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THE
PLANT WORLD

G. MASSEE.

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BOTANY.

THE PLANT WORLD.

ITS PAST, PRESENT, AND FUTURE.

AN INTRODUCTION TO THE STUDY OF BOTANY.

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OF UNIVERSITY TEACHING.

WITH FIFTY-SIX ILLUSTRATIONS.

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PREFACE.

THE idea of this little book is to furnish an introduction to the study of Botany from the standpoint of considering plants as living organisms, subject to all the varied vicissitudes that are more generally recognized as influencing animal life. From this point of view, the changes in structure and function that plants have undergone from time to time become intelligible, a point of primary importance, as a preliminary to a clear comprehension of the meaning of relationship amongst the members constituting the Vegetable Kingdom.

GEORGE MASSEE.

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BOTANY.

CHAPTER I.

PLANT ARCHITECTURE.

The Vegetable Kingdom.—Leading characters of plants contrasted with those of animals.—Origin of "Division of Labour."—Uses of the various organs of plants.—Modifications of structure caused by external agencies.—Microscopic structures.

TO those whose schooldays terminated a quarter of a century ago, the word Botany, as a rule, recalls to memory long strings of Greek or Latin names, or dry and uninteresting definitions of the various parts of plants; hence it is not difficult to understand the indifference manifested by such victims towards the study of a science which yields to none in the varied beauty of its members, neither in the manifestation of those peculiar features characteristic of life.

The popular conception of life is as a rule associated more intimately with the members of the Animal Kingdom, and more especially with the most highly developed forms with which we are most familiar, where movement and a more or less perfect development of the special senses, as seeing, hearing, etc., are present. As a matter of course, it is generally known that plants are living bodies; but there are not unfrequently indications of an inward feeling that the life of a plant must be of a very different nature to that of an animal, say a human being. Such an idea is, from the present standpoint of knowledge, a mistake; in the broader sense there is but one kind of life, and although a perfect definition of life is at present impossible, yet the important characters which separate it from every other known force are clearly understood and fall under the two headings, *growth* and *reproduction.* Growth means increase in size, along with replacement of worn out substance composing the individual, brought about in a special manner due to a combination of chemical and physical processes as follows. It is well known that both plants and animals, when quite young, are very small in bulk compared to the size assumed when full grown, and it is further generally known that growth or increase in size depends on a regular and continuous supply of food. The peculiarity of all forms of life is that the food when first taken into the body differs in chemical composition from the living body, and the latter possesses the property of chemically breaking up its food, retaining those portions that it requires for the building up of its own body, getting rid of the surplus useless matter. As illustrations of the above, a human being can convert a dinner of bread and beef into human flesh; in the same way a plant that feeds on carbonic dioxide and water containing certain substances in solution can convert these substances into what may be termed plant flesh. The food taken as a matter of course must contain all the chemical elements required for the formation of animal or plant substances respectively, but combined in different proportions and often mixed with other elements not required; and the peculiarity of living bodies, whether plant or animal, is the power of chemically decomposing these food substances, re-arranging the constituents into the required chemical compounds, and rejecting the useless surplus. As already stated, one use of food is to enable the individual to grow or increase in size, a second use is that of replacing worn out portions of the body, the result of work done; and after the full growth has been attained, the latter function of food is the most important one. In addition to the above important uses of food, it is known that during the physical and chemical changes undergone by the food material previous to its assimilation or conversion into the substance of the body, various forces are generated, as heat, electricity, etc., which may be considered as forms of energy that are factors in the complex force called life.

An illustration of change produced chemically on carbonic dioxide (CO_2) and water (H_2O) by plants in the formation of starch ($C_6H_{10}O_5$), will give some idea of the manner in which the raw food material is manipulated and re-arranged, and also how bye-products are formed.

$$\underset{\text{(Carbonic dioxide.)}}{6\,CO_2} \times \underset{\text{(Water.)}}{5\,H_2O} = \underset{\text{(Starch.)}}{C_6H_{10}O_5} + \underset{\text{(Oxygen.)}}{6\,O_2}.$$

The above chemical equation means that the raw food materials, carbonic dioxide and water, are taken into the plant in the proportion of six of the former to five of the latter, and under favourable conditions become chemically re-arranged into one part of starch, the substance required by the plant for its own use in building up its tissues, and there remains as a surplus a certain amount of oxygen which is restored as such to the atmosphere.

It must be clearly understood that the above equation does not profess to show all the various changes undergone by the crude material during its transformation into starch; all that is intended is to show the proportions of the various chemical elements before and after the change.

Carbonic dioxide and water are both *inorganic* substances; that is, their chemical composition is not necessarily the result of life; on the other hand, starch is an *organic* substance, because its chemical constitution is determined by a living body, or by life.

From the above it will be seen that the material composing the bodies of animals and plants is not of a kind peculiar to themselves, but consists of the most abundant of chemical elements forming inorganic matter, so that organic matter only means the re-arrangement of the elements or constituents of inorganic matter in new proportions, and this is true of every organic product, whether animal or vegetable.

It will have been observed that food is indispensable to the well-being of the individual; but in spite of an undiminished food supply, individuals do not continue to live on for ever, but in every form of life there is a limit to the existence of the individual terminating in death, and which is shadowed in under normal conditions by the lessened physical and chemical activity of the entire organism, resulting in the liberation of less energy, which to a great extent constitutes the flow of life manifested during the earlier period of the existence of an individual.

The comparatively short period of time constituting the life of an individual may be divided into distinct phases, the *vegetative*, and the *reproductive*. All the various functions performed for the well-being of the individual, as the assimilation of food, respiration, protection, etc., belong to the vegetative phase, whereas the reproductive phase is concerned with the formation of specialized portions of the individual which, under favourable conditions, possesses the power of growing into an organism resembling the parent. In the plant world several modes of reproduction are known which will be described at a later stage.

Other peculiarities less pronounced might also be given as distinguishing living bodies from all forms of inorganic matter, but growth or increase in size by the method defined above, and reproduction, have no parallel in inorganic nature.

A statement to the effect that plants and animals are so closely related to each other that in numerous instances it is difficult if not impossible to say with certainty to which of the two groups a given organism belongs, would doubtless be considered as a romance of science, and not intended to be literally accepted; nevertheless, such is the actual condition of things. The cause for doubting such a statement depends on the fact that those plants and animals most familiar to the unscientific person represent respectively the most perfectly developed forms belonging to each group, that is, they have the plant or animal peculiarities strongly pronounced, and consequently are in reality very dissimilar both in general structure and appearance, and if such highly developed plants and animals were alone known to us, in all probability no one would ever have suspected the close affinity between the two groups; but if we trace animals and plants backwards from the most highly developed forms of each, we come in the end to a series of living organisms in which those peculiarities that give individuality to plants and animals respectively are absent; such organisms are included in a group known as the *Protozoa,* the simplest representatives of which are amongst the most primitive of living bodies, and at the point where the plant and animal kingdoms appear to converge, consisting of exceedingly minute portions of protoplasm without any external protecting cell-wall, and furnished with one or more exceedingly slender prolongations or cilia for purposes of locomotion; such infinitesimal organisms are spoken of as the *Flagellate Protozoa,* from the presence of the cilia or flagellæ alluded to above.

The Protozoa, in common with all primitive types, are aquatic in habitat, feed on organic food, and are generally considered by zoologists as representing the starting point of the Animal Kingdom, and certainly as one of the radiating branches from this primordial group becomes more and more differentiated, we observe the characteristics that become slowly evolved in each succeeding group to constitute collectively those structures and functions which give individuality to the Animal Kingdom, and may be briefly enumerated as follows.

From a comparatively neutral starting point in the sense of presenting the minimum known amount of differentiation and division of labour, the most important feature evolved by the members of the Animal Kingdom is the specialization of structures that enables them *to feed on organic matter taken into the body in the solid form.* A second feature is *the gradual evolution of the nervous system,* which culminates in the higher groups in the development of the special senses; but it must be remembered that many of the lower groups of organisms universally admitted to belong to the Animal Kingdom are entirely destitute of every structural trace of a nervous system. A third character of a negative nature is the absence of differentiated cell-walls.

The primitive types of the Vegetable Kingdom, if not actually derived by modification from certain members usually included in the Protozoa, are certainly most nearly allied and often almost indistinguishable from the latter, and the first indication of a break away from such primordial types consisted in the development of a green colouring substance called *chlorophyll*, which enabled the organism to feed on inorganic matter; and the power of *feeding on inorganic food taken into the body of the plant in a gaseous form or in solution* is the most important characteristic of plant life, and it will be shown that the adoption of this new method of obtaining food has been the direct or indirect cause of the very great variety of form and structure presented by the vegetative parts of plants. A second important character is *the presence of highly differentiated permanent cell-walls.* No trace of nerve tissue is present in any member of the Vegetable Kingdom, nevertheless it will be shown that certain movements and responsions to external agencies manifested by some plants agree in important points with similar movements manifested by members of the Animal Kingdom, and which in the latter are considered as being the outcome of nervous excitation.

The conception as to the origin of plants and animals entertained at the present day differs from the older idea of so-called "special creation" in the belief, which on broad lines has passed beyond the theory stage and is proved by facts, that from a primordial type of life of an exceedingly low order of development, animals and plants have become gradually evolved, and that the line of departure characterized by the formation of chlorophyll which enabled its respective members to feed on inorganic matter, constitute collectively the Vegetable Kingdom, whereas the branch that varied from the primordial type in developing an internal cavity or stomach for the reception of solid organic food constituted the starting point of departure of the Animal Kingdom.

As would be expected, the earliest groups of plants and animals were but little removed structurally from the parent stock, but as additional new features were evolved, the differences became more marked, while in the highest members the differences are so great that if only the primordial type and the highest members of plants and animals existed, the origin of the latter from the former would probably never have been suspected.

For a similar reason it can be readily understood that the earliest departures from the primitive types possessing respectively plant and animal characteristics would yet possess many points in common, in fact so many that even at the present day the best authorities differ as to the exact plant or animal nature of numerous organisms hovering round the primordial group, and in which more or less visionary characters of plant and animal overlap. As plant and animal characteristics become more sharply pronounced and stereotyped, the two divisions recede from each other to the extent of the differences exhibited between a forest tree on the one hand and a human being on the other.

In addition to the animal and plant lines of departure from the primitive stock, several other types of departure are known to scientists, which for some reason or other never made much progress, that is, did not by constant modifications or emendations of the idea they started out with, keep improving their position in the struggle for life, and never gave origin to higher developments, and consequently either disappeared or still remain as so-called terminal groups. For example, on the plant side we have at least three such departures, one including the minute plants called diatoms, remarkable for having the cell-wall rendered rigid by a deposit of silica or flint, and in having the green chlorophyll—the central idea of plant-life—masked by the presence of a brown colouring matter.

In the simplest known plants belonging to the *Algæ* or Seaweed family, such structures as root, stem, leaf, flower, etc., are entirely absent, the various kinds of work performed in the higher plants by the organs above enumerated, being in the simplest plants frequently performed by a single microscopic cell, which in numerous instances constitutes an individual. Such one-celled plants are generally called in botanical language, *unicellular.* As an illustration of the mode of life of such simple organisms we may select the well-known *Pleurococcus viridis*, a minute plant belonging to the Algæ, that forms green stains on the trunks of trees, old palings, stones, etc., in fact on everything that has been exposed for any length of time to the air. If a very small portion of the green substance is placed in water and examined under the microscope with a sufficiently high magnifying power, numerous minute green balls will be seen of various sizes and presenting different appearances. If we select one of medium size that is perfectly spherical and without any lines on its surface, it will at first resemble a minute green ball, and appear devoid of structure. If a small quantity of hydrate of potash is now mixed with the water, in a very short time a thin colourless ring will appear encircling the green ball; the colourless ring is the cell-wall or protective portion of the plant that has been rendered visible by the hydrate of potash, and forms a continuous outer pellicle or skin inclosing and protecting the living portion of the plant—the protoplasm—along with the green colouring matter or chlorophyll. A plant presenting the appearance described above is in the vegetative condition, that is, simply doing the work requisite for its own individual well-being, taking into its substance carbonic dioxide and water, which its chlorophyll, under the influence of light, converts chemically into its own substance; and at the same time breathing for the same purpose that animals do, the removal of carbon from the body in the form of carbonic dioxide. After passing some time in the vegetative phase, the second or reproductive phase, for the object of continuing the same kind of plant, or *species*, in time is entered upon. Amongst the specimens under the microscope it will not be difficult to select an individual yet perfectly spherical but with a dark line across the surface; such an individual illustrates the first condition of the second or reproductive phase, the dark line corresponds to a thin wall that has grown completely across the protoplasm, thus dividing the cell into two equal parts; after the dividing wall is formed it begins at the circumference to split into two parts which will show under the microscope as a minute notch at each end of the dark line in the circumference of the cell; this splitting becomes deeper and deeper, and finally the two halves completely separate from each other and form two new individuals. Each young Pleurococcus is at first hemispherical, but within a very short time becomes spherical and enters the vegetative phase until it reaches the full size, when it divides in a similar manner to its parent, producing in turn two young plants. Reproduction by the splitting up of an entire individual into two young plants is a purely vegetative method, that is, not the result of fertilization, and is termed, reproduction by *fission* or cell-division, and is the most usual method amongst the lower forms of life, both plant and animal. When the Pleurococcus is placed under favourable circumstances, reproduction often takes place so rapidly that when the plant has formed the first wall for division into two individuals, each half commences to divide again by a wall at right angles to the first; such individuals show two lines crossing each other at right angles, and with constrictions at the margin corresponding to the amount of separation of the four individuals that has taken place. The Pleurococcus can only obtain food and live actively when a certain amount of moisture is present, consequently during very dry weather it becomes dormant and forms a dry, crumbling powder that is blown about as dust. In this dry, powdery condition, the plant possesses the power of retaining life for a long time, even many years, and when placed in a damp situation, at once expands and proceeds with its life work. As a general rule, the simpler the structure of a living organism, the greater its power of remaining alive under extreme conditions, whereas organisms presenting a great complexity of structure are limited to, comparatively speaking, one set of conditions as regards temperature, moisture, etc., and if removed from that sphere usually perish.

Fig. 1. Diagrammatic outline of *Pleurococcus* in various stages of development.—I. Vegetative stage. II. First indication of reproductive stage. III. Same, further advanced. IV. A plant dividing into four individuals. V. The four portions completely separated and rounded off. (Highly magnified.)

There are thousands of minute Algæ that agree with Pleurococcus in being unicellular and showing quite as little division of labour or differentiation of structure, the one cell having in turn to perform both vegetative and reproductive functions.

From this primitive condition of things we pass to slightly higher types of structure where the individual consists of a number of cells joined together, forming either very slender simple or branched threads composed of a single row of cells placed end to end, as in many species of fresh-water Algæ common in our ponds and streams, and forming the bright green floating masses so general during the summer; or the cells are arranged to form a thin continuous sheet often of considerable dimensions, as illustrated by many of the common red and green seaweeds. Plants that consist of more than one cell are called *multicellular*. To the multicellular type belong all flowering plants, ferns, mosses, also many of the funguses and seaweeds. Unicellular plants only occur in the seaweeds (*Algœ*), and the funguses (*Fungi*). The multicellular type of structure is not entirely new and independent of the more primitive unicellular type of plant structure, but is in reality only a modification of the latter type. It will be remembered that in the unicellular organism, the single cell could only be considered as an individual during the vegetative phase, as on entering the second or reproductive condition its own individuality was lost by becoming divided into two parts quite independent of each other and constituting two distinct individuals. This sacrifice of the individual at the termination of the vegetative phase is due to the primitive mode of reproduction by fission.

Every living body, both plant and animal, consists in the earliest condition of a single cell, and further, the single cell constituting the starting point of the multicellular plant divides by fission, forming two cells as in the unicellular type; these two cells do not separate from each other, but remain in organic contact, that is, the separating wall does not split; each cell thus formed again divides, exactly as in Pleurococcus, and thus by the repeated fission of cells that remain in contact, a tissue is formed that takes the form of slender filaments or thin, broadly extending sheets, as already stated in the simpler forms of multicellular plants, and by exactly the same process of cell-division the entire substance of the largest forest tree is built up.

An early indication of division of labour amongst the simplest of multicellular plants belonging to the Algæ is the restriction of the reproductive function to certain cells or portions of the individual, the remaining portion, usually constituting the greater part of the plant, doing vegetative work only, and frequently living for several years, giving origin each season to a number of

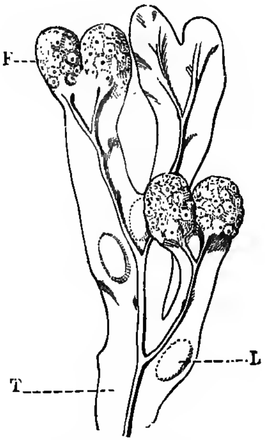

Fig. 2. A portion of one of the olive-brown seaweeds (*Fucus vesiculosus*) showing division of labour or differentiation of the individual.—*F*, thallus or vegetative portion; *T*, fructification, confined to the tips of the thallus ; *L*, air-bladders formed on the thallus for the purpose of buoying up the plant on or near the surface of the water. (Natural size.)

reproductive bodies capable of developing into new individuals. It will be noticed that the above indicated division of labour into localized vegetative and reproductive portions is contemporaneous with the formation of all the larger perennial forms of plant life, which in many instances require half a century or even more to attain their full development, a condition of things impossible so long as the act of reproduction necessitated the loss of the parent form as in the Pleurococcus type.

Closely following the division of multicellular plants into vegetative and reproductive portions, we meet with a corresponding differentiation in each part; for example, the vegetative portion of many seaweeds consists of parts resembling in appearance the root, stem, and leaves of the higher flowering plants, and although the specialization of these parts is not so complete in the seaweed as in the flowering plant, yet we have indicated in the lower forms those types of structure that by degrees become the most prominent characteristics of plant life.

In seaweeds the root-like portion, which is frequently a discoid body, only performs the mechanical function of fixing the plant to one particular spot, and is in no way concerned with the absorption of food as in the higher plants; the flattened out portion of the seaweed again, although not the exact equivalent of the leaf of a flowering plant, is nevertheless expanded into a thin sheet for the same purpose, that of exposing a large area in connection with the assimilation of food; thus we have shadowed in amongst the simplest of plants all the most important structural features of the Vegetable Kingdom.

There is no evidence of any preconceived scheme in connection with the gradual extension or evolution of the plant world from primitive types. Keeping in view the fact that protoplasm is the only vital portion of a plant, it follows that the possibility of a given plant to live under varying conditions of environment depends on the limits under which its protoplasm can perform the various functions collectively constituting life. As illustrating the wide range under which protoplasm retains its individuality and performs its functions with regard to temperature, certain minute Algæ flourish in hot springs, whereas other species find their home replete with every comfort on the surface of snow or ice in high latitudes or elevated regions, thus existing under a range of temperature varying from freezing-point to within a few degrees of the boiling-point of water. The above illustration shows the possible range of protoplasm under certain conditions, but the protoplasm of any given species that has become differentiated and stereotyped in one groove is always confined within much narrower limits with regard to all surrounding forces, as temperature, pressure, amount of moisture, etc., and, as already stated, the range becomes more restricted in proportion to the amount of differentiation and division of labour presented by an individual; consequently, while many of the lower forms of Algæ are met with living under very varying external conditions, the higher types of plant life are divided into groups that are confined, more especially by temperature and amount of moisture, to certain portions of the earth's surface.

The pioneers of plant life—Algæ—were aquatic, and the gradual extension of these forms to the dry land necessitated an unforeseen amount of division of labour not anticipated by the earliest members attempting this change of habitat; eventually, however, after many false starts, a proper method was hit upon, that is, the living organism, by a certain amount of modification of its already existing unit of structure, the cell, was enabled by degrees to establish itself on dry land, and from these primitive microscopic forms of algal life the whole of the Vegetable

Kingdom at present living on dry land has been directly derived. The division of the latter into numerous groups depending, and the endless variation in the properties of protoplasm within certain limits as illustrated by the not unfrequent occurrence of an unusual development popularly known as a "sport," meaning a departure from the ordinary type in some minor feature, such as the colour of the flower or the form of the leaf. At this stage it is necessary to state that the great variety of form, colour, and size presented by the various parts of plants are those best suited to their requirements, and not mere fanciful developments produced with no special object in view, and in many instances, as the fertilization of flowers by insects, not only is colour and form of importance, but the various parts of the flower are so constructed that certain movements take place at the proper moment with machine-like accuracy. Now if the modification of structure presented by a "sport" enables either the vegetative or reproductive portions to do their work better than by the old method, other things being equal, it is not difficult to understand that the descendants of the "sport," inheriting its peculiarity, will spread at a greater rate than the old and superseded parent stock; thus we get the foundation for a new form or variety depending on the amount of difference existing between the parent form and its aberrant offspring. As the above mentioned element of variation, due to unexplained causes, but for that reason none the less conformable to natural laws, is constantly at work, a second "sport" originating from the first will result in the production of a plant still further removed from the original type in structure, thus by repeated variations in vegetative and reproductive portions a group of plants eventually evolve, which if not traced through all the sequence of changes to the parent form, would very probably never be suspected of having evolved from the latter. It is not to be inferred from the above that all existing groups, as at present understood, have originated by variation; another factor of equal importance—*degeneration*—or the arrest and cutting down of structures already highly evolved, has in all probability produced as many or even more groups, distinct as such at the present day, than the one previously explained. The results of degeneration are as a rule more obvious in the reproductive than in the vegetative portions of plants, and illustrated by the cutting down or arrest of the *corolla* or showy portion of the flower that was of functional value when the flower was fertilized by insect agency, but has disappeared as the plant adopted the method of self-fertilization, or became so modified that the pollen or fertilizing substance is conveyed by wind. The grasses afford an illustration of a group of plants that are wind-fertilized at the present day.

Returning for a moment to the division of labour necessitated by the change from an aquatic to an aerial habitat, it was soon realized that desiccation or loss of water, an indispensable substance in connection with active life, should be guarded against; various primitive methods, each more or less successful in its way, were tried by different groups, more especially the massing together of a large number of individuals, whereby the required amount of moisture was better retained than in the case of the same number of isolated individuals; but notwithstanding the various efforts on the part of uni-

Fig. 3. Maize, or Indian corn (*Zea mays*). One of the grasses having a cluster of male or staminate flowers terminating the stem, lower down is a cluster of female or pistillate flowers having every part except the long tassel of stigmas protected by sheathing leaves or bracts. The pollen is blown from the male to the female flower by the wind.

cellular individuals, or those consisting of a few cells only, no great progress was made, and such forms, as a rule, still remain inhabitants of water; yet if, as in the case of Pleurococcus and its allies that have established themselves on dry land, active life can only proceed when the cells are supplied with the requisite amount of water, under other conditions the plant passes into a dormant or resting state. Certain members of the *Hepaticæ,* small moss-like plants, were amongst the first to solve the problem as to the method of preventing desiccation by introducing the idea of division of labour, brought about as follows: In the species of *Marchantia,* popularly known as liverworts, the vegetative portion is prostrate and in contact with the damp ground by the whole of its under surface, the outer layer of cells of the upper surface undergoing a change by which they are rendered waterproof, and thus form a protective layer that prevents evaporation of water from the tissues of the plant into the surrounding dry air. This superficial layer of modified cells constitutes the *epidermis,* and proved so effectual that the idea has never been superseded, and is still the means of preventing undue loss of moisture employed by the most highly differentiated flowering plants. The epidermis is furnished with minute apertures called *stomata* which admit of an interchange between the gaseous contents of the plant and those of the atmosphere, details of which will be given at a later stage. A second important modification of plant structure necessitated by the previous development of an epidermis was the formation of *fibro-vascular bundles,* or modified portions of the original cells of aquatic plants into elongated, thick-walled cells pointed at the tips, or elongated cells of large diameter having the walls strengthened by internal ribs arranged in various ways; these modified cells are usually arranged in groups, and in the higher plant constitute the portion called wood. To understand the value of fibro-vascular bundles to the plant, it must be remembered that Algæ, growing in water, are not furnished with an epidermis, consequently every portion of the plant's surface is capable of absorbing water containing in solution the gases required for food and respiration, also certain other elements of plant food held in solution, hence no special structures for the conduction of water from one portion of the plant to another are required. In land plants, on the other hand, the leaves and other green parts developing in the air are completely surrounded by a waterproof epidermis, that prevents the cells from taking water from the air, and no water enters the plant through the stomata, consequently the quantity of water required by the above-ground portions of the plant is in the first instance obtained from the soil by the underground portion or root, and thence passed up into the leaves. The primitive unmodified tissue, known as *fundamental tissue*, of which seaweeds are composed, does not possess the power of transmitting large quantities of water from one part of the plant to another, hence the necessity of a portion of this tissue becoming modified into fibro-vascular bundles in land plants, as these structures, especially the thick-walled portion called *xylem*, are good conductors of water, and thus serve as channels of communication between the source of water in the roots and the above-ground parts. The larger cells of the bundles, called *vessels*, usually contain air.

Finally a third modification induced by the change from an aquatic to a terrestrial habitat, although somewhat later in its appearance than that of epidermis or fibro-vascular bundles, was the evolution of the structure popularly known as the flower. The only mode of plant reproduction hitherto mentioned—fission or cell-division—is termed the *asexual* or vegetative mode, but even in the Algæ a second and much more highly evolved method is known called the *sexual* mode of reproduction, which fundamentally consists in the amalgamation of the protoplasm of two distinct bodies, presumably male and female, to form a single reproductive organ called an *oospore,* but which would popularly be called a seed. Now in all seaweeds the male or fertilizing element consists of a very minute portion of protoplasm that becomes free from the plant, and possesses the peculiarity of exhibiting spontaneous movement, swimming about in the water by means of very fine hair-like appendages or *cilia.* The object of this animal-like movement of the fertilizing body or *antherozoïd* is to enable it to come in contact with the female element with which its substance blends—the act of fertilization—and a minute body results that eventually becomes liberated from the parent plant, and under favourable conditions *germinates* or sprouts and produces in turn a plant resembling the one to which it owed its origin. This mode of sexual reproduction by means of motile antherozoids that reached the female by swimming in water is still kept up by several groups of plants that had firmly established themselves on dry land, as the Liverworts (*Hepaticæ*), Mosses (*Musci*), Ferns (*Filices*), and Club-mosses (*Lycopodiaceæ*), consequently in all the above groups there is as a rule a tendency to grow in damp districts, and the sexual mode of reproduction takes place during the winter in temperate regions, or during the rainy season in the tropics, when the presence of water enables the motile antherozoids or fertilizing bodies to find their way to the female element. It is impossible to enter into details in connection with this subject of fertilization, but it may be stated that the portion of the plant producing the sexual organs is usually very small, and could be covered by a dewdrop, which would afford a superabundance of water for the purpose of enabling the antherozoid to swim about and come in contact with the passive female element. All plants having the male element of the sexual generation possessed of spontaneous movement belong to the class of plants called *Cryptogams*, which constitutes one of the two primary subdivisions of the Vegetable Kingdom. As plants receded more and more from their primitive aquatic habitat, and became differentiated so as to carry on their entire existence on dry land, the sexual mode of fertilization by motile antherozoids that reached the female by swimming, became untenable, and by degrees a radical change took place in the structure of the male or fertilizing body. Instead of the naked, spontaneously moving antherozoid, the fertilizing bodies took the form of minute cells inclosed in a cell-wall and entirely devoid of spontaneous movement; these cells or *pollen-grains* were produced in considerable numbers in the immediate neighbourhood of the female organs, on to which they were shed when mature, thus the agency of water as the medium by which the male element reached the female was dispensed with. By the above arrangement it will be observed that both male and female elements were produced by the same plants, consequently *self-fertilization* resulted. Owing to the great advantages of *cross-fertilization* (when the male and female elements are produced on different individuals of the same kind) over self-fertilization, a further differentiation took place, and the two sexes were either produced on distinct individuals of the same species, respectively male and female, as in the willows and poplars, or on different parts of the same plant as in the hazel, and under such circumstances, the pollen being devoid of spontaneous movement had to be transported to the female by some outside agent, which in the above and numerous other examples consisted of the wind, the pollen being blown when mature from the male to the female plant. Plants that utilize the wind as the agent for bringing the pollen in contact with the *ovules,* or female bodies requiring fertilization, are termed *anemophilous.*

Anemophilous plants are often characterized by having the flowers developed before the leaves, as the latter would interfere with the pollen being blown on to the *stigma* or special structure of the female part for receiving the pollen. The anemophilous method, although as a rule securing the desired cross-fertilization, was a very extravagant way of effecting that object, enormous quantities of pollen having to be produced for the purpose of securing fertilization by what may be termed a chance method, and has been to a great extent superseded by utilizing insects as the agents for conveying the pollen from one plant to the stigma of another and thus securing cross-fertilization.

Having traced the origin of the highly differentiated group of flowering plants from the lowly aquatic seaweed, it is necessary in the next instance to indicate briefly the work done by the various specialized parts common to flowering plants in general. As already explained, the work done by an individual that completes the full cycle of life may be conveniently divided into two phases: first, vegetative; second, reproductive. In many of the lower types of plant life, as already illustrated by the species of Pleurococcus, these phases follow each other, the first being completed before the second is entered upon; this condition also holds good in numerous flowering plants—in fact, in all *annual* species, or those that last for one season only, and also in *biennial* species, or those that live for two years before completing the life-cycle. The annual species develop the vegetative portion first, this is followed by the reproductive during the same season, the last phase producing seed that produces new individuals the following year. In biennials, the first year is devoted entirely to the vegetative phase, which often concentrates a considerable amount of reserve material or surplus food in the root, as illustrated by turnips and carrots; during the second season this reserve material serves to build up the reproductive structure, consisting of a stem bearing flowers, that in due course produce seed, thus completing the life-cycle of the individual. A

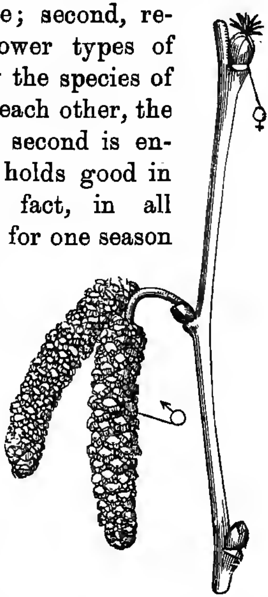

Fig. 4. A flower-bearing branch of the common hazel (*Corylus avellana*), a wind-fertilized flower. The upper flowers are pistillate or female, the lower large catkins staminate or male.

third type, comprising all trees and shrubs, and the great majority of the larger forms of vegetable life, is characterized by the vegetative portion of the individual enduring for more than two years; such are collectively known as *perennial* plants, many of which endure for a century or even longer. Under ordinary circumstances, such perennials produce a new reproductive part every season. The above sequence of the life-cycle is not absolutely stereotyped, but can under certain conditions be made to depart from the usual course of development. As an illustration, the common sweet-scented Mignonette is an annual, but if the flower buds are pinched off as they appear, the vegetative portion persists through the winter and produces an abundance of flowers the following year.

