THE JOURNAL OF MICROSCOPY

AND

NATURAL SCIENCE:

THE JOURNAL OF

THE POSTAL MICROSCOPICAL SOCIETY.

OCTOBER, 1886.

How Plants Climb.

BY H. W. S. WORSLEY-BENISON, F.L.S.,

Lecturer on Botany at Westminster Hospital; Late President of the Highbury Microscopical and Scientific Society.

TOWARDS the close of a paper on *The Power of Movement in Plants*, I briefly referred to this power as exhibited by many climbing plants. I then said that such movements came under the third or last class of the three which we then discussed—viz., *motion occurring in living parts of plants during active growth.*

I promised at some future time to say something more in detail concerning the various methods by which this climbing process is accomplished; this paper is an attempt, in some small degree, to redeem my promise.

That plants do climb, no one who takes an ordinary country walk, or sees the row of scarlet runners in his garden, or looks at a Virginia creeper, with its exquisite October hues, can for one moment question. How and why they do so, very few stay to enquire.

The student who is ignorant of the researches on this subject and of their results, leaves unread one of the most fascinating chapters in botanical romance. Prominent among such researches are those of Ludwig Palm and Hugo von Mohl in 1827, of Dutrochet in 1843, of Asa Gray in 1858, of Darwin in 1865, of Fritz Müller in the following year, and lastly of Hugo de Vries in 1873.

Although gathering information from each of these in part, I take as the chief groundwork of my paper Darwin's book entitled *The Movements and Habits of Climbing Plants*, which is now, with us, the acknowledged text-book on the subject. It is a small volume compared with most of his works, but none the less does it show the grasp and force of his mighty intellect. I can only give you a very few of the facts from which Darwin deduces the laws which govern the movements of the various classes of climbers—only attempt to lead you across the threshold of the 'Fairy Land of Science'—only go with you just through the gate which opens at our touch. You must for yourselves explore the field and search for treasure. The treasure is there, and much of it has been spread out to view, by the untiring, unceasing work of Charles Darwin, for those who have eyes, and use them for their right and reasonable purpose.

Darwin divides climbing plants into four Classes, as follows:—

I.—TWINERS.—Those which *twine spirally* round some support, unaided by any other movement.

II.—CLIMBERS.—Those ascending by the aid of *sensitive or irritable organs*, which, touching an object, clasp it. This Class is further separated into two Divisions, graduating to some extent into each other:

A.—LEAF-CLIMBERS.—Those retaining their leaves in a functional condition, and climbing by either their *petioles*, or their *produced mid-ribs*, *or tips*;

B.—TENDRIL-BEARERS.—Those having true *tendrils*, these being filamentary sensitive organs, consisting of modified *petioles*, *leaves*, *flower-stalks*, or *stipules*.

III.—HOOK-CLIMBERS, or SCRAMBLERS.—Those climbing simply by the aid of *hooks*.

IV.—ROOT-CLIMBERS.—Those ascending by means of *rootlets* attached to their supports.

Let us take the classes in the above order, and ascertain the manner in which each set of climbers pursues its way by studying a few examples.

I.—TWINERS. This is the largest class, and for several reasons appears to be the oldest and simplest type.

Darwin takes *Humulus lupulus*, the common Hop, as a fair example. Its first two or three internodes are straight and quite stationary. Then comes one that, while young, bends over to one side, and travels slowly round its support in the direction of the hands of a watch; as the next internode is developed, the two rotate, and usually a third. The ordinary velocity is soon attained, and this was found to be about 2 h. 8 m. for each revolution. As the lowest internode grows old, it gradually ceases to rotate, although the revolutions continue in the terminal two or three of the shoot, so long as the plant continues to grow. Thus, internode by internode, the shoot twines itself round its support, each 'joint' of the stem gradually becoming stationary, while the last two or three keep up the revolving motion, until the final internode, or tip, ceases to move. In most plants, Darwin found that three internodes were revolving at the same time, but in every case at least two were at work, "so that by the time the lower one ceased to revolve, the one above was in full action, with a terminal internode just commencing to move." A Hop-shoot with three internodes revolving was carefully watched. It was 14 inches long, and at such an angle to its support that its tip swept a circle of 4 ft. 9 in. This it did in 2½ hours, giving an average movement of 23 inches an hour. With another plant, one of the *Asclepiadaceæ*, a shoot consisting of five internodes, measuring altogether 31 inches, described a circle of 16 ft. 6 in. in 6 hours, giving an average speed of 33 inches an hour.

