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The Special Senses of Plants.

By J. C. Arthur.

We are told by Louise Michel, a woman of remarkable, if somewhat eccentric intellectual powers, that when in Australia sitting at her window one day her attention was attracted by the slow but regular movements of a climbing plant. Its long free end swept slowly around, like an outstretched arm reaching for something to cling to. Does it feel? is it moving in response to some inward desire? are the questions she asked herself; and thought it not improbable that an affirmative answer might be truthfully given. The last number of *Meehan's Monthly*, a journal of considerable scientific pretention, gives editorial endorsement to essentially the same views. To what extent plants have senses or sensibility is a question that thoughtful people have asked, and will continue to ask, and is indeed a subject well worthy of attention.

In the days of Aristotle plants as well as animals were distinguished from the inanimate world by the possession of a soul, to which the characteristic features of the organism as a living object, were ascribed. Aristotle's theory of a soul in plants was ably expounded by the distinguished Italian scholar, Cesalpino, in the sixteenth century. He entered into lengthy arguments regarding the seat of the soul, and concluded that it must reside in the pith, particularly in certain portions of it. With a philosophy of this nature there was nothing incongruous in the popular notion of the times that some plants were endowed with properties akin to human. Some exercised wonderful spells over persons coming into their presence, and some would "shriek like mandrakes torn out of the earth, that living mortals hearing them, run mad," as Shakespeare puts it.

This doctrine of a biologic soul, which was, however, more materialistic than spiritualistic in its application, helped to shape botanical philosophy from the time of Aristotle and earlier down to the middle of the eighteenth century, having had much to do even with determining the views of Linnæus. In its strictest form, as expounded by Cesalpino, the doctrine is not particularly startling even at the present day, for he taught that plants possess "only that kind of soul, by which they are nourished, grow, and produce their like," the capacity for sensation and movement being denied to them. If I mistake not, the popular notion of plants in our own day does not differ essentially from this scholastic philosophy of several centuries ago.

The second period of development of the ideas respecting sensation in plants, or we might better say the want of sensation in plants, was opened by the famous dictum of Linnæus that, " minerals grow, plants grow and move, animals grow, move and feel." Linnæus' great prominence as a systematist gave to this dogma special force, although in reality it was but a slight modification of the teaching of Cesalpino, already referred to, and of his successor Jung. Much of the controlling opinion of the greatest philosophical botanists down to the present century can be traced back to these two scholastics. Jung was a contemporary of Kepler, Galileo and Descartes, and dominated botanical thought in Germany, as Cesalpino had done in Italy. He expressed his view in the sentence: "*Planta est corpus vivens non sentiens.*"

The force of Linnæus' aphorism was more in its form than in its newness, in spite of the fact that he ascribed motion to plants, for it seemed to separate nature into three sharply delimited kingdoms: mineral, vegetable and animal. Botanists and zoologists have from that time to within a few years of the present been fruitlessly attempting to find infallible characters for distinguishing animals and plants. The discovery of protoplasm in 1846, of its identity in the animal and vegetable organism somewhat later, and the publication of the origin of species in 1859, brought an end to the old order of things, gave rational unity to the organic world, founded a science of biology, and converted the scholastic method of studying nature into the dynamic method. At the present time the motto of the botanist is " the study of plants as living things," and by acting upon it the science has been redeemed from the lethargic state of being " a chronicle of the dead," as Julian Hawthorne characterises it, into a subject of immediate and vital interest.

The fact that plants possess sensibility, or as the text-books now say, irritability, was made conspicuous and put beyond all doubt, even with the unlearned, when the sensitive plant (*Mimosa pudica*) was discovered in America and taken to the gardens of Europe. A plant of such easy culture in either the garden or the conservatory, and possessing such wonderful sensitiveness to touch, attracted general attention. In 1848 Brücke's memoir upon the sensitive plant appeared. It was a model for thoroughness, for ingenious methods, and lucid deduction. From this clear and unequivocal starting point it was comparatively easy to pass to the less obvious forms of irritability, and since then many kinds of reaction to stimulation in plants have been brought to light and made the subjects of investigation.