In the great majority of flowering plants the vegetative portion consists of the three following differentiated parts, each doing a specific kind of work not capable of being done by any other part.

(1) *Root.* A true root, as understood botanically, serves to fix the plant in one particular place, a mechanical and comparatively unimportant function, the more important and in fact indispensable function being that of supplying the plant with the required amount of water containing in solution certain indispensable elements of plant food; in fact the entire substance of every plant, with the exception of carbon, taken in from the atmosphere in the form of carbonic dioxide by the leaves, is absorbed in a soluble condition by the root. A marked difference between the members of the animal and vegetable kingdoms respectively consists in the power of locomotion or freedom to move from place to place by the former, whereas

the latter are, as stated above, permanently fixed to one place by the root. This marked difference depends on the nature of the food. Plant food consists of carbonic dioxide obtained from the atmosphere along with certain soluble substances present in the ground that are taken in by the roots in solution in water; now the composition of the atmosphere is practically the same everywhere, and the substances derived from the ground are very widely diffused, hence it may be stated in broad terms that wherever a plant grows, it is certain to be surrounded by its food, consequently the power of locomotion is unnecessary, the only fluctuating factor in determining the presence or absence of plant life being water, and in proportion to the relative scarcity of the latter we observe a corresponding scarcity of plant life, which is altogether absent from the dryest parts of the earth's surface, not on account of the absence of plant food, but the absence of water for dissolving the food which cannot be absorbed by the plant in the solid form. All plant food is absorbed in the gaseous or liquid condition, never as a solid. Animals, on the other hand, feed on organic food that is never so universally diffused as the inorganic food of plants, consequently the power of moving from place to place for the purpose of obtaining the requisite amount of food.

(2) *Leaves.* The green, flattened portions of a plant known as leaves perform several functions, the most important and universal being the following:—*Nutrition,* in the sense of taking in food; carbonic dioxide, as previously stated, being absorbed from the atmosphere by the green parts of plants. *Transpiration,* or the escape of water into the atmosphere in the form of vapour

through the stomata of the epidermis. *Respiration.* Oxygen is inhaled from the atmosphere through the stomata, and carbonic dioxide is returned through the same channels to the atmosphere.

Assimilation.—The water taken in by the roots passes up the xylem portion of the vascular bundles of the stem, and from thence into the leaves by their veins; there it unites with the carbonic dioxide taken in from the atmosphere, and the two are chemically changed into *starch* by the action of the chlorophyll, or green portion of the cell-contents under the influence of light. The formation of starch as above is termed assimilation.

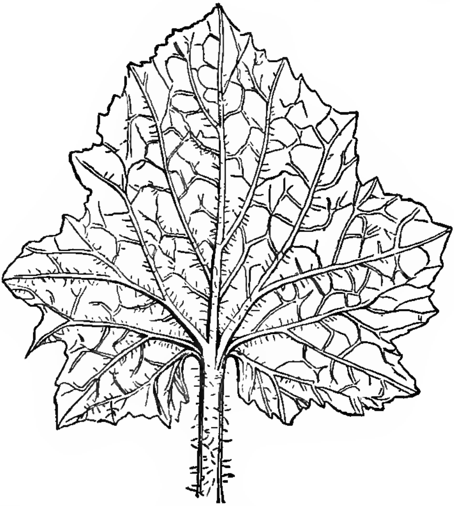

Fig. 5. Melon leaf. A typical leaf showing the stalk or *petiole,* and blade or *lamina* traversed by numerous anastomosing fibro-vascular bundles or veins.

The solid starch that has been formed in the leaf during the day becomes dissolved during the night, and passes along the veins of the leaf into the substance of the plant, where it is either used at once as a building tissue,

Fig. 6. One of the Honeysuckles (*Lonicera glauca*), showing the large irregular corolla furnished with scent and honey for attracting insects.

forming the cell-walls, or is re-solidified and stored up for future use.

The reproductive portion of the plant, *i.e.*, the flower, with all its various accompaniments, is developed for the sole purpose of producing seeds that, under suitable conditions, develop into a plant similar to the parent form. The parts of a typical flower, commencing from the outside, are as follows:—

(1) The *calyx*. Function, protective; usually consists of a ring or whorl of green leaf-like structures called *sepals*. The use of the calyx being to protect the inner parts of the flower during the bud stage, it usually either falls away or bends back and becomes inconspicuous after the expansion of the flower.

(2) *Corolla*. The second whorl of leaves, situated within the calyx or higher up on the axis of the flower. Function, usually attractive to insects in connection with the act of *pollination* or fertilization. The component parts of the corolla are called *petals*, and are usually large, coloured, and frequently in addition secrete a semi-liquid saccharine substance that serves as food for insects. The corolla varies much in size, form, and brilliancy of colouring, and is most highly developed in entomophilous or insect fertilized species.

(3) *Stamens*. Within the corolla, and consequently situated higher on the floral axis, are to be found a varying number of slender yellow stalks, each terminating in a thickened portion or knob-like head; these are the stamens, collectively constituting the male element of the flower; the stalk of the stamen is called the *filament*, and the knob-like apex, the most important part, is called the *anther*, which contains the *pollen*, or fertilizing substance.

(4) The *pistil*, or female organ of the flower, is again situated within the ring of stamens, and occupies the apex of the floral axis. It consists of one or more structures called *carpels*, that in the majority of flowering plants form closed cavities, the *ovaries*, that contain the *ovules*, or young unfertilized reproductive bodies. After fertilization the ovules undergo great structural changes—the result of fertilization—and are called *seeds*, the ovary or protective portion then also undergoes certain changes and becomes the *fruit*. There are two primary divisions of flowering plants or *Phanerogams*—

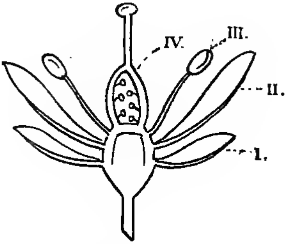

Fig. 7. Diagrammatic section of a typical flower showing the various parts in their relative positions. I., calyx; II., corolla; III., stamen, consisting of filament and anther; IV., pistil, consisting of a lower swollen portion, the ovary, and a terminal knob-like part, the stigma, supported on a stalk, the style.

(1) *Gymnosperms*, including the pines, firs, cedars, yews, etc., characterized by having the ovules naked, that is, not contained within an ovary. In the members of this group fertilization is direct, the pollen coming directly in contact with ovule.

(2) *Angiosperms*. The majority of flowering plants are included in the present division, characterized by

having the ovules concealed in an ovary, hence fertilization is indirect; the ovary terminates in a structure of variable form, called the *stigma*, the function of which is to receive the pollen, which then germinates and finds its way indirectly to the ovules for effecting fertilization.

The cells, or ultimate structures of plants, have been incidentally alluded to, but being of primary importance and indispensable to a clear comprehension of the workings of plant life, a more detailed account of the most prominent features of the cell and its modifications is necessary.

The cells of plants are, as a rule, very minute and invisible to the unaided eye, and when fully developed present the following structures, proceeding from without:—

(1) An external continuous pellicle or protective layer, known as the *cell-wall*, which although showing no visible perforations is pervious to liquids and gases. The cell-wall is composed of a substance called *cellulose*.

(2) Closely applied to the inner surface of the cell-wall is a somewhat irregular layer of *protoplasm*—the living portion of the cell.

(3) The *nucleus*, a small, differentiated portion of the protoplasm in which it is embedded.

(4) The *sap-cavity* or central cavity bounded by the layer of protoplasm.

The cell-wall is at first very thin, and of equal thickness throughout, but this condition rarely continues throughout the entire existence of the cell; in many pollen grains, also the spores of many cryptogams, the outside of the cell-wall becomes ornamented with warts, spines, or ridges that often anastomose to form a network. The cells in the central part of the stem of some of our common rushes (*Juncus*) have a *stellate* form; from a cell originally spherical several ray-like prolongations are formed due to local growth of certain portions of the cell-wall; the tips of these rays are joined to similar arms from adjoining cells, the whole forming a light and porous tissue. The original very thin wall is almost invariably thickened and strengthened by the deposition of cellulose on its inner surface, but this thickening matter is not uniformly deposited over the entire surface, certain portions of the original thin cell-wall remaining unthickened. The cells are said to

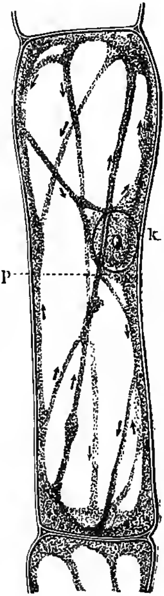

Fig. 8. A single cell of the celandine (*Chelidonium majus*) showing the cell-wall lined inside by an irregular layer of protoplasm from which strands, *p*, pass into the large central sap-cavity; *k*, the nucleus, with a nucleolus. The arrows indicate the direction of circulation of the strands of protoplasm. (Highly magnified.)

be *pitted* when the unthickened portions are small and circular; *scalariform* when elongated and arranged in parallel series. When the internal thickening takes the form of a thread-like band arranged in a spiral manner we have *spiral* cells, and *annular* when the band takes the form of detached rings.

The object of all forms of secondary thickening of the cell-wall is that of giving additional strength ; the unthickened portions that are opposite to each other in adjoining cells are left for the purpose of allowing liquids and gases to pass from cell to cell, which could not take place, or at all events very slowly, if the entire surface of the wall was thickened. The hardness and durability of wood is due to the much thickened walls of its component cells, the substance of which changes its composition with age, and at the same time usually becomes coloured.

Protoplasm is of a semi-liquid consistency, colourless, and is either homogeneous and transparent or, more frequently, turbid, owing to the presence of minute drops of oil, starch, etc. In young cells the protoplasm with the nucleus almost completely fills the cell, and the water which saturates it collects into minute drops called "*vacuoles.*" These "vacuoles" eventually run together and form the central sap-cavity. The power of spontaneous movement exhibited by protoplasm is often very marked, especially in the lower groups of plants, as seaweeds, fungi, mosses, etc., where the male or fertilizing element, called the *antherozoid*, consists of a very minute *primordial* or *naked* cell, *i.e.*, not furnished with a cell-wall, and provided with one or more exceedingly slender hair-like continuations of its protoplasm that serve as organs of locomotion and enable the antherozoid to swim in water. Even when inclosed within a rigid cell-wall, the protoplasm not unfrequently exhibits well-marked movements, the whole of the peripheral layer of protoplasm moving round the cell (*rotation*), or currents that carry along minute granules and move in its substance.

Cell-contents.—In addition to the protoplasm, which itself constitutes the cell, a considerable number of substances are met with in cells, the presence of these substances being determined by the position occupied by a given cell in the general structure of the plant. The following are the most important of cell-contents :—

(1) *Chlorophyll*, or the green colouring matter present in the superficial cells of plants. Light, being an indispensable factor in the formation of chlorophyll, it is consequently absent from the internal parts of plants, and also from underground portions, but in the latter case it can be shown that the absence of light is the cause of the absence of chlorophyll, as when the underground portion is exposed to light it often becomes green, as seen in potatoes that have been exposed to light during growth. In the majority of plants the chlorophyll consists of minute particles called *chlorophyll-grains* that are imbedded in the protoplasm, but in some of the simpler Algæ the chlorophyll is diffused as a liquid throughout the protoplasm. The almost universal green colour of the vegetable kingdom is due to the presence of chlorophyll in the superficial cells. Its important functions will be dealt with at a later stage.

(2) *Starch* first makes its appearance as a solid organic product within the chlorophyll grains, and continues to accumulate so long as the chlorophyll is exposed to

light. During the night the starch that has been formed during the day, in the cells of the leaves more especially, is dissolved, and passes along the veins of the leaf into the branches, and becomes diffused over every portion of the plant, a certain portion being used up at once in the formation of new cell-walls, the remainder being stored away for future use in certain internal tissues, or very frequently in underground parts, as bulbs, tubers, etc., that become much swollen owing to the formation of thin-walled tissue containing starch. Such swollen underground parts usually serve as vegetative reproductive bodies.

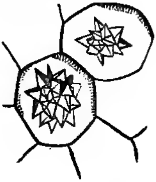

Fig. 9. Cells of beet (*Beta maritima*), containing agglomerations of crystals. (Highly magnified.)

(3) *Crystals* are of very common occurrence in the cells of plants, and almost invariably consist of oxalate of lime. When the crystals are very long and slender they are often called *raphides*, and occur in enormous quantities in the cells of some plants. If the flower-stalk of the common hyacinth is crushed, and a minute quantity of the juice examined under the microscope, numerous very slender, needle-shaped crystals will be seen floating in the liquid. Crystals are present in enormous quantities in the stems of old cactus plants, rendering them quite brittle.

The material forming crystals is not absorbed by the plant as oxalate of lime from the soil, but is formed by the plant itself; oxalic acid is one of the most general of organic acids produced by plants, and the lime finds its way into the plant as a carbonate or phosphate of lime; these eventually combine to form oxalate of lime, which may be considered as a by-product, the result of certain chemical changes taking place in the contents of the cell-sap. As a rule, crystals are deposited in those parts of plants that fall away annually, more especially the

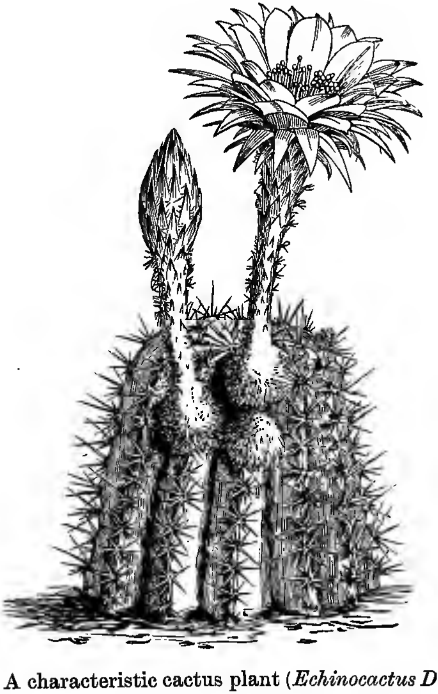

Fig. 10. A characteristic cactus plant (*Echinocactus Decaisneanus*), having the cells of the trunk filled with crystals when old. (Reduced.)

leaves, which in the spring contain a very small trace of ash or mineral matter, whereas at maturity most of the cells contain quantities of crystals.

(4) *Cell-sap.* This substance saturates the cell-wall and protoplasm, and also fills the central sap-cavity in the fully-developed cell. It is a watery solution of various substances, amongst which certain salts derived in solution from the soil are never absent; in certain cells of some plants, as sugar-cane, beet, maple, etc, large quantities of cane-sugar are present; in certain cells of the grape, and many other fruits, grape-sugar occurs; in addition, tannin and many vegetable acids are present, as also many of the blue and red colouring-matters of flowers and fruits.

The epidermis or protective covering formed on the surface of those parts of plants growing surrounded by air, usually consists of a single layer of cells that become differentiated in the following manner. The cells touch each other at every part, intercellular spaces being entirely absent; the outermost, or free surfaces of the epidermal cells become much thickened and converted into a substance impervious to water; the protoplasm and chlorophyll usually disappear at an early stage, their place being taken by air or water, the epidermis serving as a reservoir for the latter in many plants. At a very early stage of the development of the epidermis the stomata, or openings through its substance, are formed. Their mode of formation varies, to a certain extent depending on the particular species examined. If the tip of a very young leaf that is just showing at the crown of a growing hyacinth bulb is removed, and a minute portion of its epidermis removed with a pair of forceps and examined in water under the microscope, the origin and development of the stomata may be easily followed.

The cells of the epidermis as seen from the surface are brick-shaped, their long diameter being arranged in the direction of the length of the leaf. The stomata originate as follows. A certain epidermal cell is divided into two parts by a wall that is always formed at right angles to the length of the leaf. One of the small, or daughter-cells thus formed, undergoes no further development, but loses its protoplasm, becomes cuticularized, and forms an ordinary epidermal cell; the other daughter-cell, that is, the other half of the epidermal cell, now called the *mother-cell of the stoma,* retains its protoplasm

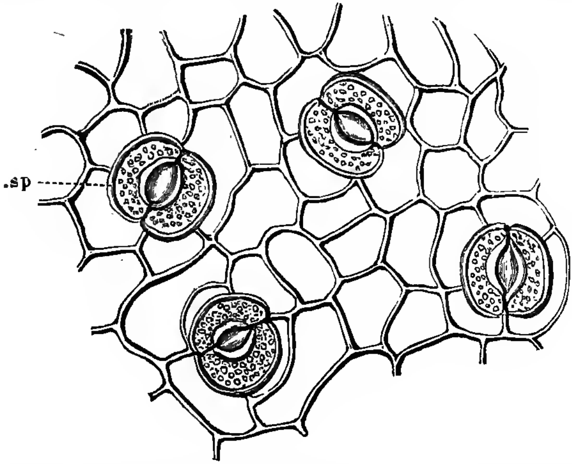

Fig. 11. A fragment of epidermis from the under surface of a leaf of *Euonymus japonica*, showing four stomata; *sp*, guard-cells of the stoma. (Highly magnified.)

and chlorophyll, and becomes divided by a wall formed at right angles to the one previously formed, or parallel to the long axis of the leaf; the two small cells thus formed from the stoma mother-cell are called the *guard-cells* of the stoma. The common-wall separating the two guard-cells splits, and the guard-cells becoming concave on the side facing each other thus form a small opening through the split wall of the epidermis into the substance of the leaf.

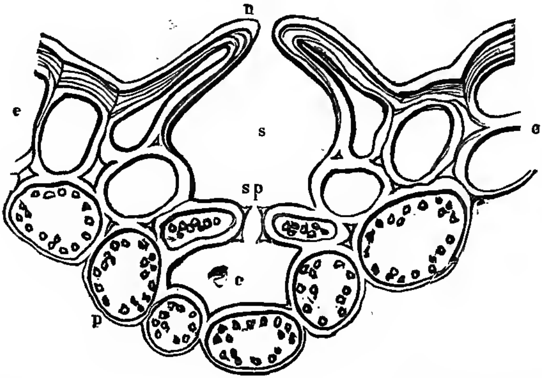

Fig. 12. Transverse section through the epidermis of the leaf of *Cycas revoluta*, one of the Cycads; *n*, the elevated epidermis; *e*, epidermal cells; *sp*, stoma; *c*, air cavity below the stoma; *p*, parenchymatous cells of the leaf. (Highly magnified.)

Stomata are most numerous and perfectly developed on leaves, and are either scattered, the most general method, arranged in groups, or, as in the fir-trees, in lines. Their number varies from 200 to 160,000 or even more in a square inch of surface. In the white garden lily there are about 60,000 in a square inch on the under surface of the leaf, and about 3,000 on the upper; in the cherry laurel, about 90,000 in a square inch of the under surface of the leaf, and none on the upper surface. When leaves grow erect, stomata are usually about equally abundant on the upper and under surface; but when growing horizontally, with one surface to the earth—the lower—and the other to the sky—the upper—stomata are usually much more numerous on the under surface. Owing to the disappearance of the greater portion of the protoplasm from epidermal cells at an early period, no secondary growth or cell-division can take place; hence, as already stated, typical epidermis is met with as the permanent covering of leaves, for the full development of a leaf takes place rapidly and is contemporaneous with that of the epidermis which is formed from its superficial layer of cells, and however long a leaf may continue to live, there is no secondary growth or increase in size. Young twigs and shoots are protected with epidermis during the first year, but at the commencement of the second year's growth, when the twig begins to increase in thickness, the epidermis, unable to grow and keep pace with the expansion of the twig, is ruptured and thrown off, its protective function being superseded by the formation of a waterproof structure called *periderm*, which is formed from the superficial cells of the twig, but differs from epidermis in not being composed of one layer of cells only, the absence of stomata, and more especially by a provision for the increase in the number of cells by means of which the periderm keeps pace with the increase in thickness of the twig.

When cells by repeated bipartition produce other similar cells that remain organically connected, the result is a tissue; and when these cells are *morphologically* (structurally) and *physiologically* (functionally) of comparatively equal value, being furnished with comparatively thin walls, and not much longer than broad, the tissue is called *cellular* or *fundamental tissue.* Some groups of plants, as Algæ and Fungi, are composed entirely of fundamental tissue, and have consequently been called *cellular plants,* whereas all other groups of plants, on account of the presence of other tissues in addition to fundamental tissue, have been called *vascular plants.* Fundamental tissue constitutes the starting point of every plant, however highly differentiated it may become, and is also indispensable at every stage of its existence, inasmuch as it is the only tissue possessing the power of growth or of adding to the bulk of the individual by cell-division, consequently where growth is taking place is a certain sign of the presence of fundamental tissue, as the tips of stems, roots, etc., such portions are called *growing-points.*

The trunks of all forest trees in the earliest condition consist of fundamental tissue, the outer layer having become differentiated into an epidermis. The fibro-vascular bundles present in the stem originate in the young leaves that appear at first as very minute papillæ or outgrowths arranged round the growing-point or apex of the stem which they protect by being arched over it during the bud stage. In the bud state the youngest leaves are so near the apex of the stem that they might probably be considered, on a superficial examination, to originate from the actual apex of the stem. Such, however, is not the case; there is no such thing known as a terminal leaf, and a thin vertical slice of a young bud examined under the microscope will show the youngest leaves to be truly lateral in origin, the centre or actual apex of the stem being composed of undifferentiated fundamental tissue.

From these young leaves the rudimentary fibro-vascular bundles pass downwards into the stem, where they usually join on to older bundles and become arranged in various ways depending on the group to which the specimen under examination belongs. Fibro-vascular bundles that originate as above from leaves are usually called *foliar vascular bundles*, or *leaf-traces.* From the above statement it will be seen that the increase in size of the trunk and branches, in other words, the formation of the fibro-vascular element, which constitutes that portion of the trunk popularly known as "wood," is entirely dependent on the presence of leaves; consequently, if during any given season the leaves of a tree are destroyed by insects or prevented by any means from attaining their full

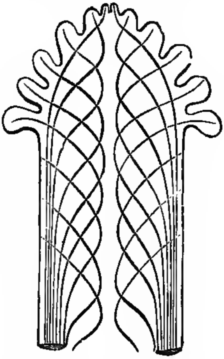

Fig. 13. Diagrammatic representation of a section of a palm stem, showing the arrangement and direction taken by the fibro-vascular bundles that originate in the leaves and pass down the stem.

development, and doing the usual amount of work, so in proportion will the formation of wood be arrested.

In rare instances a few fibro-vascular bundles originate in stems quite independent of the leaves; these are differentiated from the fundamental tissue of the growing-point at a higher level than the origin of the youngest leaves, and are known as *cauline bundles.*

In *Phanerogams,* or flowering plants, a typical fibro-vascular bundle consists of two kinds of *permanent tissue,* that is, tissue which, once formed, undergoes no further differentiation; the two kinds, as previously stated, are respectively called *phloem* or bast, and *xylem* or wood, and these are arranged *collaterally* or side by side, the phloem being outermost or nearest the periphery, the xylem innermost or nearest the centre of the trunk. In many of the Vascular Cryptogams, the arrangement of the two parts of a bundle is *concentric,* the phloem completely surrounding the xylem.

Depending on the further mode of development, and on the manner of arrangement of the fibro-vascular bundles in the stem, along with other characters derived from the seed, flower, and leaf, Phanerogams are arranged under two subdivisions, *Monocotyledons* and *Dicotyledons.*

(1) *Monocotyledons.* The fibro-vascular bundles consist of the elements phloem and xylem only, and no secondary growth, that is, no additions to the elements existing in the bundle as originally formed, takes place; such bundles are said to be *closed,* meaning, as stated above, that no additions in the way of new cells are added at a later stage, hence the bundles remain small, and for the greater part of their length isolated, coalescing by their tapering tips only with other bundles lower

down the stem. Grasses, sedges, lilies, and palms are typical Monocotyledons, and in the palms the monocotyledonous stem structure reaches its maximum of development, the bundles on entering the stem from the leaves at first curve towards the centre, then grow downwards for some distance, eventually curving back towards the periphery and anastomosing by their tapering ends with lower and older bundles, as shown in fig. 13. In palms the stem is cylindrical and terminated by a bud, the only one possessed by the tree; at a very early age the stem acquires its full diameter, and henceforth the terminal bud gives origin annually to about the same number of leaves, which consequently supply an equal number of fibro-vascular bundles that only proceed for a short distance down the stem, the lower portion, as it is left behind by the apical bud, being unable to increase in diameter on account of its bundles being closed.

(2) *Dicotyledons.* In the dicotyledonous stem a ring of detached vascular bundles, each consisting of an external phloem and an internal xylem portion, appears in the fundamental tissue about midway between the centre and the circumference of the stem; that portion of fundamental tissue lying outside the ring of vascular bundles, and bounded externally by the epidermis, is called the *primary cortex*, the central portion surrounded by the vascular ring is the *medulla* or pith, while those portions of fundamental tissue that pass between the ring of isolated vascular bundles and connect the pith with the primary cortex are called *medullary rays.* The xylem and phloem elements of the fibro-vascular bundles do not lie in contact with each other as in Monocotyledons,

Fig. 14. A palm (*Seaforthia elegans*), showing the erect, semi-cylindrical stem crowned by a rosette of large leaves that were formed by the single apical bud.

but are separated by a thin zone of fundamental tissue that has received the name of *cambium*, and which by rapid cell-formation adds periodically to the xylem and phloem elements of the bundle, which thus increases in size from year to year. Bundles furnished with cambium, and thus capable of adding to their substance periodically, are said to be *open*.

In perennial plants increase in thickness of the stem commences with the activity of the cambium situated between the phloem and xylem of each vascular bundle, by repeated bipartition of the cells of the cambium a mass of tissue is formed that becomes differentiated into the elements of phloem and xylem respectively. Owing to the position of the cambium, it will be observed that the new elements of the xylem or wood will be added to the outside of the already existing portion, whereas the additions to the phloem will be on its inner surface, but very much more material is periodically added to the xylem than to the phloem, so that while the former may

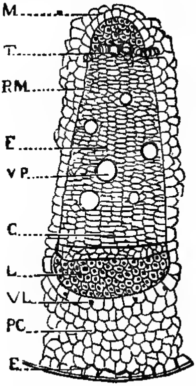

Fig. 15. Horizontal section through stem of a Dicotyledon, the melon, including one fibro-vascular bundle, which is completely surrounded by fundamental tissue composing the following parts: *M*, pith; *RM*, medullary rays; *PC*, primary cortex; the wedge-shaped bundle consists of *L*, the phloem, followed internally by the xylem, the two being separated by a thin band of cambium. The large circles in the xylem correspond to the sections of vessels. *E*, the epidermis. (Magnified.)

have increased to a yard in diameter, the latter may not be half an inch thick.

All European forest trees are Dicotyledons, and the ringed appearance seen in a trunk that has been sawn across is due to the periodical additions made by the cambium to the xylem or wood. In temperate regions, where there is only one season of growth during the year, a single ring is formed annually, hence the term *annual rings*, as applied to these markings, which may be used in determining the age of the tree with approximate accuracy; such rings give at least the minimum age of the plant. In the tropics, where there is more than one growing season during the year, two or more rings are formed by some species in one year.

The popular expression "rising of the sap" corresponds to the renewed growth of the cambium in the spring; the tender mass of thin-walled tissue thus formed readily admits of the removal of the outer portion, or "bark."

The distinct appearance of the annual rings of wood originates as follows:—The first additions to the wood made by the cambium during the spring, consists for the most part of vessels of large diameter and with comparatively thin, pitted walls; the formation of these vessels is favoured in the spring by the slight amount of pressure exerted by the bark, that has been kept moist during the winter season, but as the summer advances the bark becomes dry and rigid, and the pressure on the newly-formed wood becomes greater, consequently the formation of vessels in the xylem is superseded by that of wood cells with very small cavities and thick walls, the result being that the porous spring wood, composed of vessels with very large cavities, gradually changes towards the autumn into very dense wood, with thick cell-walls and very minute cavities. Each season the porous spring wood following abruptly on the dense wood of the preceding autumn causes the rings known as annual rings. The following are the most important types of cell structure forming xylem and phloem respectively:—

Xylem. There are two distinct types of cell structure; wood cells or *tracheides,* consisting of long, thick-walled cells with tapering, pointed ends that overlap, the walls become hard and rigid, and form the great bulk of durable wood. Water passes from the roots to the leaves through the substance of the cell-walls of the youngest and last-formed wood-cells. Tracheides are formed in most instances directly from single cambium cells; *vessels* are recognized by their large diameter

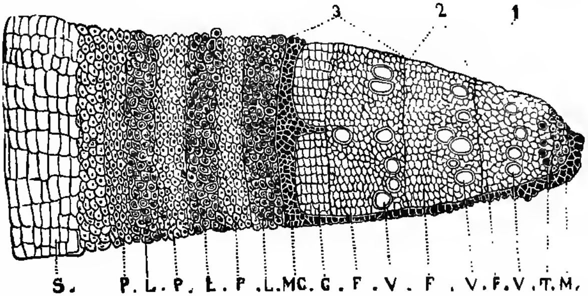

Fig. 16. Horizontal section of a Dicotyledon, the maple, showing three years' growth; *S*, cortex; *M*, pith; *C*, cambium; the figures 1, 2, 3, indicate the three annual rings of wood, including the cambium; the dark portion between the cambium and the cortex is the bast or phloem. (Magnified.)

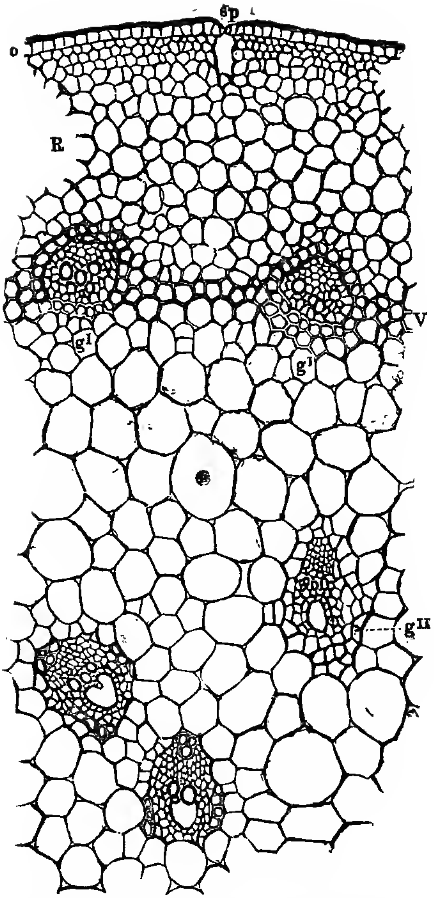

Fig. 17. Part of a transverse section through the stem of a Spiderwort (*Tradescantia Sellei*), illustrating the arrangement of the fibrovascular bundles in a monocotyledonous stem; *e*, epidermis, with a stoma, *sp*; *R*, cortex; *v*, thickening ring, with the outer vascular bundles, g^{I}; g^{II}, inner vascular bundles. (Magnified.)

and by the ends being only slightly oblique and not tapering; they originate from superposed rows of cells, some of the transverse septa being absorbed; hence the structure called a vessel consists of two or three cells thrown into one by the disappearance of their transverse walls. Vessels formed in the *primary wood,* or wood of the first year, frequently have their walls thickened internally by the deposition of strengthening material arranged in the form of a loose spiral, and are known as *spiral vessels,* while vessels that are formed in the *secondary wood*—that is, all wood or xylem formed after the first year, usually have pitted walls. *Ducts* are only vessels of extra large diameter, and furnished with pitted walls. Vessels usually contain air, but when the ascent of sap is very rapid, as in the spring, they sometimes contain water.

