The Anatomy and Physiology of VEGETABLE IRRITABILITY as illustrated by the Mimosa pudica & Dionæa muscipula.

by

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Introduction

~~Gentlemen of the Medical Faculty~~

We intend in the following pages to give a concise description of the nature of Vegetable Irritability as observed more particularly in the Mimosa pudica and Dionæa Muscipula.—

To enter fully and separately into the ~~various~~ details of Vegetable irritability as it is presented in the various natural orders would be too extended an undertaking for a student whose time must necessarily be occupied by ~~various~~ other studies. We will therefore confine our attention in this instance only to the "Mimosa pudica" and Dionæa Muscipula, and the chief points of

of inquiry will be their Anatomical Structure, and the physiology of their irritability.—

Let us here mention that this short account of what we had the good fortune to observe is but part of a more extended series of investigations of a similar nature having for its chief aim and object the elucidation and explanation of Vegetable irritability.

In the present instance no deductions but such as are derived from careful examinations of repeated experiments will be advanced and in every instance the Experiments from which conclusions are drawn will precide the inference, so that the reader may be enabled to judge whether our deductions are justifiable or not.

Diagrams will be given wherever necessary and these will be as faithful as it is in our power to make them.

With these few preliminary remarks we beg our readers kind attention.

Mimosa pudica
or
Humble plant

Polygamia Tetrandria.

Nat. ord. Leguminosæ. Tribus VIII Mimoseæ. "Decan. dolle. prod. 2, 425."

Mimosa Adanson. Flores polygami. Petala 4-5 in corollam infundibuliformem 4-5 fidam connata. Stamina ima corolla aut ovarii stipiti inserta, numero laborum æqualia, dupla triplave nempè 4 15. Legumen compresso planum 1-00 articulatum, articulis monospermis, costis (replo P. Br.) persistentibus — Stipulæ petiolares. Folia conjugato-digitata aut duplicato-pinnata. Flores roséi aut albi in capitula digesti. Folia sæpe tactu sensibilia.

Sect. I. Eumimosæ Dec. — Legumina compresso-moniliformia, nempe costis ad articulationes contractis.

Flores

Flores rosei.

III pudica.; caule herbaceo aculeato plus minùs petiolis pedunculisque sphæroso-hispidis, foliis subdigitato-pinnatis, pinnis 4 multijugis, foliolis linearibus. Dec l.c. p. 426.

Such are the Botanical characters of the "Mimosa-pudica" as given by "Decandolle" in his "Prodromus" for further account see "Dons Gardners Encyclopedia" and the "Botanical Magazine (Vol XI p 941.)"

Before entering fully into our subject it may not be amiss to give a short history of the plant under consideration.

The "Mimosa-pudica" seems to have been known from a very remote period "Theophrastus" mentions a plant of the name "Αεσχυνομενη" growing about "Memphis" in "Egypt" and Pliny speaks of "Aschynomene" so called on account of its leaves contracting at the touch of the hand.-

"Christopher A Costa" mentions a Peruvian plant "Sulugue", and by him described as the "Herba Viva" which has among other properties ascribed to it the following "Affirmârunt utilem esse virgines corruptas in integrum restituendas."

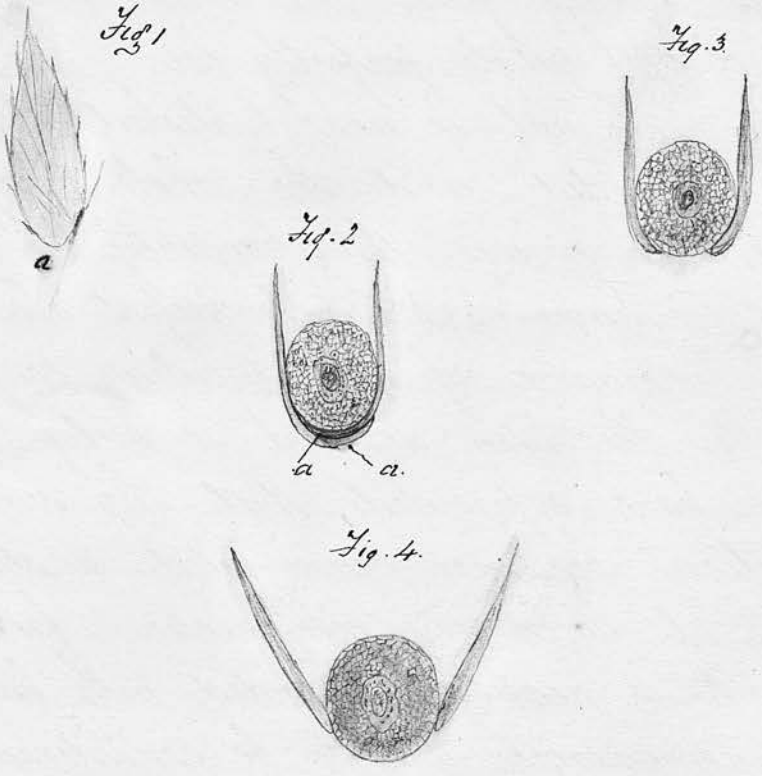
The "Mimosa-pudica" has been introduced into almost every part of the world. With a little care it grows very luxuriantly in

this

this country. It is a tender annual shrub and requires a temp^r of about from 80° to 90° F. with much light and moisture. Owing to its peculiar "sensitive" (?) property it has constantly engaged the attention of Physiologists, who have been both puzzled and baffeled to find a correct explanation to account for this interesting phenomenon — Various theories have from time to time been propounded to account for and explain the cause of this sensibility, or as it might more properly to be called "irritability", with but indifferent success. — But before we do this task ourselves let us take a glance at the Component parts of the plant and familiarise ourselves with the various existing configurations in its various phases —

"Mimosa-pudica" is a dicotyledenous plant whose primary leaves are irritable the moment they appear and continue so till they fall off, which happens soon after the appearance of the other leaves — Vernation is peculiar — The foholes are folded forwards and are regularly imbricated the one nearest the petiole overlapping the one in front of it. The pinnæ are similarly appressed and then bent forward on to the petiole — The whole young leaf

Drag^m^ No. 1



Bracts & Stipules of "Mimosa pudica."

Fig. 1. Shape of Stipule - a. pendent part protecting young joint.
" 2. Stipules folded round young joint. a. a. pendent parts.
" 3. Stipules in partially developed joint.
" 4. Stipules in fully developed joint. S.S.M.

bud is incased in a "pseudo-sheath" formed by the stipules overlapping one another at the base of the petiole. This peculiar position prevents the young leaf from showing the irritability for some time, as can readily be understood.
As the leaf advances towards maturity they (the stipules) diverge from one another and leave the base of the petiole perfectly free.
By the time this act is accomplished the foliole have all expanded and the whole leaf is then seen to possess the property of irritability (Vide diagram No 1) Imperfect observation and an ignorance of this peculiar configuration has led to the idea that it is only after the leaves have expanded, that the sensibility to excitation became manifested, a statement perfectly at variance with actual facts.
The plant is richly provided with hairs but as those appendages are to be considered at greater length when treating of the Microscopic Anatomy of the plant we may here merely allude to them.—

The leaves retain their sensibility for some length of time, but the moment the green of summer gives place to the golden hue of Autumn, all irritation is lost and those beautiful organs share the fate of

the one nearest the stem and ending with the terminal one.- If the plant is very irritable the leaves both above and below the point of irritation may partake in a similar action, but this is not generally the case.-

Sometimes this action is slower than at other times and this difference will invariably be found to depend on the temperature. The higher the temp^{re} the greater the irritability and "vice versa." But variations occur in the course of the closure of the folioles and the depressions of the petiole and pinna.- For instance if we irritate the pinna at their common junction, the closure of the folioles and the depression of the petiole will take place about the same time. Should the terminal folioles be irritated first, the closure will take place in a retrograde manner, but if the irritation applied to the terminal foliole be strong enough to prevade the whole plant, the folioles will invariably close after depression of the petiole.- In fact the excitation is centrifugal. Again if the folioles in the centre be excited closure will take place on both sides simultaneously.

Another kind of direct excitation may be produced by the sudden admission of a blast

or

or current of cold air.— When this happens the whole plant is immediately excited · and a general closure of the foioles takes place together with a drooping of the petioles and pinnæ.— The mode in which air acts as an excitant will subsequently be explained.— Besides these two direct excitants there are numerous others as violently shaking the plant, electricity, etc. etc, but as the actions produced by them are similar to those already mentioned it would be superfluous to enumerate them at greater length.—

II. Phenomena brought about indirectly or by means of reagents.—

The action that takes place when a "Mimosa-pudica" is brought under the influence of a reagent is practically speaking similar in almost every respect but when regarded in a physiological point of view of a <u>vast</u> difference.— The general phenomena are the same, but their are some minutiæ which it would be as well to notice, and we cannot do better than transcribe one or two experiments made some years ago by ourselves with Chloroform and other reagents.

