and unpleasant. The upper example is cut through to show interior.

and hollow spherical cages; and the wonder excited by this inexhaustible variety of forms is not lessened when we remember that the beginning of each was a tiny spore, smaller than the dust-motes that gyrate in the sun.

With this brief glance at the development of a Fungus spore, let us take a forward step, and consider, with equal brevity, the round of life in one of the Mosses. The Mosses (*Musci*) contain chlorophyll, and therefore occupy a more important position in the Vegetable World than the



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FIG. 200.—THE GLITTERING TOADSTOOL (*Coprinus micaceus*).

All the Coprini are very fragile fungi, rapidly melting soon after they come to maturity. Their black spores are distributed in the form of ink. The Glittering Toadstool is so called because it is sprinkled with minute specks which reflect the light, and look as though the cap had been dusted with powdered mica.

Fungi; they form, indeed, a sort of link between the higher and lower plants. When one of the microscopic spores ejected by an adult Moss-plant has fallen into congenial soil, and begins to germinate, its innermost coat (for it is double-coated) protrudes, and develops into thread-like branching filaments (the *protonema*), recalling the mycelia of Fungi, but distinguished from mycelia by containing chlorophyll in their cells (fig. 204). From these filaments arise the leafy shoots of the new, but not yet perfect Moss-plant, which is botanically known as an *oophyte* (*i.e.* egg-plant); and

this, when fully developed, produces the male and female organs of the plant—the *antheridium* and *archegonium*, as they are called—on the successful discharge of whose functions future fructification depends. In fact, the antheridium is filled with myriads of minute spiral bodies (somewhat analogous to the pollen of flowers), which it ejects upon the archegone, and so brings about fertilization (fig. 203). As a result of this process, we get the full-grown Moss-plant, with its urns and hoods (*sporangia* and *calyptræ*), as shown in the drawing (fig. 206); the urns being full of new spores—the life-germs of a future generation.



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FIG. 201.—COMMON MOREL (*Morchella esculenta*).

Esteemed by epicures. It appears in spring, usually on spots where the earth has been burnt by a gipsy fire. The spores are produced on the surface of the honeycombed head or pileus.

Do not think that the simple Moss-plants are undeserving of your notice. They will well reward the most reverent and painstaking study—indeed, few objects are so fraught with interest, whether to the microscopist or the outdoor naturalist. We know the remark is often made, in tones of careless disparagement: “They are only Mosses!” But he who speaks thus lightly has no true sense of the beautiful, and certainly can never have taken the trouble to examine these delicate organisms. Ruskin’s touching tribute to their lowly ways and tender beauty, which forms one of the choicest

passages in *Modern Painters*, might be commended to all such, and we offer no apology for quoting the famous passage: "Meek creatures!" he calls them, "the first mercy of the earth, veiling with hushed softness its dintless rocks; creatures full of pity, covering with strange and tender honour the scarred disgrace of ruin, laying quiet finger on the trembling stones to teach them rest. No words, that I know of, will say what these Mosses are. None are delicate enough, none perfect enough, none rich enough. How is one to tell of the furred and rounded bosses of beaming green—the starred divisions of rubied bloom, fine-filmed, as if the rock-spirits could spin porphyry as we do glass—the tracteries of intricate silver, the fingers of amber, lustrous, arborescent, burnished through every fibre into fitful brightness and glossy traverses of silken change, yet all subdued and passive, and framed for simplest, sweetest offices of grace? They will not be gathered, like the flowers, for chaplet or love-token; but of these the wild bird will make its nest, and the wearied child his pillow. And as they are the earth's first mercy, so they are its last gift to us; when all other service is in vain, from plant and tree, the soft Mosses and grey Lichen take up their watch by the headstone. The woods, the blossoms, the gift-bearing grasses, have done their part for a time; but these do service for ever. Trees for the builder's yard, flowers for the bride's chamber, corn for the granary, moss for the grave."

A still higher scale of Vegetable Life is reached in the Ferns. The spores of ferns are contained in a capsule or *sporangium* (fig. 207), dense clusters of which form, when ripe, those brownish patches or incrustations on the under sides of the fronds, familiarly known as the "fructification," botanically as *sori*. Each of the brown patches is, in fact, a *sorus*, and consists of a dense cluster of *sporangia*, or spore-containing vessels (fig. 208). When the spores have escaped from these vessels, and begin to germinate in the moist earth, they do not put forth delicate filaments like the Fungi and Mosses, but each produces a small green leafy expansion, which is known as the *prothallus* (fig. 209). From the under side of the prothallus



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FIG. 202.—GREATER WATER-MOSS.

Fontinalis antipyretica is found chiefly in running streams, attached to stones and wood. Very few of the true Mosses are aquatic.

slender root-hairs are given off; and along with these, the *antheridia* and *archegonia*—minute organs of reproduction, homologous with, though simpler in structure than, those of Mosses. It is only when fertilization has taken place that the egg develops into a new Fern-plant.

Thus far we have confined ourselves to spores, which are the chief means of multiplication in the lower plants, and which, as already pointed out, contain no young plant or embryo. Spore-plants have no evident flowers, and their organs of fructification were obscure to the early botanists, on which account they were called *Cryptogams*, or Hidden-marriage plants, from the Greek *kryptos*, hidden, and *gamos*, marriage. They form, indeed, one of the two great sub-kingdoms into which all plants are divided; the other sub-kingdom comprising the Seed-plants or *Phanerogams* (Greek *phaneros*, evident, and *gamos*). To the Spore-plants or *Cryptogams* belong the *Protophytes* (unicellular forms of vegetable life, whether containing chlorophyll or not), *Alge*, or Seaweeds, *Fungi*, Liverworts, Mosses, Ferns, Horsetails, Club-mosses, Water-ferns, and Selaginellas; and to these we shall revert at greater length in later chapters; the Seed-plants or *Phanerogams* embrace all the rest.

Bearing in mind what has been said about spores, let us now observe the process of germination in true seeds. On planting a grain of Wheat or Barley in suitable soil, the first change to be noticed is the swelling of the grain, and this is followed before very long by the appearance of a root—the *primary root*—and several independent root-fibres (fig. 210), the former dying before it has grown to any length. The stem, which originates in what it known as the *plumule*, appears later. The plumule is a bud consisting of several leaves on a reduced axis, and its outer sheath, in which the rest of the plumule is still enclosed, emerges

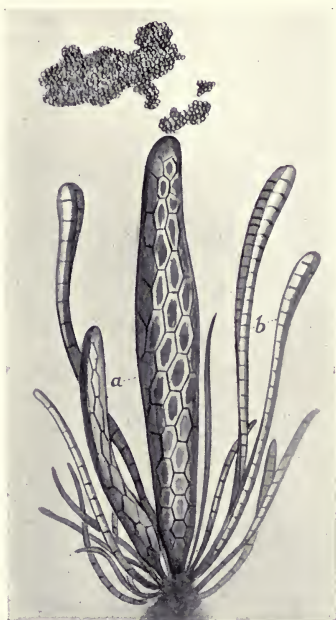


FIG. 203.—HAIR-MOSS (*Polytrichum commune*).

(a a) Antheridia. (b b) Hairs and sterile filaments (paraphyses).

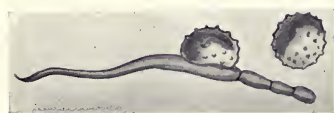


FIG. 204.—SPORE AND GERMINATING SPORE OF A MOSS-PLANT (*Gymnostomum ovatum*).



[Photo by]

[L. S. S.]

FIG. 205.—THE LADY FERNS (*Adiantum filix-femina*).
One of the most beautiful and delicate of our larger ferns. It is found of wet situations. Its fronds being of very light texture, transpiration of moisture is profuse, and unless it has free supplies at the roots it rapidly withers. EUROPE, AFRICA, ASIA, AMERICA.

first. Meanwhile, the root-fibres (which are really *adventitious roots* proceeding from the base of the plumule) continue to grow, taking a downward direction, while the stem begins to force its way towards the light and sun. Why the stem should take an upward course, contrary to the force of gravity, is not known, but the fact is interesting. Our ignorance of the ultimate causes of many other occurrences quite as common is not less complete. Why are fluids incapable of resisting a change of shape?

We cannot tell. Why does the earth attract the bodies on its surface, or the sun attract the earth? Still we are at a loss. We are familiar with facts, and are able to deduce what are called physical laws from them, but of the ultimate causes of the phenomena themselves we know nothing.

On removing a germinating grain of Barley from the ground, the young stem will be found to be surrounded at its base by a sheath (fig. 210), which is called the seed-leaf or *cotyledon*, and which should be particularly noticed. We shall refer to it again in a moment. The grain contains starch and gluten, and remains for some days adhering to the base of the young plant—a reservoir of nutriment. As growth proceeds this food supply diminishes, being conveyed to the seedling and used by it for evolving new protoplasm and cell-walls; nor is germination, properly speaking, at an end till the whole is used up, and the empty husk loosens from the plant. The proportions of starch and gluten (gluten, it should be remembered, is one of the proteids) vary in the different kinds of plants of the Grass order (Wheat, Rice, Maize, Millet, etc.), and on these relative proportions depend the alimentary properties of the various cereals.

Similar in some respects to the germination of Barley, though strikingly dissimilar in others, is the germination of a bean (figs. 212-14). In this case a primary root, formed by the direct growth and elongation of the embryo root or *radicle*, strikes



FIG. 206.—FRUCTIFICATION OF A MOSS-PLANT (*Polytrichum gracile*).

In section, showing the two loculi, or spaces, filled with spores.

down into the earth, and gives off lateral branches or secondary roots, which in their turn may send out a third series of branches, and so on (fig. 213). Meanwhile, the *plumule* or young stem, with its bent, yellow-green tuft, elevates itself above the soil, and straightens as it rises; while the tuft itself, expanding under the influence of solar light and heat, is seen to consist of two perfectly formed leaves—the first foliage leaves of the plant. Until these leaves are able to take in food from the atmosphere

and to elaborate starch, etc., for themselves, the plant is dependent upon the supply contained in its two seed-lobes or cotyledons, which, unlike the single cotyledon of a Barley grain, form the chief substance of the seed.

The young plants of Mustard (*Brassica alba*), Cress (*Lepidium*), Poppy (*Papaver*), etc., which are not thus liberally endowed, are thrown upon their own resources at a very early age, and have to work for their living almost directly they have broken from their shells. In such cases the cotyledons rise above the ground very soon after germination has commenced, and at once perform the functions of true leaves—developing chlorophyll and taking in carbon dioxide in a business-like and energetic manner. In this way the plants are kept alive and vigorous till ordinary leaves are produced.

By soaking a Bean in warm water for a short time, the thick double skin or *testa*, with which it is surrounded, may be easily removed, and the two large fleshy lobes, which are the cotyledons of the embryo, may then be separated without difficulty, and the plumule and radicle laid bare (fig. 212). Before stripping the seed, the small black scar or *hilum* should be noticed; as well as a minute aperture at one end of it, the *micropyle*, from which a small quantity of water may be expressed if the moist seed be squeezed between the finger and thumb. When the testa has been removed and the cotyledons thrown open, the root of the germling will be seen to be directed towards this aperture.

On stripping a seed of Maize (*Zea mays*), a little examination will show how small a portion of the seed the single cotyledon occupies. Indeed, when the whole of the embryo plant, consisting of plumules, radicle, and cotyledon, has been picked out of the white floury matter in which it is embedded, it will be found that the bulk of the seed remains (figs. 215–217).

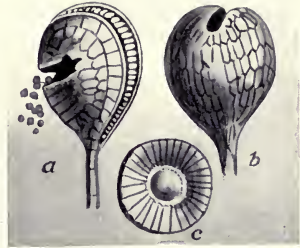


FIG. 207.—SPORANGIA OF FERNS.
(a) Maidenhair Fern (*Adiantum capillus-veneris*), with spores escaping. (b) Royal Fern (*Osmunda regalis*). (c) Bristle Fern (*Trichomanes radicans*).



FIG. 208.—ROUND-LEAVED WOODSIA (*Woodsia hyperborea*).
Part of a frond with five clusters of sori. Below, a single sorus, consisting of a cluster of sporangia.



FIG. 209.—PROTHALLUS OF A SPECIES OF MAIDENHAIR FERN SEEN FROM BELOW.

Thus in the one case the embryo forms the entire kernel of the seed; and in the other it is surrounded by a mass of albuminous tissue or *endosperm*, and occupies but a small part of the kernel. On this account, seeds

of the latter kind are called *albuminous*, while those which, like the bean, contain no surrounding nutrient matter, are said to be *exalbuminous*. The terms are somewhat misleading, however, as the substance contained in the seed is not identical in chemical composition with animal albumen. It has characteristic differences in various plants. Thus it is mealy or farinaceous in cereals; fleshy in the Barberry (*Berberis*) and Heartsease (*Viola*); oily in the Poppy (*Papaver*) and Coconut (*Cocos nucifera*); mucilaginous in the Mallow (*Malva*); cartilaginous in the berry of the Coffee-plant (*Coffea*); and hard and white like ivory in the Negro's Head Palm (*Phytalephas macrocarpa*). The endosperm of this palm forms the "vegetable ivory" of commerce.

In some seeds a part of the albuminous substance owes its origin to layers of cells outside and different from those which produce the endosperm, and hence it is given the distinguishing name of *perisperm*. In seeds of the Water-lily family (*Nymphaeaceae*), for example, the embryo plant is embedded in endosperm, which occupies the narrow end of the seed, while the rest of the albumen consists of perisperm. Ripe seeds of the Cannas (*Cannaceae*), again, have no endosperm at all, the whole of the nutrient substance being perisperm.

For important reasons of classification the number and position of the cotyledons of seeds should always be carefully noted. We have seen that the spores of Fungi, Mosses, Ferns, and other cryptogamic plants never have cotyledons—they are not true seeds. We have also seen that grains of Barley and Maize, though possessing those organs, provide but *one* with each embryo; while both the Bean and Mustard seed have *two*. Therefore, looked at with reference to the germinating body, the plants above enumerated are of three kinds: those entirely destitute of cotyledons,



FIG. 210.—A GRAIN OF BARLEY BEFORE GERMINATION, AND THE SAME GERMINATING.

Maize, though possessing those organs, provide but *one* with each embryo; while both the Bean and Mustard seed have *two*. Therefore, looked at with reference to the germinating body, the plants above enumerated are of three kinds: those entirely destitute of cotyledons,



Photo by]

[Henry Irving.

FIG. 211.—WHEAT (*Triticum vulgare*).
Showing the ears of wheat in various stages of ripeness.

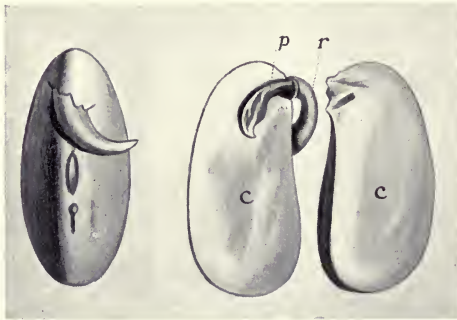


FIG. 212.—A HARICOT BEAN ON THE SECOND DAY AFTER PLANTING,

And the same with the cotyledons (c) laid open to show the plumule (p). The radicle (r) is partly hidden behind the left-hand cotyledon.

Grass, Rush, Sedge, Palm, Lily, Orchis, and Arum orders—in fact, the greater number of plants with parallel-veined leaves—are Monocotyledons; while most plants with net-veined leaves, whose name is legion, are Dicotyledons. The two great classes of Flowering Plants (Monocotyledons and Dicotyledons) have other characteristic differences, many of which will be found referred to in succeeding chapters. Thus

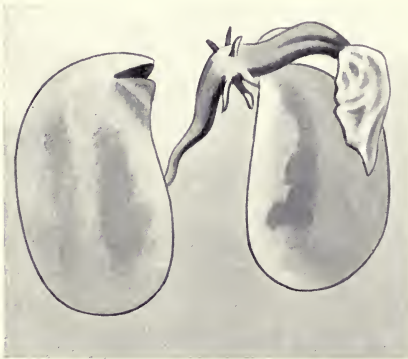


FIG. 214.—THE SAME WITH THE COTYLEDONS LAID OPEN.

or *Acotyledons*; those with only one cotyledon, or *Monocotyledons*; and those with two cotyledons, or *Dicotyledons*. The importance of this classification will be apparent when it is added that by far the greater number of known plants fall under one or another of these three divisions. Sea-weeds, Fungi, Liverworts, Mosses, Ferns, and all other cryptogamic plants belong to the first division—they are *Acotyledons*; plants of the



FIG. 213.—A HARICOT BEAN ON THE FIFTH DAY AFTER PLANTING,

Showing the plumule breaking its way through between the cotyledons.

the parts of the flower of a Monocotyledon are usually arranged in threes or sixes—three petals, three sepals, three stamens, and so on; while the floral organs of a Dicotyledon are generally arranged in fours or fives. The structure of the stem in each is also essentially different.

The seeds of a small number of Flowering Plants—chiefly parasites, as the Dodder (*Cuscuta*)—have no cotyledons; but these must be regarded as instances of vegetable degeneration, and such plants are classed among Phanerogams for other and sufficient reasons. Young plants of the Fir and Pine order (*Coniferae*) sometimes have as many as twelve or even fifteen seed-leaves, and thus form a small class by themselves, to which the name *Polycotyledons* has been given, though the term would hardly be accepted by present-day systematists. Instances have been recorded of Dicotyledons with *three* cotyledons(!), but such cases are abnormal, and should be classed among freaks of nature. Seedling Maples have manifested this

peculiarity, and a specimen of a tricotyledonous Oak may be seen in one of the museums of economic botany at Kew.

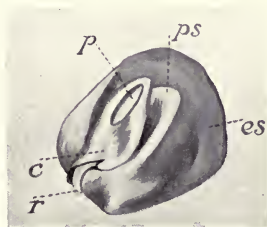


FIG. 216.—MAIZE ON THE FOURTH DAY OF GERMINATION.
The testa has been removed.

where one cotyledon rose while the other fell, the plant which exhibited this exceptional movement being a species of Wood-sorrel.

The young growing rootlets likewise exhibited a constant slow movement from side to side,* their tips, which displayed the most exquisite sensitiveness, enabling them to avoid destruction and threatened injury, and to feel their way downwards between the particles of the soil. "A radicle," says Darwin in his *Movements of Plants*, "may be compared with a burrowing animal, such as a mole, which wishes to penetrate perpendicularly down into the ground. By continually moving his head from side to side, or circumnutating, he will feel any stone or other

* The path is really a spiral—a circumnutation.



FIG. 215.—SEED OF MAIZE (*Zea mays*).

The testa removed to show the embryo, consisting of plumule, radicle, and cotyledon embedded in mealy perisperm. [*Note*—The embryo has been partly lifted out from the perisperm in order to show the several parts more clearly.]

Many curious facts have been discovered by Darwin with reference to the movements of plants, and not the least curious are those which relate to the movements of the cotyledons and roots of seedlings. Of the young plants which he examined, the cotyledons in some cases kept up a continuous movement in a vertical direction; in others they oscillated from side to side, the seed-leaves always acting together—save, indeed, in a solitary instance,

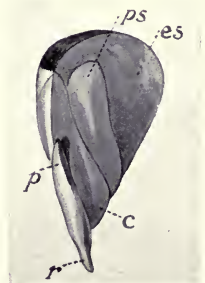


FIG. 217.—THE SAME IN VERTICAL SECTION.

obstacle, as well as any difference in the hardness of the soil, and he will turn from that side; if the earth is damper on one than on the other side, he will turn thitherwards as a better hunting-ground. Nevertheless, after each interruption, guided by the sense of gravity, he will be able to recover his downward course, and to burrow to a greater depth."

Note, too, how the sensitiveness of the root and rootlets struck Mr. James

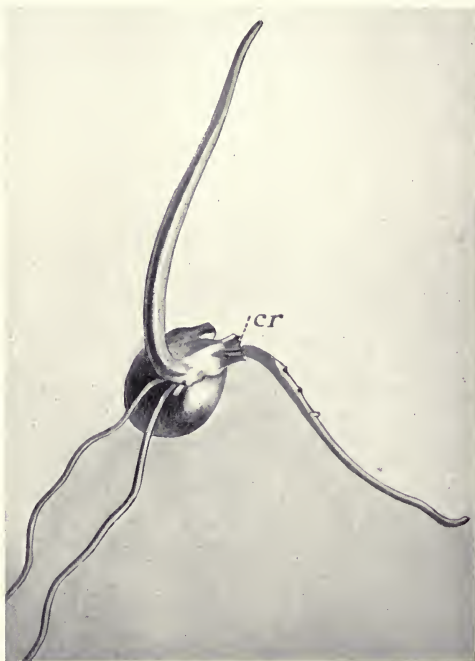


FIG. 218.—MAIZE AT A STILL LATER STAGE,

Showing the primary root which has broken through the coleorhiza (*cr*), and two adventitious roots growing from the base of the young stem.

Rodway during his study of plant life in the forests of Guiana: "Roots are undoubtedly able to distinguish suitable from unsuitable food, and though they may be poisoned now and then, this is nothing strange, as the same thing happens to man. Their sensitive tips go wandering in every direction, branching here and there in search of proper food. As long as the soil is uncongenial they press forward, and only when a good feast is discovered do they throw out that broom-like mass of fibres so conspicuous on the banks of rivers and creeks. A barren subsoil is carefully avoided by keeping to the surface, while in the rich river bottom the sour, water-logged alluvion is equally distasteful. On the sand-reef the tap-roots go down fifty feet or more, and spread most

evenly to glean every particle of food contained in the water that has percolated to these depths. On the mountain, again, every chink and cranny between the rocks is explored, the roots sometimes penetrating through narrow crevices into hollows where water has accumulated, and spreading their network of fibres over the roof, down the walls, and into the pools. In some cases it appears as if the roots smell the water at a distance, and move straight onwards until they reach it. Some epiphytes



Photo by]

[E. Step.

FIG. 219.—HORSE-CHESTNUT (*Aesculus hippocastanum*).

The lower branches of a well-clothed tree showing the pyramidal spires of blossom, which are here about one-twelfth of the actual size. The flowers are white, splashed and spotted with red and yellow. Native of the mountain regions of S. E. EUROPE.

that push their aerial roots down the trunks of trees in the forest hang them quite free when above the water, only allowing them to branch out when they reach the surface. In the first case moisture is obtained from the rain and the dew as they trickle down the little channels in the bark, while in the other a reservoir of water is below, and the plant seems to know it."

It is the tip of the root just in advance of the growing point that appears to possess the intelligence. It seems to know when a stone blocks its progress that it is no use trying to get through. It turns aside from the obstacle and goes round it, but persists in pursuing its original direction in spite of this detour. Darwin compared the root-tip to a brain.

An extremely curious instance of the motility of young roots is furnished by an Indian species of *Loranthus*, nearly related to the Mistletoe (*Viscum album*), and, like it, a parasite on trees. The fruit contains bird-lime—a peculiar viscous, tenacious, and elastic substance—and when the berry

loosens from the plant, it sticks to whatever it falls upon. The seed is embedded in the viscid pulp, and germination commences in the following manner. "The radicle," says Mr. N. E. Brown, "at first grows out, and when it has grown to about an inch in length, it develops upon its extremity a flattened disc; the radicle then curves about until the disc is applied to any object that is near at hand. If the spot upon which the disc has fastened is suitable, the germination continues, and no locomotion takes place; but if the spot should not be a favourable one, the germinating embryo has the power of changing its position. This is accomplished by the adhesive radicle raising the seed and advancing it to another spot, or, to



Photo by]

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FIG. 220.—RHUBARB (*Rheum raphaniticum*).

