C.—Insectivorous Plants.

CHAPTER XII.

(1.) *Plants and Animals.*

WE were taught in our schooldays that three great kingdoms existed in Nature: the Mineral, Vegetable, and Animal. We were taught, moreover, that these great kingdoms were very markedly distinct one from another, and that the possibility of confusion between minerals, vegetables, and animals was almost inconceivable. This is still the belief of many. But the researches of scientific thinkers during the past few years have shown that the old hard and fast lines between the three great groups of things cannot be drawn, and that the three kingdoms glide imperceptibly one into the other. All such researches and their results once more strengthen the belief in evolution rather than in special creation. Especially has the line of demarcation between plants and animals faded away under closer investigation. Aforetime, to determine whether a living thing were vegetable or animal was supposed to be an easy task. The task is still easy if the higher kinds of each kingdom are studied. Nobody would hesitate as to the position of an oak-tree or of a man. But when the lowly members of the two great kingdoms of living things are studied difficulties present themselves. The minute microscopic living things puzzle. It is often impossible to say positively whether they are vegetables or of higher nature. The two groups of organic beings, widely asunder in their loftiest conditions, approach each other ever more closely in their lower and lower forms, until at last and at lowest they glide into each other and are one. So thoroughly is this fact recognised to-day that the great German biologist Haeckel has suggested a group-name for those organisms whose exact nature it is difficult to determine. He proposes to call the dwellers in this biological no-man's land, Protista (πρωτος = first).

But, further, the distinctions between plants and animals that were wont to be given do not hold even in respect to beings that would be without hesitation named by any ordinary observer as clearly either plant or animal. The distinctions usually given in the past were the following. (*a*) The tissues of plants contain the three chemical elements, Carbon, Hydrogen, Oxygen: those of animals contain the four chemical elements, Carbon, Hydrogen, Oxygen, Nitrogen. But, first, Nitrogen is found in plant tissues and to a very considerable extent; and, second, in the body-walls of certain animals the structure supposed to be distinctive of plants, cellulose, has been encountered. (*b*) Plants have no power of sensation or of movement, whilst animals can feel and move. But many plants do respond to stimuli, as the study of climbing plants demonstrated, and as the name "Sensitive plant" reminds us. Nowadays, moreover, there is demonstration of the effects of such stimuli being transmitted through vegetable structures in definite directions, and evidence is not wanting of certain actions in particular plants that deserve the application to them of the adjective "nervous." Again, plants have undoubtedly the power of movement. Tendrils climb, the leaves of the Mimosa alter their position, the flower opens and closes, the stamen of the Berberry when touched springs forwards on to the body touching it or on to the stigma, the spores of the lower plants flit across the field of the microscope and the strange protoplasmic masses of some Fungi crawl slowly over decaying matter. In many plants there is more movement than can be observed in a Sea-anemone or a Barnacle. It is almost unnecessary to point out that the distinction cannot be maintained by insertion of the adjective 'voluntary' before the word movement, as the movements of many animals very clearly never rise to the level of movements that are under the control of the will. (*c*) Plants do not take their food into any internal cavity, and their food is of an inorganic or mineral nature; animals do take their food into an internal cavity, and their food is organic—that is, either vegetable or animal. But many undoubted animals have no true digestive cavity. The Tape-worm, whom no one would credit with vegetable proclivities, has no alimentary canal. The second part of this third distinction was that to which men clung the longest, and was the last to vanish in the light of investigation. For recently many plants have been shown to feed largely upon matter other than mineral. Thus there is a large group of plants whose food is derived from decaying organic matter that has certainly not passed to its ultimate destination, *i.e.*, the mineral condition represented by carbonic acid, water, and ammonia. These plants, feeding not upon inorganic things nor upon organic substances, but upon the latter during their slow decay or passage into the former, are called Saprophytes (σαπρος = decayed, φυτον = plant). Amongst them are some of our English orchids, and certain allies of our heaths and of our foxgloves. Again, plants exist whose food is derived from the prepared fluids of other plants, and not from the mineral kingdom directly. These, growing upon other plants, are known as parasites. Mistletoe, broom-rape, dodder, are examples of these breakers of the unjust "law" that states that the food of plants is inorganic, that of animals organic. But, finally, certain remarkable plants have of late years been under close investigation that have received, as result of that investigation, the name of carnivorous or insectivorous plants. It is to the study of the work of Charles Darwin that deals with these strange members of the vegetable kingdom that we now turn.

