Bioelectricity

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Lecture – 37

Let us resume our thirty seventh lecture. So, in the previous lecture we talked about the movement of the mimosa pudica or the touch me not plant. So, this is that is one kind of movement where you touch the plant, and it lives leafs you know curl on you know bent, and the whole leaf droops here. We will be talking about second kind of movement which is a very interesting movement where we talked about the carnivorous plants, which eats insects, and plants which respond upon touching of the insects.

So, essentially this is same thing, there is there has to be a pressure sensor or attach sensor or something like that what is a mimosa, but the mechanism is different from it, but the basic electrical activities are fairly the same. So, let us formally start this lecture with plant bioelectricity of the plant movement in the venus fly trap. So, this is basically what we are going to deal is the bioelectrical, and biomechanical phenomena of carnivorous plants the reason why is the bioelectrical, and biomechanical when we touch there is a mechanical event followed by a electrical event, where this leads to a generation of a series of ionic current of fluxes of ionic currents followed by a mechanical action. So, the way it works for those one out we aware of it.

So, there are series of plants which have very diverge geometries than you ever seen these plants have certain Aleio features most of the insects we all know that you know the insects derive honey from the flowers, and plants, and all over the place this is all we all of us know. So, these plants look really very beautiful, and the insects gets attracted either by the color or the smell or whatsoever when the set of these plants they activate certain sensor, and these plants or very unique their flowers are very unique say for example, you sit on it, I has a flap which can which will close or it will have something which will you know curve back like this there series of geometries by which it can trap the insects, and today’s lecture will be about that fascinating world of carnivorous plants, and their movement.

Where we talk about how they are trapping the insects, and certain interning phenomena, and certain unsolved mysteries of nature. So, we are talking about it. So, some of you have may have seen some of these pictures some may not have seen.

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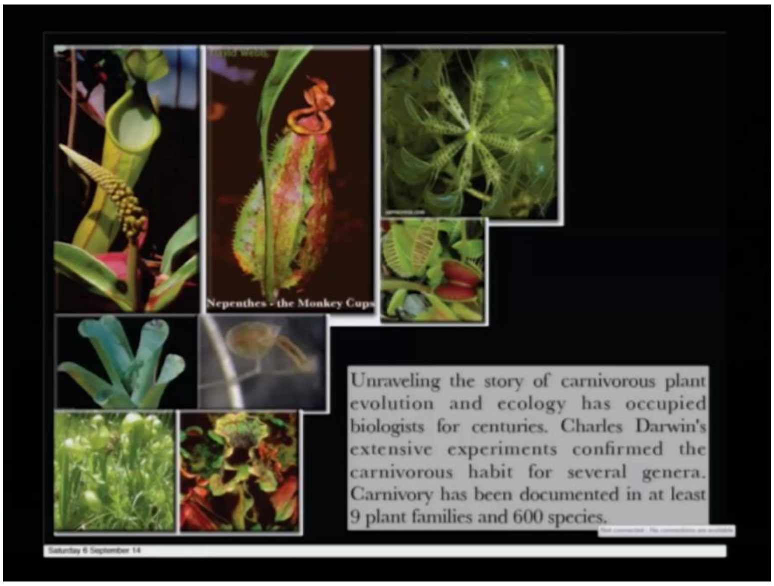

So, this they are the these are the example just handful of examples of a series of carnivorous plants which are available in nature, there is a huge population of it there are nine at least nine families of plants with six hundred species distributed all over the world, and we really do not know how they are evolved really as there is a very interesting story of evolution why they evolved how they evolved what made these plants specialized as compared to other plants which just depends on water, and other molecules you know to derive maximum part of their energy.

If you just look at the geometry of these plants in this slide from you know first second. So, the first one of you look at it there is a hood, if you see the plant. So, there is a cup like elongated cup like structure, and there is a hood. Second one if you see the same thing, but unlike a kind of you know it is much more, you know more like you know bowl shape kind of… If you see the third one, in the third one if you see extreme right third one, you will see there as if there are lot of you know you have seen the propeller or or the air of helicopter it is almost like that. So, what happens from all the four sides or all the five sides or six what one two three four five six all the seven of them you know curl back like this. So, for example, they are all spread out like this.

So, whenever they had to trap inside they all will you know become vertical, and close on it similarly if you see the fourth one very carefully. So, all those leafs which you are seeing spread out they all will know curl back similarly on the one two three four five six, and in between there is a small picture you will see where you will see some you know pointed between the two leafs flaps there are kind of these pointed structures as if there is spines spines like this you know. So, this is a different kind of structure. So, in this lecture we will be talking exclusively about this one family, but their mechanisms are same with barring aside few differences here, and there. So, we will take one of these representative example, and will talk about their story.

So, these are some of the among those six hundred species either they will be pitfall traps of the pitcher plants are the leaves folded into deep slippery pools. So, that is what I was trying to tell you. So, if you look at these plants very carefully they really look very attractive there is a very reason for insects to get attracted towards them, and not only that if you see the inner part of these plants inner part of these you know trap you will see kind of slimy or slippery kind of situation. So, if you again focus on this picture out here the first picture its very slippery, and now if you follow this. So, the pitfall traps of the pitcher plants are leaves folded into deep slippery pools filled with digestive enzymes.

So, they contain a series of enzymes which is the ability to you know digest, and digest, and small insect which plant does not produce unless, otherwise it is needed you know plants depends on its own enzymes you know to breakdown the carbohydrates unlike and so and so forth, but here these plants have a different kind of or added genetic machinery which allows it to produce series of digestive enzymes which take care of these insects insect I mean you know degrade the insect, then you have the flypaper or the sticky or adhesive traps of the sundews. So, they have a material, which exude out causing sticky mucilage, then you have the snap traps or steel traps of the venus flytrap for we are going to talking about waterwheel plant, and are hinged leaves.

