

Experiments on Dionaea muscipula (Venus' fly-trap) / by Thos. A.G. Balfour.

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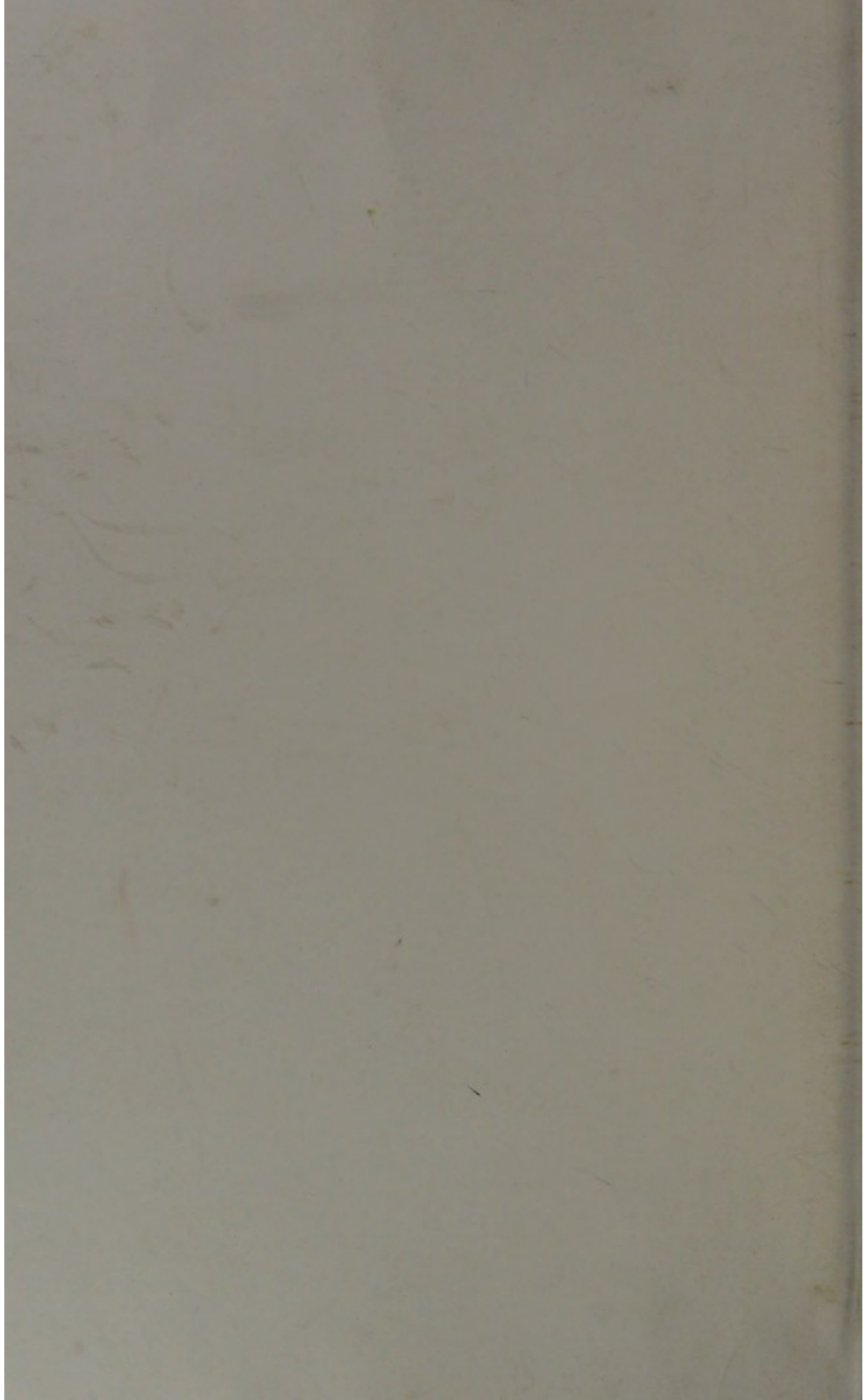


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EXPERIMENTS

ON

DIONÆA MUSCIPULA

(VENUS' FLY-TRAP).

BY

THOS. A. G. BALFOUR, M.D.

F.R.S.E., F.R.C.P.E.

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MDCCCLXXV.

I. *Account of some Experiments on Dionæa Muscipula*
(*Venus' Fly-Trap*). By THOS. A. G. BALFOUR, M.D.,
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My attention was specially directed to the subject of Dionæa, Drosera, &c., by certain articles which appeared in different journals, containing interesting accounts of what had been done in regard to these plants, and of the curious results which had been obtained. Some of these notices had an air of truth about them, while others seemed indebted for their existence rather to the vivid imagination of the

* I was much obliged to the Regius Keeper of the Garden for the opportunity of carrying on my experiments there, and I have also to acknowledge the considerate kindness of Mr M·Nab, and the valuable assistance rendered by Mr Robert Lindsay in conducting the experiments.

writer than to careful scientific observation. The interest, however, attaching to the whole subject was such that I felt most anxious to test for myself the truth or otherwise of the observations recorded.

My observations are not complete, and though in some cases they refer to points which have been already carefully studied by others, the present paper also contains some original and independent observations, and hence may not be altogether wanting in scientific interest.

In dealing with my subject I shall regard the Venus' Fly-trap (*Dionæa*) as a carnivorous plant, and I feel warranted in doing so by the opinions expressed by those who have made this plant the subject of careful study. Ellis was one of those who, about a hundred years ago, brought the peculiarities of the plant under the notice of Linnæus, &c. His letter to that famous botanist gave an excellent description of the structure and functions of the leaf, erring only in one or two points, such as in believing that the fluid secreted by the leaf was a kind of nectar to allure insects towards the sensitive part of the leaf, and in attributing to the hairs the power of transfixing the body of the captured insect. His opinion, however, was that the insect was made subservient to the nourishment of the plant.

Dr Curtis seems to have been the next observer. He resided at Wilmington, North Carolina, where he had abundant opportunities of observing the plant in its native habitat. About forty years ago he gave an able and accurate account of it, and while he corrected Ellis' mistakes regarding the time when the secretion was poured out, and showed the sensitiveness of the plant to reside in the hairs, he believed with Ellis that the plant fed on the entrapped insect.

Mr Canby, about seven years ago, while living at Wilmington also, confirmed the opinion of Ellis and Curtis as to the animal diet of the *Dionæa*.

Mr Darwin holds a similar view, and when we know that for six or seven years this distinguished naturalist has been studying the subject, and recall his wonderful and minute powers of observation, his great practical sagacity, and the fertility of his resources in devising experiments, we must attach no ordinary importance to the researches which I trust he may soon give to the world.

Dr Hooker has also stamped this opinion with the weight of his deservedly great name in the address which he delivered in August last to the British Association.

In speaking of the carnivorous habits of the *Dionæa Muscipula*, I shall divide the subject into the five following heads:—1. Irritability; 2. Contraction; 3. Secretion; 4. Digestion; 5. Absorption, including assimilation. It may seem unphysiological to place secretion and digestion under separate heads, but there are some who admit the existence of the former, but deny the latter; hence I treat of them separately.

1. *Irritability*.—This is a wonderful property, not confined to *Dionæa*, but existing in the leaves of many plants, specially of the natural order Droseraceæ, to which the *Dionæa* belongs; also in the Leguminosæ, especially in the common sensitive plant of our hot-houses (*Mimosa pudica*), and among the Oxalidaceæ, but in a peculiar degree in the sensitive *Oxalis* (*Biophytum sensitivum*). In the *Dionæa*, however, this irritability is, as first pointed out by Curtis, resident in six delicate hairs, which are placed three on each lobe in a triangular form, with the apex pointing downwards; each has a peculiar bulging at its attachment to the lobe. The position of these hairs is such that it is well-nigh impossible for an insect to avoid touching them while crawling over the leaf.

To test the accuracy of this opinion I took a needle and touched almost every portion of the surface both above and below, and also the marginal hairs, and no response was given; but no sooner did I apply the needle point to the top of one of the six hairs than immediate closure of the leaf followed.

In the sensitive plant this property seems to have no apparent relation to the wants of the system; in the *Dionæa*, however, such a relation seems to exist, for when a certain amount of animal food has been consumed, the irritability disappears, at least for a considerable time.

