THE FACULTIES OF PLANTS.

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That plants are really alive is but grudgingly conceded by even the well-informed, and when this concession is made, it is always with the mental reservation that while they may be alive after a fashion, yet their "aliveness" is not of the sort that characterizes animals. This prejudiced view finds its expression in various ways, among which may be included the habit of writing and thinking of plants as "lower" organisms, or perhaps as degenerates.

In order to appreciate the real place of plants in the world it is necessary to recall that they are composed of protoplasm, the common essential substance of plants and animals alike. Now, protoplasm has certain general primitive properties, which it exhibits no matter whether it be found in the leaf of a fern, the tip of a root, the trunk of an oak, the body of a horse, or the brain of a man. In each of these cases, however, it has taken on other specialized powers which enable it to perform the complicated work of the organism of which it forms a part.

Some time within the last hundred million years, or to be exact, about sixty million years ago, protoplasm came into existence on the surface of the earth, in a manner wholly unknown. It was probably in the form of small specks or masses of a jelly-like substance of complicated structure, although not so complex as the protoplasm of to-day, and was extremely liable to injury by almost any force. By reason of its great fragility and complexity it was necessary that it make constant adjustments to the forces (such as heat, light, chemical activity, mechanical shock, and contact) that impinged upon it. That it was capable of making adjustments made possible its continued existence until to-day.

It is impossible for us to retrace the long way back to this original stage of living matter and to ascertain all of the things it may have done in that day-before-yesterday of science. It may have started to solve the problems of existence in a score of ways not easily imaginable for us, but its forgotten failures have left no trace of their existence. Not that this primitive living matter consciously tried to find a distinct way of doing things, but in the very nature of its activity it must have done many things foredoomed to failure. Of the things that it did do, however, those that followed two general methods of procedure were successful, and by them the two main groups of organisms have been produced, which are no more to be compared than a telescope and an automobile, or an automobile and a warship, so different are they.

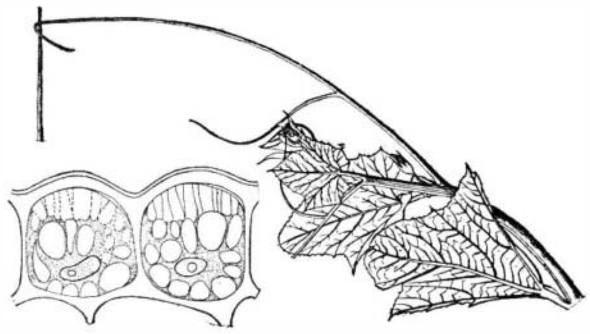
The adjustments by which protoplasm fits itself more perfectly to its surroundings are guided by its primitive property of irritability, the power of perceiving changes in the intensity of the light rays playing upon it, in the degree of heat of the air around it, of the soil on which it rests, of distinguishing between dry and moist objects, and of reacting differently to hard and soft bodies in a way that generally adapts the living substance to endure, and make use of these factors.

Having this primal capacity, the long-continued play of evolutionary forces led gradually to its development into forms which would serve the organism better and better. Irritability has been developed in the animal into the senses, and with this development there has been a constant tendency to localize and seat the different phases of it in the specialized sense-organs, which deal chiefly with one class of forces. A moment's reflection will show that it is the specialized irritability of our sense-organs that guides us, as highly differentiated masses of protoplasm, in making the thousands of adjustments that enter into our daily activities.

Light is, perhaps, the most important factor in the existence of plants, since energy is absorbed directly from its rays and is used in building up complex foods from simple substances obtained from the soil and air. If the plant is to obtain energy from light, the supposition would lie near that it must present its surfaces to the rays in such manner as to enable it to do this advantageously, for the amount of benefit to be derived from the rays would depend directly upon their intensity, and upon the angle at which they strike the surfaces. With this fact in hand one would at once suspect that the plant might have developed some power of measuring the intensity and direction of the rays.

