American Journal of Science Jan. & Feb. 1881

Asa Gray

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An abstract of the volume might be somewhat tedious, and is certainly unnecessary for biological readers, who are sure to possess and study it. But the *gist* is readily to be gathered, without running through the iterated details or scanning many of the illustrative and curious figures which record the movements under investigation, by the simple perusal of the introduction and of the concluding chapter, in which the matter of the volume is summed up.

The sum and substance of the case is, that all these powers and faculties are manifested in the seedling immediately upon germination, and most of them are then remarkably exemplified. The caulicle or initial portion of stem below the cotyledons (with the elongation and protrusion of which the germination of dicotyledonous seeds usually begins) circumnutates as soon as it comes out into the open air, and even earlier: this is the earliest manifestation of an automatic movement which is shared by all the succeeding portions of stem developed from it, in the early life of most plants whether climbers or not. In the latter, and especially in twining plants, we see this general faculty at its maximum and in beneficial exercise. More remarkable and novel it is to learn that the initial root, growing from the lower end of the caulicle (not inaptly called by Darwin the *hypocotyl*) also shares in this faculty of circumnutation. As it penetrates the soil in its downward course, it cannot largely manifest this faculty, and indeed its power of circumnutation is always small; "but the circumnutating movement will facilitate the tip entering any lateral or oblique fissure in the earth or a burrow made by an earth-worm or larva; and it is certain that roots often run down the old burrows of worms. The tip, however, in endeavoring to circumnutate will [successively] press against the earth on all sides, and this can hardly fail to be of the highest importance to the plant" (being supplemented by another faculty, that of sensitiveness at the tip presently to be mentioned); for "when the tip encounters a stone or other obstacle in the ground, or even earth on one side more compact than on the other, the root will bend away as much as it can from the obstacle or the more resisting earth, and will thus follow with unerring skill the line

of least resistance." Then, beside the almost universal heliotropic movement, by which each leaf or leaflet presents its superior surface to the direction of the greater light, Mr. Darwin shows that these organs also circumnutate, beginning even with the cotyledons or seed-leaves; although their sweeps generally form so narrow an ellipse that they move up and down in nearly the same vertical plane, a movement describing a circle being converted into one up and down.

These circumnutatory movements are of the most fundamental and therefore mysterious character. Although most commonly connected with growth, they are at bottom independent of it. This—contrary to some German physiologists—we must conclude from both DeVries' and Darwin's investigations. They are produced by the changing turgescence of the cells on different sides of a stem or footstalk, which may or may not be fixed by consequent growth or solidification. This Mr. Darwin, we presume rightly, concludes to be the faculty or susceptibility upon which heliotropism, geotropism and the like (not to speak of *apheliotropism*, *apogeotropism*, *paraheliotropism*, *diaheliotropism*, *hyponasty*, *nyctotropism*, and other terms which the incautious student may take to be powers instead of abbreviated expressions)—in other words, upon which the solar rays and some occult influence of the earth—act, modifying the sweeps or converting them into forth and back or other special movements. Among these, that which has been termed the sleep of leaves, better and briefly designated by the word nyctotropism, is thoroughly investigated in this volume, is shown to be far more general than has been supposed; and the conclusion is that the end subserved is a needful protection of the surfaces, mainly the superior surface, against cold from nocturnal radiation. *A priori*, looking at the structure of the leaf, one would have thought that the under surface had the greater need of such protection.

