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XLII. *On Divergence as the Cause of Motion in Plants.* By
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IN a former communication I have given a description of the phænomena of *divergence*, and I have endeavoured to prove the analogy of this property to the irritability of the animal system†. I shall now attempt to show that the cause of divergence is the cause of the motion in plants.

I do not think it necessary to enumerate the many instances and varieties of vital or other motion which are met with in works on vegetable physiology. Instead of extending my remarks to vegetable motion in general, I shall at present confine my observations to one kind, which, from its frequent occurrence and the very obvious nature of its effects, is particularly well suited to experimental illustration.

It seems to be essential to the healthy condition of most plants, that the upper surface of their leaves or their blossoms should be exposed to the light of the sun. I think, indeed, that there are very few, if any, of the more perfect vegetables, to which it is immaterial whether their leaves and flowers be exposed to the light or not. Such plants have, therefore, been endowed with the power of directing these parts to the light, and this motion is effected by a curvature of the stem, leaf-stalk, or flower-stalk. If a young sunflower or hollyhock be laid prostrate, the stem curves, and the apex becoming erect, the leaves are again placed in their usual relation to the rays of light. Where the stem is rigid or fixed, it is the leaf-stalks which perform this motion, as in ivy, of which I have seen the leaf-stalks contorted in the most extraordinary manner from their efforts to bring the glossy surface of the leaves under the influence of the light. I remember to have observed a *Campanula* which had been blown down by the wind, and the stem of which being too rigid and ligneous for it to be capable of curvature, the flower-stalks became curved, so as to erect the fruit, present it to the light, and preserve it from the humidity of the soil.

That motion of vegetables by which they regain the erect posture when laid prostrate, or direct their leaves towards the light, (with the exceptions afterwards to be mentioned,) is always attended with curvature of the stem, leaf-stalk, or flower-stalk; and I proceed to state the experiments and observations which convince me that the property of divergence is the essential cause of this curvature and the consequent motion above described.

* Communicated by the Author.

† See Lond. and Edinb. Phil. Mag., March 1835, vol. vi. p. 164.

I. *Effects of dividing a Stem which has undergone Curvature.*

Exp. 1.—A Jerusalem Artichoke (*Helianthus tuberosus*) was tied down horizontally to a stick. In twenty-four hours the stem had curved, so that its head was directed perpendicularly upwards. The stem was then divided at right angles to the direction of the curvature. The annexed sketch (fig. 1.), a faithful copy of one traced from the plant itself, represents the appearances before and after division. The letters *a, b, c* mark the curved stem previously to division; *d, d* the upper, *e, e* the under or outer, segment after division. The former has become more, and the latter less, curved than the original stem.

Fig. 1.

Helianthus tuberosus.

Exp. 2.—Another stem of the same plant was tied down as in the above experiment. In fifteen hours it had made a neat and obvious curve upwards. It was cut down, and the extremity and curved part were found strongly divergent on division. The upper segment became still more arched than before, whilst the lower lost its curvature and became almost straight.

II. *Effects of removal of upper Segment.*

Exp. 3.—A healthy stem of Spearmint (*Mentha viridis*) growing very erect, was carefully pegged down in a horizontal position. I then cut away the upper side for about the space of one inch and a half. The lower segment immediately hung down almost vertically. At the end of three days this plant died, the mutilated part not having at all curved upwards; but the uninjured part of the stem below had arched irregularly so as partly to erect the stem.

Exp. 4.—Two healthy stems were divided down the middle to the distance of some inches. By means of pegs they were firmly fixed down on the ground, the upper segment having been removed in each. They did not begin to turn upwards until five days after.

III. *Effects of Notching.*

Exp. 5.—Two Jerusalem Artichokes, nearly of the same size, were secured, in the same inclined position, each to a separate stick fixed in the ground. The one was then notched

on the under, and the other on the upper, side. Both immediately became slightly inclined towards the entire side. The effect was still more marked on the next day; and on the third they were both "nodding," as it were, towards the uninjured side.

Exp. 6. (Sept. 15.)—Two stems of the Jerusalem Artichoke were tied down horizontally, and all leaves removed except the terminal bunch.

In fig. 2. several notches were made in the upper side, and it became immediately slightly bent downwards. In fig. 3. the notches were made in the lower side, and it retained its position unchanged. Next day (Sept. 16), fig. 2. was much more curved downwards, and fig. 3. distinctly arched upwards. On the 17th the extremity of fig. 3. was again directed upwards. The other was still horizontal.

Sept. 21. That notched on the under side (fig. 3) was curved more than enough to make its head erect. The other, notched on the upper side, (fig. 2.) was now almost upright, but rather less arched than the first.)

Fig. 2.

Fig. 3.

Exp. 7.—A very young stem of Jerusalem Artichoke was tied down, and the stem then notched on the upper side. The notches were made near together, and pretty deep, the leaves having been previously removed. The head immediately hung downwards. In twelve days it was cut down. Though the position was somewhat changed, its power of erecting itself seemed to have been destroyed. The notched part still inclined downwards, and not even the apex was turned upwards.