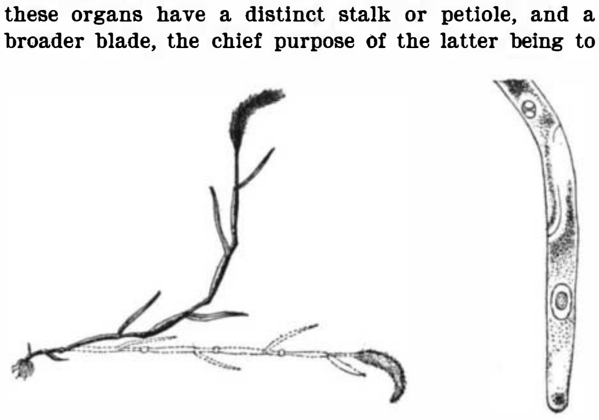
If each of us were as large as a mountain and had the tiny organism, man, in an experimental laboratory for the purpose of testing his power of distinguishing light and darkness, we might go about getting at the facts in several ways. The readiest method would be to blindfold him. Not knowing anything about eyes we might suspect that the five-digitate antennæ he used so vigorously and so variously might be able to perceive light. To test this supposition we would perhaps tie a cloth impervious to light around one arm, and seeing that he still could tell light from darkness we might swathe both arms. This test being a failure—and both the test and the failure are highly reminiscent of the ways of scientific work—we would remove the bandages from his arms and perhaps wrap them around his head, with the result that we would presently ascertain by what means this peculiar biped knew night from day.

The same method applied to a plant will lead to similar knowledge. Any group of window-plants may be seen bending toward the glass in such manner as to present the broad upper surfaces of the leaves at right angles to the strongest illumination. The whole shoot appears to be concerned in the reaction, and we must



A tendril curving around a rod. Percipient cells from the surface of the tendril sensitive to the touch of an object weighing no more than the fiftieth of a grain.

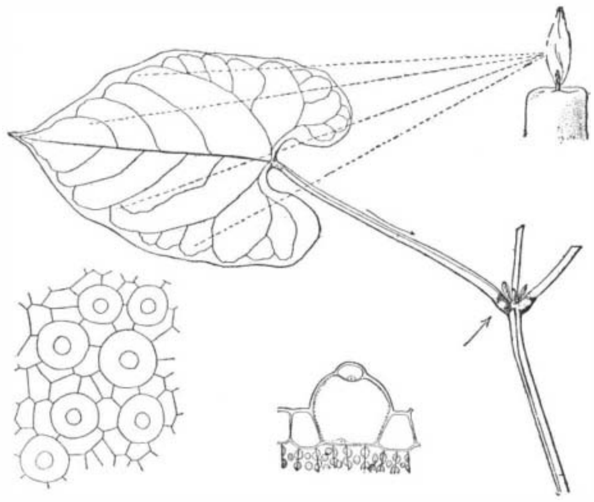
use the blindfolding method to ascertain what parts are sensitive to light. If sheets of tinfoil are bound around the stem, and it is turned away from the window, the next day it will be found to have curved back toward the window. This shows at once that the individual under treatment perceives light without the aid of the stems, although the swathed stems curve in the reaction. Next turn attention to the flowers if present, and when these are black-capped the plant still turns unerringly to the proper quarter to receive its daily dole of sunshine. The leaves are now to be considered as a seat of the light-perceiving faculty. In most cases these organs have a distinct stalk or petiole, and a broader blade, the chief purpose of the latter being to



A grass stem prostrated by wind and raised by the action of its motor organs.

spread out an expanse of green tissue which entraps the rays and makes their energy available for the chlorophyl processes. Inclose the stalk of the leaf in tinfoil or black cloth, and the plant still turns its faces to the light, but sheathe the broad surfaces of the blade and it is truly blindfolded, and now does not turn toward the window when removed from it. Some plants, however, are capable of perceiving light in a feeble but much less accurate manner on portions of the stem and petioles.

If prepared sections of the blades of some of the more delicately reacting plants are placed under the microscope it will be found that the outer walls of the



Leaf blade receiving rays of light at a stimulating angle after the signal travels down the stalk to the motor organs. Epidermal cells which converge the rays and are sensitive to oblique rays.