No 1.. Plant "Mimosa pudica" agent Chloroform Temp 80.°5 Fah.

Two

Two or three drops of chloroform were gently placed on one of the petioles (base) of a middle sized "Mimosa pudica". Almost instantly the leaf drooped and a few seconds after, the foholes began to close.— About the same time the petioles both above and below the point of application began to droop and soon after to close their foholes. "Vide Edin.r New Philosph. Jour. Sec.d Series. Vol LVI pp. 293.")
There were several leaves both above and below the point of application and they both began the closing of their foliales at the same time.— The time occupied for this complete closing was about 3 minutes from the application of the agent.— It took about one hour before the foholes were again expanded and the leaves in site.. We found that on opening its foholes the plant had entirely regained its sensibility and was not, as asserted by "Prof.r Marcet" (Edin.r N. Phil Jour. l.c.) insensible to external or direct irritation.— We must here remark that when a plant is excited by a direct excitant as cold or rather a violent shaking it resumes its normal appearance much sooner.—
The general or rather average duration in a case of direct excitation is about 8 or 10 Minutes.—
When excited by chloroform 5 6 Minutes.—
The temp of the hot house at the end of Experiment 77.5 Fahr.—

Note.—

Note—. Those leaves brought under the influence of the reagent last, were slower in closing than those to which it was immediately applied, they also expanded their foholes a few minutes sooner—

№ 2. Mimosa pudica— Chloroform. Temp. 78° Fah

The terminal leaves of this plant were more fully developed than those of the preceding one.

Some of the foholes of the lower leaves were of a Yellowish hue.

The Chloroform was applied to the penultimate leaf of the top branch and the actual point of application was the two last "pinna" or rather foholes. These foholes immediately closed and the others followed in rapid succession, and a few seconds after the petiole drooped; in all the other leaves the petiole drooped before closure of the foholes commenced.— The two leaves on either side of the penultimate one drooped about the same time— The others then followed in regular succession.— About 8 minutes elapsed before all the foholes were closed.— About half an hour after the closing of the last fohole the plant began slowly reopening, those parts more remote from the point of application sooner than those

in

in its immediate vicinity — Foholes having a Yellow or faded color were not acted upon — On directly irritating the plant immediately after opening of the foholes all the phenomena of irritability were exhibited — The time taken by the plant in this instance was about 50 minutes before it regained its normal appearance — a few minutes less than in the former experiment — This may be owing to the increase of temp. which took place in the hot house .. viz from 78° F. to 81° Far — whereas in the former it fell to 77 Farh —

No 3. Mimosa pudica — Bi Sulph of Carbon. — 85° F.

One drop of "Bi-Sulphuret of Carbon" was placed on the middle pair of foholes of a leaflet on the penullimate leaf. About 25 seconds after the leaf began closing its foholes on both sides of the point of application rapidly and regularly, — a short time afterwards (about 10 seconds) the leaf drooped. All the other leaves more or less partook in the action. The plant rapidly recovered from the effects and in about 12 minutes regained its pristine activity.

For further and fuller accounts of the action of reagents on Mimosa pudica.

See —

see." "Bot. Societies Transactions." Vol VI. part III. p. p 225 - 390."

We now pass on to another point of inquiry and one bearing more directly on our subsequent explanation of the cause and nature of Vegetable Irritability. Viz

I. What parts of the plant are irritable, — and which of those parts show this irritability best.

II. What are the changes observed in those parts when they are irritated.

I. On a careful examination of the Mimosa pudica we find that the petiole of every leaf has a distinct and peculiar hinge joint articulation with the stem and possessing a certain amount of mobility. — The configuration of the joint is eminently peculiar. At the base of each petiole there is a distinct swelling the under side of which is convex in the direction of the axis of the leaf. On the upper or superior side, or rather surface, it is perfectly straight or at most but slightly convex, that is when the leaf is at an angle of

of 45° to the stem. In a fully developed leaf this swelling is about ¼ of an inch long and rather thinner at its articular end than where it merges into the petiole of the leaf. Its centre is thicker than either of the ends. At its junction with the petiole you find a distinct nodosity, having the appearance of a rigid joint.— We have already alluded to the hairs and stipular appendages the former being distinctly irritable.—The joint just described is by far the largest and most important. It is also the most irritable, and by carefully studying it we arrive at most of our conclusions.—

The other irritable parts in the plant are the articulations of the pinnæ with the petiole and the folioles with the central leaf stalk of the pinnæ. These two joints; the leaflets or pinnæ and the foholes are slightly modified as we will subsequently point out. Beyond the parts just enumerated we are not aware of any other part being visibly irritable.—

II. On irritating the leaf of a Mimosa pudica at the bulb of the petiole an immediate change is observed in position the leaf instantaneously falls from an angle of about 45° to 175°.— On examining the bulb no change in bulk can be

be detected on the upper surface but a marked change in shape takes place. The lower surface on the contrary becomes greatly altered both in bulk and in shape, instead of being convex it has become concave. The articulation is rigid.—

In due time the leaflets become approximated and also depressed, before irritation they were seperate and elevated; a few seconds after the fohioles close, pair by pair in regular succession until closure is complete.— The fohioles in closing are carried forwards, appressed, and overlap one another in regular succession; this phenomenon will be entered upon more fully subsequently.—

Having thus taken a short look at the changes which occur in certain parts of "Mimosa pudica" our next attempt will be to explain these phenomena, and to do this satisfactorily a minute and careful investigation of the ultimate structure of the various articulations becomes absolutely necessary.— For obvious reasons the joint that will furnish us with most accurate details is the large or "petiolic" joint.— In its examination we will include also the appendages proper. We mean the hairs, for they will be found to play an important part in vegetable irritability.— Not so much in Mimosa pudica as in the Dionæa Muscipula.— The examination of this

joint

joint will not however furnish us with all the requisite data.— An important point was to be cleared up. one which has long been a sad stumbling block— —How is the irritability conveyed from one part of the plant to the other.— For the elucidation of this the petiole must be examined, and also the "interfoliar" spaces.— And to complete the whole, Microscopic examinations must be compared with the results of experiment, and by analogies so obtained an explanation attempted.— That this may be ~~done~~ the better done great convenience will be found in examining each part separtely and in regular succession and for that reason we will divide our subject into

I. What are the Microscopic appearances of a "petiolic" joint of a "Mimosa pudica"; and in what way do those peculiar appearances account for the phenomenon or irritability.

II. What relations do the Hairs bear to the ultimate structure of the joint, and what are their functions and uses.—

III. What are the appearances presented by the stalks of the leaves (petioles) and the spaces between the foholes, and how do

they

they explain the cause of the continuance of an irritation to a part distant from the point of irritation.

IV. What relation or analogy can we draw by comparing the results of experiment with Microscopic investigation and how far is the former an "experimentum "crucis" to the latter.—

By a careful study of these various points, and a diligent enquiry into the various structures to be examined we may at least harbour some hope of succeeding in our undertaking.—
Before however proceeding to do so let us briefly review what had already been done to clear up the doubts which seemed destined continually to surround this subject.—
Among the first observers if not the first we find the name of "Lindsay" who in the year 1790 performed the following experiment (subsequently rediscovered by "Dutrochet" ("sur la Struct intime des Anim: et Veg.tx" p 1848) " If the cellular tissue be cut away down to the central vascular bundle on the upper side of the articulation of a leaf stalk attached to the plant. (Mimosa p.) the cellular tissue on the under side having now lost its antagonist

antagonist can persue its expansion and the leaf thus becomes at once pressed up at a sharp angle; the reverse occurs when the cellular tissue on the under side is removed."
This experiment, unless carefully analysed, is apt to mislead and bring us to erronkous conclusions-(Viz) that both parts of the joint, upper and under, are capable of exerting an influence by expansion and contraction on its movements. We will subsequently see that this is not the case.—

"Du Bucke" has proved "Mullers Archives 1848 p.p. 452." that the phenomena of sleeping and waking returned after a short period and to a lesser or greater extent according to the place from which, and the quantity of tissue removed as described by "Dutrochet"; the phenomena were greatly modified especially when the under surface of the bulb was removed. This is an important fact and well worthy of our notice.

"Mohl" remarks- "The movement of leaves dependant on one sided expansion, of the cellular tissue may take place in various ways.— In the first place if the cellular tissue of the upper side swells up a curvature downward would naturally take place owing to the preponderance acquired over that of the other side and "vice versa" It is possible that both these actions may take

place

place simultaneously." (Mohl on the Vegetable cell (Translated by A. Henfrey) p. 153.") This is merely a statement, a surmise, an opinion. Without a single given fact to support it. We have already stated that at no time does any change occur in the size of the upper surface of the articulation and were we to admit the possibility of "Mohls" statement it must be done by ignoring facts.—

"Dutrochet" some time after he repeated the experiments of "Lindsay" put forth the following statement "The movements of a leaf always depends on the cellular tissue of that side of the articulation which is convex in the curvature expanding actively whilst the tissues of the side which becomes concave remain passive" (Dutrochet Nouv. Reserch sur l'endosmose p. 47.") This statement is not correct. Never under any circumstance does the superior side of an articulation become concave — It is always and under every normal circumstance most decidedly convex — The lower side does alternately become concave and convex, according to the position of the leaf, but the convexity of the upper side is not always indicative of a concavity of the lower and "vice versa."