So, that is what I was trying to tell you they have the hinged leaves with those sharp fine structure, then you have the suction traps unique to bladderworts are highly modified leaves in the shape of bladder with an hinged door lined with triggered hair. So, all of them have this hairy feature will be common, then you have the lobster-pot traps or the corkscrew plants are twisted tubular channels lined with hair, and glands. So, if you look very carefully through all these structures you will come across one common feature they all have these hairy appendages or spiny structure which execute or which play some significant role in this whole process of trapping the insects you know digesting it, and extracting out the nutrients. So, now if you see this picture in this slide. So, most of the time the insects kind of comes, and sit getting kind of attractive about those, and mucilage’s, and that is why it traps.

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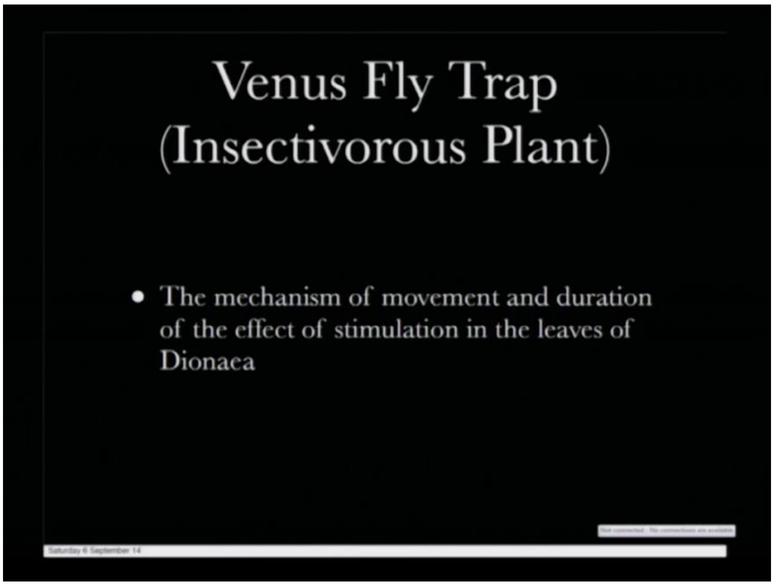

So, will talk to this more now. So, this is the trap we are going to talk about the venus fly trap or the insectivorous plant the mechanism of movements, and duration of the effects of stimulation in the leaves of dionaea

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So, this is how they look like I told you that this small picture we are showing. So, look at this fine structure of the leaves. So, they have two states either they will remain open as you could see one in one of the fly one of the leafs you see there is there is red surface that is the inner surface ok.

So, near the crease there are the two leaf jaws. So, those are the jaws joins there is a series of tiny hairs you could see these hairy structure, if an unwary insect walks across these hairs touching two or more of them in succession this is very important the leaf will close quickly enough to prevent its it its escape unable to escape between the hair-like teeth at the edges of the leaf the helpless insect is slowly digested, and absorbed by the leaf glands on the leaf surface secret several digestive enzymes that help to decompose the insects once the insect has been digested sufficiently the leaf reopens for another victim. So, now, see this picture very, very carefully you see the inners inner part of the leaf the two leafs there is o one leaf, but is just kind of curling with hinge-out there which is red, and the outer part which is green, and then you see those doors hinged doors on the edges.

Now there is something very interesting from this picture you cannot figure out on those red surface out I will be coming to that.

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Now, look at it very carefully what you see on those red surfaces you see these pointed hinge coming out, and there may be specific they are not many many numbers, then if you see in the first panel under which underneath which is written figure three you will see one two three four on one side, and probably one two three is visible to me out here now one two three four four on the other side, and if you zoom on a each one of them it at least one of them this is in the figure four what do you see as if there is you know pin which is pointing out spiny structure, and this is how it looks like now these structures are vary essentials.

So, what happens is this on these surfaces the insects gets attracted either by the color or by the smell or by some slimy the you know sticky fluid or something some fluid or whatsoever is present in between those that leaf like thing you know its looks like this. So, this the insect cones as if the insect comes out here now imagine this pen as the insect now no one of the previous slide I was telling that insect has to remain there for a certain amount of time. Now these structures what you see four on one side, now if you if you consider down the slide again there are four. So, these are the sensor elements. So, if I go back I was telling you this sorry near the crease, but the two jaw leaf jaws join there is a series of tiny hairs if an unwary insect walk across these hairs touching two or more of them in succession the leaf will close quickly enough to prevent its escape this line is important.

Now, what does that mean is these spiny structure what you see the four in one side four in other side the insect has to touch two of them n succession if it does not do, then the leaf would not close as if two of them leads to a cascade of reaction

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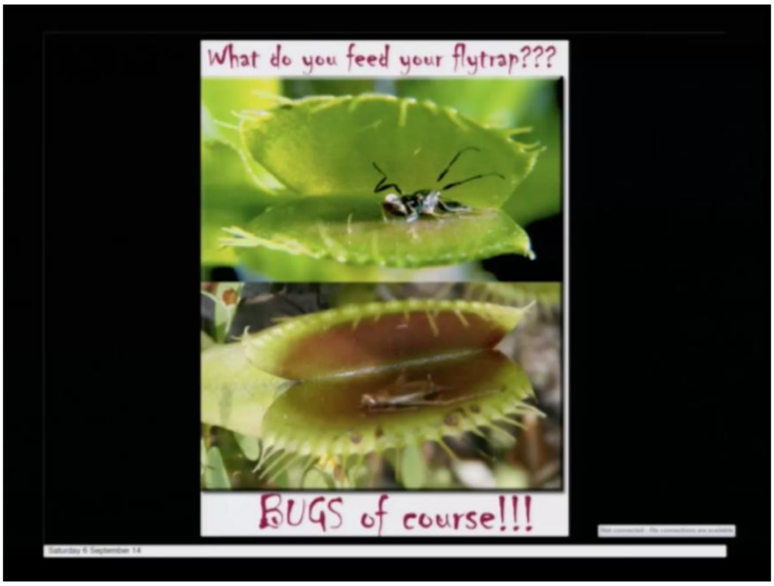

Now, if you see it when the when the insect touches two of them, then leaf closes, and it prevents its escape.