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epidermal cells are curved outward, making lenses which converge the rays upon the inner walls, and allowing them to be transmitted to the cells beneath where they play upon the green color-bodies in which the construction of food-material takes place. Imagine one of these epidermal cells to be a room with a convex skylight roof and a glass floor. When the rays come through and fall upon the floor they pass through to the room below, and drive the chlorophyl-mills making sugar and other substances. The lateral walls of the skylighted room are lined with a living layer sensitive to light, and if the leaf or the building is moved so that the rays strike the sensitive layer a signal is sent to a distant shifting mechanism. Slowly, but with unerring precision, this gets in motion and brings the leaf to a position where the rays once more come through the condensing skylight and pass through the floor to the food-making cells below. In accordance with this action the plant moves all of its leaves into fixed positions, in which they receive the daily illumination most advantageously. In certain cases the leaf-blade performs delicately gaged movements, by which it receives the rays until they become so intense as to be harmful and then the surfaces are turned away from the source of the rays. The management of the leaf-screen in either of these cases demands an automatic mechanism capable of detecting very minute variations in the intensity of light, and one which may also accomplish rapid and accurate movements.

The exactness with which the plant can measure intensity of illumination is not to be easily realized, but the following test will serve as an exemplification: A small, rapidly growing shoot, such as that of a young mustard plant, is placed in a dark room for a few hours until it has lost all effects of stimulation from light. Then two standard candles are placed at distances of three yards on opposite sides and the sensitive leaves will receive stimulation of equal intensity on both sides and may remain stark upright. If one of the candles is moved an inch closer the shoot will begin to curve toward it as toward a window. The intensity of light varies as the square of the distance from its source, and it has been found that some plants can appreciate a difference so small as one three-hundred-thousandth of the intensity of a candle at a distance of a yard. It may be seen, therefore, that but a slight movement of one candle would be necessary to disturb the equilibrium of the shoot in the experiment in the dark room. Indeed it is difficult to place the candles correctly in the first place. It is needless to say that such delicacy of reaction is far beyond the capacity of the unaided human eye. Nor is the sensitiveness of the shoot confined to an appreciation of intensity, for a marked power of distinguishing colors is shown, and the plant responds differently to various portions of the spectrum. The blue and the red do not excite the plant alike, as it bends toward the source of the first and is indifferent to the second.

The tests described above indicate that the blades of the leaves chiefly receive stimulation from light, but an examination of almost any species shows that the curvature does not take place in the blades but at the bases of the leaf-stalks, or in the stems, in portions which may be a few inches or a foot away from the blades. In almost all cases the movement takes place in tissues more or less widely separated from the part which is sensitive to illumination. This may be proven conclusively if all of a plant except the blade of a single leaf be blindfolded and then subjected to illumination from one side. The curvature will take place in parts of the plant kept in darkness, and we are justified in concluding that the light-receiving or light-perceiving organs send some kind of an impulse or signal to the distant motor tissues which cause the movement.

Some species have upright leafy shoots, while others are creeping or decumbent. In either case the machinery of the organism is exactly adapted to return and hold the root and shoot in the characteristic position. The perception of position is not one of the keenest activities of the animal, but it is of very great importance to the plant, and the mechanism by which it perceives its relation to the vertical is one of the most delicate of all vegetable structures. The essential part of the apparatus consists of cells containing numbers of freely moving granules, which rest against the delicate layers of protoplasm which line the walls. When they are in contact with the wall of the cell which is normally lowermost the organ remains at rest. If the wind lays the shoot prostrate, or if a root is diverted from its course, the granules in hundreds of cells are thrown against the lateral walls and countless signals are sent to the motor zones, and curvatures ensue which bring the tips of the organs to their proper positions. This action begins within a few minutes after a stem or root has been displaced and effectually maintains the positions of the various organs.

A large number of species of plants has become sensitive to the touch or blow of a solid object in a manner broadly analogous to the touch reactions of animals. One form of this reaction is exhibited by plants which climb by the aid or tendrils. Tendrils are generally long, slender organs sensitive on one surface only, although in some species the percipient cells cover the entire surface. When one of these organs comes into contact with a solid object the outer sensitive cells are stimulated and communicate an impulse to cells not far distant and curvature ensues within a second, or a few seconds at most, which generally results in curling the organ around the object. Singularly enough these organs distinguish between a touch and a blow. The rudest shock or jar does not set the tendril in action, so long as the sensitive cells do not receive a pressure of some continuity, but the most delicate contact of the smallest object will cause stimulation. Thus a bit of spider's thread or the finest silk fiber weighing no more than the fiftieth of a grain will serve to excite curvature. Water, or even as heavy a liquid as mercury, will not cause curvature when poured over a tendril, but if minute particles of chalk are suspended in the water the repeated contact of these bodies will set up a reaction. This is in fact an appreciation of the difference between pure and muddy water, which is probably beyond the capacity of any organ of touch of the human body. After a tendril has grasped a support by means of the above mechanism, the free portion of the organ is thrown into a corkscrew which has the effect of pulling up the stem and anchoring it by an elastic spring.