The rate of revolution varies widely in different plants. The shortest periods for one revolution ranged from 1 h. 40 m. in the white Convolvulus to 18½ hrs. in an exotic plant (*Sphærostema*). The rate by night or by day differs but little. Vigorous health and moderate warmth favour the movement. The twining *Poly-*

gonum does its work only during the middle of summer; it grows vigorously in autumn, but with no tendency to climb.

With regard to the direction which the revolving movement takes, there are very many interesting facts. We can only notice at present that some twine from left to right, or against the hands of a watch, while others take the opposite direction. These terms are used in different senses by different writers. The simplest and best method to clearly apprehend the terms is to imagine the pole, or support *in front of the observer*, and then to note in which direction the first revolution is made. If it be from right to left—*i.e.*, with the watch—it is called *sinistrorse;* if from left to right, it is *dextrorse;* the terms being used to specify the hand *towards* which the shoot twines.

By far the greater number of twiners revolve from left to right, dextrorsely; the purple and white Convolvuluses, French bean, and Morning Glory are examples. A few take the opposite direction, as, for example, Hop, Honeysuckle, and Black Bryony (*Tamus*). Very rarely do plants of the same order twine in different directions. Darwin met with no two species of the same genus that did so, but different individuals of the same species are sometimes found to twine in two ways: the Woody Nightshade (*Solanum dulcamara*) of our hedges, for example. In some cases, as in the Chili Nettle, some individuals twine in one way, some in the other, others in both, the petioles of its opposite leaves affording a fulcrum for the reversal of the spire. This double movement in the same plant is rare. It occurs in *Hibbertia*, where the twining is always dextrorse, while the revolving movement varies; thus the plant is adapted for twining in order to ascend, and at the same time is able to wind from side to side through the thick Australian scrub.

Our indigenous twiners can ascend a support as thin as ordinary thread, some, such as Woody Nightshade, being able to climb *only* round very thin and flexible stems; they can ascend stems of moderate thickness, but Honeysuckle is the only one that ever twines around tree-trunks. In the tropics, on the contrary, twiners can ascend forest-trees, and this is needful for them, or they would be unable to reach the light and air. In England, our annual twiners would be unable in their single season to reach so high as the level of our forest tree-tops, so they select smaller and shorter supports in other situations.

The main purpose of plants becoming climbers in any way is, of course, to reach such a position as to enable them to expose their leaves to the action of air and light, with as little expenditure of matter as possible. In the case of twiners, their first step is to *find* some support on which they can rely, towards the attainment of the end in view. It is *in order to find such support* that the spontaneous revolving movement is carried on by day and night, the shoot sweeping in wider and wider circles. This shows us how the plant twines, for when a revolving shoot meets with a support, this support of course arrests the movement at the point of contact, while the free portion continues revolving. Thus higher and higher parts are one by one arrested, and the shoot winds round its support. Such is Darwin's own explanation.

How is the revolving movement effected? It was formerly supposed that it was wholly due to a twisting of the shoot or stem on its own axis. This is now conclusively disproven, for many plants clearly revolve, especially among leaf-climbers and tendril-bearers, and yet their internodes are in no way twisted. We also meet with instances where different internodes are twisted in opposite ways, and even in an opposite direction to that of their revolutions. The axial torsion seems rather to bear relation to ruggedness or inequalities of the support, and to the power of revolving freely without any support.