But admitting that plants have sensibility, that is, are capable of responding to stimuli, is far from admitting that they have senses. Active protoplasm is always sensitive to some form of stimulation. If a bit of fresh striated muscle, from the leg of a frog for instance, be struck, or pricked with a needle, or shocked with a current of electricity, it will respond by contraction; and so will the protoplasm in the cells of an onion or other plant. Contractility is a universal property of living matter, although different cells of the vegetable and animal structure display it in varying intensity. There is, however much disparity between contractility and sensation. Whether this disparity is real, that is whether there is actual discontinuity, or whether it is only seeming, being the expression of extremes, is an important inquiry.

If we approach the subject from the opposite direction, we shall have a very different point of view. There is no way of securing a just conception of the extent and relations of an object, as of a house or a tree, like viewing it from different sides. To consider the contraction of the muscles of the arm when the hand has touched an uncomfortably hot surface, is to study the physiology of the movement, but to consider the mental disturbance produced by the perception of heat, is to take a very different point of view and study its psychological relations. One is the objective and the other the subjective method; both have advantages. But both methods should lead to a unity of conception; and this should be a more complete conception, than either method could give pursued by itself; just as viewing a house from the east side and from the west, is better than viewing it from one side alone. So far as I am aware, no writer has presented the psychological side (if the expression may be used) of the movements of plants, although the foremost investigators, Darwin, Sachs and Frank, make the presentation of their physiological studies attractive by use of psychological expressions. Darwin, in his work on climbing plants, describes the behavior of a plant, which failed to secure a hold upon a tall stick placed at a certain distance, the free end of the twiner, as it swept around in a circle, each time sliding past the support after being pressed against it for some time; and adds that "this movement of the shoot had a very odd appearance, as if it were disgusted with its failure, but was resolved to try again." In summing up his studies on the root tip in his volume on the power of movement in plants, the same author states that the tip of the root "acts like the brain of one of the lower animals." But we are not supposed to interpret these expressions to mean that a climbing plant has feeling or that a root thinks.

As our knowledge of nature is dependent primarily upon our powers of cognition, it is not strange that students of subjective phenomena should, like Descartes and Leibnitz, in the earlier days of the science of mind, and Hegel and Locke in more recent times, refuse to entertain any connection between mind and matter, except that of association. With the gradual unfolding of a knowledge of physiology, and the adoption of its revelations and methods, a gradual extension, overlapping and fusion of the spiritual and material, the subjective and objective, manifestations of living nature have taken place. But if we examine the writings of Bain, Carpenter or Herbert Spencer, of the English school, or Herbart, Lotze or Wundt, of the German school, or other representatives of the present liberal movement, we shall find that activity has only been transferred from the cerebral hemispheres to the ramification of the nerves, and from a search for the seat of conciousness to a study of the transmission of impulses. But it is to be remembered that the brain and nerves are the telegraphic lines and relay stations for communicating intelligence of the condition of the outside world to the sensient organism, and furthermore that many of the lower animals and all the world of plants are without nerves; they are like society before the advent of the telegraph, telephone and postal system. This large part of animate nature is, for the most part, ignored by the psychologists, and treated by the physiologists only objectively. In fact, subjective, that is obverse, physiology is in need of devotees.

There is great diversity in the use of the terms sensitiveness, sensibility and sensation, when applied outside the domain of human psychology. We are inclined to accept for our present purpose the usage adopted by Maudsley, who makes the term "sensibility" generic, and divides it into irritability, reflex action, sensorial action, and idealistic perception. In this classification organisms without nerves, which are the only ones we are now interested in, are only capable of sensations due to irritability.