Well known as a kitchen-garden plant whose leaf-stalks are used in tarts, etc. It is a native of Siberia, whence it was introduced about 350 years ago.

make the process plainer, the disc at the end of the radicle adheres very tightly to whatever it is applied to; the radicle itself straightens, and tears away the viscid berry from whatever it has adhered to, and raises it in the air. The radicle then again curves, and the berry is carried by it to another spot, where it adheres again. The disc then releases itself, and by the curving about of the radicle is advanced to another spot, where it again fixes itself. This, Dr. Watt says, has been repeated several times, so that to a certain extent the young embryo, still within the seed, moves about. It seems to select certain places in preference to others, particularly leaves. The berries on falling are almost certain to alight upon leaves, and although many germinate there, they have been observed to move from the leaves to the stem, and finally fasten there" (*Gardener's Chronicle*, 1881).

Though the direction of the roots is normally downwards, it would appear from experiments begun by Colonel Greenwood more than fifty years ago that they will grow in any direction in which they can find food. The colonel placed a number of Horse-chestnut seeds in flower-pots, which he suspended in an inverted position on wirework, and watered the seeds from above. The main-root which each seed sent down into the air presently died; but the branch-roots, which had not taken a downward course, continued to grow, and the plants flourished. He had thus stumbled upon the fact that the seedlings of the Horse-chestnut have a primary root whose downward determination nothing can pervert. This downward root is as peculiar to the seedling as the seed-leaves are, but the branch-roots will grow in any



Photo by]

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FIG. 221.—WILD CARROT (*Daucus carota*).

One of the most graceful of the smaller Umbelliferous plants. From its hard, dry, stick-like roots the thick, fleshy garden-carrots have been evolved by cultivation. EUROPE, N. AFRICA, N. ASIA.

direction. The experiment did not end here. For upwards of twenty years Colonel Greenwood preserved one of the plants in its inverted position,* by placing it on a flat stone and exchanging the flower-pot, when the branch-root grew too long for it, for a chimney-pot full of earth; and so adding another and another, as occasion required, till the column was seven feet high. Then he turned the root over a wall into a similar column of earth on the other side, thus permitting it to take, for the first time, a downward direction. When at last this much-abused organ reached the ground, the colonel removed both of the artificial columns; and the plant, with a naked, arching root, fourteen feet in length, was left to its own resources (*Athenaeum*, 1864).



FIG. 222.—GERMINATION OF THE SEED OF A PINE (*Pinus*).

Seeing that roots are such wonderful—we had almost said versatile—organs, it may be interesting to look a little at their structures. The root-section shown (fig. 224) is that of a young Maple (*Acer campestre*). Notice particularly the layers of rather long cells (*a*) at the extremity of the root. These constitute the *root-cap*,† and form a sort of protecting shield to the dense cluster of smaller cells hidden immediately within the end of the sheath, which form the growing-point of the root.

All the wear and tear to which these delicate-growing cells would be subject is borne by the sturdier root-cap; while the growing-point makes some compensation for the services thus rendered by fabricating new cells for the sheath on its inner side, as its outlying cells become worn and withered in the rough pioneer work which they perform. In the centre of the root is a bundle containing woody vessels—the *vascular cylinder* or *stele*—which constitutes, in conjunction with the rest of the

vascular system, the mechanism by means of which the crude sap is carried upwards to the leaves, there to be elaborated into nutrient material. In nearly every species of plant there is but one of these steles in each root, but in a few—chiefly palms—the roots are *polystelic*. The tissue of

* Inverted as regards the root.

† The *pileorrhiza* of some botanists.



Photo by]

[Henry Troth.

FIG. 223.—BULBOUS BUTTERCUP (*Ranunculus bulbosus*).

These plants produce special roots whose office is to draw the stem structure from which they originate down with them, to prevent their elevation above the surface. The same phenomenon has been observed in the Carrot, Evening Primrose, Martagon Lily, Monkshood, Dandelion, Daisy, and other plants.

rather thickened cells (*endoderm*) surrounding the stele is parenchyma (*pm*), which forms a strong padding and hermetically closes the central cylinder, thus preventing the passage of air while allowing that of water. It is known as the *root-sheath*. In most plants with biennial and perennial roots the root-sheath serves the further purpose of a repository for food material—starch, fat, sugar, or whatever other supplies may be needed for the next period of vegetation. Surrounding the tissue is a mass of cells (the cortex) consisting of thinner-walled parenchyma, in which also reserve materials are deposited; and then, last of all, we have the epidermis (*e*), with its unicellular root-hairs (*f*), those delicate organs by which the plant dissolves—and through which are absorbed—the inorganic substances which constitute, with water, the crude ascending sap.

As a protection against field-mice, insect larvæ, and other underground animals, many food-storing roots develop poisonous and disagreeable substances in their tissues, in the way of noxious alkaloids, fœtid gum resins, and other products well known to druggists; and it has been observed that such roots are very seldom attacked. Protected roots of this kind will be found in Soapwort, several species of Gentian (*Gentiana punctata*, *lutea*, and *pannonica*), as well as of the thick and poisonous main-roots of Monkshood (*Aconitum napellus*), the massive roots of the Rhubarb (*Rheum officinale*), and many *Umbellifere*.

The fact that the root is often a storehouse of nutritious food substances has an important morphological bearing, almost all departures from a slender

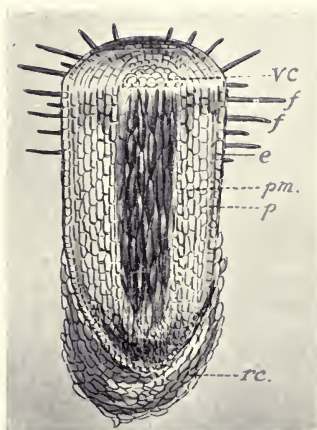


FIG. 224.—ROOT-SECTION OF YOUNG MAPLE.

(Lettering explained in the text.)

tapering form—at least in the young root—being chiefly due to it. The Carrot and Turnip, for example, are simply the primary roots of *Daucus carota* and *Brassica rapa* swollen up with reserve material (figs. 228–233; see p. 183). These primary or main roots are known as *tap-roots*; though various qualifying names—such as *conical*, *fusiform* or spindle-shaped, and *napiform* or turnip-shaped—are given, according to the special form which the tap-root assumes. Occasionally the tap-root divides into two or three forks, as in the poisonous Mandrake (*Mandragora officinalis*), where they have a fancied resemblance to the human form—though this is not the origin of the name of the plant. In days of popular ignorance and credulity the Mandrake was looked upon with superstitious awe by all classes, and its roots were said to be endowed with animal



FIG. 225.—VEGETABLE COAST-GUARDS.

Lyme-grass, Sea-sedge, Marram-grass, and Sea-holly are most useful plants on sandy shores, as their roots and underground stems hold the loose sand together, and prevent it being washed away by the sea or driven inland by the wind. See also fig. 237.

feelings, and to shriek when torn from the earth! It was, therefore, accounted dangerous to disturb them.

Fibrous roots are seen in the Grasses, Buttercup (*Ranunculus*, fig. 223), etc., the name being given to branch-roots which are very slender. The fibres sometimes penetrate to a greater depth than people are inclined to suppose, particularly when the subsoil is hard and dry, and the plants are needing more abundant nourishment. Even in rich garden soil the roots of Wheat (*Triticum*) have been traced to a perpendicular depth of five or six feet. This, however, is nothing in comparison with the depth to which some tap-roots will penetrate. One hundred and ten feet is the computed length of the tap-root of a Baobab-tree (*Adansonia digitata*) in Adanson's account of Senegal; but this, we need scarcely add, is exceptional.[†]

In the fibrous roots of many plants we find peculiar swellings and thickenings, which serve (like the different forms of tap-root) as reservoirs of nutritious matter; and these may all be described as *tuberous roots* (fig. 226). *Care must be taken, however, not to confound a tuberous root with a tuber*, which last is not a root at all, but a fleshy underground stem (cf. Chapter VII.). In *Pelargonium triste* the tubercles or swellings give the fibres a beaded

appearance, and hence the root is described as *moniliform* or necklace-shaped (fig. 230); while in the Common Dropwort (*Spiraea filipendula*) the fibres bear irregularly shaped knobs or nodules towards the ends; and this kind of root is distinguished as *nodulose* (fig. 235). Both forms are fairly common. A far less frequent form is the *annulated* (fig. 236), in which the fibre-



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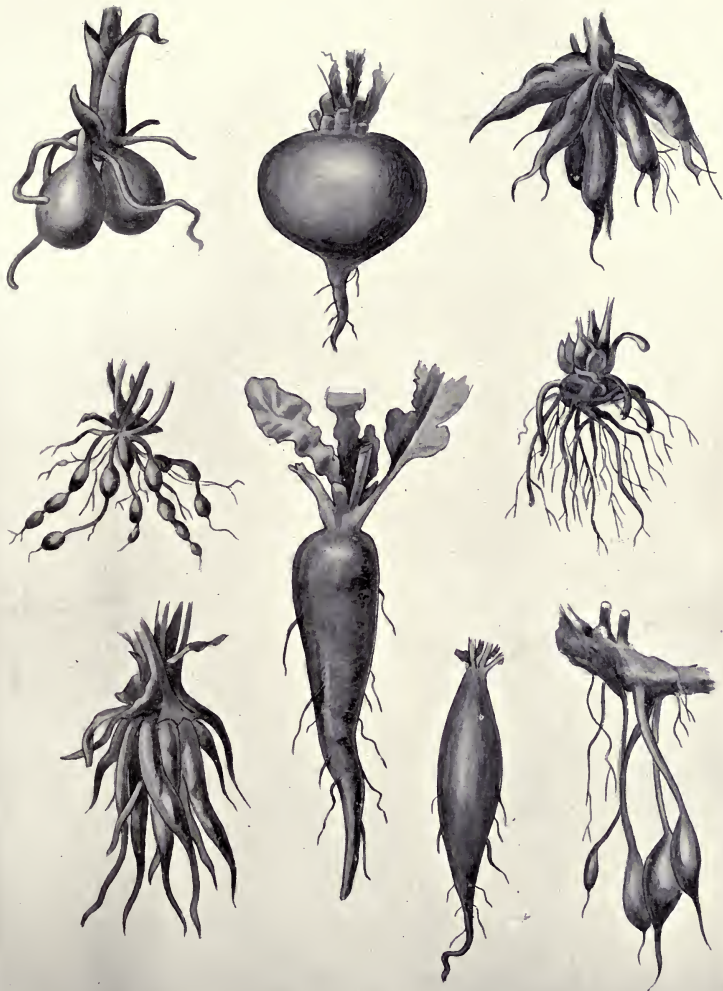
FIG. 226.—LESSER CELANDINE (*Ranunculus ficaria*).

A good example of a plant whose fibrous roots become tuberous by the storage in them of food material. One of the earliest and commonest of our spring flowers.

expansions have a ring-like appearance. Of this we have an excellent example in the well-known Brazilian plant, *Cephaelis ipecacuanha*, which yields the valuable drug of that name. Ipecacuanha formed the basis of the medicine with which the Dutch physician, Adrien Helvetius, treated dysentery so successfully in the seventeenth century; and he had cause to bless the root. The fame of the celebrated medicine spread to the Court of France, and Louis XIV. gave the fortunate doctor a thousand louis d'ors to reveal the secret of its composition.

Testicular and *fascicular* roots have also been looked upon as varieties of the fibrous form by some writers; though others—certainly with less reason—have regarded them as variations of the divided form of

tap-root. Perhaps it would be more fitting to place them in a group by themselves, for they seem rather to form a link between those classes than to belong exclusively to either. The peculiarity of the testicular root (fig. 227) is that some—usually two—of its divisions become fleshy and enlarged so as to form more or less egg-shaped expansions; while in the fascicular root the clustered rootlets become swollen along



FIGS. 227-235.—SOME FORMS OF ROOTS.

Testicular Root.
 Moniliform Root.
 Tuberos Root.

Napiform Root.
 Thickened Tap-root.

Fusiform Root.

Tuberous Fascicular Root.
 Fibrous Root.
 Nodulose Root.

their length, and look like a bundle of spindle-shaped (fusiform) roots (fig. 229).

We might tabulate the chief forms of subterranean roots in the following manner :—

TAP- ROOTS.	{	1. Conical. 2. Fusiform. 3. Napiform.	FIBROUS ROOTS.	{	1. Non-tuberous. 2. Tuberous— <i>a.</i> Moniliform. <i>b.</i> Nodulose. <i>c.</i> Annulated.	QUASI- FIBROUS ROOTS.	{	1. Tuberous Fascicular. 2. Tuberous Testicular.
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Many perennial plants of the rosette type, which like to keep their leaves flat on the ground to be safe from extirpation by browsing animals, develop a special set of roots whose function is to pull the plant down into the soil to counteract the growth of the root-stock, which would lift them above the proper level. These hauling roots go down into firm soil and take hold of it; then by contraction they pull the whole plant down sufficiently. But how do these special roots know when the proper level for the root-stock has been reached?

Certain plants with spreading fibrous roots subserve a useful purpose by binding together the loose sand on the seashore, and raising those banks which, as in Norfolk, defend the country from the encroachments of the sea. Of this sort are the Lyme-grass (*Elymus arenarius*), the Sea-sedge (*Carex arenaria*), the Marram (*Psumma arenaria*), and the beautiful Sea-holly (*Eryngium maritimum*).

The Marram, mentioned above, was the subject of an Act of Parliament in Queen Elizabeth's time, the purpose of the Act being to encourage the cultivation of this grass and prevent its destruction. Its preservation is still carefully provided for by the "bank-reeves."

The dunes on the shores of Holland and Denmark have been an object of care by the Government for an even longer period than have the English dunes; and there, also, resort is had to the cultivation of grasses and creeping plants, while burrowing and grazing animals are rigidly excluded. In certain parts of France and North America, again, similar means for resisting



FIG. 236.—ANNULATED ROOT OF *Cephaelis ipecacuanha*, AND FLOWER.



Photo by]

FIG. 237.—SAND-DUNE ON THE SUSSEX COAST.

[E. Step.

This photograph, taken from the landward side, shows how the Marram (*Panicum arenaria*) holds the loose sand together. The wind scoops out hollows in the surface where unprotected by this grass; but the immense bank as a whole keeps its form and its protective power, owing to the network of underground stems and roots which prevent any serious shifting, whilst the tough aerial stalks intercept much of the sand that would otherwise blow away.

the encroachments of shifting sands have been extensively employed for many years; and the method has been greatly improved upon and developed.

So far back as 1780, M. Brémontier, an eminent French engineer, devised the means (first suggested, it is said, by a priest of Mimizon) of fixing the dunes. The practical value of his theories, which were adopted by the Government, has been fully established by the experience of a century. An American savant, Mr. G. B. Emerson, bears this testimony: "I visited, in 1872, the region saved by Brémontier, and examined the work he had done, and its effects. The whole country, for more than a hundred miles along the Atlantic coast of Gascony and from four to eighteen landward, had been covered with sand-hills. . . . The process of ruin had been going on for centuries, and some of the sand-hills were hundreds of feet high. In the midst of this recovered region I stopped a day or two at a beautiful town, where a hundred thousand persons from Paris and other cities of France, attracted by the genial climate and the health-giving atmosphere of the pine forests, had passed the winter. I walked and drove along the sandy roads,

visited a monument to Brémontier, erected by his brother, ten miles or more inland in the redeemed territory, and saw in many places deciduous trees—oaks, ashes, beeches, and others—growing luxuriously under the protection of the pines. One cannot help feeling while enjoying this the justice of our countryman Marsh, who counted Brémontier, and Reventloy, who conducted a similar work in Denmark, as amongst the greatest benefactors of their race."

Brémontier's method is briefly this: A continuous wooden paling about



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FIG. 238.—SEA-HOLLY (*Eryngium maritimum*).

An Umbelliferous plant with blue flowers and leathery, spiny leaves that helps to keep the sea-shore sands from shifting.

four feet high is erected parallel with the shore-line, and about a hundred yards back from high-water mark, a space an inch wide being left between the boards. As the sand is not raised like dust, but glides along near the surface, it piles up in front of the paling, and passing through the crevices, is deposited behind. This goes on till the boards are buried, when they are raised one at a time, and the operation is continued. By repeating the process again and again the dune steadily rises in height and assumes a slope of from seven to twelve degrees in front, and much less on the land side. On setting the first fence, tufts of *Psamma arenaria* are planted in front, and in a belt eight times wider than the obstacle opposed. These

tufts are in quincunx order, and closer together near the paling. Those outside stop some of the sand, those farther up stop more, and thus an even slope of the desired angle is secured and maintained. The tufts are set in winter, and between them are sown seeds of the same plant, and of *Triticum junceum*, *Artemisia*, *Cakile maritima*, *Salsola*, *Ephedra*, and other maritime plants. These grasses, etc., grow upward as they are buried, and thus the sand is bound together in a fine network of fibres. Then, at a fit time, the surface is sown broadcast with a mixture of seeds of the Maritime or Cluster Pine



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FIG. 239.—BROOM (*Cytisus scoparius*).

A valuable wild shrub with pliant stems and beautiful bright yellow flowers. It grows upon poor sandy soils, to which, with the aid of the nitrifying bacteria on its roots, it imparts a considerable amount of fertility. EUROPE, N. ASIA, CANARIES, ETC.



Photo by]

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FIG. 240.—FURZE (*Ulex europæus*).

A stiff spiny shrub, often confused with Broom, and sharing the useful fertilizing properties of that plant, but more catholic as regards the soils it grows upon. Except in the seedling stage it has no leaves, which have all been converted into spines. EUROPE, CANARIES, AZORES.

(*Pinus pinaster*), the Common Broom (*Cytisus scoparius*), Dwarf Furze (*Ulex nanus*) and Marram (*Psamma arenaria*). These sprout and come up together, the tender shoots of the pine growing well when screened by the other plants. Thus the land is saved.

The planting of the same grass on the dunes of Cape Cod, in the State of New York, has been practised since colonial days; and similar conservative measures were ordered by law upon the beaches of Long Island as early as 1758. On the Florida coast, the Bermuda-grass (*Cynodon dactylon*) has been successfully used in fixing loose sands. Its roots creep to a great distance, with short flattish leaves, sending up flowering shoots a few inches high at intervals, which bear seed and spread. It runs over the sand in zig-zag form, with joints at each

angle six or eight inches apart, from each of which a root strikes into the ground, soon forming a most effectual network of roots through the loosest sand.

Roots which issue from the stem, as distinguished from those which result from the development of the radicle, are spoken of as *adventitious*. We have seen that the roots of Barley are of this description, and it is noteworthy that the greater number of Monocotyledons exhibit the same kind of growth. The well-known Pandanus-trees or Screw-pines, of which there are many species, are remarkable for their adventitious roots, which continue to be given off by the stem long after it has appeared above the ground (p. 242). These aerial roots, which are furnished at their extremities with special cup-like root-caps in which to catch the rain and dew, grow downwards in the air till they reach the ground, when the cups fall off, and the denuded organs proceed to act in the ordinary manner of underground

roots. The slender-stemmed plant, which is often top-heavy with its massive crown of leaves, derives welcome support from this very curious arrangement.

As incidental reference has just been made to *aerial roots*, perhaps this is the most fitting place to offer what little we have to say about those interesting organs.

Plants which grow within the inter-tropical regions show a very conspicuous tendency to develop roots above-ground; and the phenomenon is not confined to one family or order, but has been observed in plants very far removed from one another in the system of Nature. Moreover, the objects for which such roots are produced may vary greatly. Thus, some roots (like those of the Pandanus-trees just mentioned) answer the purpose of *supports*. The Pachiuba (*Iriartea*), a tall, erect, smooth-stemmed Palm with a large crown of curiously cut leaves, found in the Amazon region, is remarkable on this account. "Its great singularity," says Dr. Wallace, "is that the greater part of its roots are above-ground, and they successively die away, fresh ones springing out of the stem higher up, so that the whole tree is supported on three or four stout straight roots, sometimes so high that a person can stand between them with the lofty tree growing over his head. The main-roots often diverge again before they reach the ground, each into three or more smaller ones, not an inch each in diameter. Though the stem of the tree is quite smooth, the roots are thickly covered with large tuberculous prickles. Numbers of small trees of a few feet high grow all around, each standing on spreading legs, a miniature copy of its parent."

Then there are *feeding aerial roots*. A large number of tropical Orchids, epiphytic on old trees, besides possessing naked air-roots which subserve the purpose of attachment, have others which are modified for the absorption of nutriment from the surrounding atmosphere—indeed, in a few cases the Orchid has no green leaves (*e.g.* *Polyrhiza*); the roots do everything. These modified roots hang down from the stem or branch of the tree to which the plant is anchored, in white thread-like bunches, the whiteness



Photo by]

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FIG. 241.—PINE CONE.

A cone of the Cluster Pine (*Pinus pinaster*), a tree that has been of great value in reclaiming land from the sea. One-half the natural size.

being due to a papery membrane which envelops the green chlorophyll-containing cells of the true roots. This covering is composed of perforated cells, and acts like a sponge. "When it comes in contact with water in the liquid state," says Kerner, "or more especially when it is moistened by atmospheric deposits, it imbibes instantaneously its fill of water. The deeper-lying living green cells of the root are thus surrounded by a fluid envelope and are able to obtain from

Moreover, this porous tissue possesses the power of condensing aqueous vapours and other gases; so that a Tree-orchid is absolutely independent of its host for nourishment.

It will be evident from the above facts that the papery envelope has a twofold use. In the dry season it reinforces the safeguards provided by the root against too profuse transpiration on the part of the living green cells in the interior; "and in the wet season," as Kerner remarks, "it provides for the continuous supply of the requisite quantity of water." The air-roots of many Aroids and Tree-ferns answer much the same purpose; but this is not the case with the peg-like aerial roots of Ivy (*Hedera helix*), which are simply intended for mechanical support. The nourishment required by the Ivy is obtained in an entirely honourable manner by its leaves and underground roots; and the rather rough treatment which the plant has received from some writers on account of its supposed parasitical tendencies is,



FIG. 242.—SCREW-PINE (*Pandanus utilis*).

A native of Madagascar, whose aerial roots have cup-shaped extremities. From its saw-edged leaves are made sugar-bags and the familiar "mats" used by fishmongers and poulterers. Height about sixty feet.

to say the least, unfortunate. One poet charges it with having "hid the princely trunk, and sucked the verdure out on't"; but the prejudice on which the accusation is based has no foundation in fact.

The aerial roots of Ivy are, in short, an arrangement by means of which the plant clings and climbs; and though it is doubtless true that they penetrate into the bark of trees, their object is not plunder, but the obtaining a more secure anchorage. But on the other side, it must be admitted that many a fine tree is killed by the Ivy robbing it of light and air—



Photo by]

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FIG. 243.—IVY (*Hedera helix*) DESTROYING OAK (*Quercus robur*).

The Ivy, whose thick stem is here seen twining around the trunk of the Oak, is innocent until it has reached the upper branches of its host. Then, by developing numerous bush-like branches, it shuts out the light and air, and starves the Oak. Many a fine tree is killed in this manner, owing to the neglect of a little care in our woods.

smothering it, in fact, by its profuse branching when it has reached the top of the tree.