On July 3, 1874, at 2.30 P.M., a large bluebottle fly was placed on a large *Dionæa* leaf; the diet was peculiarly acceptable, and was at once secured. Twenty-four days were required for digesting it, and when the remains were removed on the 27th the hairs were stimulated repeatedly, but no signs of irritability were manifested. On July 28,

29, 30, and on August 1, the same was tried, with a like negative result.

A similar result followed in the case of other leaves after sumptuous repasts of caterpillars and raw meat and spiders; but these will again come before us.

This irritability is also more or less influenced by sunshine and shade, though, so far as my experiments go, not in the manner that one would naturally expect.

On July 20, 1874, four plants of *Dionæa* were selected—two to be placed in the shade, and the other two to remain in the sunshine. Of those in sunshine, one plant had two leaves closed by irritation, and the other had three similarly dealt with. Of those in the shade, one had four leaves closed by irritation, and the other had two thus treated.

July 21, 12.30 P.M.—All act equally well on irritation; only one of the plants in the shade had not its leaves quite so open as the others.

July 22, 3 P.M.—In sunshine, all open, and respond readily and fully to irritation. In shade, one plant has two leaves half open, and the other plant has two fully open; but all respond languidly and more or less fully.

July 23, 4 P.M.—The two plants in sunshine are not quite open, but close well on irritation. The two plants in shade have their leaves scarcely half open (the lashes are touching), but they close pretty well.

I need not weary you with details, so I pass on to the record of August 1, when the plants were, in sunshine, all about half open, but closed on irritation; while in shade two were half open, but would not close by irritation of any amount. My appended note is—"The want of sun seems here to have impaired irritability."

Again, in some cases the nature of the substance applied seems to influence to a considerable extent this property of irritability. On July 16 chloroform was dropped on the sensitive hairs of a leaf of *Dionæa*, and it instantly closed exactly as an eyelid would have done had chloroform been applied to the eye. To test whether it was the peculiar nature of the fluid, or simply the fluid touching the hairs, that had caused the closure, another *Dionæa* leaf was chosen, and a large quantity of water was let fall on it, at first drop by drop, and afterwards in large quantity, but there was no

sign of closing ; but when chloroform was added, the closure ensued in two or three seconds. These plants had not been in direct sunshine.

On July 17 new experiments were made. One or two *Dionæas* which were in bright sunshine were held below a watering-pan, and, at first, drops of water, and then a full stream, were directed on the sensitive hairs, and the leaves closed at once. This experiment, so different in result from the last, seemed entirely owing to the direct rays of the sun in which they had been placed; for on taking another *Dionæa*, which had not been so exposed, we found that, in this case, no amount of water would cause its leaf to close, but the smallest amount of chloroform did so at once. Here, then, so far as the experiments go, was a distinct evidence of the irritability being in some instances dependent on the nature of the irritant. Only the other day (June 7) I saw the leaf of a *Dionæa* nearly full of water, in contact with all the sensitive hairs, and yet no closure had been effected, but on my touching a hair with the point of a knife immediate closure resulted.

If this be found generally true regarding water, we can see how admirably provision has been made to guard the plant against the frequent closure of its leaves after every shower, which would deprive it of many chances of a good meal. Nor does the closure of the one which had been in bright sunshine at all militate against this view, for in most instances we have the sun obscured by clouds for some time before any continuous rain begins.

Again, this property seems to exist in different degrees of intensity in different plants of *Dionæa*, and sometimes in different leaves of the same plant. Thus I have found that the slightest touch on the top of a hair has been followed by instant closure, while in another leaf of the same plant this effect was only obtained after touching a hair twice.

How long is this irritability retained? The period seems to vary even in different leaves of the same plant, so that it is impossible to give a definite answer. On July 7 three leaves of one plant of *Dionæa* were closed by irritation; they were very lively and closed at once.

July 8.—Open by 10 A.M. at least; at 3 P.M. they were again closed at once on irritation.

July 10.—At 12 noon two leaves quite open, one leaf only half open, and closes languidly.

July 11.—One still close which was closed yesterday; the other two, which are open, responded somewhat languidly to irritation by a glass rod.

July 14.—Only closed very languidly; the other two responded better to stimulus, and closed firmly.

July 15 and 16.—One closes languidly; other two close at once vigorously.

July 20, 3.30 P.M.—All closed with slight languor.

July 21 and 23.—All closed slowly.

On July 25 the irritability is much exhausted.

From some of them remaining closed after this it was impossible to test further before August 1, when I left town.

We see from these dates that the irritability in one leaf began to show signs of diminution on the third day, and that the other two leaves did so on the day following. On the seventh day these two temporarily regained their irritability, and retained it till the eighth and ninth day, but it became again gradually impaired, till on the eighteenth day it was much exhausted.

No great importance can be attached to these experiments, as the irritation was only practised once a day, and sometimes, though rarely, once in two days.

Of the nature of this property we cannot, of course, speak, for we know of its existence only by the effect produced, viz., the contraction of the leaf; but there seems to be a co-ordinating power in connection with the irritability, for though one or more hairs on only one lobe of the leaf be irritated, both lobes will close synchronously. I shall have occasion to return to this subject under the second heading, and I now, therefore, proceed to speak of the effect of the irritability.

2. *Contraction*, or closure of the leaf and of its marginal spines or cilia.

This property of contractibility, like that of irritability, has a distinct relation to the wants of the plant. No doubt almost any substance, whether suited for food or not, will, if placed on one of the sensitive hairs, be followed by contraction; but it is only when the material so

introduced is capable of giving nutriment to the plant that the contraction continues. This peculiarity of the contraction is exhibited in the following instances:—

On July 4, at 3 P.M., a piece of wood was placed on a large leaf of a *Dionæa*, which instantly grasped it. It was, however, too large to be concealed, so that the wood was seen with the marginal spines embracing it.

July 6.—At 11 A.M. the leaf is quite open. At 3 P.M., however, it was found closed, which was apparently owing to the wood being so light as to be easily knocked against the hairs by the draughts in the greenhouse. This to a certain extent vitiated the experiment.

On the same day (July 4), at 3 P.M., a piece of dry plaster which had fallen from the wall, was put on another leaf of the same plant, and it was at once caught and concealed.

July 6.—At 3 P.M. the leaf was quite open, but was closed by irritation.

July 7.—At 3.30 P.M. leaf again open.

On the same day (July 4), but on the leaf of another active *Dionæa*, a piece of iron nail was placed, which was grasped instantly and vigorously.

July 6.—At 3 P.M. leaf quite open, but on pressing the iron against the sensitive hairs the leaf again closed.

July 7.—At 3.30 P.M. leaf quite open again.

On July 7 a piece of the leaf of a *Fuchsia* was placed on a *Dionæa* leaf, and caught by it

July 8.—At 2 P.M. leaf quite open.

For the same reason we find that when insects have lost their nutritive power (either from having been too long kept or from having been previously digested) we have a similar action on the part of the leaf.

Thus in the case of the *fuchsia* leaf just referred to, after the *Dionæa* leaf had opened a fly was placed beside the piece of *Fuchsia*, *i.e.* on July 8, at 2 P.M.

July 10.—Leaf open; closed by irritation.

July 11.—Leaf quite open again.

July 13.—*Fuchsia* leaf taken away and fly alone left, and leaf closed by irritation.

July 14.—Leaf again open.

July 15.—Fly looked a very shrivelled one, so I removed

it and put on the leaf a bluebottle fly (which had been dead for fully a week). Leaf closed by irritation.

July 16.—Leaf quite open (probably from fly being a dried up one).

July 17.—Leaf again open. On examining bluebottle fly it was found to be quite dry and brittle, and nothing could be squeezed from it. It was removed and a living fly introduced; the leaf closed and remained so till the 28th, by which time the fly was quite exhausted of its substance. Linnæus believed that it was in consequence of the struggles of the living insect that the contraction continued, and that after its death the leaf opened; but this view is erroneous, for even in this case, which at first sight might seem to favour it, the insect was dead very long before any opening of the lobes occurred.

So in the case of a fly previously digested by a *Dionæa*.

On July 15 a fly of this description was placed on a very healthy leaf of a *Dionæa*, which instantly closed by irritation by knife; the lashes also were at right angles.