"Burke" maintained that the articulations

articulations became relaxed when irritated, and the conclusion he came to was that the movements did not depend on the expansion of the cells but their relaxation and that that action chiefly was exhibited by the lower side (Mullers Arch. 1848. p 440) — The fact that a leaf of "Mimosa pudica" deprived of its upper bundle sank a few degrees permanently, at first sight seems to favour this view, but as we hope fully to prove that the action was owing to something totally different from relaxation we will in the meantime leave the discussion of this point.—

"Dutrochet" in his "Memoirs" retracted his previous statements and was not at a loss for another explanation — Hear what he says.—

"The movement depends on the curvature of the younger layers of wood, which in consequence of the irritation, absorbed oxygen from the vicinity in a way not further explicable, and thereby cause the curve downwards."

— How or where data were obtained to propound such a theory we are at a loss to comprehend and to us the matter is as unexplicable and even more so than to the propounder.—

"Mohl" (l.c. p 152) states that "if we cut a plate longitudinally out of the middle of the joint which of course will consist of

for the phenomenon or irritability.

On examining a section of the bulb of the petiole of Ll. Judica with a power of about 450 diameters we found the lower mass of cells to have a double wall with a number of granules floating in a viscid fluid. These cells are of various sizes and shapes, those on the circumference and roots of the hairs being, not only larger, but also more regular in shape. The granular matter in the cells on the upper surface is more or less conglomerated.- When the joint is first irritated and then subjected to examination a peculiar appearance presents itself. The lower mass seems as it were made up of a number of large oil globules, and indeed were described by "Mohl" as such, but a careful examination proves them to be nothing but the contracted cells whose granular contents have become "pro-temp" conglomerated, the thinner part of the contained fluid having escaped by transudation through the cell walls.- These granular looking cells have merely their walls increased in thickness.- In the more fully developed cells we find a larger amount of fluid, but as the cells go on developing this fluid gradually diminishes, and becomes replaced by a larger quantity of granular matter, which when the leaf becomes

of the woody bundle in the middle and of a layer of "parenchy – matous" cellular tissue on each side and then cut this plate into thin slips the middle of which is composed of the vascular bundle, and the two sides of the cellular tissue. the latter pieces immediately expand about 1/5 longitudinally, whence it is evident that the bundle is too short in proportion to the turgescent mass of cellular tissue of the articulations and that the latter is compressed in the direction of the longitudinal axis in the uninjured joint."

The author evidently forgot that his joint was not uninjured. – The first contact of the knife must have caused irritation. – Can an irritated joint strictly speaking be said to be uninjured.?

One statement more – "Mohl" (Le p 156) remarks "The side which becomes concave is alone capable of receiving stimuli." – This is an important fact. – The lower surface is the only surface that becomes concave, as it is also the only surface which we in the "petiolic" joint at least can irritate mechanically or directly. – These few notices are all that we have been able to find, they perplex rather than help us. – As we go along we will endeavour to point out their errors and show how all the observed phenomena can be explained

explained in a far simpler manner.—

—Having accidentally discovered that "Spiritus Aethers Nitrici" had the peculiar property of making a joint to which it was applied perfectly rigid & at the same time keeping it "in situ" we concluded that sections so obtained would lead to important results.— Whether our surmises were correct the issue must prove.—

Another property possessed by "Nitric Aether" is that it makes the tissues very transparent without dissolving or destroying the most delicate structure.— The advantage this reagent affords the examiner is immense, for it enables him to examine the plant under an entirely new aspect.- Structures and parts formerly unmanageable, are now examined with ease, and joints whose irritability defied all attempts at investigation are fixed and rendered immobile.— The chief obstacle has been overcome.—

The greatest difficulty of the "Sphynx" is solved, and careful and diligent attention cannot fail ultimately to afford us the satisfaction of a happy and practical solution of this "Mystery."

I. What are the Microscopic appearances of a "petiolic" joint of a "Mimosa pudica" and in what way do these peculiar appearances account for

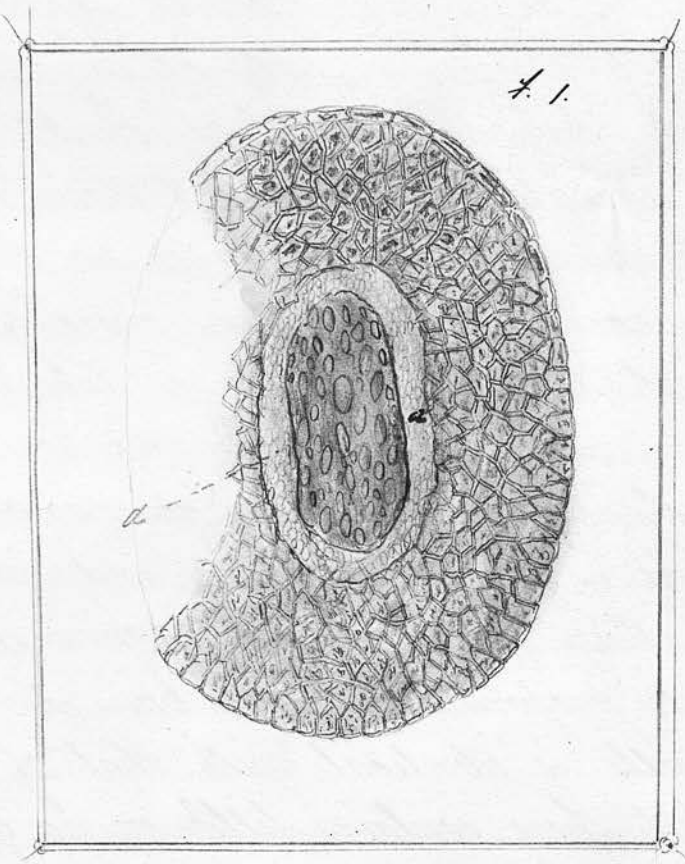
becomes of a Yellow hue entirely fills the cells.—
With this deposit we find, invariably, a sensible decrease in the irritability of the plant, and this diminution of irritability goes on proportionately with the deposition of the granular matter, so that in Autumn when the cells are completely filled all irritability ceases.—

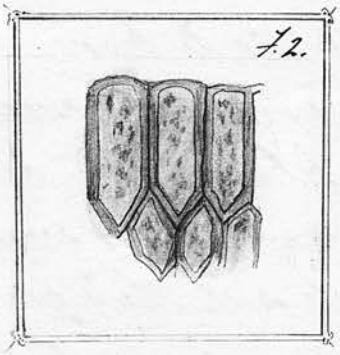
In the fully developed cell the granular matter is at a minimum, and the fluid at a maximum. When cells of irritated joints are examined (fully developed cells) in which there is little or no granular matter the cell wall is observed to be thickened and irregular, whilst the contents have a greater refractive power.

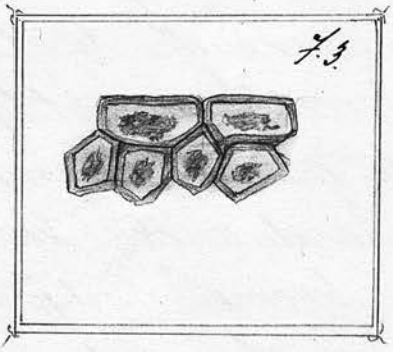
The cells forming the mass of the upper surface like those on the under surface have a double cell wall, and invariably contain granular matter which increases in amount as the plant advances to maturity.—

Before attempting to explain the cause of phenomena as deduced from these observations let us take a glance at the modifications which occur in the shape of the cells according to their respective situations in the joint and also their peculiar mode of attachment to the central vascular bundle.

Diag. N°2







f. 1. Transverse section of Petiole [illegible]
f 2. Inferior layer of cells magnified
f 3 Superior " " " " "

I. The Epidermal cells. —

a. Upper or Superior surface.. B. Lower or inferior surface. —

a. The cells on the upper surface are elongated & form a distinct layer. — They are placed one above another like bricks in a building. The cells are double walled & their contents distinctly granular. The cells in the lower layer are more compressed contain more granular matter and are not so regular in shape. Vide Diag No. 2. fig.

B. The cells on the lower surface differ in shape having the appearance of "point lace." — There is only one layer, and instead of being placed on their sides they stand on end. — They are larger and proportionately broader. — The structure of their walls is identical with that of the upper surface, but they contain little or no granular matter. On making a transverse section of the joint thin enough to allow us to trace the epidermal cells completely round the circumference the gradual change between the cells on the upper and under surface will be seen. — They gradually become modified to suit their peculiar duty. —

Those on the under surface owing to their peculiar conformation are much better adapted for contraction whereas those on the upper surface are more suited for bending and adapting themselves

cf. Code. Diag. No. 2. f. 2 & 3.

themselves to the changes in the joint.[a] The lower cells owing to their being free from granular matter can contain more fluid and this is not without its importance, whilst the granular matter in the upper epidermal cells are not without some use in the motions of the plant.

