V.—*On the Structure of some Tissues possessing Hygrometric Properties.* By E. J. QUEKETT, F.L.S., F.B.S., &c.

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THE observations contained in the following communication, will be found to have reference to the effects of *moisture* and *dryness* in causing various alterations in the form and conditions of many of the organs of plants, in the recent as well as in the dry states; and also it will be attempted to be shown that there is some peculiar structure and arrangement of the tissues in those parts where these effects are most manifest.

That there are hygroscopic properties in the tissues of plants cannot be doubted; and that these properties are not universal throughout the vegetable kingdom is also evident, by the fact being shown only in plants of particular orders, and in particular parts of various plants of all orders. As this quality is not general but special, it must be regarded in the light of an attribute of the plants so endowed by which they are enabled to exercise particular functions through this property, which are of essential importance in their economy.

Numerous are the instances where the abstraction from, and the addition of water to, portions or to some entire plants, exerts singular effects, which are found to be occasionally the very opposite in one part to that which happens in another; for instance, the application of moisture will cause a contracted portion to expand, and it will also cause a closed organ to open: the drying of the tissues will also effect the same changes, causing some organs of plants to open, and those which moisture opens to contract.

Instances of the first effects are very readily witnessed in the *mosses*, which, notwithstanding they may have been dried and shrivelled for very many years, yet when moistened they put on the appearance and characters of living specimens; some have even supposed that life is not extinct in these plants, after many years have been passed in this dry condition. There can be no doubt that this hygroscopic property of the tissues of mosses is a special provision, as they are destined to be in perfection in the winter months, and ripen in that season the means for their propagation; so that in the summer months, when the increased temperature quickly evaporates the moisture from their delicate cellular tissue, they shrivel and wither, yet they do not perish; but on the first rainy season of autumn they rapidly absorb the moisture that falls upon them, their tissues becom-

ing distended, and they again are prepared to go through the periodic performance of those functions which nature has assigned to them.

Other instances of this kind are found in the lowest tribes of Algæ, as in the *Gloiocladeæ*, which also will resume an apparently fresh state even after being dried for years.

One of the most beautiful however is to be seen in the *Lycopodium lepidophyllum* from Peru, where moisture has the twofold effect of expanding the contracted plant, and stimulating its dormant vitality.

Numerous are the instances in which moisture exerts similar effects which could be mentioned; but enough have been brought forward to illustrate the fact.

Examples where moisture causes closed seed-vessels to open are not so numerous, but Decandolle mentions that DeFrance has observed that the seed-vessels of *Epilobium*, and some other genera of the *Onagraceæ* (Evening Primrose tribe), expand when saturated with moisture and close when dry; which fact I have found to be correct in some respects. The seed-vessel of the *Mesembryanthemum* or Fig-marygold exhibits also, we are told, the same phenomenon.

The instances where the dryness of the tissues or the abstraction of moisture causes a separation and an opening of the cavities of seed-vessels and other organs, are exceedingly numerous; and some of the most beautiful contrivances have been contemplated by nature to perform various functions consequent on the changes these organs undergo, when the aqueous contents are abstracted from their tissues by that law which is impressed upon them, and operates in the season of the maturation of the fruit.

To bring forward instances of this nature, I shall select only the most common examples in which the effect of dryness in the tissues has the property of preparing the way for the dispersion of the seeds. If a poppy-capsule be examined when ripening, numerous valves or trap-doors can be discovered beneath the radiated crown, which are intended to give exit to the numerous seeds within. If the ripened seed-vessel of the *Rhododendron*, or that belonging to any of the species of *Dianthus*, *Silene*, *Cerastium*, *Geranium*, *Erodium* or *Cardamine* be examined, there will be found beautiful contrivances in all these for effecting the dispersion of the seeds by loss of moisture.

In all these examples this act is performed gradually and silently, but in some particular plants it is accompanied by a very loud report, and the seeds are violently ejected. This happens in many species of *Banksia*, and still more remarkably in *Hura crepitans*, the sand-box tree of the West Indies.

Besides these contrivances for dissemination, such as *valves*, *springs* and *explosions*, many others may be noticed of an hygroscopic nature; but amongst the various contrivances none can scarcely exceed the ingenuity displayed in those parts which are destined for aerial flights, and which cannot be exceeded by the skill of the aéronaut: notwithstanding Nature does not inflate a hollow bag with a buoyant gas, still she fabricates a machine which is capable of being wafted on the lightest winds, carrying with it a parachute containing the living germ to ripen its produce in some distant spot; — such contrivances being mostly manifested in the *Compositæ*, and especially among the *Thistles*.

