THE MOVEMENTS OF PLANTS.

By the Rev. GEORGE HENSLOW, M.A., F.L.S., F.G.S.

THE old distinction between plants and animals, that the latter can move and the former cannot, has long since been abandoned as unscientific, and only lingers as a copy book assertion; but that all plants, even when permanently fixed to the soil, have their stems, leaves, flower stalks, etc., in almost perpetual motion, is a discovery of quite recent times, and notably due to the investigations of Mr. Darwin. His latest work, which bears the title of this article,* is a treatise based on the most careful and elaborate experiments on the motions effected by the different organs of plants; and it was thought that a brief exposition of the chief of these, as well as of some movements peculiar to the parts of flowers not alluded to by Mr. Darwin, might be interesting to the readers of the *Popular Science Review*.

The majority of the movements can be embraced under the single term *circumnutation* and its modifications; it signifies a "bowing around." The stem, leaf, or other organ, when circumnutating, bends to all points of the compass successively, with a sort of rolling motion, so that the side which is uppermost in any direction becomes lowermost when it points in the opposite one. The circles or ellipses thus described by the apex of the organ, are most perfectly seen in the circumnutation of the stems of climbing plants; other organs for the most part move in ellipses, but with frequent interpolations of zigzigs, triangular loops, etc. The *projections* of such motions, when observed for some hours, exhibit most complicated and intricate lines; a great number of these projections are given by Mr. Darwin. With regard to the cause of circumnutation, Mr. Darwin says that on the whole we may at present conclude that increased growth, first on one side and then on another, is a secondary effect; and that the increased turgescence of the cells, together with the extensibility of their walls, is the primary cause of the movement of circumnutation.†

It will be advisable to treat of the different organs in a definite order, so I will proceed to describe the motions of radicles, cotyledons, hypocotyls, and epicotyls of germinating seeds; then will follow those of the stems and leaves of fully developed plants; and finally, the movements effected by the different organs of the floral region.

RADICLES.—The tip of the radicle, as soon as it protrudes from the seed coat, begins to circumnutate, and the whole growing part continues to do so, probably for as long as growth is maintained; it presumably is aided by this motion in being guided along lines of least resistance. As soon as the radicle has protruded, *geotropism* at once acts upon it. If this force be identical with gravitation, it is gravitation acting in a peculiar way; for although the radicles of germinating seeds, whether in England or at the Antipodes, point to the center of the earth, yet the influence affects the tip only, for a length of no more than the 0·02 to 0·03 of an inch, at least, in the cabbage.

This minute part, however, at once communicates some influence to a point further back, where the radicle bends downward in response to it; neither geotropism nor circumnutation can enable the radicle to penetrate the soil. This is effected by the force due to growth both longitudinally and transversely. By means of ingenious contrivances, seeds were grown under resistance; and Mr. Darwin found that transverse growth exerted a force, after six days, of more than 8 lb., and vertical growth, after twenty-four hours, of at least a ¼ lb. The *purchase* for the due effect of these forces is gained partly by the seed being below the soil, aided by the roothairs, which, in consequence of the cellulose passing into a gum-like substance, fix the radicle to the particles of the soil. The growing part, therefore, acts like a wedge of wood, which while slowly driven into a crevice, continually expands at the same time by the absorption of water; and a wedge thus acting, Mr. Darwin observes, will split even a mass of rock.

Another important property of radicles is their extreme sensitiveness to irritants, such as mechanical obstructions, caustic, and injuries by being cut, all of which induce the radicle to *bend away* from the exciting cause, as well as to the presence of moisture, which, on the contrary, induces the radicle to *bend toward* it. Any solid body which gives rise to a permanent obstruction to a radicle, causes the latter to deviate from its path till it finds no great resistance; and Mr. Darwin observes that this is the only known instance of an organ turning *away* from an irritant. By fixing cards to one side of the tips of vertically growing radicles, they were caused to tend upward, as if trying to escape from the cards, sometimes even forming complete circles, and in one case a radicle actually tied itself into a knot (Fig. 3‡). The tip in the act of forming a loop, generally rubs against the upper part of the radicle and pushes off the attached card; the loop then contracts or closes, but never disappears. The apex afterwards grows vertically downward (Fig. 2). This sensitiveness is confined to the tip for a length of from 1 mm. to 1·5 mm., while the upper adjoining part of the radicle, for a length of from 6 or 7 to even 12 mm., is excited to bend away from the side which has been irritated. After a time the radicle apparently becomes accustomed to the irritation, as occurs in the case of tendrils, and the irritant no longer affects its downward growth, which is resumed.

After a radicle, which has been deflected by some stone or root from its natural downward course, reaches the edge of the obstacle, geotropism will direct it to grow again straight downward; but geotropism is a weak force, and the radicle assists it by having its upper part, a little above the apex, sensitive to contact, but acting in a directly opposite manner to that of the tip, for it causes the radicle to bend like a tendril *toward* the touching object, so that as it rubs over the edge of an obstacle it will bend downward. This downward bending coincides with that due to geotropism, and both will cause the root to resume its original course.

