the eternal truths of God and immortality, which are the basis of all morality, of all society, of all existence. But of these principles of life, of conduct, and of belief, we find but few traces in the later writings of Mr. Carlyle or in these posthumous volumes.

ART. VIII.—1. *The Power of Movement in Plants.* By CHARLES DARWIN, LL.D., F.R.S.; assisted by FRANCIS DARWIN. London: 1880.

2. *A Text-Book of Physiology.* By M. FOSTER, M.A., M.D., F.R.S., Prælector in Physiology and Fellow of Trinity College, Cambridge. Third Edition, revised. London: 1879.

THE movement of plants has long been the object of close observation and ingenious experiment by physiologists. Very nearly a century ago it was perfectly understood that gravity, light, and contact with solid surfaces exerted a powerful influence upon the movements of growth. In 1806 Thomas Andrew Knight, the remarkable man who worthily succeeded Sir Joseph Banks as President of the Horticultural Society, and who was himself a great horticulturist, caused roots to grow horizontally outwards, instead of vertically downwards, by inducing seeds to germinate on the rim of a rapidly rotating disc, thus practically superseding the downward attraction of the earth by the outward impulse of the centrifugal whirl. Hugo von Mohl, of Tübingen, experimentally demonstrated the directive influence of light by leading the stems of young cruciferous plants to reverse the natural tendencies of their growth, and to advance downwards instead of upwards, by enclosing them in a darkened box, into which a gleam of light was reflected through a hole in the bottom by means of a mirror. The response of the leaves of the sensitive plant to the irritation of a rude touch was well known to the earliest botanists. The distinguished French physician Dutrochet, who wrote on the cause of the ascent of stems and the descent of roots in 1828, was aware that the movement of the sensitive plant was due to the transmission of the impulse from the spot where it was received to the soft cushions of cellular tissue at the base of the footstalks of the leaflets and leaves, and even ascertained that the transmission of the excitement from the point of contact was a slow-paced process, requiring something like three seconds for a journey of one inch. The

Frenchman Desfontaines carried sensitive plants about with him in his carriage to prove that they could be educated to become indifferent to jolting. Another observer about the same time ascertained that tendrils cannot untwine after they have once fixed their grip, because the curving movement by which they effect their hold is transmitted upwards along the curling stalk from the spot where the contact is first established. Dutrochet, indeed, in his last work, 'The Anatomical 'and Physiological History of Plants and Animals,' seems to have settled, as three great canons of vegetable movement, the following propositions:—That the curved position assumed by the roots and stems of plants is not altogether a consequence of growth; that the movement originates in soft, unhardened vesicles; and that the curvature is due to the expansion or swelling of the convex side of the bend, and not to the contraction of the concave part of the curvature.

Hugo von Mohl, in his excellent and well-known monograph on the vegetable cell, introduced to the English reader by Professor Henfrey's translation in 1852, remarked in one passage of the treatise that it was not at that time possible to do more than hazard empty guesses as to the external influences upon which the movements of plants depend, because no satisfactory enquiry had yet been made regarding the fact. This reproach does not, at any rate, lie at the doors of the physiologists of the present day. Several experimental observers have in recent years been directing their attention to the investigation, the last amongst them being Charles Darwin, certainly approached by none of the rest in the indefatigable and persevering way in which he has followed up the problem. That this is the case is amply proved by the distinguished enquirer's book on 'The Power of Movement in 'Plants,' which has been recently published. The volume, like most of Dr. Darwin's late works, is an elaborate and detailed account of a long series of close observations and experiments. In this case, indeed, the observations have been made by the agency of an ingenious, although simple, apparatus, devised for the purpose, and very skilfully handled.