July 16.—The leaf was open so far that the lashes were not touching, and the previously digested fly was removed and a freshly caught fly was put alive into the trap.

The leaf now remained quite close till the 24th, *i.e.*, for eight days, and was not entirely open till the 27th instant.

Again, we have similar instances where the leaves have contracted by the hairs being irritated without any foreign body being entrapped; we have seen examples of this under irritability, so that it is needless to cite them again, for in these cases the leaves always opened till the irritability was exhausted.

I now tried if I could deceive my friends, and so make sure that they would keep what I had offered them. I therefore, on July 7, added a tempting fly to the leaf with the plaster, which I have already instanced as refusing to remain closed on it, and secured its closure; but on July 8 I had the painful fact to record—"The marginal hairs look very red, the leaf was quite open at 6 A.M. The fly did not seem at all digested, but the small grains of lime which were near the sensitive hairs looked as if they had been wet, and had dried again."

I mentioned also the case with the iron nail; here I was more successful with my wiles. On July 7 a dead fly was added to the iron, and though on the 8th the leaf was again open, a little coaxing got it to close. It remained so till July 20, when from the blackness of the leaf I discovered that the dose had proved fatal, and that my success in this case had been more disastrous to me than my defeat in the last one.

In some cases, however, the leaf may close and continue so, as when a fatal shock has been given to the leaf by the administration of some poisons, or by cutting across the petiole; in this latter case the leaf generally closes very slowly.

Besides chloroform, some of the substances tried which proved poisonous, probably in some cases from the quantity used being too large, and were attended with closure of leaf, were chloride of ammonium, carbonate of soda, sulphite of soda, sulphate of soda, biborate of soda, sulphate of copper.

Where chloride of strontian was used, and also sulphate of iron, the leaves remained open, though they died.

At this time I had unfortunately no posological table to guide me as to the amount to be given in a medicinal point of view, and hence the plants succumbed to the toxic effect of the amount administered.

As there was only one experiment with each substance named, no weight can be attached to the fact of closure or otherwise, but as they are facts I record them.

The full contraction is not completed at once, and hence Dr Curtis informs us that he "has liberated flies and spiders, which have sped away as fast as fear or joy could hasten them." I have done so also; but his observation as to the rate of their speed being determined solely by joy or fear requires to be qualified by the expression "remaining ability," to be in accordance with what I have seen. On July 24, at 3.30 P.M., a large spider was enclosed in a fine large leaf of *Dionæa*; and on July 25, at 3 P.M., on opening the leaf the spider was found alive but languid, being wet with the acid fluid. So with a fly, alive after two days' confinement: it was enclosed in a *Dionæa* leaf on September 29, and on opening the leaf on October 1 the fly was alive and damp, but with no great amount

of secretion around it; on being taken out it moved about wonderfully, and in the evening seemed well, but did not attempt to fly.

The process of contraction is this: At first the lobes of the leaf approach at the upper edge, leaving a concavity inside, in which the enclosed insect is comparatively free from pressure; but some time afterwards a distinct compression of the two sides may be noticed at about an eighth of an inch below the upper edge, and ultimately one of the sides may become quite convex internally, fitting into the concavity of the opposite blade. Hence, ultimately, the creatures, if of a soft nature—such as caterpillars, centipedes, and spiders—are squeezed flat, but those with a hard external covering, *e.g.*, beetles, resist the pressure, so that the skeleton may be found retaining its natural form and size.

But the contraction of the leaf is not single but double; it is not limited to the movements of the lobes of the leaf, but is also manifested by the ciliary or marginal spines, which, when complete contraction of the lobes is effected, may be found interlocked and at right angles to the blade. After remaining thus for some time (occasionally not longer than half an hour) the marginal spines gradually rise so as to form an obtuse angle with the inner side of the lobe. In some cases the hairs never reach the right angle, but remain at the obtuse angle, more especially if the lobes close languidly.

In some instances the insect would certainly escape if it were not for the bending of the ciliary spines, which stops its progress outwards. Sometimes, however, the whole process is so slow, both in the case of lobes and spines, that these latter have not crossed before the insect reaches them, and it escapes in such cases.

July 1, 1874.—A bluebottle fly was made to walk slowly over the leaf of a fresh specimen of *Dionæa* without any contraction occurring; the leaf was again irritated by the fly, and now began to contract at a very slow rate, so much so indeed that part of the body of the fly was above the margin of the lobes when the ciliary hairs or spines pressed on its body; from which pressure, however, the fly soon freed itself. When the contraction of the leaf, about

an eighth of an inch below the margin, begins, the ciliary spines gradually separate from each other and bend backwards, in consequence of the eversion or retroversion of the margins of the leaf.

How long does the contraction continue? This is very much influenced by the amount to be digested. Thus in two instances, where a fly was entrapped, the contraction was only for eleven days; where a large bluebottle fly was caught, it was twenty-four days before the leaf opened: where a caterpillar was enclosed it was twenty-one days. In another case where a fly was caught it was sixteen days. In one instance, with beef about the size of a fly, it was fifteen days, while in another similar case it was not opened on the seventeenth day. Where a plant was gorged with meat more than twenty-four days were required. The average time of contraction seems to be between two and three weeks.

Do we know anything of the nature and cause of this contraction? My excellent friend, Dr Burdon Sanderson, showed two years ago that the peculiar electrical effect, called a negative variation, which occurs when a muscle contracts, is also exhibited where contraction of the leaf of the *Dionæa* occurs. This observation is one of great interest, as pointing to some special analogy between the animal and vegetable worlds.

As regards the question, "How does the irritability lead to the contraction?" we must confess our ignorance. Is the impression conveyed to some central organ from which a centrifugal force is transmitted, and can any interruption to the transmission of this influence interfere with the closure of the leaf? I spoke of co-ordinating power in the closing of the two lobes; now does this reside in the hypothetical central organ, and may we, under any circumstances, have this action interfered with? Mr Darwin has stated that he can produce this condition (a kind of palsy, if I may so style it) by pricking with a sharp lancet a particular part of the plant. This observation of Mr Darwin is still more interesting than Dr Sanderson's, for it points to the possibility of even a higher analogy than his. I do not know whether the paralysed portion of the leaf was on the side which was pricked, or whether there was a

crossing of the influence which produced it. Given on the authority of such an able and careful experimenter, we need not hesitate to accept it, though it is only right to state that I have not as yet been able to discover the point referred to. I have made punctures in different spots, but have never seen the operation followed by non-closure of one lobe.

On July 4, I pricked a *Dionæa* leaf near the central hair, and it closed naturally.

July 6.—Leaf open, and responded to stimulus by both lobes closing.

Only the other day I pricked with the point of a knife a portion of the midrib, almost where the petiole joins it, but no paralysis ensued.

On July 4, I also tried if I could cut off the direct transmission of the impression made on the sensitive hair, and for that purpose I performed two experiments, one on the above date and one on July 22. I first cut one leaf of *Dionæa* below the sensitive hair nearest the midrib, but on July 6 the leaf was open, and responded to stimulus by again closing.

July 13.—Leaf that had been incised from the front was now cut from the back, and immediately closed; the incision was made with a bistoury right through the one lobe and extended the same length as the sensitive hairs did, so as, if possible, to interpose between them and the hinge on the left side (looking from centre of plant).

July 14.—The leaf is closed, but not very firmly. The cut was extended to-day, and care was taken that the knife went quite through the left lobe without injuring the right one.

July 15.—Leaf closed; healthy look.

July 16.—Leaf partially opened towards petiolar end of leaf.

July 17.—Leaf decidedly more open at the petiolar end, at the part beyond that at which the cut terminates.

July 20.—Part still open, but has been closed by irritation.

July 23.—Open at end again.

The lobes in this case acted in harmony, and though the leaf did not open much, this seemed owing to the shock given to the plant.

On July 22, to test whether the influence might not be transmitted from the root, I cut the midrib of the petiole quite through at about one-third of its length from the leaf; the wings of the petiole were left entire. The leaf remained open after this operation, but was closed on irritation.

July 23.—Leaf open to only half the lashes to-day.

July 24.—At 3 P.M. leaf half open, closed on irritation

It continued to do so on July 27 and August 1.