Of plants which attain to the dignity of trees, none perhaps exhibits such a prodigality of adventitious air-roots as the time-honoured Banyan (*Ficus indica*, p. 193). It is of this tree that Milton finely says:—

The bended twigs take root, and daughters grow
About the mother tree; a pillared shade
High over-arched, and echoing walks between.
There oft the Indian herdsman, shunning heat,
Shelters in cool, and tends his pasturing herds
At loop-holes cut through thickest shade.

The parent tree, in fact, gives off aerial roots from its branches, as small tender fibres, which, increasing in length and thickness, presently reach the earth and pierce their way into it. The parts above-ground continue to grow thicker and thicker, till they attain the girth of large trunks, when they themselves become parent trees by sending out new branches from the top, and these in turn send down aerial roots, which undergo similar



Photo by]

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FIG. 244.—FLOWERS OF IVY (*Hedera helix*).

The Ivy does not flower until it has surmounted its support, and the five-pointed leaves of the climbing stem have been succeeded by the lance-shaped leaves that mark its growth as a bush. The wide-open flowers are much visited by honey-loving insects of many kinds. EUROPE, N. AFRICA, ASIA.



SCARLET PASSION-FLOWER (*Tacsonia manicata*).

The Tacsonias differ from the Common Passion-flowers (*Passiflora*) in having a long tube to the calyx. The species represented is a native of Peru, and is shown one-half the natural size.

modifications and perform similar functions, till the original tree has become a grove! The vigorous growth of these trees may be gathered from the fact that one of their seeds, which had been deposited by a bird on the crown of a Palm-tree, not only began to germinate in that strange situation, but actually sent down a root through the stem of the Palm, thus destroying its host and supplanting it!

Apropos of this subject, we must say a word or two about the parasitical vagaries of the Brazilian Balsam-tree (? *Clusia rosea*), with handsome pink and white flowers and large shining leaves, which is thus referred to by Dr. Wallace: "It grows not only as a good-sized tree out of the ground, but is also parasitical on almost every other forest

tree. Its large round whitish fruits are called 'cebola braba' (wild onion) by the natives, and are much eaten by birds, which thus probably convey the seed into the forks of lofty trees, where it seems most readily to take root in any little decaying vegetable matter, dung of birds, etc., that may be there; and when it arrives at such a size as to require more nourishment than it can there obtain, it sends down long shoots [? aerial roots] to the ground, which take root, and grow into a new stem. At Nazaré there is a tree by the roadside, out of the fork of which grows a large Mueujá Palm, and on the Palm are three or four young *Clusia*-trees, which no doubt have *Orchidææ* and Ferns again growing upon them." If we suppose (and the supposition is not extravagant) that these Ferns, at the time when Dr. Wallace visited the spot, supported and nourished on their fronds some creeping Moss-plants or Liverworts, we shall then have a four-ranked succession of guest plants—epiphytes on epiphytes, and on these epiphytes, and again epiphytes on them!



FIG. 245.—BANYAN (*Ficus indica*).

Showing the aerial roots which develop into stout props and trunks, which enable the horizontal branches to grow indefinitely and cover enormous areas.

Mr. James Rodway has much to say of the *Clusias* and their deadly work. "Woe betide the forest giant when he falls into the clutches of the *Clusia* or fig," he writes. "Its seed being provided with a pulp, which is very pleasant to the taste of a great number of birds, is carried from tree to tree and deposited on the branches. Here it germinates, the leafy stem rising upward and the roots flowing, as it were, down the trunk until they reach the soil. At first these aerial roots are soft and delicate, with apparently no more power for evil than so many small streams of pitch,



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FIG. 246.—SNOWDROP-TREE (*Halesia tetraptera*).

A beautiful North American shrub, growing to a height of fifteen or twenty feet, and representing the order Styracaceae. Its drooping bells are produced in spring before the leaves are fully expanded. They have not so close a resemblance to the Snowdrop as the name suggests.

which they resemble in their slowly flowing motion downwards. Here and there they branch, especially if an obstruction is met with, when the stream either changes its course or divides to right and left. Meanwhile, leafy branches have been developed, which push themselves through the canopy above and get into the light, where their growth is enormously accelerated. As this takes place the roots have generally reached the ground and begun to draw sustenance from below to strengthen the whole plant. Then comes a wonderful development. The hitherto soft aerial roots begin to harden and spread wider and wider, throwing out side branches which flow into and



Photo 991

FIG. 247.—CHRISTMAS ROSE (*Helleborus niger*).

This favorite winter-flowering plant is a native from Central Europe to Western Asia. The bold, leathery, and persistent leaves are good examples of the pedate form of compound leaf. The showy part of the flower consists of the sepals, the petals being reduced to nectaries which are hidden beneath the numerous stamens.

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amalgamate with each other until the whole tree-trunk is bound with a series of irregular living hoops.

"The strangler is now ready for its deadly work. The forest giant, like all exogens, must have room to increase in girth, and here he is bound by cords which are stronger than iron bands. Like an athlete he tries to expand and burst his fetters, and if they were rigid he might succeed. But the strangler is like a python, and almost seems as if provided with muscles. The bark between every interlacing bulges out and even tries to overlap, but the monster has taken every precaution against this by making its bands very numerous and wide. We can almost see the struggle, and knowing what will be the result, must pity the victim.

"As the tree becomes weaker, its leaves begin to fall, and this gives more room for its foe. Soon the strangler expands itself into a great bush, almost as large as the mass of branches and foliage it has effaced. Its glossy leaves shine in the sunlight, and it seems to glory in its work. Every branch is clean and sleek; not a lichen or fungus can find shelter anywhere. It has got on the shoulders of the forest giant, but does not intend to support in its turn even the tiniest dwarf. If we could forget its murderous work, how we should admire it! Take the *Clusia insignis*, for example. Here we have one of the most beautiful shrubs in the world. Its thick leathery leaves shine as if polished, and its green sleek branches always look clean and healthy. As it sits crowing, as it were, over its victim, the contrast between them is most striking. Perhaps the forest giant is

dying—the few leaves remaining are yellow and sickly. No flowers have been produced for two or three seasons, and even the branches look shrivelled. There is not the least hope of recovery; it only remains, therefore, to submit to the inevitable, to die and give place to the strangler." Here again, however, we have no parasitism in the true sense—the *Clusias* are merely climbers; they strangle, but do not feed upon the trees which support them.



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FIG. 248.—IVY BERRIES (*Hedera helix*).

The flowers are shown in fig. 244. The flat-topped fruits are greenish-black, one-third of an inch across, and contain from one to five seeds.



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FIG. 249.—DRYAD'S SADDLE (*Polyporus squamosus*).

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A Fungus parasitical upon various trees. Each pileus is from six inches to two feet across, of an ochreous ground tint, more or less covered with fringed red-brown scales.

Aerial roots, unless they are epiphytal, are usually more or less circular in section, though they are liable to flatten out in growth if they are of the nature of clinging or supporting roots. Parasitic roots offer more variety, and may be rounded, flattened, wart-like, ribbed, disc-shaped, netted, etc., according to the special character of their work and the peculiarities of their environment. Some epiphytal Orchids, in addition to their white cord-like hanging roots, have others of a strap-like form, which adhere so firmly to the trunks of the host trees, that it has been found impossible to loosen one of the straps without tearing away a portion of the bark. "In other species of tropical Orchids," * says Kerner, "the roots are not flat from the beginning, but become so when they come into contact with the bark. A root is often to be seen which arises as a cylindrical cord from the axis, then lays itself upon the bark in the form of a band, and farther on lifts itself once more, resuming at the same time the rope form. . . . Complete coalescence takes place between the bands and the bark, and the union is extremely close." It is affirmed by the same writer that, when the seeds of any of these tree-growing Orchids "are transferred to loose earth devoid

* *E.g. Sarcanthus rostratus.*

of humus, they perish soon after germination; whereas when sown on the bark of a tree, they not only germinate, but grow up with ease into hardy plants."

Many interesting cases are recorded of plants which, though in their normal state exhibiting no peculiarity of root growth like Banyan, Orchis, or Pandanus, yet have put forth adventitious roots from the most unlikely places when circumstances of an extraordinary nature made special demands upon their powers. It is affirmed of the Field Maple (*Acer campestre*)



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FIG. 250.—FIELD MAPLE (*Acer campestre*).

[E. Step.

The green flowers and leaves are shown of the natural size. The former are succeeded by winged fruits, similar to those of Sycamore, but with the two wings horizontal. EUROPE, N. and W. ASIA.

that if you plant it upside-down the buried stem will put forth roots, and that the tree sustains no injury by such treatment. Not every plant is able to accommodate itself thus nicely to circumstances; yet there can be no doubt that a similar latent vegetative power exists in a great number of plants. Take the Silver Birch (*Betula alba*) for an example. Some sixty years ago one of these trees was blown down in the Birch wood of Culloden, "and fell," says a writer in *Science Gossip*, "right across a deep valley or ravine, which it completely spanned; and the top branches took root on the other side. From the parent stem no less than fifteen



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FIG. 250.—BRAMBLE (*Rubus fruticosus*).

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One of the many forms of this very variable shrub. The fruits have formed, but are at present hard and red, the drupes not having yet developed the juiciness and black colour that marks the ripening of the contained seed. EUROPE, N. AFRICA, N. and W. ASIA.

trees grew up perpendicularly all in a row"; and thirty years later, when the gentleman who furnishes these particulars visited the spot, they were still vigorous and flourishing. It is matter of common knowledge also, that the foliar organs of many plants possess the power of putting forth roots—a subject to which we shall refer more particularly when we come to speak of leaves.

Every one must have observed, too, one way in which the Bramble propagates itself. The long arching shoot grows until its tip reaches the ground, into which it pushes, and then instead of leaves puts out a cluster of white roots. When these are well developed one of the buds grows into a stout stem, which shoots straight up into the air. In this way are formed those impenetrable thickets of Bramble that stud our commons and the outskirts of woods.



FIG. 252.—MANGROVE (*Rhizophora mangle*).

The trunk stands out of the swamp, supported by its curved, leg-like roots, a condition due to the seed developing roots before it drops from the tree.

It might be thought by those who are familiar with pictures of West Indian Mangrove swamps that the singular curved roots of those trees, standing high out of the water, are adventitious; but the case is otherwise. They are true normal roots, resulting, curiously enough, from the germination of the seed while the fruit is still attached to the parent branches. "In the economy of Nature," says Dr. William Hamilton, "the Mangrove performs a most important part, wresting annually fresh portions of land from the dominion of the ocean, and adding to the domain of man. This is effected in a twofold manner: by the progressive advance of their roots, and by the



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FIG. 253.—BIRCH (*Betula alba*).

This tree being blown down in a gale continued to send out new branches which took a vertical direction, also sending new roots into the soil.

aerial germination of their seeds, which do not quit their lofty cradle till they have assumed the form of actual trees,* and drop into the water with their roots ready prepared to take possession of the mud, in advance of their parent stems."

An old English navigator—that able, trustworthy writer, William Dampier—thus describes the tree: "The red Mangrove groweth commonly by the seaside, or by rivers or creeks. It always grows out of many roots, about the bigness of a man's leg, some bigger, some less, which, at about six, eight, or ten feet above the ground, join into one trunk or body, that seems to be supported by so many artificial stakes. Where this sort of tree grows it is impossible to march, by reason of these stakes, which grow so mixed one among another, that I have, when forced to go through them, gone half a mile and never set my foot on the ground, stepping from root to root." Kingsley describes a Mangrove swamp as a desolate pool, round which the Mangrove roots form an impenetrable net. As far as the eye can pierce into the tangled thicket, the roots interlace

* Hardly "trees." It would be more correct to say, "till they attained to a considerable size."

with each other, and arch down into the water in innumerable curves, by no means devoid of grace, but hideous just because they are impenetrable. The natives are quite at home in such places, however, leaping or climbing from root to root with ease and agility, though never daring to trust their weight on the treacherous marshy ground.

Many of the larger trees of India are famous for their buttress roots. Miss Gordon Cumming, who spent two years in Ceylon, was struck with the extraordinary size and height of these roots, which, as she says, "are thrown out on every side like buttresses, evidently to enable the trees to resist the rushing of floods. The buttresses are so high that full-grown men could stand in one compartment unseen by their neighbours in the next division." In the park of the Government Agent's house at Kurenegalla,

Miss Cumming saw many majestic trees supported by their own wide-spreading roots, which covered the ground for a very wide radius, forming buttresses like low walls. "The most remarkable of these," she writes, "are the Kon- and Labu-trees; there are also great Indiarubber-trees, whose roots, though not forming such high walls, are equally remarkable and labyrinthian."

The roots of the Lum-tree, a forest giant which grows on the island of Ualan, really deserve a place by themselves, and a special term would have to be invented to accurately describe their form. Dr. Hartwig considers them to be without a parallel in the Vegetable World. Each of the Lum-tree's roots runs above-ground to a con-



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FIG. 254.—SCOTS PINE (*Pinus sylvestris*).

Growing on the edge of a sand-pit, the loose earth has got washed away, allowing a good view of the upper root-system of this Conifer.



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FIG. 255.—BIRCH-TREE (*Betula alba*).

Its lightness and grace have earned it the name of "the Lady of the Woods." It is a tree that demands plenty of light, and therefore is only to be found on the outskirts of woods or in the open. EUROPE, N. ASIA, and N. AMERICA.

siderable distance, and "is surmounted by a perfectly vertical crest, gradually diminishing in size as the root recedes from the trunk, but often three or even four feet high near the base. These crests, which are very thin but perfectly smooth, regularly follow all the sinuosities of the root, and thus form, for a considerable distance round the tree, a labyrinth of the strangest appearance. Large spaces of swampy ground are often covered with their windings, and it is no easy matter to walk on the sharp edges of their vertical bands, whose interstices are generally filled with deep mud. On being struck, the larger crests emit a deep sonorous sound, like that of a kettle-drum." They are not true aerial roots, nor even epigeous roots, but rather roots of a subterraneous origin, which have been pushed through the yielding oozy soil in order to obtain the oxygen which is absent in the water-logged soil. The Marsh Cypress in a similar manner sends up woody growths from its buried roots in order to conduct oxygen to them.



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FIG. 256.—DANDELION (*Taraxacum officinale*).

All the florets in this familiar Composite flower have strap-shaped corollas, thus differing from Composites like the Daisy, which has only the outer row strap-shaped. Owing to its buoyant seeds, the Dandelion is widely distributed, being found in all cold and temperate regions.

CHAPTER VII

NATURE'S WOODCRAFT: A CHAPTER ON STEMS

Sap-laden stems, of forms grotesque and weird,
That creep, and climb, and twine, and hang in air.

WHAT is a *stem*? The term in popular language is confined to those parts of the plant which rise above the ground, but popular ideas are not always satisfactory or exact. We have seen that roots also may rise above the ground; and is not a tuber an instance of a stem which grows *beneath* the soil? The popular definition, then, will not answer. Of botanical definitions, Professor Thomé's is, perhaps, as satisfactory as any. "The stem, in its various forms," he says (*Lehrbuch*, p. 49), "is that part of the plant which bears the leaves, flowers, and fruits." This is, on the whole, a sufficient definition.

Before treating in detail of these "various forms," it would be well to make a few remarks on the structure of the stem. When dealing, on a former occasion, with the cells and vessels of plants, we named and described the three great classes into which all permanent tissues may be divided—viz. Fundamental or Ground Tissue, the Fibro-vascular System, and Epidermal Tissue; and we saw that each of these classes is represented in every well-developed foliage leaf. The annexed diagram (fig. 257) has been prepared with the view of illustrating the manner in which these tissues and vessels are distributed through the stem of an ordinary dicotyledonous plant. The figure, indeed, represents an actual model which was made for us for lecture purposes, and which consists of a column of wax, not unlike an altar candle, but furnished with eight large wicks instead of one, the wicks being arranged in a circle, at about equal distances from each other. Fitting closely round the column is a cylinder of stout paper.

We will suppose that this column represents the erect and very young stem of a Flowering Plant—say a Sun-

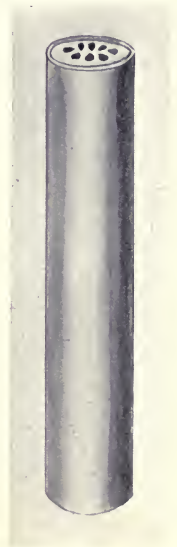


FIG. 257.—VESSELS.

Diagram illustrating the arrangement of the fibro-vascular bundles in a dicotyledonous stem.

flower stem; the paper cylinder surrounding it will then answer to the epidermis; the eight many-threaded wicks to eight separate fibro-vascular bundles; and the wax itself will represent the ground tissue. Bear in mind that the fibro-vascular bundles ("nerves" or "veins") of the leaves are always in connection with the bundles of the stem, insomuch that the latter are often regarded merely as lower portions of the leaf bundles; while a whole bundle formed by such union is said to be *common*—that is, common both to leaf and stem.

If it were possible for the wicks to increase continually in thickness, it is evident that they would at length meet, and form an unbroken circle round the innermost portion of the wax; and this is precisely what takes

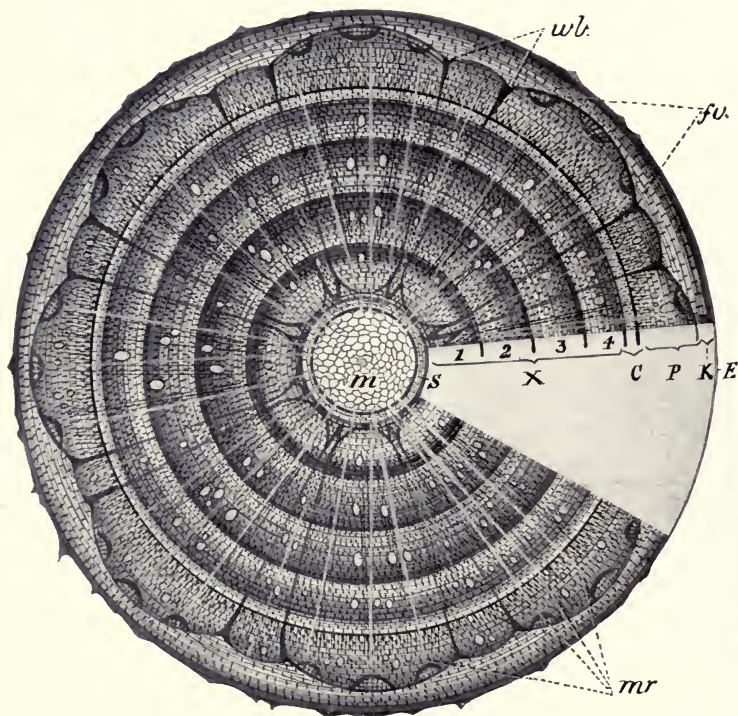


FIG. 258.—TRANSVERSE SECTION OF A FOUR-YEAR-OLD DICOTYLEDONOUS STEM (DIAGRAMMATIC).

(*m*) Medulla or pith. (*mr*) Medullary rays. (*s*) Medullary sheath. (*X*) Xylem (wood). (*P*) Bast or phloem. (*C*) Cambium ring. (*K*) Cortex. (*E*) Epidermis. The eight fibro-vascular bundles (*fv*) are united by wood and bast (*wb*) formed by the cambium between the bundles. The figures 1, 2, 3, 4, refer to the years of growth of the wood.



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FIG. 259.—ENGLISH ELM (*Ulmus campestris*).

An ancient tree that has been broken in a storm; but its abundant vitality has enabled it to partially make good the defect by new growths. The English Elm is considered a variety, or perhaps hybrid, of the Wych Elm (*Ulmus montana*). It is reproduced by suckers, as it rarely, if ever, produces fertile seed.

place with the woody bundles in the stems of dicotyledonous trees, such as the Oak, Beech, Elm, etc., though the completion of the circle is accelerated by the formation of new bundles between those already existing. The wood of timber-trees of several years' growth is nothing more than a mass of such bundles closely packed together, and surrounding that part of the ground tissue which is known as the *medulla*, or pith. Locked in as the pith then appears to be, communication is nevertheless maintained with the bark by means of narrow prolongations of the pith, which, in transverse sections of the stem, have the appearance of lines diverging from the centre. These, as having their rise in the medulla, are known as *medullary rays*. They constitute what cabinet-makers call the "silver grain" in wood.

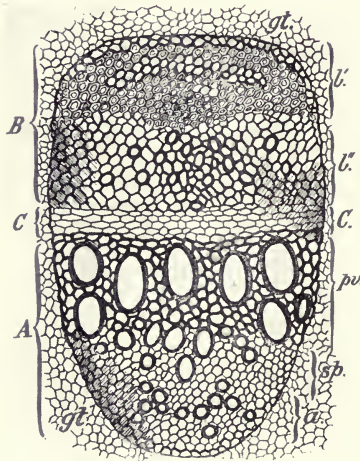


FIG. 260.—FIBRO-VASCULAR BUNDLE.

Diagram of a transverse section of bundle from an herbaceous plant. (A) Wood or xylem, consisting of (a) annular and (sp) spiral vessels surrounded by cells of the primary wood; and (pv) pitted vessels in the midst of denser woody cells. (B) Liber or phloëm, consisting of (b') hard bast and (b'') soft bast. (gt) Ground tissue.

are annular vessels (a); immediately above them, embedded in similar (that is, woody) tissue, are spiral vessels (sp); and higher still are pitted vessels of various sizes (pv), surrounded by greatly thickened wood cells. Within the brackets lettered C we have a tissue of delicate growing cells known as the *cambium layer*; and above the cambium layer an assortment of sieve-tubes, bast-fibres, and parenchymatous wood-cells, of which the innermost constitute the *soft*, and the outermost the *hard bast*.

The soft, thin-walled, growing cells, or *cambium* (a name derived from the Latin *cambio*, I exchange), really divide the bundle into two parts, of

which the inner (*A*) is called the wood or *xylem* (Greek *xylon*, wood or timber), and the outer (*B*) the liber* or *phloëm* (Greek *phloios*, bark); and it is to these growing cells that all increase of the woody bundle is due. They are filled, indeed, with protoplasm, and in the growing season are constantly undergoing division to form new cells, by which means new wood is added to the outside of the xylem, and new liber to the inside of the phloëm. All the woody bundles of the stem are, in a way, united by the cambium, which forms an unbroken ring in the stem, those portions of the ring which lie between the bundles being known as *interfascicular cambium* (fig. 261, *cr*).

As the cambium remains dormant during the winter, and the cells which it forms in the spring are larger than those of the autumn, the extent of its work each year may be easily traced—indeed, the concentric rings of wood in the trunk of a dicotyledonous tree are the abiding records of its annual and annular labours, and furnish means of forming a fairly accurate computation of the age of the tree. The interfascicular cambium serves the double purpose of lengthening the medullary rays (see fig. 258) and adding fresh phloëm and xylem between the original bundles. In fact, it assists in completing the circles of the liber and wood, thus making the stem one solid whole.

It should be added that all Flowering Plants do not have the fibro-vascular bundles arranged in the manner above described. In Monocotyledons—Palms, Lilies, Grasses, etc.—they are scattered irregularly in the stem; nor are

* The name *liber* was applied by the Romans to the inner bark or rind of a tree used for paper. Our word "library" traces back to it.