The value of this elaborate record of close observations will, however, be more justly estimated by those who have already some scientific familiarity with the matters described, than by the much larger number of the reading public who will be attracted to the book by the potent spell of its author's name and renown. It is a tedious task for those who read for the mere purposes of general information to have to wade through page after page describing eccentric orbits, and grotesque twitchings performed by the spongioles of roots and the growing points of leaves; and the task will scarcely be lightened to readers of this class when they find themselves required to note that some of the movements described are epinastic, whilst others are apogeotropic, and yet others heliotropic; and still further to observe that it is sometimes a hypocotyl, and sometimes an epicotyl, which is subject to these disturbances. To many the tediousness will not be compensated for if they get far enough to discover that these terrible-looking words, after all, only mean that it is an upper or a lower surface that grows the faster; that the movement is away from the ground, or towards the light; or that it is the part of the stem below or above the seed-leaves which extends its length. The technical words of science no doubt have their value for scientific men, but they are not attractive, or helpful to readers of more general education and intelligence. Dr. Darwin must nevertheless have had this more numerous class in his mind when, in the introduction of his book, he suggested the somewhat odd expedient of commencing its perusal at the end, or, in other words, of reading the last chapter first.

The apparatus which Dr. Darwin has employed in the prosecution of his observations on the movements of plants consists of some small rods of glass, a few window panes, cards, sealing-wax, black paint, and shellac dissolved into a thick cement with spirits of wine. The rods, which are very diminutive and light, mere short bristles of glass, are tipped at one end with small bulbs or beads of black sealing-wax to render them conspicuous to the eye, and are fixed by cement, at the other end, to the parts of the plant whose movements are to be observed. A card with a central black dot upon it is next fixed behind the moving part, and one of the window panes is placed as a transparent screen, seven inches away from the plant, either vertically in front or horizontally above, as the case may be. The observer's eye is, after this, moved to and fro outside the screen until the bead upon the glass rod just coincides with, or hides, the black dot upon the card. A corresponding black spot is then dotted in with a pointed style upon the glass sheet or screen, so that it covers or hides both the bead on the rod and the black spot on the card beyond. The black spot on the card, the bead on the rod, and the black spot on the glass are thus manifestly in one continuous straight line. After a suitable interval of time the observation is repeated, and if there has been movement on the part of the plant a new spot of pigment is dotted in on the glass. The new spot on the glass then obviously indicates the movement which has been accomplished by the black bead, but upon a considerably enlarged scale, because the distance which intervenes between the glass pane and the plant is greater than that between the plant and the card. The line connecting the bead with the screen plays the part of the long arm of a lever pivoted upon the bead, with the point of the short arm kept touching the spot on the card. The movement of the bead is thus magnified to the observer's eye by this expedient as the outline of a drawing is enlarged in the sketch made by the intervention of a pentagraph. The several spots registered upon the glass screen are afterwards connected together upon it by a black line, and the sinuous and complicated figure in this way constructed is copied upon tracing-paper, and kept as a kind of permanent chart of the movement detected by the experiment. There is, however, still the somewhat perplexing consideration to be dealt with, that the chart only represents the movement upon two planes, a vertical and a horizontal one, whereas it in reality takes place in all directions through a space of three dimensions. The tracing on the chart, therefore, has to be interpreted by the observer after it has been laid down, and the actual motion of the glass bead inferred from a close study of the jagged and irregular track. Very many of the figures are of exceeding complexity, being of the nature of scrolls, intersecting each other somewhat after the fashion of the curves traced by the geometric chuck, but aberrant and unsymmetrical instead of being recurrent and regular. Many of them look very much like a track left upon the ground by an ant that has lost its way and is endeavouring to recover its bearings. They therefore require prolonged and patient study before their real meaning can be made out, and the task of interpretation is not more attractive to the general run of readers when it is discovered how large a part is played in the book by these perplexing charts. There are not less than 162 of them contained upon its pages.

The conclusions which Dr. Darwin has himself drawn from these puzzles are, however, as interesting as they are important. In the first place he demonstrates from them that all the growing parts of plants, whether connected with root, stem, or leaves, are unceasingly nodding round—that is, they extend themselves, in the main, along a spiral line of advance; but they nod to and fro as they do so, sometimes forward and backward, and sometimes from side to side. They advance, so to speak, with a fitful and uncertain, and not with a steady, pace, now jerking upwards with a sudden start, and now jerking backwards with a sort of rebound, so that the actual track through space of any given point of the structure is an irregular ellipse, broken by zigzags and minor curves, and continually changing both its form and plane. It is this fitful movement that Dr. Darwin has designated by the happiest of his new coinage of terms. He calls it by the quite intelligible epithet 'circumnutation.'