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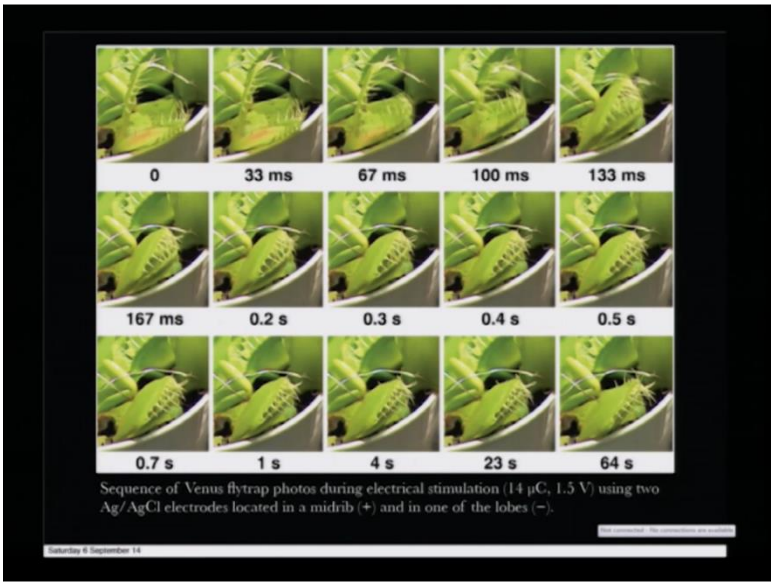

So, this is very important that you understand this part. So, now, see the sequence of events how this is taking place zero second. Now this is this has been done without a insect how it has been done. So, these experiments could be done in several. So, we discover that it has to know touch those two white from where from this it has to come if an unwary insect walks across these hairs touching two or more of them in succession the leaf will close quickly enough to prevent its escape. So, the way it figured it out is very interesting.

So, now let us come back to this picture, now you take a mechanical prove you see this picture, and you start patching those four on one side four on other side one after the other in succession one, but there is a very tricky time delay.

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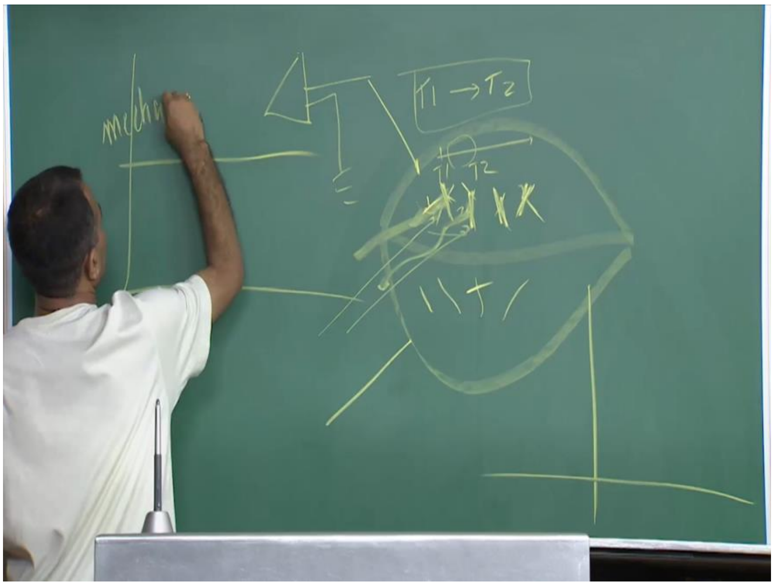

Now, if I show you on the board its looks like this say for example, this is if this is a inner surface with those spiny structures coming out. So, I take a mechanical probe like this touch it followed by the second one this is the first touch, then this is a second touch, and this first, and second touch has to be done in such a way that there is very limited like if in between touch one, and touch two there is a huge gap of time, then this phenomena would not be seen you understand this phenomena can only be seen if there is an optimal time between t one touch one followed by touch two.

If this does not happen that optimal time window, then you would not be able to see this closer phenomena that is what it meant when the insect comes it has to touch this, and this or this or this, and this in succession with a very limited time delay if that does not take place you would not be able to see this process. Now if you follow this with this picture on the board or now if you follow this picture on the slide that will make more sense. So, this is what you see out here there is a mechanical probe which is touching those four, and four hair like structure zero second thirty five milli second sixty seven milli second like wise up to sixty four seconds, and in that whole process by inserting an electrode. So, the wait has been done these are the outer surface you insert electrodes like this. And you can you do the recording from a huygen amplifier about how the electrical activities are taking place when you are touching. So, what do you see essentially out here there is a electrode which is inserted here, and there is a mechanical stimular which is you know ensuring that you know you are disturbing this, this surface this is how it works you have to touch the mechanical these sensor elements, and you have to do the mechanical electrical recording simultaneously. So, you touch it electrical recording you touch it. So, if you plot the graph like this it should it should be like this. So, this is for the mechanical stimulus.

So, stimulus followed by an electrical signal stimulus followed by an electrical signal small delay out here this is how it works. So, this is exactly what this picture is trying to show you that zero second thirty three milli second like wise up to sixty four seconds, and on 64 seconds you will see the leaf has closed, and by trial, and error by doing these things people had figured out how this venus flytrap works.