Dutrochet, in reference to the Sensitive Plant, believes that there are two kinds of cells, the one exhibiting the power of contraction and the other the power of distension, and that these are situated, though in a reverse order, at the swelling of leaflets and the pulvinus of the petiole, the contractile cells being above in the one case and below in the other, and consequently the place of irritation is, in the one case, above, and, in the other, in the pulvinus below; and as the over distension of the other kind of cells is, in his view, the immediate cause of the movement, the leaflets are forced to take an upward direction, while the petiole falls down; and he thinks that his view is confirmed by the effects of cutting the lower part of the pulvinus, which would interrupt the process on which his theory is founded.

Dr Carpenter adopts these views, and applies them to the explanation of the closing of the *Dionæa* leaf. But whatever we may think as to the Sensitive Plant,* it certainly seems to fail in the *Dionæa*; for I have in two instances cut off a considerable slice from the lower portion of the midrib and yet the leaf has closed, so that some other explanation than that of contractile and distensible cells is here necessary. Again, if we take the case of the *Droseras*, which are congeners of the *Dionæa*, we find that in *D. longifolia*, *Whitakerii*, *rotundifolia*, &c., the mode of con-

* I have tried some experiments on the upper and lower parts of the attachment of the petiole, and I must own that, though they have been far from being quite confirmatory of Dutrochet's view, there was one instance which seemed to support it: a portion of the upper part of the petiole was cut away, and some days afterwards on touching the pulvinus the petiole did not descend to the same length as the others did, though from the weakening of the base of the petiole we should have expected it to have gone down further than any of them.

traction is just a reversal of the circinate vernation which they exhibited while being developed. Now, if this process depends on these kinds of cells, are we to believe that they can perform directly opposite functions? Or do the two sets of cells change places? Or, thirdly, are no such cells necessary to effect the evolution of the plant? Then, I ask, why should they be necessary in the other case, *i.e.*, in its contraction? Besides, in the case of *Dionæa*, how can the distensible cells at the lower portion of the midrib effect the closure of the marginal bristles, which are an essential part of this wonderful contrivance for entrapping insects?

No attempted explanation, of which I am aware, is satisfactory. If I might be allowed to throw out a suggestion, I should be inclined to look for the explanation of the closing rather to the spiral vessels, which are very abundant both in *Dionæa* and *Drosera*, and which from their distribution and arrangement seem to play an important part. I shall only instance the peculiar expansion of the spiral as it enters the glandular head of the hair of *Drosera dichotoma* or *binata*. We know that elasticity is an inherent property of the spiral, and that consequently it may either contract or expand according to the forces applied to it; and in the case of *Drosera binata* any shortening of the spiral would certainly cause the secreting head to bend. Of course, I do not mean to say that spirals will explain all the phenomena, but they may hold a very important place. I have spoken of the abundant spirals in *Dionæa* and *Drosera*, and I take this opportunity of expressing my appreciation of the kindness of Mr Sadler, who has given me valuable aid in investigating the microscopic structure of these plants. But to return from this digression. From the midrib of the *Dionæa* we have at short distances spirals passing off at right angles across the lobes and entering the interior of the spines or marginal bristles. They proceed to the very end of the spines, though we have not yet made out how they terminate there. But even this relation might help us to understand how the double closure of lobes and spines might be effected.

While we contemplate the marvellous but secret connection between the irritability and contraction, and mark

the matchless wisdom displayed in the whole contrivance, we have the unspeakable satisfaction of knowing, and of reverently exclaiming, that "This also cometh forth from the Lord of hosts, who is wonderful in counsel and excellent in working."

3. *Secretion*.—Ellis believed that the viscous fluid secreted was a kind of nectar, to allure the insect to the sensitive part of the leaf; but this view is entirely negatived by the fact that it is not poured out till after the capture of the insect, and it sometimes does not occur till about thirty-six or forty-eight hours after that event, though it appears to me to be generally found at the end of twenty-four hours, if not sooner. Professor Dewar, who very kindly examined some of the secretion for me, informed me that it contained no sugar. Mr Darwin showed that the secretion was acid, and Professor Dewar writes me that the acid which he discovered was "formic acid, and that the secretion also contained chlorides; that it was of a viscid nature, and on keeping did not decompose to any great extent."* I feel deeply indebted to him for the very kind way in which he undertook to examine the secretion for me; and when I inform you that the produce of some twenty-four or twenty-five leaves amounted to only about 1 or 1½ drachm, you will at once see the trouble and difficulty of making an analysis in such a case, and I can only add that I feel most grateful to him for having done so.

The presence of formic acid in the secretion of *Dionæa* is peculiarly interesting. Of course most of you know that this acid derives its name from having been first found in ants, specially in the species *Formica rufa*; and Will has shown that the poisonous principle in certain caterpillars, especially in *Bombyx processionea*, consists of this acid, and that it occurs in a concentrated state in all the parts of this creature. It is also regarded as highly probable that the irritation caused by the stings of various insects is due to the same acid. In man it has been found in the blood and in the juices of muscles and of the spleen, also in the thymus gland. It is the principal volatile constituent of

* The name of Professor Dewar is the best guarantee for the accuracy of this analysis.

the sweat, and has been found in the urine, and, what is specially interesting to us, in vomited matters.

But it has also been found in plants, for it occurs in Stinging Nettles, and in some species, *e.g.*, *Urtica urentissima*, the effects produced by the sting are, as the name implies, peculiarly severe. In the plants in which it is found it is generally regarded as the result of decomposition, and this seems confirmed in the case of *Pinus Abies*, by the fact that it is found in larger amount in the needles which have fallen off than in those which are dried while fresh. As might have been expected from this circumstance, the acid is also found in oil of turpentine; and when this has been kept in leaden vessels crystals of formate of lead are sometimes found.

When the fruit of *Sapindus Saponaria* and that of *Tamarindus indica* are distilled with water and sulphuric acid, formic acid is obtained as one of the products. Gorup Besanez thinks that it may be formed by oxidation of tartaric acid originally present in the fruit; and Döbereiner has actually obtained formic acid by distilling ten parts of tartaric acid with fourteen parts of binoxide of manganese and from thirty to forty-five parts of water.

Formic acid can easily be obtained from vegetable products; thus, starch and sugar when oxidised by manganese and sulphuric acid yield it. It is also got by the action of oil of vitriol on ligneous tissue, also by distilling oxalic acid with sand and glycerine, and also from carbonic acid in water, by passing through it a current of electricity. But though it might easily be formed in plants, it has not as yet been often found, and hence one of the sources of interest in this case.

Mr Andrew Murray, in an article in the "Gardeners' Chronicle" for September 1874, takes Dr Hooker to task for his views regarding the carnivorous habits of the *Dionæa*, and he thinks that he (Dr Hooker) has attached too great weight to the statements of Ellis. As a solution of the difficulty, he suggests two questions which seem to me very reasonable: the first is, "Is the secretion never present until after an insect has been captured?" In answer, I may say that I do not remember having seen it under other circumstances, and, as I said above, it is always some

little time after the insect has been caught before it appears. His second question is, "Whether it is always present after an insect has been secured?" My experience is that if the plant be healthy it is always so. I am speaking of living insects. Is this fluid a real secretion, or is it merely the exudation of the juices of the plant which are distinctly acid? There can be no doubt that it is truly a secretion. Its viscid nature would itself prove that the juices must have undergone some change. But I have better evidence, for I tried whether mere pressure would cause this fluid to appear.

September 26.—At 3.50 P.M. a portion of litmus was placed on the internal surface of a leaf of *Dionæa*, on which a piece of flattened wood had been previously firmly pressed, and no change in colour followed. The litmus was then moistened with water and applied as before, but without any change. The moistened litmus was then placed between the two portions of leaf, and these were firmly and strongly compressed by the fingers, and yet the litmus was unchanged in colour.

What secretes it? Ellis long ago stated that the surface of the leaf was studded over with red glands, which secreted what he regarded as sweet fluid, but which we know to be of an acid nature. These glands are among the most beautiful objects in nature, their graceful symmetry, the regularity of their cells, and their lovely colour render them most attractive microscopic objects. In some leaves, however, their colour is green and not red. If beauty of form and brilliancy of colour can be appreciated by flies, then we have a sufficient object of attraction for these insects, without having recourse to Ellis' nectar. They are very numerous, being studded over the upper surface of the leaf (excepting a small strip at the base of the marginal spines), and being most abundant and in lines in the immediate neighbourhood of the sensitive hairs. They are somewhat elevated above the surface, and have a dome shape; the cells, which by their juxtaposition present a crenate margin, contain in their interior numerous red rounded cells, which seem to contain the secretion.