The nodding movement of growing plants is next traced to the vesicles of the structure being at alternate intervals more turgid with water and more freely extensile at opposite sides of the growing mass. The alternation of the movement, or swaying from side to side, is ascribed to the vesicles requiring intervals of recruiting and rest after each spasm of exertion. The forward jerk in many instances was not more than a thousandth part of an inch, and the rebound a much slower movement of still smaller extent; and then, after a few seconds of repose, a fresh forward jerk was made, which more than covered the preceding retreat. The backward movement appeared to be mainly, if not entirely, due to the resilient elasticity of the resisting tissue, which reacted up to a limited extent after it had been put upon the stretch by the previous jerk. The forward movement Dr. Darwin himself likens to a 'microscopically minute earthquake in the textures of the 'plant,' brought about in consequence of the vesicles becoming more and more turgid on one side, until the weakest part suddenly yields and bends to the strain. The circumnutating movement is manifestly controlled and modified by the influence of light, of the alternation of darkness with light, and of gravity, all of which combine to fix the precise lines of the progress.

When a young radicle breaks through the outer coat of a germinating seed, it immediately begins to circumnutate, but soon bends downwards in its spiral course on account of the action of gravity upon its extremity or tip. Dr. Darwin's experiments, however, appear to show that the attraction of gravitation is restricted to the actual tip, but that the impulse or impact is then transmitted to a higher part of the rootlet, where it brings about a one-sided turgescence, and so causes the rootlet to bend. As soon as the tip touches the surface of the soil, it begins to penetrate the outer layer, making its way in by the rocking movement of its point. If it happens in the first gravity for an hour and a half, were cut off, and the radicles set so that they were directed immediately downwards; but they then moved off transversely to one side, in obedience to the influence that had been lodged in the tissues of their upper part before the tips were removed. After two or three days of horizontal growth, however, new tips were formed at the extremities, and the downward growth was thenceforth resumed.

When the growing stem of a germinating seedling has arched itself up out of the ground, it straightens itself by the quickened growth of the concavity of the arch, and so lifts its seed-leaves into the air. These then assume their proper function of aerial leaves, decomposing carbonic acid and elaborating fresh nourishment for the plant. The upper part of the stem forthwith begins to circumnutate vigorously through the air. New leaves and branches next appear, and every shoot, footstalk, and leaflet, obedient to the primary impulse of vegetable existence, forthwith starts nodding in a little spiral ellipse of its own. But a new and very potent agent, which was not known to the rootlet, is now brought into play. The circumnutating parts are all deluged with light, and almost everywhere that light falls with greater intensity upon one side of the leaf or stem than on the other. This determines a bending towards the light. The growth or extension of tissue takes place most rapidly where the light falls with least force. On the most strongly illuminated side the fixation of carbon and consequent hardening of tissue take the place of growth. The distribution and movement of the leaves are in the same way influenced by circumnutation, controlled and directed by the luminous influence.

The so-called sleep of leaves is merely a modified form of these combined operations. It consists, in the main, of the flat leaves of plants assuming, towards evening or night, a vertical position upon their footstalks, or of the leaflets of compound leaves folding themselves vertically together into a similar (although inverted) position to the one assumed by the wings of the butterfly when the insect is at rest upon a flower. All the leaves which perform this movement have cushions of soft cellular texture, known as pulvinuli, upon the footstalk just beneath the blade. It has been long known that these soft expansions of the footstalks are the efficient instruments of the mechanism. The action is periodical, and dependent upon the alternations of darkness and light. The designation 'sleep of plants' was in the first instance given to gravity for an hour and a half, were cut off, and the radicles set so that they were directed immediately downwards; but they then moved off transversely to one side, in obedience to the influence that had been lodged in the tissues of their upper part before the tips were removed. After two or three days of horizontal growth, however, new tips were formed at the extremities, and the downward growth was thenceforth resumed.