Other thinkers had been busy with the animal-eating plants before him. As far back as 1782 a patient German had studied the little sun-dew. Trécul in France, Nitschke in Germany, Mrs. Treat in America, and Mr. Alfred Bennett in England had been at work upon the same plant. At Belfast, in 1874, Dr. Hooker, as president of the British Association, set society into a fashionable flutter, and gave rise to quite a little chorus of "Remarkables! Dear me's! Very extraordinary's!" by reading an address upon Carnivorous Plants. But it was reserved for a greater than any of these to complete their work, and to complete it so very thoroughly that it would almost seem as if nothing were left to reward the toils of future laborers. In truth, no other of Charles Darwin's works shows better than this one the notable thoroughness of the man. The minute investigation, the infinite patience, the endless making of experiments and careful recordal of results, the attention to innumerable minutiæ, the doggedly persistent repetition of observations and trials, the steady accumulation of details before any attempt is made at a generalisation, are perhaps almost more observable in this book on the insectivorous plants than in any other of his works. In addition comes out very clearly herein his intense desire to get at truth and truth only. Preconceived notions are not for him. He states the arguments for the conclusions that would strengthen the position of the great theory of Evolution only less clearly than he states those that tell against that theory. No man was ever more of judge than he; no man was ever less of advocate. Of his calm, dispassionate method of weighing evidence with but the one desire to arrive at what is true actuating him, a typical instance is furnished in the third chapter of this very book, where the proximate causes of the protoplasmic aggregation in the cells of the sun-dew are under consideration.

The obligations of Charles Darwin to other workers in the same field as himself are always paid with a cordiality and courtesy that must be as gratifying to them as they are natural to him. It is pleasurable to find in the work now under consideration, as in many others from the same hand, that of those fellow-workers some bear his honored name. The references to the help by pen and pencil rendered by the sons of the great naturalist to their illustrious father become invested with a deeper interest to us all when we remember that to-day the names of his children are becoming famous, not alone for the father's sake, but on account of the good work done in the very branches of knowledge wherein he has built for himself an everlasting name.

In the attempt to interpret between the investigator of the insect-eating plants and the student, the plan followed will be substantially one with that of the book itself. The sun-dew itself will be considered as one of the most remarkable types of flesh-eating plants. The curious Venus' fly-trap will be studied. Certain plants allied to these last twain will be noticed. The bladder-wort and its congeners will constitute the last set of organisms calling for attention under the head of Insectivorous Plants.

CHAPTER XIII.

(2.) *The Sun-Dew.*

A TINY plant growing in peaty soil with lowly mosses for its companions, a plant that would be inconspicuous but for the frequent glisten of the sunlight upon its drop-studded leaves: these same leaves, not more than six in number, growing out horizontally close to the ground, their length somewhat less than their breadth, and their faces covered with small stalks that end in rounded heads, each whereof is surrounded by a large drop of viscid fluid: that is the Sun-Dew or Drosera. Let us, following the Master, call the small stalks "tentacles," the rounded heads that form and are bathed in the viscid fluid, glands.

Let us watch the Sun-Dew. It grows in the barrenest of soil. Around it are vegetating a few spare Sphagnums or bog-mosses. These gather their food from the air rather than from the soil wherein they grow. In very truth, this last would yield but little supply. The Sun-Dew is in the same condition. From the soil it can derive little or no food. Its supply must come from the air. And as you watch the little plant, lo! the food comes. A fluttering insect moves with vague, irregular flight through the warm air over the barren land. Its flutterings carry it hither and thither, and at last against the motionless leaves of the Sun-Dew. It touches with vibrating wing or dependent feet the glistening spots that have possibly allured it from afar, and its flight is for ever at an end. The gland that has caught the hapless one secretes more and more fluid, and the victim is more and more hopelessly entangled. And now other tentacles begin slowly to bend towards the place where the captive still struggles faintly. From all parts of the leaf they move inwards remorselessly, until their glands are in contact with the insect, and are at work upon it. As the glands of tentacles that were at first remote touch the living food the amount of the secretion increases. The fluid that is thus poured out alters moreover in quality. It becomes acid. The insect thus caught, thus surrounded by scores of fatal claspers, struggles. But its struggles grow feebler as it becomes weaker. The clammy moisture clogs its breathing pores, and stifles it. Its strength fails, its life ebbs away. But a little while, and that which a few minutes agone was a flash of bright color on a sunny day, and the very emblem of gaiety and care-freedom, is an inert soiled mass imbedded in the fluid of the Sun-Dew. And again a little while, and the tentacles slowly move back to their old places, the leaf is as it was before, and a gust of wind blows away a fragment or two of dust, that is all that is left of the captured insect. The rest has been digested by the plant.

The movements of these strange tentacles have been subjected to an analysis by Charles Darwin searching and complete. The results of this patient investigation we now study.

(*a*) Movements of the tentacles due to the contact of solid bodies. The body must touch the glands. It is not enough for it to rest on or even in the fluid secreted by them. Absolute contact (as it is called) must take place. Mere transitory touches are of little or no value as causing inflexion of the tentacles on the Sun-Dew leaf. A slight pressure is far more effective than a very vigorous touch. This peculiarity is of service to the plant, as often in the wind-stirred marshes swaying grasses or fragments blown from far-away plants and caught by the eddying wind must roughly brush against the leaves, and in these cases inflexion of the tentacles would be useless. But it is of advantage that the pressure of the minute feet of a struggling insect on the glands should cause the tentacles on distant parts to move towards the place where the insect is. Drops of water falling upon the leaves produce no effect, and the importance of this negative result will be patent to those who remember the rainy nature of the districts where Sun-Dews most do congregate.