IV. *Parts which are not divergent are not capable of Motion.*

a. The living sprays of all trees, and all herbaceous stems which have become rigid and acquired ligneous matter, are, I believe, invariably incapable of raising themselves up by curving, if laid down, and they are not divergent on division.

b. Many plants which whilst young were capable of motion and divergent on division, lose the property of diver-

gence, and with it the capacity for motion, when they become old, as after flowering.

Exp. 8.—I bent down two spikes of Lavender (*Lavandula Spica*), the one being a very young one not yet in flower, the other almost out of flower. The former raised itself up again, the latter did not. The former was divergent, the latter not.

c. Whilst engaged in the experiments of which I am now giving an account, it was my constant practice to carry a lancet about me, and on every known plant which occurred in my rambles to try the effect of that simple experiment by which it is ascertained whether a plant be divergent or not. The list of plants in which this property was so detected is, as before stated, too long for insertion, but I shall enumerate the principal exceptions, which are not numerous.

1. *Juncus conglomeratus*. Probably every species of Rush.

2. *Iris Pseudacorus*; the leaves divided lengthwise through their narrow diameter.

3. Garden Carnation (*Dianthus*); the flower-stem.

4. Indian Corn (*Zea Mays*?), culms of Wheat, and other Grasses.

Now, it is a most curious fact, that none of the plants or parts of plants above mentioned curve up like ordinary divergent vegetables. It is immaterial to the different species of Rush in which position their green culms be placed; and they are therefore not endowed with the power of raising themselves up when laid down. Besides, from their great flexibility and slender form they are little exposed to this accident, and have plenty of successors or neighbours which, springing up around them, supply their place, if they be destroyed.

2. The leaves of *Iris*, so far as I have been able to observe, are equally incapable of vital motion as they are of *curving*, and they are destitute of divergent power, except when divided through their long diameter.

3. Every monocotyledonous plant with a jointed stem is either destitute entirely of divergence, or possesses it only in a slight degree; and they are equally without the capacity of curving their stems. Let a culm of one of the *Gramina* be pegged down horizontally on the ground, and it will gradually raise itself up. But this is not done by curving the stem, as in other plants, but the joints assume an angular figure, and thus the stem becomes erect, as seen in the drawings of a gigantic grass, the Indian Corn plant. See figs. 4 and 5. (next page.)

It is perfectly evident from this, that the moving power resides, not in the stem generally, but in the neighbourhood of the joints. And as the intermediate space (except when very young) is not divergent on division, we have here, in my

opinion, a most curious and unexpected illustration of the theory which I have been attempting to prove.

Let us now review the facts and experiments which have been adduced, and see what may be reasonably made out from them.

It has been proved by dividing the stem of a plant which has already undergone curvature upwards, (Exp. 1. and 2.) that both the segments are endowed with the property of divergence.

It is evident also from the same experiments, that the lower segment cannot contribute to this motion, as any effect which it may have must be greatest in an opposite direction.

The motion or curvature upwards must therefore depend on the other, the upper segment; and when we see the great, the excessive force with which the upper segment retracts on being freed from the antagonism of the lower segment, we can hardly fail to believe, that in this retraction (or rather in its cause) we have discovered an adequate, and I think the true source of the motion.

Hence, I come to the conclusion, that the kind of motion here treated of is the result of the contractile force or divergence of the upper segment prevailing over that of the lower.

Fig. 4.

Fig. 5.

It will, no doubt, immediately occur to the reader, that to substantiate the above inference it is incumbent on me to show, that removal or destruction of the upper segment is followed by loss or diminution of the power of curving upwards. Now although, on account of the facility with which new matter (probably endowed with moving fibres) is added to mutilated plants, it be very difficult entirely to prevent stems curving upwards by removal of the upper segment, yet I have occasionally seen the experiment succeed, and I can confidently affirm, that the process, if not prevented, is much retarded, and of this fact the experiments above described are a sufficient proof. In Exp. 3. the part of the stem of Spearmint from which the upper segment had been removed had not curved upwards at the end of three days, and in Exp. 4. this action did not begin until five days after. In the natural state this would certainly have occurred in about twenty-four hours.

We conclude, then, that as in the first series of experiments the cause of motion was traced into the upper segment of a divided stem, so we here find that removal of this part *prevents* or *retards* the same motion.

The experiments on the effects of notching curiously confirm and illustrate the inferences drawn from the preceding experiments.

By the process of notching, we artificially weaken the contractility of one side, and enable that of the other to exert itself so as to arch the stem. In this way curvature or motion in almost any direction may be produced at will, as in Exp. 5. Exp. 6. shows the effect of notching in delaying the motion upwards; one stem notched on the upper side was still horizontal on the second day after the operation.

In Exp. 7. the process of notching has so completely destroyed the action of the upper portion of the stem, that at the end of twelve days the stem was still inclined downwards, and even the apex was not turned upwards.

If anything more be necessary to establish the fact that divergence is the cause of the motion in plants here treated of, it is to show that the want of this property is attended with the want of the power of motion. And this I think is clearly made out by the facts stated in section IV.

I have thus endeavoured to trace a certain kind of vegetable motion to that property which I have termed divergence, the analogy of which to irritability or contractility I have laboured to prove, 1st, by its supposed vital nature; 2ndly, by its being sensible to stimulants; and 3rdly, by its being the cause of vital motion.

Shrewsbury, July 18, 1835.

HENRY JOHNSON.