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Dr. Darwin has now shown that this night-bending movement of leaves is itself only one form of circumnutation. It is a large orbital movement in a vertical direction, having a period of twenty-four hours, and brought about by the unequal action of light on opposite sides of the pulvinuli, or cushion-like enlargements of the footstalks. The turgescence and growth are so modified on opposite sides by difference of illumination, that the leaf is bent upon the soft, easily yielding swelling of the footstalk, as upon a joint. A very ingenious experiment was devised to prove that it is the difference of light, rather than its absolute influence, which is the cause of the bending. One pot of the seedlings of a cassia was kept in a dark part of a room, and its seed-leaves remained closed; another similar pot was placed in the sunshine near the window, and its seed-leaves unfolded. Both pots were then removed into the subdued or half light of the middle of the room, and the folded leaves then opened, because they had been brought into a stronger light, but the unfolded seed-leaves at the same time closed, because the change with them had been from sunshine to shade. Seedlings were artificially bent towards the light by illuminating them on one side for two or three minutes at a time by a small wax taper, and by repeating this, with intervals of darkness between, for about three-quarters of an hour. It was found that more bending could be produced in twenty minutes by this process of alternation of darkness and light than by steady exposure to strong light for an hour. These experiments are as conclusive as they are interesting.

The explanation of the purpose of these curious movements of plants, at which Dr. Darwin has arrived, is to the effect that they are all a provision for protecting the leaves from the injurious effect of a too rapid radiation of heat at night. The blade of the leaflet that is opposed horizontally to a cloudless sky at night is very much more severely chilled than one which is for the time hung with its narrow edge towards the sky, or in which the radiating surfaces are folded into close contact. Dr. Darwin found by direct experiment that dew is deposited at night upon horizontally expanded leaves, when no trace of it appears upon folded or vertical ones. In various experiments, leaflets which were pinned open died from frost, whilst others near, which were left free to fold themselves up, suffered no injury. Dr. Darwin also proved by his experimental apparatus that the night-bending movement is in some measure continuous through the entire twenty-four hours. There is no period of absolute rest. It is merely that the general diurnal circumnutating progress is quickened at one time, and retarded at another.

Dr. Darwin does not pretend to know anything whatever as to the way in which light, gravitation, pressure, contact, and innate physical states act upon the vesicles to produce these capricious and fitful modifications of growth. All that he contends for is that those influences are not themselves the primary cause of the movements, but merely lead to a temporary increase or diminution of the spontaneous changes of turgescence already in progress in the vessels, and which are themselves indicated by the circumnutation of leaves, stems, and rootlets. He believes that the clasping of tendrils and the folding of the leaflets of the sensitive plant when touched are less immediately connected with the fundamental movement of circumnutation. But he thinks that the difference is still more one of degree than of kind, and that in all such cases the irritant merely starts a change of turgescence similar to the one which ordinarily occurs in the circumnutation of growth.

The tips of the rootlets of plants are obviously parts of the very highest vital importance. They are endowed with a keen faculty of discrimination, and, in a certain sense, of perception. Dr. Darwin, indeed, seems inclined to regard them as possessing almost the attributes of a vegetable brain, as appears from the following noteworthy passage:—

'We believe that there is no structure in plants more wonderful, as far as its functions are concerned, than the tip of the radicle. If the tip be lightly pressed, or burnt, or cut, it transmits an influence to the upper adjoining part, causing it to bend away from the affected side; and, what is more surprising, the tip can distinguish between a slightly harder and softer object, by which it is simultaneously pressed on opposite sides. If, however, the radicle is pressed by a similar object a little above the tip, the pressed part does not transmit any influence to the more distant parts, but bends abruptly towards the object. If the tip perceives the air to be moister on one side than on the other, it likewise transmits an influence to the upper adjoining part, which bends towards the source of moisture. When the tip is excited by light (though in the case of the radicles this was ascertained in only a single instance), the adjoining part bends from the light; but when excited by gravitation the same part bends towards the centre of gravity. In almost every case we can clearly perceive the final purpose or advantage of the several movements. Two, or perhaps more, of the exciting causes often act simultaneously on the tip, and one conquers the other, no doubt in accordance with its importance for the life of the plant. The course pursued by the radicle in penetrating the ground must be determined by the tip; hence it has acquired such diverse kinds of sensitiveness. It is hardly an exaggeration to say that the tip of the radicle thus endowed, and having the power of directing the movements of the adjoining parts, acts like the brain of one of the lower animals; the brain being seated within the anterior end of the body, receiving impressions from the sense-organs, and directing the several movements.'