That Ellis was right in supposing these to be secreting glands can scarcely be doubted, if we consider their structure and the position which they occupy on the leaf

relatively to the fluid which is poured out. But there is an argument from analogy which seems quite legitimate and conclusive, and it is this: in other genera of the same natural order, as, for example, the *Droseras*, we find that the secretion in their case is effected by glands of a similar colour, and there can be little doubt that these sparkling vegetable rubies have a similar ultimate design, viz., to attract the insects within the reach of the secretion, which is accomplished at once in the *Drosera*, but only after a time in the *Dionæa*.

This secretion is not poured out needlessly.

The following experiments will afford the best answer to Mr Murray's first question:—

July 4.—A piece of wood on leaf of *Dionæa*, a piece of lime on another leaf of same plant, and a piece of iron on yet another.

July 6.—Exactly forty-eight hours afterwards no fluid was secreted in any of these cases.

Even when a fly is shrivelled up, if the secretion be poured out in any quantity whatever it is long delayed, thus—

July 7.—Piece of fuchsia on *Dionæa* leaf.

July 8.—Leaf open, and a fly now added.

July 10.—Do., no secretion, closes readily.

July 13.—Fuchsia leaf with white fungus on it; this leaf and the bottom of the leaf of *Dionæa* are moist; fluid faintly acid.

The mere moisture, the faintly acid character, and the long delay in this particular case, establish the fact of there being no needless waste of the secretion.

But this peculiarity is also manifested in another way, so far as I have seen in one or two instances. The acid secretion, after being poured out, either changes so as to be much less acid, or the subsequent fluid poured out has only a faint acidity, while that in contact with the insect is intensely so.

Examples.—A *Dionæa* leaf containing a fly was open on the seventh day, and a great deal of fluid was found, specially at the distal end of the leaf, where the fly was; this was very acid, but fluid at petiolar end only feebly reddened litmus.

What amount of secretion is poured out? This seems to vary according to the creature or substance introduced. If it is a *bonne bouche*, such as a fat spider, or a smooth caterpillar, or a fresh fly, or a piece of raw meat, the secretion seems abundant, but if a shrivelled fly be inclosed there is, as we have already seen, little or no secretion. We know the old saying about "making our teeth water," which refers to the increased secretion of saliva which is poured out when a choice morsel is before us, or placed in our mouths, or, as Frerich has shown, even when it is introduced into the stomach by a fistulous aperture, without ever being in the mouth. No doubt this also bears a relation to the amount to be digested, for a good spider is not only a tasty article of diet, but contains a large amount of material available for nutrition.

July 24.—At 3.30 P.M., a living spider of large size was inclosed in a large healthy *Dionæa* leaf.

July 27.—The spider was dead, and was surrounded with fluid, which forms almost a little well near the apex of the leaf. Six tubes* of secretion were withdrawn, and the remaining fluid, which was small in amount, was carefully mopped up. The first two tubes had clear fluid, but the other four had a whitish opalescent appearance (all more or less gummy to the touch), and the fluid was acid in all. The leaf was allowed to close.

July 28.—At 3.30 P.M., spider again surrounded with fluid, and five tubes of secretion were removed, which was somewhat viscid and quite acid, and only slightly opalescent. One of the lobes was unfortunately torn a little in opening it up; the leaf was treated as on the former day.

July 29.—Small amount of fluid to-day, only about a half-tubeful, quite acid, and somewhat viscid.

July 30.—No secretion to-day, either on the spider, which is quite dry, or on the lobes of the leaf.

Aug. 1.—There is a damp appearance on spider and leaf to-day, but no accumulation of fluid.

Another experiment was tried on July 25. A living spider of smaller size was put on the leaf of another plant. On July 27, at 4 P.M., it was surrounded with fluid, which

* The tubes which were employed were the medium-sized capillary ones used in vaccination.

was all wiped away, as a whitish semi-fluid substance was found coming from the hinder part of the spider (a similar substance may have caused the opalescence in the former case also). The leaf was allowed to close.

July 28.—One tube of clear fluid was taken away to-day; it was acid. The rest was wiped up.

July 29.—Little fluid to-day; only enough to half fill a tube. It was neutral.

Aug. 1.—There was simply a dampness on spider and on sides of leaf.

Yet another experiment was made with a spider, which in this instance was a very fat one, and apparently in an interesting condition! It was entrapped on July 27, 1874, and on the 28th it was found surrounded with fluid: two tubefuls of this were removed, and the remainder was wiped off.

July 29.—The interior of the spider seems squeezed out, the fluid about it is abundant and quite acid; two and a half tubefuls were taken, which had a reddish colour from contents of spider.

July 30.—The fat spider is much broken down, and a great deal of fluid of a reddish colour (from mixing with contents of spider) was removed. Four tubefuls were taken.

Aug. 1.—Two and a half tubefuls of reddish fluid withdrawn, and the spider was left damp. This experiment, like many others, was abruptly terminated at this date, as the Scottish Alpine Botanical Club can brook no delay.

There was one circumstance which I noted on more than one occasion. It was this: that if the meat was not put well down, so as to be near the sensitive hairs, there was little or no secretion. I shall give one example. On July 1, 1874, at 3 P.M., a piece of raw beef, about the size of a bluebottle fly, was brought into contact with the hairs of a leaf of *Dionæa*; in this case the contraction was rather rapid, and the meat, having been slightly moved, was fixed at the part of the leaf a little below the marginal bristles or spines, and there it was found on July 3, looking dark, dry, and somewhat shrivelled. On that date, however, I pushed it down to the hinge, and, in twenty-three hours after it had been pushed down, on separating the lobes,

the intermediate space was found very full of fluid, and the meat was pale, like veal, and partly digested.

Now, if these observations be proved to hold generally good, it would point to a beautiful relation existing between all the properties already mentioned, viz., irritability, contraction, and secretion; for we must remember that a piece of meat placed near the marginal spines is not in accordance with the natural process, which renders it necessary that the insect should be down in the neighbourhood of the hairs when it is caught, so that no insect would naturally be found in such a position as the beef was, unless the plant were very sickly and closed so slowly that the creature would have time to creep up to that position, but this would indicate in the plant a feeble or unhealthy condition, and, under such circumstances, abstinence from animal food is usually enjoined.

I come now to speak of the fourth head, which is

4. *Digestion*, or the action of the contraction and secretion in favouring the solution of the animal matter, and preparing a pulp suitable for absorption. If this effect is produced then there can be no question that true digestion has occurred, whether it be in the stomach of a man, or of a beast, or in the leaf of a plant, or in the interior of a glass vessel. No doubt it may be a more complicated process in the one case than in the other, but the essential parts of the process are alike in all; and I cannot see why Mr Murray should so strenuously oppose the use of the term digestion in the case of *Dionæa*. Dr Hooker, I am certain, knew well the structure and functions of the human stomach when, by way of illustration, he beautifully compared the action of the *Dionæa* leaf to it. Mr Murray cannot suffer this statement to pass; and he asserts that even in this Dr Hooker "will scarcely deny that, put it any way he likes, the analogy is of the feeblest." And Mr M. goes on to say, "Would it not be an anomaly in the economy of nature if a complicated apparatus should be provided to do something which is of no advantage to the plant, and which it seems to be able to do quite well without? Of course there are no flies for the *Pinguicula* to feed on in winter, and yet it grows as well then as in summer. For three weeks of the time I observed it we had a great

deal of rain, and the leaves were washed free from all remains of flies, yet the plants seemed to thrive better and better. *Drosera* was in the same predicament, and I presume *Dionæa* must be so too." Now in these sentences there are two or three assumptions which it might be well to notice; the first is that "the process is of no use to the plant." He is referring to *Pinguicula*, but from his concluding sentence, he seems to include *Dionæa* also. On what grounds does he rest this opinion? Mr Lindsay, a very intelligent and careful observer, informed me that when young plants of *Dionæa* were grown under bell-jars they found that they never throve so well as those which were left free. As regards his remarks about the rain washing off the remains of flies, he seems to forget that where there were "remains" the substance must have gone to feed the plant; and if not entirely gone, the rains which swept them away must have favoured their decay and brought them in contact with the roots of the plants, and thus have contributed to the nourishment, for no one, so far as I know, ever asserted that the leaf was the only medium through which the *Dionæa* was supplied. Surely Mr Murray must know that though there is such admirable provision in the human mouth, stomach, &c., for receiving food for the nourishment of the body, yet the skin may absorb nutriment, as in the case of baths of milk, but who would assert that the fact of the one doing so precludes the action of the other?