An eminent Bavarian botanist, Nägeli, has philosophised upon the subject of universal sentience. "In the higher animals," he says, "sensation is distinctly present in the movements consequent upon irritation. We must therefore credit the lower animals with it as well, and we have no reason to deny it in the case of plants and inorganic bodies." This claim for continuity is attractive, but is much too sweeping, and not sufficiently logical. No good purpose can be subserved by crediting minerals with feeling, which we find Nägeli has done because their molecules exhibit the attracting and repelling forces of chemical affinity. His assignment of sensation to plants rests upon no better basis. Probably no author has given more earnest attention and study to this subject than G. H. Lewes, the distinguished English psychologist. He has told us, in his volume on the object, scope and method in the study of psychology, that he was at one time fascinated with the idea of a comparative psychology, which should begin with simple organisms and thereby gain in strength of interpretation upon reaching man. He began to collect materials with this view, but afterward abandoned the project as impracticable. We may parenthetically remark that his failure to secure material in this way to interpret human action does not disprove the feasibility and usefulness of a comparative psychology in which man shall receive only the share of prominence due him as a member of the organic series. However, his studies made possible a far clearer insight into the distribution of sensibility in organisms. One of his illustrations, very familiar to every laboratory student, is especially pertinent. He says: "Touch the eye of a frog, and there is at once the response of a reflex closure of the eyelid. Touch the hairs of a Venus fly-trap (*Dionœa muscipula*), and there is at once the response of a reflex closure of the leaf. Confine the frog and the dionœa under a glass shade, and place there a sponge, over which ether has been sprinkled. Both plant and animal breathe this air in which there is vapor of ether, and as this vapor penetrates to their tissues we observe a gradual cessation of all sensibility; first the reflex actions cease, then the irritability of the particular tissues ceases. Stupor has supervened for both. Now remove the glass shade; the vapor dissipates, the fresh air penetrates to the tissues in exchange for the vitiated air, and both frog and dionœa slowly recover their sensibility." From this experiment he justly concludes "that the animal and plant organisms have with their common structure common properties, and that if we call one of these properties sensibility in the animal, we must call it thus in the plant."

This, and many other equally satisfactory observations, appear to lay so good a foundation for a proper appreciation of the scope of sensibility that we are surprised and disheartened to find him finally in a hopeless muddle of plants, monads and molecules, and when he has affirmed that "sensibility stands for the objective phenomena exhibited by an organism under stimulation," he must needs add, to save himself from possible entanglement, "or, more definitely, for the reaction of a neuromuscular mechanism." No great progress can be hoped for in the study of nerveless organisms by a constant comparison of their behavior with that of organisms with nerves and nerve centers. There is need of a different method.

This review of the present state of knowledge regarding the relations of sensibility in plants and animals shows an astonishing absence of agreement and a total lack of a rational basis. The confusion, it seems to me, is due to a disregard of the conditions under which sensibility has been developed in the two divisions of the organic world. Knowing that irritability is a fundamental property of all living matter, let us ask ourselves what advantages the animal or plant could secure by its special development. That is, given this universal property of organisms, how could it be developed into special senses? It is unquestionable that the paramount necessity of the organism is self-preservation. To secure food, to keep out of harm's way, to obtain the proper supply of air, moisture and heat, may be considered the fundamental necessities of every organism, whether man or monad, tree or microbe. Considering for the present only the higher organisms, we note that, if an animal desires food, its sight and scent aid in searching for it, if in danger its sight and hearing enable it to escape, when food is obtained taste and smell indicate whether it is to be eaten or rejected, while touch gives a variety of sensations relating to food, bodily comfort and protection. Our present purpose does not require any mention of intellectual sensations. All the lower animals, down to the simplest unicellular forms, "the little lumps of protoplasm" described by Hæckel, possess one or more of these senses, and some animals may possibly possess other kinds in addition. The point to be especially noted here is that each individual animal (with a few exceptions among the lowest forms) has the power to flee when its senses indicate danger, or to advance when desirous of food, or to seek another place if the present one is too wet or too dry, too hot or too cold.

Let us examine plants in a parallel way. If they need food do they have sight and scent to aid them in searching for it? No, because they are firmly attached to one spot; roaming about is impossible, and to see and smell would be useless. If they were in bodily danger, no acuteness of sight or hearing would avail them in the least. Were the aspen quaking through fear of some horrible calamity, it could not move an inch out of the path of destruction. Again, plants take no solid food, and have no use for a sense of taste. In short, animals are endowed with a set of senses which would be practically useless to plants, from the fact that the latter are, with very few exceptions, fixed instead of being locomotive organisms.

But are there no movements within the power of a fixed organism that can be brought about by the action of stimuli, which may aid in self-preservation or improving the conditions of existence? I think that a little reflection will show that there are; and if we can find that plants have developed special mechanism in connection with a superior localized sensitiveness to enable them to take advantage of the conditions of their existence, we shall have demonstrated the possession of special senses.