Nevertheless, seeing that although many plants, not being twiners, are axially twisted, and that this tendency is much stronger and more frequent in plants that do twine, it is probable that there is some relation between the power to twine and the presence of their axial twisting.

The revolving movement is effected as follows:—It is a successive *bowing over of the stem*, first in one direction, then in another, and so on, until a circle has been completed—*i.e.*, the stem is *pulled over*, so to speak, by some internal force, acting in turn *all round* the stem in the direction in which it is sweeping, so that the circuit is made without any real twisting. This is not easy to explain in words, but suppose we paint a dotted line along the upper or convex side of a shoot bent towards the South. Let it move round a quarter of a circle, say to the East: the dotted line will be on the *side* of the shoot facing the North; move the shoot another 90 degrees, *i.e.*, to the North: the dots are on the under or concave surface; when the shoot points West, the dots again appear on the side; bring it round South again, and the dots appear once more on the upper or convex surface. No twisting has taken place, but the shoot has completed its circle of sweeping, and this by successive bowings over of itself in the direction of its revolving movement.

Now, let us substitute for the dotted line on the convex surface, a very much more rapid growth of the cells on *this surface* than on the other three, preceded by turgescence of the cells. This unequal increase of growth would cause the shoot to bend down in the opposite direction, making the Southern side concave—in other words, it effects the bending of the shoot to the South. Now, let this turgescence and unequal increase of growth creep round the shoot (just as we made the dotted line to twist round it) in successive stages, until it has gone the entire round of the shoot. As it travels, it causes each part of the circumference to bend or bow to the opposite side, the result being that the shoot gradually sweeps in an entire circle round the support, the circumference of the circle being dependent on the length of the shoot and its inclination to the support.

In this, we have the true explanation of the revolving movement, or, as it is now termed, *circumnutation.* I referred to this same process of turgescence, succeeded by unequal growth on one side, when describing the phenomenon of Heliotropism. A similar process explains the folding of young leaves over the end of their stem, and their subsequent unfolding, the under surface suffering increase of growth in the former case, the upper surface growing more rapidly in the latter.

The circumnutation of twining-plants is simply the ordinary circumnutation of the stems and roots of seedlings, and of leaves in general, *modified by being increased in amplitude.*

The power is innate, and is not excited by external agencies, beyond those necessary for growth and vigour. The process itself once clearly understood, the revolving movement of climbing-plants is no longer the mystery it was before.

We pass now to our second Class. This consists of plants climbing by means of sensitive or irritable organs, which, touching any object, clasp it in some way or other. These are—

II.—CLIMBERS. We divide this class into two groups for convenience' sake :—

A.—LEAF-CLIMBERS.

B.—TENDRIL-BEARERS.

In some cases these shade the one into the other.

A.—LEAF-CLIMBERS.

These are intermediate in some respects between twiners and tendril-bearers. They climb in two ways; some by means of their *petioles*, and others by their produced *mid-ribs, or tips.*

In nearly all the species examined by Darwin, the young internodes showed a revolving power, in some cases quite as regular as in a twining-plant; in most cases the revolutions were rapid.

The purpose of the revolving in these leaf-climbers is not to climb around a support, but to enable the leaf-stalks, or the leaf-tips, as the case may be, to get near to some object which they can clasp. Of course this power of revolution greatly assists the plants in making use of their sensitive organs.

As in true twiners, the first internodes do not revolve, nor do the petioles or tips of the earliest formed leaves appear to be sensitive.

There are some eight orders in which we find leaves with clasping *petioles.* Prominent among these are sundry species of *Clematis*, *Tropæolum*, *Solanum*, and *Fumaria.* In many of these there is a tendency to revolve in opposite directions, thus differing from true twiners. They are, of course, inferior twiners.

The petioles are enabled to clasp any object in virtue of *an extreme sensitiveness to touch.* On being touched, or rubbed, they bend towards the irritating object, or towards the point of irritation. If they find a twig or stalk of any kind, they grasp it, sometimes taking two or three turns round it. If they find nothing to hold by, they gradually uncoil and straighten themselves again; in this position they remain permanently.