Not only are all these movements incipient in the seedling, but some of them are manifested more rapidly and extensively than in most mature plants. This should needs be, since, as Mr. Darwin states it, "Seedlings are subjected to a severe struggle for life, and it appears to be highly important to them that they should adapt themselves as quickly and as perfectly as possible to their conditions." Very properly, therefore, no small part of this volume is devoted to the seedling and to the behavior of its several parts. The most novel and unexpected results relate to the young root. Judging from its simplicity and from the medium in which it is developed, one would not look there for the endowments which Mr. Darwin finds in it. But this root-tip and the vegetable cells which compose it conspire to teach us that most simple structures may be wonderfully gifted. The tiny root exhibits three kinds of movement; first that of circumnutation, in which, endeavoring to bend in all directions its tip "will press on all sides, and thus be able to discriminate between the harder and softer adjoining surfaces, . . . and to bend from the harder soil and follow the lines of least resistance," so modifying advantageously its course from that to which geotropism constantly tends to give it. Moreover, the growing end of the root is sensitive to contact, and in a complex manner. If pressed above the tip, it bends there toward or around the impinging body, much as the end of a tendril bends around a support: thus it may follow, as roots do, along the unequal surface of a solid body. But, thirdly, if the tip itself be locally pressed, it exhibits different and more surprising sensitiveness, for it transmits an influence to an upper adjoining part, causing it to bend away from the affected side. This sensitiveness to contact is confined to little more than one millimeter of the tip; the part which bends is 6 or 7 or even 12 millimeters above. So, when the sensitive tip in its downward growth strikes obliquely upon a stone or other obstacle, the part above at this distance, to which some influence must be transmitted bends and carries the point away from the obstacle. Yet later, whenever a new portion of the side impinges upon the stone or other body, it will bend at that part toward instead of away from it, and so follow along its surface. It is the tip, likewise, which can discern that the air is moister on one side than on the other, and which thence "transmits an influence to the upper adjoining part, which bends towards the source of moisture." It is the tip only which is sensitive to gravitation. Well may Mr. Darwin affirm that there is no structure in plants wonderful, as far as its functions are concerned, than the tip of the radicle." Also, that, "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 the most striking resemblance is the localization of their sensitiveness and the transmission of an influence to an excited part which consequently moves. Yet plants do not of course possess nerves or a central nervous system; and we may infer that with animals such structures serve only for the more perfect transmission of impressions and for the more complete intercommunication of the several parts." The closing sentence of the book may be appended to this." 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 movements "excited by light and gravitation," as well as the nyctotropic or sleep-movements so-called, are (as we have already stated) all referred by Mr. Darwin to modified circumnutation, "which is omnipresent whilst growth lasts and after growth has ceased whenever pulvini are present," as in several classes of leaves. As respects the relation of external agents to the movements, note Mr. Darwin's remark: "When we speak of modified circumnutation we mean that light, or the alternations of light and darkness, gravitation, slight pressure or other irritants and certain innate or constitutional states of the plant, do not directly cause the movement; they merely lead to a temperary increase or diminution of those spontaneous changes in the turgescence of the cells which are already in progress."

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These circumnutatory movements are of the most fundamental and therefore mysterious character. Although most commonly connected with growth, they are at bottom independent of it. This—contrary to some German physiologists—we must conclude from both DeVries' and Darwin's investigations. They are pro-

duced by the changing turgescence of the cells on different sides of a stem or footstalk, which may or may not be fixed by consequent growth or solidification. This Mr. Darwin, we presume rightly, concludes to be the faculty or susceptibility upon which heliotropism, geotropism and the like (not to speak of *apheliotropism*, *apogeotropism*, *paraheliotropism*, *diaheliotropism*, *hyponasty*, *nyctotropism*, and other terms which the incautious student may take to be powers instead of abbreviated expressions)—in other words, upon which the solar rays and some occult influence of the earth—act, modifying the sweeps or converting them into forth and back or other special movements. Among these, that which has been termed the sleep of leaves, better and briefly designated by the word nyctotropism, is thoroughly investigated in this volume, is shown to be far more general than has been supposed; and the conclusion is that the end subserved is a needful protection of the surfaces, mainly the superior surface, against cold from nocturnal radiation. *A priori*, looking at the structure of the leaf, one would have thought that the under surface had the greater need of such protection.

Not only are all these movements incipient in the seedling, but some of them are manifested more rapidly and extensively than in most mature plants. This should needs be, since, as Mr. Darwin states it, "Seedlings are subjected to a severe struggle for life, and it appears to be highly important to them that they should adapt themselves as quickly and as perfectly as possible to their conditions." Very properly, therefore, no small part of this volume is devoted to the seedling and to the behavior of its several parts. The most novel and unexpected results relate to the young root. Judging from its simplicity and from the medium in which it is developed, one would not look there for the endowments which Mr. Darwin finds in it. But this root-tip and the vegetable cells which compose it conspire to teach us that most simple structures may be wonderfully gifted. The tiny root exhibits three kinds of movement; first that of circumnutation, in which, endeavoring to bend in all directions its tip "will press on all sides, and thus be able to discriminate between the harder and softer adjoining surfaces, . . . and to bend from the harder soil and follow the lines of least resistance," so modifying advantageously its course from that to which geotropism constantly tends to give it. Moreover, the growing end of the root is sensitive to contact, and in a complex manner. If pressed above the tip, it bends there toward or around the impinging body, much as the end of a tendril bends around a support: thus it may follow, as roots do, along the unequal surface of a solid body. But, thirdly, if the tip itself be locally pressed, it exhibits different and more surprising sensitiveness, for it transmits an influence to an upper adjoining part, causing it to bend away from the affected side. This sensitiveness to contact is confined to little more than one millimeter of the tip; the part which bends is 6 or 7 or even 12 millimeters above. So, when the sen-