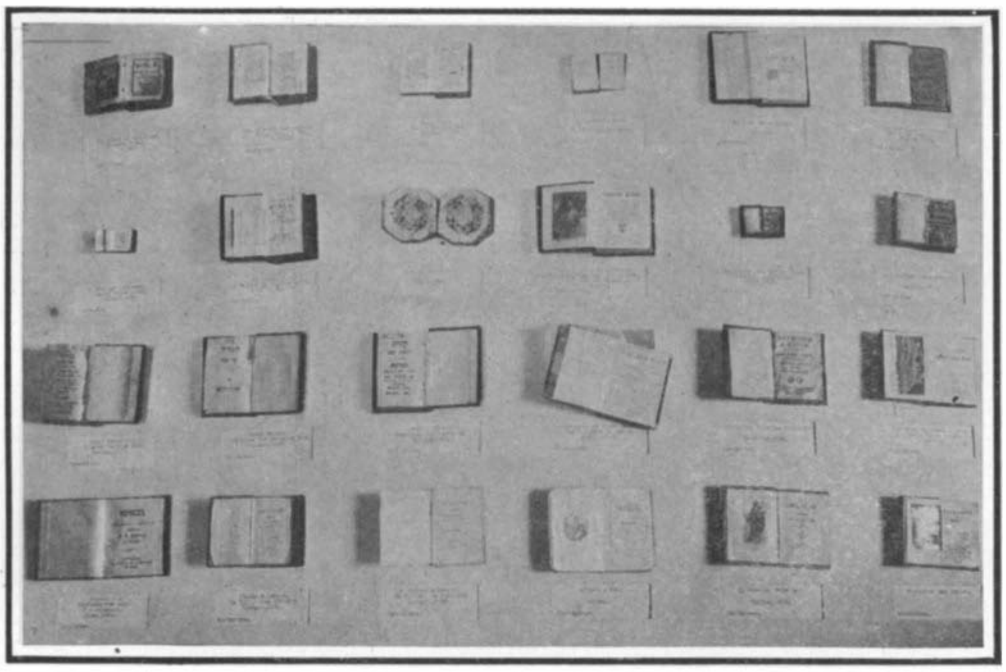
The "sensitive plant" (Mimosa), a small decumbent shrub native to the tropics, offers a striking illustration of another form of sensitiveness to mechanical stimuli, by which shocks and blows, but not contact are appreciated. The base of the leaf-stalk is attached to the stem by a highly developed pulvinus, or motor organ. The slightest shock or jar will cause this motor organ to act, and the leaf is quickly dropped through an arc of ninety degrees. If a stronger stimulus is given, an impression is conveyed up and down the stem to other leaves, and the effect of a single snip of the scissors on a leaflet may be transmitted through a stem a yard in length at a rate of a third of an inch per second, in a manner highly reminiscent of the action of nerves.

The space at command does not allow even a simple description of all of the capacities for adjustment to the external world displayed by plants. In addition to making external responses, or reactions to external forces, a perfect correlation exists between the different organs by which efficient co-operation is secured. Nowhere is this better illustrated than in the common poppy. During the growth of the flower stalk and bud, they are held in the form of a shepherd's crook with the bud pendulous from the tip. When the innumerable divisions and the complicated quadrille of the chromosomes in the ovary of the flower have finally brought the precious egg-cells to a stage where they are ready to receive the chromosomes from the elongating pollen-tubes, the completion or attainment of this stage results in a signal being sent to the curved stalk a few inches away, and it quickly straightens: as the bud expands simultaneously the saucer-shaped flower opens and faces the sky ready to receive the fertilizing pollen. Once this is received the changes ensuing result in sending off a second signal to the motor zone of the stalk and the curvature reforms the shepherd's crook, which holds the capsule pendulous to drop the seeds when mature.