There is no requirement for plants more universal or more necessary than that their roots should penetrate the soil and their foliage be spread to the air. Yet the root or shoot has no more power to deviate from extension in a straight line unless acted on by some external force, than a cannon ball or other moving body has to vary *its* course from a straight line. If a seed in germinating should lie in such a position that the roots point upward and the stem downward, some device is needed by which the plantlet may readjust itself, by either turning over bodily, or changing the direction of its growing parts. As everyone knows the latter alternative is adopted, and the roots bend down and penetrate the earth, while the stem bends up and lifts its foliage into the air. It is so apparently a matter of course that stems grow up and roots grow down, that we may never have given a thought to an explanation of the process. Even botanists have only recently felt the full necessity for accounting for the fact, as it has been only a decade since Vöchting announced his theory of rectipetality, or the inherent tendency of growing organs to extend in a straight line unless acted upon by outside forces.

There is only one force known that acts uniformly in the direction of the center of the earth, that is gravity; and it was the genius of Andrew Knight, an Englishman, to demonstrate as long ago as 1806, that this force does furnish the directive influence in securing verticality to plants. He grew plants on revolving wheels, and found that they responded to centrifugal force, and that when the wheel was placed horizontally and revolved at a speed that made the centrifugal force equal that of gravity, both roots and stems grew obliquely, taking the position of a resultant of the two forces, that is, of forty-five degrees to the vertical.

But this discovery of Knight's was not very fruitful, for no one could tell how gravity could produce the effect ascribed to it. If it pulled the root down, why did it push the stem up? The stem is as heavy as the root, why are not both attracted toward the center of the earth? It was a curious paradox to say that the same force acted now one way and now exactly the reverse on different parts of the same plant; as if pulling and pushing were the same thing. It was supposed that gravity acted upon the root as it does upon a mass of taffy candy, drawing it downward. But Sachs showed in 1873 that the root of a bean fixed horizontally over mercury could penetrate the mercury in assuming a vertical position. As mercury is thirteen and a half times as heavy as water, or the tissue of a young root, it is evident that far more force was expended in penetrating the mercury than could have been derived from the physical action of gravity, that, is, from the simple weight of the root. The experiment has since been tried in another and more obvious way by harnessing a root tip lying horizontal to a weight suspended over a pulley, the weight being raised as the root bends downward in response to gravity. From these experiments we must conclude that gravity does not act physically but physiologically to induce the curvature, that is, it acts as a stimulus. It is a small spark that fires the gun. The same spark will fire a pistol or a cannon, the result depending solely upon the amount and arrangement of the explosive material. So in the root, if there is the proper mechanism and storage of force, gravity will release this force and cause the bending, the amount of work done being enormously out of proportion to the initial expenditure of energy. But when the bending takes place, will it be upward or downward? If it were a purely mechanical device, it is evident that by knowing the structure of the organ, one could predict the direction of movement under stimulation. But we shall have to look beyond and above simply mechanical laws for an explanation. The wooden horse could not have destroyed Troy without a guiding principle within more intelligent and effective than mechanical force.

But in attempting to solve the problem, do not let us attempt too much. Let us accept such an explanation as we would consider satisfactory in case of a similar problem regarding the behavior of an animal. To see with our eyes and not with our fingers, to hear only with our ears, taste with the tongue, and so on for the other senses, seems like a matter of course. But to explain why the nerves of the eye are only sensitive to light, of the ear to sound, of the fingers to impact and temperature, and so on, there being no structural differences detectable between the various sets of nerves that bring about such diverse results, we are content to say that it is due to a specialization of sensibility. The nerves at the tips of the fingers are more sensitive to touch than those at the back of the hand. The fingers have nerves that respond when stimulated by heat, but in the eye the nerves will not respond to heat but will respond to light. We do not marvel at this, it is everyday knowledge. We put it in scientific language by saying that irritability, a universal property of living matter, has been developed and specialized in different organs so as to respond differently to different stimulation. Fundamentally there is agreement, but the results of specialization are diverse. In the plant the root has a special sensitiveness to gravity, which is manifested by causing it to bend earthward, the stem possesses a sensitiveness which causes it to bend skyward. To meet its conditions of existence the plant has developed a special sense, that of geotropism, by which it is enabled to take advantage of the directive influence of gravity to place and keep itself upright in the world. It has a sense which animals, with their freedom of movement, appear to be nearly or entirely without. Animals assume an upright position, not in response to a direct gravity sense, but to secure the most comfortable adjustment of the weight of the parts of the body. Uprightness is a question of weight in the animal, a question of special sense in the plant.