Finally, Mr. Darwin observes, the several co-ordinated movements by which radicles are enabled to perform their proper functions are admirably perfect. In whatever direction the primary radicle first protrudes from the seed, geotropism guides it perpendicularly downward; the radicles emitted from the primary are, however only acted upon by geotropism in such a manner as to cause them to bend obliquely downward, unless the end of the primary radicle be cut away, then the secondary ones grow vertically downward. The tertiary radicles are not influenced by geotropism; hence all the rootlets grow in the most advantageous manner, and the whole soil is thus closely searched.

HYPOCOTYLS AND EPICOTYLS.—The radicle having penetrated the soil, the hypocotyl, as the axis below the cotyledons is called, begins to develop, at least in those seeds which elevate their cotyledons above ground; but it is the plumule or epicotyl which alone does so of seeds which retain their cotyledons below the soil. In either case the organ commences its growth in the form of an arch, such being the result of an innate tendency in the case of the plumule to assume that form; the inner concave surface then growing more rapidly than the outer and convex, tends to raise the summit of the arch out of the ground. The apex of the stem, being ultimately freed from the soil, soon straightens itself and becomes erect.

In whatever position the seeds may lie, *apogeotropism* acts upon the arch, and the two legs become vertical; the entire arch circumnutates more or less the whole time as the nature of the soil permits. Mr. Darwin aptly compares the whole process of extrication of the arch from beneath the soil to a man thrown down on his hands and knees, at the same time to one side, by a load of hay falling upon him. He would first endeavor to get his arched back upright, wriggling at the same time in all directions to free himself a little from the surrounding pressure; and this may represent the combined effects of apogeotropism and circumnutation. The man, still wriggling, would then raise his arched back as high as he could; as soon as the man felt himself at all free, he would raise the upper part of his body, while still on his knees and still wriggling. This will represent the bowing backward of the basal leg of the arch, which aids in the withdrawal of the cotyledons from the buried and ruptured seed coats.

COTYLEDONS.—Cotyledons are in constant movement, chiefly in a vertical plane, and commonly rise up once and descend once in 24 hours; some move much oftener, thus, those of *Ipomœa cœrulea* moved thirteen times either upward or downward in 16h. 18m. As the motion when perfected gave ellipses, cotyledons may be said to circumnutate. In a large majority of instances observed by Mr. Darwin, the cotyledons sank a little downward in the forenoon, and rose a little in the afternoon or evening, thus exhibiting a certain periodicity in their movements, no doubt in connection with the daily alternations of light and darkness. When the cotyledons rise or fall to such a degree as to be vertical, or at an angle of at least 60° above or below the horizon, they are said to be asleep; the object gained being, as in leaves, to escape injury by radiation at night.

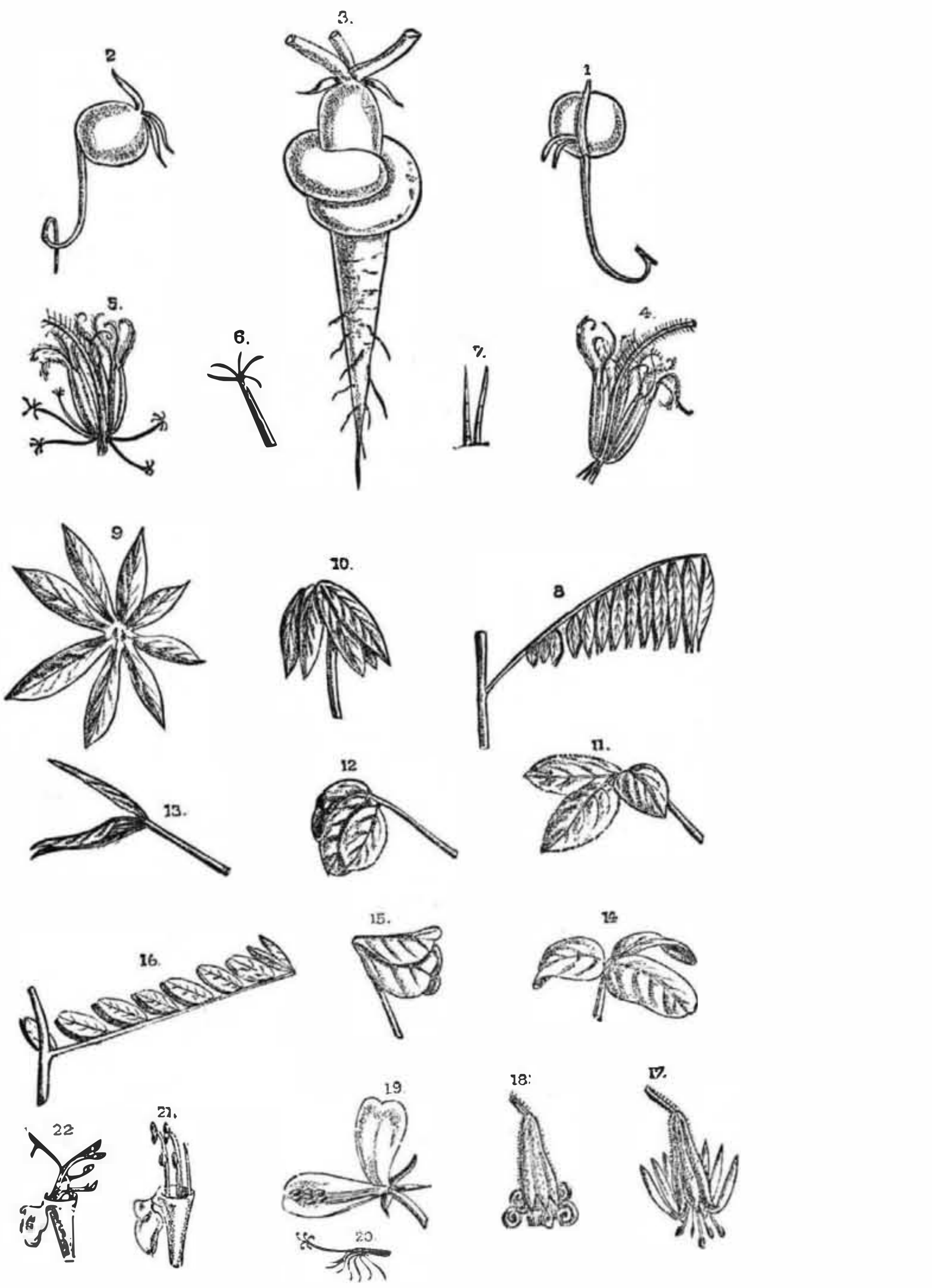
STEMS.—Several experiments with stems of plants of various orders showed that they continually circumnutate; and in the case of stem-climbers the circumnutation is of the most perfect kind.* An interesting modification of the process occurs in stolons or runners, which consist of much elongated flexible branches, that run along the surface of the ground and form roots at a distance from the parent plant; the circumnutation is so great in amplitude that it may almost be compared with that of climbing plants. The stolons are thus aided in passing over obstacles, and in winding between the stems of surrounding plants.