In no instance, however, does the activity of the plant involve choice or decision, or anything except the most generalized form of consciousness. The sensory functions are purely reflexive, and there is no central organ where impressions are received, and from whence signals are sent out, but the percipient organs themselves send impulses direct to the motor tracts.

It is to be seen, therefore, that plants are not degenerates, nor are they lower than animals in any sense: no matter what development they may achieve, or what progress they may make in improvement, they become more widely separated from the animal. Instead of being a lower branch of the phylogenetic tree which has produced animals, they form a separate phylum arising from the common substratum of primitive protoplasm. They constitute a distinct group following a path widely divergent from that of animals, and make the numberless adjustments necessary to their continued existence by a set of sensory faculties wholly characteristic.

During the six hundred thousand centuries that plants have been in existence they have moved unconsciously toward the perfection of a mechanism which receives stimuli, gains impressions, and transmts impulses with a delicacy and accuracy superior to that of the animal in some instances, and fairly commensurate with their needs in all cases.



A COLLECTION OF MINIATURE BOOKS. THE LARGEST IS BUT TWO INCHES IN HEIGHT.

A LIBRARY IN MINIATURE.

Pictured in the accompanying engraving is one of the most important divisions of the Congressional Library at Washington, yet all of the books it contains could be put into a good-sized overcoat pocket. The collection is indeed a library in miniature. The largest book is but two inches in height, while the smallest can actually be placed on a man's thumbnail with room to spare. The piece of cardboard on which the books are fastened is only three feet in length and it contains twenty-four of the tiny volumes. A comparison of the tiniest with the largest book in the collection will give a better idea of the minute size of these works, yet everyone is a complete book in printing and binding. The smallest contains about fifty pages of printed matter, although the characters are so fine that a microscope is required to read them.

MODERN IMPROVEMENTS IN DRYDOCK CONSTRUCTION.

BY H. A. CRAFTS.

Numerous and quite important technical improvements are to be observed in the construction of the modern graving drydock, and these improvements are especially in evidence on the Pacific coast. One of the more difficult problems of operating a drydock is the handling of the bilge blocks, which have to be very nicely adjusted in order to receive any vessel that may be let down upon them. In fact, the master of every vessel that is about to be drydocked is required to furnish the manager of the dock with exact drawings of the outward contour of his hull, in order that the drydock people may be able to adjust both their keelson blocks and bilge blocks so that the vessel may be settled upon them with exactitude in all parts.

Of course, the adjustment of the keelson blocks is a comparatively easy task; because they are all set upon a right line, and only need to be regulated as to their elevations. But it is quite a different thing when it comes to placing a long individual bilge block so that it will receive the weight assigned to it simultaneously and with the same pressure as every other block. There must be both horizontal and vertical adjustment in order that the hull may not be subjected to any degree of wrenching in any of its parts.

But it is in the mode of constructing the bilge ways that the improvements introduced by Mr. Holmes, the chief engineer of the San Francisco Dry Dock Company, are most apparent. The old-fashioned bilgeway, and one still in quite common use, especially in the government drydocks, is raised above the level of the dock floor, and the blocks are confined to the trackage by a system of steel clamps, falling on both sides and catching a piece of armor running along the edge of the way.