2. The Configuration of the cells at the roots of the hairs. — As this comes more properly under the description of the hairs and their attachments we will defer description till then.

3. The peculiar mode of attachment to the central vascular bundle There is a totally different kind of cell immediately encircling the central vascular bundle entirely different from those we have hitherto examined. As far as can be made out with "Nachets" highest powers they have no double cell wall, are very small, and applied closely to the central vascular bundle completely separting the other cells from it, like the isolating medium in an "Electric" cable. Into this mass the surrounding cells gradually become incorporated and no clear and definite line of demarcation can be detected. — True, there is a more or less distinct line of termination, but that line cannot be said to indicate a complete separation for on examination a few cells are found

to

to extend beyond it. (Diag 2. f. 1. (a))

Having now briefly given the "Microscopic" appearances of the cells, and also pointed their contracted state in joints examined after irritation let us for a moment examine into the action of an independant cell— We have seen that the power of irritability ceases with the disappearance of the fluid contents, that when the cells contract their walls become thicker, that the fluid contained is extruded and finally that those parts not subject to irritation, instead of containing fluid are filled with granular matter.— That the cells on the superior surface are peculiarly adapted for change of shape and those on the under aspect for change of size.— When a cell becomes irritated it contracts, and exudes its fluid.—

This fluid applied to the cells in the immediate vicinity causes contraction in those cells which it comes in contact with, and thus the whole mass becomes contracted.— This contraction is a peculiarity possessed only by the cells on the lower surface in the petiolic joint.— We know from "Dutrochets" experiments that the actions were greatly modified where the under bundle was removed and their entire cessation would most probably have been

been the result had part of the sides been removed as well.— The contractile cells are not confined merely to the lower surface but also to some extent along the sides.—

The idea maintained by "Burke" that the motion depended on a relaxation of the joint is erroneous.

The reason why the plant sank a few degrees permanently after removal, was because the lower mass of cells secondarily acted as a kind of support of the leaf. which being taken away the leaf gravitated downwards not by any relaxation of the joint but by its own weight.— Again the upper bundle of cells by its elasticity prevented the undue elevation of the leaf by the expansion of the cells.— This guard being removed the action was unchecked and hence the more than usual elevation of the joint.—

Our opinion is that each cell must be looked upon as an independant structure a complete secreting gland.— The outer coat is certainly contractile, whereas the inner one must be viewed as a secreting membrane.— They differ in structure and polarize light differently. Their fluid contents have the power of causing contraction of the outer coats

coats.- How else could irritation spread over the whole joint when the point of irritation is caused by the mere application of the point of a pin?- That the action is due to the fluid contained being exuded is indicated by the leaf taking some few seconds when a point merely is irritated before it drops, whereas when the bulb is touched over a larger surface irritation is exhibited more suddenly.- After a time the influence of the exuded fluid wears off, the rigidity caused by the contraction of the cells is removed, the cells become refilled, they re-expand, and by so doing raise the leaf to its normal position.- On irritating the plant immediately after it has recovered from the first excitation it is observed to descend much slower. This is owing to the fluid being in less quantity than before. After repeated excitations tolerance is engendered and the plant becomes insensible to that kind of excitation, and it is only after sufficient time is allowed for that tolerance to wear off that irritability reappears.- Again when the leaf becomes older and more wax is deposited in its walls, there also is a diminution of fluid.- Not only is there less power of contraction but an equall obstacle to transudation.

Collateral evidence also gives us proof that contraction is the agent or rather cause of the

movements

movements.-

I. Whatever is favourable to the phenomena of contraction under other circumstances causes a depression in the leaves, and other parts of "Mimosa pudica." Sudden diminution of temperature will instantaneously cause depression of its leaves, and if even a small diminution of temp.e takes place the plant becomes modified as regards the rapidity with which it resumes its pristine form. (Vide p. 2.) Chloroform when injected into the flabby tissues of an animal recently dead causes instant rigidity of the parts (Brown Sequard)- This is due to the contraction of the muscles - A similar influence is exerted on the cell walls, and the moment this action is so far exhausted as to cause no further contractibility the cells expand and the plant resumes its natural form.- The cells recover from the effects of the chloroform slower than from mere mechanical irritation. This is owing to a true anæsthetic influence exerted over the cell wall,- they become for a time paralysed as it were.-

3. Whatever causes or favours expansion in contractile tissues causes a more upright position in the leaf.- Two plants irritated in the same temp and then removed to different temperatures, the one in the highest temperature will be expanded much

much sooner than the other. (vide p 12).

4. Whatever neutralises the effect of contraction will retain the plant in "situ." This is seen in plants subjected to "Sp. Ætheris Nitrici." (vide p 22)

5. Microscopic investigations confirm the truth of the contraction. — The cells on the lower surface are much smaller and thicker in their walls after than before irritation, and a peculiar irregularity in the walls further confirms this belief.

These facts cannot but lead us to the conclusion "That the whole phenomena of the movements depend upon certain contractile cells, and that in the "peliolic" joint they are situated on the lower surface."

We pointed out a peculiarity in the cells in the upper surface of the joint, their contained granular matter. — This matter plays an important point in the second or "retrograde" movement after irritation. — When the leaf falls these cells naturally bend and become slightly compressed. This compression can but be slight owing to the solid nature of the contents of the cell. These granules necessarily become so many "fulcra" or points of resistance, and thereby increase the elasticity and power of the cells, which increase of power is of great

importance

importance in relieving the expanding cells on the lower surface from the incumbent weight and also in assisting in the drawing up of the leaf.— The use of the cells on the upper surface being limited to this extending power the greater their elasticity the better, and this increased resistancy is furnished by the presence of these granules.

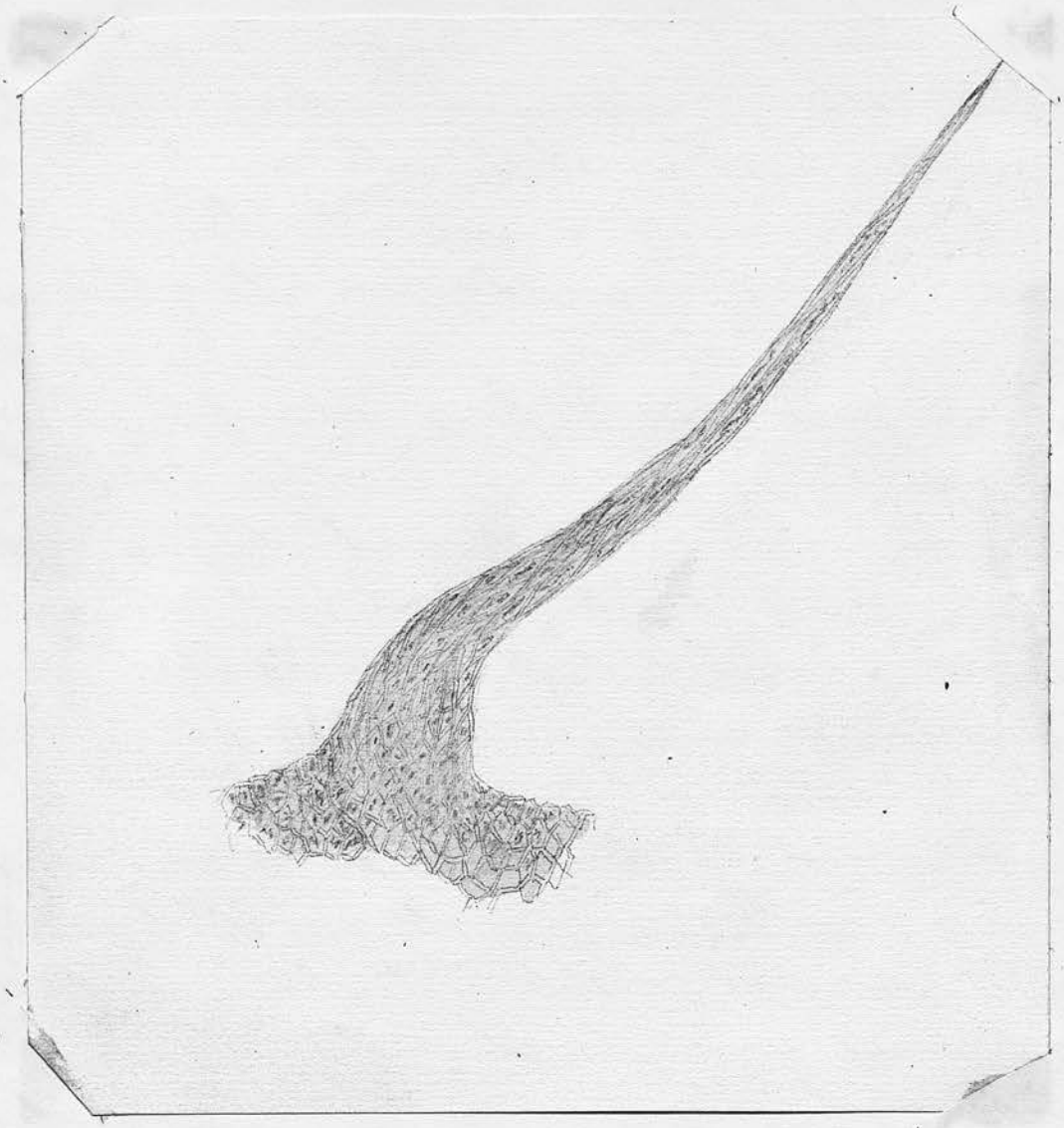
The soft central tissue noticed as occupying the position round the vascular bundle affords an increased play to the contraction and expansion of cells, and were it not for this peculiar arrangement, the movement would either be very limited or the weight of the leaf when combined with the force of contraction would materially injure the joint.— (Vide Diag.— nº2. Fig 1. p 25)