It may be objected to this designation of the gravity sense in plants as a special rather than a general sense, that it is diffused throughout the plant and not confined to particular, specialized organs. This objection has some show of validity, but is not formidable. The apparent difference is not fundamental, but necessitated by certain structural features. Animals have a jointed, or wholly mobile body. In the jointed forms, and often in the others, there is an arrangement of muscles, with a communication of nerves with which to bring about movement as a response to stimulation. Plants, on the contrary, have a rigid body; the sensitive protoplasm being divided into innumerable minute particles, each little mass separated from its neighbors by thick, nearly rigid walls of wood or cellulose. It used to be a favorite illustration to say that a plant was like a great prison, with innumerable cells separated by thick walls, each cell occupied by a prisoner. Although the individual prisoners may be strong men, and be in a frenzied state of activity, beating the sides of rooms, yet a spectator looking at the outside of the prison would see no movement of the walls, no evidence of life. With the discovery of continuity of protoplasm between plant cells, an English discovery of 1882, we have learned that to have our illustration really accurate, we should suppose all the cells of the prison to be connected by telephone. We must furthermore provide towers, with walls that are thinner and of flexible material. Now, if an alarm is given, all the prisoners being apprised at once, or nearly so, act in concert. The spectator on the outside sees no movement in the thick-walled part of the structure, but he sees the towers sway. We must further suppose that the men in the thick-walled cells, finding their efforts are useless, no longer make any response when the alarm is given, while those in the thin-walled cells, finding their efforts rewarded, become constantly more active and learn how to combine their efforts for greater efficiency.

The application to the plant is obvious. Although the force which a plant can exert amounts to several atmospheres, it is only in the young tender portions, usually at the ends of the branches of the stem and root, that this force can be successfully applied to secure movement of the whole organ. It therefore comes about that movement in plants is oftenest associated with growth. This arrangement permits each root tip and growing stem to have its own kind and degree of sensitiveness. Thus we find by experiment that while the first root which starts from a seed, the tap root, is sensitive to gravity in such a way that it places itself parallel to to the direction of the impinging force and points directly downward, the secondary roots, which branch from it, are sensitive after a different fashion, and instead of growing parallel to the force, grow at an angle to it, the exact angle being different for different kinds of plants. The tertiary roots, or next set of branches, are usually very little sensitive to gravity, or if they are sensitive they assume a nearly horizontal position. The stems react in a similar way, except that the general direction is upward instead of downward, and in consequence of the diversity of sensitiveness of the primary and secondary shoots, the branches are spread out to the air and light, imparting to each species of the tree and herb its characteristic appearance.

But if there is no nerve-like communication between one root tip and another, or between one stem end and another, there is sometimes a distinct transmission of impulse from the cells receiving the stimulation to the cells a short distance away where the movement is consummated. Thus, in the tip of the primary root Darwin found that only the cells at the very tip were sensitive. If so small a piece as the twentieth of an inch be removed from the end of the root by cutting or burning, all power of movement is lost. This remarkable localization has been denied by Sachs and Detlefsen, who characterize Darwin's claim as sensational, but the fact has quite recently been fully verified by Wiesner, who finds that if the root is weakly sensitive, the seat of irritability coincides with the zone of most rapid growth, but if highly sensitive, it will be at a distance.

To sum up the characteristics of the gravity sense: It is localized in or near the ends of growing roots, stems and other organs of the plant; it is developed in varying strength in different organs; it sets up movement of the organ in response to stimulation; the direction of movement will depend upon the specific kind of sensibility acquired by that organ; the direction of the movement will always bear some definite relation to the vertical without regard to the position of the plant.