In some passages of his book Dr. Darwin seems inclined to regard the power of movement in plants as analogous to the motor power of animals. This is a doctrine which has been accepted with favour in recent years by a considerable school of comparative physiologists, and it is one which has become especially dear to the hearts of evolutionists. The general tenor of the observations here so elaborately described can hardly, however, be received as tending to strengthen this view. Dr. Darwin traces all movement in plants back to circumnutation. But animals do not circumnutate. Their movements are of a strikingly different character from the nodding and staggering gyration which is here pointed to as the primary process in the plant. The stems, roots, and leaves are thrust out in consequence of the interstitial deposit of new material in the growing textures, and the extending shoots assume a spiral form of advance because the thrust is exerted more on one side than on the other. The onward projection is thus essentially a process of growth from the addition of substance, and all the irregularities in the halting progress are immediately ascribed to a purely physical cause, the swelling or increased turgidity of the tissue at the point where the sidelong thrust occurs. The only circumstance that at all warrants the assumption of a resemblance in the strongly contrasted processes is the fact, which Dr. Darwin has brought prominently into notice, that the mechanical impulse of the disturbing influence originates not at the spot upon which the impact falls, but at a somewhat distant place, to which the effect of that impact is transmitted by an intermediate agency seated in the organisation of the plant. He is obviously aware that this is the strong point of the argument for resemblance which he suggests, as in one notable paragraph he says: 'But 'the most striking resemblance is the localisation of sensitive'ness, and the transmission of an influence from the excited 'part to another, which consequently moves.' The effect here alluded to is, no doubt, very remarkable, and well deserving of the further examination which it will assuredly receive at the hands of physiologists. But it can hardly be conceived to be strong enough to support any comprehensive hypothesis of the identity of vegetable and animal movements. Dr. Darwin himself says, 'Plants do not, of course, possess nerves or a 'central nervous system.' But he then deprecatingly and somewhat significantly adds, 'and we may infer that with 'animals such structures serve only for the more perfect trans-'mission of impressions, and for the more complete intercom-'munication of the several parts.'

The dissimilarity between the circumnutating movements of plants and animal movement is obvious at a glance when one of the simplest instances of animal movement is taken for the purpose of comparison. It at once reveals that spontaneity and so-called voluntary character of the animal movement, which the older physiologists had no difficulty in recognising as its distinctive mark. In his monograph on the vegetable cell Von Mohl very clearly expresses the view which was at that time held by the best authorities in the following passage:—

> 'Great as the similarity to animal motion is in many of these plant-movements, they are always devoid of the character of volition, so that altogether no more definite and profound distinction between plants and animals can be found than the total want of voluntary motion in the former, and the presence of this same in the latter.'