II. What are the relations of the hairs to the ultimate structure of the plant, and what are their functions and uses.

It is by a careful examination of the hairs and tracing their continuity with the cells in the interior of the mass at the bulb of the petiole that we obtain a correct idea of the individual cell.

Let us place one of these hairs under a power

Drag.r N.o III



Compound hair. Mimosa pudica

power of about 250 diameters and carefully describe what we see.— Beginning at the apese, we find a single elongated spindle shaped cell, having a distinct double cell wall, a slightly refractive fluid, and a few granules. At the other end we find one or more similarly shaped cells joining and twisting round the terminal cell.+ These cells are twisted one on the other something like the "strands" of a rope.— As we near the base the cells gradually become shorter and more numerous, they assume more varied forms, and at length when we reach the base can hardly distinguish them from the surrounding structure. (Vide Dg. 3.)
In the young plant the terminal cell of the hair is furnished with a prolongation which disappears when the plant arrives at maturity.
The hair described is one taken from the lower surface of the petiolic joint.= The use of the hair in the young plant is evidently to protect the joint. Insects instinctively avoid hairy parts and even should a stray intruder alight on the joint the hairs with their terminal prolongations act as pretty efficient guardians to the young joint.—

These hairs are also found to act as points of excitation as we may safely satisfy ourselves

Drag. N.° V

Fig 1

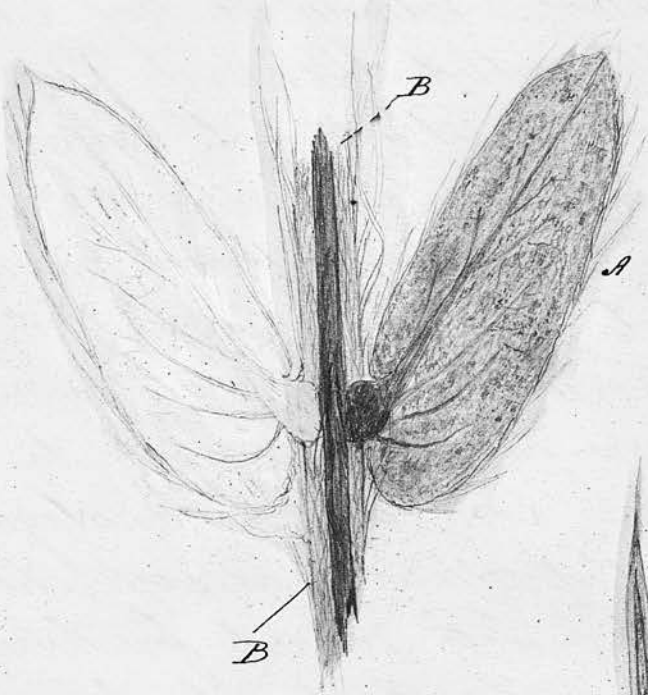


Fig 2

Fig 1 { A Foliales with hairs on their margin.
B B Continuation of hairs and conducting cells on midrib of pinna.

Fig 2. Magnified compound hair (Pinna)

"Mimosa pudica"

ourselves by irritating one on the petiole extremity when the result will be immediate falling of the leaf.- These hairs are like their analogies the cells variously modified.- They are found to be most numerous on those parts most sensible to irritation.- (Vide Diag No 4.)
Round the margin of the foholes they form a distinct structure.- Edging the leaf is a distinct layer of double walled cells, and these hairs can be traced directly to that margin and from the margin to the small bulb attached to each foliole.- The hairs do not play that important part in the "Mimosa pudica" as they do in the "Dionæa Muscipula" but nevertheless their action is prominent enough to merit our attention.- They are the analogues of the double walled cells.-and as such should be looked upon with interest for their termination affords us abundant scope for examining an individual cell.-

The hairs found on the margin of the foliole and bulb of the foliole (Vide diag 5) are continued down along the stem.- but this leads us on to

III. The appearances on the stalks (petioles) and the spaces between the foholes, and

Diag.ma N.o VI

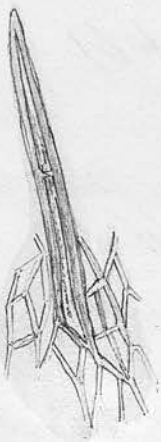


Fig I Hairs on petiole

Fig 2 " " " magnified

" Mimosa pudica "

and what does their peculiar configuartion indicate.

On examining a petiole kept long enough in "Nitric Ether" to render the cells covering the vascular bundle transparent the following appearance is observed.- A number of hairs are found to spring from the cells forming that covering and intimately incorporated with the forming cells.- These hairs are composed either of a single double walled cell or of two single cells placed end to end.- They contain a fluid of high refractive power and also a small quantity of granular matter.- On tracing their continuity with the surrounding cells we find them distinctly blending and becoming incorporated with those cells.- In fact they are nothing more than ~~x~~ prolonged cells which are either single or transversely divided by a distinct septum.- (Vide diag. No 6)

The cells from which these hairs spring, are of a longitudinal shape, placed with their long diameter in a line with the axis of the petiole.- They are a prolongation upwards of the cells at the base, having characters exactly similar to those on the under surface but only modified in shape.- This coating entirely surrounds the petiole, and communicates directly

directly with the contractile bulb at the base of the leaflets.— These bases or contractile parts have a structure very much resembling that at the petiolic joint, and are furnished with a number of hairs similar in structure but smaller than those described, which are found on that part.— From this joint a cellular expansion is continued, completely surrounding the joint, to the bulbs of the first pair of foholes.— Covering and intimately connected with their joints, it extends along the margins of the foholes, giving of several hairs, compounded at the base, and single ones round the margins. [Vide diag. 5] These hairs are not so large, but are much longer in their terminal cell. When these hairs are single, they are longer and more slender than those found on the petiole. From the base of one foliole to the base of another, there is a continuation of the contractile tissue of the bulbs, from which very long single celled hairs are given off, longer than those on the margin of the leaves. All these hairs have the typical double wall, with enclosed fluid and granular matter. The connection of the bulb with the stem is similar to that of the petiole. The large square shaped cells gradually become more elongated and as they have the bulb cover or rather encircle the whole stem.— As they approach

a

a joint or leaf they gradually become shorter and proportionally broader till they merge into the bulb of the petiole.

Let us now trace the continuance of this encircleing mass of cells. Beginning at the terminal foliöles. We find hairs and cells encircleing the margin of the foliöles, and blending with the bulbs at their bases.- From these bulbs the chain of continuity is carried on to the next pair of foliöles, and so on and on till they become incorporated with the bulging at the base of the leaflets. Thence along the petiole, they are carried on to the bulb at the base, and from the base they extend in both directions upwards and downwards till they meet other joints.- The chain of continuity being still further extended, we ultimately connect and bring into relation the most distant parts of the plant.- This "chain" of cells if we may so call them act the part of "telegraphing wires" and convey the action from one part to another.- The action of this battery is simple.- One part being irritated contracts, and by so doing exudes its contents or rather fluid. This fluid acting as a stimulus or irritant causes the cells with which it comes in contact to contract.- These contractions cause a greater flow of fluid and engenders a corresponding amount of rapidity.- Whenever the action arrives at a part

whose

whose configuration admits of motion, the phenomena termed irritability are observed.— Still advanceing the fluid at length reaches the bulb of the leaflets, they close, next the "petiolic" joint is affected, the leaf falls.— The fluid having now arrived at a part where it extends both up- and downwards, follows both these directions, arrives at the "petiolic joints" both above and below the points of irritation, lights up an action in each of those leaves, immediately passes on to the next, leaving those affected in passing to pursue their independent action, repeats its former action with undiminished violence, and in due time affects the whole plant.— Thus from the foliules down their stalks, along the petiole, up and down the stem, branching at the various leaves, this action is successively conveyed prostrating and effecting every thing as it sweeps onwards.