There is another act performed by the aid of moisture and dryness which approaches somewhat near to locomotion: this occurs in the fruit of *Erodium*, and in the parts surrounding the fruit of *Avena fatua*, commonly known as the “*animated oat*,” where, by the twisting by dryness and untwisting by moisture of the awn, change of place is the result.

Notwithstanding the parts selected here as examples are entire organs, and where the hygroscopic action is most marked, still all parts of plants and all tissues are more or less susceptible of absorbing a certain amount of moisture, which causes an increase in their bulk. This is seen in woody portions, as in doors, which close well enough in summer, but are so enlarged by the damp of winter as to be closed with difficulty, yet regain their natural size on the return of the dry season. This reciprocating condition of ligneous parts has been satisfactorily and ingeniously shown by Mr. Edgworth, who has contrived to convert this alternate state of expansion and contraction into a power acting in one direction, and thereby he has contrived to convert a peculiar form of *wooden stool* into a locomotive machine.*

Enough has been said to establish the broad principle of the hygroscopic properties of vegetable tissues in particular instances, and in the next place it becomes necessary to examine if, where these characters are so evident and accompanied with such marked effects,

* The stool was made of wood that absorbs moisture readily (deal cut endways from the plank was used by the author), and into it fixed four legs, inclining all in one direction, at about 20° with the top, each terminated with a point of metal, which, from the inclination of the legs, would only allow the stool to be moved in one direction. As it expanded by moisture it would cause one pair of legs to recede a small space from the other, and when it contracted, the legs that first receded could not be again brought to the spots from which they moved, but the legs which remained fixed by expansion now will be moved by contraction, and by the changes occasioned in the wood by expansion and contraction, caused the stool to move always in the same direction.

there can be discovered by the microscope anything in the arrangement and nature of the tissues of those parts which exhibit the above alterations and separation of their several portions, that will account for these changes satisfactorily.

In plants like mosses or other vegetables which merely expand and contract by the application of moisture, without disturbing the relation the several parts bear to each other, nothing can be seen in such beyond the ordinary character of cellular tissue, and in all probability the avidity for water in these plants depends upon some different chemical characters of the tissues themselves, when contrasted with cellular tissue not so hygroscopic; this power of absorption being always most in new, and in those tissues which are devoid of deposits.

When however other examples are examined where evident displacement or separation of parts obtains, and this always in the same direction and attended always with like results, then it can be discovered that not only is the tissue more hygroscopic at that part, but the arrangement is such as to ensure the effect nature has intended. Let us take, for example, the capsule of some plant of the order *Caryophyllææ*, as *Cerastium*, and it will be found that when that organ approaches maturity, the apex, which was pointed and entire, will open by splitting into five equal valves, which curl outwards, making one complete coil, and always in the same direction; by the application of moisture the valves will resume their original position, and when dry take on the curled form again.

If one of these valves be examined it will be found to be thin and diaphanous where it forms part of the body of the capsule, but where it is hygroscopic it is horny and opaque. When a section taken from the edge of the valve or curled part longitudinally is examined by the microscope, it will be found that the tissues will be different on the exterior and internal surfaces, both however cellular; but the inner layer, or the cells of the convex border, are of different dimensions from the outer, being neither so large nor having so thick walls, (though they are thicker than ordinary cells); whilst those of the outer layer are almost solid, and the only cavity they have is indicated by thin spaces between a series of lines, the chief one of which is in the direction of the longer axis of the cell, the others connected to it at right angles. These cells are of most curious structure, and form an interesting object for the vegetable anatomist.

In this arrangement of parts it must be evident that by the shrinking of the tissues of the seed-vessel by loss of moisture, there will occur unequal contraction, and that side will be curved which con-

tracts the most forcibly, and by this curvature one valve must necessarily be removed from the next, evidently showing that the tissues act as unequal antagonists to each other.

A very analogous effect can be observed in the species of *Geranium*, which, if examined before the fruit is quite ripe, will be found to have the several carpels attached to the base of an elongated receptacle, and the apices of each (styles) to be attached to its whole length. When maturation arrives, by the loss of moisture the lengthened apex of each carpel evinces a tendency to be curved outwards, and this tendency increases to such extent, that ultimately it overcomes the adhesion which existed between the receptacle and itself, excepting at the point, and separates from it with considerable elastic force, and ejects the seed from the carpel through a naturally formed aperture, at the same moment when it assumes a curved form, still maintaining adhesion by its apex to the receptacle.