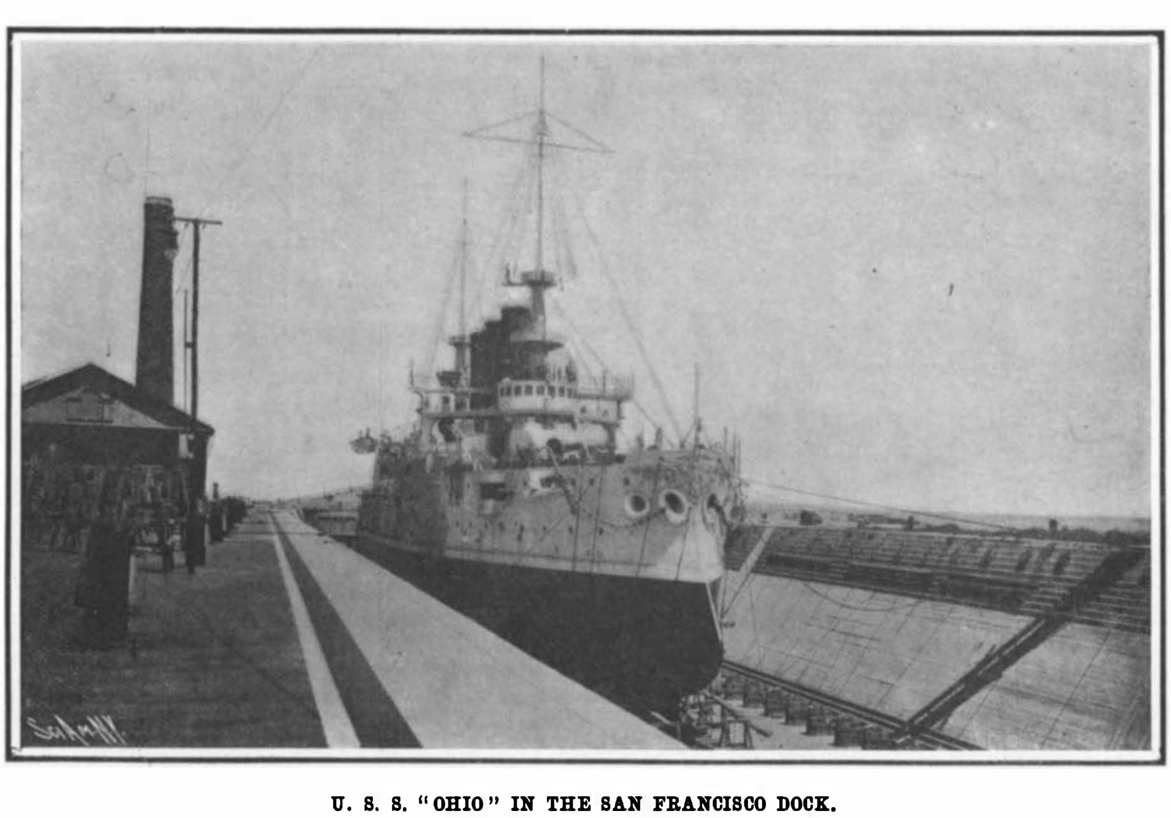
These raised bilgeways are always much in the way in operating a dock; and with a view to doing away with these incumbrances, Mr. Holmes has abolished the raised ways or tracks entirely, and has arranged the bilge blocks to run on a level with the dock floor, being at the same time guided by clamps that drop down into slots let into the dock floor and clutch strips of metal armor with which the slot is edged, very much after the fashion of the slot in the cable street railroad.

Thus the dock floor is left perfectly free and open, while at the same time the bilge blocks may be run back and forth just as well as if they were operated upon raised ways.

Both lines of bilge blocks are arranged so that they can be operated from one side of the dock, whereas it used to be the custom, and the custom is to some degree extant to-day, to operate each line of blocks independently from its own side of the dock. By the new plan, a pair of companion blocks, that is, a block and its opposite, may be operated by one man and from one side of the dock, and the thing is done by means of a combination of lead lines and hoist blocks. By pulling one pair of lead lines the bilge blocks are made to approach each other, and by pulling another pair they are made to recede from each other. An improvement has also been made in the method of drainage. The floors of the government drydocks are drained by a system of small sewers, and much trouble is experienced by these sewers becoming clogged. The new method does away with sewers entirely, and drains the dock floor from the surface. Drainage is effected from each end of the dock to the center, and into the main sump or pump pit, by a system of open gutters, the gutters being 2½ inches wide and 6 inches deep. By this means the floors can be cleaned by the use of a common "squeegee," or rubber-armed scraper, into the gutters and then flushed with a hose. Likewise the gutters, being open, may be easily cleaned out should they become clogged or foul.

Another innovation concerns the method of cleaning the gate seat. Of course, it will be understood that it is necessary for the caisson of a drydock to fit into the gate seat perfectly, otherwise there will be a leakage so soon as the dock is pumped out.

In order to clean the gate seat, Mr. Holmes has devised a new method. A system of water pipes built into the masonry of the gate seat discharges upon the seat. These pipes are connected with the donkey engine of the dock, and powerful jets of water are projected through them upon the gate seat.



U. S. S. "OHIO" IN THE SAN FRANCISCO DOCK.