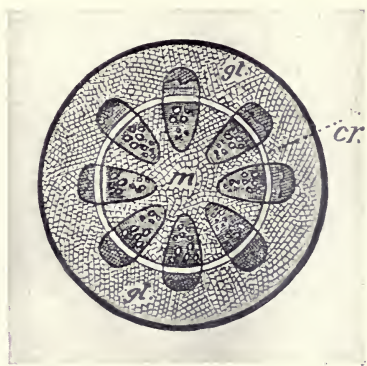


FIG. 261.—DICOTYLEDONOUS STEM.

Diagram of transverse section. The eight fibro-vascular bundles are seen embedded in the ground tissue (*st*). (*m*) Medulla or pith. (*cr*) Cambium ring.

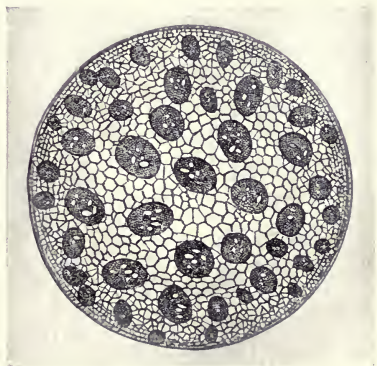


FIG. 262.—RAVENNA GRASS (*Erianthus ravennae*).

A transverse section of this Monocotyledon showing the closed fibro-vascular bundles embedded in ground tissue.

these bundles provided with vitally active cambium; so that when they cease to grow (at an early stage in the history of the plant) the stem also ceases to increase in thickness. The section of a stem of Ravenna Grass (*Erianthus ravennae*), which is shown in fig. 262, contains a portion of one of these closed fibro-vascular bundles. Flowerless Plants, or Cryptogams, usually do not contain them at all; but where they are present they sometimes form an irregular and broken ring near the outside of the stem, as in the Ferns, and in other cases constitute the axis of the stem, and are solitary. The Pillworts (*Pilularia*, fig. 267), a family of flowerless plants

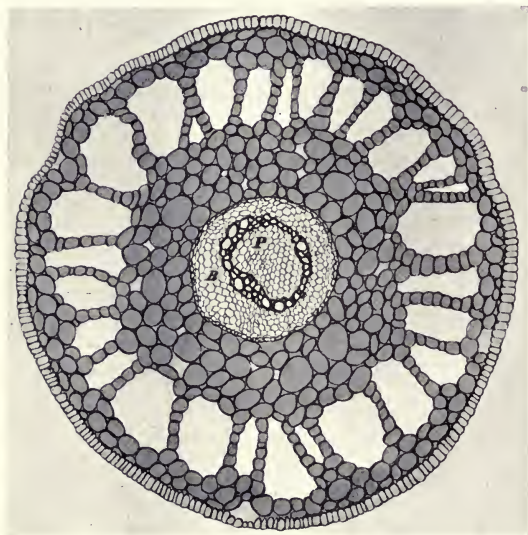


FIG. 263.—PILLWORT (*Pilularia globulifera*).

Transverse section of stem showing axial fibro-vascular strand. *P* is the parenchyma, surrounded by the dark ring of xylem, outside of which is the bast (*B*) within the bundle sheath. Outside this again are the cortex and epidermis.

are very much like roots, not in their forms merely, but also in their habits. We allude to those which grow underground—to rhizomes, tubers, bulbs, and corms.

Rhizomes, of which the Flag (*Iris*), Solomon's Seal (*Polygonatum*, figs. 265 and 269), and Lily of the Valley (*Convallaria majalis*) offer familiar examples, are subterranean stems of horizontal growth, which give off roots below and leaf- and flower-bearing shoots above. Such stems are always spoken of as roots by the old writers. Gerarde, for example, refers to the rhizome of the *Iris* as "gladen rotys" in the following curious recipe for a cosmetic:

specially partial to marshy and inundated ground, offer interesting examples of axial fibro-vascular bundles. All the Flowering Plants, and those among the Cryptogams which have these bundles in their stems, also contain them in the roots; so that a system of vessels extends from root to leaves in each plant, and forms, as we were seeing in Chapter III., the skeleton or framework on which the plant is built up.

The external forms of stems exhibit even greater variety than the external forms of roots. Some stems



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FIG. 264.—GRASSES IN FLOWER.

The flowering stem of a grass is a wonderful structure. Fine as it is, it is hollow; and when one considers its height and the pull of its branches upon it, its strength is enormous. Seen when the flowers are just open, it is a thing of great beauty. Were it less common it would receive more attention—and admiration.



FIG. 265.—RHIZOME OF SOLOMON'S SEAL.
The cut-off base of this year's stem is shown just behind the growing point. Behind it the scars left by the decay of earlier stems.

function in that they enable plants to form vigorous colonies, which are not only able to hold their own against the attacks of a competitive species of plant, but enable the ovules of its individual stems to be more certainly fertilized than would be the case were the individuals scattered. A familiar instance is seen in the way the Common Daisy, having taken advantage of a small bare spot on a lawn, proceeds to enlarge its territory by sending out offshoots all around. Had it grown as a single plant the summer growth of the neighbouring grasses would have deprived it of light and air; but if unchecked by the gardener the Daisy patch extends, and, amalgamating with other patches, would soon extirpate the grass. It is this method of spreading, too, that enables the useful Marram of the sand-dunes to hold the loose sands together. Other examples of this habit in common plants will be found in the Dog's Mercury and the Stinging Nettle.

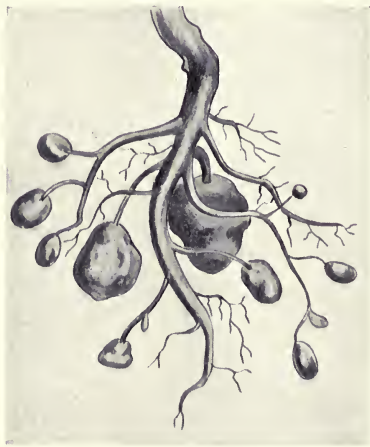


FIG. 266.—POTATO-PLANT,
Showing underground portion of stem with tubers and root-fibres.

“Do take ij parties of the poudre of gladen rotys [Iris roots], and the iij part of the poudre of ellebre [Hellebore], that some men clepen cloffynge, and medele both these poudres togider in honey. A plaster of this wole purge and cleanse the face of frekels, also it will resolve the pockys and whelkys of the face.”

Rhizomes have a very important function in that they enable plants to form vigorous colonies, which are not only able to hold their own against the attacks of a competitive species of plant, but enable the ovules of its individual stems to be more certainly fertilized than would be the case were the individuals scattered. A familiar instance is seen in the way the Common Daisy, having taken advantage of a small bare spot on a lawn, proceeds to enlarge its territory by sending out offshoots all around. Had it grown as a single plant the summer growth of the neighbouring grasses would have deprived it of light and air; but if unchecked by the gardener the Daisy patch extends, and, amalgamating with other patches, would soon extirpate the grass. It is this method of spreading, too, that enables the useful Marram of the sand-dunes to hold the loose sands together. Other examples of this habit in common plants will be found in the Dog's Mercury and the Stinging Nettle.

Tubers are most conveniently studied in the Potato-plant (*Solanum tuberosum*, fig. 266). A potato is, in fact, a true stem, and its “eyes” are buds, each of which is capable of producing a new plant. Thomas Heriot (a fellow-voyager with Sir Walter Raleigh, who was the first to introduce the potato into this country) describes the tubers as “round, some as large as a walnut, others much larger. They grow in damp soils, many hanging together as if fixed on ropes.” The Jerusalem Artichoke (*Helianthus tuberosus*) and the Chinese Yam (*Dioscorea batatas*, fig. 268) are other familiar examples of edible tubers.

Bulbs are subterranean stems not

unlike buds, with thick, fleshy scales folded round a conical axis (fig. 273). *Corms* are somewhat similar, but their scales are thin, few, and membranous; and the axis of a corm is much thicker than the axis of a bulb (fig. 272). The *Crocus*, *Cyclamen*, and *Gladiolus* offer good examples of the corm; and instances of bulbs are furnished by the Lily, Onion, Star

of Bethlehem, Snakeshead, and Hyacinth. Both these forms of underground stem are storehouses of food material, husbanding the strength and energy acquired by the plant during one season for the exigencies of the next. The reserve of food is largely drawn upon by the plant at the time of flowering, but if flowering be prevented, a very considerable saving of expenditure is the result; while the bulb, which is continually receiving fresh supplies of nutriment from the leaves, is found to be larger at the end of the growing season than at the commencement. A Lily, or other bulbous plant, by having the buds cut out year after year just before the period of flowering, accumulates an abnormal quantity of food-material (starch); and when at last the plant

is permitted to flower, it is able to compensate itself for former deprivements by making an exceptionally grand display. Herein lies the secret of the size and beauty of many "florists' flowers."

Many of these bulbous plants grow in places where, for many months, owing to the absence of rain, the land is a desert. Deep in the ground



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FIG. 267.—PILLWORT (*Pillularia globulifera*).

Scarcely to be distinguished from grass at a glance. It has a long, thread-like, creeping rhizome from which long, slender leaves arise singly or in pairs, and between their bases are the spherical spore-cases. EUROPE, NORTH OF THE ALPS.

where they have withdrawn all their living material, they are preserved from drying up, and when the rainy season begins they at once become active above-ground, and the desert becomes a garden of brilliant flowers. Such a transformation may be witnessed in the Karoo, in South Africa. Among its plants the *Brunsvigia* is conspicuous by reason of its umbels of scarlet flowers, which, it is said, may be seen at the distance of a mile.

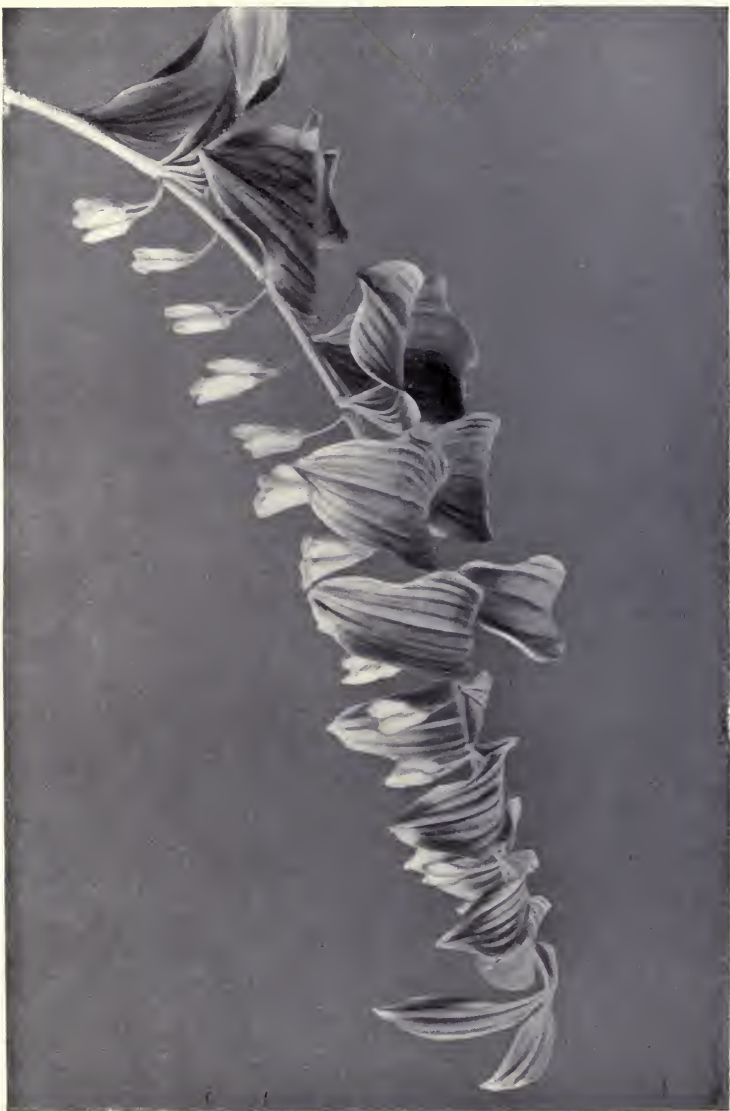


FIG. 268. — CHINESE YAM (*Dioscorea batatas*).

The tubers are a valuable food, used like the Potato.

Among certain plants with underground stems a kind of motion occurs, to which it may be worth while to make a brief allusion. Some plants, for example, appear one season in a spot at a little distance from that which they occupied in the previous season, and thus appear to travel, the shifting of position being effected by means of the sucker-like subterranean stems annually formed by the parent, which projects them to a certain distance and then perishes. The corms of many plants of the Iris order (*Iridaceae*) exhibit a similar property, each forming a new corm at its apex every year, which feeds upon the parent till the latter is quite dry. Growth goes on in this way, year by year; the corms continually rising, not, indeed, "by stepping-stones of their dead selves," but by stepping-stones of their dead *parents*, "to higher things," till the surface of the earth is reached. Then the corms become dispersed by the scratching of birds and small mammals, and each in its new position sends a thick shoot deep into the soil, through which the material of the above-ground corm is conveyed to form a new one at a suitable depth, or, by the production of special roots, the corm is pulled down to the proper level.

Yet the above instances of vegetable progression have, after all, nothing very remarkable about them, the so-called motion being strictly analogous to the progression of an ordinary aerial stem by the formation of fresh branches year after year. True motion does, however, exist in a large number of above-ground stems, such as the tips of the runners or *stolons* of the Strawberry-plant (*Fragaria*, fig. 278) and the growing points of the stems of the Ivy (*Hedera*), Raspberry (*Rubus idaeus*), etc., which Darwin, Sachs, and others have observed to rotate just as do the cotyledons and rootlets of the Bean (*Vicia faba*), Pea (*Pisum sativum*), Wood-sorrel (*Oxalis acetosella*), etc. Circumnutation is, indeed, a *general* characteristic of aerial stems.



[Photo 59]

FIG. 219.—SOLOMON'S SEAL (*Polygonatum multiflorum*).

One of the Lily family. Its thick, fleshy rhizome creeps underground, from which are seen up the annual arching stems. The greenish-white tubular flowers hang in small clusters of two to five, below the arch. The photo is half natural size. EUROPE, SIBERIA, MANCHURIA.

[E. Steyer.]

Aerial stems present a far greater variety of forms than those which grow beneath the soil. In some cases the trunk is simple and unbranched, as in the Palms, when it is called a *caudex*; in others—to wit, the stems of most woody trees and shrubs—the branches are numerous. A stem that is weak and not woody, and which perishes annually down to the root, is *herbaceous*. Then there are root-shaped stems and knotted stems; ascending



Photo by]

[E. Step.

FIG. 270.—SNAKE'S HEAD (*Fritillaria meleagris*).

A native Lily that grows in moist meadows. Its dull purple flowers are chequered with light and dark tints. The photo, which is two-thirds of the natural size, includes the rare white variety. EUROPE, W. ASIA.

stems and trailing stems; twining stems and climbing stems; and all these may—and do—assume a bewildering diversity of forms—cylindrical, triangular, quadrangular, ribbed, compressed, etc. How singular, for example, is the mode of growth of those glorious tropical climbers, the Bauhinias! Here (fig. 275) is a drawing of part of the stem of a Demeraran species, which the natives call “bush-rope” and the sailors “land-turtles’ ladders,” and which offers as neat an example of Nature’s wood-carving as one could wish to see. It is probable that the undulating central part of such stems protects the sap-conducting tissues of the plants against strain. The edges of the stem are almost straight, and form a sort of frame-

work to the sinuous middle part; so that, as Kerner says, “in the case of a longitudinal tension the frame only is affected at first,” and “the tissues in the centre can still uninterruptedly conduct the sap to and from the branches which arise from its broad surface” (*Natural History of Plants*). “Often three or four of these bush-ropes,” says Dr. Hartwig, “join tree to tree, and branch to branch; others descending from on high take root as



Photo by]

[E. Step.

FIG. 271.—STAR OF BETHLEHEM (*Ornithogalum umbellatum*).

One of the most beautiful of the smaller liliaceous flowers. The grass-like leaves have a white line down the centre, and the white flowers come up in a loose cluster (corymb) of from six to ten. It is naturalized in places here, but is a native of Europe south of Belgium. About one-third of the natural size.

soon as their extremity touches the ground, and appear like shrouds and stays supporting the mainmast of a line-of-battle ship; while others send out parallel, oblique, horizontal, and perpendicular shoots in all directions. Frequently trees above a hundred feet high, up-rooted by the storm, are stopped in their fall by these amazing cables of Nature, and are thus enabled to send forth vigorous shoots, though far from their perpendicular, with their trunks inclined to every degree from the meridian to the horizon. Their heads remain firmly supported by the bush-ropes; many of their roots soon reflex themselves in the earth, and frequently a strong shoot will sprout out perpendicularly from near the root of the reclined trunk, and in time become a stately tree."

The Buttress-trees of the virgin forests of Central America, again, have very peculiar stems. They are provided, as their name implies, with buttresses from six inches to a foot thick, which project from the stems like walls to a distance of several feet, thus affording room for a comfortable hut in the angle between them. Then there are the Pao-Barringudos of

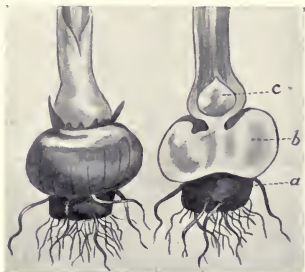


FIG. 272.—SAFFRON CROCUS (*Crocus sativus*).

Corn and section of same. (a) Old corm; (b) new corm; (c) bud.

Mention was made a moment ago of "woody trees and shrubs," an expression which recalls the old and somewhat vague classification of Flowering Plants into herbs, shrubs, and trees. Botanists differ very considerably in their definitions of these three forms, and it is hardly necessary to discuss the points of difference; probably most persons have a tolerably correct idea of the

the Brazilian forests, whose stems bulge out in the middle like enormous barrels; and the Delabecheas or Bottle-trees of tropical Australia, which have the same lumpish mode of growth (fig. 277), to say nothing of the *Caulotretus* or Monkey-ladders, and the numberless other tropical tree-climbers, whose singular varieties of stem-form—flattened and warty, ridged and contorted, net-like and interlacing—are the wonder of travellers. We shall return to some of these tropical curiosities presently when considering the means by which slender and weak-stemmed plants maintain an erect position.

Herbs are plants of comparatively small size, usually with soft and succulent stems, which die down to their base every year. The crown or root-stock itself may survive, and produce either a fresh plant year after year, when the herb is said to be *perennial*, or only the following year, and then it is *biennial*. If the herb dies completely—roots and all—in the first year, it is an *annual*. Perennial plants with branching *woody* stems, which do not attain to the dignity of trees, or, in other words, do not exceed about twenty feet in height, are *shrubs*; while perennials of larger growth, if characterized by a distinct primary stem or trunk, may be fairly classed among *trees*. No hard-and-fast dividing lines can be drawn between these three forms, however, herbs passing into shrubs, and shrubs into trees, by endless gradations.



FIG. 273.—GARDEN HYACINTH (*Hyacinthus orientalis*).

Section of bulb, showing the overlapping leaves of which it is composed.

It may be remarked in this connection that the modifying effect of climate



Photo by]

[J. T. Newman.

FIG. 274.—*Brunsvigia josephinae*.

A singular bulbous plant of the Karoo in South Africa, where for many months no rain falls. In the rainy season they at once become active, and send up their umbels of scarlet flowers, developing their leaves later.

on the size of plants of the same genus, and even of the same species, is in some cases extremely curious. Heat is a great stimulus to growth, and many plants which attain to the dignity of trees in tropical and sub-tropical countries will degenerate into mere shrubs when grown in more temperate regions. Speaking generally, the farther north we go



FIG. 275.—“BUSH-ROPE.”
Portion of stem of a *Bauhinia*.

the more stunted is the vegetation; but the difference observable in plants of the same species even when growing in neighbouring countries is frequently very marked. A striking illustration of the above facts is afforded by the Willows (*Salix*), some of which in this country are timber-trees of considerable dimensions, while in the Arctic regions their representatives seldom attain the height of *nine inches*! *Salix herbacea*, *myrtilloides*, *pyrenaica*, and *reticulata*, all species found in the ice-regions of North America, arrive at maturity and bear their flower-catkins when they are scarcely six inches above the ground! Some of these small trailing forms we have on our own moors and heaths.

To come back to the stem. The points on the stem where leaves are given off and buds formed are called *nodes*; the spaces between, *internodes*. Recently Professor L. Celakovsky, of Prague, has propounded a new theory respecting the building up of the stem. As just stated, the view formerly held by botanists was that the internode consisted of all that section of the stem lying between two nodes, but in Celakovsky's opinion this view requires some qualification when applied to dicotyledons. According to a notice of this theory by W. C. W[orsdell] in the *New Phytologist*, the Bohemian botanist divides stems into two classes—*holocyclic* and *mericyclic*. Holocyclic stems consist of a series of joints or internodes placed one above another, each occupying the entire

diameter of the axis and terminating at the node in a leaf. As each leaf arises from that portion of the apex which becomes the stem-joint to which it belongs, we may regard, he says, the leaf along with the latter as a morphological unity, and term it a *Sprossglied* (shoot segment). The entire monocotyledonous embryo (apart from the root) represents a first such *Sprossglied*, the hypocotyl being its holocyclic *Stengelglied* (stem-

joint). Holocyclic articulation is characteristic of monocotyledons. The mericyclic stem differs materially from the holocyclic, the stem-joints or internodes being arranged *side by side* (juxtaposed) as well as superposed; and therefore occupy only a portion of the diameter. Thus, in the case of leaves arranged spirally on a stem, the internode is only a segment of the diameter extending from one leaf to that which comes exactly above or below it. This arrangement of leaves is made clear in the next chapter, but for our present purpose it may be said that according to the number of leaves in one complete turn of the spiral round the stem, so there is



Photo by]

[E. Step.

FIG. 276.—WOOD-SORREL (*Oxalis acetosella*).

The plant is sensitive to atmospheric changes. The leaflets fold down close to the leaf-stalk at night and on the approach of rain. A slight jar of the leaf-stalk will produce the same effect. If a plant is put into a dark cupboard the leaflets will assume the nocturnal pose, and if then brought out into full daylight will spread out at once.

a corresponding number of segments or internodes juxtaposed in its diameter, and all beginning on different levels. When the leaves form a whorl, as in the Bedstraws (*Galium*) and Woodruff (*Asperula*), there will be as many internodes as leaves, but all beginning and ending at the same level. We cannot go into all the details here; but we may say in brief that whereas the former theory of Braun and Sachs regarded the stem as a pre-existing basis on which the leaf is developed, Celakovsky holds with Fleischer and Hegelmaier that the leaf is first formed and develops from its base a *Stengelglied* or internode.

A hollow and unbranched stem, the internodes of which are separated

by thickened nodes, as in the Grasses, is a *culm*; while a pithy stem without thickened nodes is a *calamus*. We have good examples of this sort of stem in the Rushes. Our English Grasses, it must be confessed, give but a poor idea of the dignity of a culm, and one must make a journey to India, or South China, or the Eastern Archipelago, where the colossal Bamboos abound, in order to obtain a truer idea. Every one of those polished jointed stems is a culm. Sometimes as many as a hundred of them "spring from a single root, not seldom as thick as a man, and towering to a height of eighty or a hundred feet" (Hartwig).