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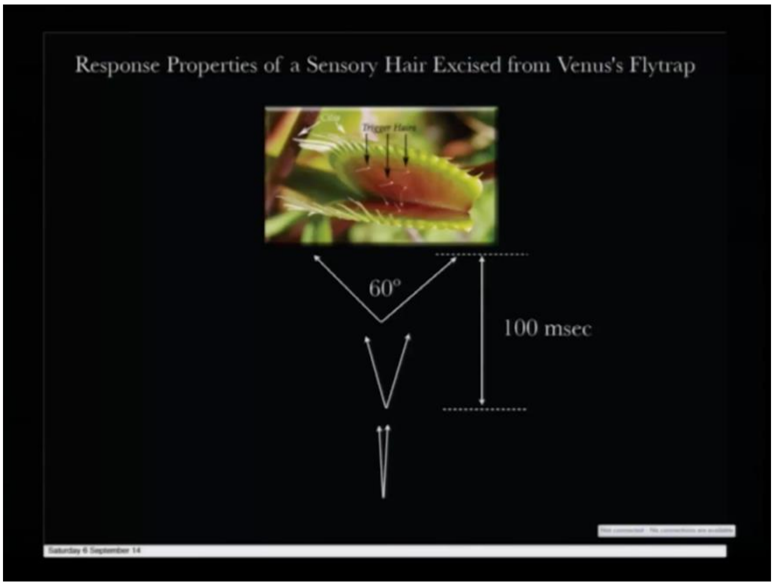

Now, this is the kind of response properties of sensory hairs excised from the venus's flytrap. So, those what you see are called that trigger hairs. So, this is these are those trigger hairs what I showing in the board when these trigger hairs are triggered you see the closing motion of those along hinge along the venus flytrap those trigger hairs are are in certain angle, and over hundred milli second time their angle changes likewise now you could see if you see the slide you will be able to figure it out much better ok.

So, this is how that moment takes place. So, trap closure, and trap closure memory trap closure is a precisely controlled process, this is not a random process this is very, very tightly controlled process as I was trying to tell you as I was showing you where you given a stimulus with a delay you will see electrical response. So, there is an optimal time window between these two that optimal time window discovery is very one of the very interesting feet for those people who are working in this area.

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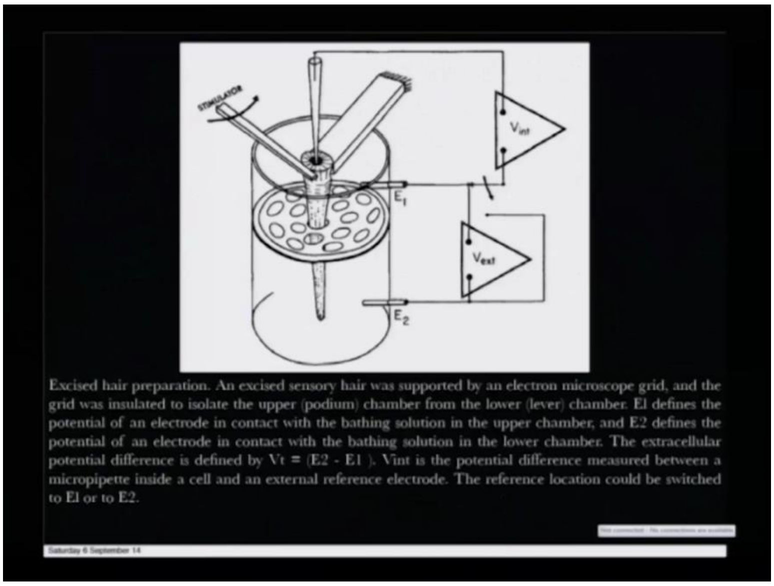

So, coming back how these studies are being done first of all in order to understand it. So, the way these studies are been done something like this.

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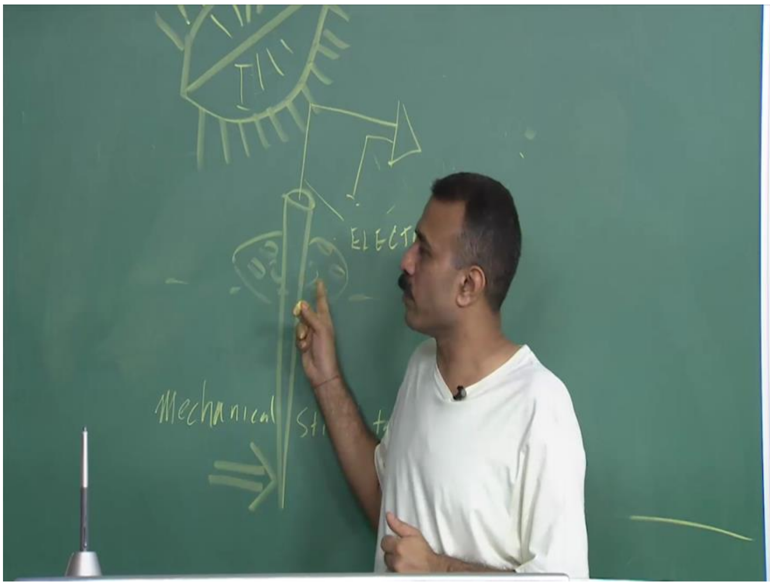

You see the slide picture, and I will show you. So, if this is a venus flytrap situation with. You know all those tiny structures, and and these are those specific cell now you remove it like this you remove a specific spine like this now what do you do you insert an electrode out here again keep it, and and you have a mechanical sensor which is hitting on it mechanical stimulator, and here we go electrode now this is what I was trying to show you in the slide if you see this slide this is exactly what it is you have a electrode which is inserted through the centre, and at the mechanical stimulator which is you know hitting upon it. So, whenever you are hitting upon it what you are doing you are measuring the electrical activity.