The simultaneous action up and down the stalk is important as explaining the hitherto strange fact, that the lower as well as the upper leaves partake in an irritation strong enough to affect the whole plant.—(Vide p. 110)

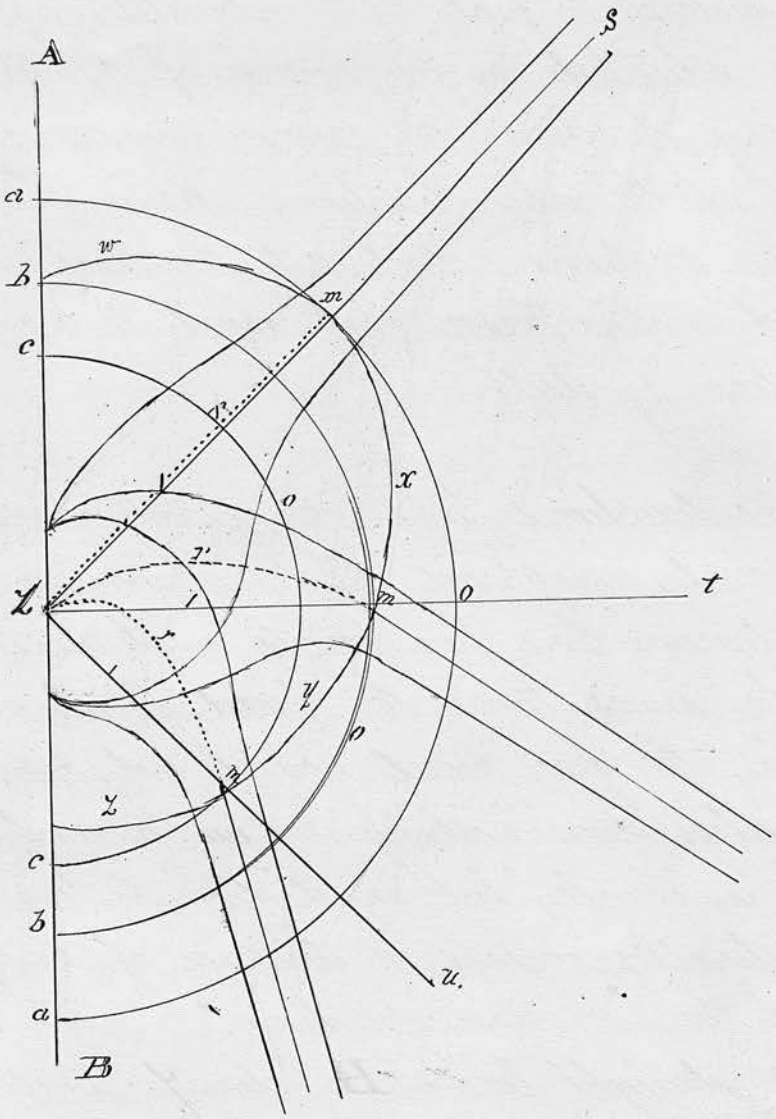
IV. The relation of experiment, and microscopic research "clash in" here most beautifully.—

When a plant has Chloroform applied to one

one of the terminal foholes of a pinna, that pinnae is the only one whose foholes close before the leaflet droops. In all the other pinnæ or leaflets (the terms are synonymous) drooping precedes closure. This is because in all the pinnæ subsequently affected irritation began at the base, at the point of radiation of the conveying medium. — The leaf whose pinnæ were first irritated droops after the closure of the foholes. - all the others droop before the foholes are affected. — The reason is the same as that given in regard to the pinnae. — In fact by bearing in mind the course and relation of the conveying medium we can explain almost all the observed phenomena in experiments with anæsthetics and other agents. —. Experiments prove the truth of our observations and this is the more important when we bear in mind that the experiments were made not with a view to explain, the use of what was seen under the microscope, but that the latter investigation revealed the cause of the former.

Another and not less interesting point still remains to be considered. — What are the courses described by the various parts of the plant; and how do their motions help us to ascertain the site of the contractile part of the cellular mass. —

Diagr. No VII



Course of movement. Petiolic joint. "Mimosa pudica"

I. What is the course described by the leaf as a whole when the petiolic joint is irritated?— Before answering this question let us again state that motion is owing to contraction. The petiole droops and "ergo" the contractile power is on the under side.— In fact the contractile agency is always situated in the course of the part moved, this being the case the course necessarily indicate the site of the cells of action. Having thus explained how the motions point out the position of the power of motion, our next object is to examine the motion by itself.

When contractions take place between a free and fixed point, unopposed by counteracting media curvature between those two points must result, and if at the same time the fixed point acted as a centre, the free point could not, owing to its continually diminishing radius during contraction describe a circle, but must describe an ovospheroid— ? This actually occurs in the case of the petiolic joint of the "Mimosa pudica."

Draw a straight line A B. (diag. 1) and let that represent the stem of the plant, and let a point Z. in that line be the fixed point.— Next fix upon another point say M; for the free point join the points Z. M. by a straight line Z + M. which will

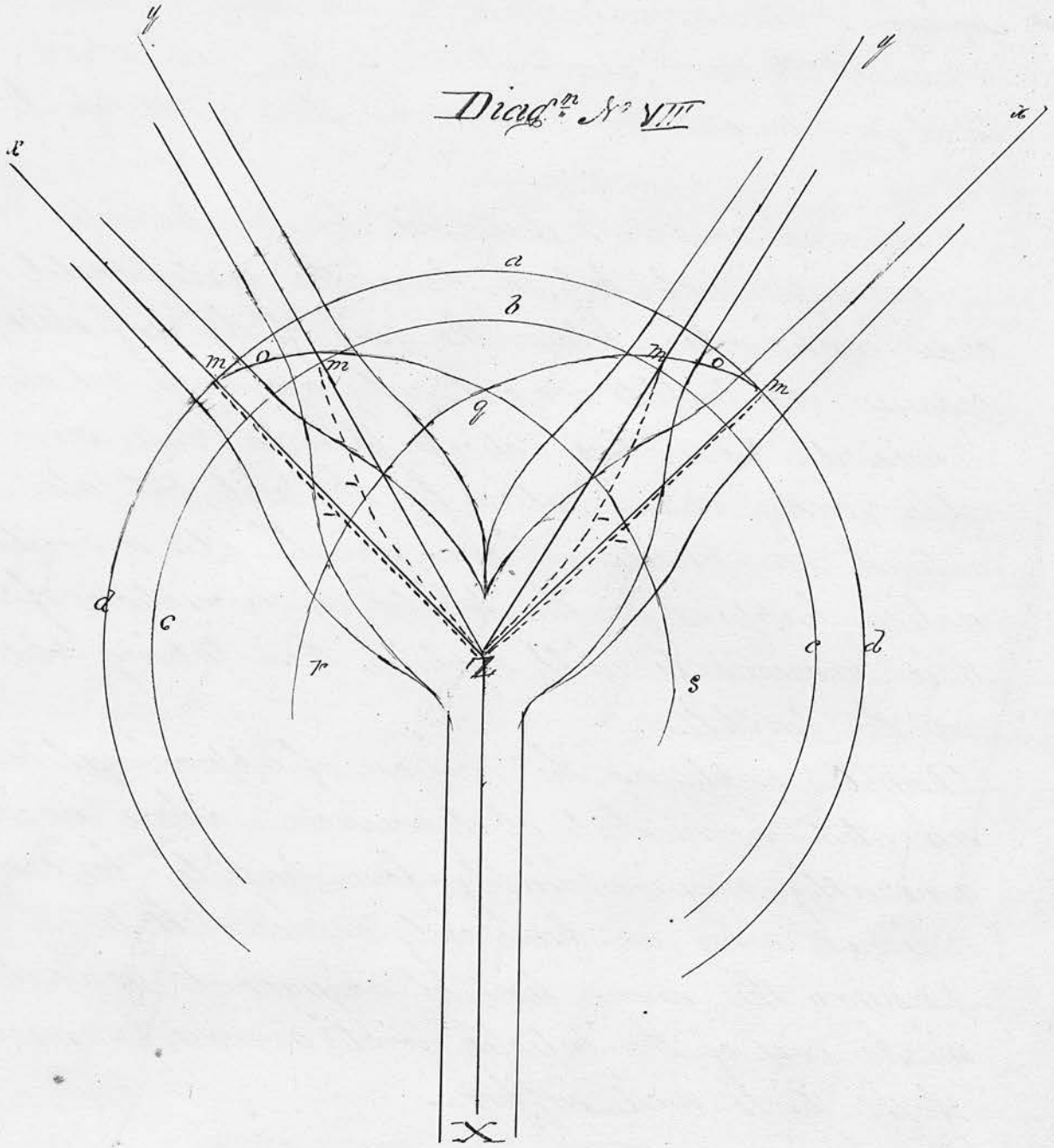
will represent the true plane. This plane, namely a line drawn at any time between L & M. will also be the direct plane. For convenience sake superadd to the direct plane an imaginary line L r M. running parallel to it and let it represent the true plane. The true and direct plane being one and the same thing when the plant is in the normal position a second line is not mathematically correct. — It is merely here at least introduced for convenience sake.) — With the radius L m describe an arch, a.o.a. — This would be the course described by the true radius or axis had no change occured. — If now by any cause approximation of the point M took place the direct axis of the leaf becomes shorter. — In "Mimosa pudica" when the leaf droops this actually occurs, owing to a curve which the inferior contractile cells create in the vascular bundle. — For convenience sake let the course of the leaf be divided into three stages. — 1. The normal L.O. the horizontal L p. and the depressed L.g. — When the leaf is in the second stage, owing to the contractile power of the cells on the under surface the vascular bundle is bent, and by this movement the free point M, is approximated to the stem A.B. A descent has also taken place and during that gradual approximation was made. — A straight line between the points L. M. will give the direct axis and if