* For full description of tw ners and other climbing plants, the reader is referred to Mr. Darwin's work on "The Movements and Habits of Climbing Plants." See also *Pop. Sci. Rev.*, vol. v., p. 55.

* "The Power of Movement in Plants." By Charles Darwin, LL.D., F.R.S., assisted by Francis Darwin. 8vo London: Murray. 1880.

† P. 2, 3. I have not here or elsewhere added inverted commas, for throughout this paper I have largely interwoven Mr. Darwin's sentences with my own.

‡ The figure of the radish is not from Mr. Darwin's work, but from a drawing made many years ago, and which would seem now to have received its explanation.



EXPLANATION OF THE FIGURES.

Figs. 1, 2, 8–16, *after Darwin.*
Figs. 4–7, 19–22, *ad nat.*
Figs. 17, 18, *after Kerner.*

FIGS. 1 and 2. *Zea mays;* radicles excited to bend away from little squares of card attached to one side of their tips. In Fig. 2 the card has been rubbed off.

FIG. 3. A radish, of which the radicle had tied itself into a knot, probably in the same manner as in the case described and figured by Mr. Darwin, by the apex continually moving away from some obstruction until it had passed through the loop, as seen in Fig. 2. Reduced one-half.

FIG. 4. Pendulous head of florets of *Trifolium subterraneum;* the fertile flowers reflexed, the abortive still erect, forming a vertical cone.

FIG. 5. The same with abortive florets, now developed and becoming reflexed.

FIG. 6. A barren floret enlarged. It consists of the rigid "calyx-tube" supporting claw-like sepal globes.

FIG. 7. Multicellular hairs from the calyx, which exhibit aggregation under the process of absorption of nitrogenous matters. Figs. 4–7, enlarged.

FIG. 8. Leaf of *Averrhoa bilimbi* asleep, with its leaflets pendulous; much reduced.

FIG. 9. Leaf of *Lupinus pilosus* seen vertically from above, by day.

FIG. 10. Leaf of the same seen laterally, at night. Figs. 9 and 10 reduced.

FIG. 11. Leaf of *Melilotus officinalis*, during daytime.

FIG. 12. Leaf of the same asleep.

FIG. 13. Leaf of same asleep, seen vertically from above. Figs. 11–13 enlarged.

FIG. 14. Leaf of *Trifolium repens*, during the day.

FIG. 15. Leaf of same asleep, at night.

FIG. 16. Leaf of *Coronilla rosea* asleep, with its leaflets thrown upward.

FIG. 17. Flower of *Silene nutans* by night, the petals unrolled.

FIG. 18. The same by day, the petals being rolled up.

FIG. 19. Flower of oak-leafed *Pelargonium*, to show the position of the stamens *before* fertilization. The style and stigmas immature.

FIG. 20. The same, with filaments reflexed *after* fertilization; the anthers have fallen. The stigmas are now in the position of the anthers.

FIG. 21. Flower of *Teucrium scorodonia*, to show the position of the stamens *before* fertilization.

FIG. 22. Same after fertilization, the stamens having retired, while the stigmas now occupy their position.

ILLUSTRATIONS OF PLANT MOVEMENTS.