In some species, the young leaves spontaneously shift their position—*i.e.*, without any external stimulus; their petioles gradually bend down until at right angles to the stem ; remaining there for a time, they arch downward until the leaf points to the ground with its tip incurled. This is their fashion of looking out for a support, which the revolving motion of the shoot may bring them near to. They then act as I have just indicated, according to whether they find the support they seek, or fail to find it.

A petiole coming into contact with a support for a short time only, usually continues curved for some time, but can afterwards regain its upright position, and so be ready to act once more ; but if it clasp its support for any length of time, then it cannot straighten again. In some species, markedly so in some of the *Clematis* family, the petiole having coiled around its support, in two or three days begins to swell, and gradually thicken, either laterally, or through its whole diameter, until it becomes twice as thick as an unclasped petiole. It then becomes much more woody internally, like a stem, and instead of being easily snapped in two, it is so tough and rigid that force is needed to break it.

This change of structure gives greater durability, firmness, and strength ; it hinders the unwinding of the petiole, and of course enables it to withstand the force of the wind, or of shock from any other cause. The appearance of a cross-section of such a petiole under the microscope, shows a *complete ring* of woody tissue, as opposed to the semi-lunar one of an ordinary leaf-stalk. It is a fact worthy of note that this change is effected merely by the act of clasping a support.

Petioles are usually sensitive only when young. They are sensitive on all sides, although this differs in different species.

The rate at which they respond to a touch varies. In some species of *Tropæolum* a slight rub took effect in three minutes ; in others the response occupied six, ten, or even twenty minutes. In other cases—for instance, in some species of *Clematis*—it took several hours. In others, two or three days or more pass by before the process is complete.

The degree of sensitiveness varies. In some, a weight of only one-sixteenth of a grain will cause bending to ensue ; in others, the touch of the exceedingly fine flower-stalks of the Quaking-grass *(Briza)*.

This sensitiveness extends in some cases to the stems and to the flower-stalks. In the latter case the reason is hard to find, since no use is made of this property for climbing purposes.

Four families exhibit the power of climbing by their produced *mid-ribs, or tips.*

Two notable cases are *Gloriosa*, a genus of *Liliaceæ*, and *Nepenthes*, the Pitcher-plant.

In *Gloriosa*, the tip of the leaf grows into a ribbon-like projection, which gradually coils down into a well-formed hook. Only the inner or under surface in this case is sensitive to touch. If the hook becomes coiled into a ring it loses its sensitiveness entirely. When very young the plant can support itself, and no hooks are developed ; when it has done growing the sensitiveness vanishes. In neither case are the hooks needed ; therefore, they are either absent or their sensitiveness departs.

In *Nepenthes*, the curled tip of the leaf is used both for climbing by, and as a support for, the pitcher. The coiled portion in the latter case is, nevertheless, thickened by way of providing additional strength.

B.—TENDRIL-BEARERS.

These are plants having true tendrils—*i.e.*, thread-like sensitive organs, which are used exclusively for climbing. We do not in this definition include spines, hooks, or rootlets.

Tendrils may be modifications of *petioles*, *leaves* (or portions of leaves), *flower-stalks*, or *stipules.* Sometimes the *branches* are so modified as to become tendrils. In some cases authorities are in dispute over the homological nature of certain tendrils. These we shall do wisely to let alone, confining our remarks to such tendrils as those whose homology is pretty clearly made out.

I can only in such a paper as this give the merest outline of the facts and functions of tendril life—a sketch of the more prominent and interesting points, referring the reader to pages 84—182 in Darwin's book for fuller detail, pages well worth diligent study and verification.

1.—*Tendrils which are modified Petioles.*

Of these a good example is that of *Lathyrus*, the Yellow Vetchling. There are no true leaves, their places being functionally supplied by large stipules. The petiole, or perhaps this and the mid-rib as well, is converted into a true tendril, sensitive chiefly on the concave side at the end. It does not revolve, but the young internodes do so, carrying the tendrils with them.