The excessive smallness of the solid particles that will cause inflexion is most remarkable. Thus, a particle weighing only $\frac{1}{78740}$ grain or ·000822 milligram caused inflexion. But, in connexion with this subject, perhaps the most remarkable thing is the indirect inflexion. That a tentacle whose own gland is touched should bend is strange enough. That tentacles remote from those actually touched should have transmitted to them through the tissues of the leaf some influence that causes them to bend and the glands on their summits to secrete more fluid and more acid fluid is yet more strange. The fact, to those who remember how in the animal kingdom nerves will transmit an influence to glands and modify the nature of their secretion, is of deepest significance.

(*b*) Aggregation of protoplasm. The cells of the tentacles are full of protoplasm. Before a touch has made impression on the glands the contents of the cells are a purple fluid, quite homogenous—that is, continuous and similar throughout and bounded by colorless protoplasm externally. This protoplasm, it will be observed, lies between the cell-wall and the homogenous purple fluid. *After* contact of a solid body the purple matter is found no longer continuous but broken up into variously-shaped masses that are suspended in a colorless fluid. Once again the smallness of the particles causing this change is notable. Absorption by a gland of $\frac{1}{134400}$ grain or ·000482 milligram causes aggregation of the protoplasm in the cells of the tentacles.

The process is not the result of the inbending of the tentacles. It precedes this movement. If the glands of the tentacles on the centre of the leaf are touched they send influence to the glands on the marginal tentacles, and these in turn send influence down their supporting stalks, for the aggregation works from above downwards. Again the student of animal physiology is impressed with the remarkable suggestion involved herein. When a nerve-ending in the hand is impressed, and the impression is transmitted up the nerve to the brain so that we feel, our belief is that some actual change occurs in the very structure of the nerve as the transmission takes place. Here in the Sun-Dew we actually *see* a change of structure take place under our very eyes as influence that it is almost impossible not to call nervous is transmitted.

(*c*) The effect of heat. Heat, light, electricity, magnetism, life seem all to be but modes of vibration of particles of matter almost inconceivably minute. As investigation proceeds the connexion between all these forms of movement of minute atoms grows constantly more evident to us. We are yet but in the infancy of our knowledge of this subject. What we do know is nevertheless full of deepest interest. Notice the curious gradation of effects of rising temperature upon our Sun-Dew leaves. (i.) With a temperature between 48° and 51° C. there is quick inflexion and the leaf survives. (ii.) With a temperature about 54° there is no inflexion but the leaf survives. (iii.) With a temperature of 65° the leaf is not inflected and dies.

(*d*) Action of various fluids upon the leaves. (i.) Organic fluids. Fluids taken from the animal and vegetable kingdoms are roughly divided into those containing only carbon, hydrogen, oxygen (non-nitrogenous), and those containing carbon, hydrogen, oxygen and nitrogen (nitrogenous). The former have no effect upon the leaves of Drosera: the latter invariably cause inflexion. The little plant seems to be able to tell with unfailing accuracy whether nitrogen be present or not in a fluid that is submitted to it. Here is a remarkable test as to the presence or absence of nitrogen in organic fluids that hitherto has not been known to fail. (ii.) Salts of ammonium. Ammonia is a compound containing three atoms of hydrogen and one atom of nitrogen. Dissolved in water and then combined with acids ammonia gives rise to a series of salts called ammonium salts. These all, of course, contain nitrogen. Solutions of these salts were found by Charles Darwin to affect the leaves, causing both inflexion of the tentacles and aggregation of the protoplasm in their cells. They do not effect these changes, however, if their solutions are taken in after the ordinary fashion by the roots. Ammonium carbonate causes a certain amount of inflexion, ammonium nitrate causes more, ammonium phosphate most. This succession is not without interest. Nitrogen and phosphorus are especially animal elements, far more largely present in animal structures than in vegetable. As the quantities of these increase in the salts under consideration the effect of solutions of the salts upon the Sun-Dew increases also. Thus, ammonium carbonate contains $29\frac{1}{6}$ parts by weight of nitrogen in 100 parts of the salt, ammonium nitrate contains 35 in 100, ammonium phosphate $28\frac{28}{149}$ of nitrogen and $20\frac{120}{149}$ of phosphorus in 100. Of this last salt $\frac{1}{20000000}$ grain absorbed by a gland of Drosera causes some impulse to be sent down the whole length of the supporting tentacle, an impulse resulting in the bending of the tentacle through an angle of more than 180°. (iii.) Salts generally. The outcome of many experiments is that the nature of the metal in the salt is of much more importance than the nature of the acid, and in this result there is once more affinity with animals. Again, salts of sodium cause inflexion and the plant lives. Salts of potassium kill the Sun-Dew. Sodium salts can be introduced in small quantities into the blood of animals without any ill result following. Potassium salts are fatal. (iv.) Poisons. Under the action of strychnine and nicotine, poisons fatal to animals because of their effect on the nervous system, Drosera dies. But under the action of morphia, belladonna, alcohol, curare, poisons fatal to animals because of their effect on the nervous system, Drosera does not die. As to these last, however, the observation may be made that they act on motor-nerves—*i.e.*, on nerves that supply muscles, and it is difficult at present to conceive of the Sun-Dew as possessing representatives of these.