The simplest form in which animal movement can be observed is that which is presented by the protoplasmic, or 'first-'mould,' substance of animal organisation. As soon as the complex organisable material, provided by the successive processes of constructive elaboration, has received the final impress of life from the touch of some already living structure, it forthwith begins to move by the exercise of a newly acquired property. The movement manifested is indeed so constant in its association with life that its occurrence is familiarly looked upon as a proof of the presence of vitality. But the movement thus developed is of a very remarkable kind. The living protoplasm streams or surges about within itself, and the internal and intrinsic surging is maintained without appreciable cessation. The molecules of the mass hold together with just adhesiveness enough to prevent them from falling asunder; but they slide to and fro over each other in all directions in the most free and unconstrained way, as gelatinised water might be conceived to do. Any small isolated fragment of this animated jelly is thus always changing its form. There is, indeed, a minute creature of the group of animalcules, well known to microscopic observers, that is entirely composed of this undifferentiated protoplasm—that is, of protoplasm in which every part is exactly like the rest, and in which there is no distinction or differentiation into special organs, such as muscle, nerve, and bone. It is known as the amœba,* or 'changeling,' on account of the Proteus-like transformations of its shape—a most expressive name, which was conferred upon it by Christian Godfrey Ehrenberg, one of the fathers of microscopic observation, and author of the great work on 'Infusorial Animalcules,' published in Germany in 1838. The creature is found most commonly in the slime which collects upon submerged or floating objects. It is apparently destitute even of a skin, and it has no internal organ of any kind. It is simply a small mass of animated jelly, possessing the power of streaming half coherently about under some mysterious and apparently spontaneously exerted impulse. When first placed upon the glass slide of a microscope, it presents the aspect of a small, round, transparent mass; but finger-like processes soon begin to be pushed out from the pulp in various directions, somewhat after the manner of the horns of a snail. Some one of these having at last fixed itself to the glass, the rest of the mobile jelly rolls over the attached part, and then begins to push out other processes. The amœba, in reality, travels along the glass in this grotesque shambling way. By the mere flow of its half-coherent living substance, it not only changes its form, but shifts its position. If, during its Protean shambling progress, it comes in contact with any fragmentary morsel suitable to be turned to account as food, it spreads itself over the fragment until it envelopes it within its own substance, and in that way extemporises a digestive cavity or stomach, where the morsel soon gets dissolved and converted into living protoplasm. Indigestible matters, which cannot be so turned to account, are dismissed by a reversal of the process; the fluent jelly loosening its grasp, rolling itself off, and so leaving them behind as it moves away in some other direction.

* From *amoibos*, exchanging or transforming. Although the name amœba was contrived for this animalcule by Ehrenberg, the creature itself was previously known as the *Proteus diffluens*, under which designation it appeared, in 1786, in Müller's 'Animalcula Infusoria.' Its real nature was, however, so little understood by the earlier observers, that it was at first spoken of as possessing many stomachs, and was classed with the forms then distinguished as Polygastrica. One keen observer, after Ehrenberg's change of its name, alluded to the clear way in which its *internal organisation* could be seen. This curious mistake was, however, obviously due to the almost constant presence of foreign bodies enveloped in its soft fluent mass.

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supply of energy or power capable of doing work, and in the breathing animal, as a result of the dissolution and destruction of the cohesive integrity of previously built-up molecules.

But the amœba of the microscope, it is here to be understood, is hardly to be looked upon as an exceptional case of vital organisation, although it is familiarly spoken of as a little animal, or animalcule. It is rather a fragment of the universal material, of which animal bodies are made, accidentally caught when engaged upon a roving commission. The bodies of all animals, even of the highest type of organisation, not excepting that of man himself, are now regarded by physiologists as groups of amœbas associated together for the advantage the well-organised division of labour confers. Each body is a colony of these living plastic lumps. But, as the separate amœbic individuals are arranged in the group, clusters are told off for different services, and are then specially equipped for the task which is committed to their charge. Some are made into vesicles adapted for the construction of cartilage; some are converted into bone; some are moulded into the contractile fibres of muscular flesh, and some into the more highly finished and specially endowed vesicles and tubules of nerve-structure and brain. But all such diversities of structure, provided for the working out of the end of specialised vitality, begin as clusterings of fluent protoplasm, in all respects identical with the specimen to which Ehrenberg drew attention in its erratic isolation. In the flowing stream of the blood, the colourless granules, which are microscopically seen floating along in the current, and which have been termed white corpuscles, are neither more nor less than lumps of freshly formed living protoplasm, in process of distribution to the different parts where the foundations of new structure are being laid. They, each and all, possess the same power of fluent mobility and restless change of form, which is more conveniently observed in the amœba animalcule. They individually present all the grotesque portraiture of that Protean changeling. But, when they reach their ultimate destinations, the differentiation, or adaptation of each to the work to which it is destined, is accomplished simply by the exaltation of some one or other of its inherent proclivities, and by the lowering or subordination of the rest. In the muscular tissue, fluent mobility is the property most prominently brought into play; in the nervous tissues, it is the irritability, or readiness of response to extraneous impact, which is thrown into relief; in the construction of such organs as the liver, the stomach, and the kidneys, the chemical power of effecting molecular transformation is most prominently developed; and in bone, the masses of protoplasm are densely infiltrated and packed with hard lime for the construction of the mechanical framework of the body—its strong pillars and rigid walls. In his admirably executed and classical 'Text-Book of Physiology'—which for its excellences, whether of condensation or completeness, is everywhere deserving of the most unqualified praise—Professor Foster puts this view of the case very happily in the following paragraph, which is perhaps as telling an illustration of the distinction it is our object to establish as it is possible to desire. He says:—