Phloem or bast, like the xylem, consists of two distinct elements; *sieve-tubes,* with thin side walls, but having the transverse septa much thickened and perforated with numerous minute holes; these thickened and perforated septa are called *sieve-plates.* Sieve-tubes, or soft bast, correspond to the vessels present in the xylem, and contain albuminous substances; *bast-fibres,* constituting the hard bast, consist of very much elongated, thick-walled cells with tapering extremities, and correspond to the tracheides of the xylem, but differ from the latter in their walls, although usually very much thickened, not becoming rigid, but remaining pliant. The hard bast is the part used in most textile fabrics, as "linen," "jute," "hemp," "Russia matting," etc., "cotton" is an exception to the above, and consists of long, thin-walled cells of cellular tissue that spring from the testa or

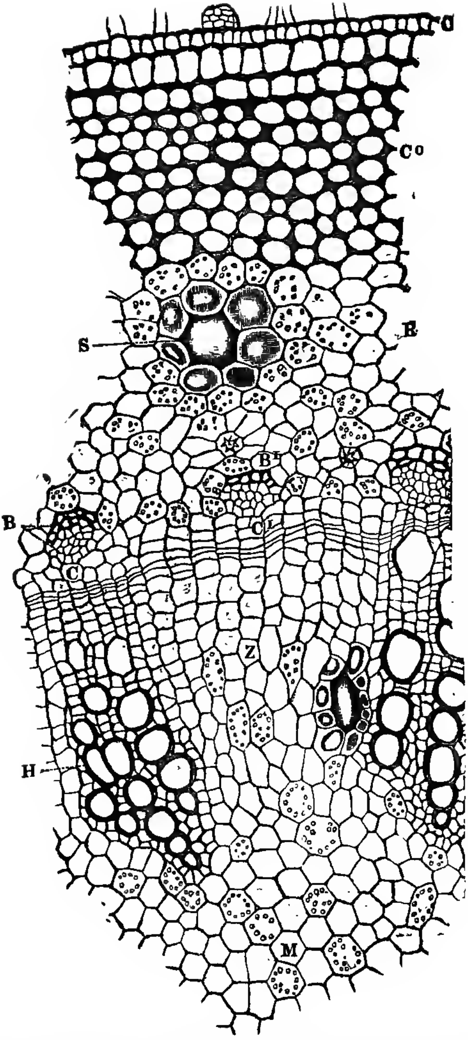

Fig 18. Transverse section through a young stem of *Bœhmeria argentea*, a Dicotyledon; *O*, epidermis; *Co*, outer cortex (collenchyma); *B*, inner cortex; *S*, intercellular space; *C*, cambium; *B*, bast; *H*, xylem portion of vascular bundle; *Z*, medullary ray; *M*, pith. (Magnified 120 times.)

skin of the cotton seed, and collectively serve as a dispersive organ for floating away the seeds in a similar manner to the *pappus* or " clock " of dandelion and thistle fruits.

CHAPTER II.

CHEMISTRY AND PHYSICS OF PLANT LIFE.

Nature of Plant Food and how it is obtained.—Influence of Light on Plant Life.—Influence of the Vegetable Kingdom on surroundings. —Origin of Carnivorous Plants.—Saprophytes.—Parasites.—Retrogression.

CHARACTERISTIC plants furnished with the green colouring matter called chlorophyll, as previously stated, feed on inorganic food obtained partly from the atmosphere, partly from the soil or substance in which the roots are fixed. The only food material obtained from the atmosphere is *carbonic-dioxide* (CO_2) ; the remainder is taken in by the roots dissolved in water, and although different food substances are required by different plants, yet the following may be considered as being indispensable to the majority of plants :—

Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur (S) ; these form the organic compounds of the plant, that is to say, combinations of carbon with other elements which, on exposure of the plant to great heat, are for the most part resolved into volatile products, as water (H_2O), carbonic dioxide (CO_2), ammonia (NH_3), etc.

Phosphorus (p), Potassium (K), Iron (Fe), Calcium, (Ca), Magnesium (Mg) ; these go to form the inorganic non-volatile compounds of the plant that remain as a white ash after the plant has been burnt.

In addition to the above, various other elements occur in certain plants, but their connection with nutrition has not yet been proved; amongst these are, Manganese (Mn), Sodium (Na), Lithium (Li), Iodine (I), Bromine (Br), Silicon (Si), and in rarer cases some of the metals, as Aluminium (Al), Copper (Cu), Cobalt (Co), Barium (Ba), Zinc (Zn), Nickel (Ni), Strontium (Sr).

Chlorine (Cl) has so far been proved by experiment to be an indispensable food element in the case of one plant only, the Buckwheat.

Direct experimental cultures with plants have proved that they can be grown and perfectly nourished if supplied with the requisite elements in compounds suitable for absorption; the same experiments have also proved that certain substances often met with in their ash are not necessary for their growth, inasmuch as equally healthy plants can be produced when such elements are intentionally kept away from their food supply. Such substances, which usually occur in very small quantities in plants, may be considered as having been absorbed by the plant along with the necessary food.

The above food constituents are not taken into the plant as elements, but as compounds; carbon, for example, is obtained from carbonic dioxide; nitrogen, although so abundant an element in the atmosphere, is never assimilated in the free form, but as nitrates or compounds of ammonia that are soluble in water; hydrogen is obtained from the decomposition of water; the remaining substances are taken by the plant in the form of compounds soluble in water; thus sulphur is obtained from the sulphates of the soil, such as calcic sulphate ($CaSO_4$); phosphorus from phosphates, etc.

The elements mentioned as forming the organic matters of the plant, as protoplasm, starch, cellulose, etc., actually build up the substance of the plant, whereas those forming the inorganic parts, or ash, do not necessarily enter into the composition of the tissues, nevertheless in many instances their presence has been proved to be indispensable in connection with certain chemical changes resulting in the formation of certain substances upon which the life of the plant depends. Thus, iron obtained in the form of a chloride or sulphide is necessary for the chemical production of the green colour of chlorophyll, if iron is intentionally withheld from plant food used in experimental culture, the parts that would be normally green become yellowish only, even if exposed to light, whereas if very minute traces of iron are added to the food of such a plant, the chlorophyll is very soon formed. Iron does not enter into the composition of chlorophyll, but its presence in very small proportions is necessary to set up the chemical changes that result in the formation of this substance. The very general occurrence of chlorophyll-bearing plants on all parts of the earth shows the wide range of iron in a soluble form present in the soil. The formation of starch depends on the presence of potassium. It must be understood that potassium is not the only factor necessary for the formation of starch; but if this substance is absent, even if all other conditions are favourable, as in the case of iron and chlorophyll so also with starch which contains no potassium, the latter being necessary for promoting the chemical changes resulting in the formation of starch. Phosphorus in like manner bears a similar relation to the albuminoids, as these are only formed when phosphates are present in the cells.

The plant obtains its food from surroundings in a purely physical manner. In the case of submerged aquatics, both carbonic dioxide and all salts are introduced in solution in water which is absorbed by the plant. In the case of terrestrial plants, the carbonic dioxide of the atmosphere is taken in by those parts containing chlorophyll, more especially the leaves, according to the well-known law of gaseous diffusion, which may be briefly expressed as follows:—When two or more gases that do not act chemically on each other are liberated in contact with each other, they gradually diffuse or mix until every portion consists of an equal admixture of all the gases, and when they have thus diffused themselves uniformly through one another, they never separate again in the order of their specific gravities.

The green parts of plants decompose carbonic dioxide during the day, that is, so long as the chlorophyll is exposed to light; hence the gas that passes from the atmosphere through the stomata into the interior at once loses its individuality. Consequently, obeying the law of diffusion, the gas is constantly passing into the leaf in the attempt to restore equilibrium, and by this purely physical process the plant obtains its carbonic dioxide. During the night, when the chlorophyll can no longer perform its functions, the inflow of carbonic dioxide ceases when the equilibrium between the outer air and the gaseous contents of the leaf is effected. In many of the lower plants, where stomata are absent, diffusion takes place through the cell-wall; this takes place to some extent in the higher plants also.

The roots of plants growing in damp soil, and not exposed to desiccation, are not furnished with an epidermis, and in many plants certain of the external cells of the youngest rootlets grow out into very delicate, one-celled hairs known as *root-hairs;* these are for the purpose of absorbing water from the surrounding soil that contain food substances in solution. In some plants root-hairs are not developed, when the superficial cells of the root perform their function.

The mode by which water is taken up by the root-hairs or cells of the root from the soil is due to the working of a physical law called *osmosis,* which may be stated as follows. When two liquids of different densities are separated by a pervious membrane, the denser liquid will attract a large proportion of the rarer liquid to itself through the membrane—the act of *endosmose*—a very small proportion of the denser liquid will at the same time pass through the membrane and mingle with the rarer liquid—the act of *exosmose.* The above law can be demonstrated by a simple experiment. If the bladder of a sheep that has been well washed in a weak solution of potassic hydrate, to remove the fat, be half filled with a fairly strong solution of salt and water, and then completely submerged in a bucket of pure water, it will be found after a while to be quite full of liquid, the dense salt and water having drawn through the membrane a large quantity of the rarer water. The cell-walls of root-hairs are permeable to liquids, and the contained cell-sap is normally much denser than the water in the soil, that rarely contains more than three per cent. of substances in solution, consequently the latter passes into the substance of the plant by endosmose.

It is a well-known fact that the ash of different kinds of plants growing close together in the same soil or water, may and does differ considerably in composition; this at first sight suggests a certain selective power possessed by plants, absorbing certain substances and rejecting others; when all the facts are analyzed, however, there is no evidence of any selection due to the presence or influence of the life of the organism, and the entire selective process can be fully explained by the laws of diffusion as previously explained. A given substance held in solution by the water in contact with the root of the plant will continue to diffuse into the plant until equilibrium is restored; if the substance is not consumed and chemically changed by the plant, the equilibrium once established remains permanent, and no more of the substance enters the plant, whereas if the substance is at once chemically changed on entering the plant, as in the case of carbonic dioxide already explained, a constant inflow is maintained in the endeavour to restore equilibrium. Since the chemical work done by different plants is varied in its nature, the difference in composition of the ash of different plants can be readily understood.

The above explanation will illustrate the object of the *rotation of crops* as practised by the farmer. The various food substances derived from the soil by plants are as a rule only soluble in very small proportions in rain water, the efficacy of which to promote this condition depends in many instances on the presence of small proportions of certain gases in solution, consequently if the same crop was grown for several years in succession on the same portion of ground, and the produce removed, as is usual in the case of cultivated crops, the supply of special food required by the particular plant would be exhausted; whereas, other substances that have been slowly dissolved, but of no value to the particular plant grown, would be wasted, the principle of rotation of crops overcomes this difficulty, and supplies each particular kind of plant sown with its own special kind of food. As an illustration of the above:—

Wheat, barley, and oats always contain a considerable amount of silica or flint in their ash, and this substance may be considered as the predominant inorganic food required by the above plants; peas, beans, and clover require lime, whereas potatoes and turnips require potash as their speciality. Now if any one of the above crops was sown for many years in succession on the same land, and the entire crop removed, it can be readily understood that the special food required would become scarce, whereas if wheat is sown one season and turnips the next, the latter crop not requiring silica, this substance would slowly dissolve and accumulate, and thus be present in sufficient quantity when the turn for sowing wheat came round.

In some virgin soils, rich in the various food constituents required by special plants, the same crop may be grown many years in succession, but eventually exhaustion takes place and the crop becomes deficient. The fact of forests and tracts of heath, etc., occupying the same position for centuries appears to contradict the above statement respecting the rotation of crops, but it must be remembered that in the case of forests all the inorganic materials removed from the soil are being constantly returned in the form of dead leaves and wood, so that practically the supply remains the same in quantity, and is used up over and over again by different generations of plants or even by the same plant. The object of manure is to artificially replace plant food in the soil when crops are grown and the produce removed.

The influence of light on plant life is exercised in a variety of ways, the following being amongst the most important:—

Assimilation. This term is generally used to express the decomposition of carbonic dioxide and water by chlorophyll under the influence of light, and thus differs considerably from the function expressed by the same term by the animal physiologist. As already explained, assimilation takes place only in those superficial cells containing chlorophyll, and further the chlorophyll can only exercise its function when exposed to light. The superficial cells of most young parts of plants growing in the air contain chlorophyll, and consequently assist in assimilation; but leaves are the most important organs in this connection, their general structure and flattening out into a thin sheet being for the purpose of exposing the greatest amount of surface from a given amount of material. Other important functions performed by leaves, as *respiration, transpiration,* etc., will be explained at a later stage.

The general structure of a typical leaf growing in a more or less horizontal direction is as follows. Every part is covered with the epidermis, and as a general rule the stomata or openings through the epidermis are most numerous on the under surface—the surface pointing to the earth. A single row of cells lying just below the epidermis of the upper surface of the leaf—the surface pointing to the sky—are closely packed together side by side, and arranged like a palisade with their ends pointing to the epidermis. This layer constitutes the *palisade tissue* of the leaf, so named on account of the arrangement of the cells already mentioned. The cells of this tissue are richly supplied with chlorophyll and give the deep green colour to the upper surface of the leaf, and their most important function is that of assimilation. The cells of the lower half of the thickness of the leaf form a loose spongy tissue with numerous large intercellular spaces, and contain less chlorophyll than the palisade cells, hence the paler colour of the under surface of the leaf. The intercellular spaces contain gases taken in for assimilation by the upper surface of the leaf, and also water vapour that escapes by transpiration from the leaf into the air, hence we observe that there is a division of labour in the work done by a leaf, the upper surface performing chemical work—assimilation—the under surface physical. The fibro-vascular bundles or "veins" of the leaf are in continuity with those of the branch from which the leaf originates, and form a network in the spongy, lower part of the leaf, and in many plants project from the under surface. The veins consist of phloem and xylem, the latter lies nearest the upper surface of the leaf which it supplies with water that has passed up from the root. The phloem forms the under side of the veins, and conducts from the leaf into the plant during darkness the assimilated material made by the leaf when exposed to light.

Chlorophyll grains are always imbedded in the protoplasm from which indeed they are formed, their formation commences while the cells are still in darkness, for example in young leaves before the expansion of the leaf-bud, and continues until they assume the sickly yellow colour presented by plants that have developed in the dark, as under logs or stones; for their further development, that is, the formation of the bright green colour, two conditions are necessary, exposure to light, and the presence of iron in solution in the cell-sap. The chlorophyll-grains do not fill the cell, but are arranged in the protoplasm just under the cell-wall, the central portion of the cell being filled with sap or the raw material ready for undergoing assimilation.

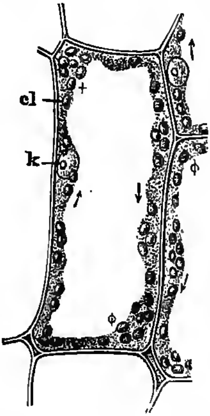

Fig. 19. Cell from the leaf of *Vallisneria spiralis*. The nucleus, *k*, and chlorophyll-grains, *cl*, are seen imbedded in the parietal layer of protoplasm. The arrows indicate the direction of the currents of protoplasm. (Highly magnified.)

The first observable product of assimilation is *starch*, which makes its appearance as small colourless grains in the chlorophyll-grains. Examined under the microscope, starch-grains present a characteristic appearance, being composed of alternating dark and light bands that are arranged, depending on the particular kind of starch examined, either concentrically or eccentrically round a hilum or starting point. This layered appearance is due to the alternation of dense layers with more watery layers, the hilum being the most watery portion of the whole grain. Starch is readily recognized by becoming blue when mixed with a weak, cold, watery solution of iodine. If the mixture is heated, the blue colour disappears but returns on cooling. The great majority of edible products furnished by the vegetable kingdom consist of starch which is obtained from those parts where it has been stored up by the plant for its own future use, as in seeds or fruits, as wheat, barley, rice, indian corn, sago, etc., the meal consisting of starch along with the cells in which it was contained; starch is sometimes replaced by sugar, as in ripe fruits, sugar-cane, beet, etc.

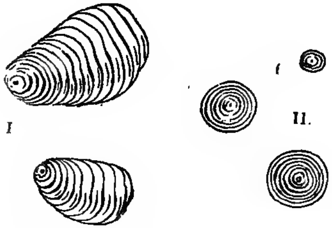

Fig. 20. *I*, Potato starch, with an eccentric hilum; *II*, Tapioca starch, with a central hilum. (Highly magnified.)

The above process of assimilation or conversion of carbonic dioxide into an organic compound is the only one known, hence all carbon present in the tissues of either plants or animals is in the first instance derived from the carbonic dioxide decomposed in the chlorophyll-grains.

Having shown the importance of light in connection with the very existence of plant life, it is necessary to enter a little more in detail respecting the influence exercised by this agent. It is generally known that what is termed solar light or popularly speaking sunlight, although apparently a white or colourless light, consists in reality of a mixture of several rays of light of different colours. These colours can be separated from each other by proper means, and constitute the solar spectrum, the colours being arranged in the following order: red, orange, yellow, green, blue, indigo, violet. Each colour possesses an individuality of its own, and so far as plant life is concerned it has been proved by experiment that the red end of the spectrum—that is, from the red to the green ray inclusive—is alone of value in enabling plants to effect certain chemical changes. As an example: if a plant showing the yellow colour due to being grown in darkness is exposed to the rays of the red end of the spectrum, the bright green chlorophyll will soon become visible, whereas if exposed to the violet end of the spectrum—blue to violet—no change in colour or formation of chlorophyll takes place. In like manner assimilation, or the formation of starch within the chlorophyll-grains depends entirely on the rays of the red end of the spectrum, no starch being formed when exposed to the violet end of the spectrum. The yellow ray is most powerful in promoting the formation of both chlorophyll and starch.

On the other hand all physical work promoted by light, as mechanical movements, are entirely due to the rays of the violet end of the spectrum. If seedlings of any twining plant be taken and exposed to the rays of the red end of the spectrum, no attempt at twining will take place, but the plant, if previously yellow, will soon become green, and thus continue to grow, as its chlorophyll will enable it to assimilate. If a similar seedling be exposed to the rays of the violet end it will commence to twine round its support, but not being able to develop chlorophyll will soon perish, thus proving that although all the rays of light are of service to plants, yet special kinds of work depend entirely on the influence exerted by particular rays.

Heliotropism.—Paradoxical as it may appear in face of the above statements, it is nevertheless a fact that light retards the growth of plants, or in other words, when plants are unequally exposed to light the side with least light grows fastest. This is clearly shown in the case of plants grown in a window, which always bend towards the light, not because, as usually believed, they like the light and are bending towards it, but, on the contrary, because the shaded side of the stem grows much faster than the one exposed to the bright light, and consequently becomes longer and convex, the shorter side becoming concave. If a mirror, or even a sheet of white paper is placed behind a plant growing in a window so that the light is reflected on to its dark side it continues to grow erect, whereas another plant of the same kind not so provided will bend towards the light. Plants that are influenced in this particular way by light are said to be *heliotropic*, and when the bending is towards the light, *positively heliotropic.* A few plants, as the common ivy, when unequally lighted, bend away from the light, owing to the side exposed to most light growing fastest. This habit is of value to the ivy, as its young shoots are thus pressed close to the wall or tree up which it is growing, and kept in this position until they have become plainly anchored by means of the numerous root-like organs of attachment that enter the crevices of the supporting body. Plants that bend away from the light are said to be *negatively heliotropic.*

Light also acts in a marked manner on many of the lower forms of plant life, some moving towards the light, others away from it.

Water, as already stated, is indispensable to all plants during active growth. Growing points require much water for the purpose of conveying the formative materials required for the building up of new tissues, and a certain amount of water is also used up in such formations. A cell containing protoplasm saturated with a large amount of water will give up water to a cell containing a smaller proportion of this substance, and as the young cells are almost entirely filled with dense protoplasm, there is a constant *slow movement* of water towards growing points induced by osmotic action and by the water being used up as it reaches these points. A second *rapid movement* of water is distinct from the slow movement, and supplies the water that plants exhale in the form of watery vapour through the stomata of the leaves into the air. The water is taken up by the root and is conveyed along the walls of the youngest portion of the xylem to the leaves. In darkness the stomata are almost or quite closed, so that little or no transpiration takes place. As light and heat are increased the stomata open, being specially influenced by bright light, and under these conditions the amount of watery vapour given off increases. The rigidity of leaves and young shoots depends on the presence of a proper amount of water in the cells; consequently, when the leaves exhale more moisture than is taken up by the roots the plant withers or droops. The drooping of plants on a very hot day is due to the above cause. During the night, when darkness and a lower temperature retard transpiration, the plants revive, as the root continues to take in water, which enters the cells and restores their turgidity.

Gravitation exercises a powerful influence on the growing parts of plants, the upward direction of the stem and the downward direction of the root being influenced by this force. The action of gravitation on growing parts of plants is called *Geotropism.* If a seedling plant be placed horizontally the stem curves upwards, and the root downwards; the former is negatively geotropic, the latter positively geotropic. The branches and leaves of plants are also affected by geotropism. The cause of geotropism is the unequal growth of the cells on opposite sides of the stem or root, as in the case of heliotropism; hence we get similar results brought about by distinct forces, and in a state of nature the habit of every plant is the result of the influence of the various forces to which it is exposed; but as there is a distinct individuality in the life of each kind of plant, so we find that the various forces act in different proportions on different species, the result being a difference of habit as illustrated by the erect branches of the poplar and the spreading branches of the oak. That the above explanation as to habit being the result of the balance set up between the life of a given species and surrounding forces is in the main correct, is shown by the variation of habit that can be induced in a plant when intentionally placed under unusual conditions relative to the forces that under normal conditions collectively determine its habit. When seeds are caused to germinate on a horizontally-placed rotating plate, the plantlets are placed under the influence of centrifugal force, a factor that exerts no influence on them in a state of nature; but under these artificial conditions this force at once disturbs the previous balance arrived at between the plant and its surrounding potent forces, and we find that the rootlets follow the centrifugal force and grow outwards, also downwards, due to the influence of geotropism; the stem, on the contrary, grows towards the centre of the plate and also upwards. When a number of plates are used that rotate at different speeds different directions can be given to the root and stem depending on the predominance given to centrifugal force or gravitation, the two dominant external forces in the experiment. Other external influences also possess the power of neutralizing the influence of geotropism as exercised under normal conditions. Thus, when seeds, as those of the bean, are grown in a wire sieve filled with damp sawdust, the main roots are at first positively geotropic and consequently grow downwards, but after passing through the bottom of the sieve into dry air they bend upwards again and enter the sawdust, being drawn by the water, which, under these exceptional conditions, completely neutralizes the action of geotropism. This attracting influence of water is termed *Hydrotropism*.

The influence exercised by the vegetable kingdom on surroundings in performing those functions necessary for the welfare of its own members is very varied and important from the point of view of animal life. The exhalation of watery vapour into the air has already been alluded to, and it has been proved that this function influences to a very great extent the climate of a country. Where forests have been cut down on a large scale, as is frequently the case in newly occupied regions, the springs have become less abundant or completely dried up. On the other hand, where the rains are excessive the climate has been rendered drier by the cutting down of the forests. This was especially marked in the neighbourhood of Rio Janeiro, where the climate was rendered dry by the removal of the dense forest surrounding the city, and eventually the rain had so much diminished that the Brazilian Government were compelled to pass a law prohibiting the further cutting down of trees. Experiments have shown that a sunflower $3\frac{1}{2}$ feet high, weighing 3 lbs., and with a leaf area of about 5,616 square inches, exhaled 20 ounces of liquid in the course of a day; a cabbage plant, with a leaf area of about 2,736 square inches, exhaled on an average about 19 ounces of water in a day.

It is usually stated that green plants purify the atmosphere from the point of view of animal life by removing carbonic dioxide and restoring oxygen, and this is perfectly true; but it is equally true that every plant also gives off carbonic dioxide into the atmosphere and removes oxygen, exactly as all animals do, and in connection with the same function, that of *respiration*, or breathing. A little attention to the fact that the removal and restoration of carbonic dioxide to the atmosphere is respectively the outcome of two distinct functions will make clear what at first might be considered as a contradictory statement.

In the act of nutrition, as already explained, carbonic dioxide is removed from the atmosphere in considerable quantities and used by the plant as food. This function can only be exercised when the plant is exposed to light, and ceases when the plant is placed in darkness; consequently, in a state of nature, plants only remove carbonic dioxide from the atmosphere during the day. This act is accompanied by the restoration of a considerable amount of free oxygen to the atmosphere, in fact, an equal amount to that taken in chemical combination with the carbon as carbonic dioxide. The function of respiration, which is common to all forms of life, both animal and vegetable, is a purifying process, exercised for the purpose of removing certain worn-out material, especially carbon, from the body; this substance is removed in the gaseous form as carbonic dioxide. Oxygen is inhaled from the atmosphere, and, chemically combining in the tissues with the waste carbon, is exhaled or returned to the atmosphere as carbonic dioxide. This exchange of gases in the plant world is mainly due to diffusion, the mechanical auxiliaries present in connection with respiration in the higher animals being absent from plants. The function of respiration, in plants as in animals, is unaffected by the presence or absence of light, and is exercised uninterruptedly during the life of the individual; hence in the performance of this function plants are always removing oxygen from and adding carbonic dioxide to the atmosphere; but the respiration of plants is a comparatively slow process, and as very much more carbonic dioxide is removed from the atmosphere and oxygen restored to it during the presence of light, in the act of nutrition than is the converse in the function of respiration even during the whole day, consequently the statement that plants purify the atmosphere is perfectly true, yet it is necessary to remember clearly the manner in which this function is effected.

If the above explanation has been understood, it will be seen that living plants tend to purify the atmosphere of an apartment during the day by removing much more carbonic dioxide from the atmosphere than they give off, and also by adding oxygen to the air, whereas during the night oxygen only is removed from the atmosphere and carbonic acid alone liberated, thus rendering the atmosphere impure for animal life. The above are the results that would be obtained by experimenting with plants in a closed volume of air under the two given conditions, but in a well-ventilated room, unless the amount of plant life is excessive, on account of the slow process of respiration, no inconvenience would be experienced.

The element nitrogen, being one of the constituents of protoplasm, is required by all plants, and, although abundant in the atmosphere, is never taken in direct in this form, but is obtained from salts of ammonia and nitrates present in the soil. Some plants, however, do not obtain the whole of their nitrogen in this manner, but, according to the extent of differentiation they have undergone in connection with this function, obtain a greater or less amount from members of the Animal Kingdom, and for this reason are known as *carnivorous plants*, or the term *insectivorous* plants is sometimes

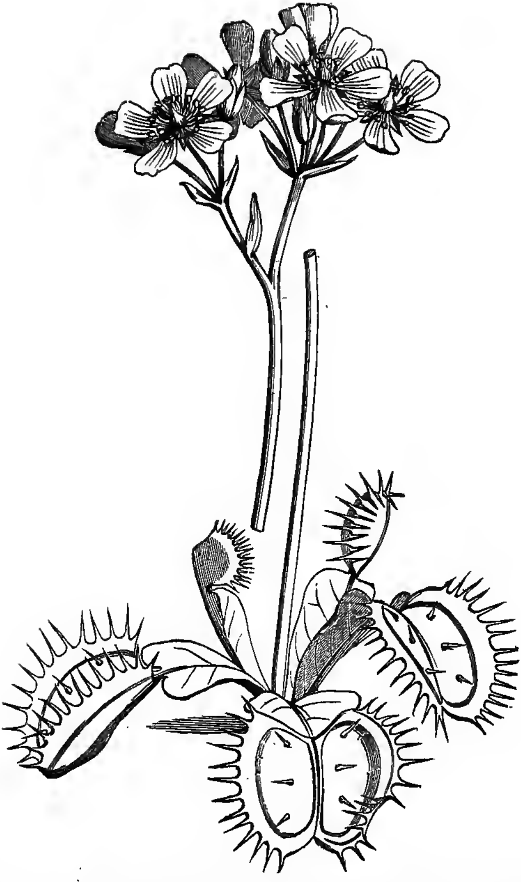

Fig. 21. Venus's Fly-trap (*Dionœa muscipula*), a carnivorous plant. The leaves are sensitive to contact, and in the undisturbed condition are expanded. When either of the three small hairs situated on each half of the upper surface of the leaf are irritated by contact with a small insect, the two halves of the leaf close together and remain closed until the irritation has ceased. (Natural size.)

used, because the members of the animal kingdom captured by plants are usually insects.

This peculiar carnivorous propensity exhibited by certain plants does not appear to have been possessed by such for all time, but must rather be looked upon as an acquired character. The evidence in favour of this idea is the fact that carnivorous plants occur belonging to widely separated families of plants, and, further, that every phase of differentiation in the development of those characters that enable a plant to benefit by a carnivorous habit is met with in the various members included under this heading.