(*e*) The digestive power of Drosera. Drosera, or the Sun-Dew, has remarkable power of recognising, under any disguise the presence of the element nitrogen in most compounds submitted to its action. The results of certain other of the experiments of Charles Darwin confirming this view may with advantage be given here. (i.) Action on food stuffs. Of substances producing no effect upon the plant when they were submitted to the action of its leaves were gum arabic, sugar, starch, dilute alcohol, olive oil, tea. The chemical composition of the first four of these is as follows :

Gum Arabic...	$C^6 H^{10} O^5$
Sugar	$C^{12} H^{22} O^{11}$
Alcohol...	$C^2 H^6 O$
Olive Oil	$(C^3 H^5)^2 (C^{18} H^{32} O)^3 O^3$

i.e., gum consists of 6 atoms of carbon, 10 of hydrogen, 5 of oxygen, and so on. The action of tea, or rather its non-action, is somewhat remarkable. For tea, as a plant, contains albuminous matter, and that contains nitrogen. Possibly in the drying of the leaves of the tea plant the albuminous matter they may have contained is rendered insoluble. But this is not a sufficient explanation, as when the alkaloid principle of tea, called theine, is applied to the leaves, still no result follows. The formula of theine is $C^8 H^{10} N^4 O^2$. It contains nitrogen, but does not cause the tentacles to inflect.

Of substances producing effect upon the plant when they were submitted to the action of its leaves were milk, urine, albumen, infusion of raw meat, mucus from the throat, saliva, isinglass. Milk contains casein, whose composition is C. 53·8, H.7, N. 15·8, O. 22·4, S. 1 per cent. Urine contains uric acid, $C^5 H^4 N^4 O^3$, and also salts of ammonium. Albumen has composition, C. 53·8, H. 7, N. 15·5, O. 22·5, S. 1·2. Meat contains large quantities of albuminoids. The action of mucus seems due to the admixture of albuminous matter from the food, or of saliva. Isinglass is the substance of the swim-bladder or rudimentary lung of the sturgeon, and is rich in nitrogen.

(ii.) Secretion. The digestive power of the secretion next comes under consideration. That the leaves of the Sun-Dew absorb was very early rendered beyond doubt. The next inquiry was as to whether they did something more than absorb. Were they capable not only of absorbing, but of digesting? Digestion implies the preparation of food for tissue-forming, and this preparation involves at least the rendering of that food soluble. The result of many laborious and carefully recorded experiments is the important generalisation that the digestive action of Drosera is as nearly as possible identical with that of the fluid poured into the stomach of the higher animals. That digestive fluid of the higher animals, known as gastric juice, had for much time been regarded as specially "vital" in its working, and men were not wanting who were ready to declare that nothing in imitation of its action or of any other "vital" action could ever be effected by man. But man has not merely imitated, but performed not a few actions that were once called "vital" in his laboratory, and amongst others this function of digestion can be performed—artificially, but thoroughly—in the laboratory to-day. All this is good news to the evolutionist and to him that believes in man's advancing power, and this good news is strengthened yet again by the announcement that by Drosera, by a little marsh plant not very high in the scale of plants, a function nearly identical with that of the digestion of animals is performed.

For those who have made no special study of the physiology of animals it may be stated that in the gastric juice of the higher animals two principal things are present. One is a ferment called pepsin. This, like ferments generally, is organic, nitrogenous, able, existing in small quantity, to work change in much substance of the body to be acted upon. With this pepsin is associated an acid, very generally hydrochloric acid (H Cl). In the secretion of the leaves of the Sun-Dew a ferment is present. With this ferment is associated an acid, apparently one of that great series of fat acids, of which formic acid, once obtained from the *Formica* or ant, and acetic acid or vinegar, are the first two members. Just as the introduction of an alkali, such as potash, soda, or ammonia, into the acid gastric juice of the stomach of a higher animal, causing neutralisation of the acid, stops the action of the gastric juice upon the food materials, so the introduction of an alkali, such as potash, soda, or ammonia, into the acid secretion of the Drosera, causing neutralisation of the acid, stops the action of the secretion of the leaves upon the food materials.

(iii.) Comparison with animals. To trace out yet further the striking analogy or likeness of function obtaining between the Drosera fluid and that of the stomach of man, let us see what substances are digested by both fluids under favorable conditions, what substances are not affected by them. (*a*) Those acted upon by the secretion formed by the glands of the Sun-Dew leaves and by the gastric juice of animals. They are albumen or the white of egg, cubes whereof very soon after their immersion in the leaf-fluid had their angles and edges gradually rounded off (this rounding off of edges and points is highly characteristic of the action of gastric juice upon albumen): meat after it had been cooked; fibrin or the material of the clot of blood, slow in its action because from some cause it fails to excite other glands remote from the place of contact, and therefore does not cause so much inflexion nor secretion; syntonin or muscle-fibrin, very rapid in its action; areolar or connective tissue, quickly digested but not causing excitement of the leaves to any great extent; cartilage, fibro-cartilage, bone, in acting whereon the acid secretion first attacks the salts and especially the calcium phosphate of bone, and does not make digestive inroads upon the more animal part of bone until the mineral is no longer attacked; gelatin slowly attacked, as it is by animals, ordinary casein, not affected to any great extent, that casein which is artificially prepared, much affected; in this double action upon the natural and artificial casein resembling once again the gastric juice of man. Gluten prepared from wheat does not, nitrogenous and nutritious as it is, submit to the action of the secretion formed by the leaves of the Drosera, but as it is a very powerful substance it is at least possible that it is strong enough to poison the leaf and prevent any action at all.