2.—*Tendrils which are modified leaves.*

Several orders contain examples of this type of tendril. A familiar one is *Pisum sativum*, the common Garden Pea. Here the leaf has a few pairs of leaflets, one or two pairs of tendrils, and a terminal one, often branched—*i.e.*, some lateral leaflets and the terminal ones are changed into tendrils. The young internodes and the tendrils revolve in ellipses. The motion in this case is independent of light, the latter neither retarding nor quickening it. When young the tendrils are sensitive to so small an irritant as a loop of thread one seventh of a grain in weight—*i.e.*, on their concave surface only.

Many other examples could be quoted. The *Bignoniaceæ*, or Trumpet-flower Order, furnish perhaps the best. Darwin made extensive researches on many species of *Bignonia*, which I cannot stay to quote now. Some species have tendrils with claws like those of a bird, highly sensitive, and capable of such firm grasping that Darwin says these species could probably ascend a highly polished stem, even when tossed by storms. The claws end in hooks, which, of course, increase the power of the grip. *Bignonia Tweediana* can twine, has clasping petioles as well as hooked tendrils, and moreover presently emits aërial roots from the bases of its leaves, which curl round the support. It thus very curiously unites four different movements of climbing plants, viz., twining, leaf-climbing, tendril-climbing, and root-climbing.

" One species climbs by spirally twining and then by grasping the stick with opposite tendrils alternately, like a sailor climbing a rope, hand over hand. Another pulls itself up like a sailor seizing with both hands together a rope above his head." Others develop an instinct for inserting the sharp ends of their tendrils into chinks and crevices of wood, or any other support which may possess these, sometimes prying into one hole, and, finding it not to its liking, seeking another ! In *Bignonia capreolata*, after the tips had crawled into the crevices, or the hooked ends had seized on a projecting point, the tips began to swell for two or three days, and then to form whitish balls or discs, one twentieth of an inch in diameter. These secreted a viscid matter, which would firmly glue together 50 or 60 fibres of flax or wool in a mass. This power is used naturally by this species to fasten itself to the forest-trees of North America, which are covered with mosses, lichen, and other rugged and rough organisms.

3.—*Tendrils which are modified flower-peduncles.*

Excellent examples of such tendrils are seen in the Vine, the Virginia Creeper, and the Passion-flower. The first two belong to one order, the *Vitaceæ.* In these the action is much the same as in the cases of tendrils which are modified leaves

In the Vine the tendril is two-branched, one branch always having a scale at its base. Rubbing causes the branches to bend, but they will afterwards become straight again. A tendril clasping any object contracts spirally. Of this, later on. There is clear spontaneous movement in the tendrils. We can trace every single stage of gradation from the state of flower-stalk to that of a true tendril; from one bearing 30 or 40 flower-buds even to a full-sized perfect tendril bearing one flower-bud! Hence we cannot question the nature of the tendril in the Vine. Where the flower-stalk and the flower-tendril exist together, the latter is always at such an angle with the former that it assists later on in carrying the burden of the fruit.

In the Virginia Creeper there is no revolving of either internodes or tendrils; only a movement away from the light to the dark, a process seen in several tendril-bearers. The tendrils are specially adapted for attachment to a flat wall or other surface by bringing their hooked tips into contact with it. These then develop the well-known discs or cushions of a bright-red tint. These undoubtedly secrete a viscid fluid, inasmuch as they can cling to smooth polished surfaces, such as an Ivy-leaf or painted wood. Warm water with dilute acetic acid and alcohol will not loosen any flinty particles that may have become attached to the discs, but warm, essential oils will loosen them entirely, pointing to a resinous fluid as the one secreted. Discs are not developed except under the stimulus of contact. The attached tendrils contract spirally; unattached ones do not, but in time shrivel up and drop away. The spirally-contracted tendril becomes very elastic. At first it is brittle and weak, but soon acquires strength and increases in thickness. It dies during the next winter, but adheres firmly, although dead, to the wall and to its own stem. Such tendrils will remain like this for 5, 10, or 15 years! Darwin found that a single disc-bearing branch would bear a strain of two pounds; a whole tendril, usually carrying five branches, would therefore endure a strain of ten pounds!