Again, Mr Murray says, "The entrapped insects do melt away under the influence of the secretion, but no more, I apprehend, than they would do under the influence of any other feeble acid. Now, the secretion is slightly acid; not quite so much as the juices of the plant itself, but still slightly so. The juices of most plants are acid." . . . "It is not an unnatural assumption that the secretion exuded will participate more or less (less rather than more) in its acidity; and so it does." He then, in reference to the acid juices of plants, exclaims, "Here is a means of dissolution which is applied universally to assist decay; but something more is needed to make digestion. If you apply the litmus paper to the moist or half-rotten leaves of *Sphagnum* or *Polytrichum* you will find them much more

acid than the *Pinguicula*; but no one will consequently propose to endow them with digestive powers." And, after other remarks, he concludes thus, "I do not believe that had this question not been complicated by the curious machinery of *Dionæa*, for which it is so difficult to find a purpose, that we should ever have heard of carnivorous plants or digesting vegetables." This argument, if carried out, would apply equally to the acid secretion of the stomachs of men and of the lower animals; for, stated in the broad and general way in which he has put it, we might explain that, as acid is the general agent of decay throughout all nature, we cannot believe that we should ever have heard of carnivorous beasts or digesting animals if it had not been for the curious machinery found in their bodies. And had we only lived before the structure and functions of the stomach had been so thoroughly investigated we might have boldly asserted that no true digestion did take place in that organ, but only a process similar to that which we see around us, whether in the *kitchen* or in the *mill*, or throughout *all nature*; and we might have fortified our position by an appeal to most eminent authorities, for Hippocrates held that digestion was merely a *cooking* process; while Borelli, Boerhaave, and others regarded it as a mere *mechanical trituration*; while Plistonius held that it was simply a *putrefaction*.

But surely, after all, there is a decided difference between the juice of a plant and its secretion. In the *Dionæa* I grant that the acid character is of about equal intensity in both. In the *Drosera dichotoma*, however, it is far otherwise, for while the juice is quite acid, the drops of secretion are scarcely, if at all, so. But in both *Dionæa* and *Drosera* we find that while the juice is thin and watery, the secretions are gummy and tenacious, which certainly indicates that a great change has been effected by the secreting cells.

Another circumstance indicating digestion is this, that putrefaction does not occur during the whole period, even when we find that the secretion has become only faintly acid. This certainly is not what we should find under ordinary circumstances. Even the *Sphagnum* is no exception. Mr Murray is right in saying that it is acid, but he makes a great mistake when he asserts that the disappear-

ance of insects in the *Dionæa* and *Drosera* is simply by a process of decay caused by the acid fluid, just as in the case of the *Sphagnum*. On June 8, 1875, I placed a piece of raw beef in the centre of a considerable amount of *Sphagnum*, partly green and partly decayed, and again I placed another piece more loosely amongst the leaves of this plant; while, on the other hand, I put a similar piece of raw beef on the leaf of a *Dionæa*. On June 10, at 6 P.M., the first two pieces were putrid, while the piece in *Dionæa* had no bad smell whatever.

I could give many illustrations of this, as almost all the ordinary experiments attested it. In order, however, to prove that the mere exclusion of much air and the coolness of the leaf had nothing to do with the absence of decay, I took a piece of meat, and having selected a leaf of *Stadmannia australis* (which was in the same house with the *Dionæa*), on July 4, 1874, I got Mr Lindsay to tie the meat up in the leaf, which was then folded several times. On July 6 the meat had a darkish look and a putrid smell, and on wetting it with water only a very faint red was given to litmus, which indicated that ammonia, one of the earliest products of decomposition of animal matter, had been developed to such an extent as nearly to neutralise the natural acid of the beef. On July 11 the meat was very putrid and quite decayed.

But a more striking instance, inasmuch as it illustrated both processes, was this. Mr Lindsay had gorged some leaves with raw beef—so great was the quantity given that the meat projected beyond the marginal spines or bristles. This was done on July 4, 1874.

On July 6, on opening one of the leaves, it was found that, while the portion of meat beyond the marginal hairs was dark and dry, and had a faintly putrid odour, the portion contained within the leaf was white and had the appearance of having been macerated, and had no apparent putridity, but seemed quite fresh. The meat was now taken from the leaf, and the tainted portion having been cut off from the fresh portion, this latter was put under a wooden box (to keep away flies) to see if the partial digestion which it had undergone would retard decay. This was done on July 6.

July 7.—The tainted meat cut away is much more putrid, while the partially digested meat has no smell.

Another interesting fact is, that when meat is partially decayed, if it be put amongst the secretion it will lose its smell.

On July 6, one of the gorged leaves, of which the part projecting gave a very putrid smell, had this portion pushed within the leaf, and on July 8 no putrid odour could be discovered. On opening the leaf there was much acid juice, and the meat was much whiter, but no smell was discoverable.

How is the process carried on, and what is the result?—In answer to these questions I would say, slowly but steadily; and if we select raw beef for observing the changes, we find that it soon loses its red colour, as in the instances just cited, and is gradually disintegrated more and more till ultimately the state of pulp is produced. In one instance, viz., that of a piece of raw beef, about the size of a bluebottle fly, which was introduced on July 1, it was found on July 23 reduced to the state of pulp, quite free from smell.

Ex uno disce omnes.

I have been speaking of healthy plants, in which all the functions were normally discharged; but we have pathological as well as physiological conditions to consider, and unfortunately many of these conditions are induced by imperfect digestion, owing to artificial feeding, and hence dyspepsia in different forms is not uncommon. Some articles of diet are peculiarly difficult of digestion, and ought never to be indulged in by a *Dionæa*: such is cheese; hard boiled albumen they can digest pretty well, but this coagulated and compressed casein they cannot manage. Mr Canby lost one of his patients among the *Dionæas* by ordering it a diet of cheese, and my own experience is equally painful.

On July 8, 1874, I had eleven patients under my care at one time, and to one of these a diet of cheese was prescribed. After Mr Canby's experience I felt anxious about him, and watched him carefully.

On July 9 the entry in my note-book is—"Leaf healthy and quite closed except at farthest point, where it is open

about one-eighth of an inch, and lets out a clear acid fluid smelling of cheese." This vomiting evidently indicated considerable irritation, and the smell of cheese which attended the ejected fluid showed clearly that that substance had not yet been digested. However, as he had a healthy look and a firm grasp, I was not so alarmed.

My next note is a short one, on July 10, 12 noon:—"Leaf closed, not injured." The vomiting had apparently ceased, which, with the general appearance, was re-assuring.

July 11, 3 P.M.—Much the same as yesterday.

At 4 P.M., on July 13, he was still quite healthy and firmly closed.

July 14.—Much as previously.

On July 15 I had so little time that I scarcely saw my patient.

July 16 contains notes of the other patients, but his case is omitted, probably from being much *in statu quo*.

On July 18, 4.15 P.M., the short notice is, "Cheese closed," which means that he had still considerable muscular power remaining.

July 20, 3.30 P.M.—Same note.

But on July 21 my alarm was excited, for though the muscular power was good, yet biliary disturbance was indicated, for the note is to the following effect:—"Still closed, but yellowish on blades, and two lashes of a dark colour." These symptoms were unmistakably serious, and, as I suppose I had formed the worst prognosis of the case, I had prudently withdrawn. I find no further attendance marked. This was on the thirteenth day.

Nothing is more injurious than overloading the stomach, and hence the common advice is, "Not to cram like John Bull." I had generally been very particular in the amount which I had prescribed, but on one occasion after I had left, Mr Lindsay had, in defiance of all proper dietetic rules, gorged four fine healthy *Dionæa* leaves to such an extent that on the following day, July 6, I was horrified at finding some of the beef sticking out of the mouths of three of them. In the case of one of these I promptly applied a remedy by pulling the meat out of its throat by my fingers, and thus saving it from threatened suffocation—the mouth

immediately closed, and all danger was at an end, as I find on July 13 the note—"Leaf still closed by the lashes crossing, but the lobes are slightly separated."