(β) In its negative action, as to digestion, upon various substances the fluid formed upon this remarkable leaf again strikingly resembles that fluid secreted by the stomach. Human nails and hair, bird's feathers, all epidermic in their origin, fibro-elastic tissue, mucin from mucous membranes, pepsin the ferment itself, urea ($C\ H^4\ N^2\ O$) a refuse product of animal decay, chitin the hard part of the coats of insects, cellulose or the material constituting the wall of the vegetable cell, chlorophyll or the green color matter of plants, fats, oils, and starch are not affected by the fluid secreted by the leaves of Drosera. But also none of these is acted upon by gastric juice. Negatively, therefore, as well as positively, is likeness in function or analogy between these two fluids established; the one fluid formed by the tiny glands on the tiny tentacles on the leaves of a tiny plant, the other formed by the peptic glands in the walls of the stomach of a man.

(f) The Sensitiveness of the Leaves and the direction of transmission of motor impulse. (i.) The sensitive part. Many experiments establish the fact that only the glands and the very summits of the tentacles are sensitive, and that the amount of excitement undergone by the leaves depends upon the nature and the quantity of the substance applied, the number of times it is made to touch the leaf, the number of glands touched. (ii.) Transmission of impulse. In every case when a gland on the top of a tentacle is touched, a moving impulse must travel thence to the basal part of the tentacle and cause inflexion of that basal region, and this journey of the motor impulse down the tentacle is performed at velocity much greater than that at which the impulse travels from tentacle to tentacle across the leaf. When that impulse has reached the point of junction of a central

tentacle and the leaf-blade, it spreads centrifugally in every direction and the nearest tentacles bend first. But when the tentacle earliest affected is marginal though that tentacle bends first, it is not until after its bending has carried its gland, food-laden, into contact with a central gland that the marginal tentacles close to the first are affected. They seem to depend for their movement upon impulse radiated from the central tentacles after these last have been stimulated by contact with the gland first affected. The transmission of this strange influence across the blade of the leaf is much slower than its transmission lengthways, a fact to be borne in mind anon. The action is not reflex. There does not appear to be in any case, as far as transmission of motor impulse is concerned, the flow in one direction and then the flow in another direction more or less opposed to the former that is always implied in reflex action. The impulse to movement passes directly from tentacle to tentacle. But in the succession of aggregation of protoplasm in individual cells before referred to, there is a curious imitation of or identity with reflex action in animals. A gland of the centre is stimulated. Its cells show aggregation of their protoplasmic contents from above downwards. From the tentacle whereof these cells consist impulse moves outwards to other tentacles. These contract at their bases as soon as the stimulus reaches them. But the aggregation of the protoplasm in the cells of these distant tentacles begins in the upper cells, not in the lower. The stimulus, influence, what you will, travels from the first tentacle athwart the leaf to the base of another tentacle, ascends that and then is reflected downwards, causing aggregation of the protoplasm of individual cells from above downwards. (iii.) The tissue that transmits. Three tissues present themselves in the Sun-Dew leaf: the fundamental or cellular, the fibro-vascular or the veins, the epidermal on the exterior. After many minutely laborious experiments Charles Darwin has demonstrated that the first of these three is the real transmitter of motor impulse. This fact explains two or three others. It explains the pause in the process of aggregation of protoplasm in successive cells. The delay appears to be due to the stoppage of the transmission of influence by the intervening cell-walls. It explains the more rapid transmission down the tentacles as compared with the transmission across the blade, for in the former the cells are longer than elsewhere, and there is a sort of confinement of the influence within the tentacle for a time. It explains the more rapid transmission along the tentacle than athwart the leaf, as the cells of the fundamental tissue are four times as long as broad. It explains the incurving of the tentacles, as the cells of the leaf-blade converge towards the tentacle base, and transmitting accumulated influence thither, cause inbending. The strange history of the Sun-Dew has been told. Its fellows equally remarkable will be studied next.

CHAPTER XIV.

(3.) *Venus' Fly-trap and its allies.*

a. *DIONŒA MUSCIPULA.* In the eastern region of North Carolina lives the Venus' fly trap, whose scientific name is *Dionœa muscipula.* i. Structure. The interest of this plant to us centres in its leaves. The petiole or leaf-stalk is leaflike. The blade has its right and left halves not in the same plane, but making one with the other an angle of rather less than 90°. The leaf bears the following structures: filaments, spikes, glands, octofids, hairs.