Of the Passion-flower I can only say that *Passiflora gracilis* was found by Darwin to exceed all other climbing plants in rapidity of action, and all tendril-bearers in the sensitiveness of its tendrils.

4.—*Tendrils which are modified Stipules.*

I simply name one case—*Smilax aspera*—where this occurs. Their position places the matter beyond doubt. As they grow they diverge from each other, and are thus enabled to clasp an object *behind* the stem. They avoid the light, and do not spirally contract. Neither they nor their internodes revolve. *Smilax* is in all respects an imperfect climber. There are no tendrils in the young state; the stem is zigzagged and furnished with spines, growing only to some eight feet high. The reason of the existence of these tendrils is not easy to explain. Darwin regards it as a kind of degraded relic of a genus formerly possessing highly organised tendrils, seeing that even now some species have much longer ones than *S. aspera*.

A few isolated and brief remarks on tendril-life as a whole must close our somewhat rambling study of this class. In most tendril-bearers the young internodes revolve in ellipses, varying in rate from one to five hours, a smaller range than that of twiners. Twining power is almost *nil*, but the revolving motion serves to aid the tendrils in finding support. Tendrils themselves revolve spontaneously in most cases, sometimes *with* the internodes, sometimes at slower speed; some do not revolve—*e.g.*, *Lathyrus*, as we saw just now. In one case—the Virginia Creeper—neither internodes nor tendrils revolve.

Tendrils revolve by curving of the whole length, except the base and tip. The movement is due to unequal growth travelling round the tendril and bowing it, a process we saw before in the twining stem. To this cause is due not only revolution, but movement to and from the light, and spiral contraction.

Darwin thinks that motion following touch in tendrils is due to contraction of cells on the concave side ; a point on which he differs from Sachs, who attributes this motion, as well as all others, to the unequal growth spoken of.

Tendrils, when revolving, manage, in a way very wonderful to see, to avoid clasping the stem to which they belong (Gray).

All tendrils are sensitive, the degree, of course, varying. They curve towards the side touched. Usually they are not sensitive to the touch of other *tendrils*, or of *water-drops*. Has the latter fact anything to do with their relation to showers of rain ?

Some tendrils are retarded in their movement by light, others quickened ; others, as those of the Pea, not influenced at all. In some the invariable bending from light to dark is as certain as that of a vane from the wind.

Tendrils contract spirally when their ends are caught by any object. This shortens them, and renders them elastic. This spiral contraction is almost without exception ; it may ensue in the branches only, as in the Pea ; in most cases, the base does not contract.

It is due to unequal growth. It is independent of revolving motion, and not necessarily related to the act of clasping, since many tendrils unattached perform this act either as a helix or as a spire *(Passiflora)*. In this case there is only *one* spire formed, but in attached tendrils the spire is always double and reversed, with a straight part between the two spires. There is, of course, a simple physical reason for this, into which I cannot now enter more fully. (" Climbing Plants," pp. 166—169.)

For a summary of the use and service of contraction, I refer the reader to Darwin's own words ("Climbing Plants," pp. 163, 164).

III.—Hook-Climbers.

Examples are seen in *Galium aparine*, Brambles, and some Roses. There is no revolving power, the plants climbing solely by the hooks. *Smilax* and Hop, belonging to former classes, have hooks.

IV.—Root-Climbers.

Of these, Ivy is a very good type. *Rhus*, or Poison Ivy, is another. *Ficus repens*, a species of Fig, emits drops of viscid fluid to assist its upward progress. *Cuscuta* (Dodder) has root-like suckers used for a similar purpose.

Sutton, Surrey; July, 1886.