a

a circle b.o.b. be described with this axeis as a radius it will be found smaller than the one described with the direct axeis in the first or normal position of the leaf.. As the leaf falls the point m, continues to be approximated, and the curve in the true axeis becomes larger.- Another line drawn from Z. to M. in the now depressed state of the leaf will indicate the direct axeis, and using that axeis as a radius it will be found to be smaller than the one immediately preceding: marked by the line c.o.c. is the arc described by the direct radius in the third stage of the plant.- We find the arcs gradually becoming smaller.- This being the case the course described by the leaf during its descent could not have been a circle.- Had it been then all the radii between the two points Z. M. would have been of the same length, but diminishing as they do in a regular ratio the course could not have been anything but an oval or Elepse.- If the intermediate radii be carefully supplied and a continuous line be drawn from point to point between the distance travelled by the leaf that line would form part of an oval marked in the diag.m by the line W.X.Y.Z.

The first radius being the longest and in the plane of the normal position of the leaf, the oval must necessarily be in the same plane. Viz. at an angle of 45° to the stem with which it is connected..

A



Pinnæ. Course of Movement. "Mimosa pudica"

A leaf in its descent describes an oval in the plane of the normal position of the leaf which is at an angle of 45° to the stem of the plant.

A similar course is described by the leaflets forming the leaf, but in them the ovals would cross each other below the axis of the leaf stalk, because the leaflets are not only appressed but also depressed. These two actions taking place simultaneously cause not only the oval but also a twist, a kind of "ovo-spiral." As a similar action happens in the foholes a description of their movements will explain those taking place in the leaflets.-

(Diag. 8) explains the motion of approximation seperated from that of depression. There are generally, nay invariably four leaflets, for convenience sake we have only represented two.-

Pursuing the same line of argument as we did in the case of the "petiolic joint" a mere enumeration of the parts will suffice.-

L.X.. The plane of the "petiole" of the leaf.
L - A fixed point on which the radii move.
L x.. L y. The two positions of the leaflet. L.x. being the normal.
L. m.- The true axis marked by dotted lines.

L m

L. m. The direct radii or axes.

d,a,d.- The arch described by the true radii or axes of the leaflets in their normal position.

c.b.c. The arch described by the direct radii after the approximation of the various leaflets.

o.g.1 o.g.3. Courses described by the free points of the true axes.

g.— The point where the courses cross each other.-

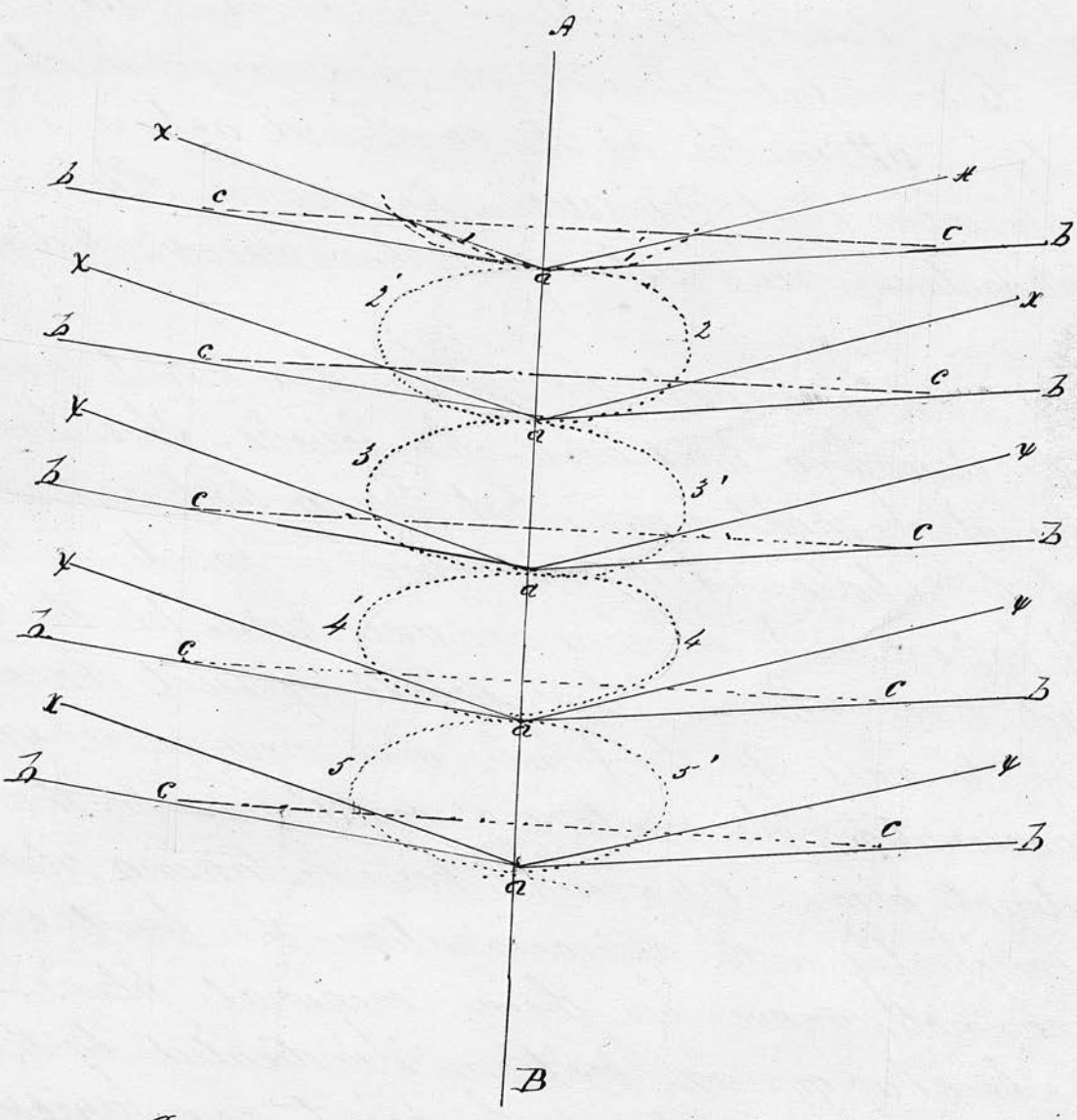
The force which regulated this movement had it existed uncombined with depression would be found on the inner side, but being conjoined with depression it is more than likely that its sight is partially at the side and partially at the lower surface. Divide a circle into two, and place that line diagonally, the part represented on the lower side would indicate the position of the acting force.-

In the foholes a similar compound movement takes the place, and in this instance also the course indicates the sight of the contractile cells.-

We presume our readers are by this time familiar with the simple movement of approximation and will fully understand us when we allude to it. The combined movements are best studied in the folioles and for that purpose let us as briefly as possible

examine

Diag.ᵐ N.ᵒ XX



Compound movement of folioles. "Mimosa pudica"

examine their closing.-

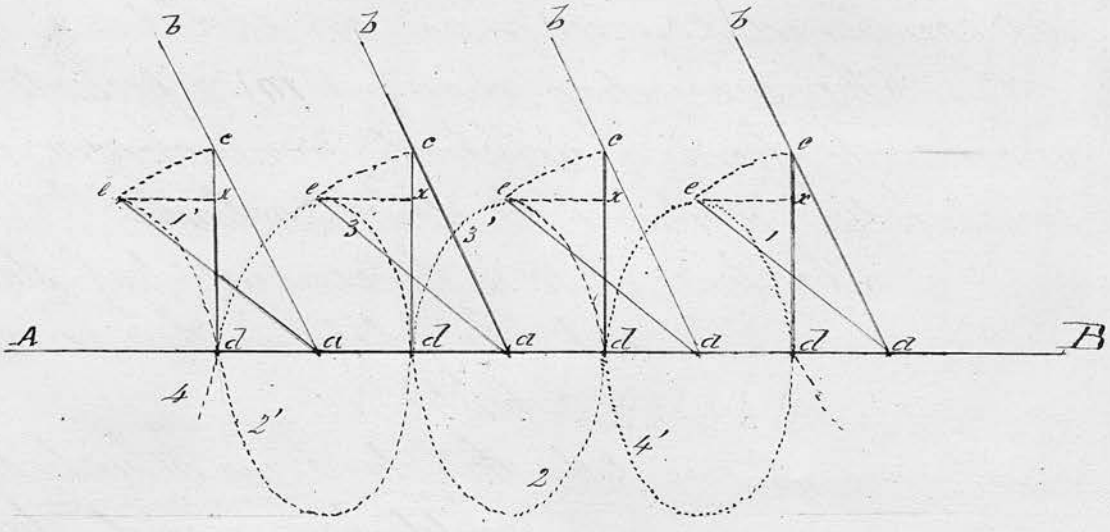
On irritating a foliole we find that when closed, instead of standing on end and slightly forward as they would do in the natural course of events they are appressed.- On watching their closure we can distinctly follow the point of the foliole in its graceful curved sweep, a movement only attainable by the combined action of appression and depression.- To explain this more satisfactorily we must again have recourse to digrams.