Carnivorous plants are generally inhabitants of swamps or marshy places as the sundews (*Drosera*), butterworts (*Pinguicula*), pitcher plants (*Nepenthes*), etc., others, as the bladderwort (*Utricularia*), are aquatic. Most agree in having imperfectly developed roots or in being entirely rootless. The leaves of carnivorous plants, either entirely or in part, are the portions modified for the purpose of capturing insects. In some kinds, as the sundews, the leaves are sensitive and close round the insect alighting on the upper surface which is furnished with glands that secrete an acid and a substance closely resembling pepsine; these secretions, which closely resemble in composition and function gastric juice, act on the body of the insect, and a true process of digestion, similar to what occurs in the stomach of an animal, takes place, in fact, the leaf when curled up and digesting an insect may be compared to an extemporized stomach. The leaves of our common sundews are bright red on the upper surface, possibly for the purpose of attracting insects, and are furnished round the margin with a row

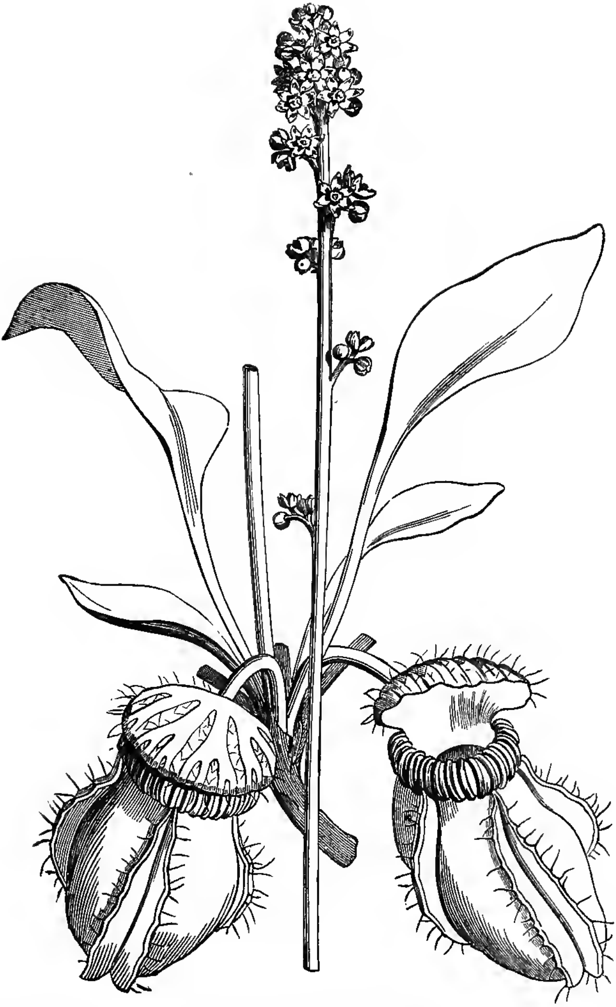

Fig. 22. *Cephalotus follicularis,* a carnivorous plant met with in Australian swamps, showing some of the leaves modified into pitchers or *ascidia* that are furnished with a movable lid.

of glandular hairs, each of which secretes at its swollen tip a sparkling drop of viscid fluid which increases in size as the sun's heat increases, hence the popular name of sundew. If an insect comes in contact with a single gland, more fluid is secreted, and as the victim struggles its movements only hurry on its own destruction, other glands bend over to the place where the struggle is going on, until finally the insect is surrounded by the leaf and eventually digested, after which the leaf slowly expands, the remains of the insect being removed by wind or rain. Nepenthes agrees with the sundew in digesting its prey, the digested matter being then absorbed. In Utricularia and *Sarracenia* the insects are not digested but become putrescent on the surface of the leaf or in the pitchers, the putrescent matter being then absorbed. In the butterwort, not uncommon in some parts of England, the leaves form a rosette lying on the ground, are of a pale yellow-green colour, and covered on the upper surface with a viscid exudation which acts like birdlime to any insect alighting on its surface. When irritated by the struggles of the insect the leaf curls slowly inwards and enfolds its victim, expanding again when the irritation has ceased and the nitrogenous portions of the insect have been absorbed. The butterwort digests its food after the fashion of the sundew, but on the whole it does not appear to be specially adapted for the capture of living insects, and depends more on dead nitrogenous matter being deposited on the leaf. The popular name of butterwort is derived from the fact that the leaves were at one time used for the purpose of curdling or giving consistency to milk, due to the presence of the digestive fluid in the leaves. It is

Fig. 23. *Nepenthes gracilis*, a pitcher-plant inhabiting swamps in the East Indies. Some of the leaves are normal, others have the midrib continued as a long, slender, tendril-like stalk that becomes expanded at the apex into a hollow pitcher-like body furnished with a lateral opening near the apex, and constructed for the purpose of capturing and digesting insects.

interesting to note that a substance called rennet, consisting of portions of calves' stomachs, is still used for a similar purpose, its efficacy being also due to the presence of gastric juice. In Utricularia or bladderwort, the plants are aquatic and rootless, and the much cut leaves bear several little bladders that act as traps to water-fleas and other minute aquatic animals. Finally, in many exotic species, popularly known as pitcher plants, certain of the leaves are modified into hollow pitcher-like receptacles specially arranged for the capture of insects, or, in some species where the pitchers are large, of humming birds or small animals. In the species of Sarracenia, inhabiting the turfy, spongy bogs of America, the pitcher-shaped leaves are very effective fly-traps. A sugary juice is secreted round the mouth of the pitcher that attracts insects, which descend lower in the tube, and are precipitated into a watery secretion filling the bottom of the pitcher, their egress being prevented by a ring of reflexed hairs. The walls of the lower portion of the inside of the pitcher are lined with glands that secrete a digestive fluid that mixes with the water in the pitcher.

Parasites and Saprophytes.—The foregoing remarks respecting the nutrition of plants and their influence on surroundings, applied solely to what may be termed typical plants; that is, plants developing chlorophyll, which embraces the great bulk of the members of the vegetable kingdom. There are, however, a very large number of true plants that never develop chlorophyll, and consequently cannot assimilate inorganic matter as food, but, like numbers of the animal kingdom, require organic food. Such plants fall naturally under two sections. (1) *Parasites,* plants that obtain their food from the bodies of living plants or animals; as examples may be mentioned the various species of broomrape (*Orobanche*), the dodders (*Cuscuta*), and numerous species of fungi, as the mildews causing the potato disease, also that of the hop, vine, etc., to which may be added those fungi popularly known as "rust," "mildew," and "bunt," that are so very destructive to many of our important cultivated plants, more especially the cereals. Several species of fungi grow on the bodies of living insects; the disease known as "muscardine," that commits such havoc with the caterpillar of the silkworm moth, is caused by a fungus. The plant or animal to which the parasite is attached, and from which it derives its food, is termed the *host,* a term which, if plants could express their feelings, would probably be considered as sarcastic, inasmuch as the hospitality is altogether involuntary, and greatly to the detriment of the host. Parasitism is an acquired function. Parasites occur in natural orders of plants that are widely separated from each other, proving that this function has originated independently at many points, and, judging from the relative amount of modification presented by different plants for the purpose of enabling them to hold their own under the new conditions imposed by becoming parasites, it would appear that this retrogression or falling back from the characteristic mode of plant nutrition had occurred at widely-separated periods of time; but this need not necessarily be so, as it is well known that plants, like animals, vary to a very marked extent in their power of adaptation to changed conditions, some that possess what may be termed an elastic constitution, readily accommodating themselves to very marked changes, others being rigid, either entirely disappear or retire into the background when placed under similar conditions. A second reason in support of the idea that parasitism is an acquired function that has been gradually evolved, and is still going on at the present day, is the transitional forms from chlorophyll-producing plants to others entirely destitute of chlorophyll. The well-known mistletoe (*Viscum album*) is an example of such a transitional species, being a parasite to the extent of obtaining from the host upon which it grows all the food and water taken from the soil by the roots of the host plant; but the leaves of the mistletoe contain chlorophyll, hence it still retains and exercises the property of taking in carbonic dioxide from the air, and of producing starch in the normal manner. The stage of parasitism reached by this plant is that of taxing a host plant to supply the required amount of water with food substances in solution, instead of taking them directly from the soil for itself. In the figwort order (*Scrophulariaceæ*), as understood in the broader sense, we have even in British species an interesting sequence in the evolution of parasitism; the species of eyebright (*Euphrasia*), yellow rattle (*Rhinanthus*), lousewort (*Pedicularis*), and *Bartsia*, all common plants of our meadows and moorlands, have leaves furnished with the normal amount of chlorophyll, and, so far as general appearance goes, appear to obtain the whole of their food in the manner normal to ordinary plants; but in reality all are to a certain extent parasites, or, as one might say, have broken away from the normal plant-mode of obtaining food, and resorted to a device for obtaining a certain portion by a means which, if secured at a less cost in the first instance, leads eventually to a comparative loss of freedom and individuality. All the species enumerated only grow and flourish when in close contact with other plants. In every instance the seeds on germination give origin to a root that in the first instance derives food by absorbing water from the soil, but this first-formed root soon perishes, and the later-formed or secondary roots become attached to the roots of other plants, from which they draw the liquid portion of their food. If seeds of either of the above plants are intentionally sown apart from other plants, it will be found that after a very brief existence they die, having become so far differentiated on the road towards parasitism, that their roots cannot take in food direct from the soil, yet in every example the leaves are still green and capable of assimilation. It is interesting to note that in the earliest condition, that is, immediately after the germination of the seed, the young plants obtain all their food by the typical method. In the toothwort (*Lathræa squamaria*), and the species of broomrape (*Orobanche*), the change in the direction of parasitism has been carried much further; not only has the chlorophyll been completely suppressed, but even the leaves themselves have become reduced to mere scale-like structures of no functional value, and the plant depends entirely on its host for its supply of already assimilated food, the only trace of individuality retained by such pronounced parasites being the power of rearranging the food thus obtained and building up the reproductive portion of their degenerated structure. In extreme cases of parasitism, as illustrated by the species of *Rafflesia*, natives of the

East Indian Archipelago, the vegetative part is reduced to an absorbent portion that is completely buried in the substance of the host; the flowers, or reproductive portion, on the other hand, often attaining enormous dimensions, the flowers of *Rafflesia Arnoldi* measuring nearly three feet in diameter. This loss of balance due to a parasitic habit between the vegetative and reproductive parts of plants, has its counterpart in the animal world, where such parasites as the tapeworm are reduced to the reproductive portion, and, like the last-named animal, many parasitic plants belonging to the fungi spend different periods of their existence or life-cycle on different host-plants; thus the common "rust" of wheat and other cereals, *Puccinia graminis* appears in the early summer on the leaves and stems as bright rust-coloured streaks, hence the popular name; if the spores or reproductive bodies which constitute the rust-coloured powder be examined under the microscope, they will be found to consist individually of a single cell with a bright brown rough cell-wall; these spores as soon as mature, if carried by wind or rain on to other grass-leaves or stems, germinate at once, the mycelium penetrating into the tissues, where in a short time it produces similar rust-coloured streaks, that burst through the epidermis and appear on the surface, ready to be transported and form the starting-point for a new colony; in this manner the rust spreads rapidly during the summer months, and being a thorough parasite, robs the host of a considerable amount of assimilated food originally elaborated for its own use; towards the autumn, the streaks on the stem and leaves become somewhat darker in colour, and if a portion of the powder is examined under the microscope, a number of spores as already described will be seen, but mixed with these, and produced by the same mycelium or vegetative portion of the fungus, will be found spores of a totally different form and colour, each consisting of two superposed cells furnished with a smooth, brown cell-wall; as the season advances, the streaks formed on the stem and leaves are almost black, and on examination the spores will be found to consist entirely of the last described two-celled kind, the one-celled first formed kind having entirely disappeared. If the above explanation has been understood, it will be seen that the fungus during its development has completely changed the nature of its spores or reproductive bodies not only in colour and structure, but what is of more importance, in function also; the two-celled spores produced in the autumn cannot germinate at once when mature, but pass the winter in an unaltered condition, being carried to the ground by the fall and decay of the leaves or stems on which they are produced. The following spring these spores germinate as follows: each cell of the spore produces a short slender branch or germ-tube, that produces near its tip two or three very minute spores called *promycelium spores.* These minute spores can only germinate when carried by wind or some other means on to the surface of the newly-expanded leaves of the common barberry (*Berberis vulgaris*) ; when once located in this position germination commences, and soon a slender germ-tube is produced by the spore, that at once bores through the epidermis of the leaf, and develops a mycelium or vegetative portion at the expense of the leaf; after a time the mycelium produces dense clusters of yellow spores, at first arranged in chains, inclosed in an external covering; the whole cluster eventually bursts through the epidermis of the leaf, the external covering is ruptured at the top into a number of teeth that curl backwards, the dense mass of golden-yellow spores being now dry and powdery, and in this state are readily blown away by the wind. This stage of the parasite is popularly known as "cluster-cups," on account of the membrane covering the spores more or less resembling a cup with a toothed margin after bursting open, and in being produced in clusters. Finally, the spores of the cluster-cup stage must be carried by some means on to the surface of a grass leaf or stem, where they at once germinate, the germ-tube entering the leaf through a stoma, where a mycelium is formed that gives origin to the rust-coloured streaks consisting of the one-celled spores that the description commenced with. Until recently the three stages described above were considered as totally distinct individuals. The term *Heterœcism* is used to express the fact that a parasite passes different phases of its life-cycle on different host-plants. The above is not an isolated or exceptional example; we have in Britain alone numerous heterœcismal species of fungi, the cluster-cup or *Æcidium* stage being amongst the most beautiful of microscopic objects.

Up to the present true parasites have been dealt with, and in such instances everything is in favour of the parasite, the host being in no instance benefited by the presence of its unwelcome guest, but in some instances we find that parasite and host have become so thoroughly adjusted that both benefit mutually by the combination. This condition of things is called *mutualism* or *commensalism*, and in the vegetable world is well shown in the large group of cryptogamic plants called *Lichens*, that were until recently considered autonomous plants, as their relations, the Algæ and Fungi, are in reality. It has, however, been clearly proved that every lichen is what may be termed a compound organism, consisting of a fungus and an alga leading a life of mutualism, and

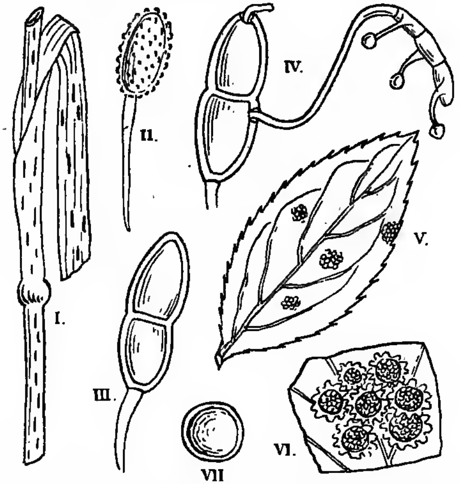

Fig. 24. Illustrations of the life-cycle of the parasitic fungus known as "rust" on wheat and other grasses (*Puccinia graminis*). I. the rust-coloured streaks of the fungus on stem and leaf of wheat plant (natural size); II. spore of the spring stage, known as *uredospores* (highly magnified); III. two-celled spore of autumn stage, known as *teleutospores* (highly magnified); IV. a teleutospore germinating and producing a promycelium bearing three promycelium-spores (highly magnified); V. a leaf of the barberry bearing groups of the "cluster-cup" or *Æcidium* stage (natural size); VI. a portion of a barberry leaf with a group of "cluster-cups" (slightly magnified); VII. a single spore belonging to the æcidium stage, called an *æcidiospore* (highly magnified).

together constituting the individual. The algal element, being possessed of chlorophyll, assimilates carbonic dioxide and forms organic carbon compounds, while the mycelium of the fungus portion absorbs water containing mineral substances in solution. The mycelium of the fungal portion of the lichen clasps the cells of the alga so closely that a transfusion of the substances absorbed by the two respectively takes place; but this differs from a case of true parasitism, inasmuch as alga and fungus mutually benefit. The fruit of every lichen is formed entirely by the fungal element. The formation of a new lichen depends on the spores produced by previous lichen germinating in contact with an alga the cells of which are clasped by the mycelium of the germinating spore, and growth or increase in size is effected by the independent and contemporaneous growth of the two individuals. This perfect balance and readjustment of the division of labour between two originally distinct plants to form a third possessing pronounced peculiarities of its own, with a corresponding loss of individuality of its components, is a marked illustration of the adaptability of life, and is not an isolated example, as mutualism in every phase of development exists in various divisions of both the animal and plant kingdoms, and well authenticated instances of mutualism between plants and animals are also on record.

(2) *Saprophytes.* Plants that obtain their food from dead organic matter, and are always destitute of chlorophyll, or at all events possess such minute traces as to be of no functional value in assimilation, but is of interest as one of the proofs of their having degenerated from chlorophyll-bearing ancestors, other points of evidence

in this connection being the close morphological or structural agreement with species that yet produce chlorophyll. As examples of saprophytes may be mentioned the numerous species of fungi popularly known as "toadstools" that grow on rotten wood, manure, etc., also other species of fungi, as the common mushroom (*Agaricus campestris*), that grow on the ground, and which might be supposed to feed on inorganic food like green plants; but this is not the case, the mycelium of the fungus absorbs organic food supplied by decaying vegetable matter present in the soil. Amongst saprophytic flowering plants found in Britain may be mentioned the bird's-nest orchis (*Neottia nidus-avis*), and the coral-root orchis (*Corallorhiza innata*).

Typical parasites and saprophytes, having no chlorophyll, never remove carbonic dioxide from the atmosphere, neither do they give out oxygen, but act like animals in removing oxygen and giving off carbonic dioxide in the act of respiration. Such plants are not influenced by light in connection with nutrition.

Comparing saprophytes and parasites with plants producing chlorophyll, it will be observed that the former class save a considerable amount of labour by obtaining their food more or less ready made, but this gain is more than neutralized by a loss of individuality and freedom, and are necessarily more limited in their distribution. A green plant can establish itself wherever there is a supply of moisture, proper soil, and a suitable temperature; the atmosphere being everywhere is not a determining factor. The parasite requires all the above conditions to enable its host to be present, *plus* the host; and as many parasites have become so specialized as to be able to procure their food from one particular kind of host, it follows that its distribution is determined by that of its host. Saprophytes, only requiring decomposing organic matter, have a somewhat wider range, being confined to those regions where life exists, but some saprophytes appear to be partial to special kinds of organic food.

Metastasis. The substance formed by assimilation in the chlorophyll-grains, which is usually starch, sometimes fat, or rarely cane-sugar; this constitutes the raw material from which all the substances present in plant tissues are formed. In this elaboration, oxygen, nitrogen, and the various mineral substances taken from the soil are also utilized. The most important and indispensable of substances formed by the plant are those concerned in the formation of the protoplasm and the cell-wall; such are called *plastic* substances. The plastic substances are not used up entirely in the organs where they are formed, but change their position and are either used up at once in the formation of new cells, or are stored up as *reserve material* for future use. The change in position of elaborated material is usually accompanied by a change in chemical composition for the purpose of facilitating the transport. This is the process of *Metastasis* or *Metabolism.* The solid starch formed in chlorophyll-grains is converted into a glucoside, in which condition it can travel along the stem, and is converted back into starch when it reaches the specialized part destined to store it up until required for use; all seeds contain a supply of reserve material for the purpose of furnishing the young plantlet with its first food until it develops green leaves and is able to assimilate for itself. Potato tubers, swollen roots, bulbs, and the trunks of trees also contain reserve material for future use. During the process of metabolism a great many products are formed that are of no known use in plant economy, and may be termed by-products of metastasis; as examples may be mentioned several volatile oils, acids, alkaloids, resinous matters, etc. *Degradation products,* as the various kinds of gum, are produced by the more or less complete disintegration of cell-walls, and cannot be re-converted back into plastic or formative material.

CHAPTER III.

PROTECTIVE ARRANGEMENTS.

Origin of the Vegetable Kingdom.—The struggle for existence. —Protection against climate.—Protection against living enemies.—Saving of energy and expenditure of material exhibited in modern modes of protection.

IT is generally admitted that the entire Vegetable Kingdom clothing the earth at the present day—as also those groups unsuccessful in the bitter fight for life, and only known to us by their fossil remains—have evolved by a slow series of changes from the Algæ or seaweeds, hence the members of this group may be considered as the pioneers of plant life. It is not intended to discuss the various ideas respecting the origin of life, but—granted life—to indicate the leading modifications that have taken place in the members of the plant world and to which are collectively due the enormous variety of structure presented by plants at the present day.

Protection in the broader sense, as including all the various arrangements and contrivances for enabling an individual to do a given amount of work in a better manner and with a less expenditure of energy and material than heretofore, appears to be the one aim of every member of the Vegetable Kingdom at the present day. Self-sacrifice and philanthropy are factors not

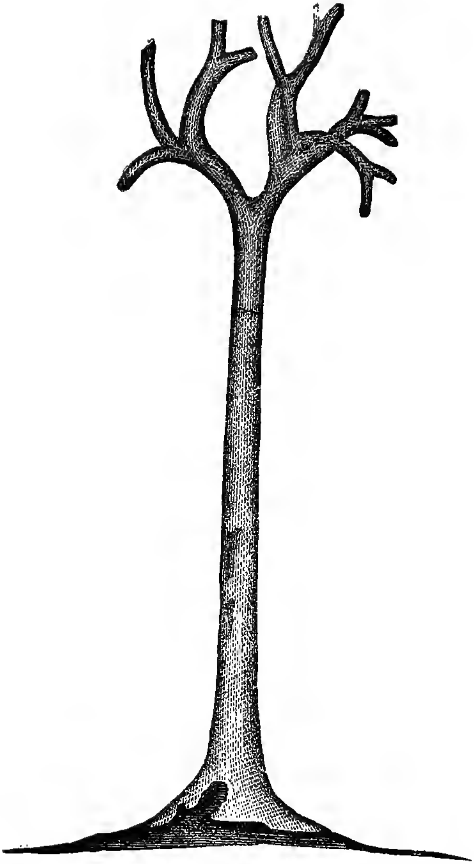

Fig. 25. Trunk and portions of the branches of a fossil called *Lepidodendron*, illustrating a group of plants that formed vast forests during the Carboniferous period, but which have been extinct now for many geological ages. (Much reduced.)

exercised by plants in reality, although, as in some of the higher members of the Animal Kingdom, suggestions of these virtues are paraded by certain plants for the purpose of accomplishing an object by surreptitious methods.

The proofs of the evolution of all groups of plants from seaweeds must be sought in more advanced works than the present, where the evidence will be found more convincing than is generally considered by those who have never paid special attention to the study of plant life. The fact that seaweeds still remain as seaweeds, or, in other words, the reason why all the lower types of plants have not evolved and got away from their primitive starting-point, is not known; neither is it known why the half dozen children constituting a family do not all exhibit exactly the same tendencies in every respect; we all know that such is not usually if ever the case, and the variations of degree presented by the members of a family should at least convince those most opposed to evolution that all human beings are not cast in the same mould, but that there must be a certain amount of internal structural difference to account for the difference of external manifestations; for if the structure and composition of every human being was absolutely identical, it would be contrary to all experience to expect other than absolutely identical results. The same argument in favour of infinitesimal differences between the members of a family apply equally to the half dozen peas taken out of the same pod, and if the truth of even the slightest amount of variation is admitted as existing in the members of a group, to what extent may this variation extend? The evolutionist's answer would be that the limits of variation, as also its direction at different times and under different conditions, are at present unknown. The person opposed to evolution or the numerous class that are quite indifferent on the subject and are only acquainted with the traditional origin of all forms of life, while compelled to admit a certain amount of individual variation, argue that every given plant and animal was always what it is at the present day, and ask, why do not the marked changes from one form to another, that you ask us to believe, still go on at the present day? The first statement, that things are now what they always were, is simply expressing an opinion that finds no support in nature; if species had been the same in all time past, then we should expect to find their fossil remains in the rocks, but this is not the case; what we do find is, as already stated, in the early geological formations, the remains of plants belonging to types that have long ago become entirely extinct; the same is true of animal remains; in other instances vast remains of plants occur in a fossil condition, which, from their abundance and structure, prove that geological ages ago they were far more abundant and highly organized than their survivors are at the present day; such groups may be said to have long ago passed the maximum of their development and are now on the decline. This condition of things is illustrated by the group of plants known as *Gymnosperms,* which includes the pines, firs, yews, cycads, etc., characterized by the absence of fruit in a botanical sense, and by the naked *ovules* or young seeds. The Gymnosperms as a group were in the heyday of their prosperity, and the monarchs of the vegetable world, both on account of the high organization and size during

Fig. 26. A cycad (*Cycas circinalis*), illustrating a type of plant life that was abundant in early geological ages, but now on the wane, and fast disappearing. The general habit resembles that of the modern palms, but its affinities are widely separated from those plants. (Much reduced.)

the Mesozoic period; their decline is first indicated in cretaceous times, and since that period up to the present has been increasing. A few representatives yet remain, but, as is well known, they do not stand in the first rank of plants either structurally or numerically, being quietly superseded by the group known as *Angiosperms,* characterized by having the seed inclosed from the earliest stage in a special structure, the fruit, and including the great bulk of vegetation existing at the present day.

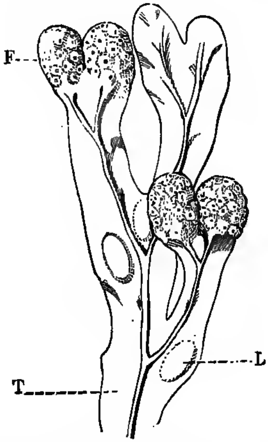

Fig. 27. A portion of one of the large olive-brown seaweeds (*Fucus vesiculosus*), showing the air-containing cavities, *L*, that act as floats or buoys; *T*, thallus or vegetative portion; *F*, fruit-bearing tips. (Natural size.)

Submerged aquatic plants show the least amount of specialization in connection with protection against either enemies or climate, and in such primitive groups as the Algæ protective arrangements are almost entirely absent;

it is true that in some species the taste is very pungent, but this does not avail them against the nibblings of certain molluscs. In other species specialized strands of cellulose are present for the purpose of strengthening the cell-walls and to neutralize the strain exerted on the tissues by the movement of the water; others, again, have special contrivances in the way of hollowed-out portions of the thallus or vegetative portion of the plant that contain air for the purpose of enabling the plant to float on the surface of the water, and thus expose itself to light in connection with the function of assimilation.

Notwithstanding the primitive nature of the Algæ as a group, we find the leading ideas of plant life clearly indicated within the group. In the simplest *unicellular* or one-celled microscopic forms, the single cell is often spherical, and even when we come to *multicellular* species consisting of numerous cells, the same idea of solidity is present; but in the higher groups we find this weak point rectified, and the substance of the vegetative portion flattened out into comparatively thin sheets —leaves in fact in function—for the purpose of exposing the greatest amount of area possible from a given quantity of material, thus enabling the organism to assimilate a greater amount of food, an indispensable necessity for the well-being of the individual. In connection with reproduction, or the continuation of the species in time, there is a sequence from the primitive asexual or vegetative mode to highly differentiated sexual methods, which are so arranged as to render possible the invigorating influence of cross fertilization; and from the algæ upwards, the great variety of forms occurring in plant life are to a great extent due to the various successful and unsuccessful modifications of the crude ideas of nutrition and reproduction that were contemporaneous with the appearance of the simplest members of the Vegetable Kingdom.

The most complete and highly differentiated protective arrangements are met with in Phanerogams, and even here the aquatic forms show least specialization in this respect. Amongst terrestrial species the modes of protection even against the same enemy are very varied in the different species. Leaving for the present the contrivances for protection in connection with the reproductive portion (that will be described later on), we find the various arrangements for protecting the individual to fall under two headings—protection against climate, and protection against living enemies. As would be expected, the two divisions meet and overlap at many points, for it may be stated as a general rule that every case of specialization originates for the performance of a certain specific function, and if the experiment proves a success, and consequently becomes a permanent feature, further modifications are superadded which may serve purposes widely different from the original, and thus by various modifications and amendments, such structures, that originated in a simple form and for a specific purpose, become extremely complicated, not only by the addition or modification of parts that still perform functions of service to the plant, but also by the remains in various stages, of structures that at one time performed work of real service to the individual, but which for some reason or other have been superseded; but such structures, when once fully evolved, cannot be at once arrested by the plant when no longer of service, but remain for a long time in a rudimentary condition.

(1.) *Protection against climate.*—All climatic conditions are not equally favourable for the development of plant life, and as would be expected, in proportion as plants have adapted themselves to live under more and more unfavourable climatic conditions, the more marked will be the modifications undergone to combat these conditions. Taking as the typical plant structure living under favourable conditions, we find in the majority of instances a stem more or less erect, and bearing flattened leaves, borne in a scattered manner on branches for the purpose of exposing each leaf to the light, an indispensable condition for the performance of its functions, as already explained. A marked departure from this general arrangement of stem and leaf is illustrated by certain groups of plants that grow in very arid regions. The cactus family, characteristic of and almost entirely confined to the dry regions of Western North America, is remarkable for the partial or complete suppression of leaves, but to compensate for the arrest of these important organs, the stem is furnished with chlorophyll, and usually has prominent ridges or wings, for the purpose of exposing a larger amount of assimilating surface than would be the case with the ordinary cylindrical trunk. Clusters of spines that originate from certain abortive buds are usually present, and act as protective organs against herbivorous animals that would otherwise browse on the succulent and watery stems. In Central Africa a similar habit is assumed by the members of a widely-separated order of plants, the spurges; in fact, so close is the resemblance in habit that these plants are usually considered as cactuses by travellers. The object of the above described modification is obvious; if ordinary leaves were developed, the extreme heat and aridity would cause transpiration of water to take place at a much greater rate from the thin layers of tissue than could be supplied by the roots, the leaves would consequently become flaccid and unable to perform their functions, whereas when the entire mass of tissue is embodied in a solid, succulent trunk furnished with chlorophyll, less surface is exposed, and a phase of life, if not the highest, is maintained. It is a case of doing the best under the circumstances, and, as would be expected, cactuses have not made any startling development since they adopted their present mode of life. As a rule, plants of dry regions are characterized by thick fleshy leaves, and the stem remains green and succulent, thus aiding the leaves in the functions of assimilation, respiration, etc.

The most modern group of plants, the Angiosperms, are divided into two primary divisions: *Monocotyledons*, including the palms, lilies, grasses, sedges, etc., and *Dicotyledons*, that includes all European forest trees except the firs and pines that belong, as previously stated, to the Gymnosperms, and the great bulk of smaller flowering plants excepting the groups named above. The broad features of evolution presented by leaves can be well studied in the sequence presented by the members of our own flora. In Monocotyledons, geologically the oldest group, the leaves are generally long and narrow and with the edge or margin entire or uncut, as seen in grasses, sedges, daffodils, lily of the valley, etc. Such structures agree literally with the stock definition of a leaf, as given in antiquated text-books—"a flattened-out expansion of the stem;" and this is in reality what the typical leaf originally is, an expansion of a plate of tissue containing all the important elements of the stem, to which it is attached by a broad base, with the fibrò-vascular bundles, or veins, sunk in the parenchymatous portion, running in a parallel series and not forming a network; and when the leaves grow erect, as in the grasses, irises, etc., the two surfaces agree in structure; in fact, it may be said that the utility of the leaf was thoroughly realised by monocotyledonous plants, and the fundamental idea thoroughly developed, whereas in the dicotyledons those improvements and finishing touches were evolved that, surface area being equal, enables the perfectly-evolved leaf of the Dicotyledon to do far more work than its primitive monocotyledonous prototype.