On that date, however, a nasty jaundiced appearance manifested itself in the other three patients, who had been left to retain the excessive amount of beef. Digestion in their cases was very seriously impaired, as offensive eructations testified.

I shall give the notes. July 13.—The three surfeited ones are quite closed (this is now the ninth day after the gorging), but have a dingy yellow and unhealthy look, which applies also to the upper part of the petiole. On opening one of them the meat is about one-eighth of an inch from the edges, and fluid abounds which has now only a faint acid re-action; but there is a slightly tainted smell about the meat, which seems to be considerably digested.

On opening another leaf, the meat seemed less digested, but it was lower down, and there was scarcely any perceptible smell. Fluid here was also faintly acid. On the blades of these two leaves there are slight darkish-brown discolorations on the outsides.

On opening the third leaf a part of the meat was dark and projecting between the margins. Here there was a more putrid smell. The fluid was faintly acid. This leaf has a shrivelled look outside, and also a slight discoloration here and there on the blade.

I have continuous notes to July 28, which I need not give *in extenso*; suffice it to say that one of them was in a pitiable condition, and was executed on the 24th. One of the remaining two had by that date recovered wonderfully, the whole meat having been dissolved, and his breath being quite sweet; while the other had only partially recovered, there being still a faint smell like that of old meat perceptible in his breath.

July 28 has the note "As before."

The capacity of their stomachs is not large, two flies being apparently sufficient to satisfy them, if given in succession; but a surfeit is extremely dangerous, for, though they may sometimes escape a fatal issue, they may suffer long and severely from stomach complaint.

All their diseases, however, are not owing to improper

diet, but when the general health is impaired the secretion is not poured out in sufficient amount to digest the food, as the following example will show:—A yellowish-looking leaf, which, if we had been living in the days when the doctrine of signatures was prevalent, would certainly have been prescribed as an infallible cure to any one suffering from hepatic derangement; this leaf, I say, was selected, and a small beetle enclosed within it. On opening it afterwards the leaf was found dry, and so was the beetle, but on pressing the beetle slightly a good deal of fluid was forced out of it, indicating that in consequence of the ill-health of the leaf there had been no power of secreting fluid, and hence the contents of the beetle had not been removed.

Amount capable of being digested.—As I have already said, two good flies or two good spiders seem to be all that the *Dionæa* leaf can, at least for some time, digest with comfort to itself. Now, if we multiply these by the number of the leaves, we shall find the amount of food which, by its foliar stomach, a plant of *Dionæa* can digest. The leaves are, on an average, about six to each plant, so that if all the leaves were equally successful in their capture we should have a dozen of flies as the amount of food devoured by the leaves.

I shall give an example of how much one leaf digested. On June 30, 1874, a *Dionæa* with four or five leaves, within one of which, at least, a fly had previously been enclosed, was chosen, and on a fresh leaf a spider of good size was made to crawl and was immediately entrapped. On July 13 the remains of the spider were removed, and seemed to be a mere shell. On placing these under the microscope the legs seemed nearly transparent; there was one portion opaque and dark, but on pressing it firmly nothing came out. On this, the thirteenth day, another spider was placed on the same leaf, and was somewhat languidly entrapped. On August 1, the leaf was almost open (*i.e.*, on the nineteenth day), and the remains of the spider, which were of small amount, were removed, and now it was found that the leaf would not close on irritation by another spider, or by the blade of a knife, or by touching it with the finger.

5. *Absorption, including Assimilation*.—Duchartre objected

to this idea of absorption on the ground that it was not in accordance with our knowledge of the functions of leaves, and to the whole course of the nutrition of vegetables, and therefore was not to be seriously entertained. This argument reminds one of the miserably fallacious arguments against miracles by Hume. It is in both cases a mere *petitio principii*. All plants are not constituted like the *Dionæa*, and if it has such a peculiarity in structure, why should it not have a similar one in function?

Other objectors may say, True, the insect is digested and reduced to a semi-fluid pulp, but this is simply for the purpose of allowing it to run down the channelled petiole, and so of reaching the absorbent roots of the plant. Mr Canby at one time thought that such was the case, but he afterwards discovered his mistake.

Two answers may be given to the above objection.

1. In a healthy *Dionæa*, where the natural food of the plant has been taken and in the normal amount, no fluid does run down the petiole. Three flies were placed on three leaves of *Dionæa*, and pieces of litmus were attached to the petioles on Sept. 26; and on Sept. 28, at 4 P.M., the litmus was not in the least degree reddened. On Sept. 29 the same, and so on Oct. 1 and Oct. 3, and yet on this latter date one of the leaves was opened, and a considerable quantity of fluid of an acid nature was found. This was on the seventh day.

2. The second is that the leaf is found quite dry on the surface, with only the slightest indication, if even that, of remains, and if we open the leaf from time to time we can see the process of change going on, and the gradual diminution of the amount.

Example, piece of raw meat on leaf of *Dionæa* on July 1. On July 18 there seemed very little difference on the external appearance from what had been noticed on the 4th, when it was pale, like veal, and partially digested; but on the 23d the beef was found in a soft thin pulp and in small bulk. On the 24th almost all gone, and on the 25th small thin dry flakes are all that remain.

In this case the whole process of digestion and absorption took twenty-four days, but the absorption seemed to go on at a much more rapid rate towards the end.

The first answer proves that there was no escape from the leaf, and the second declares that after a certain time nothing, or next to nothing, was found in the leaf; and if these considerations do not shut us up to the conclusion that absorption had taken place, I fear we must have an equally great difficulty in establishing the fact of absorption by the roots of plants or by the lacteals and lymphatics of animals.

I understand that some one has asserted that the disappearance of the food is not owing to absorption, but to its being devoured by Bacteria and Vibrios. Well, if these be, as Professor Lister supposes, vegetable and not animal bodies, we may as well believe in the digestion and absorption by the larger plants as by the smaller ones; but we must remember that these minute bodies are now generally regarded as the cause of decomposition, with its attendant noxious gases, but, as we have seen in a normal case of digestion in the *Dionæa*, we have none of these present.

How is absorption effected? I cannot as yet say. I tried the following experiment to discover it, but I failed, in consequence of the vital elective power of the absorbent cells or vessels. On July 16, 1874, I put insects and beef, which I had stained red or blue by steeping them in a solution of cochineal or in one of sulphate of indigo, and I hoped that by the colours in the cells I might be able to trace the course of the absorbed material; but these colours were pressed out from between the leaves, and entirely disappointed my expectations. On examining the surface of the leaf of a *Dionæa* you find two sets of stomata, the one set presenting the usual appearance, with two or four cells surrounding the opening. These are found on both sides of the leaf, though, as is usually the case, much more abundantly on the lower side than on the upper. The other set are of a brownish colour, and are peculiar, inasmuch as, in addition to the central cells, there are from five to eight peristomatic cells, which are of such delicate structure that they fold upon themselves with the utmost ease. These seem confined to the lower side of the leaf. Bearing in mind, then, these two kinds of stomata, let us next direct our attention again to the beautiful red glands to which we referred in speaking

of secretion, and if we examine them very carefully by the microscope we occasionally see in the centre of the cells, and apparently connected with them, bodies presenting an appearance not unlike stomata, and it has struck me that probably these are the mouths of absorbent ducts. When we consider the double supply of stomata which this plant possesses, we can hardly doubt that all the ordinary functions of such organs are well discharged by them; and is it not reasonable to suppose that these other bodies, placed in the immediate vicinity of the pulp formed by the contents of the secreting cells, are intended for absorbing that substance, and so rendering it available for the nutrition of the plant?

II. *Additional Experiments on Dionæa Muscipula.**

Since I wrote the foregoing paper, our esteemed President, Sir Robert Christison, was good enough to suggest that I might try the effect of pepper on *Dionæa Muscipula*, and see whether or not the same kind of secretion was poured out under its influence as when animal food was administered; and, at the same time, he alluded to the interesting experiments of Tiedemann and Gmelin, which showed that, while with other condiments a mucous secretion was alone poured out, when pepper was employed the true gastric juice was secreted by the stomach.