But, what other senses have plants? Next to a proper position, most plants need a suitable exposure to light. I shall not attempt to show the numerous and wonderful ways in which plants respond to light. Everyone knows how plants lighted from one side, as when placed before a window, bend toward the light. This is a true sensitiveness, for it results in bringing about definite movement. It is not, however, at all like seeing, for it will be noticed that it is not the amount of light, but the direction of light to which the organs respond. The stems place themselves parallel to the direction of the incident rays—that is, point toward the window, while the leaves place themselves at right angles to the direction of the light—that is, with their upper surfaces to the window. Leaves and stems, therefore, show a sensitiveness characteristic of each. Some stems, however, like those of the Virginia creeper, turn away from the light, enabling them to cling to dark walls. Roots, which are generally buried in the soil, rarely exhibit sensitiveness to light, and when they do, it is usually to turn from it. If light comes to the organ from two directions, it will bend toward the source of the stronger light, and differences which will affect the plant are far more minute than can be detected by the eye.

As in the case of roots, certain stems place themselves, not parallel with the direction of the light, but at some particular angle to it, in accordance with some inherent necessity. Not as many parts of the plant, as a rule, are sensitive to light as to gravitation, but the degree of development of the sense is often greater.

Some plants also show a sensitiveness to moisture, especially in their roots, causing them to bend toward or away from the moist surface. Certain molds are remarkably sensitive in this way. Errara presented a paper before the British Association, last year, in which he gave the results of his experiments with *Phycomyces nitens*, a tall-growing mold. It proved to be so sensitive that the experimenter was enabled to detect the hygroscopic character of certain substances not before known to be in the least degree hygroscopic. Thus it bent toward alum, and careful physical tests showed that alum was truly hygroscopic to a minute degree, although the property had never before been ascribed to it.

Certain plants are also sensitive to heat. Here, again, it is the direction of the radient energy, rather than the amount, to which they respond. In my own laboratory, experiments have shown that young plants of corn will bend toward the source of heat, which in this case was a lamp placed behind a screen of blackened tin, while beans bent away from it.

But probably the most varied and wonderful of all the plant senses is the sensitiveness to contact. In the animal the somewhat similar sense of touch is more diffused over the body, and takes on more variety than any of the other senses, and in plants it has even greater diversity than in animals. In the tendrils of certain plants, notably in the passion vine (*Passiflora cærulea*) "this sensitiveness is often exquisitely fine, indeed, it seems more delicate than the tactile sense of animals." Unlike the other plant senses, it has risen above the necessity of being confined to young, growing parts, and sometimes resides in special organs, as in the cushions on the leaves of the sensitive plant, by which they are able to suddenly shut up tightly when touched, or in the prehensile-like tentacles of the leaves of sundew, which shut over and catch a live insect and secure it for digestion by the plant.

Plants are thus seen to react sensitively to gravity, light, moisture, heat and contact. Each is a special kind of sensitiveness, having its own method of reaction. Two or more kinds of sensitiveness may reside in the same organ, when its position will be a resultant of the several forces. There are, consequently, no exclusive organs of sense, although there is more or less localization in certain parts; and there are no nerves, although the motor impulse may be transmitted some distance, even as far as twenty inches or more in very vigorous sensitive plants, that is, in Mimosa.

To complete the comparison I should say there are no muscles in plants, although they execute movements of very considerable amplitude. The real mechanism by which the movements are accomplished, is not well understood. There is agreement, however, in assuming it to be due to the movement of water. Herbs, and the soft parts of all plants are kept distended and firm by internal water pressure, just as a rubber bag would be filled and made tense if tied to an open faucet of the city water works. Each cell acts like a separate distended bag. By stimulation the water is made to flow from the various cells in one side of the organ into the empty spaces surrounding the same and contiguous cells; the pressure is released on one side and the organ bends over in that direction. But this process is much complicated by growth, and other conditions too recondite to be explained here.

There are some peculiarities of plant senses which need special emphasis. All the senses, except that of contact, have for their end the adjustment of the plant as a whole, and of each of its organs, in a suitable position for best development. The contact sense has been more variedly developed, aiding the plant to climb, to catch insects for food, and if we are to accept Darwin's suggestion, to enable the sensitive plant in particular to escape the injury of hail storms. All the movements are very slow, except a few like the insect-catching and hail-avoiding movements, and their wonderful diversity and extent are only realized by instituting carefully devised experiments, and the use of delicate instruments.