So, if you reach through this excise here preparation here you see the excise sensory hair was supported by an electron microscopic grid. So, the electron microscopic grid what you see out here in this picture is this you see this electron. So, this is the electron microscopic grid, and if you follow this, and was insulated to isolate the upper podium chamber from the lower chamber even define the potential of an electrode in contact with the bathing solution with it. So, you are measuring with respect to the bathing solution, and then you have this mechanical stimulated coming through it this is how most of this electrical activities of these kind of sensorial elements are being discovered over the period of time.

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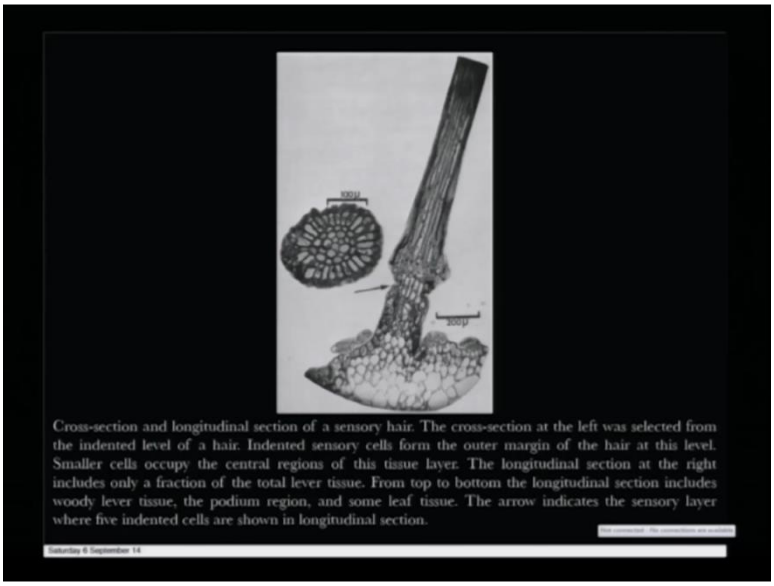

So, now moving on to the in slide next slide, if you look at this structure very carefully this is the cross sectional longitudinal section of the hair cells. So, these are called hair cells please do not mistake like you have hairs cells in the ear also very similar to that the, but these are the hair cells of the plants, but the functionally they are they are same both of them are mechanical sensitive structures one is in plant, and other one is in the ear now the cross sectional longitudinal section of the hair cells the cross section at the left was selected from a indented level of a hair indented sensory cells from the outer margin. So, basically if you see this structure this structure is something like this. So, they have on the periphery you have the sensory elements that is where you are this kind of touch sensors are acting on the surface. So, these are those sensory cells what you see out here in that structure and.

If you follow the slide now the longitudinal section of the right smaller cells occupied by this central region of the tissue, and the longitudinal section of the right includes faction of the total level tissue from the top, and bottom the longitudinal section includes podium region. So, there are certain parts which are you know nonliving part.

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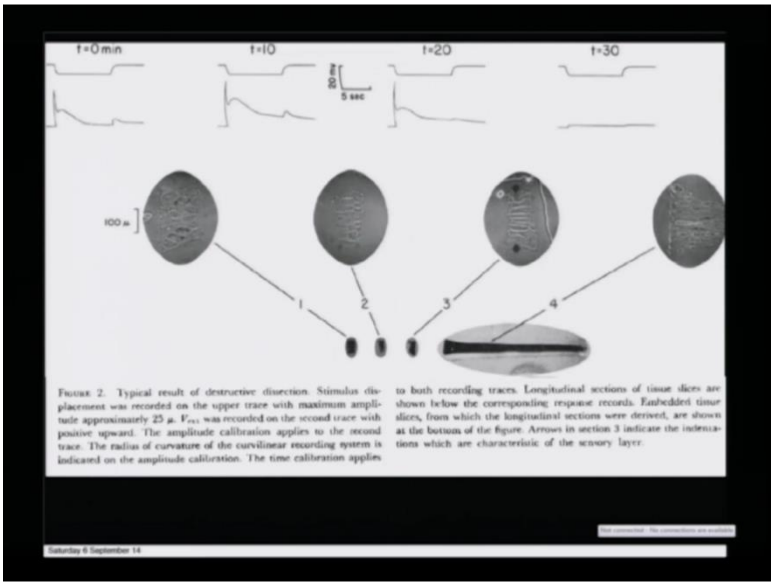

And their this thing out there now from here, if you look at it you can now stimulate them, and typical results of destructive situations you can really do a series of recordings based on how much stimulation or mechanical stimulation you are giving over a period of time.

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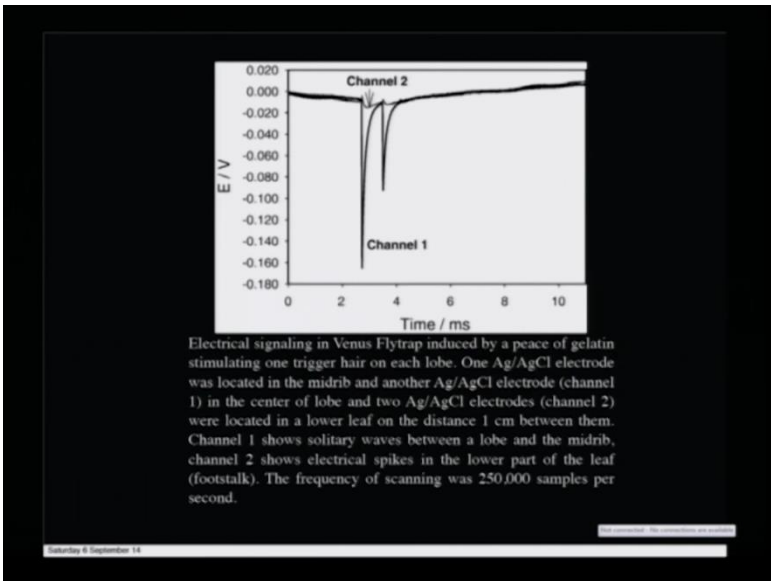

Now, you can go through this is a very interesting thing, but why I will be more interested is to develop how people have developed this in a algorithm out there the electrical signal in venus flytrap induced by a piece of gelatin.