In the dicotyledonous leaf there is often a more or less elongated stalk or *petiole* that serves to carry the leaf away from the branch producing it and placing it under favourable conditions with regard to light. As a rule, the leaves are placed horizontally, and exhibit a bilateral structure; that is, having the two sides differently organized, as already explained, thus introducing a division of labour not met with in the leaves of the majority of Monocotyledons. The fibro-vascular bundles are well developed, the larger branches being connected by innumerable small veinlets, the whole forming a complicated network best seen in the so-called "skeleton leaf." This arrangement of the veins insures a supply of material for assimilative purposes to every part of the leaf, and also at once removes the assimilated material from the leaf to be utilized at once in other parts of the plant or to be stored up for future use. Although the points already enumerated show the higher development of the dicotyledonous over the monocotyledonous leaf, yet undoubtedly the greatest advance made by the leaves of the group under consideration is that connected with protection against both climate and living enemies. The former only will be considered at present. In Monocotyledons, the leaf, when once fully expanded, remains rigid and motionless, its working surface being constantly exposed to the chills of the night air and to the dust settling down and covering up its chlorophyll

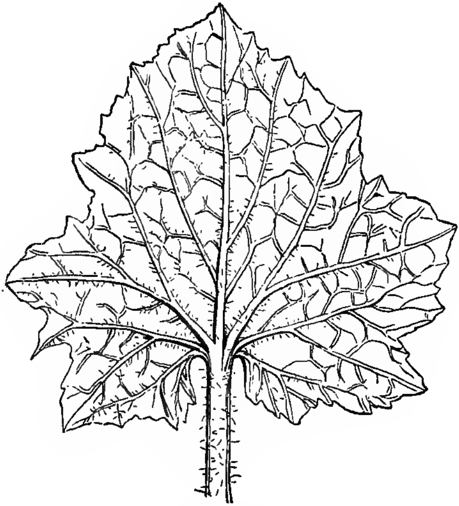

Fig. 28. Leaf of melon, a typical Dicotyledon, showing stalk or petiole, prominent anastomosing veins forming a network and projecting from the under surface, also the cut edge or margin.

and stomata, for it will be remembered that leaves can only perform their most important function, that of assimilation, when exposed to light; hence it would be a great advantage if leaves could pack themselves up during the night when unable to work, and this point has been reached by many Dicotyledons. The leaves of many Dicotyledons are still rigid and incapable of protecting themselves by closing up at night or on dull days when the light is insufficient to enable them to perform their functions; but the vast majority are moving in this direction, the first indication of such a move being an indication of toothing along the margin. From the primitive phase of cut margin as illustrated by the cherry or apple leaf, there is a sequence in the depth of the indentations through the stage presented by the ivy and the dandelion, until eventually we get the cutting so deep that it reaches to the principal vein or midrib of the leaf, and the portions of cut-up blade or lamina are only attached to the midrib by the principal vein of each portion of the leaf by a joint or articulation that renders possible the movement of the jointed portion called a *leaflet;* when this stage has been reached the leaf is described as *compound.* There are two types of compound leaf, the earliest being illustrated by the dog-rose, and known as the *pinnate* type, where several pairs of leaflets are arranged at some distance apart along the midrib, the latter being terminated by a single leaflet; the leaves of peas, beans, and laburnum belong to this type. The second plan is where all the leaflets spring from the end of the stalk like a fan, as in the horse-chesnut and lupin. This last arrangement is brought about by the arrest or non-development of the naked portions of the midrib between the pairs of leaflets in the pinnate type.

When a species has reached the stage of producing compound leaves, the next step necessary for the folding up of the leaf is the evolution of a certain amount of irritability or responsion to external agents, as light and heat, by the protoplasm. The closing of the leaflets of compound leaves is usually influenced by the relative amount of light, providing the temperature is sufficiently high. The closing and opening depends entirely on changes taking place in the joints or articulations of the leaflets and of the joint that connects the entire leaf to the branch. These changes again are due to the movement of water from the cells of one side of the joint to the other, the movement of the water being set up by the influence exercised by external agents on the

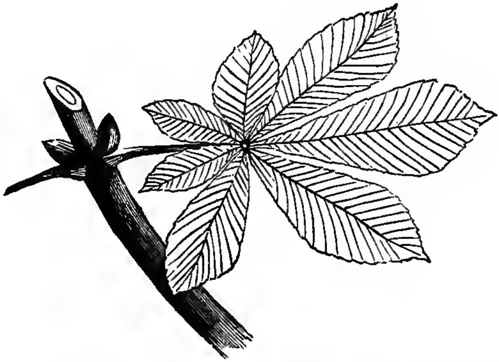

Fig. 29. A digitately compound leaf of the horse-chestnut (*Æsculus hippocastanum*). The young leaves are sensitive and close up at night.

protoplasm. The closing and opening of leaves is well seen in the wood sorrel (*Oxalis acetosella*), many of the clovers (*Trifolium*), etc., and more especially in what is popularly known as the "sensitive plant" (*Mimosa pudica*), where this faculty has become so thoroughly perfected as to be not only influenced by the amount of light, which usually causes the closed or "sleeping" condition during darkness, and the "waking" or expanded condition during the day, but to respond at once to the slightest mechanical irritation, and in this case the transmission of local irritation from one part of the plant to another, equivalent to the transmission by nerve-power in the animal world, causes every leaf on the tree to close within a minute or two after the slightest touch at any one point, even the irritation caused by touching a leaf with, say, the point of a pencil.

The amount of work done by a given area of leaf surface depends on the amount of light received by every portion of that surface; consequently the arrangement of leaves from this point of view is of great importance. In many Monocotyledons, as the grasses, sedges, and most bulbous plants, most or all the leaves spring from one point near the ground; this is also the case with some Dicotyledons, as the dandelion, dog-daisy, primrose, etc. Such an arrangement of leaves in the form of a rosette is a primitive and comparatively imperfect method, inasmuch as some of the lower leaves, after costing energy and material to make, are of little service to the plant, being overshadowed by the upper leaves; this weak point was remedied to some extent by the development of a tall stem that elevated the leaves and exposed them to more favourable conditions

Fig. 30. A tropical orchid (*Oncidium Papilio*) showing a rosette of leaves springing from a very short stem near the root, hence called radical leaves. (Reduced.)

for fulfilling their functions; but in the cycads, screw-pines, and palms, the leaves still retained the densely crowded rosette arrangement, whereas in Dicotyledons this difficulty was removed by lengthening the stem between the individual leaves, which resulted in their being scattered at distant intervals on the twig, as in the ash, oak, rose, etc.

Plants belonging to cold regions are characterized by having the leaves covered with a dense felt of soft interwoven hairs for purposes of warmth. When such plants are acclimatized to warmer regions, this protection in many instances is much reduced or completely disappears.

The protection of the individual by various modifications that enables a given amount of leaf surface to do the greatest possible amount of work, is very clearly shown in the evolution of the stem or trunk. In Monocotyledons, as already explained, the trunk is usually unbranched, and bears at the top a dense rosette of large leaves as in the palms; one or two palms and the screw-pines are exceptional in having a branched stem, but the leaf arrangement is the same. In Dicotyledons we find the main trunk broken up into numerous spreading branches bearing many small leaves scattered at intervals on the twigs, so that practically every inch of leaf surface is fully exposed to the light, and consequently there is no manufacture of leaf material that when made cannot fully perform its functions on account of imperfect exposure to light. From geological evidence, the earliest type of stem for the purposes of removing the leaves beyond the reach of herbivorous animals, and at the same time exposing them to light and air, was the

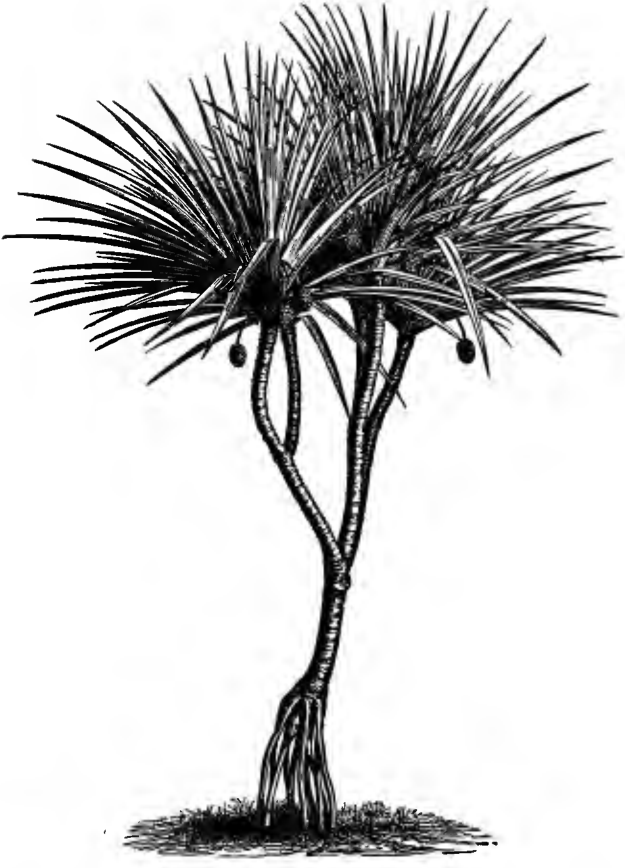

Fig. 31. The screw-pine (*Pandanus candelabrum*), a Monocotyledon that has developed a stem and assumed tree-like proportions, but the leaves are still developed in dense terminal clusters. The plants inhabit swamps, and the numerous roots sent down from the stem are for the purpose of giving stability to the plant in the loose mud. (Much reduced.)

rigid, erect, woody trunk, an ancient type of which is shown at fig. 25. This plan of structure, with various modifications as it passed through Monocotyledons with the single terminal bud, to the dicotyledonous plan of breaking up into numerous branches and bearing an indefinite number of buds, is even at the present day most general, and certainly such a framework as seen in the oak or the beech is a very effectual arrangement for defying the elements under ordinary circumstances. In the mode of arrangement of the branches there is a gradual evolution or improvement observable, that is most to the purpose—that of equally exposing all the leaves to light in the latest phase of plant development, the dicotyledonous group. In the Gymnosperms, the usual arrangement of the branches is in whorls or verticils produced at intervals on the stem; these whorls of branches grow out at right angles to the stem, and the secondary branches all grow in the same plane forming tier above tier, each one overshadowed by the tier above, and consequently only receiving a comparatively small amount of light as compared with the typical dicotyledonous arrangement as illustrated by the ash or the oak, where the numerous primary branches start from the top of the trunk and spread in every direction, the youngest portions that bear the leaves being always produced at the circumference of the head, consequently the great bulk of the leaves are produced at the circumference where they are fully exposed to light. In spite of the many modifications and improvements, external and internal, already indicated, the massive trunk idea must be considered as a failure, its advantages being neutralized by its extreme cost to the plant, for it must be remembered that every particle of the enormous amount of material constituting the trunk and branches of a tree have been converted by the plant into what they are from inorganic matter derived from the air and the soil, borrowed as it were for a purpose by the plant, and retained so long as its own life-force predominates, and all this enormous amount of work for the purpose of protecting itself from enemies and securing the share of light necessary for holding its own in the struggle for existence. This arrangement also places the flowers or reproductive organs in favourable positions for securing cross-fertilization, and thus secures as far as possible the continuance of the species in time. It may be asked, if the development of the trunk has done so much for the vegetable kingdom, what more can be desired. We are not cognizant of the possibilities of life, not even plant life; and if all the above advantages can be secured with a less expenditure of energy, it will by most people be admitted as an improvement, and expressing plant ideas from the human method of reasoning, many modern plants have realised this fact, and have in part or entirely forsaken the old-fashioned massive trunk idea, which may be described as the method of accomplishing an object by brute force, depending on sheer strength, regardless of cost, and in its place developed a certain amount of sensibility—a step in the direction of the animal kingdom—manifested by the more highly organized protoplasm possessing a greater control over other forces, as light and heat, and utilizing them for its own advantage. It is impossible in the space at command to trace all the varied attempts in this connection, and all that can be done is to indicate the modern methods that have superseded the old-fashioned woody trunk. The long, slender, weak-stemmed climbing and twining plants illustrate the later method. As British examples, we may mention the ivy, honeysuckle, convolvulus, etc.; amongst exotic plants, the vines, and those numerous forms that stretch from tree to tree in tropical forests. Our roses and brambles illustrate an incipient attempt in this direction, their spines, that were in all probability protective against animals, becoming in many species curved downwards, and serving as anchors that hook on to neighbouring plants, and thus become elevated to a certain extent at the cost of the neighbour. The method by which the ivy clings to its support has been already explained. Coming to such plants as the hop, where the stem twines round a suitable support, we encounter a higher stage of development due to the influence of light, or rather to the more highly organized protoplasm being enabled to utilize light to a greater extent than plants lower down in the scale of life. The highest stage of development reached by plants that have adopted the long slender stem is illustrated by the grapevine and most of the peas and vetches. In such plants the stem does not coil round a support, but is firmly anchored by numerous slender threads known as *tendrils* that become firmly coiled round the slender branches of other trees. These tendrils are not new special parts developed for this purpose in addition to the parts previously possessed by such plants, but are old parts modified to serve this special purpose. The tendrils of the vine are modified flower-stalks, those of the peas and vetches in like manner are portions of the leaves. Tendrils differ from twining stems in not coiling up

Fig. 32. A species of passion-flower (*Passiflora cœrulea*), showing tendrils that are coiled up at the tip. (Natural size.)

under the influence of light and heat alone, this movement depending on mechanical irritation. If the tendrils of the passion-flower or those of the bryony (*Bryonia dioica*) are examined, it will be seen that in the young condition they spread out from the stem either straight or slightly curved, and remain for some time in this condition, until the weak branch bearing them is brought into contact with some neighbouring branch by the wind or some other means, or in some plants the tendrils themselves revolve, searching for a suitable body round which they can coil. If the tendrils come in contact with a flat surface or a thick branch, no change takes place, but when made to touch a thin twig, the tendril within a short time coils its tip round the support, and then becomes rigid, so that it cannot be uncoiled without breaking. This rigidity is necessary to prevent the coiled portion being drawn out by the weight of its own branch when moved by the wind. After the tip of the tendril is firmly fixed to its support, the intermediate portion undergoes a spiral contraction by which the tendril is shortened. This spiral contraction of that portion of the tendril between its base and tip is of value from two points of view; it gives elasticity, and consequently greater strength, and also draws the branch higher up so as to expose its leaves more fully to the light. If a tendril that has become attached by the tip is examined, it will be seen that one portion of the intermediate part is twisted in one direction and another portion in the opposite direction, with an intermediate straight part; but for this arrangement, it will be understood that a body fixed at both ends and undergoing spiral contraction would be ruptured.

(2.) *Protection against living enemies.* The modifications undergone by plants necessitated by climatic influence are not more varied than those required to combat successfully the attacks of living enemies, and the difficulty in the latter case is intensified by the fact that, being possessed of life, and consequently possessing the power of modification or adaptation to circumstances it follows that when a plant has evolved an arrangement to ward off the attacks of its special enemy, the latter in turn changes its tactics, and by a similar modification often successfully overcomes the obstacle placed in its way. There is no evidence in support of the view that plants or animals were specially created to serve as food for their neighbours, and wherever this happens it always resolves itself into the condition of the victim being overcome by the superior physical or mental power of the victor. Man's mental development has placed numerous members of both the plant and animal kingdoms under his control, and this sphere of influence has gone on increasing with the development of that power. The same ideas are true of groups of plants; the forest tree type of vegetation with the massive trunk and spreading branches at one time bid fair to become the dominant race, but the sheer strength method on which they depended has been superseded by the greater adaptivity and more especially the greater susceptibility of the protoplasm to external agents, in the smaller members of the Vegetable Kingdom, and many of these latter are now utilizing the trunks of the older type as a means of support; in some instances strangulation of the trunk is effected by the modern twiner, as in the honeysuckle, or is compelled by the dominant parasite to surrender a portion of the food elaborated for its own use.

Amongst the most prominent and general modes of protection of vegetative parts against the attacks of living enemies may be mentioned *prickles,* as in roses and brambles, which may either be straight, and thus prevent the nibblings of animals, or in more advanced species, curved, thus enabling the weak stem to climb and carry its leaves out of harm's way. *Spines,* that are sharp-pointed abortive branches, serving the same purpose as prickles, as in the common sloe or blackthorn (*Prunus spinosa*). *Rigid hairs* on leaves and stem, as in the borage (*Borago officinalis*), and comfrey (*Symphytum officinale*). *Stinging hairs,* as in the common nettles (*Urtica dioica,* and *U. urens*), in these cases the stinging hairs are mixed on the leaves and stem with ordinary rigid hairs, of which they are higher developments, distinguished by the lower or basal swollen portion of the hair containing an irritating liquid that is ejected when the tip of the hair is broken off. *Bitter taste,* often accompanied by a strong scent, as in wormwood (*Artemisia vulgaris*), chamomile (*Anthemis nobilis*), and the leaves and fruit of the walnut (*Juglans regia*). *Poisonous alkaloids,* as in the species of *Strychnos,* which contain two very poisonous alkaloids, strychnine and brucine, in the root and the seeds; decoctions of species of Strychnos are used by the Javanese and the natives of South America to poison their arrows. Some of the species, as *Strychnos nux-vomica,* are valuable medicines, depending on the strychnine they contain, which acts as a powerful excitant of the spinal cord and nerves; thus the most effective protective arrangements evolved by plants can be turned to account, and consequently lead to the destruction of the individuals they were designed to protect. Our common arum (*Arum maculatum*), popularly known as "Lords and Ladies," has an intensely acrid substance present in the leaves, which effectually protects it from the attacks of mammals and caterpillars, but not from the attacks of parasitic fungi, which appear to be indifferent to all protective contrivances exhibited by plants, nearly every plant supporting one or more of these minute pests, the effects of which will be realized by mentioning the potato disease, "rust" and "smut" in the various cereals, and the hop disease, all due to parasitic fungi. The leaves of many exotic evergreens are often much injured by the presence of parasitic lichens that spread over the surface.

Fig. 33. "Lords and Ladies" (*Arum maculatum*), a plant that protects its leaves from mammals and insects by the presence of an acrid substance. (Reduced.)

CHAPTER IV.

REPRODUCTION OF PLANTS.

Vegetative or asexual method.—Sexual method.—Gradual evolution and advantages of the latter method.—Alternation of generations.—Cross-fertilization.—Protection of reproductive portions of plants.

IN many of the primitive types of plant life the only known mode of reproduction is by fission or cell division, as already explained in the case of *Pleurococcus vulgaris.* In other simple multicellular fresh-water Algæ, as the species of *Nostoc,* that form blue-green or brownish gelatinous masses on damp paths and shady places after wet weather, the cells are arranged in a single row, forming long filaments that are variously contorted and imbedded in mucilage; during the reproductive phase these filaments break up into short pieces which escape from the gelatinous matrix, each fragment forming the starting-point of a new individual, the filament rapidly increasing in length by repeated fission of its component cells. In vegetative or asexual reproduction the portion destined to form the starting-point of a new individual always consists of one or more cells formed by the ordinary method of cell-division, whereas in the sexual mode the reproductive body is invariably the result of the blending together of the protoplasm belonging to two distinct cells, respectively male and female, which form a single cell. The above examples illustrate the primitive form of asexual reproduction, which involves the destruction or loss of individuality of the parent plant, but commencing with the Algæ and running through most groups of Cryptogams we find a higher asexual mode, where specialized and usually comparatively small portions of the individual are told off for the purpose; such portions fall away when mature, and in many cases are not distinguished popularly from sexually produced seeds. Although the sexual method of reproduction is universal in phanerogams, yet the primitive asexual method has not completely died out, but manifests itself in a variety of ways. As examples, the propagation of plants by cuttings, which may be considered analogous to the breaking up of a *Nostoc* into portions capable of reproducing the species or kind, thus proving that all the essentials constituting the life of the individual are present in the protoplasm of every cell; whereas in the great number of plants that cannot be reproduced vegetatively by cuttings or other asexual methods, the protoplasm has become more sharply differentiated into series, one capable of governing the work necessary for the existence of the individual, the vegetative portion, and incapable of exercising the functions necessary for reproduction; a second concerned specially with reproduction, but with little capacity for vegetative work. The tubers of the potato and bulbs are also asexual modes of reproduction still retained by phanerogams.

Sexually formed reproductive bodies, known as seeds in the higher plants, originate, as already stated, from a single cell that owes its important properties to the mingling of the whole or a portion of the protoplasm of two distinct cells; this mingling of protoplasm constitutes the act of fertilization. If the two cells concerned in fertilization are produced by the same plant, self-fertilization is the result; if produced by distinct plants of the same kind, cross-fertilization is effected.

Sexual reproduction is shadowed in amongst the primitive types of Algæ, under the form of motile portions of protoplasm that escape from the cells and swim about in the water by means of very delicate cilia or prolongations of their protoplasmic substance; such cells are not furnished with a cell-wall, and after swimming about for some time, approach each other in pairs, which eventually blend together, withdraw their cilia, and form a cell that soon secretes a cell-wall. This cell either at once, or more frequently after a period of rest, germinates and gives origin to the vegetative condition of a new individual. This, the most primitive condition of sexual reproduction, is known as *conjugation.* In many cases the two conjugating cells are similar in shape and size, and externally present no functional differences; in other forms one, presumably the male element, is smaller than the other, the female; but in many instances bodies that usually conjugate become inclosed in a cell-wall without doing so, and at the proper time germinate and produce plants agreeing in every respect with those originating from cells resulting from conjugation, proving that the sexual method is not indispensable, but rather in the first phase of evolution. Reproduction by conjugation occurs only in certain groups of the Algæ and Fungi, and in the general evolution of sexual reproduction, one change has been from that primitive condition where the two elements—male and female—are both motile, or possessed of voluntary movement, to the condition attained by all Phanerogams, where both are passive or motionless, and in numerous instances their union, as will be explained in detail, is effected by modifications of the plant that enable it to utilize external agents for this purpose, as the wind, or even members of the Animal Kingdom, mostly insects.

A marked differentiation of sexes has been reached in the common large olive-brown seaweeds included under the generic name of *Fucus* (Fig. 27), where the protoplasm of the female cell becomes divided into four or eight portions depending on the kind examined; when ready for fertilization the wall of the cell splits, and the separate portions of protoplasm—each a cell without a cell-wall—escape into the water, but are entirely devoid of voluntary movement; at the same time the protoplasm of the male cells divides into a large number of minute cells, each furnished with cilia and without a cell-wall; these cells, called *antherozoids*, escape into the water and swim about until they come in contact with a passive oosphere, fertilization being effected by the blending of the two bodies. In *Fucus*, then, the point has been reached where the female organ is passive or motionless; but the peculiarity of this batch of plants consists in the female portion or oosphere escaping from the parent plant before fertilization, a weak point, not to say a decided mistake, and terminating abruptly with the small batch of seaweeds where it originated, the weak point consisting in the absolute necessity on the part of the fertilized body, on germination, to commence assimilating food for itself from the very first, even before a single additional cell could be added to its size, whereas where the oosphere remains in contact with the whole or a portion of the parent plant after fertilization, a certain amount of food is supplied by the parent which gives the germinating plant a start in life, in fact, supplies it with a reserve of food that it can draw upon until it has built up assimilating structures; hence, other things being equal, it is not to be wondered at that the free oosphere idea is not dominant.

In some species of *Fucus*, in fact in most, a given plant produces either antherozoids or oospheres only; in fact, the plants are male or female, hence cross-fertilization is absolutely secured.

In the remainder of the Cryptogams, as the mosses, ferns, and club-mosses, the oosphere is motionless and remains in contact with the parent plant at least until germination commences, the antherozoids in all cases being motile, as in *Fucus*, and reaching the oosphere through the agency of water, and this point more than any other constitutes the distinction between *Cryptogams* and *Phanerogams*, the two primary divisions of the Vegetable Kingdom. This in turn explains the absence from Cryptogams of those showy portions of the flower so conspicuous in most Phanerogams, and evolved for the purpose of attracting insects in connection with fertilization, the methods of which will eventually be described in detail. Remembering that the primordial types of plant life were aquatic forms, the advantage of voluntary movements of the portions concerned with fertilization in such is obvious, the male organs or antheroids swimming freely in the water until they came in contact with the oospheres. The various attempts of ancient aquatic types to establish themselves on dry land was finally accomplished through the liverwort (*Hepaticœ*) and moss (*Musci*) groups, which form a connecting link between the primordial aquatic Algæ and the dry land vegetation of the present day; nevertheless the mode of fertilization by means of motile antherozoids that reached the oospheres by swimming in water was so strongly stereotyped that, as already stated, it held good through the liverworts (*Hepaticœ*), mosses (*Musci*), horsetails (*Equisetaceœ*), ferns (*Filices*), club-mosses (*Lycopodiaceœ*), and other groups constituting the Cryptogams, even after these groups had become much modified in other respects to enable them to live surrounded by dry air, and the tardiness displayed in effecting a corresponding change in the mode of effecting fertilization is the main reason why the above groups are more limited in their distribution, and take a back place in the social scale of vegetation growing on dry land at the present day. The drawback alluded to is due to the fact that the sexual mode of reproduction necessitates the presence of water to enable the motile antherozoids to come in contact with the oospheres; hence Cryptogams are as a group confined to damp situations, or the sexually produced reproductive bodies are formed during the winter, as seen in our mosses, that look bright and vigorous during that period of the year, and shrivel up during the summer if growing in dry situations, conditions that are not followed by those members of the plant world that have made most progress.

It has been already stated that on the evolution and perfection of the sexual mode of reproduction, the more antiquated asexual mode did not at once disappear, but lingered on, and manifests itself even amongst the most advanced of dry land plants, yet from a broad point of view it is seen that the asexual mode of reproduction degenerated in proportion as the sexual mode became perfected; and in many of the higher plants, where the asexual mode is at the present day predominant, as in many bulbous plants, this is due to a resuscitation of the old method necessitated by surroundings being unfavourable for the continuance of the sexual method.

Amongst Cryptogams we find as a rule the asexual and sexual modes of reproduction both present, and in many groups occurring at definite periods in the life-cycle of the individual. This regular alternation of the two modes is known as *Alternation of Generations*, a phenomenon clearly illustrated in the ferns and mosses. It is generally known that towards the autumn the under surface of the fronds of ferns bear dark brown patches, either as rounded spots or elongated streak-like lines, depending on the kind of fern examined; these patches consist of exceedingly minute one-celled reproductive bodies called *spores*, that are produced in numbers in special structures called *sporangia*. Each spore, when placed under favourable circumstances, is capable of germination and producing eventually a new fern plant. On germination the spore first gives origin to a slender filament which, by cell-division at the tip, soon expands and forms a small structure lying flat on the ground and rarely exceeding a quarter of an inch in diameter; this is called a *prothallus*, and constitutes the first or *sexual stage* in the life-cycle of the fern. All the cells of the prothallus contain chlorophyll, and after existing for some time doing vegetative work the reproductive stage is entered upon; certain of the cells undergo a series of changes, resulting in the formation of oospheres, other cells giving origin to antherozoids. The oosphere after fertilization is called an *oospore*, and lies perfectly free in a special portion of the prothallus, but is not organically attached to it in any way, secreting a new cell-wall of its own after fertilization, and forms the starting-point of the second (*asexual*) stage or generation, which closes the life-cycle of the fern. The oospore by cell-division develops directly into what is popularly considered as the whole of the fern plant; that is, the portion bearing green fronds, these in turn producing the spores on the under surface, these spores are not the result of sexual fertilization as in the case of the oospore produced by the prothallus, but are purely asexual or vegetative in origin, and on germination produce the sexual generation. Alternation of generations first showed itself distinctly when plants succeeded in establishing themselves on dry land, and in the mosses and ferns the two generations are very sharply defined, but in the last-named group this idea of having two distinct phases in the life-cycle of the individual, connected at one stage by a single cell—the oospore—attained its maximum, and in the groups that followed, as the club-mosses, selaginellas, quilworts, etc., the sexual generation as a distinct and vegetative structure became gradually suppressed, and in phanerogams has altogether disappeared, the only remaining portion being the indispensable sexual organs—pollen grains and oospheres, the latter after fertilization forming by cell-division the *embryo* or young plantlet, which is for some time protected and supplied with food from structures belonging to the asexual phase of the parent plant, the whole forming the *seed.* From the above it will be observed that the entire bulk of every phanerogam is homologous with the asexual phase of those cryptogams having distinct alternation of generations.

The advantages of the changes indicated depend on the fact that in cases of cross-fertilization a greater number of seeds are produced than by self-fertilized plants of the same kind, and further, the seeds resulting from cross-fertilization produce stronger and more vigorous plants than those resulting from self-fertilization; consequently those groups of plants showing a tendency to favour the sexual mode of reproduction, being more robust than the other types, took possession of the most favourable positions and spread at a much greater rate than those cryptogams encumbered with sexual and asexual phases, because the latter mode did nothing towards invigorating the species, consequently in phanerogams, as already stated, the presence of the asexual mode of reproduction is either a remaining vestige of the old idea, or its revival under conditions unfavourable for the full development of the sexual method of reproduction.

The term "flowerless plants," as often applied to cryptogams, is misleading, in fact, not correct; the idea of a flowering plant being one that reproduces itself sexually, a condition true of the great majority of cryptogams, but, as already explained, the particular method by which the antherozoid or fertilizing body reaches the oosphere does not necessitate the presence of those showy and conspicuous portions that popularly constitute the flower. The latter was considered by the older botanists to be entirely absent, hence the origin of the term "flowerless plants," a mistake which, on account of its being a mistake, still persists.

The progress made by the higher cryptogams in getting away from their primordial aquatic habitat and taking possession of the dry land has been noticed, also the drawback to further extension in this direction owing to the retention of the ancient mode of fertilization, which depended on the presence of a certain amount of moisture to enable the antherozoid to reach the oosphere. This drawback was first overcome by the group of plants known as Gymnosperms, the earliest of phanerogams, where the fertilizing body, instead of being a naked motile cell—antherozoid—consists of a cell furnished with a cell-wall, and not possessed of spontaneous movement, consequently the means of reaching the oosphere for the purpose of effecting fertilization depended on one of the two following methods. (1) The stamens producing the pollen, and the pistil containing the oospheres, or *ovules*, as they are generally termed in phanerogamic plants, are placed in such close proximity that the pollen falls directly on to the ovules or stigma; or, (2) when the stamens and pistils are produced at a distance from each other, the transportation of the pollen to the pistil depended entirely on external agents, generally wind or insects. The first method implied self-fertilization, the second, generally cross-fertilization, and to the second method, which in its most perfect and economical way is effected by the agency of insects, is due the evolution of those parts of the reproductive structure possessing colour—usually the corolla—scent, and nectar.