sitive tip in its downward growth strikes obliquely upon a stone or other obstacle, the part above at this distance, to which some influence must be transmitted, bends and carries the point away from the obstacle. Yet later, whenever a new portion of the side impinges upon the stone or other body, it will bend at that part toward instead of away from it, and so follow along its surface. It is the tip, likewise, which can discern that the air is moister on one side than on the other, and which thence "transmits an influence to the upper adjoining part, which bends toward the source of moisture." It is the tip only which is sensitive to gravitation. Well may Mr. Darwin affirm that there is no structure in plants more wonderful, as far as its functions are concerned, than the tip of the radicle. Also, that, "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 the most striking resemblance is the localization of their sensitiveness and the transmission of an influence to an excited part which consequently moves. Yet plants do not of course possess nerves or a central nervous system; and we may infer that with animals such structures serve only for the more perfect transmission of impressions and for the more complete intercommunication of the several parts." The closing sentence of the book may be appended to this. "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 movements "excited by light and gravitation," as well as the nyctotropic or sleep-movements so-called, are (as we have already stated) all referred by Mr. Darwin to modified circumnutation, "which is omnipresent whilst growth lasts, and after growth has ceased whenever pulvini are present," as in several classes of leaves. As respects the relation of external agents to the movements, note Mr. Darwin's remark: "When we speak of modified circumnutation we mean that light, or the alternations of light and darkness, gravitation, slight pressure or other irritants and certain innate or constitutional states of the plant, do not directly cause the movement; they merely lead to a temporary increase or diminution of those spontaneous changes in the turgescence of the cells which are already in progress."

Certain parts of plants turn or grow earthward. When this is attributed to gravitation, as it commonly is, the physicists have opportunity to complain of a misuse of the term. Although Mr. Darwin, like other writers, speaks of the influence of light and of gravitation in the same breath, without discrimination, we note with satisfaction his disagreement with those who "look at the bending of a radicle towards the center of the earth as the direct result of gravitation," and note especially the concluding *dictum*. "Gravity does not appear to act in a more direct manner on a radicle than it does on any lowly organized animal, which moves away when it feels some weight or pressure."

Why, we would ask, need the word *gravity* or *gravitation* be used at all in this connection?

The introduction to this volume contains a short article upon the terminology which is adopted in it, chiefly as regards such words as *epinasty* and *hyponasty*, geotropism and related terms, which it is most convenient to employ, and also the names of the several parts of the embryo and seedling. This is, we believe, almost the first English book in which the axial part of the dicotyledonous embryo below the cotyledons (the *radicle* of the systematic botanists even of the present day) is distinctly recognized as hypocotyledonous or initial stem, although on the continent and in America this has long been taught and accepted. None the less so although the term *radicle* has been retained for it (until recently by the present writer, at least), in order not to break with the terminology of systematic works. Mr. Darwin, in this volume, shortens the expression of "hypocotyledonous stem" into the term *hypocotyl*,—a fairly good English term, certainly better than the French *tigelle*. The objection to both is that the words will not take a substantive Latin form, as all such terms should. Wherefore the better name—an old one which we have reverted to in the last edition of the Botanical Text-book (Structural Botany)—is *caulicle* or *cauliculus*. The initial root, which grows from the lower end of the caulicle (or "hypocotyl") Mr. Darwin calls the radicle, following in this the ordinary English usage, except in very definitely distinguishing it from the cauline part above it. Being simply *root*, we have preferred uniformly to call it so, thus avoiding a word which the systematists have all along applied to the caulicle. Although initial stem and initial root are most clearly discriminated in the present volume, yet, in the accounts of the germination of the ordinary Dicotyledons, it appears to be implied or stated, either that it is the root-part which first projects from the seed-coats and that the stem-part begins its development later, or that the axial part of the embryo conspicuously preëxisting in the seed is root and not stem. We take it to be quite otherwise, namely, that this axial part in the seed is cauline, and that ordinarily it protrudes or makes some growth in length before root-formation begins.

A few misprints of names of plants will in nowise mislead or trouble any botanist, except possibly in the case of *Apium graveolens*, which on p. 422 and 424, and in the index, is printed *Apios*. A. G.

2. *Eucalyptographia: A Descriptive Atlas of the Eucalypts of Australia and the adjoining islands;* by Baron Ferd. von Müller, K.C.M.G. London and Melbourne: 1880.—This is the sixth decade of the Atlas, and contains descriptions of the following species: *Eucalyptus buprestium*, *globulus*, *megacarpa*, *miniata*, *occidentalis*, *peltata*, *punctata*, *setosa*, *stellulata* and *tetragona*. The detailed account of *Eucalyptus globulus*, the ordinary "Blue Gum-tree," contains many facts of interest, which may be here briefly noticed.