FIG. 277.—BOTTLE-TREE (*Delabechia rupestris*).

A native of tropical Australia.

Miss Gordon Cumming tells us that in Ceylon these giant Grasses "peep above ground during the rains, about July, and shoot up at the rate of twelve inches in twenty-four hours. The Malacca Bamboo [*Bambusa maxima*], which is the largest known species, continues growing till it attains a height sometimes considerably above a hundred feet, with an average diameter of nine inches." Picture for a moment the grace of our meadow Grasses, united with the lordly growth of the Italian Poplar (*Populus nigra*), and we shall have a faint idea of the beauty and dignity of this form of stem.

Branches occasionally take remarkable and misleading forms. The dark green leaf-like expansions of the Butcher's Broom (*Ruscus aculeatus*) are really branches—flattened branches or *cladodes*—on which the little greenish flower is borne. This is one of the most curious of our native plants, and the only woody monocotyledon indigenous to British soil. In the southern half of Britain it is common locally in woods where the surface soil is clay, sand, or gravel, and on windy heathlands one is pretty sure to meet with it. The cladode shown in fig. 283 is not a cladode of the Butcher's Broom, but of a Jamaica shrub, *Phyllanthus angustifolius*, which belongs to quite another family and order. There is also a small



[Photo by]

FIG. 278.—WILD STRAWBERRY (*Fragaria vesca*).

The leaves, flower, and fruit in various stages of development are here shown. The plant largely propagates itself by long stolons or runners which cover a considerable area of ground around the old plant. On these buds are formed, which first themselves by roots and eventually a new network community. Photo about two-thirds of the natural size. KILHOPE, N. and W. ASYL, N. AMERICA.

[E. Steg.]

genus of evergreen shrubs, consisting of only four species, which bears its flowers in much the same manner; indeed, they have received on that account the appropriate name of *Phyllocladus*, from the Greek *phullon*, leaf, and *klados*, a branch. They belong to the Cone-bearing order (*Conifere*) and are natives of Borneo and New Zealand. Somewhat analogous to the leaf branches of this family are the flat two-edged membranous branches of the Arrow-jointed Genista (*G. sagittalis*, fig. 284), a not uncommon plant in English gardens.

Branches which are arrested in their growth to form hard points are known as *thorns* or *spines*. Thus the thorns of the Hawthorn (*Crataegus oxyacantha*, Blackthorn (*Prunus spinosa*, fig. 285), Spiny Rest-harrow (*Ononis spinosa*), etc., are simply metamorphosed branches; for they contain, like true branches, fibro-vascular bundles. Under cultivation the thorns often disappear, and fruitful branches are borne in their stead—a fact which suggests the interesting inquiry, What is the purpose of thorns in the economy of Nature? Dr. Burnett offered an ingenious answer to this question upwards of seventy years ago, though possibly even he is indebted



Photo by]

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FIG. 279.—BRAMBLE (*Rubus fruticosus*).

A portion of a branch laden with its juicy fruit—the ever-popular Blackberry.



MOUTAN PEONY (*Paeonia moutan*).

The Moutan, sometimes called Tree Peony, differs from the Common Peony in having much branched shrubby stems, and in the disc of the flower enveloping the base of the more numerous carpels. The flowers are very large, both single and double, and vary in colour from white through all shades of red. It is a native of China, where it is widely cultivated.

for the thought to a still earlier botanist. "In open tracts of country, the very circumstance of the sterility of the soil must prevent the production of many plants; and of those which grow, few will be enabled to perfect many seeds. It is necessary, therefore, to protect such as are produced from extermination by the browsing of cattle, otherwise not only would the progeny be cancelled, but also the present generation be cut off. And what more beautiful and simple expedient could have been devised than ordaining that the very barrenness of the soil, which precludes the abundant generation by seed, should at the very same time, and by the very same means, render the abortive buds (abortive for the production of fruit) a defensive armour to protect the individual plant, and to guard the scantier crop which the half-starved stem can bear? That such an armature is produced by the abortion or partial development of buds and branches, there is abundant proof. For not only are thorns found in every stage, varying from their simple dormant or winter state, when, if opened, they contain the rudiments of leaves, through leaf-bearing spines to rigid thorns on the one hand, or leaf-clad branches on the other; but the very organs, *i.e.* buds, which, when the plant is half-starved, are partly developed as spines, and partly only as branches, become, when an abundant supply of nourishment is provided, altogether leafy branches; the buds have all been wholly developed, none have degenerated into thorns, and the plant is tamed. The Common Rest-harrow (*Ononis arvensis*) is a familiar example immediately in point, for of it there are two well-known varieties called *O. spinosa* and *O. inermis*, from the circumstance of this being smooth and destitute of thorns, while that is covered with them. These two varieties I have often seen growing together on the same heath; the one well-clad with its offensive and defensive arms, and furnished with few leaves to tempt the appetite of cattle; the others, upon or near to which a careless cow had dropped a profusion of manure, replete with leaves and blossoms, but wholly destitute of thorns, and just in such a state as to furnish an agreeable repast to the animal by which it had been so richly endowed."



FIG. 280. — BAMBOO.

A portion of the culm, showing several thickened nodes.

The wonderful way in which stems seem able to adapt themselves to circumstances, terrene, climatic, and otherwise, is even more strikingly illustrated in the tropical Spurges (Euphorbiaceæ). These adopt the forms and habits of the Cactee, an order of plants from which they are widely separated, developing the same succulent tissue (a provision against rainless

seasons), a tough leathery membrane to retard evaporation, and formidable spines as a protection from browsing cattle. Sometimes these spines get into the breasts of buffaloes and other large animals, causing inflammation and even death, and the wild asses of the desert are often lamed by them. Compare the stems of the two species of African Spurge (*Euphorbia grandicornis* and *E. abyssinica*) shown in fig. 286 with the slender European species (*Euphorbia spinosa*).



FIG. 281.—CLUB RUSH (*Scirpus pungens*),

Showing triangular stem or calamus; also flowers.

Weak-stemmed plants, which object to the low earth-trailing life that satisfies a Strawberry-plant or Creeping Buttercup, resort to all manners of devices in order to grow upwards. Thus the Ivy (*Hedera helix*) climbs by means of its short and multitudinous aerial roots—it is a *root-climber*; the Bramble (*Rubus fruticosus*) and the Wild Rose (*Rosa arvensis*)—*hook climbers*—develop prickles on their stems, whose curved points enable the plant to cling to whatever will help its ascent; the Traveller's Joy (*Clematis vitalba*) and Garden Nasturtium (*Tropaeolum majus*)—*leaf climbers* both—gain the desired end by means of their leaf-stalks, which they twist round the nearest support; the Vine (*Vitis vinifera*) and Virginia Creeper (*Vitis quinquefolia*) mount upwards by help of tendrils, which, in the plants named, are metamorphosed branches with adhesive discs, but in others—as the Sweet Pea (*Lathyrus odoratus*), Yellow Vetchling (*L. aphaca*), *Smilax*, and (possibly) White Bryony (*Bryonia dioica*)—are metamorphosed leaves and stipules.* *Ercilla volubilis*, a Chilian climber, attaches itself to any available support by means of adhesive discs borne directly upon the branches just above the axils of the leaves. Lastly, the stem itself may entwine the supporting object, when its spiral course is in some plants always to the left (e.g. the Convolvulus, Black Bryony, and the Scarlet Runner Bean), in others always to the right, as the Hop (*Humulus lupulus*) and Honeysuckle, albeit external conditions have no influence on the maintenance of these directions. The climbing proclivities of the Hop are greatly facilitated by the development of innumerable anvil-shaped hooks on the ridges of its hexagonal branches.

Plants whose shoots twine always to the right—i.e. clockwise—are called *dextrorse climbers*; while those whose shoots take the opposite direction—i.e. counter-clockwise—are described as *sinistrorse climbers*. "It is a matter of indifference to the direction of these movements," says Kerner,

* Some are of opinion that the so-called climbing stipules of the Bryony are really extra-axillary branches.



Photo by]

[E. Step.

FIG. 282.—WOODRUFF (*Asperula odorata*).

The leaves are borne in whorls, and there are as many internodes as leaves, but all begin at the same level. Woodruff in drying gives off an odour resembling that of new-mown hay. EUROPE (except Peninsula), N. AND W. ASIA.



FIG. 283.—*Phyllanthus angustifolius*.

A leaf-like branch, bearing flowers.



FIG. 284.—*Genista sagittalis*,

Showing two-edged membranous branch and twigs.

“whether we allow light, warmth, or humidity to operate on this side or that; the particular species always twists in the same direction, the Hop towards the right, the Convolvulus [and Dodder] towards the left. More than this, even if the twining portion is continuously bound in an opposite direction, the result is all the same; the plant cannot be coerced into any other path, and will not depart from the direction peculiar to it. It continues to twist and twine according to an innate tendency inherited from generation to generation, and we can only refer the different directions of twisting to internal causes, to the peculiar constitution of the living protoplasm in each particular plant.” It has been asserted by Darwin that the Bittersweet (*Solanum dulcamara*), a trailer rather than a twiner, is both a left-handed and a right-handed climber when growing near slender stems. Kerner, however, affirms that in many species of climbing plants whose stems, like that of the Bittersweet, increase in thickness from year to year, “the twining is not very conspicuous,” and adds of the plant in question that it forms a kind of link “between plants with twining and those with interweaving stems.”

Travellers tell us that we must go abroad in order to obtain just ideas of the habits and eccentricities of climbing and twining plants; and the accounts which they bring us from the far-off forests of the Amazon and West Indies, from India and the South Pacific Islands, are well calculated to kindle a desire to go thither. They tell us of foot-tangling Mamures,* with creeping stems and fan-shaped leaves, which interlace with wire-like branches of other plants hanging from above. “You look up and around, and then you find that the air is full of wires, that are hung up in a network of fine branches to half a dozen different sorts of young trees, and intertwined with as

* *Carludovica*, a genus of monocotyledonous plants, most of which are climbing and palm-like, and all of which are tropical. The genus is included in the order Cyathaceae.

many different species of slender creepers. You thought at your first glance among the tree-stems that you were looking through open air; you find that you are looking through a labyrinth of wire-rigging, and must use the cutlass right and left at every five steps" (Kingsley). Some of these climbers are "twisted in strands like cables; others have thick stems contorted in every variety of shape, entwining snake-like round the tree-trunks, or forming gigantic loops and coils among the larger branches; others, again, are of zig-zag shape, or indented, like the steps of a staircase, sweeping from the ground to a giddy height" (Bates).

Herb disputes with herb, shrub with shrub, and tree with tree, for every cubic foot of air and soil. It is one grand struggle for existence.* Nor do the weakest always go to the wall. By employing artifice the slender clinging plant sometimes destroys the strong-limbed self-supporting giant; the unfittest rather than the fittest thus surviving in the struggle. This is well illustrated in the *Maregravia*s, and particularly in *Maregravia umbellata*, which abounds in the woods of Jamaica, and which assumes such a variety of forms in the process of growth that it is often mistaken for different plants. At its first appearance it is but a poor, thin, weak-stemmed climber, bearing a few heart-shaped leaves; but it is also provided with aerial roots, and by means of these it attaches itself to the sturdy trunk of any tree that is conveniently contiguous, and mounts

* An Indian Grass—*Panicum arboreescens*—whose stem is no thicker than a goose-quill, rises as high as the tallest trees in this contest for light and air.



Photo by]

[E. Stev.

FIG. 285.—BLACKTHORN (*Prunus spinosa*).

The long spines are here shown to be modified branches by their bearing the flowers. The leaves have not yet appeared. EUROPE.

and mounts through the dense leafy gloom of the forest till it reaches some region of unobstructed light, overtopping the foliage of the tree by which it climbed. With that it changes its tactics, the whole plant being transformed as by the touch of a magician's wand. The stem rapidly strengthens and increases in size, flattening and moulding itself over the larger branches of its supporter; and presently it sends down numerous slender, dependent, and individual branches from the upper part, at the same time throwing off



FIG. 286.—SPURGES (*Euphorbia*).

To the left is *Euphorbia grandicornis*, in the middle *E. abyssinica*, to the right *E. spinosa*; the first two African, the third European.

cord is studded, at intervals of a few inches, with whorls of stout and acute prickles which are hooked backwards, and perform an important part in the economy of the plant. We see how it sprawls along the

* The *Calami* supply most of the walking-canes of commerce, of which some twenty millions, valued at about £40,000, are annually imported. Mr. Gosse was a careful observer, but "almost a quarter of a mile" is a surprising length for any of these *Calami*. The statement needs confirmation.

its now useless lower leaves and roots. Last of all, the plant separates from its host—leaving the tree perhaps in a dying state—and becomes a self-supporting withy shrub, capable of producing flowers and nectar, and, in due season, abundance of ripe fruit.

Another extraordinary climber is one of the Climbing Palms. "Though no thicker than your finger, it will be found," says Mr. P. H. Gosse in *Omphalos*, "almost a quarter of a mile in length. This is a kind of Cane (*Calamus* *); its slender jointed and polished stem is encased in the closely sheathing and tubular bases of the leaves, which are spiny on their midribs, spiny on their pinnae, and horridly spiny on the long and tough whip-lash in which the point of each leaf terminates. This lengthened



Photo by]

[E. Step.

FIG. 287.—WHITE BRYONY (*Bryonia dioica*).

A hedgerow climber, belonging to the Cucumber family. It climbs by the aid of tendrils which contract into spirals. It is the only British representative of the family, and here it is restricted to the South. EUROPE, NORTH AFRICA, WEST ASIA.

ground a few yards, then climbs up a tree, runs over the summit, descends on the opposite side to the ground, mounts over another tree, and thus pursues its worm-like course. Now as the pinnate leaves are put forth at every joint, the formidably armed flagellum affords a secure hold-fast to the climbing stem, which otherwise would be liable to be blown prostrate by the first gust of wind; the recurved hooks, however, catch in the leaves and twigs of the trees, and effectually maintain the domination of the prickly intruder."

Writing of a forest in the interior of Shag Island, in the Hauraki Gulf, four miles from the mainland of New Zealand, Froude, the historian, says: "We turned from the path into the forest, forcing our way with difficulty through the thicket. Suddenly we came on a spot where three-quarters of an acre, or an acre, stood bare of any kind of undergrowth, but arched over by the interwoven branches of four or five gigantic Pokutukama-trees, whose trunks stood as the columns of a natural hall or temple. The ground was dusty and hard, *without trace of vegetation*. The roots twisted and coiled over it like a nest of knotted pythons; while other pythons, the Rata parasites [*Metrosideros robusta*] wreathed themselves round the vast stems, twined up among the boughs, and disappeared among the leaves. It was like the horrid shade of some Druid's grove." "Without trace of vegetation"—those words are significant. Though the statement is a negative one, it tells of a warfare of vegetation, too—but a warfare that is accomplished. The victors are the Pokutukama-trees and the Ratas, which alone survive. How many youthful plants—Blackwood-trees, Ti-trees, Acacias, Tree-

Photo by]

[E. Step.

FIG. 288.—VIRGINIA CREEPER (*Vitis quinquefolia*),

Showing leaves and tendrils. The tips of the tendrils develop into clinging discs when they come in contact with any firm substance.

ferns, and so forth—have been crushed out of being by these vegetable pythons!

To much the same purpose speaks a recent traveller, Mr. James Rodway. Species of *Loranthaceæ*—the Mistletoe family—propagated by birds, are parasitic on the forest trees of Guiana. "As the parasite gets strong, its long extensions spread from branch to branch, and from twig to twig, everywhere extending octopus-like arms provided with sucking-discs, which adhere to and bleed the tree in a hundred different places. Branch after branch is dried up, but as the loranth has many strings to his bow, this does not hurt him much. There are always more to conquer, and unless the tree stands alone, which is, of course, impossible in the forest, he rarely comes to grief. It is not to his advantage that the tree should die quickly, and therefore the longer it can support him the better. However, even the most sturdy giant of the forest suffers greatly from such continual depletion, and may be so weakened as to lag behind in the race for life, with the ultimate result that it is smothered by its fellows."

Circumnutation, which has been shown to be so general in the growing ends of stems, is seen to excess in the climbing organs of weak-

stemmed plants, and is the means by which they are enabled to feel about (if one may so say) in search of support. Thus the apex of the stem of a Hop-plant (*Humulus lupulus*), fourteen inches in length, has been known to sweep round in a circle nineteen inches in diameter in quest of something to lay hold of, and the long shoot of a tropical *Asclepiad*, observed by Darwin, beating this record, described a circle five feet in diameter. As the weather was hot, the plant was allowed to stand on the naturalist's



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FIG. 289.—HOOKS OF WILD ROSE (*Rosa canina*).

For the purpose of resting its long weak stems on stronger shrubs in climbing, the Wild Rose develops its prickles into flat curved hooks.

study table, and he watched with interest the long shoot sweeping this grand circle, night and day, in search of some object round which to twine.

Ceropegia sandersoni, a closely allied plant (fig. 296), exhibits the same interesting phenomenon.

The movement, which has received the name of *circumnutation*, is, indeed, related to, if not identical with, that which enables a shoot to climb upwards—a fact of which it is easy to satisfy oneself by bringing the circumnating shoot of a Hopplant in contact with any upright object that would serve as a support, when the shoot will at once begin to entwine about it. Kerner suggests that such movements may be caused by the action of co-operating protoplasts in certain rows of cells on the circumference of the shoot; though what it is that impels them to this work he does not pretend to say. To him it is “just as puzzling as the stimulus to the production of partition-walls in the interior of a cell”—and that, as we have shown, is one of the sealed mysteries of biological science.



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FIG. 290.—WHITE CLEMATIS (*Clematis montana*).

The Clematis climbs by twisting its leaf-stalk round any support that comes handy. These stalks harden like wire, and are attached to the woody stems long after the leaves have fallen.

We will conclude this chapter with some remarks on *the sizes of stems*. In prehistoric ages the Animal World had its giants both on land and sea, of which the rocks bear witness in the fossil remains of mastodon and



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FIG. 291.—HEDGE BINDWEED (*Calystegia sepium*).

This beautiful weed climbs by twining its entire length round some other stem, in the same manner as that adopted by the Hop, but in the reverse direction, i.e. to the left. EUROPE, N. AFRICA, N. ASIA, TEMPERATE AMERICA, AUSTRALASIA.

pterodactylus, of plesiosaurus and ichthyosaurus; but the Vegetable World has its giants *now*. Think of the Wellingtonias (*Sequoia*) of California, in their sheltered valleys five thousand feet above the level of the sea, with stems three hundred feet and more in height, and ninety, one hundred, or even a hundred and twenty feet in circumference. Think of the mighty



Photo by]

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FIG. 292.—GREATER STITCHWORT (*Stellaria holostea*).

It climbs the hedge by sticking out its stiff leaves at right angles with the weak stem. EUROPE, W. ASIA.

Eucalyptus-trees of Western Australia, rising from the glens of the Warren River and the deep recesses of the Dandenong, and piercing the sky four and five hundred feet up—trees that might look down upon the spire of Strasburg Cathedral, or cast their shadows over the Great Pyramid!* Think of the great Banyan-tree of the Nerbuddah, with its three hundred and twenty main trunks and three thousand smaller ones, covering an area of two thousand feet—a giant which shelters beneath its umbrageous arms a host of Custard-apple and other fruit trees. Think, too, of the Silk-cotton-trees (*Bombax ceiba*) of Yucatan, with stems so large that in some cases fifteen men, with arms extended, can scarce embrace a single trunk;

and of the lofty *Moras* of Guiana, of which, as we have seen, Waterton has left so vivid a picture. "Heedless and bankrupt in all curiosity must he be"—again we quote from the hero of the *Wanderings*—"who can journey through the forests of Guiana without stopping to take a view

* A Eucalyptus-tree measured by Froude, the historian, was forty-five feet round at the height of his shoulder (*Oceans*, p. 127).

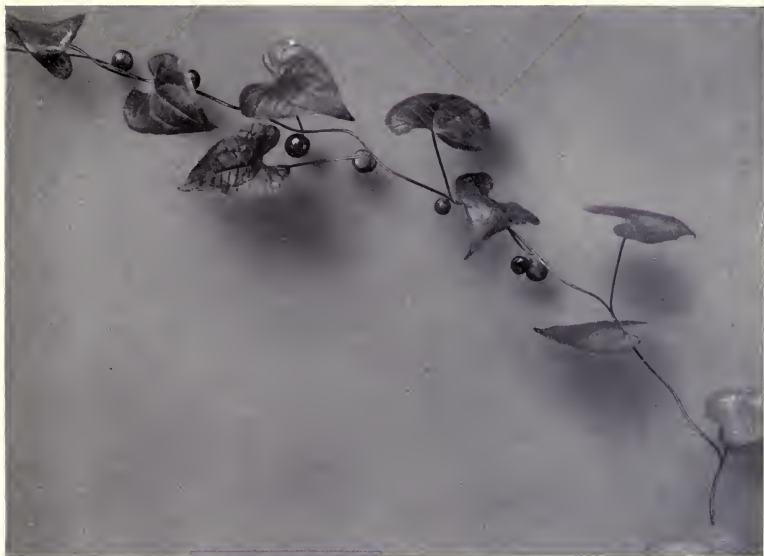


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FIG. 293.—BLACK BRYONY (*Tamus communis*).

Like the *Convolvulus*, the Black Bryony climbs by twining always to the left. It is the only British representative of the Yam family. The specimen photographed is a young plant; in older individuals the red berries are produced in bunches. EUROPE, N. AFRICA. W. ASIA.

of the towering *Mora*. Its topmost branch, when naked with age, or dried by accident, is the favourite resort of the toucan. Many a time has this singular bird felt the shot faintly strike him from the gun of the fowler beneath, and owed his life to the distance betwixt them." Would that some of our English song-birds, growing scarcer amongst us every year, had trees as high to nest in!

The "Monster Cactus" which reached Kew Gardens in 1846 measured nine and a half feet in circumference and weighed a ton. Eight strong mules were required to draw it over the mountains of Mexico, and ten men to place it in the scales at the Royal Gardens (see fig. 96). Considering that Cactuses are only succulent plants, these statistics are indeed astonishing.

The length attained by the fleshy stems of many Seaweeds may be referred to in this connection. One species of Sea-wrack, *Macrocystis pyrifera*, which abounds in the southern oceans between Tierra del Fuego and New Zealand, though its stalk is not thicker than a pen-holder, sometimes measures upwards of nine hundred feet in length; and *Lessonia*,

another plant of the same interesting family (Laminariaceæ), attains to tree-like dimensions and has a stem as thick as a man's thigh. Probably the extraordinary length of some of these ocean Thallophytes is the originating cause of most fables about the sea-serpent.

To return for a moment to plants with woody stems. There is a Chestnut-tree (*Castanea vesca*) on Mount Etna, which measures a hundred and eighty feet in circumference; a Plane-tree (*Platanus orientalis*) near



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FIG. 294.—BRAMBLE AND HONEYSUCKLE.

The Bramble (*Rubus fruticosus*) largely climbs by means of stout spines. The Honeysuckle does so by twining. See fig. 295.

kept so accurately and so very thick, that the sun never looked into it." Another famous member of the same family existed—perhaps still exists—at Neustadt, in Wurtemberg, whose huge limbs were supported by numerous stone columns.