So, gelatin is acting as a stimulating one trigger at here on each lobe. So, one a g a g c l electrode was located in the midrib, and the a g a g c l electrode is located in the center of the lobe the channel one shows the solitary way between the lobe, and the midrib, and the channel two shows the electrical spikes in the lower part of the leaf. So, this is how these recordings. So, if you go back to this recording or even you know this is how it is pretty much the same assembly all these recordings are been done.

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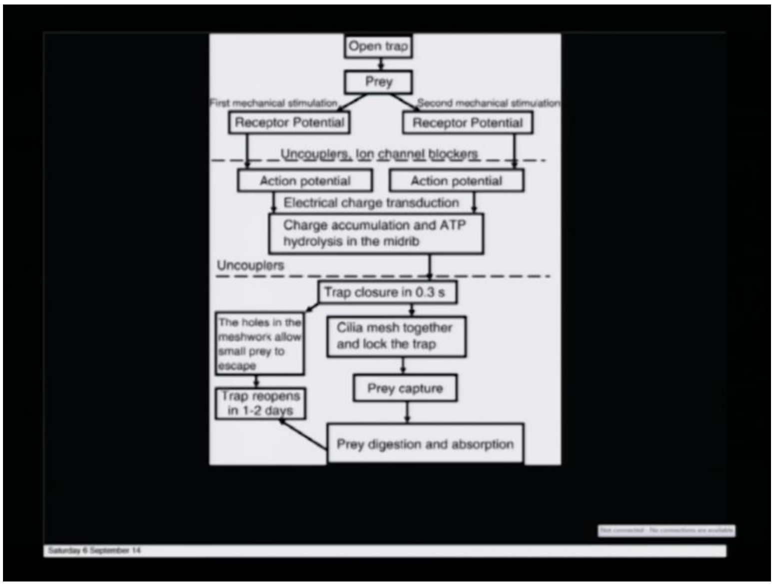

Now, coming back what exactly is happening if you really look at it very carefully. So, this is the open trap now follow it very carefully now there is a prey. So, this is a open trap now these are prey which are here this is the prey if touch this one. So, this generates a receptor potential r p one.

Now, see the slide receptor potential the first mechanical stimulus followed by it puts it like this on this one, and generates another receptor potential which we are calling as r p two this is exactly the same thing. Now if you follow the slide this is exactly the same thing what happens when the light falls on your carbon cones or the sound wave hits upon the hair cells of the ear likewise it is it is a same thing. So, there is a change in the receptor potential followed by uncouples or ion channels occur they gets activated, and as soon as those ion channel blockers gets activated this leads to two different action potentials one action potential is coming from r p one the other one other action potential is generated from the other one where it is get.

So, one action potential out here another action potential out here a p two, and you have a p one now there are two action potentials which are generated now these two action potentials if we follow the slide now this leads to the electrical charge transaction, and charge accumulation in the a t p, and hydrolysis in the midrib now followed by the next level. So, the part one if you follow this slide very carefully you see there are two dotted lines first one is the sensory activity part two is the electrical activity now comes up part three part three is your mechanical activity. So, looks to it trap closure in point three seconds two holes in the meshwork allows the small prey to escape.

So, they are situation when say for example, these two are folding, and the insect is really analyze left what will happen? Now this algorithm will work coming back to the slide if you follow the left hand the holes in the meshwork allows the small prey to escape if that happens this system senses, and within one or two days it will open otherwise if the trap closes in point three seconds, and they the insect fails to you know escape from it, then the prey is captured this is followed by now on these surfaces there are lot of digestive enzymes which are synthesizing in the enzymes which are present here. So, if this one closes.

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So, now the trap becomes one second, one second this first you have the sensory activity, where your insect has touched on those you know hair cells followed by that change in the receptor potential one receptor potential two leading to an action potential a p one a p two, and this whole thing is electrical activity, now followed by mechanical action. Now this mechanical action is in the form of this is the open situation here is closed situation as soon as this one closes is a lot of secretion of from the surrounding cells out here lot of secretion of digestive enzymes.

The reason why this whole mechanism depends on two receptor potential changes or two action potential changes probably is nature is very conservative it does not allow the mistakes to take place. So, you know there may be reflection or something the just by, but the insect may just ran away or you know something else. So, in order to ensure that there is it must have must have in an drastic process, and the time time difference between the two that is very critical from receptor potential one receptor potential two if there is this time window goes really high, then this whole processes is going to you know canceled out is now going to take place. So, this is very important that this takes place very fast I mean there is a optimal time window without that optimal time window this cannot be executed this is very, very, very clear.

Now if we look at the different plant memories what we are having today evolved. So, electrical signaling in a memory play fundamental role in plant responses. So, one of the thing is the most for most one is this storage, and recall function in the seedlings when the seed generates this is the classic example of it has certain degree of memory it remembers it next is a chromatin remodeling the plant development. So, these are over all, then you have the trans generation memory of stress they could respond to the stress has a they have already memory recalls switch by which they know how to respond, then you have the fourth one as the immunological memory of tobacco plants, and mountain birches I wish all used to go through this you know go through go to google.