'We may therefore consider the complex body of a higher animal as a compound of so many tissues, each tissue corresponding to one of the fundamental qualities of protoplasm, to the development of which it is specially devoted by the division of labour. It must, however, be remembered that there is a distinct limit to the division of labour. In each and every tissue, in addition to its leading quality, there are more or less pronounced remnants of all the other protoplasmic qualities. Thus, though we may call one tissue *par excellence* metabolic,* all the tissues are to a greater or less extent metabolic. The energy of each, whatever be its particular mode, has its source in the breaking up of the protoplasm. Chemical changes, including the assumption of oxygen, and the production, complete or partial, of carbonic acid, and therefore also entailing a certain amount of secretion and excretion, must take place in each and every tissue. And so with all the other fundamental properties of protoplasm. Even contractility, which for obvious mechanical reasons is soonest reduced where not wanted, is present in many other tissues besides muscle. And it need hardly be said that each tissue retains the power of assimilation. However thoroughly the material of food be prepared by digestion and subsequent metabolic action, the last stages of its conversion into living protoplasm are effected directly and alone by the tissue of which it is about to form a part.'

But, as soon as this transmutation of the protoplasm into special organs has been accomplished, it becomes indispensable to the harmonious co-operation of the several parts that intercommunication between them shall be arranged. There must be channels laid down for transmission of impressions, for exchange of signals, from place to place, and for the connexion of the whole into a co-ordinated system. It is this purpose, as the author of the Text-Book proceeds to show, which is accomplished by the circulation of the blood and by the agency of the nerves. The blood circulation is the bond by which the new protoplasmic material is distributed to all vitally act-

* Transmutable.

ing and vitally moving parts, and by which they are cleared from the waste products of the animated or breathing consumption. The nerves are the bonds by which the remote oases of protoplasm, separated by intervening tracts of less vitalised material, are connected, so that the impulses experienced in one part may be transmitted for setting up associated and correlated discharges of work-performing energy in other parts of the systematised organisation.

In the more highly endowed animals it is the gradual conversion of the living protoplasm into special organs which confers upon the body its particular external character and shape, comprising the central and crowning skull for the safe lodgment of the nerve-core with its outlying apparatus of organs of sense, the internal cavities for the accommodation of stomach, liver, and lungs, and the external appendage of mobile and flexible limbs. But, as the power of movement is, in the animal, one of the most important endowments for the great purposes of life, motor mechanisms of the most refined ingenuity and the most perfect construction are distributed to all parts of the frame, in every one of which the prime mover is muscular contraction. It is in reference to this that Professor Foster very aptly remarks: 'In fact, the 'greater part of the animal body is a collection of muscular 'machines, some serving for locomotion, others for special 'manœuvres of particular members and parts, others as an assis'tance to the senses, and yet others for the production of voice, 'and, in man, of speech.'

But in all these the physical conditions of muscular action are precisely those which have been alluded to as conferring moving power upon the amœba and unformed protoplasm. 'The amœboid movements,' as Professor Foster truly says, 'are identical in their fundamental nature with those which, 'occurring in a muscle, cause contraction. A muscular 'contraction is essentially a regular, an amœboid movement, 'an irregular flow of protoplasm.' In both there is the same consumption of substance under the oxidising blast, and the same production of moving energy out of molecular destruction. The movement, therefore, is obviously in absolute contrast with the one which is observed in plants, and remarkably sustains the view of the older physiologists, rather than the tendencies of the newer school to regard animal movement as an evolution of the process in plants, which Dr. Darwin has in these late observations so thoroughly identified with mere irregularities of growth. Von Mohl's philosophic deduction, that the want of voluntary motion in plants, and its constant presence in animals, is a profound distinction, is certainly in no sense weakened by Dr. Darwin's demonstration that all movement in plants is modified circumnutation, and that circumnutation is the combined result of turgescence and growth.