I had much pleasure in complying with this interesting suggestion, though, in consequence of other engagements, I regret that I can only as yet record one of my experiments with that agent.

On June 24th 1875, at 4 P.M., two leaves of *Dionæa* were selected, and a small piece of white pepper was placed on the one leaf, while a similar piece of black pepper was placed on the other.

June 25.—The leaf with the white pepper is open, and the pepper is lying on the moss below. That with the black pepper is quite closed. On opening the leaf it is found moist inside, and the fluid gives an acid reaction with litmus. A very minute fly is, however, also found inside the leaf. This last circumstance may in the eyes of some

* Read 8th July 1875.

be regarded as vitiating the whole experiment; but, as it was at once removed, and could only have been in for a short time, and that at the very beginning of the process, I am not inclined to regard it as influencing the result.

June 26.—The leaf with the black pepper is firmly closed, and, on being opened, is found wet with acid fluid. The other leaf, to which the white pepper had been again added, is quite open.

June 28.—Same as at last report on the 26th.

June 29.—Leaf with black pepper is still firmly compressed. The other leaf had now a portion of pimento added instead of white pepper.

July 1.—Leaf open; allspice lying on moss below.

July 3.—The leaf with black pepper continues quite close, but a light brown colour is observed at one end of the leaf. The contained fluid still reddens litmus. The other leaf had had a piece of black pepper substituted for the allspice, and to-day it is found partially opened, but no fluid is inside.

July 5.—The original leaf with black pepper is still closed, and the edges are everted.

July 6.—Same as yesterday.

I trust that, on a future occasion, I may be able to lay before the Society a sufficient number of facts to enable us to come to a satisfactory conclusion on this subject, as some of the experiments are still going on, and others will be instituted. Meanwhile, if we can ignore any influence from the short presence of the unwelcome little fly, we may, so far as the present experiment goes, conclude that black pepper acts on the leaf of a *Dionæa* in a way similar to that in which meat and insects do.

Sensitive Hairs cut off.

June 29, 1875.—Six sensitive hairs cut off.

June 30.—Lobes closed.

July 1.—Leaf open, and will not close on irritation.

July 2.—Leaf open, but closed slowly on irritation being applied to part where hairs had been.

July 3.—Lest some portions of hairs might have been

left, every possible trace was most carefully removed, yet the leaf closed slowly.

July 5.—Fine sunshine to-day. Leaf open, and looks quite healthy and natural *minus* the hairs; irritation, though repeated several times over the part where the hairs used to be, will not cause the leaf to close.

July 7.—Quite open to-day, but closes easily on irritation of the part where hairs had been.

Another experiment.—On July 3d another leaf had five sensitive hairs (which were all that it had) cut off by a sharp bistoury. When the fingers which kept it open during the operation were removed, the lobes seemed at first to remain open, but very gradually closed in a most peculiar way. Thus the right lobe moved very little, and was *concave externally*, the left lobe moved across the middle line, and by its external convexity allowed the other lobe to fit into it; but, in consequence of thus stretching over, it was not able to reach with its edge the level of the edge of the right one, and its spines are as nearly as they can be at right angles, while the spines of the right side are nearly erect.

July 5.—The leaf is close at both ends up to near where spines begin. The leaf has same appearance as on 3d inst., the convexity of the one internally fitting into the internal concavity of the other (left side). The leaf is partially open along the spines, and it seems more open in the very middle, in consequence of the left lobe bulging out more at that part than at either end. The spines on the right lobe are nearly erect, while those on the left bend over. There is a small amount of fluid at the bottom on midrib, and on applying litmus it was found to be very faintly acid. This acid fluid may have exuded from the slightly *injured* leaf, and may have been the mere juice of the plant.

July 6.—Similar to-day, but a little more open, and is quite unaffected by all attempts to close it by irritation. Both to-day and yesterday there was fine sunshine and also heat.

July 7.—The leaf was open as it was yesterday, but by a good rub with a pencil it nearly closes. It presents the same appearance of erectness of spines on right lobe, and of bending over of those on left lobe.

Another experiment was made on June 30, 1875. On that day three sensitive hairs were cut off, *i.e.*, all the hairs from one lobe, and the leaf was watched to see if any bad effect would result from the shock. As no mischief accrued, it was irritated on July 1, and it closed pretty well.

On July 3 the three sensitive hairs on the opposite lobe were also removed, and the leaf closed slowly. The spines on the outer half of the left lobe are nearly erect.

July 5.—The leaf is open to-day; but, though irritated all over the parts where the hairs had been, there was no response whatever.

July 6.—The leaf was again touched to-day as it had been yesterday; but, though carefully watched, there was not the least indication of any movement. After having noted this satisfactory result, I began in about twenty or thirty minutes afterwards to replace the pots on the shelves, when, to my utter amazement, I discovered that the leaf was then closed, but rather awkwardly, as the spines on the right side, instead of crossing those on the left, were turned inwards. On careful examination we could find no remains of any of the hairs which had been cut.

July 7.—Leaf quite open to-day. It closed slowly, but not perfectly,—the spines cross at an angle of about 45° .

The results of these experiments were somewhat puzzling. Why should the leaf close at all after the sensitive hairs have been completely removed? Can it be that, as we find in other instances in nature, a compensating power has been conferred on the tissues in the vicinity, so that when irritated they do call into action the contractile tendency of the lobes, though not with the same rapidity or certainty as the sensitive hairs did?

One thing, however, is apparent from these experiments, which is, that the sensitive hairs are the organs by the stimulation of which the instantaneous and perfect closure is effected, and that they seem to exert a peculiar co-ordinating influence over all the parts of the leaf; for when that influence is withdrawn, we find that the process of closing is effected in an awkward and disorderly manner.

One Lobe cut away.

On July 2 I tried another experiment with somewhat interesting results. I cut longitudinally through the centre of a midrib, and thus removed one entire lobe. The remaining lobe immediately began to turn round, first at the petiolar end, and then at the distal end of the lobe. A dead fly was inserted into the partially closed distal end.

July 3.—The lobe has turned more round, and that portion of it near the petiole has brought the edge on a line with the midrib, and the spines project over it. The distal part has not turned so far round, but by pressure has pushed the fly somewhat out. The fly was pushed farther in to-day.

By the 7th it had projected beyond the midrib. The fly was firmly held; acid juice was poured out abundantly around it, and digestion proceeded.

In experiments on uninjured leaves I had sometimes observed that one lobe pressed with apparently more force than the other, and hence was seen with its margin considerably lower than the edge of its opponent, while at the same time the lobe bulged outwards, which was a necessary result of its edge being pressed lower down. The experiment which I have just detailed shows clearly that, in the ordinary cases of closing, the trap of the *Dionæa* is formed by the lobes acting with equal and opposing forces, and that it is to this peculiarity that we owe the difference between the *Dionæa* and the *Drosera rotundifolia*, *D. anglica*, &c.; for though belonging to the same natural order, and subsisting on the same diet, these *Droseras* and some other species (*e.g.* *D. Whitakerii*, &c.), curl round their victim, and the above experiment shows that when one of the lobes of *Dionæa* is removed, the *generic* tendency at once manifests itself.

Marginal Spines cut away.

On June 29, 1875, I cut off the spines or cilia from the margin of both lobes, and under these circumstances it was evident what an important part they play in the completion

of the trap, as without them I believe that scarcely a fly of any vigour or energy could be caught; for even a weak and disabled one nearly escaped.

July 1.—Leaf open. An injured fly, which was consequently slow in its movements, was placed on it; and even it was only partially caught and retained, which it would not in all likelihood have been if the bases of the spines had not been left, which firmly clasped the fly by the middle.

The first part of the book is devoted to a general introduction to the subject of the history of the world. The author discusses the various theories of the origin of life and the development of the human race. He also touches upon the different stages of civilization and the progress of science and art. The second part of the book is a detailed account of the history of the world from the beginning of time to the present day. It covers the various empires, kingdoms, and nations that have existed on the earth. The author describes the rise and fall of these powers and the events that have shaped the course of human history. The third part of the book is a summary of the main events and characters of the world's history. It provides a concise overview of the most important moments and figures that have influenced the world. The book is written in a clear and engaging style, making it accessible to a wide range of readers. It is a valuable resource for anyone interested in the history of the world and the human race.