But it is not size alone which makes a tree noteworthy, else would the tropical Tumboas or Welwitschias—well called *mirabilis* or "wonderful"—find no place of mention here (fig. 297). The Welwitschias are not, indeed, giants of the Vegetable World, but their stems are, none the less, curiosities.

Constantinople with a diameter of nearly fifty feet; and Lime-trees (*Tilia*) in Lithuania with a girth of eighty-seven feet; though none of these offers anything remarkable in regard to height. They are dwarfs, indeed, beside the Eucalyptus-trees of Australia and the Wellingtonias of California. There are other venerable old Limes besides those of Lithuania. At Chalouse, in Switzerland, there stood one of these trees in Evelyn's time, "under which was a bower composed of its branches, capable of containing three hundred persons sitting at ease. It had a fountain set about with many tables formed only of the boughs, to which the ascent was by steps, all



[Photo by]

FIG. 295.—HONEYSTICKLE (*Lonicera periclymenum*).

The Honeystickle twines always to the right, the coils afterwards becoming woody and of considerable thickness, so that they defy all efforts of their supporting victim to break them. Hazel and other stems may often be found looking like huge corkscrews, the deep spiral groove being caused by the Honeystickle's grip preventing expansion along this spiral line. W. LINDSEY.

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The first European discovery of the plant was made by Mr. C. J. Atkinson, who forwarded specimens to the Botanical Museum at Cape Town, but was otherwise rather reticent concerning the discovery. There was no occasion for reticence. *Welwitschia mirabilis* is an unique plant—a monotypic genus, indeed—totally unlike every other member of the Vegetable Kingdom, both in appearance and mode of growth, and therefore a plant to be taken account of. Fortunately, within a few years of its discovery, the celebrated botanical traveller, Dr. Welwitsch, rediscovered it. While exploring the waste and arid deserts of South-West Tropical Africa, not far from Cape Negro, the doctor came upon a hard rough-looking disc, elevated some ten or twelve inches from the ground, and having a diameter



FIG. 296.—*Ceropogia sundersoni*.

The flower of a climber whose growing tip makes circular movements in search of a support.

of from three to four feet. It was the stem of a *Tumboa*. From deep grooves in the circumference of the stem, two opposite leaves—tough, brown, and torn into innumerable thongs—hung down and trailed, curling, along the sand to a distance of five or six feet in both directions. These were the true leaves.* It has since been discovered that only two such leaves are developed on every plant, and that they persist during the long life of the individual. The flowers which resemble the cones of the Larch, spring up annually in crimson clusters round the edge of the disc, though the wood is of a stony hardness. The concentric layers which compose the stem show that growth in thickness takes place as in dicotyledons; but upward growth is arrested at an early period.

The age of many forest-trees is enormous. The great Chestnut of Tortworth is believed to have been a flourishing young sapling in the time of Egbert; an Oak in Normandy—the *chêne chapelle*—which was converted into a chapel some two centuries ago, was probably at that time seven hundred years old; while the famous Salcey Oak is probably much older than either, and the Winfarthing Oak (see fig. 244) on the Earl of Albemarle's estate near Diss, in Norfolk, is perhaps more patriarchal still. But the Methuselah of the race, according to Mr. W. Senior, is the famous Greendale Oak at Welbeck, which is believed to have weathered the storms of fifteen centuries. About a hundred and sixty years ago this

* Not the cotyledons, as was at first supposed. Two cotyledons are, indeed, produced, but they fall away while the plant is still quite young.

tree "was deprived of its heart by the eccentric desire of the then owner to make a tunnel through the trunk. This novel piece of engineering was effected without any apparent injury to the tree. An opening was made through which a Duke of Portland drove a carriage and six horses, and three horsemen could ride abreast. The arch is 10 ft. 3 in. high, and 6 ft. 3 in. wide." The Greendale Oak has no longer the Cowthorpe Oak at Wetherby, in Yorkshire, as a competitor. This tree was reported to be in possession of "a few green leaves" so late as the year 1880, and was then thought to be about eighteen centuries old, but it is now a ruin. In 1776 its circumference three feet from the ground was forty-eight feet, though Jesse, sixty years ago, gave its measurement at the base as seventy-eight feet. The Winfarthing Oak, mentioned above, measured seventy feet in circumference at the base of its trunk in 1820, and, in the opinion of some judges, is quite as ancient as its Welbeck rival. It is said that it was an old tree at the time of the Norman Conquest.

Other large Oaks mentioned by Jesse include the Salcey

Forest Oak, Northamptonshire, as being forty-six feet in circumference, presumably at the base of the trunk; the Flitton Oak in Devonshire, thirty-three feet at one foot above the ground; the Hempstead Oak in Essex, fifty-three feet; and the Merton Oak in Norfolk, sixty-three feet. He also mentions the remains, at Ellerslie in Renfrewshire, of the Wallace Oak, in which it is said William Wallace and three hundred of his followers hid themselves from the English.

Nor are Oaks and Chestnuts the only trees famous for longevity. An Ivy (*Hedera helix*) near Montpellier is nearly four hundred and sixty

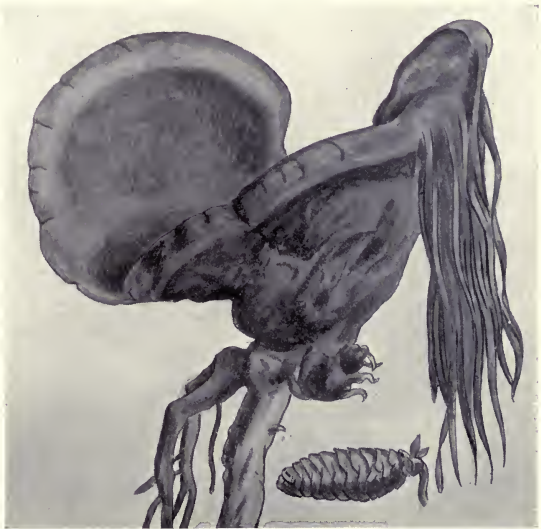


FIG. 297.—TUMBOA (*Welwitschia mirabilis*).

A remarkable plant of tropical Africa, consisting of a hard disc from which is given off on opposite sides a pair of leaves torn into leathery thongs which are six feet in length. A flower-cone is shown below.

years old, and a Rose-tree at Hildesheim, in Germany, can be traced back to the time of Charlemagne. There are Cedars (*Cedrus libani*) on Mount Lebanon from six hundred to eight hundred years old; and Lime-trees (*Tilia vulgaris*) near Friburg that have existed for one thousand two hundred and thirty years. The Yew-trees (*Taxus baccata*) of Fountains Abbey are believed to have been in a flourishing condition twelve centuries ago; "the Olives (*Olea oleaster*) in the Garden of Gethsemane were full-grown when the Saracens were expelled from Jerusalem; and a Cypress



FIG. 293.—THE GREENDALE OAK, WELBECK.

Believed to be over fifteen hundred years old. A former owner had a passage cut through the bole to allow his carriage to pass through.

as the older Wellingtonias, however, some of which were lusty millenarians when that veteran was a baby!

Here let us pause, though not for want of matter to carry us farther. The topic, indeed, is inexhaustible. Even in a subject so apparently tame and dry as the stems of plants, how much there is to interest and inform! How infinite in variety, how wealthy in resource, how wonderful, is Nature—whichever way we turn, on whatever class of objects we fix the eye! How many curious facts—morphological and biological—have been before

(*Cupressus sempervirens*) at Somma, in Lombardy, is said to have been a tree in the time of Julius Cæsar. Yet the sacred Bo-tree (*Ficus religiosa*) [at Anarajapoor] is older than the oldest of these by a century, and would almost seem to verify the prophecy pronounced when it was planted, that it would 'flourish and be green for ever.' It was under a Bo-tree that Gautama reclined when he passed through the crisis of his ministry; and Buddhist superstition sees in that event the origin of the quivering of the Bo-tree's heart-shaped leaves. Even the patriarchal giant of Anarajapoor is not so ancient



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FIG. 299.—ACORNS AND LEAVES OF PEDUNCULATE OAK (*Quercus pedunculata*).

This form of the Common Oak (*Quercus robur*) is by some authors considered a distinct species. Its distinguishing characters are—the leaves are nearly or quite without stalks, and the flowers and acorns are on long stalks. The Oak is native from the Atlas range and Syria in the south almost up to the Arctic circle.



FIG. 300.—THE WINFARTHING OAK, NEAR DISS.

A tree of great age, whose trunk is over seventy feet in circumference at its base.

how provident for the future plant! Think of the endless variety of external forms in root and stem; of the habits, metamorphoses, and motions of those organs; of their latent vegetative possibilities, their vigorous growth, their longevity. Poets would even persuade us that they have passions like ourselves—envies and jealousies, loves and antipathies; and one almost wonders at times if the thought is only fanciful. But we are treading on forbidden ground.

us since we began! Glance back for a moment and consider a few of them. Recall a leading fact here and there. Think of the *structure* of a plant with reference only to leaf, root, and stem (for the flower as yet we have not reached); think of the millions of cells and vessels which compose it; of the provision for the upward and downward flow of sap; of its life-sustaining and life-destroying secretions; of the means by which its growth is effected. What lessons in patience and prudence, in thrift and economy, the plants could teach us! How sentient and wise they appear to be—how steady and methodical—

CHAPTER VIII

LEAF-BEGINNINGS AND LEAF-FORMS

“Only leaves? Yet where would any of us be to-day but for the silent offices of leaves?”—*Finger-post Essays.*

HAVING treated at some length in a previous chapter of the internal structure and functions of the leaves of the plants, we may now devote a few pages to their external forms—a subject by no means easy to treat in a popular manner. Nevertheless, we think that it has recommendations of its own and will not be found unfruitful of interest.

The beginning of the leaf is the *bud*. The foliage buds which we see expanding in the spring are formed the autumn before; and the busy



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FIG. 301.—HORSE-CHESTNUT (*Æsculus hippocastanum*).

On the right is a leaf with a normal leaf-stalk; on the left one with broad furry stalk; and in the centre a bud-scale. The intermediate character of the left-hand leaf shows that the bud-scale is a modified leaf.

protoplasts, as though aware that the nipping frosts of winter will have to be faced by these nurslings of the Vegetable World, provide them with jackets which effectually keep out the cold, and which may be thrown off with the milder spring's return. These jackets are botanically known as *scale-leaves* or *bud-scales* (fig. 302).

In some plants—as the Horse-chestnut (*Æsculus hippocastanum*)—the scales are covered with a gluey substance, resulting from the conversion into mucilage of a layer of epidermal cells beneath the cuticle, which increases their efficiency as bud protectors; while in many species of Willow (*Salix*) and not a few other plants the scales are provided with a coating of soft hair or down. When bud-scales are not developed, the leaf-like appendages—*stipules*—at the bases of the young leaves frequently serve as protectors; or the leaves themselves may be covered with wool. In the majority of cases—the Indiarubber-plant (*Ficus elastica*) may be cited as an example—these protective coverings drop off when the leaf is strong enough to bear exposure to sun and weather (fig. 304); but in others they persist throughout the life of the plant. The membranous stipules of the Tulip-tree (*Liriodendron tulipifera*) close over the young leaf like the shells of a walnut; and on pulling them apart the folded leaf may be seen curled up, and looking as snug as a kitten in a basket (fig. 307). These stipules shrivel and fall off directly their work is done.



FIG. 302.—CHRISTMAS ROSE (*Helleborus niger*).

The smaller figure shows a leaf-bud before opening; in the larger figure it has emerged from the bud-scale.

Another and more familiar form of protective bud-scales is the brown, dry, chaffy-looking growth which covers the tender green fronds of many Ferns, and which may be well studied in the Common Scale-fern (*Asplenium ceterach*), one of the prettiest of our mural species. The closely packed overlapping scales, which are of a rust-coloured brown, completely cover the under surface of the fronds; and in this case are persistent, for the plant grows in exposed situations and cannot afford to dispense with its chaffy undervest as it grows older. When dry winds prevail or the sun is in his fiercer moods, the fronds roll up, and thus make the most of their protective scales. The leaves of *evergreen* plants, which, though they have to brave the rigours of winter, lose their scales at an early period, are provided with a specially tough and water-tight epidermis, and their smooth glossy surfaces are admirably adapted to prevent the accumulation of snow upon them. Good examples are offered by the Common Holly (*Ilex aquifolium*) and the Sweet Bay-tree (*Laurus nobilis*).

Buds are usually formed either at the ends of branches, when they are



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FIG. 303.—HORSE-CHESTNUT (*Æsculus hippocastanum*).

A new shoot. Below, the first leaves of a new branch; above them, the gummy bud-scales from which the limp upper leaves and stem ending in the flower-buds have emerged.

called *terminal*, or in the axils of leaves, when they are said to be *axillary*; and they are frequently found in both positions on the same plant. Those which fall under neither of these categories are described as *adventitious*. Adventitious buds apparently give rise to most of the leafy shoots on old tree-trunks;* and not infrequently they are developed on roots. Injury to the aerial parts of certain plants will induce the formation of *root-buds*. The felling of a tree, for example, may be the occasion for a whole crop of underground buds; for the protoplasts in the root may—and often *do*—recover from the shock, and being diverted from their regular work, they busy themselves in the formation of buds, from which, in due course, arise new leaf-shoots, containing all the promise and potency of future trunks.

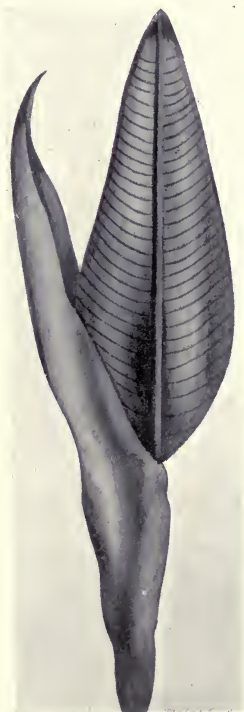


FIG. 304.—INDIARUBBER
(*Ficus elastica*).

Young leaf expanding and throwing
off scale.

Occasionally adventitious buds are borne on leaves, and to such the name *epiphyllous* has been applied. If a leaf of one of the large-leaved species of *Begonia* or of *Gloxinia* be planted in a suitable soil, it will put out roots from its stalk, and buds from various parts of the blade—a fact of which horticulturists take every advantage. When it is desired to multiply any of these plants, the nurseryman collects a number of the older leaves, and having made incisions with a sharp knife across the principal nerves on the under side, he spreads the leaves on sand or coconut fibre, and shades them carefully from the sun. As a result of this treatment, bulbils presently appear at the lower ends of the nerves, and when these have attained to a certain size, they are removed and placed in separate pots. Each bulbil is now a distinct plant.

Epiphyllous buds are sometimes met with on Liliaceous and Orchideous plants, as well as on the Lady's-smock or Cuckoo-flower (*Cardamine pratensis*) and the Celandine (*Chelidonium majus*); but the plant which is most celebrated for its bud-bearing leaves is probably *Bryophyllum calycinum*, an Indian evergreen shrub of the House-leek family, common enough nowadays in English stovehouses, where it is grown as a curiosity. The thick fleshy leaves of this plant (fig. 309) need no artificial incisions to stimulate their productiveness. Nature has already notched the

* Possibly, however, such buds are more often axillary buds which have lain dormant.



Photo by]

FIG. 305.—SCALY SPLEENWORT (*Asplenium ceterach*).

[E. Step.

The back of the frond is covered with golden-brown chaffy scales, which protect it before expansion and when it rolls up as though dead in dry weather. EUROPE, N. AFRICA, W. ASIA, HIMALAYA.

leaves at the margin, and every full-sized leaf, even when growing on the parent plant, exhibits at each of the notches a group of cells—the embryo bud—which to the naked eye appears like a speck. When one of these leaves is removed and placed in a moist situation, the buds develop and leafy shoots appear; while the old leaf soon falls to decay, and the young plants become independent and self-supporting.

A New Zealand Fern, *Asplenium bulbiferum*, is likewise noted for its budding propensities. The buds are borne on the divisions (*pinnules*) of the older fronds, which are so prolific that a single plant may be the parent of many hundreds of new individuals. Other Ferns—as *Asplenium edgeworthii*, *Ceratopteris thalictroides*, *Gleichenia cryptocarpa*, *G. flabellata*, and *G. cunninghami*—display the same vital energy; indeed, there is reason for believing that a fern-frond is simply a cladode or flattened branch, and that the buds are normally produced like the flower-buds of the cladodes of the Butcher's Broom. A graceful North American species of Hart's-tongue Fern known as the Jumping-leaf (*Scolopendrium rhizophyllum*) usually produces buds at the ends of its narrow lanced-shaped fronds. The fronds bend over until their slender tips touch the ground, when roots form



FIG. 306.—ORIENTAL PLANE-TREE (*Platanus orientalis*.)

A leaf-bud with its protecting cap removed.

on the under surface at the points of contact, and from the upper surface new fronds arise (fig. 308). It may be well to remark here that the plant known as the Butcher's Broom *Helwingia* (*H. rusciflora*), the flower-buds of which are seated on the foliage-leaf, is not to be classed with plants like *Bryophyllum*, and for this reason: *the flower-buds of Helwingia are not true epiphyllous buds*. They do not spring from the *tissues* of the leaves on which they are seated, but from the *axes* of the leaves, and with these axes they are connected by strands, which are simply disguised flower-stalks. In short, the buds are not the result of protoplasmic activity in the leaf-tissue, but spring from the rudimentary flower-stalks, which differ from ordinary flower-stalks by being fused with the midrib of the leaf. Another plant which somewhat resembles *Helwingia* in this respect is *Phyllonoma ruscifolium*, a Mexican shrub; but the leaf in this case is surmounted by a long acumen below the base of which the flowers appear.



FIG. 307.—TULIP-TREE (*Liriodendron tulipifera*.) Young leaf lying between the stipules, one of which has been removed.

The manner in which the young rudimentary leaves are arranged in the leaf-buds—in scientific parlance, their *vernation* or *prefoliation*—forms an interesting study. Each species of plant has its own particular method of folding its unexpanded leaves, and a definitive term is applied to each. In the Ferns (*Filices*) the fronds are coiled from tip to base (*circinate*); in the Grasses (*Gramineæ*) from one side to the other (*convolute*); in the Violet (*Viola*) the lateral margins are simultaneously rolled inwards towards the midrib (*involute*); in the Cowslip (*Primula*) and Dock (*Rumex*) a similar rolling is seen, but outwards (*revolute*); in the Currant (*Ribes*) and Beech (*Fagus*) the leaf is plaited with several folds lengthwise (*plicate*); and in the Cherry and Plum (*Prunus*) it is folded flat from the midrib with the edges in contact (*conduplicate*). These distinguishing names being descriptive are easily acquired; but we do not lay stress upon them just now. The fact that we *would* emphasize (and it is *very* remarkable) is this—that the tissues forming the leaves are manufactured *folded up!* We can understand a loom weaving a material, and *then* folding it; but here is the material folded up, and unfolding only when it is all woven!



[Photo 191]

FIG. 308.—WALKING FERN (*Scelopendrium rhizophyllum*),
Whose fronds root at their tips and give rise to new plants, NORTH AMERICA.

[Henry Traill.

The arrangement of the mature and developed leaves on the stem is also worthy of attention. To regard the mass of foliage on a tree as an orderly arranged series of organs might seem to be a far-fetched thought; yet order reigns in nature where the unpractised eye sees only disorder. It was long ago remarked by Charles Bonnet, an eminent Swiss naturalist of the eighteenth century, that leaves and their modifications have normally a spiral arrangement on the stem. The fact (for the truth of the observation is beyond question) is more easily understood of the foliar than of the floral leaves, and may be better seen in some plants than in others. It is spoken of as phyllotaxy.



FIG. 309.—*Bryophyllum calycinum*.

Formation of buds at the edges of a leaf.

The leaves of a Cherry-tree (*Cerasus*) will furnish a suitable illustration. Here (fig. 313) is a piece of a branch with all the leaves belonging to it. We will number them in their order of growth, 1, 2, 3, 4, 5, and 6. Now for our spiral. Commencing at number 1, draw a chalk line from the base of the leaf to the base of number 2, and from thence to the same point in leaf 3, and so on, to the base of each leaf in succession till number 6 is reached. See now what has happened! The chalk line has traversed in a spiral manner exactly twice round the branch, and the beginning of the line at number 1 is exactly under the end of the line at number 6; or, in other words, the first leaf corresponds vertically with the sixth. Had the fragment of branch been longer, and contained eleven leaves instead of six, we should have found on continuing the line in the same manner—that is, from base to base of the additional leaves—that the point of the chalk would have travelled, as before, twice round the branch in order to reach number 11. Moreover, and as a consequence, the leaf specified would have been found to be in the same vertical line as 1 and 6. As to the other leaves, number 7 would have been found to be over number 2, 8 over 3, 9 over 4, and 10 over 5—in fact, the interesting discovery would have been reached that the leaves are disposed on the branches in *cycles* of five; and the way would have been cleared for the statement that the laws which regulate the foliar arrangement of all plants, and the floral no less than the foliar, may be reduced to the same mathematical precision (fig. 313).

Not, of course, that the leaves of all plants fall under the same arrange-

ment as the Cherry. In monocotyledons—particularly the Grasses—the arrangement is often two-ranked (*distichous*); that is to say, the third leaf is over the first, the fifth over the third, etc.; while on the opposite side of the stem the fourth leaf is over the second, the sixth over the fourth, and so on.

A three-ranked (*tristichous*) arrangement is, however, by far the most common among monocotyledons. The cycles in such instances are three-leaved, numbers 4, 7, 10, 13, etc., each commencing a new cycle. An eight-ranked (*octastichous*) arrangement (eight leaves in a cycle) is found in the Holly (*Ilex*), Aconite, and many other plants. The above are, perhaps, the most common varieties of *phyllotaxis*, but the list is very far from exhausted when these have been enumerated. A Fir-cone is simply a collection of modified leaves, arranged in a highly characteristic spiral manner.

All plants, we must remember, do not possess leaves. The Broomrapes and

Dodders, for example—those thriftless parasites which feed upon the juices elaborated by the host plants to which they attach themselves—have no need of leaves. The *Cacti* and many tropical *Euphorbias* are also deficient in these organs, though their spines are really metamorphosed leaves or branches, affording them (as we saw on a former occasion) protection from



Photo by]

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FIG. 310.—LADY'S SMOCK (*Cardamine pratensis*).

Sometimes called Cuckoo-flower. A familiar spring flower in moist meadows. The pinnate leaves often bear buds in their axils which develop into new plants.

herbivorous wild animals. Leafless plants, however, are exceptional among Phanerogams, and it is only when we descend the scale of Vegetable Life, and place ourselves among the Cryptogams, or Flowerless Plants, that a general absence of leaves becomes apparent. The Ferns have them, it is true, their green *fronds* being among the chief beauties of Nature. The Mosses have them also, but their minute and delicate leaves are destitute both of woody vessels and stomata, and can scarcely be ranked with the busy sap-elaborating organs of Flowering Plants. The Fungi are provided with nothing analogous to leaves; nor is any provision necessary, as the food on which they thrive is derived from a host (plant or animal) or from decomposed organic matter which does not need to be elaborated by exposure to light and air. They are known, therefore, as saprophytes, or feeders upon rotten substances.



FIG. 311.—SWEET VIOLET (*Viola odorata*).
An example of Involute venation.