PEDUNCLES.—Flower stems form no exception to axial structures in the habit of circumnutating; but the effect is curiously modified by geotropism in the case of *Trifolium subterraneum*, and by apheliotropism in that of *Cyclamen persicum*, in both of which plants the object gained is the burying the unripe pods beneath the soil, leaves, etc. The flower-heads of *Trifolium subterraneum* produce but three or four perfect flowers at the base, all the other flowers above consisting only of cylindrical calyx-tubes with stiff spreading lobes, forming claw-like projections (Figs. 4–6). As soon as the perfect flowers wither, they bend back upon the peduncles. This movement is due to *epinasty*, a word coined to imply that the upper surface of an organ grows more quickly than the lower surface, and thus causes it to bend downward. While the perfect flowers are thus bending, the whole peduncle curves downward and increases much in length, even from 6 to 9 inches if necessary, until the flower-head reaches the ground. At this period the younger, imperfect, central flowers are still pressed closely together, and form a rather rigid conical projection. The depth to which the flower-heads can penetrate varies from 0·25 to 0·06 inch. In the case of a plant kept in the house, a head partly buried itself in sand in six hours; with plants growing out-of-doors, Mr. Darwin believes that they bury themselves in a much shorter time. After the heads are buried, the central aborted flowers increase considerably in length and rigidity, and become bleached; they gradually curve, one after the other, upward or toward the peduncle (Fig. 5). In thus moving, the long claws on their summits carry with them some earth; hence a flower-head which has been buried for a sufficient time forms a rather large ball, the aborted flowers having caught up the earth with the claw-like sepal-lobes, act somewhat like the hands of a mole, which force the earth backward and the body forward.

The calyxes of all the flowers are clothed with simple and multicellular hairs (Fig. 7), which, on absorbing carbonate of ammonia presented to them, exhibited protoplasmic aggregation. As Mr. Darwin observes that only a few of the flower-heads, which from their position are not able to reach the ground and bury themselves, yield seeds, whereas the buried ones never failed to produce as many seeds as there had been perfect flowers, it may be reasonably conjectured that the object gained is to nourish the ripening seeds directly through their surfaces, and so to supplement root action. The capsules of cyclamen and of the wood sorrel *Oxalis acetosella*, are occasionally buried, but then only beneath dead leaves or moss.

LEAVES.—The movements of certain leaves which are said to sleep have long been observed, but it would seem that probably all leaves and cotyledons circumnutate, and that the so-called sleep is only a remarkable modification or development of this general kind of movement, accompanied, however, by other and often complicated motions. The seat of the movement generally lies in the petiole, but sometimes both in the petiole and blade, or in the blade alone. The movement is chiefly in a vertical plane; but as the ascending and descending lines never coincide, there is always some lateral movement, and thus irregular ellipses are formed. There is a periodicity in the movements of leaves, for they often or generally rise a little in the evening and early part of the night, and sink again on the following morning, this periodicity being determined by daily alternations of light and darkness, as already mentioned in the case of cotyledons. These periodic movements occur where there is no *pulvinus*, for where this is found, the movement is amplified into *nyctitropic*, or sleep-movements.

Leaves, Mr. Darwin says, when they go to sleep move either upward or downward; or in the case of the leaflets of compound leaves, forward, that is, toward the apex of the leaf, or backward, that is, toward its base; or again, they may rotate on their own axis without moving either upward or downward; but in almost every case the plane of the blade is so placed as to stand nearly or quite vertically at night. Moreover, the upper surface of each leaf, and more especially of each leaflet, is often brought into close contact with that of the opposite one, as the upper surfaces appear to require more protection than the lower.

The nyctitropic movements of leaves and cotyledons are effected in two ways, first, by means of pulvini, which become ultimately more turgescent on opposite sides; and secondly, by increased growth along one side of the petiole or mid-rib, and then on the opposite side. This difference between the two means of movement consists chiefly in the turgescence of the cells of a fully-developed pulvinus not being followed by growth. The movements effected by growth on the alternate sides are confined to young growing leaves, while those effected by means of a pulvinus last for a long time.

The evil effects which result if sleeping leaflets be prevented from pressing their upper surfaces together, so as to protect them from radiation, were well seen in experiments of Mr. Darwin's, in which he pressed down the leaflets of *Oxalis, Marsilia*, etc., so that they could not bring their upper surfaces into contact; the result was that the leaves were killed. Thus of twenty-four leaves of *Marsilia* extended horizontally, exposed to the zenith and to unobstructed radiation, twenty were killed and one injured, while a relatively very small proportion of the leaves, which had been allowed to go to sleep with their leaflets vertically dependent were killed or injured. Mr. Darwin noticed that the difference in the amount of dew on the pinned open leaflets and on those which had gone to sleep, was generally conspicuous, the latter being sometimes absolutely dry, while the leaflets which had been horizontal were coated with large beads of dew. Another fact observable was that when leaves were kept motionless, they are more liable to injury than when they were slightly waved about by the wind, and thus got a little warmed by the surrounding air.