It is also to be noted that the same organ always responds to the same stimulus with the same corresponding movement. If, for instance, the light strikes a shoot from the east, it bends toward the east, if possessed of positive direct irritability. There is no opportunity for choice. The plant secures a diversity of movement by having each set of organs endowed with their own specific form of irritability. As there is no choice in the character of the response, so there can be no volition, and consequently no mental activity, no psychic life, even of ever so humble and rudimentary nature.

This brings us back to our starting point. When we trace the development of irritability as a universal property of protoplasm into its various phases of sensibility, and mental activity, the first and fundamental division of organic life is into fixed and motile organisms, without regard to its animal and vegetal nature. To the motile forms belongs a psychic or mental character, whether they be animals or plants. A most interesting exposition of the psychic development attained by motile plants, like the pandorina, volvox, and other small (essentially microscopic) forms, comparing them with animals of a similar degree of complexity, is given in Binet's work on the psychic life of micro-organisms, a work without sensational features, and with many suggestive and interesting statements. But fixed plants have no psychic life; their sensibility does not rise above that of specific irritability, although often attaining a marvelous development. Aristotle's notion, which is still too prevalent, of an ascending complexity in vital phenomena from plants to man, should be wholly abandoned. The only way of viewing nature, to secure proper interpretation, is that of two parallel lines of development, one through motile forms, and the other through fixed forms. Each line of development has worked out peculiarities of its own—in fact, there is little agreement. If the special senses of man and the higher animals show wonderful adaptations, the special senses of plants, although very dissimilar, will, when well known, appear quite as remarkable.

The observation of Sachs, the venerable professor at Würtzburg, and one of the most far-seeing of physiological botanists, is particularly pertinent in this connection. "We have no necessity," he says, "to refer to the physiology of nerves in order to obtain greater clearness as to the phenomena of irritability in plants; it will, perhaps, on the contrary, eventually result that we shall obtain from the process of irritability in plants data for the explanation of the physiology of nerves, and this, although it is as yet a distant hope, gives a special attraction to the study of the irritable phenomena of plants." The attitude of botany as a science in its historical development toward plants as objects of study, has been most happily characterized by Professor Patrick Geddes, of the University College, Dundee, whose words I shall use in my closing remarks: "To the dawning intelligence of the race, the forest is vaguely astir with a life which man does not clearly separate from his own—a mystery of growth which has left its mark deep in the history of all religions. A later and more self-conscious mind molds this omnipresent life into anthropomorphic shapes; so a Dryad hides in every tree, while Pan roams through the glade. These anthropomorphic shapes are next formalized away from the living realities they symbolize; they become mere shadowy gods, then fairies and fables. The tree (or what remains of it) is now something economically useful; it has also a popular and a systematic name; but to utilitarian and Linnæan alike, the form and substance seems the main thing, not the life. 'Great Pan is dead,' the botanist is as prosaic and unseeing as the woodcutter, in fact, essentially is one; at best with finer tools, and like him does his best work away from the wild wood altogether. But as the ages of fetishism, of Hellenic anthropomorphism passed away, so now the formal and utilitarian and analytic spirit is passing also in its turn. Science is entering a new and brighter Hellas; the Dryad, living and breathing, moving and sensitive is again within her tree; nay, better, the plant is herself the living Dryad, her beauty radiant in the sun."

PAPERS READ.

GEOLOGY.

On the induration of certain tertiary rocks in northeastern Arkansas. By R. Ellsworth Call

In northeastern Arkansas, west of the St. Francis river, stretching from the Missouri line to the Mississippi river at Helena, is Crowley's Ridge, the only pronounced topographic feature in the region. The width of this particular ridge varies from six or seven miles to a half mile, the northern portion being the widest. The general geological features of Crowley's Ridge have been elsewhere given* and need not be rehearsed at this time. It will be sufficient to say that the ridge is the remains of a plateau to the westward of which once flowed the Mississippi river which cut out the great valley now occupied by the White and Black rivers and other streams of the region. Later its channel was changed to the eastward by the penetration of the previous barrier near Cape Girardeau, in Missouri; it still occupies a portion of that ancient valley across which it has several times shifted its course. It has resulted from these great changes that the eastern valley has been dug deeper and wider than was the ancient channel on the west. Crowley's Ridge, therefore, stands as a residual product of erosion.

*Vide Geological Survey of Arkansas, report for 1889, Vol. II, "The Geology of Crowley's Ridge," by R. Ellsworth Call.