The typical flower of a phanerogamic plant, as shown in the diagramic representation on p. 31, consists of four whorls or verticils, the lowest on the axis or flower-stalk, and outermost is the calyx, function protective; next the *corolla*, function attractive, in the sense of acting as a coloured advertisement indicating to insects the where-

Fig. 34. *Fuchsia globosa*, a Phanerogamic plant with a complete flower, that is, having the four whorls, calyx, corolla, stamens, and pistil present. (Natural size.)

abouts of nectar—their food—the corolla is a feature of the reproductive portion peculiar to phanerogams for the purpose indicated above; the equivalent of the calyx as a protective organ being present in some cryptogams, as mosses. Following the calyx and corolla are the stamens and pistil, the essential organs. At the present day the flowers of numerous plants do not possess all the parts mentioned above; of the two essential whorls, some flowers have stamens only, and others of the same species pistils only, but the order of arrangement of the parts present, and the vestiges of the missing whorls in a more or less rudimentary condition suggests that the earliest flowers were hermaphrodite, that is, having stamens and pistil present, and such were in all probability self-fertilized.

In Gymnosperms the flowers are unisexual, the staminate and pistillate flowers being in some species present on the same plant—*monœcious*—as in the Scotch fir (*Pinus sylvestris*), or the male and female plants are on different plants—*diœcious*—as in the yew (*Taxus baccata*), or as in the juniper (*Juniperus communis*) the male and female flowers are sometimes on distinct plants, sometimes on the same plant, in fact, in cases where the sexes are nominally separated at the present day it is not unusual to meet with all stages of reversion to the old bisexual or hermaphrodite type of flower, clearly indicating the origin of the modern unisexual type as being due to the suppression or non-development of one of the two essential whorls for the purpose of preventing self-fertilization. Many Angiosperms also have unisexual flowers, monœcious as in the hazel, arum, etc., diœcious, as the willows, poplars, and hop. The earliest idea in connection with preventing self-fertilization, and consequently securing cross-fertilization, was the evolution of unisexual flowers, and this was not brought about by the special formation of such in addition to those already existing, but, as already stated, by the modification of the old hermaphrodite form of flower. So long as the two kinds of flower—staminate and pistillate—were present on the same plant, as in the hazel, the prevention of self-fertilization was not absolute, this point being attained only when one of the two sexes was completely arrested on a given tree, as in the willows, where the bright yellow catkins of the goat willow (*Salix caprœa*), popularly known as "palms", are the clusters of staminate flowers, the trees of the same species bearing the female catkins, that are green and inconspicuous, make but little show, and are ignored for decorative purposes. This early attempt to secure cross-fertilization was certainly effective, but too expensive in many ways, and it will be seen that later ideas in this direction were equally effective with a much less expenditure of energy and bulk of material. All

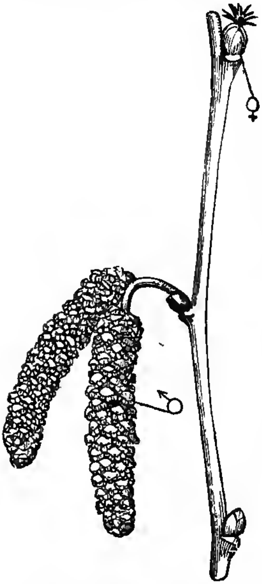

Fig. 35. The hazel (*Corylus avellana*), a monœcious plant; ♀, pistillate flowers having bright crimson protruding stigmas; ♂, catkins of staminate flowers. (Natural size.)

the Gymnosperms and many monœcious and diœcious Angiosperms are *anemophilous* or wind-fertilized, that is, fertilization depended on the pollen being carried by the wind and brought in contact with the ovule or the stigma. This uncertain method necessitated the production of enormous quantities of pollen to insure fertilization, the "showers of sulphur" being in reality wind-transported pollen of pine-trees brought to the earth, and consequently wasted, by rain; this extravagant primitive arrangement was succeeded by more economical and exact methods in Angiosperms.

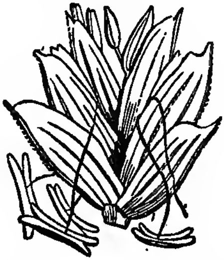

Fig. 36. Portion of an ear of wheat, an anemophilous or wind-fertilized plant, showing the protruding anthers supported on long, slender filaments or stalks. (Enlarged.)

In many anemophilous plants, as the hazel, willows, poplars, etc., the flowers appear in early spring before the leaves, as the presence of the latter would interfere with the pollen being blown on to the stigma. In many species the stamens are suspended beyond the flower on long, slender stalks or filaments, thus enabling the wind to scatter the pollen; the stigmas are also often elongated and project beyond the flower, and are rough with hairs for the purpose of catching the pollen; these peculiarities can be well seen in the grasses and plantains (*Plantago*).

It is in the highest and most modern group of flowering plants—Angiosperms—that we meet with the most profound modifications of the flower for the purpose of securing cross-fertilization, insects being the agents employed in transferring the pollen from one plant to the stigma of another plant of the same kind, and in this group of plants the present form, colour, and fragrance of flowers, also the secretion of nectar has gradually evolved through the unconscious selection exercised by insects in their search for food, which is furnished by the sugary liquid or nectar present in many flowers, and this object is the only one the insect has in view, the transportation of pollen being an entirely unconscious act; and although in many plants that are visited by insects, the chances of meeting with nectar are uncertain as is the chance of cross-fertilization, yet in numerous other instances the modifications that have taken place in both the flower and the insect have resulted in what may be called mutualism, differing only from the mutualism between algæ and fungi that form lichens in the two organisms retaining their individuality and liberty of action, yet so thoroughly interdependent that their individual existence depends equally on the existence of both; that is, there are certain plants that have become so thoroughly modified that fertilization can only be effected by particular insects, the latter in turn being able to obtain their food alone from the flower they can fertilize. Looking at such a case of perfected mutualism as that just indicated, naturally supports the old idea of a preconceived arrangement and special creation of two distinct forms of life adapted from the first to mutually assist each other, but when we see on every hand other forms of life exhibiting every phase from the crudest attempts in the direction of mutualism as defined above, and further, when careful examination of those members that have reached the highest known stage of perfection in this respect, reveals the presence of degenerate organs and parts, clearly proving that such have attained to their present perfection by a series of changes, then the force of the modern idea of evolution, or gradual change of the entire organism or portions thereof to successfully surmount new obstacles or to benefit more from the forces at command, becomes apparent.

Fig. 37. Daffodil (*Narcissus pseudo-Narcissus*). A regular or symmetrical flower having three sepals forming the outer whorl or calyx; three petals forming the second whorl or corolla, within which is a tubular-shaped additional attractive organ with a frilled margin, the corona, this in turn incloses six stamens and a single style supporting the stigma at its tip. (Natural size.)

Cross-fertilization was undoubtedly the first and main incentive in promoting the various changes that flowers have undergone for the purpose of facilitating the visits of insects; but even if this were not the case, the idea would be a success from the economical point of view, as insect-fertilized flowers by their greater exactness of arrangements insure fertilization with a much less expenditure of material than is the case with either wind-fertilized or self-fertilized plants. In the latter class the flowers are regular in form, that is, the sepals are of equal size, as are also the petals, as illustrated by the buttercup, wild rose, and tiger-lily, and in addition are perfectly free from each other; in fact, the stamp of a primitive flower is the perfect freedom from each other of all its components, a character illustrated by our buttercups; the stamens in such plants are usually numerous, the haphazard method of fertilization requiring a very large amount of pollen to make certain this indispensable process. In some flowers colour has not yet been evolved, but this is usually the case, and numerous flowers have not yet got beyond this stage, which is the first step in the sequence leading up to the fully evolved insect-fertilized flower. Along with the advent of colour, we find as a rule arrangements for the secretion of nectar, the production of which is confined to specially modified portions of the flower called nectaries. Nectaries occur on different parts of the flower in different plants. In the buttercup a nectary or honey gland is present at the base or narrow point of attachment of each petal on its upper surface; in the columbine, a plant belonging to the same order as the buttercup (*Ranunculaceæ*), we find each of the five petals prolonged downwards into a hollow horn-like projection or spur, also a nectary; and in other plants belonging to the same order there is a sequence in the evolution of the nectary from the comparatively unprotected form presented by the buttercup, which is accessible to insects that cannot fertilize the flower, to the elongated spur-like form that secures the nectar from being sipped by insects that cannot fertilize the flower, and at the same time making it more accessible to those long "tongued" insects, as bees, etc., that can effect this object. But, as already mentioned, insects adapt themselves to circumstances as well as plants do, and we find adventurous ants and minute beetles that have a taste for nectar, but cannot fertilize the flower, overcome the difficulty placed in their way by the plant in secreting its nectar at the bottom of a long slender tube or spur, by venturing down the narrow passage. This defeat is in turn remedied in many plants by a further modification of parts; in the violets the opening to the spur is guarded by the growth of two slender spines from two of the anthers that pass down into the spur, these completely prevent the bodily entrance of any small insect, at the same time leaving sufficient space for the slender tongue of the insect specially adapted to effect fertilization. The common red dead-nettle prevents the entrance of minute insects to the honey situated at the bottom of the tube-shaped corolla by the development of a ring of hairs that grow from the inside of the corolla-tube and meet in the centre. Some short-tongued bees that cannot reach the honey situated at the bottom of a long spur or corolla-tube have acquired the habit of biting through the corolla-tube and sipping the nectar. In the common garden nasturtium (*Tropæolum majus*) the long spur is a development of the calyx. Another advantage of the spur over the open nectary is that the nectar is prevented from being washed away by rain.

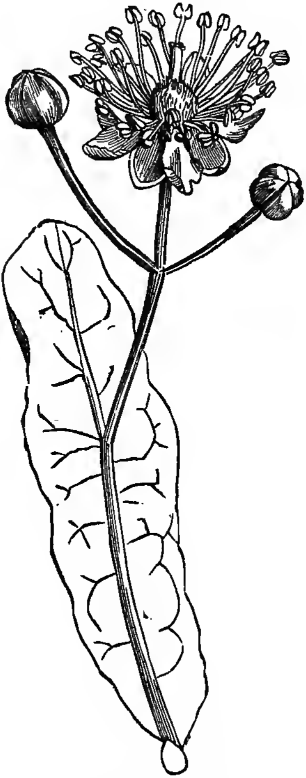

Fig. 38. Lime (*Tilia Europæa*). Showing a regular and perfect flower, with the parts (except those of the pistil) free from each other; there is no colour in the flower, but bees are informed of the proximity of a lime tree by the strong scent; the flowers also secrete large quantities of nectar. The flower-stalk is attached for half its length to a leaf-like bract that serves as a dispersive organ of the fruit when mature, becoming dry and light, and being blown by the wind for some distance, carrying the fruit along with it. (Natural size.)

So long as the flower is constructed on the buttercup type, that is, regular in form, and all the parts free from each other, the power of self-fertilization is retained, and this is the most general mode, although the presence of colour, and in some cases of nectar also, attracts insects which undoubtedly do in many instances effect cross-fertilization.

The old method of securing cross-fertilization by completely arresting the development of the stamens in all the flowers on one tree and all the pistils in those of another, is modified in most Angiosperms, who have fallen back on the primitive hermaphrodite type of flower, and by a double series of changes have succeeded in preventing self-fertilization and secured the advantages of cross-fertilization. Some of the most pronounced contrivances for preventing self-fertilization are to be found amongst our common wild flowers; perhaps the most general arrangement is in the stamens becoming mature and shedding their pollen before the ovules of the same flower are ready for fertilization, and this in the majority of instances is the only thing absolutely guarded against, although the pollen from one plant must in many instances be conveyed by insects to the stigmas of flowers belonging to a different plant of the same kind, and thus effect cross-fertilization between two distinct individuals. Flowers having the stamens mature before the pistil are said to be *proterandrous;* examples, the geraniums, pinks, willow-herbs, and in fact most flowers that have both stamens and pistil. In comparatively few flowers the pistil is mature before the stamens, as in the arum, figwort (*Scrophularia nodosa*), plantain, etc.; such flowers are termed *proterogynous.* In other examples the difference in position of the stamens and pistil in the flowers of different individuals of the same kind to some extent prevents self-fertilization, and certainly favours cross-fertilization. If a number of plants of the primrose or cowslip are examined it will be found that all the flowers of a given plant have the pistil at the top of the tube of the corolla and the stamens halfway down the tube; or, on the contrary, the stamens are at the top of the tube and the pistil halfway down. Such flowers are termed *Heteromorphous*, as distinguished from *Homomorphous* flowers, that have in all cases the stamens and pistil occupying the same relative positions. Heteromorphic flowers that have two forms of flower depending on difference of position of stamens and pistil,

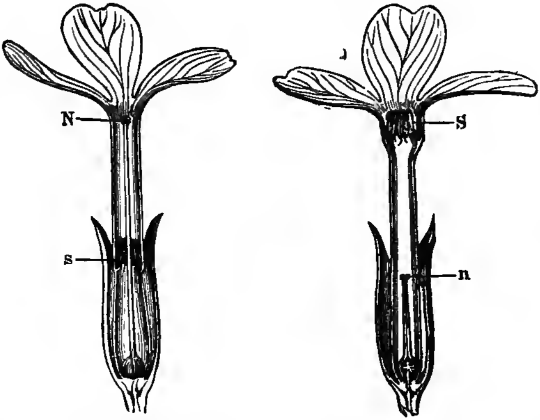

Fig. 39. Oxlip (*Primula elatior*). A dimorphic flower. The left-hand figure represents the long-styled form with the stigma, *N*, at the top of the corolla-tube, and the stamens, *s*, halfway down the tube. The right-hand figure shows the short-styled form with the stamens, *S*, at the top of the tube, and the stigma, *n*, on a short style halfway down the tube. (Slightly magnified.)

as in the primrose, are called *Dimorphous;* those with three forms, as loosestrife (*Lythrum salicaria*), are called *Trimorphous*. The facilities afforded by heteromorphism in connection with cross-fertilization, is clearly shown by the species of *Primula*, Fig. 39, which includes the primrose and cowslip. An insect in obtaining nectar from the base of the coralla-tube of a long-styled primrose flower would dust its "tongue" with pollen at a point which would exactly come in contact with the stigma when it visited a short-styled flower. Conversely, when visiting a short-styled flower the pollen would adhere to that portion of the "tongue" that would come in contact with the stigma of a long-styled flower.

A further guard against self-fertilization evolved by many plants depends on the fact that the pollen of a given flower when placed on the stigma of the same flower is slower in forming pollen-tubes, and thus effecting fertilization, than the pollen from another flower of the same kind, and in some plants this idea is carried so far that the pollen will not fertilize the ovules of the same flower producing it, but when placed on the stigma actually induces a toxic effect that results in the death of the unfertilized ovules.

The sign that a plant has reached the stage of almost or altogether entire dependence on insect aid for effecting fertilization is indicated by the irregularity or unsymmetrical structure of the corolla, accompanied by the growing together to a greater or less extent of its component petals. Several important groups of plants belonging to this category have the corolla consisting of petals of unequal size, and so arranged that a median line divides it into two equal parts, but the petals are still free from each other. Well-known examples are, violets (*Violaceæ*); peas, beans, and vetches (*Leguminosæ*); and orchids (*Orchidaceæ*). In the last-named order there is a sequence from self-fertilized plants to others that display the most perfect arrangements for cross-fertilization met with in the Vegetable Kingdom. Orchids belong to the same division of Angiosperms as the lilies—Monocotyledons—and, like the latter, belong to the type of regular flower with three free sepals, three free petals, six stamens, and a pistil consisting of three carpels grown together. The common tiger lily still shows this structure, but the orchids, which may be said, as a group, to have devoted their whole energy to the perfection of the method of cross-fertilization with the greatest amount of certainty combined with the minimum expenditure of material, have developed an irregular flower. This irregularity in the simplest type consists in the modification of form of one of the three petals, the *posterior* or uppermost; this modified petal is known as the lip or *labellum*. In other species more of the sepals and petals become changed, and there is a general tendency on the part of the flower to become compressed laterally, thus shadowing in the tubular type of flower, open at the mouth and becoming narrower downwards towards the point where the stamens and pistil are situated; the object of this arrangement being to compel the insect, when sipping the nectar, to bring some portion of its body in contact with the stamens or stigma as the case may be. In such flowers the lowermost or *anterior* petal is usually large, and stands out as a landing stage on which the insect alights. A curious feature in the evolution of the flower in orchids consists in the fact

Fig. 40. An exotic orchid (*Oncidium papilio*). The flower is irregular, the sepals and petals together resemble a butterfly in shape; hence the botanical name. (Reduced.)

that the petal forming the labellum, intended as the landing-stage for insects, appeared at the upper or posterior part of the flower, and consequently proved useless for the purpose intended, and although the mistake was discovered, it appears that the line of departure first taken could not be checked, and orchids continue to grow the posterior petal as a landing-stage and then, by a half-turn of the long, inferior ovary, reverse the original position of the flower and bring the labellum or landing-stage to the anterior or under side of the flower, where it is of use to insects. In the great majority of plants the pollen is dry and powdery, the individual pollen-grains remaining distinct; this is the case in a few orchids, but in the great majority the pollen-grains are stuck together in masses, two of which are present in an anther which is situated above the stigma in such a position that self-fertilization is impossible. When a bee visits an orchid flower for the purpose of obtaining the nectar situated in the spur that is a backward continuation of the labellum, its head comes in contact with the anther, and the two pollen masses become attached to its head by a slender viscid stalk. At the moment of removal the two pollen-masses stand erect on the front part of the head of the insect, but in a very short time bend forwards and downwards, in fact bend downwards until they are as much below their original level as the stigma of the orchid flower is below the stamen. When the ovules are ready for fertilization the stigma becomes viscid, and a bee carrying the pollen-masses on its head, on entering a flower in this condition, brings the pollen into contact with the viscid stigma, to which it adheres. The mutualism between orchids and insects has become so perfect that in the great majority of species there is only one fertile stamen present, yet the whole working is so exact that cross-fertilization is even more certain than is self-fertilization in the case of allied groups having the full complement of six stamens, and even if cross-fertilization was in itself of no importance, the advantage of being able to dispense with five stamens alone would compensate for the evolution from the primitive type, as the change has not necessitated the development of entirely additional structures, but only a modification of parts already present.

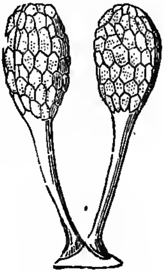

Fig. 41. Pollen-masses of an orchid. The upper thickened portion consists of the pollen-grains stuck together by a viscid gum-like substance that forms two slender stalks terminating in a flattened portion below. This flat part adheres to the head of the insect. (Highly magnified.)

The type of having the petals more or less grown together to form a tube is well illustrated by the white dead-nettle (*Lamium album*), where the five petals are very irregular in shape and size, and grown together in such a manner as to form two large lip-like portions, the upper arched lip being formed of two petals, and serving to protect the stamens and pistil from rain; the lower lip consists of three petals grown together, and serves as a landing-stage for insects that visit the flower. The stamens are four in number, the fifth posterior stamen present in less highly evolved allied plants being completely arrested, a single long style divided at the tip lies along with the stamens under the large arched upper lip. •The two lips of the corolla become joined together at some distance down, and form a curved tube, at the bottom of which the nectar or honey is secreted. The above type of corolla is called *bilabiate* on account of the two prominent lips, and is characteristic of the large natural order of plants called *Labiatæ*, but occurs also in allied orders of plants, as the figwort order (*Scrophulariaceæ*), etc. The dead-nettle flower is proterandrous; the stamens become ripe in pairs. The first pair when ready to shed their pollen curve downwards from under the upper lip and place their anthers in such a position that they come in contact with the back of an insect visiting the flower for nectar, the pollen being dusted on to the insect's back. After the pollen is removed the anthers shrivel up and disappear, the second pair in turn bending down into the position previously occupied by the first pair. Finally, after the second pair of stamens have had their pollen removed and disappeared, the pistil curves down from under the upper lip and places its stigmas in the position previously occupied by the anthers, consequently a bee on entering the flower with pollen on its back, obtained from another flower, unconsciously effects cross-fertilization by bringing the pollen in contact with the stigma.

The above arrangement for securing cross-fertilization, although comparatively perfect in its way, is eclipsed from every point of view by the contrivances for this same object presented by the species of sage

(*Salvia*), belonging to the same order of plants as the white dead-nettle. The corolla of the sage flower is formed on the bilabiate type, but owing to the certainty of securing fertilization the stamens are reduced to two, and these two have each only one of the usual two anther-lobes present, so that in reality there is only present the amount of pollen produced by one normal anther.

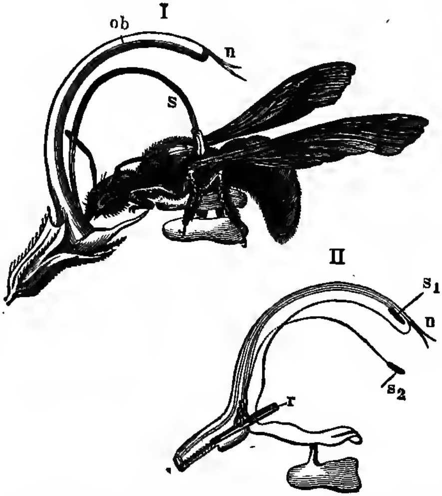

Fig. 42. One of the sages (*Salvia scalarea*). In Fig. I., *ob* is the large curved upper lip of the corolla; *n*, the tip of the style with its two stigmas; *s*, an anther that has come down upon the back of the insect; Fig. II., *s* 1 and *s* 2, the two stamens; *n*, the tip of the style showing the two stigmas; *r*, the portion of the anther that the insect's head comes in contact with in thrusting down the tube of the corolla to reach the honey, when this part is pressed downwards it causes the stamen to suddenly spring down upon the insect's back. The lip or landing-stage has a second platform springing from its under surface, on which the insect stands.

There is a lip on which the insect alights as in the dead-nettle, but the special contrivance of the sage consists in an arrangement by which the insect, in thrusting its head into the tube of the corolla, causes the mature anther to come suddenly down upon its back and shed its pollen, after which it shrivels and disappears, the second anther then being ready to act in a similar manner. Eventually the style curves down as in the dead-nettle.

The advantage of the latter method over that of the white dead-nettle is as follows. In the last-named plant the stamens, when mature, curve down into position and shed their pollen whether an insect visits the flower or not, whereas in the sage the stamen remains under the upper lip until mechanically forced down by the presence of an insect; then the force with which it comes down on the insect's back causes the pollen to escape from the anther.

Numerous other equally effective and interesting arrangements for preventing self-fertilization, and at the same time favouring cross-fertilization, exist; space alone forbids a detailed description of such. In some exotic plants, fertilization is effected by small birds.

The various colours of flowers are not, as might be supposed, the result of chance, and without any special object in view; but, remembering that the only known use of colour in the flower is that of an advertisement indicating their presence to insects or birds in connection with fertilization, so we find that the evolution of colour is, as a rule, contemporaneous with that of structure bearing on fertilization. Yellow is the primitive colour of flowers, and characteristic of those that are self-fertilized, or at all events retain that power as illustrated by buttercups and many regular flowers with the component parts free from each other; marked exceptions to this rule, however, are not rare, as in the primrose and many of its allies, and more especially in the composite plants, as the dandelion, hawkweeds, etc., also in the common toadflax. The various shades of red passing into purple follows yellow, and are characteristic of flowers that have become irregular and more adapted for insect-fertilization, as the red dead-nettle; but here again many regular flowers that are self-fertilized are red. Pure blue is the rarest colour presented by flowers, most so-called blue flowers having a more or less decided red tinge, nevertheless blue or bluish-purple colour is usually present in flowers that have advanced structural arrangements for insect-fertilization, as seen in monkshood, larkspur, etc.; but here again we have an almost clear blue anemone (*Anemone appenina*) that certainly belongs to the self-fertilizing batch, so with many others. Sir John Lubbock has clearly demonstrated that bees recognize certain colours, and it appears that the colour of a flower is of use in indicating to insects the presence of a meal or otherwise, their only object in visiting it. The strongest proof of the gradual evolution of colours in the sequence indicated—yellow, red, blue—is shown in plants under cultivation, where if a flower that is blue in a state of nature is cultivated, which means being placed under a comparatively new set of conditions, it not unfrequently produces red and yellow varieties, whereas if a naturally yellow flower is experimented with it never ascends to the red or blue series. To appreciate fully this remark, it is necessary to understand that the changes induced by cultivation, popularly considered to raise the plant above its previous level of development, are in reality always of a degenerate nature, causing the plant to fall back to a lower level, or by developing to an extraordinary extent one part of its structure at the expense of the remaining portions, and so disturbing the natural balance of its economy, that when neglected it never retains the abnormal condition assumed under cultivation, but soon returns to the wild or normal state. There are two principal objects in view in cultivating plants; utility, as sources of food, etc., and in the second place, as affording pleasure by the very varied combinations of form, and colour, and perfume afforded. From the first standpoint, it will be seen that, as a rule, as already stated, one particular part of the plant is alone of value, hence those methods of cultivation are adopted that favour the development of this particular part. As illustrations may be named the disproportionate quantity of fruit desired, and this too, to be of the first class, must be free from seeds; in the potato plant, the swollen tips of certain underground branches—potatoes — are alone of value, hence the whole object of the gardener is to get an abnormally excessive development of this portion of the plant. When gardeners and their employers are educated up to the point of realizing that the constitution of a plant, as that of an animal, can be overtaxed, and that this overtaxation results in disease, as manifested by the potato-disease, and in fact the diseases of most of our important food-producing plants, which can in many instances be proved to result from abnormal treatment, and a craving to obtain more from the plant than it can yield without grave injury to itself, and consequent loss to its short-sighted owner or "sweater." In the case of plants grown for their beauty, a "double flower" is usually considered the proper thing to produce; this again is a decided retrogression or degeneration, the stamens and pistil under the unusual treatment termed cultivation, fall back to the condition of flattened leaves from which they evolved, and in consequence the flower is prevented by this retrogression from performing the function for which it was gradually evolved, hence the cultivated plant could not possibly retain its changed character due to cultivation, and at the same time hold its own in the struggle for life unaided by man, any more than could those miserable bandy-legged dogs that are so highly prized on account of their very morbidity, and whose only function seems to be that of indicating the calibre of mind of the owner.

From what has been said respecting the complex evolution of the flower in connection with insect-fertilization, it might reasonably be supposed that a process having effected such a complete revolution over previously existing modes of fertilization, and having also reached such approximate perfection, would in a broad sense, subject to minor modifications, endure for all time; nevertheless, the evidence forthcoming does not support this view, and we are perhaps at the present day witnessing the maximum development of the insect-fertilizing idea, with its necessary accompaniment of brilliant colour and fragrance, which, like the preceding period of wind-fertilized plants, will gradually pass away, being superseded by a newer idea, which is already manifesting itself in various quarters of the globe, and is very clearly illustrated in our own wild violets. The corolla in the violet is very highly differentiated for the purpose of favouring insect-fertilization, although the petals are not grown together, yet the corolla presents the bilabiate type, with the lower lip standing out as a landing-stage, there is a well-developed spur containing nectar, and having the entrance guarded against the entrance of small insects in a manner already described; the coloration passes in the various species from yellow to very dark blue with just a tinge of red; scent, as is well known, is present in some species; in fact, the whole structure of the flower shows that self-fertilization was almost impossible, and that the visits of insects was indispensable, yet all these elaborate arrangements have not prevented the violets from evolving something even more effectual and at the same time more economical in connection with fertilization, and in reality the old-fashioned coloured flower, evolved for aiding insect-fertilization, is now of no use to the plant; but, as previously explained, when a structure is evolved, it cannot be at once arrested, even when completely superseded and useless, and this is the condition that most of the violets now find themselves in, encumbered with an old effete type of arrangement for securing insect-fertilization. The new type of flower present in many violets appears later in the season than the old type of flower, from which it differs fundamentally in being self-fertilized, the sepals remaining closed until fertilization is effected, petals are absent or rudimentary, the stamens reduced to one or two, and containing only a small quantity of pollen, but being placed in contact with the stigma, fertilization is insured. These permanently closed, self-fertilized flowers are called *Cleistogamous.* The pansy (*Viola tricolor*) is the only British violet in which seeds are produced generally by the old type of flower; in the others, as the dog violet (*Viola canina*), the sweet violet (*Viola odorata*), etc., a few seeds may occasionally be produced by the old type of flower, but it has in reality been superseded by the cleistogamous flower. The reversion to the self-fertilized method of fertilization seems, and really is, unintelligible from the present standpoint of knowledge, assuming that cross-fertilization really invigorates and helps plants in the struggle for existence, and judging from the proved superiority of the offspring in the animal kingdom resulting from parents having no blood-relationship, this idea appears to be true; nevertheless, in the case of the violets and many other groups this is certainly the direction in which things are tending at the present day. If it be eventually demonstrated that what appears to be self-fertilization in cleistogamous flowers, by some modification in the stamens and ovules, produces equally vigorous offspring as by the method of cross-fertilization, then the change becomes intelligible, as the plant would save the enormous amount of material at present necessary for the purpose of attracting and supplying insects with food. It may not be the pleasantest of ideas to realize the possibility of the gradual disappearance of the showy portion of the flower, but we are, or think we are, a self-sacrificing race, and would not begrudge the loss of our favourite flowers, if shown to be of advantage, even to plants.

The various forms of *Inflorescence,* or massing of flowers into dense clusters, have in many groups of plants obviously been evolved, or, in other words, those modifications of inflorescence over previously existing ones that favoured cross-fertilization, have predominated in the struggle for existence, continually being carried on amongst new structural departures from the older forms. In the early types of flowers possessing colour, the herald of all those various complications eventually evolved for purpose of cross-fertilization, and which still retain perfectly the power of self-fertilization, illustrated by many of the lilies, geraniums, buttercups, roses, etc., we find the flowers large and presenting a blaze of colour, in fact division of labour and the formation of communities for mutual good were ideas not evolved at the early period of the cross-fertilization epoch, and why the above-named plants along with numerous others have never passed beyond this phase cannot at present be explained; however, numerous other plants have broken away from the old extravagant state of things where each individual flower had to do everything for itself, and consequently assumed large dimensions for the purpose of making its presence known to insects. The line of departure consisted in reducing the size of the individual flower, and at the same time in concentrating numerous flowers into a cluster, the gain being an enormous saving of material, without sacrificing the primary object of colour and scent as advertisements to insects, this principle being equally effective in a large quantity of small flowers massed together as in isolated large flowers. A comparison of the dense mass of individually small flowers forming the inflorescence of the lilac (*Syringa vulgaris*), with the large solitary flowers of the red corn poppy (*Papaver rhœas*), will illustrate the above-stated view.