And you know give smirches, and see what all these significant really, because we are only talking about the electrical phenomena by there are different memory events which are taking place in plants now, then on the fifth one if you come in the slide vernalization, and the epigenetic memory of winter winter hardness, and cold hardness, and all those things induced resistance the sixth one, and susceptibility of to herbivores, then you have the seventh one the memory response of abscissa cascade entrained plants, then you have the eighth one as the phototropically, and gravitropically induced memory in maize, then the ninth one ozone sensitivity of grapevine as a memory effect in the perennial crop of plants, then the tenth one which we have talked about the memory of stimulus this is exactly what we talked about this is called the memory of the stimulus or...

We have talked about, and of the eleventh one you see in the slide systematic acquired resistance in plants exposed to pathogen over a period of time you know they act on it, then you have the electrical memory in the venus flytrap twelveth one what we have talked here.

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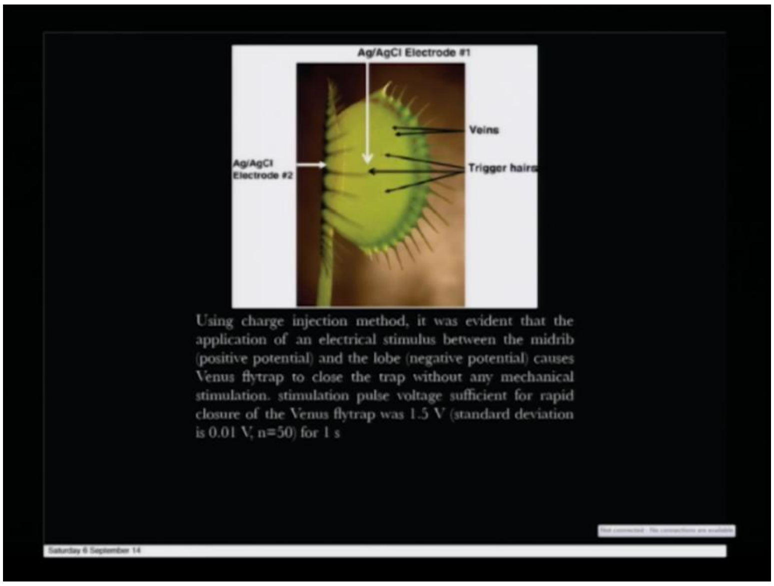

So, the way the electrodes are being. So, here I will be discussing with some of the mechanism how it is being done. So, you see the veins out there, and you see the trigger here which are present there in the shadow way. Now using charge injection method it was evident that the application of an electrical stimulus. So, this is very interesting to note. So, as of now we talked about that there has to be a mechanical stimulus there has to be mechanical stimulus before this whole process takes place now .

It was being observed that whenever there is a change in the receptor potential out here what receptor potential change means; that means, those tissue are sitting at a resetting membrane potential which is shown by r m p. Now by some mechanical stimulus on, then this there is a change in r m p resetting membrane potential, and that is what we are talking about resetting potential change fine that is what? If you remember sorry the receptor potential change now come back to this slide, now if I could the go on the third line open trap prey, and receptor potential. So, there is a mechanical stimulation leading to receptor potential change, but think of it without giving mechanical stimulus if electrically I induced a receptor potential change I change the potential electrically will this whole process be executed now coming back to the slide just imagine.

If I this you see this slide mechanical refers mechanical stimulation second mechanical stimulation what I was trying to show you know the mechanical stimulation taking place here mechanical stimulation taking place here likewise in the r p one r p two this is the mechanical stimulation here mechanical stimulation here I do not give the mechanical stimulation what I did is I change the receptor potential by an electrical will still this whole cascade of event coming back to the slides we look at it will this whole cascade of event takes place that is the experiment which was being done using charge injection method you can actually change the potential of the receptor receptor potential has to be change by charge injection using charge injection method.

It was evident that application of an electrical stimulus between the midrib positive potential, and the lobe negative potential causes venus flytrap to close without mark this line without any mechanical stimulus stimulation pulse voltage sufficient for rapid closure of the venus flytrap was one point five volt this is very interesting to note that this process is in a natural condition, this is the process is influenced by the mechanical response obtained by the plant, because of insects on top of it, but you actually can (( )) the whole process of the closure without the mechanical stimulus just by inserting an electrode here inserting an electrode here, and you know injecting current to change the receptor potential, if you change the receptor potential this whole cascade of event will follow without doubt.

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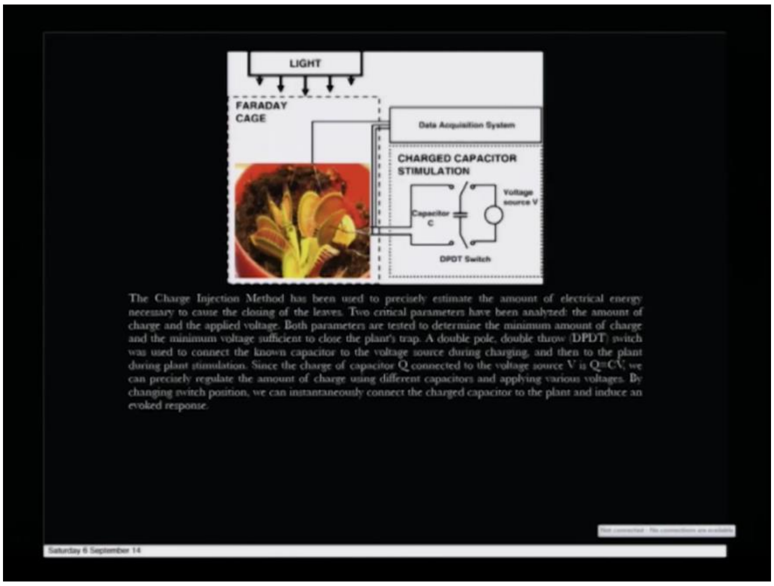

So, what is the take home, and the here in the slide if you come back to the slide you will see this is how these kind of you know charge kind of methods have been followed being used precisely to estimate the amount of electrical energy necessary to cause the. So, what is your essentially doing. So, there is a mechanical energy here. So, now, you replacing the mechanical touch, and sensation with an electrical stimulus. So, when you are talking about the electrical stimulus essentially what you are telling is we are injecting a specific amount of charge particles.