Cotyledons, as well as leaves, may sleep; the former seem to do so more commonly than leaves. Of 153 genera observed by Mr. Darwin, one or more species of twenty-six of these genera placed their cotyledons at night so as to stand vertically, having generally moved through an angle of at least 60°. In a large majority of genera the movement is a rising one. In all the species of *Oxalis* observed by Mr. Darwin, the cotyledons are provided with a pulvinus; and he adds that this organ has become more or less rudimentary in *O. corniculata*, in which the amount of upward movement of the cotyledons at night is very variable, but never enough to be called sleep. Similarly, in the Leguminosæ, all the cotyledons which sleep have pulvini. As this organ has been referred to several times, it will be as well to describe it. It constitutes a cushion or joint, and consists of a mass of small cells, usually of a pale color in the case of that attached to cotyledons from the absence of chlorophyl, and having a convex outline. The development of a pulvinus follows from the growth of the cells over a small defined space of the petiole being almost arrested at an early stage. As a pulvinus is formed by this arrestment of the growth of its cells, movements dependent on their action may be long continued without any increase in length of the part thus provided; and such long-continued movements seem to be one chief end gained by the developement of a pulvinus.

It will be desirable now to give a few illustrations of nyctitropic movements from Mr. Darwin's observations.

Averrhoa bilimbi (Fig. 8).—The leaflets of this plant move spontaneously in a very marked manner during the day, are sensitive to touch, and sleep at night, when the leaflets hang vertically down and motionless.

Lupinus.—The digitate leaves of this genus sleep in three different ways. One of the simplest is that all the leaflets become steeply inclined downward at night, having been horizontal during the day, as those of *L. pilosus* (Figs. 9, 10), when asleep are often inclined at an angle of 50° beneath the horizon. In *L. hartwegii* and *L. luteus*, the leaflets, instead of moving downward, rise at night, forming a hollow cone with moderately steep sides.

With several other species, the position is remarkable. On the same leaf the shorter leaflets, which generally face the center of the plant, sink at night, while the longer ones on the opposite side rise, the intermediate and lateral ones merely twisting on their own axis; the result is that all the leaflets on the same leaf stand at night more or less inclined, or even quite erect, forming a vertical star.

Melilotus.—The species in this genus sleep in a curious fashion. The three leaflets of each leaf twist through an angle of 90°, so that their blades stand vertically at night, with an edge presented to the zenith; the two lateral leaflets always twist so that their upper surfaces are directed toward the terminal leaflet. This latter leaflet moves in another and more remarkable manner, for while its blade is twisting and becoming vertical, the whole leaflet bends to one side, and invariably to the side toward which its upper surface is directed; so that if this surface faces, say, the west, the whole leaflet bends to the west, until it comes into contact with the upper and vertical surface of the western lateral leaflet. Thus the upper surface of the terminal and of one of the two lateral leaflets is well protected. It may be added that the petioles and sub-petioles continually circumnutate during the whole twenty-four hours. (Figs. 11, 12, 13.)

Cassia corymbosa, during the day; and the same, asleep, at night.

Trifolium repens.—During the day, the leaflets of this plant are expanded horizontally (Fig. 14), but at night the two lateral leaflets twist and approach each other until their upper surfaces come into contact; at the same time they bend downward in a plane at right angles to that of their former position, until their mid-ribs form an angle of about 45° with the upper part of the petiole, this change of position requiring a considerable amount of torsion in the pulvinus. The terminal leaflet merely rises up without any twisting, and bends over until it rests on and forms a roof over the edges of the now vertical lateral leaflets (Fig. 15).

Coronilla rosea.—This plant affords an instance of leaflets rising at night from having been horizontal during the day. The leaflets at the same time bend backward toward the base of the petiole, until their mid-ribs form with it angles of from 40° to 50° in a vertical plane (Fig. 16).

Cassia.—The nyctitropic movements of the leaves in many species of Cassia are highly complex. Mr. Darwin's observations were made chiefly on *C. floribunda* and *corymbosa*, and he furnishes the following description. The horizontally extended leaflets sink down vertically at night, but not simply, as in so many other genera, for each leaflet rotates on its own axis, so that its lower surface faces outward. The upper surfaces of the opposite leaflets are thus brought into contact with one another beneath the petiole, and are well protected, as shown in the woodcut.* The rotation and other movements are effected by means of a well developed pulvinus at the base of each leaflet, as could be plainly seen when a straight, narrow black line had been painted along it during the day. The two terminal leaflets in the daytime include rather less than a right angle, but their divergence increases greatly while they sink downward and rotate, so that they stand laterally at night, as may be seen in the figure; moreover, they move somewhat backward, so as to point toward the base of the petiole. In one instance Mr. Darwin found that the mid-rib of a terminal leaflet formed at night an angle of 36°, with a line dropped perpendicularly from the end of the petiole. The second pair of leaflets likewise moves a little backward, but less than the terminal pair; and the third pair moves vertically downward, or even a little forward. Thus all the leaflets in those species which bear only three or four pairs, tend to form a single packet, with their upper surfaces in contact and their lower surfaces turned outward. Lastly, the main petiole rises at night, but with leaves of different ages to very different degrees; thus some rose through an angle of only 12°, and others as much as 41°.