If this elongated portion of the carpel be examined, either by making a transverse or longitudinal section, which can be well done in *Geranium sanguineum* or *dissectum*, it will be readily seen that the part which curves is composed of two tissues of different colours and densities, the most dense being situated externally and on the concave face of the organ; the effect being exactly similar to that produced by riveting together a flat piece of brass to a similar piece of steel, and exposing the whole to the same temperature. As these expand unequally when heated together, a curvature is formed, the convexity of which, of course, will be on the side of the most expansive metal.

The elongated beak of the carpel of *Erodium cicutarium* and other species is, like the *Geranium*, attached to an elongated receptacle, which it leaves not by a sudden elastic spring, but by the carpel becoming detached first, and then the apex twisting several times, until at last it separates itself from the receptacle. In the structure this elongated portion of the fruit is somewhat like the *Geranium*. It presents in the transverse section an elliptical outline, and exhibits on one side a tissue composed of woody fibres, with extremely thick parietes, there being scarcely any canal in their interior, and on the other a still more dense tissue; at the spot where these tissues unite the fibres possess a greater canal and a looser character, which appears a change gradually effected on one side only, for where the fibres possess the greatest calibre, there is no gradual diminution towards the other of their thickness.

The organ is not composed equally of the two kinds, but one occu-

pies about four fifths, the other the remainder; if these tissues of unequal density occupied an equal share of the organ, a strong curve would be the result; but as the *Erodium* has no aperture to eject the seed if there were a sudden jerk attending its separation, that act is not required, consequently the apparatus for disengagement is somewhat modified.

It appears from observations that besides this arrangement for producing an alteration of form, that there exist some peculiar hygro-metric properties; for when longitudinal sections of this portion are placed under the microscopic and water is added, they do not appear to expand equably, one side expanding before the other, and appearing to slide in advance of it. If this be the case in the entire organ, it is readily seen that it is obliged to accommodate itself to the spiral form by losing the moisture from its tissue.

By far the most curious set of hygroscopic actions are manifested in the expansion of the *pappus* or seed-down of some plants belonging to the order *Compositæ*. The calyx of the florets of these plants does not put on the leafy character common to most flowers, but is composed of many curiously constructed feathery hairs, which appear to be the representatives of that organ in a very rudimentary condition; and by the design of Nature is destined to serve a most curious part in the dissemination of these plants. When the seed-down of *Cnicus eriophorus* is examined in its natural situation, it is found to be arranged on the apex of the fruit, like the hairs in a pencil brush, crowded amongst hundreds belonging to other florets, and so compressed by those by which it is surrounded, as to be unable to expand the numerous parts of which it is composed; but by the continued drying of the tissues the whole mass of seed-downs partakes of the same struggle to expand their rays, and coupled with the contraction of the receptacle on which they are situated, the numerous mass becomes at length detached. When freed from the pressure of each other, the heat of an autumn day causes the expansion of the several filaments, which, radiating from the same centre, soon arrange themselves into a globular figure, the seed being attached to the centre. In this state each becomes the sport of the wind; the passing current wafting it from its place of birth, bears it away, and it obeys the dictates of the element till the breeze slackens, when it descends slowly to the earth, and if the place of its descent be charged with moisture, then its career is stopped, that becoming either the place of its growth or of its destruction.

Such is the nature of the office of this seed-down, but the most in-

teresting part is to determine in what manner this appendage to the fruit is converted by a little sunshine or increased temperature into a globular shape. My attention was given to this subject from observing so many of these spheres floating in the air in the most dense parts of this metropolis in October last, which showed how perfectly the apparatus which Nature had contrived answered the purpose, for it must be evident that they must have grown many miles from the heart of the city, where several specimens were taken whilst descending to the earth.

It was imagined at first that the mechanism was something similar to the spines of an *Echinus*, being articulated to the apex of the fruit, and when the fruit contracted by drying the points of attachment became more approximated, and caused the several rays to expand;—but on more minute examination it was found that the seed-down was not connected directly with the fruit, but all its rays were attached to a ring, which was easily separable, together with the entire apparatus, from the fruit, and still was capable of expanding and closing precisely as if it remained in its natural situation. In *Leontodon* and *Tragopogon* the pappus is elevated on the attenuated apex of the fruit.