Let A.B. a/ represent the middle of a leaflet and the diverging lines a c b - the folioles. These lines are at a slight angle, that being the true direction of the folioles. Next fix upon a point in the foholes. c. c. to serve as an axis and let the dotted line between those points represent the course of the axes. If the folioles were now merely approximated the points c. c. would move in their direct plane. Appression however taking place conjointly with approximation the points c. c. cannot move in their original plane.- The change in position is indicated by the lines a. e. x. e being the point now representing the position of the axis.- Had the action of appression been separate from that of approximation, the plane would have been found

a/ (Diag. 9.)

between

Diag.r X



Broadside view of Mimosa pudica (Linnaeus)

between the points c.c. The actions however being conjoined the course could not have the planes, c.c. but must necessarily follow the curve of the axis, and that is an ovo spiral. Vide diag (No 9) The lines 1. 2. 3. 4. 1' 2' 3' 4'. On following the spiral we find, looking on the leaf as alternately pinated, that the course of this spiral is 1/2, the conclusion we therefore came to is this.

The movements of approximation and appression, go on conjointly and cause a twist in the course of the foliole and owing to the course in mere approximation being an oval the combined course is an ovo spiral.-

The succeeding diag (No 10) represents these movements from a different point of view and even better explains the double action.

The line A. B. is the central leaf stalk.

a. b. the foholes in their normal position.

c.d. the plane in which they would have moved had there been no appression.

C. The axes in the various foholes.

E.C. The distance of appression also the divergeance from the true plaine.-

E.a. position of the foholes in their appressed

appressed state.

e. A point midway between the two foholes.

—Here again the half of the spiral passes through the foliole above on the opposite side and ends on the second above it on the same side.—The lines. 1.2.3.4. 1'2'3'4' show the course of the continued spiral.——

—Having now finished the first part of our subject so far at least as an analysis of structure and motion is concerned nothing remains but to draw a few general conclusions, but we will defer this till after the description of the irritability in Dionæa Muscipula.—

Dionæa Muscipula
or
Venus fly trap.

Lin. Syst. Decandria Monogynia.

Nat Ord. Droseraceæ.—

Dionæa.— Sepala et petala 5 Stam: 10–20. antheris lateraliter dehiscentibus.— Stylus 1. Stigma Orbiculatum. Capsula 5-valves, 1 locularis. Semina ∞ in substantiâ cellulosâ ad basim capsulæ semi-immersa.—

Dionæa Muscipula. 4 in Amer: boreali.— Herba glabra; folia radicalia petiolo apice dilato limbo bilobo ciliato irritabili complicato. Decandolle. prod. tol 1. p. 320.— Porr Gardeners dictionary. Vol 1. p. 347.—

A long historical account of the plant will here be out of place, for various reasons.
1. Because the object of our paper is to describe the Anatomy and Physiology and not the history.

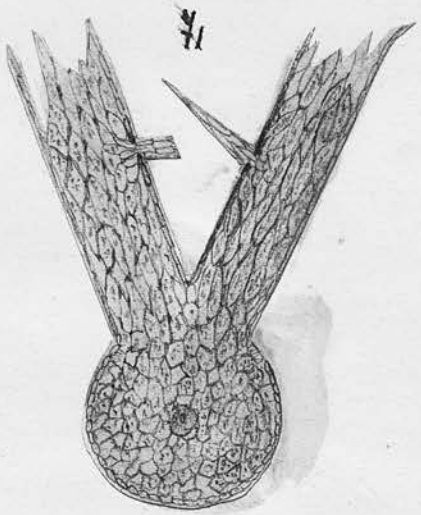
2. Because it would extend the length of our paper beyond the intended limit, and
3. Because it is not necessary for the object we have in view.—

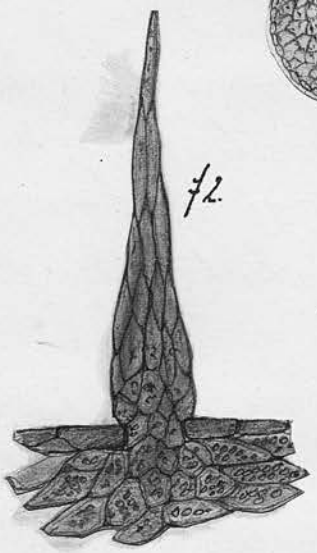
When the Dionæa is fully expanded it is subject to excitation or irritability.— The extent of this varies and depends directly on the amount of the temperature in which the plant is kept.
Like the "Mimosa pudica" it is excitated by the actions of various reagents, and what has been stated of that plant applies equally well to the Dionæa.—
The causes which act and produce excitation having already been fully entered upon need not again be repeated.— Some peculiarities however both in structure and action require a few words.—

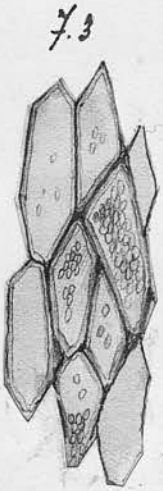
We are all aware that when the hairs on the inner surface of the blade of a Dionæa are irritated the blade immediately closes.— Why this should be so an examination of the structure of the plant will at once explain.—
On examining one of these hairs a structure similar to that in the Mimosa is observed.— The hairs are formed in the same way viz of a series of double celled walls, the only

difference

Diagr. N.° XI.







difference being that the cells are larger. —

On making a transverse section the hair was found to communicate directly with a mass of double walled cells, within the blade. In fact the hair was nothing but a prolongation of these cells through an aperture in the Epidermis. — (Vide Diag 15 No 2.) The hair on entering the blade is grasped as it were by a ring of Epidermis, and at that particular part is slightly constricted. It bulges as it were over the side of the opening. — The Epidermis did not differ from that in ordinary plants, the cells forming it were single walled cells. — Immediately under the Epidermis and forming the "body" of the blade were a number of large elongated double walled cells containing a large quantity of starch granules.. That these granules were starch was plainly demonstrated by the characteristic reaction of Iodine. — These cells were in structure similar to those forming the bulb of the petiole in Mimosa but only much larger. — The cells in Dionaea vary in size, being longer and larger in the expansion than in the joint. — (Vide J3) In the joint the cells are more circular and are joined to a vascular bundle in the centre. (Vide Diag 15 Fig 1) It cannot but strike the observer that the shape of the cells in their different situations vary according to their special duty. —

The

The hairs in the Dionaea are, practically speaking of far greater importance than those found in the Mimosa.—— Their relations are highly instructive and greatly tend to confirm the opinion that irritability is in fact nothing but contractility of cells visibly exhibited according to modifications of structure.—

In proof of this we may adduce the following experiment,— If a pin or any sharp instrument be made to penetrate the protective Epidermis, and irritate any of the cells forming the mass of the blade, the blade immediately closes.—— Excitation is set up as formerly explained p. by contraction and excudation, and this is rendered visible by the closure of the leaf.— It is owing to this protective Epidermis that the leaf does not close when simply touched, not covering the hairs touching them suffices to exhibit the phenomena of contraction.——

We cannot conclude this paper without saying a word about the coloring matter. It is not contained in the Epidermal cells, but is placed upon them, the coloring matter is contained in cells, arranged in a rosette like form, something like rubies. (Vide Diagram) and can be easily scraped of with the knife.—

Thus

Thus much we have been able to ascertain about the nature of Vegetable irritability, and it would be unjust were we not to mention the kindness of Prof^r Balfour and M^r M^c Nab. R. B. G. in rendering us every assistance and facility for conducting our Experiments. —

The subject is an interesting one, and well worthy of further attention and study. — although beset with many difficulties, they are not insurmountable, and the student who directs his attention to this branch of Botanical research cannot fail to be ultimately rewarded. — He will find that

"Nature never did betray
The heart that loved her, 'tis her privilege
Through all the years of this our Life, to lead
From joy to joy." —

"Wordsworth"

Index

Dionaa