We are quite aware that the assertion of the resemblance, which we here contest, has been made in somewhat cautious language. Thus, in the one passage in which the analogy is perhaps the most pointedly affirmed, the author's own words are to the following effect: 'It is impossible not to be struck with 'the resemblance between the foregoing movements of plants 'and many of the actions performed unconsciously *by the lower* '*animals.*' But our own comment upon this is that the amœba, which we have taken as the typical illustration of the power of animal movement, is itself *the lowest* of low animals, at the same time that it is in its entire organisation identical with the most universally diffused of animated structures. It is at once the protozoon, as well as the protoplasm, of the animal kingdom. It plays, in our argument, identically the same part that the circumnutating root and stem-tissue assume in Dr. Darwin's exposition. As he finds structure-consolidating growth in every diversity of plant-movement, we find protoplasmic oxidation and combustion underlying each movement of the animal.

There are, however, other forms of movement which are shared by both animals and plants, as, for instance, and supereminently, the well-known ciliary movement. Exigency of space prevents these from being further alluded to upon this occasion. We must, however, just state that nothing of the character of a satisfactory hypothesis can yet be based upon these movements, because their intrinsic nature is still absolutely unknown. All efforts to detect the mechanism by which they are brought about have hitherto signally failed. But the effect is certainly a feature common to the two contrasted kingdoms of living existence, rather than a border attribute by which one slides into the other. It is something at once distinct from either the growth-movement of Dr. Darwin, or the animal movement evolved from oxidation. Each little cilium, or lash, bends upon itself into the form of a sickle, or after the fashion of a carter's whip, and strikes with some considerable force in the direction in which it bends, and then straightens itself back in a more gentle way, so that the principal part of its flapping stroke is expended in the direction of the quicker movement. When the cilia are attached to a fixed solid surface, immersed in water or other liquid, the lashing movement produces a wave-like disturbance in the liquid. But when they are attached to light vesicles floating freely in water, they serve as oars or propelling paddles, and drive the vesicles along. It is in this latter form that they are met with in plant structures. The spores, or imperfect seeds, of many of the most lowly water plants are enabled to swarm to new growing grounds by their instrumentality. But they are even more abundantly encountered in the bodies of the higher animals, being in them closely set upon the free surface of mucous membranes, which lead to the outer air, and in connexion with these they perform the good service of keeping the liquid secretions moving towards the outlet of escape. They do this in the air-tubes of the lungs and in the windpipe. Whilst engaged in this work their movement is quite unceasing, and the lashing is manifestly an involuntary operation. It is continued, indeed, long after the death of the organic membranes to which the lashing cilia are attached, and long after all arrest of the flow of blood. If the windpipe of an ox is slit open shortly after the death of the animal and a small piece of its lining membrane is cut off and placed flat upon the table, weights of as much as 100 grains deposited upon its surface may be seen to be shunted along in the direction of the ciliary impulse. Powdered charcoal dusted over the membrane is gradually cleared away by being brushed off at one end. In some remarkable instances this lashing movement of the ciliary processes of mucous membrane has been found to continue as long as three weeks after the death of the animal from which the scrap of membrane has been taken. It is therefore obvious that this kind of activity is something, at any rate, of a much lower grade than the spontaneous and voluntary manifestation of work-producing force, which, for the purposes of this article, has been spoken of as the movement proper of animal life.

ART. IX.—*Ilios: the City and Country of the Trojans.* The Results of Researches and Discoveries on the Site of Troy and throughout the Troad in the years 1871–73, 78–79. By Dr. HENRY SCHLIEMANN. London: 1880.

It is now about a hundred years since the site of Homeric Troy became a question for modern travellers and scholars. Three places in the Troad have, since then, been the chief competitors for the honour. Le Chevalier, whose visits were made in 1785–86, fixed on Bunarbashi, a village situated at