(*a*) *The filaments.*—These are six in number, three on the upper face of each half of the leaf-blade. They are exceedingly sensitive, and the slightest touch upon any one of them is followed by a sudden clapping together of the two parts of the leaf so that the two halves of the upper face thereof are brought into contact. Near the base of the filament is a joint, so that when this closure of the two halves of the lamina occurs the six filaments are bent down flat, parallel to the surface of the leaf-blade and are not broken. The filaments of the Fly-trap support no glands, form no secretion. They are exceedingly sensitive, a touch upon them causing the instantaneous closure of the leaf. And yet if drops of water are allowed to fall upon the filaments no movement takes place. This negative response to the action of water must be of value to a plant living in a rainy district and subject, therefore, to frequent percussion of falling rain-drops. It is a distinct advantage to such a plant not to close every moment upon drops of non-nutritious water. Further, if the touch upon these sensitive filaments is due to bodies of such nature as wandering grass-blades, wind-borne fragments of no nutrient value, the leaves open again almost as soon as they have closed. This also must be of value as such "accidental" contact of useless particles must often occur in its American home, and the more rapidly the leaf re-opens the more rapidly will it be ready to receive, capture, and digest more food-yielding substances. On the other hand if the body striking upon the waiting filament be nitrogenous and nitrogen-yielding the leaves remain closed for many days.

(*β*) *The spikes.*—These are arranged on the leaf-margin and in such fashion that when the leaf-blade closes upon itself the spikes of its two moieties interlock. But when the leaf first closes its two parts are not in close contact. There is room therefore between its two parts for movements of the captured insect, and the spikes are not yet closely interlocked. Small insects can escape through the elongated spaces between the spikes. But as the halves of the leaf come more closely together, these interspaces diminish in size and eventually become closed. A large insect once caught can never escape. A small insect does escape, and the leaf, opening again, waits for his larger fellow. This also is of advantage, as it is better for the plant to bide its time until a moderately-sized insect is caught, and to allow the smaller fry to escape ere it goes to the trouble of secreting a digestive fluid.

(*γ*) *Glands.*—On the upper surface, *i.e.* the same as that whereon the sensitive filaments stand, are many reddish glands. These do not habitually secret fluid, but when nitrogenous bodies come into contact with them, secretion sets in and absorption follows.

(*δ*) *Octofids.*—These are tiny projections consisting of eight spreading arms of red or orange color scattered over the petiole and the under service of the lamina. They are probably homologous with the papillæ on the leaves of Drosera.

(*ε*) *Hairs.*—Minute, simple, pointed hairs upon the under surface of the leaf.

(ii.) Action. Let us now consider the action of all these parts. Imagine the leaf of the Venus' fly-trap as the plant grows in its Carolina home. Leafy petiole, broad lamina with its two parts nearly at right angles one with the other, each part bearing its three sensitive filaments, the leaf margins provided with long rigid spikes, the leaf surfaces studded with purple glands. An insect alights upon the leaf and touches one of the six filaments. Instantly, with no long delay as in Drosera, the two halves of the leaf-blade close in towards each other. The spikes on the margins interlock. The insect if small escapes. But the larger insect struggles as the walls of its prison close in upon it. Its struggles stimulate the glands. They secrete their digestive fluid. The insect is crushed and soaked to death. Between the closely apposed halves of the leaf the imprisoned being dies and is digested and absorbed. Later the leaf slowly opens: the insect is gone, and with outspread tentacles its devourer awaits once more its prey. If the leaf has closed simply because a filament has been touched, say by the finger, or if the enclosed object contains no nitrogen, or if containing nitrogen, the object is dry and not damp, though the leaf-lobes close in towards each other, they do not gradually press themselves into close contact all over their surface as they do when they have seized an edible body.

As in the Sun-Dew, the strange impulse that causes in the Dionœa such sudden results is transmitted through the cellular tissue, not by way of fibres or vessels. The fact is rendered especially clear in the plant under consideration by the demonstration of the fact that no fibres or vessels enter the sensitive filaments at all.