The maximum of development in the massing together of minute flowers to form an effective mass has been attained by the various members constituting the order of plants known as *Compositæ,* represented by such well-known plants as thistles, dandelions, daisies, chrysanthemums, sunflowers, etc., where the head in all cases does not consist of a single large flower, but of an enormous assemblage of closely-packed small flowers. In addition to the idea of concentration of small flowers met with in Compositæ, we are also introduced to a high development of division of labour in many instances. In the common dog-daisy (*Bellis perennis*) the central yellow portion of each head of flowers consists of minute yellow florets; these collectively form the disc, their function being more especially to produce seeds, whereas the white radiating portion of the head, each portion of which represents a flower, serves for attractive purposes, the florets being incomplete and not producing seed. Both disc and ray florets have the petals adhering together, but in the former the corolla is regular, in the latter irregular. A similar division of labour is seen in the inflorescence of the ox-eye daisy (*Chrysanthemum leucanthemum*), sunflower (*Helianthus annuus*), etc., whereas in the dandelion (*Taraxacum officinale*), and the thistles (*Carduus*), all the florets are fertile and of one shape, showing no division of labour in the direction indicated above.

In the case of scattered flowers, each flower originates in the angle between a *floral-bract* or leaf-like structure, and the stem, each flower with its floral-bract being separated from those above and below by a naked portion of flower-stalk; in such cases the flowers are protected during the bud stage by the calyx. This arrangement is met with in the inflorescence of the laburnum, red currant, lupin, etc. Now, if we imagine all the naked portions of flower-stalk between the flowers and their floral-bracts to be removed or not developed, and at the same time have the flowers sessile or without stalks, then we get the crowded inflorescence characteristic of composite plants as already described, which consists of a dense cluster of *sessile* or stalkless small flowers crowded at the top of a much swollen and flattened out flower-stalk, each floret accompanied by its floral-bract, the latter collectively forming the *involucre*, or outer row of green leaves seen on the under side of the daisy, sunflower, etc., and which might at first be mistaken for a calyx; the involucre incloses and protects the entire inflorescence during its early stage of development, hence the calyx of each individual flower is not required to perform its original function of protection, and in some species, as the dog-daisy and nipplewort, has become quite rudimentary, whereas in other species possessing more aptness in turning things to account, have found out a new use for the calyx, and utilize it as a dispersive organ for the purpose of carrying away from the neighbourhood of the parent plant the mature fruits. Under this new form the modified calyx, which has given up its cell-contents and become light and feathery for the purpose of floating away its attached fruit, is known botanically as the *pappus*, popularly as "clocks" in the dandelion; thistle-down is also a form of pappus, but it is important to remember that every form of down or dispersive arrangement for the purpose of scattering seeds or fruits is not a pappus, that is, a modified calyx, the down of poplar-seeds, for example, having quite a different origin. It is interesting to note that the important features mentioned as characterizing the members of the order Compositæ—the reduction in the size of the flowers and their concentration into dense heads; the involucre as a protective organ; and the pappus, a dispersive organ, are not new factors added, but simply modifications of organs previously existing; and within the order we have every transition from the older and original function of the parts enumerated above to that of their complete modification; if this were not the case, it is very doubtful whether we should ever have been able to state that the pappus is a modified calyx. This is what is meant by the term evolution. The best proof that one or more departures from the ordinary track, evolved by a group of plants, are of real service in enabling the organisms concerned to better maintain their position in the struggle for existence, is shown by their geographical distribution, and in this respect the members of the natural order Compositæ stand out prominent. In addition to the points of advantage already indicated, composite plants produce very minute fruits that are easily carried by the wind and are thus dispersed over wide areas; their protective arrangements are also well developed, and there is what may be termed an all-round provision and tendency to meet circumstances and

Fig. 43. Fruit of dandelion surmounted by a stalked pappus. (Slightly magnified.)

make the best of whatever set of surroundings they may encounter, the result being that there are at least ten thousand known species, or about one-tenth of all known flowering plants scattered over the surface of the globe.

It has been stated that ants and minute insects are as a rule useless in effecting the cross-fertilization of flowers, except in the case of some of the less differentiated open kinds; and in the more highly evolved types very varied arrangements are present for the purpose of preventing such creeping insects from reaching the inflorescence. Amongst such contrivances may be noted the presence of a viscid substance on the stem, or the presence of numerous hairs pointing downwards and becoming longer and more numerous in the region of the flowers, as in the cow-parsnip (*Heracleum sphondylium*). In the wild teasel (*Dipsacus sylvestris*), the opposite pairs of leaves are adherent to each other by their margins for some distance, forming a receptacle capable of holding a considerable quantity of water that surrounds the stem just above the origin of the leaves, and any insect creeping up the stem as far as the first pair of leaves is confronted with this miniature pool, which must be crossed before the stem can again be reached; and as there are usually from six to eight pairs of leaves, each with its pool of water, it can be understood that insects incapable of flight, and at the same time not possessed of natatory powers, rarely reach the inflorescence at the top of the stem. A similar contrivance is met with in other plants.

In concluding this portion of the subject allusion must be made to the various modes by which the inflorescence is protected against adverse climatic conditions, also

Fig 44. Dwarf palm (*Chamærops humilis*); showing the large floral-bract or *spathe* that protects the inflorescence during its early stage of development. The present species is the only palm indigenous to Europe, and it is confined to the southern portion, being more abundant on the neighbouring shores of Africa. (Reduced.)

against living enemies, during the early stage of development, in fact in many instances until the flowers are ready for fertilization. The involucre in Compositæ has been already described. In the group of Monocotyledons the inflorescence is frequently protected by a single large floral-bract called a *spathe;* this structure is well seen in the palms, where it is frequently very large, inclosing in some species a single inflorescence bearing nearly 300,000 flowers. The spathe is also highly evolved

Fig. 45. *Tornelia Fragrans,* sometimes known by the name *Monstera deliciosa,* a plant belonging to the Aroid family, showing the large spathe covering the inflorescence. The fleshy *spadix* or stalk of the inflorescence bearing perfumed and well-tasted fruits is constantly sold in Mexican markets, where it rivals the pine-apple in estimation. The leaves are very large, deeply cut into narrow segments, and towards the centre irregularly perforated. (Much reduced.)

in the arum family (*Aroideæ*), and is a striking feature in our "lords and ladies," the "Nile lily" (*Richardia Æthiopica*), where it is white, and the species of *Caladium*, where it is often bright vermilion or crimson, and performs an attractive as well as a protective function.

A spathe also protects the flowers in the snowdrop, daffodil, etc., and remains as a shrivelled brown membrane, after the expansion of the inflorescence. In the cow-parsnip the large inflorescence is at first inclosed within the inflated leaf-stalk.

CHAPTER V.

RELATIONSHIP AMONGST PLANTS.

Characters of importance in proving relationship. — Primary Divisions of the Vegetable Kingdom.—Natural Orders of Plants.—What is a species?

IT is not intended in the present place to enter into a lengthened dissertation on the Classification of plants, but solely to indicate in broad lines the most generally acknowledged characters supposed to be of value in indicating inter-relationship amongst plants. From what has been already written it will have been realized that evolution in the broader sense is recognized as the cause of the great variety of *morphological* or structural, and *physiological* or functional differences presented by plants at the present day, as opposed to the older idea of a special creation, in the sense of every plant having existed from an ideal starting-point up to the present in a comparatively unaltered condition. Having indicated the principle of variation or evolution as affording the basis on which plant affinity or relationship is founded, it is necessary in the first instance to explain a few of the most important terms employed by systematists who deal with plant affinities. Although the modern or so-called natural system of classification, as opposed to the earlier artificial methods employed by Linnæus and other writers, professes to take into consideration all important characters in formulating the lines of true relationship or descent, yet in reality the most advanced natural systems derive most of their important characters from the reproductive phase, and more especially those furnished by the flower and the fruit, which necessarily includes the seed. The structures present in a typical flower have been already described and illustrated in a diagrammatic manner in Fig. 7; the actual necessity for the presence of a flower, as understood in Phanerogams, resulting from the compulsory change in the mode of fertilization when plants established themselves on dry land, has also been discussed, and it now remains to show, that in spite of the distinct structural characters presented by flowers, their componont parts are not new additions to those possessed by cryptogams, but merely modifications of previously-existing structures, in fact it may be truly said that the reproductive portion of a phanerogam is nothing more than a changed portion of its older vegetative structure. The vegetative portion of a plant developed above ground, leaving out of question for the moment certain minor features, consists of a stem bearing leaves, the latter being scattered or separated from each other by internodes, a feature, from the vegetative point of view, of prime importance, inasmuch as it enables the individual leaves to secure the required amount of exposure to light, a point on which the performance of their most important function, that of assimilation, depends. Leaves do not appear hap-hazard on a twig, but develop according to a definite law, known as *acropetal* development, which means that the oldest leaf is situated at the base or oldest portion of the twig, and the youngest nearest the tip or growing-point. A young leaf never appears on a twig below, or lower down, than another leaf that is already developed, and when it is stated that the parts of a flower are modified leaves, what is meant in reality is that the various whorls of the flower follow the same acropetal law of development as foliar organs or leaves, and not that sepals, petals, stamens and carpels are in the young condition leaves that afterwards change their functions. The reversion of all the parts of the flower to foliar or leaf-like organs, a not uncommon occurrence, supports the above view. As in the case of foliage leaves it has been shown to be an advantage that these should be separated from each other by internodes, so in the case of the flower it is a decided advantage that all the parts should be concentrated; this is effected by the suppression or non-development of the internodes of the stem, and although this is in most flowers and inflorescences the case, yet careful attention to the order of development shows signs of the ancient idea of acropetal development. If an expanding sunflower inflorescence is watched it will be noticed that the ray florets do not expand simultaneously all round, but that expansion commences at one point and gradually works round to that point, the first florets to expand occupying a position in the concentrated arrangement corresponding to the lowest and oldest leaves on an elongated stem, while those that are latest in expanding correspond to the youngest leaves on a lengthened twig. The same idea is observed in the development of the various parts of many flowers; the sepals, petals, and stamens, that respectively appear to grow in whorls at the same level of the stem, not appearing simultaneously but in succession. In many flowers well-developed internodes are present between the respective whorls. The advantages of concentration of the parts of a flower are obvious. The sepals form a whorl that overlaps and protects every internal part until ready to expand. The concentration of the petals, in which the attractive feature of colour resides, makes the flower conspicuous at a distance to an insect on the wing; finally, during the early self-fertilizing epoch the concentration of the stamens in the immediate vicinity of the stigma was imperative, and even when the self-fertilization method was gradually superseded by that of cross-fertilization, the various contrivances for preventing self-fertilization did not necessitate the removal of the stamens from the position occupied during the earlier condition of things. Throughout the Vegetable Kingdom, and in connection with every function, there is a decided stand against radical and abrupt changes, in spite of, as one may be allowed to express it, obvious advantages; but at the same time no impediment is placed in the way of modifications; traits which, if manifested by ourselves, would indicate a lukewarm confidence in the proposed change, coupled with a determination not to completely forsake an old tried method until the new idea had fully proved its superiority.

Returning to the general build of a typical flower, we meet with in early types, four whorls or verticils of organs, calyx, corolla, stamens, and carpels, developed in acropetal succession, the calyx being the oldest whorl and consequently lowest down on the branch or axis of the flower, and the carpels the youngest and occupying the top or youngest portion of the stem, the four whorls being, in every primitive flower, separated by very short internodes. In the common field buttercup, which illustrates a simple and uncomplicated type of flower, we meet with, commencing from below, a calyx composed of five leaves or *sepals,* springing independently from the stem, and perfectly free from each other; such a calyx is termed *polysepalous.* Next we come to the corolla, consisting of five yellow petals also growing directly from the stem, and quite free from each other—hence called *polypetalous.* Within the corolla, and consequently an internode higher up the stem, is situated a considerable number of stamens, each of which originates directly from the stem; and finally, at the tip or apex of the stem of the flower, we find a number of closed leaves or *carpels,* each containing a single seed, springing independently or free from each other, from the tip of the floral axis; the carpels collectively form the fruit, and a fruit composed of free carpels, that is, not grown to each other, is said to be *apocarpous.* The above indicated sequence of development of the four whorls constituting a flower is in reality the only one that exists in the flower, but owing to the subsequent growing together of the components of any one whorl, or of the different whorls with each other, we meet with flowers exhibiting such different structural peculiarities and appearances from those presented by primitive types, as the buttercup, that unless the transitions from one to the other are clearly traced, it is difficult to realize that the two are built on the same plan. If the flower of the primrose is next examined, the sepals will be found cohering together and forming a tube, the tips alone being free; this type of calyx is termed *gamosepalous;* the petals are also grown together, forming a *gamopetalous* corolla; five stamens are present, which appear to grow from the inside of the corolla-tube, and are described on this account as *epipetalous;* finally the five carpels with their styles and stigmas are completely grown together at every point; when the carpels are grown together the constituent pistil is termed *syncarpous.* In the primrose, although there is a growing together of components of the various whorls, yet the flower is regular, a still later type being illustrated by the snapdragon (*Antirrhinum*), dead-nettle (*Lamium*), honeysuckle (*Lonicera*), etc., where the flower is irregular, due to a difference in size and shape of the component sepals and petals, for the purpose, already explained, of facilitating the visits of insects. The relative position occupied by the stamens, or rather the particular portion of the flower from which they appear to originate, is of primary importance in the classification of plants, and requires to be clearly understood. When the stamens grow directly from the *thalamus* or

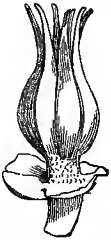

Fig. 46. Christmas rose (*Helleborus*), showing the apocarpous pistil.

Fig. 47. Primrose (*Primula vulgaris*) showing the syncarpous pistil.

axis of the flower, and are not in any way adherent to any of the other whorls, they are said to be *hypogynous.* This arrangement of the stamens is seen in buttercups, poppies, geraniums, etc., and in reality is the only position from which stamens originate in every known flower; but in numerous instances the stamens, instead of remaining perfectly free from the other whorls of the flower, become adherent to a greater or less extent, and in such cases appear at first sight as if they actually started in the first instance from the organ to which they are adherent. When stamens appear to grow from the calyx, as in the roses, brambles, saxifrages, etc., they are described as perigynous. When the stamens appear to grow from the petals they are described as *epipetalous;* and, with very rare exceptions, the stamens are always epipetalous when the corolla is gamopetalous. Stamens that appear to originate from the top of the ovary, as in the parsnip (*Pastinaca sativum*), and cicely (*Myrrhis odorata*), are described as *epigynous;* while finally in the orchids, the one or two stamens present are adherent to the style, and are said to be *gynandrous.* The various positions occupied by stamens as described above are not sharply separated from each other, but connected by intermediate stages; for example, in the

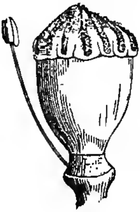

Fig. 48. Red corn-poppy (*Papaver rhœas*) showing the hypogynous stamens originating directly from the thalamus or axis of the flower; the superior pistil is syncarpous, and surmounted by several radiating, minutely velvety stigmas. (Natural size.)

order known as *Crassulaceæ,* including the stonecrops (*Sedum*), and houseleek (*Sempervivum*), it is in many species a difficult matter to say whether the stamens are hypogynous or perigynous; the same is true of the sundew order (*Droseraceæ*). In other instances the stamens of a flower become more or less adherent amongst themselves; in the mallows and the hollyhock all the filaments grow together, the anthers remaining distinct, whereas in composite plants the anthers are grown together, the filaments remaining distinct. All the changes undergone by stamens from the fundamental hypogynous position and perfect freedom from each other, bear directly on the subject of insect-fertilization.

Returning to the pistil or central and terminal portion of the flower, we find that the two conditions of apocarpous and syncarpous, depending on the freedom or adherence of its component parts, called *carpels,* are again connected by intermediate conditions as seen in the saxifrages. The pistil varies considerably in structure and appearance in different plants, but the three following parts, clearly shown in the primrose, fig. 46, are usually present. The lower swollen portion, which contains the ovules or unfertilized seeds, is the *ovary;* this is surmounted by a slender stalk-like body, the *style,* which in turn is terminated by the knob-like *stigma.* The ovary is the indispensable portion, which, after the fertilization of the ovules—then called *seeds*—undergoes important changes, often increasing considerably in size, and is then known as the *fruit;* hence it will be observed that ovule and seed are names applied to the same organ at different stages of development; the same remark applies to the terms "ovary" and "fruit." The stigma is the specialized portion of the pistil on which the pollen is deposited; while the use of the style, comparatively the least important part of the pistil, and often entirely absent, as in the poppy, is for the purpose of placing the stigma in the most favourable position for receiving the pollen.

Fig. 49. *Fuchsia globosa.* The flower has an inferior ovary, the calyx is coloured and gamosepalous, the sepals being united to form a tube for about half their length, the four tips being free and spreading; the corolla is polypetalous. All whorls of the flower consist of four parts or multiples of four; there are four sepals, four petals, eight stamens, and four carpels forming the syncarpous, inferior ovary. (Natural size.)

A very remarkable change in the position of the ovary, relative to the other whorls of the flower, requires notice.

It has already been stated that in primitive flowers, as buttercups, poppies, etc., the pistil is situated highest up, or terminal, on the central axis of the flower, and perfectly free from the other whorls; when this is the case, the ovary is said to be *superior.* If the flower of a snowdrop, gooseberry, or *Fuchsia* is examined, the calyx and corolla will be found to originate from the top of the ovary, the latter being apparently lowest down on the axis of the flower; in such cases the ovary is described as *inferior.* It must be understood that there are not two primitive types of flower structure, one with the ovary superior, the other having the ovary inferior; but

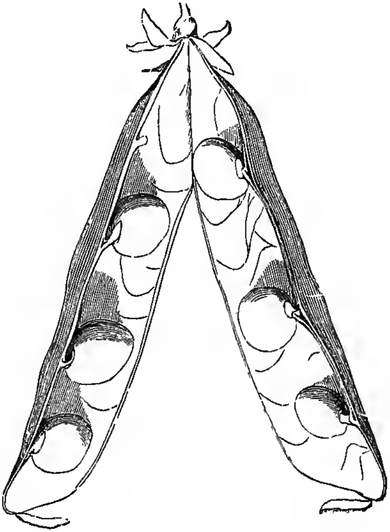

Fig. 50. Pod of the pea, illustrating a fruit composed of a single carpel.

in reality the flower with an inferior ovary is a modification or evolution from the earlier type where the ovary is superior. A transition stage, where the normally inferior whorls—sepals, petals, and stamens—have only crept halfway up the ovary before becoming free from it, is seen in some of the saxifrages, houseleeks, etc.

The appearance of the ovary when mature—that is, the fruit—is in many instances so widely different from the ordinary conception of a leaf-like structure, that unless the transitional phases are indicated, it would be difficult to realize the fact that the carpels or components of the ovary are in reality modified organs originating, and, in the early stage, presenting the characters peculiar to leaves. This idea will be made clear by the examination of the pod of a common pea, which is a carpel or leaf folded so that its two edges meet and grow together, thus forming a closed cavity, the ovary. The tip of the carpellary leaf forms the stigma, and the ovules or young seeds spring from the two margins of the carpel and grow into the cavity formed by the closed-up carpel. In the pea a single carpel constitutes the fruit, but in most instances the fruit is composed of more than one carpel. The fruit of the marsh marigold (*Caltha palustris*) consists of a number of carpels which, like that of the pea, still remain comparatively unchanged and present a leaf-like appearance; and as these carpels remain free from each other, the fruit, which consists collectively of all the carpels belonging to one flower, is *apocarpous.* The *syncarpous* ovary, on the contrary, is composed of two, or generally more, carpels arranged in a whorl and grown to each other by their edges. The number of carpels forming a syncarpous ovary is in many cases clearly indicated externally by grooves along the ovary corresponding to the junction of the margins of the component carpels, as in the tiger-lily, whereas in other cases, as that of the hazel-nut, the "shell," which is the fruit consisting of two carpels, shows no external evidence as to number of carpels forming it at maturity, and in addition has become hard and woody, thus departing from the leaf-like carpel of the pea. The object of becoming hard and woody is for the purpose of protecting the inclosed seed, popularly known as the "kernel."

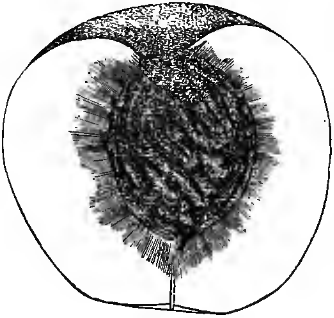

Fig. 51. Fruit of the peach (*Persica vulgaris*), cut open and showing the structure of the fruit, which includes the outermost skin, the succulent portion, and also the "stone," the seed being the portion usually called the "kernel." (Natural size.)

Speaking of the "shell" of the hazel-nut as a fruit may possibly cause some surprise, but the popular conception of a fruit as being that of something good to eat, is not in accordance with the botanical definition; according to the latter, the carpels at maturity constitute the fruit, whatever their consistency and properties may be, and the earliest function of the fruit in the ovary condition is that of protecting the young ovules, and all subsequent changes in its condition are connected with either continued protection of the seed, as in the case of the hazel-nut, already mentioned, the walnut, cocoa-nut, etc.;

or for dispersive purposes—that is, by some means facilitating the removal of the fruit from the neighbourhood of the parent plant, and depositing it in pastures new. The contrivances for effecting dispersion are very varied, and are mostly confined to those fruits that are *indehiscent,* or do not open in a definite manner at maturity for the purpose of allowing the seeds to escape; as examples of such may be mentioned, peach, gooseberry, orange, cocoa-nut, etc. The succulent and edible nature of the group of fruits popularly known as stone-fruits, and many others, is a dispersive contrivance; the fruits are eaten by animals, and consequently the seeds are dropped at maybe a considerable distance from the parent plant; in many such cases the seed is inclosed in a hard "shell," which is a specialized portion of the fruit for the object of protecting the seed from harm during its passage through the alimentary canal. The bright colours of most edible fruits are attractive in function, indicating to birds or mammals their whereabouts. In other instances the surface of the fruit is furnished with hooked spines that catch hold of the wool or hair of an animal, and are thus dispersed; the fruit of our common bedstraws (*Galium*), popularly known as "cleavers," illustrate this idea. In another group of fruits, certain portions of the fruit are flattened out into flat, wing-like portions for the purpose of utilizing the wind as a dispersive agent; amongst such may be mentioned the fruit of the ash, sycamore, etc.

Fruits that open in a definite manner at maturity for the purpose of allowing the seeds to escape are said to be *dehiscent;* examples, pea, wallflower, violet, poppy, etc. In some instances the seeds are dispersed by the sudden dehiscence or opening of the fruit, as in the wood-sorrel (*Oxalis acetosella*) and the geraniums.

Important characters for classificatory purposes are derived from the structure of the seed in Angiosperms. Following the fertilization of the oosphere, important changes take place in the ovule, one of which is the accumulation of a certain amount of reserve material destined to serve as the first food for the young plantlet on germination; this arrangement is universal, as it will be remembered that the assimilation of food depends on the presence of green leaves, and the increase in size of the tiny seedling up to the point of having leaves of functional value is carried on entirely at the expense of the material, known as *endosperm*, provided by the parent plant. Contemporaneous with the appearance of

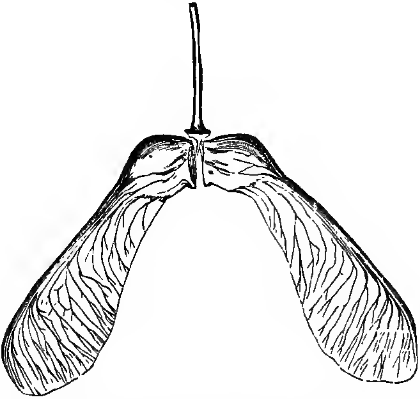

Fig. 52. Fruit of the maple, showing wing-like flattened expansions for the purpose of effecting removal from the tree by the wind. (Natural size.)

the endosperm in the ovule, and surrounding the fertilized oosphere—now the oospore—the latter by repeated cell-division assumes the form of a tiny plantlet contained entirely within the ovule—now the seed—and called the embryo; the development of the embryo continues until the most important portions of the vegetative phase of the plant are formed, namely, a minute stem or *plumule,* which is continued downwards as the root or *radicle,* and in addition, either one or two minute leaves or *cotyledons.* The presence of either one or two cotyledons in the embyro depending on the species examined is so constant that it constitutes one of the most important characters used in breaking up the Angiosperms into two primary divisions—*Monocotyledons,* where one cotyledon is present on the embryo; examples—palms, grasses, sedges, lilies, etc.; *Dicotyledons,* where the embryo has two opposite cotyledons; examples—buttercups, roses, peas, oak, hazel, etc.

The following arrangement illustrates the primary sections into which the vegetable kingdom is divided:—

VEGETABLE KINGDOM.

I. *Cryptogamia.*

Asexual reproduction by cell-division, by motile antherozoids, or in the higher groups by highly differentiated spores. Sexual reproduction by oospheres that are fertilized by motile antherozoids, water being the agent that enables the antherozoids to reach the oosphere. After fertilization, the oospore does not become differentiated by cell-division into an embryo previous to entering the resting stage. Alternation of generations is often sharply marked.

The following are the most important groups or natural orders of Cryptogams:—

Seaweeds and their fresh-water allies (*Algæ*); mushrooms, toadstools, puffballs, rusts, mildews, lichens (*Fungi*); liverworts and mosses (*Muscineæ*); ferns (*Filices*); clubmosses (*Lycopodiaceæ*); horsetails (*Equisetaceæ*); quillworts, salvinias, marsileas (*Rhizocarpeæ*).

II. *Phanerogamia.*

Sexual reproduction by oospheres that are fertilized by passive or non-motile pollen grains; these are brought into contact with the oosphere by the agency of wind or of insects, or the two sexes grow in immediate contact, so that no external agency is required. The fertilized oosphere by cell-division develops into a minute plantlet or embryo while still inclosed within its protective covering, the whole constituting the seed, which at maturity enters the resting stage. Asexual reproduction by spores. Alternation of generations absent.

To the present section belong all plants not enumerated under the preceding section, and popularly known as flowering plants, on account of the usually conspicuous flower; nevertheless, in very many phanerogams the flower is comparatively inconspicuous, or very minute and entirely devoid of colour, as in the grasses, sedges, and many forest trees.

In connection with the classification of plants, it is of the greatest importance to bear in mind the fact that the characters of sections given in books do not include all the important features presented by the members constituting the group, but only those that are most pronounced and general, and for these reasons considered as being of value in indicating true relationship; and even these characters are not equally conspicuous in all the included species, but gradually disappear and are replaced by vestiges of other characters that in turn become more pronounced, and constitute the leading characteristics of a neighbouring section, hence book characters only cover the most typical representatives of a given allied group of plants, and it is often a matter of personal opinion as to which of two or more sections certain plants should be placed in, that occupy the neutral or transitional line between one section and another, by possessing, as stated above, the dying out characteristics of one group, and the incipient indications of those which in the fully evolved condition constitute the marked features of an allied group.

The above remarks apply to the two primary divisions of the Vegetable Kingdom as given above. Cryptogams and Phanerogams do not constitute two sections allied to each other by the broad ties of plant individuality only, such as the presence of chlorophyll and consequent power of feeding on inorganic matter, but in the closer affinity indicated by numerous points of agreement in matters of detail; in fact, Cryptogams, as the oldest section in point of time, appears to have emphasized two points in its evolution that stand out conspicuously in the higher types, namely, alternation of generations, which implied the breaking up of the complete life-cycle of an individual into two phases, one sexual, the other asexual; the second feature is the presence of motile male bodies or antherozoids; an additional negative feature is the absence of high differentiation in the fertilized body or oospore previous to immediate germination. The cutting down of one of the two phases or generations—the sexual one—is carried to a very considerable extent in Cryptogams, that is in plants that yet have motile antherozoids, and consequently reach the female part to be fertilized through the agency of water; but as plant-life extended from its original aquatic habitat, water as the agent for bringing the male or fertilizing body in contact with the female was gradually superseded as already explained, by other agents; consequently the male body lost its motility and became transported by wind or insects. When evolution reached the point where the sexual phase as a distinct structure had been arrested, and the old motile antherozoid replaced by non-motile pollen, also a higher development of the fertilized oosphere resulting in the formation of an embryo previous to immediate germination, then these combined characteristics constitute the key-note to the botanist's conception of a Phanerogam, as opposed to a Cryptogam, which it will be observed turns in reality mostly on the particular way in which the male or fertilizing body is conveyed to the female. But Phanerogams did not appear with a spurt as a new creation; in other words, the features given above as characterizing a Phanerogam did not appear simultaneously, and even in Phanerogams the rudimentary remains of structures characteristic of Cryptogams, as the prothallus or sexual generation, are still present in Gymnosperms. On the other hand such features as the highly developed embryo, characteristic of Phanerogams, is clearly indicated in some of the higher

Cryptogams, where the fertilizing body is still a motile antherozoid.

It is not intended to enter further into the classification of Cryptogams. The Phanerogams are divided into the two following primary divisions :—

PHANEROGAMIA.

I.—*Gymnospermeæ.*

Fibro-vascular bundles open, arranged concentrically. Ovules naked, produced on open carpellary leaves; fertilization direct, the pollen coming in actual contact with the ovule.

The following natural orders are all that are included in the Gymnospermous division of Phanerogams :—

Coniferæ, including firs, pines, cedars, yews, araucarias, etc. The female inflorescence usually consists of a collection of carpels crowded on a long axis and forming a cone; hence the name of the order.

Cycadeæ, including the cycads, zamias, etc. The species resemble tree-ferns and palms in general appearance, having a more or less elongated trunk crowned by a tuft of very large, much divided leaves.

Gymnosperms are geologically the oldest group of Phanerogams, and most nearly allied to their predecessors, the Cryptogams, and still retain vestiges of structural peculiarities that were well developed and characteristic of the last-named group, such as traces of the prothallus in the pollen-grain and ovule, the occurrence of several oospheres in the ovule, the formation of endosperm previous to fertilization, etc.

Fig. 53. *Cycas circinalis*, a gymnospermous plant belonging to the order *Cycadeæ*, showing the palm-like habit. (Much reduced.)

The species are trees or shrubs, herbaceous species being absent. Finally, all are anemophilous, or wind-fertilized.

II.—*Angiospermeæ.*

Fibro-vascular bundles either closed and scattered or open and arranged concentrically. Ovules developed within the cavity formed by closed carpellary leaves; fertilization consequently indirect, the pollen being received on the stigma, where it forms a pollen-tube that eventually comes in contact with the ovule.