A systematic description of the various forms of leaves would, we fear, be very wearisome. The names themselves are as numerous as the names of the English sovereigns from Egbert to George V., and by no means as easy to remember. Not only has every part of a typical leaf its Latin appellation, but every sort of margin, base, and apex has a qualifying cognomen. In a Grass-leaf, for example (fig. 321), the flattened upper part of the leaf is called the *blade*; the portion enfolding the stem is the *sheath*; and the scale-like formation between the sheath and blade is the *ligule*. Moreover, the leaf is *parallel-veined*—i.e. the fibrous bundles which form the skeleton run side by side without

interlacing—a characteristic feature of almost all monocotyledons;* its margin is *entire*—i.e. it is even and smooth all round—and its shape is *linear*, that is, narrow and straight and several times longer than its width.

The parts of a dicotyledonous leaf have an even greater number of distinguishing names. Take, for instance, the *compound* leaf of the Dog-rose (*Rosa canina*), the Ash (*Fraxinus excelsior*), Sainfoin (*Onobrychis viciifolia*), Silver-weed (*Potentilla anserina*), or Kidney Vetch (*Anthyllis vulneraria*). The leaf as a whole is called compound because its stalk bears numerous leaflets, it is *pinnate* (Lat. *pinnatus*, feathered) because leaflets grow featherwise along the sides of the stalk, and it is *unequally* or *impari-*

* There are three or four British monocotyledons—notably the Black Bryony (*Tamus communis*) and the Cuckoo-pint (*Arum maculatum*)—which have net-veined leaves.



Photo by]

[E. Step.

FIG. 312.—FERN FRONDS UNROLLING.

This photograph of the Lady Fern is a good example of Circinate vernation, the bud appearing as though the frond had been rolled up from the tip to its base.

pinnate because there is an odd lobe at the extremity.* The leaflets themselves are *net-veined*, the large central vein in each being known as the *midrib*; their shapes are *broadly elliptical*, and their sharp, saw-like margins are *serrate* (Lat. *serratus*, saw-like). The portion of the leaf-stalk at the base of the leaf is the *petiole* (Lat. *petiolus*, a little foot); but beyond the first pair of leaflets it is called the *rachis* (Greek *rachis*, the spine). The two small leaf-like organs at the base of the petiole are *stipules* (Lat. *stipula*, a blade).



FIG. 313.—FIVE-RANKED (PENTASTICHOUS) ARRANGEMENT OF LEAVES OF THE CHERRY.

Now, all this is very bewildering; nevertheless, a few walks in the country, if the neighbourhood be at all favourable for botanizing, will soon familiarize one with the principal leaf-forms, and more will probably be learnt in a single hour thus spent (with text-book in hand for reference) than in five or six hours of wearying desk-work. There is a spot which we could mention, not twenty miles from London, which is peculiarly adapted for this purpose.

It is a charming piece of Surrey landscape, in his lifetime a favourite spot with that prince of Nature-interpreters, Richard Jefferies; so we will transport ourselves thither in imagination, and saunter

together down the shady lane, not yet disfigured by lamp-post or flaming

* Compound leaves which have no such terminal lobe, but all the leaflets of which run in pairs (fig. 315), are described as *pari-pinnate* (Lat. *par*, *paris*, equal, and *pinnatus*). We get this form in the Vetches (*Vicia*). In many of the Acacias each of the *pinnae* of the pinnate leaves is itself pinnate, so that the form is doubly or *bi-pinnate*; while in the Lesser Meadow-rue (*Thalictrum minus*) the division is carried a step further, and we have a *tri-pinnate* form.



WALKER'S CATTLEYA (*Cattleya Walkeriana*).

The Cattleyas are a favourite genus of evergreen Orchids, producing some of the finest of flowers. Walker's Cattleya has sweet scented flowers five inches across, usually borne in pairs. The long stout bodies are the pseudo-bulbs in which nourishment is stored to tide the plant over the dry season. It is a native of Brazil.



Photo by]

[E. Step.

FIG. 314.—WILD CHERRY (*Prunus avium*).

The flowers are produced before the leaves are fully expanded. At this stage they will be seen to have the two halves of the leaf-blade folded with their upper surfaces in contact.

pillar letter-box, and beside a narrow stream which separates the parson's few acres from the neighbouring farm, and so on to the schoolmaster's cottage, gathering our leaves by the way. Lane, stream, meadow, corn-field, cottage garden—these will supply all, and more than all, the forms required, and future rambles will help to fix in the memory the facts elicited.

Behold, then, the lane!—winding, odorous, leafy; a spot for poesy, such as might rouse the happy muse in a Clare or Cowper, or move to loving activity the pencil of a Birket Foster. It is a bright June day, and the song of birds, the hum of innumerable flying insects, and the click of the grasshopper make music the whole way long. Noble Horse-chestnut-trees (*Æsculus hippocastanum*) rise out of the lane-side hedges at every few paces, and their branches meet over us, their spreading *digitate* leaves affording welcome shade (fig. 303). An ivy-clad Oak (*Quercus robur*) is also passed, easily to be recognized by its knotty, widespread branches and wealth of *sinuate* leaves (fig. 317). Shakespeare, whose quick eye let nothing escape him, called this tree “the unwedgeable and

gnarled Oak," and no description could be more appropriate. Notice the Ivy (*Hedera helix*), a familiar object everywhere. The beauty of its light-veined leaves has often been celebrated by poets. Observe particularly the direction of the principal veins in one of these leaves. They radiate outwards from the base of the leaf, like the outspread fingers of the hand ; and hence are called *palmately veined*.



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[E. Step.

FIG. 315.—TUFTED VETCH (*Vicia cracca*).

The finest of our Vetches, the bright blue flowers being gathered into a dense raceme which makes them very conspicuous. The plant climbs by means of tendrils, which are a continuation of the rachis.

The leaves on the climbing stems of the Ivy are always lobed, and the depressions or sinuses between the lobes are usually shallow ; but in other leaves—as the Common Ragwort (*Senecio jacobaea*)—they are deep and pinnate (fig. 318). That bushy-looking weed, whose pale green purple-edged flowers must be sought for earlier in the year, is the Stinking Hellebore (*Helleborus foetidus*) ; and we are fortunate in meeting with a specimen here, as the plant is rarely found growing wild. Its palmately veined leaves are deeply divided, on which account they are

called *palmati-partite* (fig. 316) ; while the downward-turned lobes at the base of each define their place as among *pedate* leaves. Palmati-partite leaves should be carefully distinguished, on the one hand, from palmately lobed (*palmatifid*) leaves, the divisions of which do not extend so far as those of the former ; and, on the other hand, from palmately cleft (*palmatisect*) leaves, in which the divisions extend very nearly to the base. The



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[E. Step.

FIG. 316.—STINKING HELLEBORE (*Helleborus foetidus*).

The foliage offers good examples of the pedate leaf. The sepals constitute the conspicuous part of the flower, and are pale yellow-green rimmed with red-purple. The petals have been converted into nectaries, and are hidden below the stamens. It is a native of Western Europe only, and a rare plant in the South and East of England.



Photo by]

[J. Holmes.

FIG. 317.—THE OAK (*Quercus robur*).

Showing a normal trunk with its principal limbs, grown in the open. In woods the limbs and branches are less spreading.

branch of Ivy which we were just examining offers examples of palmatifid leaves, and the well-known Monkshood (*Aconitum napellus*), of which the school-master's garden will furnish specimens, bears leaves of the deeply cut palmatisect form (fig. 319).

As we are now down among the grass, we may pause a moment to admire the splendid white blossoms and pretty leaves of the little Trefoil, creeping in and out between the cool blades. It is a species of Clover or Trefoil (*Trifolium subterraneum*, fig. 319). Notice that the tiny leaflets all spring from the top of the *petiole* or leaf-stalk, just as in

the case of the Horse-chestnut-leaf gathered at the beginning of our walk; and as these leaflets are always three in number in the Trefoil, its leaves are said to be 3-foliolate or *ternate*. We say "always three in number;" but now and again a sprig with only two leaflets will turn up, and if the happy finder of this *rarum folium* be an East-country maiden, she will probably treasure it as a charm.

A Clover, a Clover of two,
Put it on your right shoe;
The first young man you meet,
In meadow, lane, or street,
You'll have him, or one of his name.

So runs the rhyme; while the finding of a 4-foliolate Clover-leaf is said to be a hardly less auspicious event:

If you find an even Ash-leaf or a four-leaved Clover,
Look to meet your true love ere the day be over.

But two- and four-leaved Clovers must be regarded as abnormal occurrences, the 3-foliolate form being sufficiently common to be characteristic; and hence the Latin name of the genus—*Trifolium*—is quite appropriate. Horse-chestnut-leaves, on the other hand, regularly vary as to the number of their leaflets, and you will often find on the same tree 5-foliolate or *quinate* forms, 7-foliolate or *septenate*, and so on. When a ternate leaf is further subdivided, it becomes either *biterminate* or *triterminate*, as in the Masterwort (*Peucedanum ostruthium*) and Baneberry (*Actæa spicata*) respectively. The Herb-paris (*Paris quadrifolia*), which should be looked for in moist and shady woods, has, as its Latin name implies, 4-foliolate (*quadrate*) leaves.

Let us linger among these meadow Grasses a moment longer while we examine a single blade of one of them, with Ruskin for our guide and teacher. "Nothing there, as it seems, of notable goodness and beauty," he says to us. "A very little strength and a very little tallness, and a few delicate long lines meeting in a point—not a perfect point, either, but blunt and unfinished, by no means a creditable or apparently much-cared-for example of Nature's workmanship, made only to be trodden on to-day, and tomorrow to be cast into the oven—and a little pale and hollow stalk, feeble and flaccid, leading down to the dull



[Photo by]

[E. Step.]

FIG. 318.—RAGWORT (*Senecio jacobæa*).

The leaves are deeply cut into lobes in a pinnatifid manner. The bright yellow flower-heads are grouped in dense corymbs.

brown fibres of roots. And yet, think of it well, and judge whether, of all the gorgeous flowers that beam in summer, and of all strong and goodly trees, pleasant to the eyes, or good for food—stately Palm and Pine, strong Ash and Oak, scented Citron, burdened Vine—there be any by man so deeply loved, by God so highly graced, as that narrow point of feeble green.” The specimen we have gathered is the Sweet-scented

Vernal-grass (*Anthoxanthum odoratum*), a grass to which our summer hayfields owe much of their fragrance. The scent is a volatile oil contained in minute glands in the husk-like valves or glumes of the flowers (fig. 321).

But we are now at the end of the lane, and fields, farm, and stream are all in view. On pushing open the crazy swing-gate, the first weed to greet our gaze is the rare Yellow Star-thistle (*Centaurea solstitialis*), whose flower-head, surrounded by a collar of needle-like spines, is just preparing to open. Mark the absence of petioles on its leaves, which are therefore called *sessile*. In another week the yellow florets will be open, and you will find in their delicate structures much that will repay attention. Yonder, not five paces off, is a cluster of the Common Buttercup (*Ranunculus*), with its golden cup—the “winking Mary-buds” of Shakespeare. Here, instead of the absence of leaf-stalks, you have petioles of an unusual length. Observe how they clasp the stems with their expanded bases.

We name such leaves *amplexicaul*, or stem-clasping. Other familiar plants which may be cited as furnishing examples of amplexicaul leaves are the Groundsel (*Senecio vulgaris*) and the Shepherd's Purse (*Capsella bursa-pastoris*), in each of which the base of the leaf clasps the stem; and almost any species of the great Umbelliferous family, in which the clasping is done by the swollen base of the leaf-stalk.

Now step a little nearer to the stream that skirts the meadow, and regard carefully the tall plant which lifts its purple crest by the water's



FIG. 319.—MONKSHOOD AND TREFOIL.

The Monkshood (upper) is a good example of the palmatifid leaf. Below it is the Subterranean Clover with ternate leaves or trefoils.



Photo by]

[W. Rossiter.

FIG. 320.—COTTON THISTLE (*Onopordon bracteatum*).

The spiral arrangement of the spiny leaves on the stem is very clearly marked in the illustration.

edge. It is a Marsh Plume-thistle (*Cnicus palustris*). Its brown-tinged thorny leaves recall old Chaucer's lines :

For thistles sharp of many maners,
Netlis, thornes, and crooked briers;
For moche they distroubled me,
For sore I dredid to harmèd be.

Notice that the lower part of the leaf is united for a certain length with the stem, which is on that account called *winged*. The leaf is *decurent* (fig. 322).

As we are now so close to the hedge, peep through the gap into the cornfield beyond, and observe that singular plant with small greenish yellow flowers, whose stem, branched at the top, passes almost through the centre of the oval leaves (fig. 323). It is the Common Hare's-ear (*Bupleurum rotundifolium*). Our Saxon forefathers called it Thorow-wax, from the circumstance of the stalk going through (A.S. *thorow*) the leaf; *wax* being the old word for "grow." Our Latin-loving botanists of to-day call such leaves *perfoliate*. Ah! you have smelt the Honeysuckle. Had you waited another week you would have been too late, for this is the rare Perfoliate Honeysuckle (*Lonicera caprifolium*), which seldom flowers after June, and which is almost confined to Oxfordshire and Cambridgeshire. There it is, twining in and out among the Privet bushes. Observe its sessile upper leaves (fig. 323), which look as if they have grown together at their bases. Leaves which offer this singular appearance are described as *connate*. More familiar examples may be found in the Yellow Wort (*Chlora perfoliata*) and the Teasel (*Dipsacus sylvestris*, fig. 324).

Before moving away you should notice the lance-shaped (*lanceolate*) leaves of the bush which supports the Honeysuckle—viz. the Privet (*Ligustrum*, fig. 328)—and also the egg-shaped (*ovate*) leaves of the Crab-tree (*Pyrus malus*) which over-shadows them. With these last may be contrasted the smooth pale green leaves of the Water-pimpernel (*Samolus valerandi*), growing on the margins of the stream below. They are broadest and roundest at the apex, and taper towards the base—in other words, are inversely egg-shaped or *obovate*.

How various is Nature! The lane, the meadow, the cornfield, the hedgerow, the brookside, even the tiny stream itself, have something fresh to show at every step. Here are Violets (*Viola*) with their pretty heart-shaped (*cordate*)



FIG. 321.—
VERNAL-GRASS.

leaves, though it is vain to seek for flowers on them now. The capricious days of April are the days when the nodding Violet blows. And here is Wood-sorrel (*Oxalis*), which children delight in, though for esculent rather than æsthetic reasons. The form of the bright green leaflets which compose its ternate leaves is just the reverse of the leaf-form of the Violet; for the rounded lobes are at the apex of each. Here the shape is called *obcordate*. You will notice also that there is a notch at the blunt apex of each leaflet, as though a piece had been cut out. All apices which have this peculiarity are *emarginate*.

Do not mistake that pretty yellow-flowered creeper, with quinate leaves and inversely egg-shaped leaflets, for a species of Buttercup. It is the Creeping Cinquefoil (*Potentilla reptans*, fig. 326). You will meet with it on almost every wayside bank, and often, as here, winding its devious way among the linear leaves of the meadow Grasses. That other creeper, with fragrant kidney-shaped (*reniform*) leaves, is a frequent companion of the Cinquefoil, delighting, like its quinate friend, in sunny banks and meadows. Its stalked and downy leaves, whose *crenate* margins should be noted well (figs. 327, 331), were in great request for tea in olden times, when the plant was sold by the "herbe-women of Chepeside" under the names of Gill-by-the-ground, Hay-maid, Cat's-foot, etc. It is the familiar Ground Ivy (*Nepeta*



Photo by]

[E. Step.

FIG. 322.—MARSH-PLUME-THISTLE (*Cnicus palustris*).

The leaves are decurrent, that is, continued as wings far down the stem.

glechoma). The small yellow flowers which peep through the tall grass in the corner of the meadow belong to a species of *Medicago*—the Spotted Clover of Cornish nomenclature, the *Medicago maculata* or Spotted Medick of botanists. The little purple spot in the centre of each of its *cuneate* or wedge-shaped leaflets explains the origin of its specific name. Keep a sharp eye on the hedges for a taller, purple-flowered species of this genus, the Lucerne (*M. sativa*), whose serrated leaflets offer good examples of the

oblong form. The flattened apices of the leaflets sometimes have a sharp point about the middle, and then they are called *mucronate*.

Daisies (*Bellis perennis*) are everywhere—the commonest of all flowers, yet the flower that is never common! Who of us that loves Nature has not felt something of Chaucer's delight in what a later poet has called the "wee, modest, crimson-tippet flower"—"the little dazy that at evening closes"? gladly confessing with him that this

is of all floures the floure,
Fulfilled of all vertue and hon-
oure;
And evir like faire and fresh of
hewe,
As well in winter as in summer
newe.

But it is the broad round leaves, whose margins taper down to the base, rather than the pretty pink-tipped florets, that we have to notice (fig. 332). They are called *spatulate*; though you would probably find on examining other specimens that the leaves more generally incline to the inversely ovate form, like those of the Water-pimpernel. The London Pride (*Saxifraga umbrosa*) offers a more fixed type of spatulate leaf; but there is small chance of finding it growing wild in these parts (fig. 330).
Before we cross the narrow footbridge and leave the stream at our back,



FIG. 323.—PERFOLIATE HONEYSUCKLE (*Lonicera caprifolium*), WITH CONNATE LEAVES; AND PERFOLIATE LEAVES OF HARE'S-EAR (*Bupleurum rotundifolium*).



Photo by]

[E. Step.

FIG. 324.—TEASEL (*Dipsacus sylvestris*).

The leaves are united round the stem, and the lower pairs form capacious basins in which dew and rain collect, imposing an impassable barrier to the ascent of creeping insects.



FIG. 325.—RENIFORM LEAF OF A SPECIES OF ARISTOLOCHIA.

lobes at the base of the leaf turn outwards, whence they are classed with halb-ert-shaped or *hastate* leaves. Those aquatic plants with white flowers and three-lobed floating leaves, growing beyond the long *sword-shaped* leaves of the Yellow Flag (*Iris pseudacorus*), are Water-crowfoots (*Ranunculus aquatilis*). On pulling one of them up, it will be found that its submerged leaves are quite different from the floating leaves, being divided into hair-like segments. Such leaves are called *filiform*; while plants which

pluck a leaf of that handsome water-plant with the white three-petalled flowers. It is the Common Arrowhead (*Sagittaria sagittifolia*). *Sagitta* is the Latin word for "arrow," and you have only to glance at the leaf in order to appreciate the fitness of its name (fig. 329). All arrow-shaped leaves are termed *sagittate*; and those who have been much in the country parts of Norfolk and Suffolk will have noticed this attractive form in the leaves of the Tower Mustard (*Turritis glabra*), which grows rather plentifully on the drier banks. The pink-flowered Sheep's-sorrel (*Rumex acetosa*), which may be met with on dry heaths and downs, has somewhat similar leaves, though the two



FIG. 326.—CINQUEFOIL (*Potentilla reptans*). With quinate or five-parted leaves, and an epicalyx to the flowers.

produce

two or more different kinds of leaf on the same stem are said to be *heterophyllous*. We shall have more to say about submerged and floating leaves on a future occasion.

Beauty is everywhere. Nature's brightest colours meet the eye at every step, for June is emphatically the month of flowers. How they glint and glow among the Barley!—though the farmer who owns the field has little praise to bestow upon them—be sure of that!



FIG. 327.—GROUND IVY (*Nepeta glechoma*), Showing reniform leaves in pairs.

There are velvet Campions, white and red,
And Poppies, like morning glories spread,
That flash and glance with their scarlet sheen
The stalks of the bearded grain between

—not to mention the numerous representatives of the White Mustard (*Sinapis alba*), Corn-spurrey (*Spergula arvensis*), Hare's-ear (*Bupleurum*), Corn-cockle (*Agrostemma githago*), Succory (*Cichorium intybus*), etc. But the Poppies (*Papaver rhæas*) are pre-eminent. They "fill every interstice between the Barley-stalks, their scarlet petals turned back in very languor of exuberant colour, as the awns, drooping over, caress them" (Jefferies). Observe the irregular leaves of these frail beauties, with their divisions extending very nearly to the midrib. We call a leaf of this kind *pinnatisect*. If you

compare with these a leaf of the White Mustard (*Sinapis alba*), that tallish plant with yellow four-petalled flowers, you will find that it is not so deeply divided, though the divisions, as in the Poppy, follow the direction of the principal veins. It is *pinnatifid*. Leaves of this plant may also be described as *lyrate*, from their general resemblance to a lyre, their terminal lobes being much the largest, and the other lobes decreasing gradually towards the base.

Ere quitting the field, secure a specimen of the Corn-spurrey (*Spergula arvensis*). This plant is a friend of farmers when found on meadow-land,

but a troublesome obnoxious weed here among the corn. Its small white flowers are very sensitive to atmospheric changes. One writer affirms that he has seen a whole field, which was whitened with its blossoms, entirely changed in appearance by the petals closing when a black cloud passed over and discharged a few drops of rain. The plant may always be recognized by its slender *cylindrical* leaves, arranged in *whorls* round the stem. Leaves which thus grow in whorls are said to be *verticillate*.



Photo by

[E. Step.]

FIG. 328.—PRIVET (*Ligustrum vulgare*).

Showing the lance-shaped, opposite leaves and black berries.

Yonder dainty little plant, with bright scarlet flowers, is the Scarlet Pimpernel or Poor Man's Weather-glass (*Anagallis arvensis*), which is no less sensitive to the weather than the Corn-spurrey. Gerarde tells us that the closing of the flowers "betokeneth rain and foul weather; contrarywise, if they be spread abroad, fair weather." But as they have definite hours for opening and closing despite the weather, absolute confidence must not be placed in them as weather prophets. You will notice that the sea-green sessile leaves are placed in pairs on opposite sides of the stem; hence they are described as *opposite*, to distinguish them from *alternate* leaves, which issue singly from their nodes, and which, as they succeed each

other, are placed alternately on different sides of the stem. Notice further in the Pimpernel that each pair of leaves crosses the pair immediately below it at right angles, for which reason they are said to be *decussate*. The Lilac (*Syringa vulgaris*), Privet (*Ligustrum vulgare*), and Sycamore (*Acer pseudo-platanus*) are other familiar examples of decussate leaves.

Here is the stile, and we may as well step over it, and cross the dusty road to the schoolmaster's cottage. Observe as you do so the plant with prostrate stem and pale greyish lilac flowers. It is the Dwarf Mallow (*Malva rotundifolia*), a lover of farmyards, field borders, and dry waysides. The specific name of the plant is derived from its sub-rotund or *orbicular* leaves—a form which we have not hitherto met with (fig. 333). Among Orientals these leaves have long been in use for culinary purposes; indeed, it has been supposed that this is the plant referred



FIG. 329.—LEAF OF ARROW-HEAD.

A typical example of the aerial leaves of this aquatic plant. For other forms see fig. 335.

to by Job, when he bitterly complains of the derision of men younger than himself, "whose fathers he would have disdained to have set with the dogs of his flock," and whose employment was once no better than to "cut up mallows by the bushes."

At last we are at the cottage. The little Pearlworts (*Sagina procumbens*), straggling over the garden path, show that the neatly fenced garden has been allowed to run somewhat wild of late. They are among the smallest of our wild-flowers, and their awl-shaped (*subulate*) leaves are scarcely thicker than a pack-thread. The Dandelions (*Taraxacum officinale*) witness of the same neglect, and are disputing every inch of space with their tinier neighbours. Observe the *runcinate* leaves of this weed, the pointed



Photo by]

FIG. 330.—LONDON PRIDE (*Saxifraga umbrosa*).