b. Aldrovanda vesiculosa, a native of Germany and of Australia. It would seem to be a minute Venus' fly-trap, whose habitat is water. In water it floats rootless. Its curious leaves stand in the midst of certain rigid protective projections. The two halves of its leaf-blade are more closely approximated than are those of Dionœa, and thus the capture of aquatic insects is rendered more easy. The structures upon the leaf of Aldrovanda are very similar to those upon the leaf of Dionœa. They are hairs, points, glands, quadrifids. (i.) *The hairs.* These represent the filaments of the fly-trap. They are on the upper surface of the leaf, are many, long, pointed. They have two articulations, not one as in Dionœa, and thus are not broken when the two halves of the leaf close together, despite their length. (ii.) *Points.* These are upon the margins of the leaf. As the margin of the leaf is infolded the free ends of these points are turned towards the mid-rib of the leaf. They seem at first sight to prevent the escape of prey, but this function is not theirs. It seems rather that these marginal points absorb decaying organic matter. We have seen already in these insect-eating plants forms that catch, kill, and devour living creatures, and in Aldrovanda itself we shall see the same series of actions. But we shall also encounter later on plants that do not kill and then digest insects, but that commence their operations upon dead and decaying organic matter. Aldrovanda is a link between the Sun-Dew on the one hand and these last upon the other. By part of its leaves Aldrovanda catches, kills, digests: by another part it absorbs the decaying materials yielded by dead organic bodies. And this other part is the point-bearing margin. These points, therefore, have little or nothing in common with the spikes of Dionœa, save their position on the leaf-margin. (iii.) *Glands.* On the upper surface of the leaf, near the mid-rib, are many colorless glands that appear to secrete a digestive fluid after contact with organic bodies. In this again is resemblance to Dionœa rather than to Drosera. (iv.) *Quadrifids.* On the upper surface of the leaf nearer the margin are prominences carrying four radiating processes. These represent the octofids of Dionœa. Their function is that of the points upon the margin. They absorb matter already in a state of decay.

c. Drosophyllum Lusitanicum. A Portuguese plant, with tentacles and sessile or non-stalked glands. (i.) *The tentacles.* These, mushroom-shaped, have no power of movement or of causing movement. The secretion of the glands they bear is acid even before the glands are excited by contact of living matter. (ii.) *The sessile glands.* These do not secrete spontaneously. They only secrete when upon them is placed nitrogenous organic matter. They will absorb such nitrogenous matter with sufficient rapidity. The action appears to be thus. An insect attracted by the glistening secretion on the stalked glands flies to the plant. It is caught by the viscid fluid of the glands touched and of other adjacent glands. It becomes hopelessly entangled, and with clogged wings and legs sinks deeper and deeper down into a morass of viscidity. Thus it reaches the sessile glands. They secrete digesting fluid, and the dead insect is digested and absorbed.

d. Roridula, a Cape of Good Hope plant, resembles the last, but has no sessile glands, and as the upper surface of the leaf is studded with many sharp, erect hairs, this is not unnatural.

e. *Byblis*, of Western Australia, like Drosophyllum, has sessile as well as stalked glands.

CHAPTER XV

(4.) *The Butterwort and Bladderwort.*

WE have, under the guidance of Charles Darwin, studied the action of the Sun-Dew with its sticky glands raised on stalks and its power of bringing many glands to bear upon the captured insect: the Venus' fly-trap with its sensitive filaments and sudden close upon an intruding animal: the allies of these with the lengthy names and habits akin to those of the Drosera and Dionœa. A quartette of remarkable plants, differing from all these in their food relations, remain for consideration. *a. Pinguicula.* There is a minute plant to be found in the Highlands, in wet, boggy places, during the months of May and July. Its common name is the butterwort. Its technical name is Pinguicula. Upon the leaves of this plant are many hairs that are constantly forming a viscid, colorless fluid. These hairs are not sensitive in the same sense as are the filaments of the Fly-trap, and, indeed, the plant is not adapted for catching living insects. These may, apparently, touch the leaves with entire impunity. But dead bodies of animal nature and nitrogenous matters generally appear to act as follows. Contact with them causes an increased amount of secretion on the part of the glandular hairs. The secretion at the same time becomes acid. The margins of the leaves, always somewhat incurved towards the mid-rib upon the front face, when under the stimulus of contact with dead animal matter, move further and further in towards the mid-rib, pushing before and beneath them the exciting substance. Thus is the latter brought into contact with more and more of the glandular hairs, and these under the stimulus pour out more and more of their secretion. This in its turn digests the animal matter exposed to its action after the same fashion as does the Sun-Dew. Pinguicula, therefore, digests dead animal matter. It does not catch and kill and then digest. Nor can it be fairly urged that of such dead animal matter, the supply would be too small to be of value. Insect life is so frequent in the districts where Pinguicula dwells that insect death must be very rife. The gusts of wind must carry multitudes of fragments of dead matter in all directions, and there is much likelihood of some such fragments being borne into contact with the viscid leaves of the butterwort.

b. Utricularia. To the same natural order as Pinguicula belongs the Utricularia, the bladderwort. One species of this strange genus is aquatic, another is in the main subterranean. The aquatic form floats freely, rootless in the water of pools and ditches in Scotland and Ireland. Its leaves carry little bladders about 1-8th to 1-4th of an inch in diameter. Each leaf bears two or three bladders. These organs are full of water. Entrance into the bladder is effected through an opening at one part guarded by a valve or sort of trap-door opening inwards and sloping into the cavity. The entrance is further guarded by bristles that only allow of the passage inwards of animals not too large for the plant to deal with. Lining the interior of the bladder are many quadrifid processes. Nothing in this plant seems to be sensitive. No part shows the power of movement so remarkable in the Sun-dew and Fly-trap. It would appear that small water animals make their way into the bladder by passing between the guard bristles and forcing open the sloping valve that opens inwards. Once within the cavity exit is impossible. The valve closes again and as it opens inwards there is no escape. The imprisoned animal swims about freely for some little time within the bladder, but ere long it dies. There is no evidence of any fatal influence of the plant upon its prey. The prisoner appears to die of starvation rather than by any more positive death. There is also no evidence of any actual digestion. A true digestive fluid does not appear to be secreted. The Utricularia, like Pinguicula its ally, absorbs the decaying animal matter and makes this part of itself. The absorption is effected by the quadrifids, whose protoplasm, like that of the hairs of Pinguicula, shows after absorption the same kind of aggregation noticeable in the Sun-Dew.