* I am indebted to the courtesy of Mr. Darwin for the loan of the blocks for these figures

The influence of light upon the movements of plants is various. Thus the so-called heliotropic movements are determined by the direction of the light, while periodic movements are affected by changes in its intensity. On the other hand apheliotropism implies that a plant bends from the light, a rare phenomenon, at least in a well marked degree. Parts of plants under the influence of diaheliotropism place themselves more or less transversely to the direction whence the light proceeds, and are thus fully illuminated. Lastly, some leaves rise or sink or twist so as to avoid great intensity of light. Such a phenomenon, Mr. Darwin suggests, should be called paraheliotropic. All these movements consist of modified circumnutation. Space forbids a detailed description of these effects; but one curious result of Mr. Darwin's investigation is worth recording, and that is the transmitted effects of light. When, for example, the cotyledon of *Phalaris canariensis* is exposed to light, the upper part bends first, and afterwards the bending gradually extends to the base, and even a little below the ground. By protecting the whole upper half of the cotyledon from light, the lower part, though fully exposed to light, was prevented from becoming curved. Hence it is to be concluded that when seedlings are freely exposed to a lateral light, some influence is transmitted from the upper to the lower part, causing the latter to bend.

FLOWERS.—There are many instances of the various parts of flowers moving under the influence of stimuli; but the immediate causes in the different cases have not been so thoroughly investigated as by Mr. Darwin in the case of the vegetative organs, and at present, therefore, but little can be said beyond the fact that they do move. Thus, commencing with bracts, it may easily be seen how the erect bracts of the involucre of the dandelion become reflexed as soon as the fruit is ripened, thus allowing the parachute-like achenes to escape easily. Moving corollas are very numerous. A large series of plants might be mentioned of which the corollas close up, either as soon as the sun is obscured, as *Mesembryanthemum, Anagallis arvensis, Convolvulus*, etc., or else at evening, such as many Compositæ, including the Daisy and Dandelion, re expanding on the return of light. Conversely, some night-flowering plants unfurl their petals only at night, coiling them up by day. As an illustration *Silene nutans* may be taken, concerning which Dr. Kerner tells us* that a flower lasts three days and three nights; with the approach of dusk the bifid limbs of the petals spread out with a flat surface, and fall back upon the calyx. In this position they remain through the night; curling themselves up into an incurved spire and becoming longitudinally creased at the same time on the return of sunlight and a warm temperature. No sooner does evening return than the wrinkles disappear, the petals become smooth, uncurl themselves, and falling back against the calyx, the corolla is again expanded (Figs. 17, 18).

In the Pea family, or Leguminosæ, there are several instances of the corolla having a power to move when irritated. Thus in the genera *Genista* and *Indigo*, the claws of the petals act like springs kept in a state of tension; for when the corolla is touched, as by an insect in search of honey, the claws suddenly curl downward, and the petals consequently drop vertically, while the stamens, previously concealed within the keel petals, are violently thrown upward, showering the bee with pollen.†

The movement of stamens is perhaps more curious, and apparently intimately connected with the phenomenon of insect fertilization. As an example of slow movement, *Parnassia palustris* may be mentioned. In this flower each stamen in succession rises up, places the anther on the stigma, and having shed its pollen, retires and falls back upon the petals. Each stamen occupies about twenty-four hours in rising up and discharging its pollen, and takes about the same time to recede, the whole period being eight

* "Flowers and their Unbidden Guests," p. 132

† *Journ. of Linn. Soc.*, vol. ix., p. 355, and vol. x., p. 468.

days, but varying according to circumstances of temperature, moisture, etc.*

Berberis furnishes an instance of rapid motion; for if the stamens be touched at the base of the filament, they instantly spring forward and strike the stigma, having previously lain on the surface of the spreading petals. The effects of the irritation on the filament of *Berberis* have been observed and described by M. E. Heckel.† It appears that the cells of the irritable part are arranged in a parallel manner (the back of the filament being insensible). Their contents are yellow and disseminated throughout the cavity. After irritation theyundergo aggregation and contract into the center of the cell, and the cell wall is striated transversely. The cells of the back of the filament are contracted in repose, but extended in irritation.

The stamens of the common Lucerne, *Medicago sativa*, as also of other species of that genus, suddenly curve upward and remain rigidly fixed in an arched condition, having been previously horizontal.‡

Mr. Darwin has described numerous instances in the family Orchidaceæ, in which the *pollinia*, as of the common *Orchis mascula* and others, or of *Catasetum*, etc., have remarkable powers of movement; in the former cases slow, but in the latter rapid. In every case there is discernible some special adaptation to the fertilization of the flowers by insect aid.§

Stylidium affords another illustration of rapid motion. In this flower the stamens and style are consolidated into a column, which is curiously bent and hangs over one side of the flower. If it be touched near the base, it instantly flies over to the other side. A very similar motion occurs in the pistil of *Maranta*.