Angiosperms as a group include the latest or most modern types of plant evolution, and embody in many groups the relative perfection of structure and adaptation to circumstances which has taken geological ages to evolve. The outcome of this evolution shows itself in the elimination of many antiquated structures that performed perfectly the functions required, but at too great an expenditure of energy and material, and in all the most highly differentiated groups, the outcome of unconscious evolution tends towards one grand idea, that of securing the greatest benefit with the least possible outlay. Angiosperms include all flowering plants, with the exception of the cycads and conifers, enumerated under Gymnosperms; the various members present all grades, from the tiniest wayside weed to the forest tree, and in point of duration from a single season to that of a period extending over centuries. Wind-fertilization and self-fertilization are both still in vogue, but in the great majority of species, insect-fertilization is more or less completely relied upon, and the enormous variety of floral evolution in connection

Fig. 54. *Livistonia australis,* a palm with large fern-shaped leaves. The palms, along with the screw-pines, are the only Monocotyledons that assume tree-like proportions. (Much reduced.)

with this idea is certainly the most conspicuous of features characteristic of Angiosperms.

Angiosperms in turn are divided into the two following primary sections, depending on minor modifications of the important structural characters of the group.

I. *Monocotyledones.*

Fibro-vascular bundles closed, scattered. Embryo with one cotyledon. Whorls of the flower in threes or multiples of three.

Other features characteristic of the present section are the arrangement of the veins of the leaf, which are usually described as parallel in arrangement, the complex network, seen best in a "skeleton leaf" and characteristic of the following section, being usually absent. The general build of the leaf is also comparatively simple, being usually long and narrow, as illustrated by grasses and snowdrops, the margin as a rule is entire, the leaf is not articulated to the stem, but after having performed its functions remains hanging to the stem until it decays. There is also an absence of so-called sensibility, or responsions in the way of movements to external stimuli. The spathe, as already explained, is a form of floral protection met with only in the present group. A common mode of vegetative reproduction is by the formation of bulbs, which generally consist of a number of closely-packed modified leaves that are usually fleshy, owing to the presence of store food materials, starch, etc. The two outermost floral whorls, calyx and corolla, are usually coloured, and together are often called the *Perianth.*

The following are amongst the most characteristic orders of Monocotyledons. *Palmæ,* palms; *Liliaceæ,* lilies, hyacinths, tulips; *Gramineæ,* grasses, including bamboos, sugar-cane, and the various cereals, as wheat, rice, oats, maize, etc.; *Orchideæ,* orchids; *Irideæ,* iris, gladiolus, etc.; *Amaryllideæ,* snowdrop, daffodil, snowflake, etc.

The plants belonging to the order *Aroideæ,* including our "lords and ladies" (*Arum maculatum*) and the Nile lily (*Richardia æthiopica*), have the veins of the leaves forming a network as in Dicotyledons.

II. *Dicotyledones.*

Fibro-vascular bundles open, arranged concentrically. Embryo with two opposite cotyledons. Whorls of flower in fives or multiples of five; rarely in multiples of two.

The leaves in the present group attain a much higher degree of specialization than in the Monocotyledons, and there is a perfect sequence in the various species, from the uncut simple leaf with an entire margin to the much divided compound leaf possessed of the power of closing and thus protecting its working surface when conditions are unfavourable for the performance of its functions. Protection against climate is often present in alpine or subarctic species under the form of a dense coating of interwoven hairs, giving to the leaf the appearance of felt. In the majority of species the leaves, whether simple or compound, are articulated to the branch from which they spring, and at the end of the season at once fall off, leaving a clean leaf-scar on the branch. In "evergreen" plants the leaves live for a longer period than one season, and do not all fall away at one time, but the old leaves fall away after new ones have become fully developed. The modifications of leaves into tendrils, in the case of weak-stemmed plants, and also as organs of nutrition in insectivorous plants, have already been noticed.

As a rule, so long as the corolla is polypetalous and regular, and the stamens hypogynous, the latter are numerous and the mode of self-fertilization predominates, whereas when special provision has been made for favouring insect-fertilization, suggested by the irregular gamopetalous corolla, the stamens never exceed ten in number, far more frequently five only, and in many instances even fewer, being reduced in the sage, thyme, valerian, etc., to one or two. A marked division of labour is usually present in the two outermost whorls of the flower, the calyx being green and protective in function, the corolla coloured and attractive. In some cases, however, the calyx is coloured, when it is described as *petaloid*, as in the *Fuchsias* (fig. 49); in pendulous flowers the calyx is frequently larger than the corolla and petaloid, becoming the most conspicuous attractive whorl, or it is reduced to exceedingly small proportions, so as not to interfere with the attractive features of the corolla, as in heaths and the harebell (*Campanula rotundifolia*). In many flowers the corolla is entirely absent, and in such cases the calyx is often brightly coloured, as in the marsh-marigold (*Caltha palustris*), wood anemone (*Anemone nemorosa*), etc.

So far the groups considered have been of primary importance, the result of certain characters being constant in thousands of species, which, however, differ widely amongst themselves in minor points of detail. The most pronounced of these minor points constitute in turn the characters of so-called Natural Orders.

In the Dicotyledons alone there are over two hundred such Natural Orders, that is, Dicotyledonous plants can be broken up into over two hundred groups, each characterized by the possession of certain structural features

Fig. 55. One of the honeysuckles (*Lonicera glauca*), a typical Dicotyledon, having the corolla gamopetalous and irregular; stamens five, epipetalous; ovary inferior. The opposite pairs of leaves are connate, or grown together for some distance. (Natural size.)

in common, and at the same time not possessed by the members of any other group. From the philosophical point of view, supported by evidence of the mutation and change in species that cannot be denied by the bitterest opponents of evolution, it may be assumed that the primary divisions of the vegetable kingdom enumerated above originated as side branches from previously existing groups. From Cryptogams as the starting-point of plant life we get, as already shown, Phanerogams; the latter appearing as Gymnosperms, that were followed later in time by Angiosperms; the latter again being first evolved as Monocotyledons, followed by Dicotyledons.

It is important to understand that in the gradual evolution of plants, the groups do not follow each other in an unbroken sequence, by which is meant, the structural peculiarities characterizing a given group are not evolved or supplemental to the characters possessed by the most highly organized members of the group from which it evolved, but in reality new groups originate from the simpler and primitive members of the preceding or parent group, so that the early members of a new group are for a time much simpler in organization than the most perfect forms of the older; but the new group commences with what may be expressed as the germ of a new idea, and if this new idea better enables its members to hold their own in the struggle for existence, we find the new group gradually surpassing the parent group in numbers and also in distribution in space, due to the advantages derived from the possession of the new feature, which need not necessarily imply increased complexity of structure, but, on the other hand, as a rule, substitutes simplicity of mechanism combined with accuracy of detail in place of what may comparatively be termed a "rule-of-thumb" arrangement; this idea is illustrated in both vegetative and reproductive parts; it is only necessary to mention compound, sensitive leaves, and the various contrivances for insect-fertilization as compared with antiquated leaves and flowers. The extension of modern groups is illustrated by the subordinate position occupied at the present day by cryptogams, once the only group in existence, and in like manner gymnosperms, the oldest of the phanerogamic series, that were in turn monarchs of the plant world, have yielded in numbers and position to angiosperms, which at the present day take the lead, due more especially to the scrupulous exactness with which the law of "Division of Labour" is carried out.

The large divisions of phanerogams are in turn broken up into so-called *Natural Orders*, characterized by minor points of agreement; and again, Orders are divided into still smaller groups known as *Genera*, and finally the different kinds or *species* constituting a genus are distinguished from each other by less important or what may be termed local characteristics. As to the peculiarities of structure and otherwise that constitute a species, there is a wide difference of opinion, but the following gives an idea as to the scientific conception of a species, that is, all those plants that at the present day so resemble each other in structure and function as to justify the idea that they have originated from a single ancestor.

CHAPTER VI.

FOSSIL PLANTS.

Vegetation of early Geological periods.—Disappearance of groups of Plants.—The evolution of plants corroborated by Geological evidence.

OWING to the minute size and delicacy of structure of many of the early types of plant life belonging to the Algæ and Fungi, these would hardly be expected to occur in a fossilized condition, nevertheless, certain microscopic types of fungi, closely allied to the fungus causing the potato disease at the present day, have been detected in sections of fossil wood belonging to the Carboniferous period, and the microscopic group of Algæ called diatoms also occur in immense numbers in various formations dating from the Carboniferous, where two species occur that have passed down to the present day without undergoing the minutest observable change in any direction, and still exist in considerable numbers. This at first sight appears directly opposed to the theory of evolution, without, however, in reality being so, and only proves that a change of environment is at least a very important factor in promoting those modifications of structure that eventually become sufficiently marked to constitute what we term new species or groups. One important feature clearly shown in the geological record is that each important group of plants commences in a small way, that is, its components are comparatively few, simple in organization, and comparatively limited in distribution; as the group evolves, we find that the number of species increases at a comparatively rapid rate, the same being true of the general organization and distribution in space; this goes on until a maximum of development is reached, after which there is in every instance a contraction as it were, indicated by a weeding out and disappearance by degrees of those species least able to hold their ground in the increased struggle for life, accompanied by a general deterioration in structure, and narrowing of the area of distribution. From the above account it will be seen that the life-history of a group of plants may be diagrammatically represented by a spindle-shaped figure, its base or starting-point corresponding to the first geological evidence of its existence, then gradually widening out to its maximum point of development, then again contracting, becoming thinner and thinner, indicating its gradual decline, until the present period is reached, for although in some cases the living representatives are exceedingly few in numbers, limited in distribution, and degenerate in structure compared with the same group at the period of its maximum of development, yet every important group represented in a higher stage of development during some earlier geological epoch has existed up to the present time, although sections or natural orders belonging to certain groups have geological ages ago become quite extinct, and are only known to us by their fossil remains. In such cases the general structure and microscopic details afford the proofs of affinity.

The following order of succession of Stratified Formations or Geological periods will enable the reader to trace the gradual evolution of plant groups —

Post-tertiary, or Quarternary.	Recent and Prehistoric.
	Pleistocene or Glacial.
Caniozoic, or Tertiary.	Pliocene.
	Miocene.
	Oligocene.
	Eocene.
Mesozoic, or Secondary.	Cretaceous.
	Jurassic.
	Liassic.
	Triassic.
Palæozoic, or Primary.	Permian.
	Carboniferous.
	Devonian.
	Silurian.
Archæan.	Laurentian.

CRYPTOGAMS.

Algæ.

The Algæ, or seaweeds, geologically the oldest known plants, first occur in the Laurentian series, and continue to the present day.

Filices.

The ferns first appear in the Devonian, attain their maximum of development towards the end of the Carboniferous age, then, with the exception of a second feeble attempt at extension about the commencement of the Tertiary period, gradually diminish in importance up to the present time.

Equisetaceæ.

The horsetails and their allies, amongst the earliest of Vascular Cryptogams, appear late in the Silurian, attain their maximum in the Carboniferous, and then gradually decrease, being represented at the present day by only one genus, including about twenty-five species; these are marsh plants of diminutive size and degraded structure as compared with their forest-forming progenitors of the Carboniferous period, such as *Calamites*.

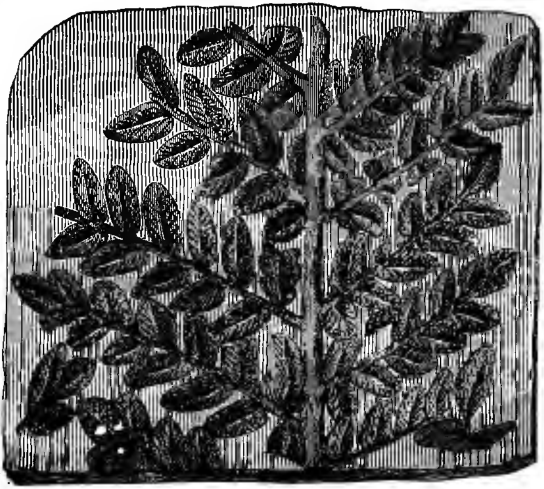

Fig. 56. *Neuropteris heterophylla*, a fossil fern belonging to the Carboniferous period. (Natural size.)

Lycopodiaceæ.

The club-mosses are contemporaneous in their appearance and period of maximum development with the Equisetaceæ, and like the latter assumed large dimensions and formed forests during the Carboniferous age, their remains contributing largely towards the formation of coal. At the present day the remaining members of the group are few and of small size.

From the above it will be seen that all the groups of Cryptogams attained their maximum of development during the primary epoch, and mostly during the Carboniferous period, which on this account has been termed the age of Cryptogams. Several orders that during that period formed extensive forests, as the species of *Sigillaria, Lepidodendron, Calamites,* etc., have long ago become extinct.

PHANEROGAMS.

Gymnosperms.

Coniferæ.

Conifers, the earliest of Phanerogams, first occur in the Devonian rocks, their maximum extending through the mesozoic period, after which a decline took place that has continued up to the present time.

Cycadaceæ.

The Cycads appear in limited numbers in the Carboniferous age, suddenly attain a wide-spread maximum during the Jurassic period, of which they are highly characteristic; this is followed by a slow decline through the Cretaceous age, after which the falling-off in numbers is rapid, but few surviving at the present day.

ANGIOSPERMS.

Monocotyledons.

The earliest known representatives of the most modern group of plants appear in Permian rocks, attain their maximum about the middle of the Tertiary epoch, and at the present day are just on the decline.

Dicotyledons.

Dicotyledonous plants appear about the middle of the Cretaceous age, and are still evolving, being more numerous at the present day than during any previous period.

It is interesting to note how comparatively soon in every instance the maximum of development and extension in space, or geographical distribution, is attained after the advent of a given group, compared with the complete obliteration of the same after the maximum is past.

The following paragraph from Dr. Geikie's "Class-Book of Geology" is a fitting conclusion to the present chapter.

"It is undoubtedly the greatest triumph of geological science to have demonstrated that the present plants and animals of the globe were not the first inhabitants of the earth, but that they have appeared only as the descendants of a vast ancestry, the latest comers in a majestic procession, which has been marching through an unknown series of ages. At the head of this procession we ourselves stand, heirs of all the progress of the past and moving forward into the future wherein progress towards something higher and nobler must still be for us, as it has been for all creation, the guiding law."

CHAPTER VII.

GEOGRAPHICAL DISTRIBUTION OF PLANTS.

Principal factors influencing the distribution of plants.—British Flora, past and present.—Distribution of Cryptogams.—Distribution of Phanerogams.

THE influence of temperature on plant life has already been alluded to, and this factor is amongst the most important in determining the distribution of plants at the present day. The fact of certain groups of plants occurring only in particular regions does not prove that that particular region is the only one suited to their requirements, as it has been proved in many instances that when such locally occurring plants have been introduced by human agency into new localities, they have not only established themselves, but in several instances have monopolized the new area, and more or less completely driven out the previously-existing indigenous flora. Numerous common European weeds that have been unintentionally introduced into new areas have spread at an enormous rate, driving the native plants before them, and causing serious inconvenience to the settlers in such districts; as an illustration may be mentioned the spread of the common thistle on the pampas of Buenos Ayres, where at one time it almost completely covered thousands of acres with a rank growth, greatly to the disadvantage of the sheep-farming industry. A similar example on a smaller scale followed the accidental introduction of the American water-weed into Britain, which at one time threatened to choke up many of our canals and rivers, but in both the above-mentioned cases, and also in many others, after the first spurt made by an alien on finding itself in what to it proves to be virgin soil, a gradual decrease in its vigour of growth and consequent distribution takes place, and it settles down to the level of having to hold its own in the struggle for existence, or in some instances almost entirely disappears. Similar waves of inundation by parasitic plants, more especially microscopic species of fungi, have been observed, which after causing serious devastation for a certain period, recede, either altogether or to such an extent as not to materially influence the continuance of the species of plant on which they are parasitic. In connection with the above it is sufficient to note the potato disease, due to the ravages of a minute fungus known as *Phytophthora infestans*; the hollyhock disease, caused by an equally minute fungus called *Puccinia malvacearum*; finally, the destructive silk-worm disease known as "muscardine" is also due to the ravages of a minute fungus, *Botrytis Bassiana*, which attacks and destroys the living insect.

As already stated, every plant of high organization is much influenced by temperature; in other words, a certain amount of temperature is necessary to enable it to perform all its functions properly. Hence we speak of a palm region, cactus region, etc., meaning that the particular group mentioned is highly characteristic and abundant in the region indicated, but not at the same time monopolizing the entire district.

The latitude of a place does not necessarily tell the range of temperature, the isothermal lines, or those running through places having the same mean annual temperature, are in the region of the equator more or less parallel with the lines of latitude, but as we recede from the equator the two are widely separated, the divergence depending on the proximity of the ocean, mountain ranges, etc. The annual isotherm of 50° passes through latitude 42° 30′ in eastern America, 51° 30′ in England, and 40° in Eastern Asia; nevertheless the floras of these places are widely different, depending on the fact that the mean annual temperature may be the same in a place having a moderate summer and winter temperature as in another having a very hot and short summer and a very long cold winter. The last mentioned distribution of heat is productive of a short and sudden burst of floral glow as seen in the Swiss Alps, or in high latitudes, as in Iceland, whereas the first mentioned distribution of temperature favours a prolonged activity of the different members of a flora, as seen in England.

Light has already been shown to be indispensable to the existence of all plants whose assimilation depends on the presence of chlorophyll, but at the same time this factor to some extent influences the distribution of plants. Some kinds require full exposure to light; others flourish best in the shade.

The varying density of the atmosphere at different elevations appears to produce little or no effect on plant life, nor to be the cause of any morphological or physiological peculiarities. A comparison of arctic vegetation growing but little above the sea-level with that growing at an elevation of 17,000 feet in the Himalayas, where 15 inches of pressure were removed, showed no observable difference in the habits and characters of such plants as were common to the two regions. Again, the common plants of the lowland portions of India that bloom during the cold season are identical with the same species that bloom at great elevations in the same country during the alpine summer; hence the variation sometimes observable between lowland and alpine forms of the same species does not depend on diminished atmospheric pressure.

Moisture exerts a marked influence on the distribution of plants as existing at the present time. The very existence of life depends on the presence of water. The plants of moist regions are often of a loose, spongy texture with large, soft, smooth leaves, whereas those characteristic of regions where there is but little moisture in the air have the leaves firm and of a hard, dry texture, as seen in many Australian plants, whereas in very arid regions the leaves are often small and scanty, and the stem covered with prominent spines.

Mountain ranges, deserts, and seas are unsurpassable barriers to the migration and distribution of plants; in the case of mountains a two-fold difficulty is presented; the plants of low areas would be exposed to an increasing degree of cold as they ascended, and at the same time would have to struggle with the vegetation indigenous to the regions on which they encroached, hence as a rule the floras on the opposite sides of elevated mountain ranges are often very distinct, not necessarily due, however, to the impracticability of changing sides, but to the different climatal conditions usually present on the opposite sides of a mountain range, depending on the relative amount of heat and moisture present. Most fruits and seeds quickly perish when immersed in sea-water; the fruit of the cocoa-nut is, however, an exception to this rule, not suffering by prolonged immersion, and is frequently carried for long distances by ocean currents, and on being stranded under favourable conditions of temperature, germinates at once; by this means coral islands often receive their first stock of palm trees.

The gradual adaptation of plants to particular conditions, determined mostly by the relative amount of heat, moisture, and light, has resulted in what is termed the geographical distribution of plants, or the predominance of certain plants in particular areas at the present day. From geological evidence, as will be shown later on, the areas that at the present day are characterized by certain plants, were during earlier geological periods clothed with vegetation which at the present time is only to be met with in widely distant regions. This change is due to the altered climatic conditions that certain areas have undergone from time to time. A brief account of the influence of climate and geographical changes on the flora of a district may be to some extent realized from a brief sketch of the compulsory migrations and wholesale destruction of consecutive floras that have from time to time clothed the area known as Great Britain at the present day.

The ancient flora, consisting chiefly of Cryptogams and Gymnosperms, as Zamias and Cycads, that occupied the site of what is now England must have been completely obliterated during the latter part of the Cretaceous period, when all the land was submerged and covered by a deep sea, in the bed of which the chalk was slowly deposited. The comparatively uniform warm temperature of the globe, indicated by the world-wide diffusion of the same species in Palæozoic and less conspicuously in Mesozoic time, at the commencement of the tertiary period merged into the modern phase of graduated and often extreme temperatures, and this change of climatic conditions determined a corresponding change in life. During the first two periods individuals predominated ; that is, the luxuriant vegetation of early times consisted of numerous individuals belonging to comparatively few groups, whereas at the present day groups or genera predominate, the comparatively homogeneous nature of the ancient flora being broken up into numerous minor sections depending on the various lines of departure taken by the ancient types in their endeavours to accommodate themselves to the new conditions.

At the close of the Cretaceous period great geographical changes took place, the bed of the Cretaceous sea was gradually and irregularly elevated, and the present site of England was once more dry land. During the Eocene period the temperature of England, as of Europe, was tropical, and the flora of our country during that period has its nearest living representatives in the hotter parts of India, Australia, Africa, and America. As examples of the flora of that period may be mentioned palms, aroids, cactuses, figs, eucalyptus, etc. All these have long since disappeared from Europe, but their fossil remains are abundant in eocene rocks. To this period belongs the London clay, which contains many beautifully-preserved fossils. Sheppey is also a noted locality for fossils, the fruits of palms being common, accompanied by the remains of turtles and nautilus shells, etc. The Bagshot Beds near Bournemouth, and Alum Bay in the Isle of Wight, have seams of clay that are rich in fossil leaves.

During Miocene times the British Isles appear to to have been for the most part dry land, the Bovey Tracey Beds occurring between Exeter and Teignmouth, however, belong to this period, and contain the remains of numerous plants, mostly leaves, the commonest being that of a great coniferous tree, *Sequoia Couttsiœ,* which appears to be closely allied to the gigantic *Wellingtonia Gigantea* of California. Leaves of species of vine, cinnamon, and fig are also common, pointing to a continuation of the warm climate of the previous period. The flora that clothed the European Alps during this period was not unlike the vegetation of the forests of India and Australia at the present time. During the latter portion of the Miocene age there are evidences of a cooling down of the climate, the characteristic vegetation consisting of beeches, elms, poplars, hornbeams, etc.

During the Pliocene age the flora shows a gradual decrease of temperature, the tropical types of vegetation of Eocene and Miocene times gradually retreating southwards, their place being taken by trees that still exist here at present, as oaks, poplars, willows, alders, etc., mixed, however, with forms that now occur in warmer climates, as bamboos, sarsaparillas, magnolias, and figs. In British rocks belonging to this period, which are almost entirely confined to Norfolk and Suffolk, the fossil remains of cones of the Scotch fir, leaves of white and yellow water-lilies, oak, hazel, bogbean, blackthorn, etc., occur. During this period the geographical features of Europe were very different to those of the present time; the Irish Sea and the English Channel had not then been formed, and England at that time was continuous with the Continent by way of France and Spain, the North Sea only extending as far south as Kent, the Straits of Dover and the English Channel being formed at a much later period. At this time the flora of England was probably much the same as that of France, Spain, and Portugal at the present day, and we have remaining in the South of England a few plants that have existed from that period. As examples of the remains of this ancient flora may be mentioned the marsh wood spurge (*Euphorbia pilosa*), found in Somersetshire, and at the present day a common species in the Mediterranean region; the large-flowered butterwort (*Pinguicula grandiflora*), occurring in Ireland, and *Pinguicula lusitanica*, found in a few places in the west of England, are both characteristic Iberian plants.

The Pleistocene or Glacial period that followed the Pliocene, almost completely obliterated the existing flora of Great Britain, which along with the whole of Northern Europe, was completely buried beneath an ice-sheet, in many places several thousands of feet thick, driving southwards before it the flora and fauna of the northern portion of Europe. At this period an arctic vegetation spread over Northern and Central Europe, reaching as far as the Pyrenees, and accompanied by characteristic northern animals, as the reindeer, etc. In England the ice-sheet did not pass south of the Thames valley, consequently in the southernmost portions, the plants already enumerated as remnants of the Pliocene age managed to hold their own. During this period of intense cold a new alpine flora was established in Wales and Scotland, when the mountain summits of these countries were low islands, or members of chains of islands that extended to Scandinavia through a glacial sea, and a fair proportion of the Scotch Alpine flora arrived during this period from the last-named area.

At the period when the arctic rigour of the glacial period gave way to the present conditions of climate, the area now occupied by the German Ocean was dry land; in other words, England formed a western extension of the continent, and along this route the great bulk of our lowland flora, as existing at the present day, reached us from the Germanic region of the mainland.

In a general view of the distribution of plants over the surface of the globe as existing at the present day, it is observable that there is far less adaptation to exist under extreme climatic conditions amongst Cryptogams than amongst Phanerogams. This is, to a great extent, due to the fact that in Cryptogams the primordial method of utilizing water as the agent for enabling the antherozoid, or fertilizing body, to reach the oosphere has been constantly adhered to in every group; and although Cryptogams can endure a greater amount of cold than Phanerogams, being found in higher latitudes and at greater elevations, on the other hand Phanerogams are far more abundant in arid regions than Cryptogams.

Marine vegetation, with very few exceptions, consists of Algæ, and in the sea there are fairly well defined zones of vegetation. As a rule the green and olive-brown groups of seaweeds are most numerous in cold regions, whereas red seaweeds become more abundant as the tropics are approached. The larger highly-organized seaweeds do not grow at a very great depth, but form a fringe round the shores. Amongst Algæ we meet with considerable variety as regards adaptation to circumstances; many species are true parasites, cases of mutualism or commensalism between Algæ and some of the lower forms of animal life are on record. The dimensions of Algæ are very various, the diatoms are unicellular and microscopic, whereas *Macrocystis pyrifera* is frequently five hundred feet in length. The species of *Lessonia* grow erect with the habit of forest trees, forming in fact submarine forests.

Ferns occur in all climates between the polar regions, where, however, few species occur, to the tropics, where they are by far most abundant and attain their maximum of development. Many genera are limited to equatorial regions, or extend very little beyond; on the other hand, few genera are confined to a single continent. The tree-ferns are tropical, although some species extend to Tasmania and New Zealand. On the Andes they grow along with the cinchona trees at an elevation of four to eight thousand feet. The majority of ferns thrive only under a peculiar combination of climatic conditions, dry regions producing very few species; damp, shady places, with a comparatively equable temperature, suit them best, consequently we meet with the greatest percentage compared with the entire flora in insular climates; in fact, the smaller and more distant from continents islands are, the larger is the proportion which ferns bear to Phanerogamic plants.

The family of ferns has probably more fossil representatives than any other group of plants, and occur in all fossiliferous formations from the Devonian upwards, being especially abundant during the Carboniferous period. The fossil species present the same broad features as those existing at the present day; no fossil ferns have as yet been discovered that cannot be referred to some existing type.

The distribution of Phanerogams may be studied from two standpoints; latitude and altitude, the predominating factor in determining the distribution being in both cases temperature, and a series of changes can be traced in the lowland flora from the equator to the poles, each zone being characterized by the predominance of certain groups of vegetation that often give a feature to the landscape. These zones of vegetation do not follow the parallels of latitude, but are undulatory, corresponding with the isotherm of the particular month in which there is the greatest development of vegetable life.

In *very high latitudes,* lichens and mosses are only met with, then follow grasses, species of saxifrage, buttercup, woodrush, etc., species of rhododendron with showy flowers are also present in the Arctic Zone. Amongst trees the birch predominates, and extends nearly to the North Cape; firs and pines are also present.

In the *Sub-arctic zone,* including the northern parts of Norway, Siberia, Iceland, and the Faroe Islands, firs and willows are the predominating trees, and in some localities are very much dwarfed, but in Siberia very extensive pine forests occur. Poplars and birches are also present. Grasses and ling (*Calluna vulgaris*), also junipers, are amongst the social or gregarious plants that form features in the physiognomy of certain districts in this zone in northern latitudes. In the southern hemisphere the same zone embraces a few barren islands.

The *Cold Temperate Zone* in the Northern Hemisphere includes England, Northern France, Germany, etc.; the forest trees are all dicotyledons, amongst which conifers predominate; the heaths and grasses are the most conspicuous of social plants. This region is most favourable for the cultivation of wheat.

The *Warm Temperate Zone* includes in Europe the southern flora as far as the Pyrenees, also the mountains of the south of France and the North of Greece, Asia Minor, a zone extending between the Black sea and the Caspian, Northern China, Japan, and a belt in North America are also included. It is sometimes spoken of as the zone of evergreen trees, and includes numerous sub-tropical forms, as laurels, myrtles, figs, vines, etc. The dwarf palm (*Chamerops humilis*), a small species, is the only European representative of the Palm order.

The *Sub-tropical Zone* extends from the tropics to 34° north and south latitude, with a mean annual temperature ranging between 60° and 70° Fahr., and a summer temperature between 74° and 83° Fahr. In this zone vegetation is green throughout the year. It has been called the region of Myrtaceæ and Lauraceæ on account of the predominance of species belonging to these orders. Heaths and their Australian representatives, epacrids, are also conspicuous. The arid regions occurring in this zone have each a marked flora, as the cactus group in Mexico, the euphorbius or spurges in Africa, and numerous succulent and fleshy plants in the Asiatic region. The date-palm also constitutes a feature of the arid region in Egypt.

The *Tropical Zone*, extending from the 15th degree on each side of the equator to lat. 23°, having a mean annual temperature of 73° to 79° Fahr., and a summer heat of 80° to 86° Fahr., is characterized by the abundance of tree-ferns and numerous species of *Ficus;* this zone is also the head-quarters of the orders *Piperaceæ* and *Melastomaceæ.*

Equatorial Zone, extending 15° on each side of the equator, has a mean annual temperature of 79° to 85° Fahr.; the characteristic vegetation consists of palms, bananas, arborescent grasses (as the bamboo, sugar-cane, etc.), orchids, and species belonging to the order *Zingiberaceæ*, as the ginger plant, etc.

Comparing the zones of altitude with those of latitude the following gives a broad idea of the relative elevation at which the groups previously mentioned occur.

Equatorial Region of palms and bananas extend from the sea-level to 2,000 feet.

Tropical Region of tree-ferns and figs, 2,000 to 3,800 feet.

Sub-tropical Region of myrtles and laurels from 3,800 to 6,000 feet.

Warm Temperate Region of evergreen dicotyledonous trees, 6,000 to 8,000 feet.

Cold Temperate Region of deciduous dicotyledonous trees, 8,000 to 9,500 feet.

Sub-arctic Region of conifers, from 9,500 to 11,500 feet.

Arctic Region, characterized by bright-flowered rhododendrons, 11,500 to 13,500 feet.

Polar Region of alpine plants, a few species of flowering plants, mosses, and lichens, the last-named usually being the last to appear in both latitude and altitude.

It must be clearly understood that the altitudes given are merely approximate, and not of universal application; in fact, as a rule, when the same species occur on both sides of a mountain, the altitude at which they occur varies considerably on opposite sides. This will be readily understood when the variation in the snow-line is remembered. This in the Peruvian Andes exceeds 18,000 feet; in the Himalayas, in lat. 26° N., the snow-line is about 18,000 feet on the north side and 15,500 feet on the south side; whereas in Norway it is under 4,000 feet, and close to the Arctic Ocean it is 2,000 feet.

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