c. Polypompholyx and *Genlisea.* A plant named Polypompholyx is almost identical in structure and in action with the bladderwort, and a Brazilian plant known as Genlisea ends this remarkable series of vegetable structures. In Genlisea the bladders have a very long neck, the external opening of which is provided with sharp hairs pointing downwards. These allow a small animal to pass inwards and down towards the bladder far below, but they very effectually prevent its return.

CHAPTER XVI.

(5.) *Evolution of Insect Eating Plants.*

AND now, in conclusion, after this our study of the insect-eating plants, the evolutionist is fain to ask what possibilities seem to be of the evolution of such remarkable plants as Drosera or Dionœa. They are so remarkable in their action that the temptation would be strong for a lazy thinker to say, "Oh, these have not been evolved from others. They are special creations." In truth their behavior is in many respects so widely different from that of ordinary vegetables that it does seem difficult to conceive of the possibility of their evolution from other plants. But a little patience, a little listening to the Master's voice and the difficulty is not so great.

The special peculiarities that render these organisms so distinct from other members of the same kingdom are—(*a*) sensitiveness, (*b*) movement, (*c*) aggregation of protoplasm, (*d*) digestive and absorptive power.

(a) Sensitiveness.—This property of susceptibility to stimuli is not confined to these plants. The closing of leaves and flower-leaves in the dark, their expansion under the sunlight, indicate sensitiveness. Still better illustration in this connexion is the Mimosa or Sensitive plant, for it responds to the mechanical stimulus of a touch, as the sensitive filaments of the Venus' fly-trap respond.

(b) Movement.—The examples given above are also illustrations of the motile power possessed by certain parts of certain plants. But the examples known to-day of movements in plants might be multiplied almost indefinitely. Both the kinds of motion encountered in the insectivorous plants are seen in other organisms, for the slow movement of the leaves of the Sensitive plant parallels the gradual incurving of the "tentacles" of the Sun-Dew, and the spring inwards of the stamen of the Berberry when its base is

touched, is as sudden as the leaf-closure of the Fly-trap. Further, it is to be noticed that these movements of plants and parts of plants are due to one kind of tissue only. That tissue is the fundamental or cellular tissue. Wherever motion takes places it is referable to contraction of cellular tissue. Fibres and vessels take no part in the work. The movements of the Drosera and of Dionœa are dependent upon the same cellular tissue.

(c) Aggregation of Protoplasm.—Certain plants that carry glandular hairs upon their stems and leaves appear to absorb animal matter that may be entangled in the viscid fluid secreted by the hairs. Some at least of these plants show in the cells of the hairs aggregation of protoplasm. Thus the Saxifrages, best known to the non-botanical reader through the medium of the "London Pride," the Primula, the Scarlet Geranium or Pelargonium, the Heaths, the Marvel of Peru, the Tobacco plant, all have glandular hairs. Of these the Saxifrages, Primula, Pelargonium all rapidly absorb animal matter, and the protoplasm in the cells of the hairs undergoes aggregation. The Saxifrages, which show this process best of all, are allied in structure to the Sun-Dew.

(d) Absorptive and Digestive Power.—Of the capacity for absorbing animal matter as resident in some degree in plants other than the insectivorous, mention has just been made. Whether outside those dealt with in the book now slipping from our hands plants occur able to secrete a digestive fluid is at present open to question. That many plants do secrete fluid, and a fluid in some cases of acid nature, is assured. But whether any such fluid has the power of actual digestion of organic matter is as yet doubtful. It must however be noted that all the plants we have recently studied have not the full digestive ability. In truth the gradations are gradual enough to satisfy the evolutionist's mind at least in some measure. Commencing with the absorbent, glandular hairs of Saxifraga, and the retention of dead matter by the viscid glands of Pinguicula, he observes next the capture of unwary insects in the pitchers of the pitcher plants of the East Indian and Chinese swamps, their decay and absorption. He passes then to the mechanical seizure of the like animals in the bladders of Utricularia. In all these cases he sees absorption of decaying organic matter, no killing,

and probably no true digestion. But studying Aldrovanda, he meets therein with one part of the leaf devoted to the absorption of decaying organic matter and another to the capture and the killing and the digestion of living beings. Again, in Byblis, Roridula, Drosophyllum, the power of seizing and killing and digesting alone appears. The earlier cruder form of work is gone. And through these he passes up to the final and most specialised stages of all, where the Sun-Dew with its viscid shining glands entangles, slowly seizes, and digests the insect, or the Fly-trap on a touch of its sensitive filaments closes suddenly upon its prey.