Some flowers have the stamens in a certain position on first expanding, but they take up another position subsequently. This I found to be the case with *Alisma plantago*. On first expanding the stamens spread out, their anthers being extrorse, but afterward they curl backward over the stigmas, thereby in all probability effecting self-fertilization. In several flowers of different species the filaments retire after the anthers have shed the pollen or fallen off, as in the lemon-scented and oak-leafed *Pelargoniums*, and in *Teucrium scorodonia*, or wood-sage. In both of these the anthers mature some time before the stigmas, and assume a position adapted to insects to transport their pollen. Subsequently the filaments bend away, and the styles now take up the same position that the filaments had previously held (Figs. 19-22).

Space will not allow further descriptions, but enough has now been said to show how extensive and varied are the movements effected by the different organs of plants, and the advantages accruing to them by possessing such powers of motion.—*Popular Science Review.*

ON THE DISPOSITION OF COLOR MARKINGS OF DOMESTIC ANIMALS.

By WM. H. BREWER, Professor of Agriculture in Yale College.‖

FOR some years I have been making and recording observations on the color-markings of domestic animals, and read a paper before the Connecticut Academy of Sciences, "On the Foot-markings of Horses," and another, "On the Color-markings of Domestic Animals and their Relations to those of Wild Animals." The present paper is but a further extension of the same subject, and is offered at this time in the hope that I may get suggestions from other observers, as well as to publish before this body facts which have had a merely limited publication before. The tables upon which the conclusions are based will be published at another time.

It is common for horses of otherwise solid colors, particularly bays, browns, blacks, and others with dark-colored legs, to have one or more of the legs above the hoof marked with white; a white ring or stocking extending a greater or less distance up the leg and ending suddenly. More rarely it is a mere blotch, and when thus restricted it is oftenest on the back side of the leg. The hoof may or may not be white, but is liable to be white if there is a white stocking above it.

Observations made in several different States, and extending to several thousands of foot-marked horses, show that *more of the white feet are on the left side than on the right.*

There are fifteen ways in which the four feet may be marked, the sixteenth being no white feet. The left hind foot is the one most often white and the right fore foot the least often, the order of frequency of white feet being the left hind, the right hind, the left fore, the right fore. If but one foot is white it is oftenest on the left side.

If three feet are white, two of them are oftenest on the left side.

If two feet on one side and none on the other are white, then these two are oftenest on the left side. The relative frequency of each, and of each combination, as well as the percentage found with the various colored horses, with other data relative to color, will be given at another time, as I have not had the time to prepare the tables for this meeting.

The hind feet are much oftener marked than the fore, and if we examine cases where only the two hind feet are white, in a majority of cases the amount of white on the left is the greater, the white extending farther up the leg. This is probably also true where only the two fore feet are marked, but that is such a rare marking that I cannot make this generalization from actual observation. And here let me say that, in the disposition of white feet, some combinations are so rare that it would be an important datum in the identification of stolen or lost horses, the percentage of horses of any one color having, say, only the right fore foot or the two fore feet marked, is very small.

Observations on spotted horses show that a majority have more white on the left than on the right side.

This shows itself in two ways. In the first place, if there is merely a white spot on the horse (other than on the face or just above the hoof), then it is oftenest on the left side.

In the second place, if the horses are decidedly spotted (calico horses, or pintos), then the area of white, so far as could be judged by the eye, is largest on the left side in a majority of cases. Formerly spotted horses were fashionable, as they still are among semi-barbarous peoples, among Indians, and on particular ranches in the far West, but now they are so unfashionable in the older States that it is not easy to find a sufficiently large number of cases for extensive generalization, but, so far as observed, a majority are as stated. I have not included in this those cases where several

* Baxter's "British Flora," vol. i. .(70)

† *Bull. Soc. Bot. Fr.*, 1874, vol. xxi., p. 208.

‡ *Journ. of Linn. Soc.*, vol. ix., p. 327.

§ See Fertilization of Orchids.

‖ Read before the American Association, Cincinnati, Ohio, August, 1881.

such horses came from the same ranch, and where a similarity of marking might be the result of family heredity.

I think, therefore, that I have proved that, as regards horses with white marks or spots, these are most often found on the left side, and also that the quantity of white is greatest on that side.

Mules are rarely spotted, although it sometimes occurs, and are specially bred in some places, but I have never seen a foot-marked mule; that is, a mule with otherwise solid colors but with a white foot or stocking, as horses have. Spotted mules may have white legs and feet.

As to horned cattle, the data are less satisfactory. In the first place they are not foot-marked as horses are, but in quite another way. If white occurs it is in blotches and patches, these most often, I think, on the front side of the leg, not extending to the hoofs, and not in a clean, well-defined white ring or stocking, as is common with horses. Moreover, at agricultural fairs and similar places where we see many breeds exhibited together, the results are usually vitiated, because of the families or strains exhibited together.

However, so far as my observations go, they point in the same direction, and I strongly suspect that the same law holds true with cattle that I have proved to be true with horses, although my observations are too few to establish it on large numerical data.

The same may be said of dogs, but here the disposition of marked feet has no value, because white feet is a fancy "point" which is bred to in some breeds. If the right and left are shown in dogs by color, I have not been able to verify it, but it is strongly shown by the tail, if not by color, in the vast majority of cases the tail being carried on the left side. With some breeds this has long been a character, and even in breeds where this is not a "point" it is usually true. It is not true, however, that dogs which carry the tail to the left are not afflicted with rabies, as has often been affirmed.