[E. Step.

The foliage offers a good type of the spatulate leaf, and the edges are crenately toothed. The plant is wild in the West and South-west of Ireland: also in Spain, Portugal, and Corsica.

lobes of which turn downwards, whence their name, from *runcina*, a saw. They are also called *radical* leaves, but the term is founded on error, for though they appear to spring from the root, they really arise from the much-shortened stem, and this is the case with most—if not all—so-called radical leaves. Where, as in the Pearlwort, it is evident on a superficial examination that the leaves proceed from the stem, they are termed *cauline*.

How gay the Tropæolums look, with their bright orange and yellow flowers, and handsome *peltate* leaves! Peltate (Lat. *pelta*, a shield) is a good name, for the leaves are held aloft by the plant like true shields, the peculiar insertion of the stalk or petiole on the under side of the blade giving them that appearance. The peltate leaves of the Sacred Lotus (*Nelumbium speciosum*), one of the beautiful aquatic plants to be seen in the Victoria Regia House at Kew, sometimes measure as much as two feet in diameter (fig. 337). Those hardy Begonias in the centre bed rival the Tropæolums in brilliancy of colour. Notice well their unequal-sided or *oblique* leaves (fig. 336), which are characteristic of the large family of succulent herbs to which these plants belong.

Ah, you have pricked your hand against the hedge! There was need to warn you of the Holly's *spiny* leaves; but doubtless the offender will be forgiven on account of its associations, and the pleasure which its green



Photo by]

FIG. 331.—GROUND IVY (*Nepeta glechoma*).

[E. Step.

A familiar heldegrow plant, with opposite, kidney-shaped leaves and blue-purple labiate flowers.



Photo by]

FIG. 332.—DAISY (*Bellis perennis*).

[E. Step.

The leaves are of the spatulate shape, and form a rosette from which arise the composite flowers on scapes.

and glossy leaves afford when other trees are stripped and brown. Southey says :

When all the summer trees are seen
 So bright and green,
 The Holly-leaves their fadeless hues display
 Less bright than they ;

But when the bare and wintry woods
 we see,
 What then so cheerful as the Holly-
 tree ?

The Holly (*Ilex*) is, in short, an *evergreen*, the leaves of one year remaining on the plant through the winter, until those of the next spring have formed; in which respect it resembles the Ivy and Laurel. Many of the Conifers (Pines, Yews, Junipers, etc.) have needle-shaped (*acicular*) leaves, which persist for many years (fig. 339). The great majority of plants, however, shed their leaves in the autumn—they are *deciduous*.

A far more dangerous fellow than our red-berried Christmas friend is the plant whose straggling woody stem finds support against the Holly's tougher boughs. Its drooping clusters of lurid purple flowers, with yellow anthers united into a cone, at once proclaim it to be the Woody Nightshade, or Bittersweet (*Solanum dulcamara*). Notice its upper leaves, the small basal lobes of which form two little wings, or ears. Such leaves



FIG. 333.—DWARF MALLOW.
Orbicular or sub-rotund leaf.

perceive that the teeth point outwards, and not, like the teeth in a serrated margin, towards the apex of the leaf.

It is fortunate that the garden contains a specimen of the Tulip-tree (*Liriodendron tulipifera*). Notice the curiously abrupt or truncated termination of the leaves, which gives them the appearance of having their upper extremities cut off. No plant furnishes better examples of a *truncate* leaf than this. We would press the importance of always noting the forms of leaf apices when preparing schedules of plants. Trivial points of this kind are often of assistance in determining species and varieties.



FIG. 334.—PIMPERNEL.

With opposite and decussate leaves, each pair crossing those above and below it.

are called *auriculate*. This plant is not the Deadly Nightshade, but persons are said to have been poisoned by eating its roots.

There, within a finger's length of the nearer of the *Tropæolums*, is a Saxifrage; but not the one which we were wanting just now. It is the kidney-shaped species (*Saxifraga geum*), and the sharply toothed or *dentate* margins of its leaves should receive attention, as they are the first instances of such a margin that have come before us. You will

In addition to the forms already described—namely, the mucronate, emarginate, and truncate—four others may be briefly alluded to. Two of these—the *acute* and *obtuse* (*i.e.* blunted)—are extremely common, and hardly need to be described; the third is the *retuse*, which differs from the obtuse in having a broad, shallow notch in the middle, as may be seen in the leaves of the Red Whortleberry (*Vaccinium vitis-idaea*); and lastly the *acuminate*, in which the apex narrows suddenly and lengthens into a point or *acumen*. A somewhat extreme example of the latter form is furnished by the Mexican shrub *Phyllonoma ruscifolium*, which, however (as we saw earlier), is chiefly interesting because of the peculiar growth of its flowers, which are produced in little bunches on the upper surface of the midrib, just below the base of the acumen. If, as some have suggested, the lower part of the leaf is really a cladode, then the acumen alone is the true leaf, and should be described as lance-shaped rather than acuminate. However, it is quite unnecessary to go so far afield

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FIG. 335.—ARROW-HEAD (*Sagittaria sagittifolia*).

In this photograph of the growing plant may be seen the gradual transition from the almost oval floating leaves with rounded lobes and a shallow sinus, to the very long and slender aerial leaves of true arrow-shape, with long, full-like lobes and a deep sinus. The few three-petaled flowers are shown also. KUROKI, ASIA.

[E. Stp.



FIG. 336.—BEGONIA.
An example of an oblique leaf.

a sound knowledge of plants presupposes a thorough acquaintance with the forms of leaves, we would recommend the practice of keeping a scrap-book, in which the leaves



FIG. 338.—DANDELION.
A runcinate leaf.

for specimens of leaves with acuminate apices. Two of our British Willows—the Osier and White Willow (*Salix viminalis* and *S. alba*)—offer excellent examples, particularly the former; and although we have passed neither of these on the way, the White Willow is so common throughout the country that there need be no difficulty in obtaining specimens.

So ends our excursion. All the principal leaf-forms have now been touched upon, and we have really travelled over most of the ground covered by the text-books. We trust that what the present plan has lost in method it has gained in interest. To those who would pursue the subject further (and let it not be forgotten that

be mounted and arranged. Let one page be devoted to net-veined leaves; another to parallel-

veined; a third and a fourth to compound and single leaves respectively; a fifth to the different kinds of apex; and so on, till every variety of shape is represented and classified. In this way one is brought face to face with many curious and instructive facts, of which even the fullest treatises say nothing, and the foundation of a trustworthy knowledge of botany is laid that will be found increasingly valuable the further such investigations are pushed. Thus, too, will one's acquaintance with Nature herself become more and more extended, and the facts which we have been accumulating by steady patience and reverent study will yield in the near future an abundant harvest of joy.



FIG. 337.—LEAF OF SACRED LOTUS.
The leaf-stalk being attached to the centre of the underside, the leaf is said to be petiolate.



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[E. Step.

FIG. 333.—JUNIPER (*Juniperus communis*).

This evergreen shrub has spine-tipped, needle-shaped leaves. The berry-like cones are coated with a waxy "bloom," and are known as baccate cones. It is native in Europe, N. Africa, Asia, and N. America.

CHAPTER IX

THE LEAF IN RELATION TO ITS ENVIRONMENT

A change in the surroundings of any plant can so react upon it as to cause it to change. By the attempt, conscious or unconscious, to adjust itself to the new conditions, a true physiological change is gradually wrought within the organism.—PROFESSOR DRUMMOND.

ALTHOUGH the previous chapter was devoted chiefly to the consideration of the forms of leaves, we must now briefly resume the subject in order to refer to a few forms not hitherto noticed—curious and exceptional forms, of which, in most cases, our British plants afford no examples. This will pave the way to the subject more especially before us—namely, the adaptation of foliage leaves to their environment.

The subject of environment, in so far as the *sustaining* of vegetable life and vigour is concerned, has been already dealt with in preceding chapters, where we have seen that, while in the plant itself resides the principle of Life, in the environment are found the *conditions* of Life; and that without the fulfilment of those conditions—in other words, without the regular supply of heat, air, water, inorganic substances,

and so forth, to the living tissues—the plant would languish and die. This part of the ground—the most important part without doubt—we do not propose to retrace. What will be before us in the pages immediately succeeding is the effect of environment in *modifying the structure* rather than in sustaining the life of the plant—the effect, indeed, which is evident in what is called Variation. This may appear to be anticipating, but many of the morphological facts



FIG. 340.—LEAF OF A *Laportea*.

With a cup-like enlargement of the extremity of the mid-rib.

which have been grouped together for preliminary mention are intimately connected with the phenomena of Variation.

Of the multifarious leaf forms which the Vegetable World presents, few, perhaps, are so singular as those of the *Sarracenia* and *Nepenthes*. These have already been treated at considerable length in Chapter IV., when the insectivorous habits of plants were before us; and we may therefore dismiss them here in few words. In both genera the insect-catching pitchers are themselves the leaves, but they have this difference: in *Sarracenia* the tall trumpet-shaped portion of the leaf is looked upon as an expansion of the petiole or leaf-

stalk, and the lid as the lamina or blade; while in *Nepenthes* the pitcher is regarded as a modification of the lamina, the lid being a special prolongation of the apex. In the Australian Pitcher-plant (*Cephalotus follicularis*) the parts of the singular tankard-shaped leaves correspond rather with those of *Sarracenia* than of *Nepenthes*. Leaves of the pitcher class are called *ascidiform*, from the Greek *askidion*, a little bottle.

Recently, at Kew, one of the attendants pointed out to us a species of *Laportea*, lately arrived from New Guinea, each of the leaves of which was finished off at the apex as a little cup (fig. 340); but we were unable to ascertain what purpose these ascidiform appendages fulfill in the economy of the plant. They can hardly be insect-traps like the pitchers of *Nepenthes*, as the downward curve of the leaf gives the cups an inverted position. One would like to know whether, in their natural habitat, a vertical position is ever assumed by the leaf.



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[E. Step.

FIG. 341.—LIME (*Tilia platyphyllos*),
Showing the heart-shaped leaves and globose fruits with the long bracts attached.

If, as is generally agreed, the trumpet-shaped portion of the leaves of *Sarracenia* is really an expansion of the petiole, it would be botanically described as a *phyllode*, and thus would answer to the leafy expansion of the petiole of certain Australian species of *Acacia*—as, for instance, *Acacia melanoxylon*, which, when young, possesses bipinnate leaves with flattened petioles, but which are succeeded by others more phyllode-like as the plant grows older, until at last the leaflets (*pinnae*) entirely disappear, and phyllodes only are produced. The phyllodes have the appearance, and perform all the functions, of normally developed foliage-leaves.

There is a tendency among the *Acacias*, as well as some closely allied



FIG. 342.—HETEROPHYLOUS LEAF OF HONEY-LOCUST-TREE.

Some of the leaflets are entire, others broken up in various degrees into smaller leaflets.

plants, to develop different forms of leaf on *the same individual* with a capriciousness that is extraordinary. Not only will you find pinnate, bipinnate, and tripinnate leaves on the one plant, but instances are not uncommon in which a single leaf inclines to all these forms at once. The leaf of the Honey-locust-tree (*Gleditsia triacanthos*) is a case in point (fig. 342). The tree is a native of North America, where its long thorny branches wage incessant war with the unarmed Maple-trees, in close proximity to which it is usually found growing. Surely if plants, like animals, are liable to be affected by changes of the moon, the Honey-locust-tree has fallen under the baneful influence! It reminds one of those old Lime-trees (*Tilia platyphyllos*)

mentioned by Dr. Burnett, which, instead of developing the cordate or obliquely cordate leaves of this species, regularly put forth leaves of a hooded (*cucullate*) form. These trees were growing in the churchyard of Scidlitz, in Bohemia, seventy years ago—possibly they are still growing there. In Burnett's time the peasants affirmed that the production of the hooded leaves was due to the fact that some monks from a neighbouring convent had been hanged on the trees!

Those who have what Americans would call "a big swallow" may be satisfied with this explanation, but the diversity of form in the normally heterophyllous leaves of *Gleditsia triacanthos*, *Acacia heterophylla*, etc., has no such convenient story to account for it, nor are we in a position to suggest

a probable explanation—indeed, it is only when we turn to aquatic plants that the special usefulness of heterophyllous leaves becomes apparent. Mention has been made of the Water-crowfoot (*Ranunculus aquatilis*), whose submerged leaves are so different from the floating ones, the former consisting merely of narrow thread-like segments, while the latter are three-lobed with dentate margins. This difference may be partly accounted for by the fact that the submerged leaves, being less favourably situated for light than the others, make the most of the rays that visit them by assuming the shredded form. It has been further remarked that aquatic plants which develop filiform leaves are usually, if not always, found in *running* water; and how well are they adapted for such environment!—yielding readily to the current, and participating in its movements without injury. These observations apply equally to the Potamogetons (*P. heterophyllus*, *rufescens*, and *spathulatus*), to the Water-caltrops (*Trapa natans*), and to the Cabomba (*Cabomba aquatica*, figs. 343, 344). The latter may be studied to advantage in the Victoria Regia House at Kew.

The buoyancy of floating leaves is, in not a few cases, secured by special air-channels, which may be situated either in the blade or the leaf-stalk—more frequently the latter. In the Brazilian Pickerel-weed (*Pontederia crassipes*), the swollen and hollow leaf-stalks act as floats to the whole plant, which, as it does not root itself to the mud, is carried hither and thither by wind and current like a rudderless ship. In *Desmanthus natans*, an aquatic plant of the Leguminous order, the stem takes the form of “a large-celled, spongy, air-containing mantle,” which subserves the same purpose as the leaf-stalks of the Pickerel-weed, and is, in fact, a veritable swimming apparatus.

As a consequence of their situation, aquatic plants imbibe much more water than land plants, and the transpiration is proportionately greater. One sees in this fact the advantage of their broad, flat, floating leaves, which, lying side by side on the surface of the water, present so large a field for the sun's operations; for it will be remembered that transpiration takes place through the stomata, and that these organs, in aquatic plants, are placed on the upper surface of the leaves. When it is stated that a single Water-lily-leaf of very ordinary size may contain as many as eleven



FIG. 343.—CABOMBA.
A submerged leaf.



FIG. 344.—CABOMBA.
An aerial leaf and flower.

and a half million stomata, one may realise what liberal provision is made for the removal of superfluous moisture.

Still further to assist this end, the under sides of many floating leaves are coloured violet or crimson by a pigment known as *anthocyanin* (sometimes called *cyanophyll*), which has the remarkable property of changing light into heat, and thus of giving increased warmth to the parts where



FIG. 345.—*Godwinia gigas*.

A Central American Arum, whose leaves are fourteen feet in length.

transpiration is going on. This foliage painting is seen to perfection in the magnificent leaves of the *Victoria regia*. Our drawing (see fig. 346), which was made from one of the specimens at Kew, fails to do justice to the tropical queen, which, indeed, must be seen in its native habitat to be properly appreciated. The plant was first discovered by Sir Robert Schomburgk during his explorations in South America on behalf of the Royal Geographical Society; and the distinguished traveller thus records the event: "It was on January 1st, 1837, while contending with the difficulties which Nature interposed in different forms to stem our progress up the River Berbice (lat. 4° 30' N., long. 52° W.),

that we arrived at a part where the river expanded and formed a currentless basin. Some object on the southern extremity of this basin attracted my attention, and I was unable to form an idea what it could be; but animating the crew to increase the rate of their paddling, we soon came opposite the object which had raised my curiosity, and behold, a vegetable wonder! All calamities were forgotten; I was a botanist, and felt myself rewarded! There were gigantic leaves, five to six feet across, flat, with a



FIG. 346.—THE GIANT WATER-LILY (*Victoria regia*).

At the base of the picture, left-hand corner, is shown a Brazilian aquatic plant (*Pontederia crassipes*). The palm on the right is *Trachycarpus excelsa*.

[By A. E. Knight.]

broad rim, light green above and vivid crimson below, floating upon the water; while in character with the wonderful foliage I saw luxuriant flowers, each consisting of numerous petals, passing in alternate tints from pure white to rose and pink. The smooth water was covered with the blossoms, and as I rowed from one to the other I always found something new to admire. . . .

Ascending the river, we found this plant frequently, and the higher we advanced the more gigantic did the specimen become: one leaf we measured was 6 ft. 5 in. in diameter, the rim five and a half inches high, and the flowers a foot and a quarter across."

The under surfaces of these leaves—as, indeed, of nearly all floating leaves—afford resting-places for numberless aquatic insects and snails; while certain birds which prey on fish use the leaves as rafts. The French traveller Marcoy, who saw large numbers of the Victoria Lilies on the Nuña Lake, Peru, likens the collective effect of the leaves to a splendid carpet, on which, to quote his own expression, "quite a multitude of stilt-plovers, ibises, jacanas, anhunas, savacas, Brazilian ostriches, and spoonbills disported themselves." The jacanas mentioned by Marcoy are the *Parva* of naturalists—wading birds, somewhat analogous both in structure and habits to the European water-hen, and their light bodies and long toes enable them to walk on the floating leaves with as much facility as if they were on land.

Large as are the leaves of the Victoria Lily, they are by no means the largest known. The *Godwinia* (or *Dracontium*) *gigas* (fig. 345), a species of Arum discovered in Central America by Dr. Seeman so recently as 1869, produces a leaf no less than fourteen feet long. Its stalk, which is beautifully mottled with purple and yellow, has been compared to a huge snake

standing erect at the bidding of an Eastern charmer. But there are greater leaves even than this. At Kew, not long since, one of the Sago Palms bore fronds* which were upwards of forty feet in length; and we believe that

* In speaking of Palm-leaves as "fronds," we use popular language. In botanical terminology a frond is the leaf of a Fern or other Cryptogam, though in recent years the tendency has been to speak of fern-leaves, not fronds.



FIG. 347.—LATTICE-LEAF.

In this Madagascar plant the perforations of the leaf are so numerous that it resembles a skeleton leaf.

even larger ones have been met with. Nevertheless, the Victoria Lily is the largest of floating leaves, and well deserves all the praise that has been lavished upon it.

Forty years ago the eminent German botanist Hildebrand gave an account of some interesting observations on the physiology of the floating leaves of *Marsilea quadrifolia*, in the *Botanische Zeitung*. He found that when a plant of this species is sunk beneath the surface of the water, so

that all the leaves are more or less deeply covered, those leaves which are fully developed at the time of immersion remain unchanged, while those which are not so far advanced undergo a remarkable change, the petioles gradually lengthening in succession according to their position on the stem, and soon over-topping those which were already formed. At first the four leaflets do not increase, but presently they begin to enlarge, and by the time the surface of the water is reached they exceed in size the ordinary leaves, forming a four-rayed star on the surface. While the petioles of the ordinary leaves are stiff, so that they stand erect out of the water, these floating leaves are weak and flexible, like those of water-lilies, allowing the leaf to maintain its position on the surface with the rise and fall of the water. Their upper surface is shining and coated with wax, so that the water flows off them. If immersed in deeper water, the petioles will lengthen still further even to the extent of three feet.

Before passing from water-plants, we must call attention to that delicate Madagascar aquatic, the Lattice-leaf-plant (*Ouvirandra fenestralis*), which is remarkable from the fact that the network of its leaves, instead of being filled up with tissue (parenchyma) in the ordinary way, is left open, the chlorophyll in each leaf being contained in a thin layer of cells which covers the strands (fig. 347). The plant is entirely submerged, and when viewed from above has the appearance of a large oval piece of green net spread out upon the mud in which its roots are fixed. This appearance is due to



FIG. 348.—*Monstera deliciosa*.
The remarkable perforated leaf of this tropical Aroid.

the procumbent position of the lace-like leaves, which form a rosette round the short mud-embedded stem. They remind one, as Kerner aptly says, of autumn leaves which have fallen into water and lost all their parenchyma through maceration, the skeletons alone remaining. It may be added that a few of the Seaweeds (e.g. *Agarum gmelini* and *Thalassiophyllum clathrus*)

offer the same peculiarity as *Ouvirandra*, their fronds being perforated in a very beautiful manner.

The existence of leaf-holes in certain land-plants is also to be noted. Such perforations are confined to the large upper leaves of tropical plants like the Aroids (*Monstera deliciosa*, etc., fig. 348), which, but for this provision, would entirely exclude the sun from the lower leaves, and thus impair the activity of the green tissues. The deep incisions and clefts which give such beauty of outline to palmatisect and pinnatisect leaves evidently subserve a similar purpose; while the disposition of the leaves on the stem, and of the leaflets on the petiole, has definite relation to the same important end.

It is highly probable, also, that the *lacinated* (fringed) forms of specially large leaves bear the same relation to the wind that the thread-like forms of submerged leaves do to water—that is, they present no large unbroken surfaces to the varying currents of air, and thus escape rupture during heavy storms. In many cases tearing is prevented by a strengthening of the epidermal cells, particularly at the edges of the leaves, where of course the strain is



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[E. Step.

FIG. 349.—REEDMACE (*Typha latifolia*).

Commonly confused with the Bulrush (*Scirpus lacustris*). Note the spiral twist of all the long strap-shaped leaves, so that the whole surface is never presented to the wind.



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[E. Step.

FIG. 350.—PURPLE CROCUS (*Crocus officinalis*).

The narrow linear leaves have a white channel down the centre, and the underside is white. The margins are rolled back towards the midrib. The beautiful purple flowers with their darker streaks are spring favourites in every garden. It is a native of Middle and Southern Europe.

greatest. This is well illustrated in the leathery leaves of the Holly (*Ilex*) and the Indiarubber-plant (*Ficus elastica*).

Leaves which assume a vertical position are specially exposed to the violence of the wind. The currents of air usually take a course which is parallel to the earth and therefore strike against such leaves at right angles, so that special adaptations are needed to enable the latter to retain their upright position. In many of the Grasses—the Common Reed (*Phragmites communis*) may serve as an example—the leaf-blades turn on the haulms (which is the stalk of a grass of any kind) like weathercocks. In the Reedmace (*Typha latifolia*, fig. 349) the leaf is spirally twisted, so that a whole surface is never presented to the wind—an arrangement the advantage of which is sufficiently obvious. In other plants, protection from the wind is secured by the leaf being hollow. It is well known that a tube resists flexion more effectually than a solid body; and tubular or *fistular* leaves will maintain their erect position even in the roughest weather. Examples of the fistular leaf are presented by the Common Onion (*Allium cepa*) and other bulbous plants. In the Purple Crocus (*C. officinalis*) the edges of the leaf roll over towards the white central stripe so as to form a sort of double tube; and thus this little harbinger of spring is able “to take the winds of March with beauty” (fig. 351).



FIG. 351.—CROCUS.
A two-barrelled fistular leaf.

When speaking of buds, we showed that the chief purpose of the woolly growth which often covers them is to protect the young leaves from the cold winds and nipping frosts of winter. It must not be imagined, however, that this is also the chief purpose of the wool and hairs which cover more or less thickly the surfaces of many adult leaves. Heat, rather than cold, is the danger to which the mature leaf is exposed, and the purpose of its covering hairs is not so much to promote warmth as to prevent excessive exhalation. Just as the succulent stems of the Cactuses and many tropical Euphorbias are provided with a leathery membrane to retard evaporation, so, and for the same reason, a great number of leaves are provided with hair-like structures, which, by shielding the epidermis from the direct rays of the sun, reduce transpiration and save the leaves from untimely desiccation.

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