To account for the radiated expansion of the filaments, seated around a thin ring, was still more difficult; which, on examination by the microscope, appears to be composed of minute granular cellular tissue, constituting a narrow band which connects the bases of the rays. On looking at the structure of the rays themselves, they were found to be composed not of one simple feathery hair, but that numerous fine hairs were condensed into a bundle, and the apices of the whole becoming detached at unequal heights, caused the feathery structure on their exterior. On examining the connection of the base of each with the ring, it was found to be wedge-shaped or conical for a slight distance up the shaft.

When these several parts are in their natural position, before expansion, it is not impossible, I conceive, that the shafts of the rays touch each other for some distance, and that the conical ends are therefore a little removed from each other; when the moisture has been dissipated the ring contracts, and by so doing brings the conical ends of the rays into close contact, and they are obliged to assume a circular arrangement by the extremities diverging and the bases approximating each other, like the wedge-shaped stones of an arch. If this force, which acts horizontally, be imagined to act also in every vertical plane, we may then have the several rays taking on the figure of the specimen. By the application of moisture the ring expands,

and the rays collapse to their original position. Notwithstanding this mechanical explanation may account for the fact in some way, yet some of the rays take occasionally a direction that leads me to believe that besides this force arising from the hygrometric nature of the ring, they possess in their structure individually hygroscopic properties, and are capable, like the *Geranium* and others, of moving and taking a definite direction by the loss of moisture.

The above instances, though numerous others might be selected, give illustrations of the action of the evaporation causing the separation of parts, opening of valves, and the expansion of various organs of plants, but it happens in the species of *Epilobium* and *Oenothera*, that moisture performs the same part. In these it will be found that tissues having different contractile powers are opposed to each other as before, but in the reverse method to that which has been described.

Such are sufficient examples to prove that wherever change of position or form occurs by moisture or dryness, there is some peculiar structure of the part; — the tissues having different hygroscopic properties, and these tissues so arranged as to be antagonists to each other. For if there were not this antagonism, the parts being composed only of one tissue of uniform density, there would be merely shrivelling in length or thickness, and we should never find spiral or curved portions in any organ occurring from loss of moisture. Whilst these several parts are young, no displacement occurs, the balance of this power in the tissues being preserved, but as soon as the equilibrium is disturbed, then the effects before mentioned ensue.

To account for these actions consequent on the hygroscopic properties the theory of *endosmose* has been brought forward, which is ingenious, and would be satisfactory if the arrangement of parts were always in accordance with that theory; when dryness performs the duty, we should expect the dense tissue to be on the *reverse side of the curve to which it is found*.

If we examine the section of the valve of *Cerastium*, it is seen that the most dense tissue is on the concave surface, the same in *Geranium*: yet the application of moisture straightens these organs instead of increasing the curve; consequently endosmose will not explain the phenomenon in all instances.

When in those organs which, by loss of moisture, have the concavity of the curve on the side where the tissue is most dense, one of two circumstances must happen in producing it: — 1. Either that the natural condition of the dense tissue is elastic, and having a tendency of its own to bend, and when not opposed by a counteracting force

(as by the looser being charged with fluid), it then coils as a spring—or in the other case, by both tissues losing their moisture, the denser contracts the most forcibly and the curve is toward that side where it is placed. By the addition of moisture the elasticity of the denser is destroyed, and the filling of the cells of the looser restores the equilibrium and the parts regain their natural position.

When we consider the nature of this power,—its various degrees from being barely perceptible until it alarms us by the violence of its reports, and reflect what its effects are and in what parts of plants it is generally to be observed, which will be the most frequent in the organs of reproduction; one is almost led to believe it to be a power given to plants, which is in some measure the representative of the muscular system in animals: for if in plants we discover any change of place of an entire plant, or of any organ, so as to alter its position or remove it completely from the parent, though it is but a feeble act of locomotion, yet it is performed by this power, and almost the whole of the numerous means of promoting the escape of seeds from the seed-vessel depend on the separation of the parts by means of their peculiarly adapted structures.

Besides these properties there can be no doubt that this same power is employed under vital agency, in regulating elasticity, expansion of flowers, opening of the anthers for the dispersion of the pollen, and other functions which are hidden from our examination.

The marked effects which have been mentioned are only a few that have been selected on account of the instances being so well known, but others are to be found with the greatest frequency; scarcely can a plant be examined in which these actions are not evident in some parts of its structure; each of which forms but another instance of the wisdom and intelligence displayed in the structure and contrivances exhibited in the vegetable creation.