With swine as with dogs, the disposition of white feet has no value in this discussion, because with some breeds (as in the Berkshires) it is a fancy point bred to, and I have not carried my observations to the relative areas of white on the two sides of spotted hogs in a sufficiently large number of cases to generalize, but enough, however, to induce suspicions that the rule holds good here too.*

From the observations made on the disposition of color, it seems to me probable that, with all our spotted domestic animals, white appears more frequently and in larger quantity on the left side.

And if in domestic animals, why not in wild animals? Of these, except in the few cases seen in menageries and stuffed skins in museums—all too few for any generalization, but yet indicating that way—I have no data of value, except with skunks. As is well known, these vary much as to white, and in the skins I have examined the majority had most white on the left side, but the number was too small (only about sixty) to base generalizations upon.

As the result of a long investigation (by no means finished), I very strongly suspect this is a law of nature, and that as color is one of the characters (in vertebrates) most sensitive to various influences, it is the first to show a tendency of difference between the right and left side, which culminates in the right-handedness of man.†

As white color is often found correlated with certain physical weakness, it early suggested itself to me that the predominance of white on the left side was an indication that that was physically the weaker side, and the same thing has been suggested by several persons to whom I have told my observations.

The relation of the color-markings of domestic animals to bilateral symmetry has been the subject of discussion, the statement having been reiterated in various shapes and ways, that wild animals are similarly marked (if marked at all) on both sides, whereas with domestic animals the rule is that there is no such symmetry.

My own belief, founded on numerous observations on various kinds of domestic animals, is that there is no such difference, and that the difference is one of degree and not of kind. The disposition and kind of the color-markings of wild animals is doubtless related to protection and to ornament, and both of these would apply to both sides alike. If there is any reason why markings or dispositions of color on one side are either protective or ornamental, these reasons are equally strong for the other side, and so we might expect to find bilateral symmetry even more perfect than it really is, for the symmetry assumed is general rather than special. I have examined many skins of marked animals, tigers, leopards, cougars, and other species of the cat family, as well as zebras, in fact *all* the skins of marked animals to which I have had access, and I find the symmetry is never absolute in the details. The markings of the two sides resemble each other strongly in a general way, but when examined spot for spot, stripe by stripe, they will be found to vary in every character except the most general, not only between different animals, but the two sides of the same animal. This is true even of spotted serpents.

With our larger wild animals, if spots occur, as they often do by sporting, they make the creature conspicuous to its enemies, they are the reverse of protective, and they are thus quickly eliminated from the herd. Not so with domestic animals; irregular spots are marks facilitating recognition, and have a value often in proving ownership, and thus become protective.

Spots irregularly disposed on domestic animals have had a protective value among partially civilized people since the days of Jacob certainly, and probably much longer.

But with our modern breeders fashion largely decides this. In breeds where markings are a "point" in breeding they are symmetrically disposed, as are the white feet on Newfoundland dogs or Berkshire pigs, the broad white belt on the "sheeted breed" of cattle, and other breeds that regularly suggest themselves. In all such cases the markings are as symmetrical in a general way as with wild animals where the selection has been directed by nature, and even more so than in the skunk.

If they are not breeder's points, then they are not protective, and are as irregular as are the sportive colorings sometimes found in wild animals. The spotted bears and buffaloes (sports) occasionally seen are as irregularly marked as are the cows of our herds or the calico horses occasionally seen in our streets. Moreover, with the spotted breeds, even if the colors are irregularly disposed, there is a tendency toward symmetry in a majority of cases, as is easily proved

* Unlike the dog, the curl of the pig's tail is as often on one side as on the other, and the same animal may be carried on either side, according to the taste or fancy of the wearer.

† We frequently see statements floating on the literature of the day, relative to the right-handedness of animals being indicated by horses stepping the right foot first, elephants using the left tusk by preference, and a number of other statements of a similar character; but so far as I have been able to observe, I have not found one of these to be borne out by fact.

by comparing the markings of the two sides, the feet, the lines on the back, etc., on any breed of spotted cattle at any agricultural fair, and even on calico horses. If a number of cases are observed, the color is found to be usually disposed as if there was an effort toward bilateral symmetry, if one examines them in detail spot by spot, over back, sides, about eyes, ears, legs, and face.

Each of the points of this paper I purpose to elaborate more in detail at some future time.

RABBITS AND GOATS NEAR THE SOUTH POLE.

MR. E. J. CHIPMAN, mate of the whaler Pilot's Bride, who has just returned from a voyage to the Antarctic Ocean, says the forty pairs of rabbits and the twelve goats that were taken from Capetown to Kerguelen in 1875 have thrived wonderfully, the island fairly swarming with rabbits, while the goats number some hundreds. Teal duck are found about the island in large flocks, and what with roast kid and duck, and stewed rabbit, and plenty of Kerguelen cabbage, Captain Fuller's crew of twenty-eight men had an agreeable change in their diet while there.

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