So, this is what the charge injection methods will highlight has been used precisely to estimate the amount of electrical energy necessary to cause the closing of the use the two critical parameters have been analyzed the amount of charge and the applied voltage both parameters are tested to determine the minimum amount of charge, and minimum voltage sufficient to close the plants trap the double pole double throw d p d t switch was used to connect the known capacitor to source during charging, and then to the plant during plant stimulation.

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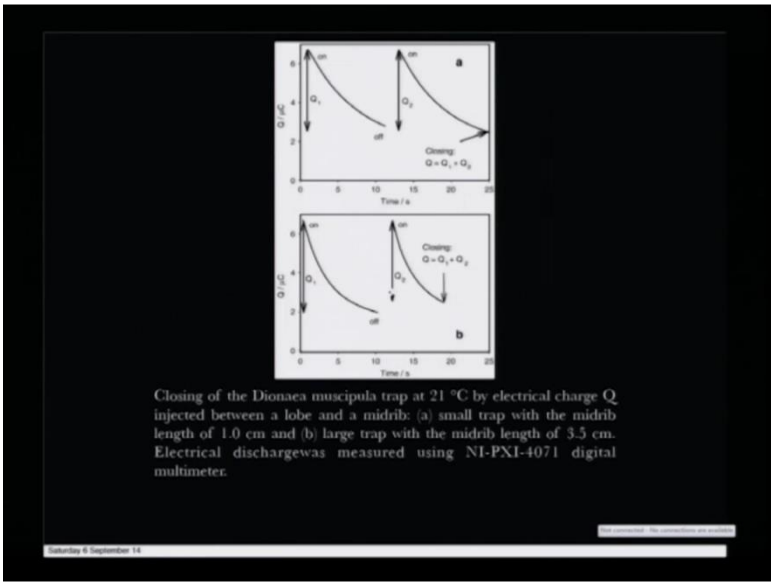

So, this is how this whole thing is being used been carried out t quantify the charge, and quantify the charging voltage, and this is how this whole thing is being followed. So, you see there are on off, on off at the two levels.

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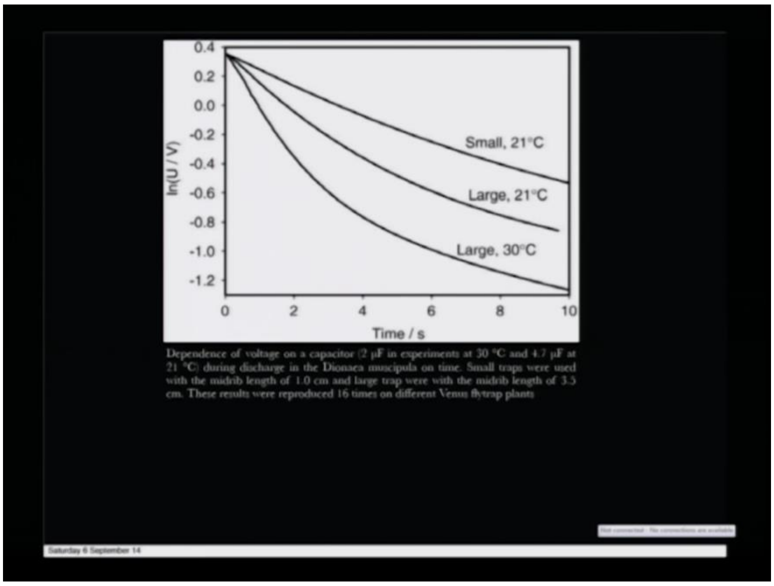

So, I wish you guys kind of go through them in a small large depending on how much charge you are giving the closure mechanism changes its slow. So, now if you see the slide open trap first stimulation second stimulation wait for mechanism stimulation by the prey change in the receptor potential.

The sensory memory action potential which is a short term memory followed by a t p a t p hydrolysis which is basically a biochemical phenomena followed by a proton transport fast h plus transport water transport through aquaporins which are the water channels fast trap closure. So, small prey if the holes in the cilia mesh allows the small prey to escape that trapped reopens two days, but if that is not the case, and if your if the insect is completely trapped, and with the effect of the digestive enzymes which are secreted by the leaf surface the cilia mesh is locked looking into the slide if you realize, then it would not open before four or five days ok.

So, this is the overall the schematics which could be done, and you can execute the whole process at the line two of the slide by electrical stimulation by giving you giving it charge. So, there are several models which are involved in it one of them is called in the slide you see hydro hydro-elastic curvature model I wish you people to go through them basically it says that after receptor potential action potential are generated which are propagated to the midrib of the plant through the plasmodesmata. So, these are the connections if you remember in lecture thirty six I showed you what the plasmodesmata is on the connection with a dilemma four lemmas all those things. So, those plasmodesmatas very important. So, please go through the lecture thirty six to see I gave I gave you in between, and schematics of the plasmodesmata.

Now following on the slide action potential can be inhibited by uncouples. So, you can use different kind of you know potassium channel blockers, and you can stop this action potential. So, you can actually stop this work process here itself you may not allow this to proceed further now coming back to the third the venus flytrap memorizes the first electrical signal for a short period of time, and as soon as second action potential propagates to the midrib in one to forty seconds. So, this is the time electrical signals. So, between this, and this has to take place between one to forty this is that is the critical time what I was telling you the t between t one, and t two or some mechanical stimulation at one mechanical stimulation two.

If there is one to forty seconds delay, then this process of a t p hydrolysis, and everything is going to take place, if you see the slide that is the third third box is going to tell you about that if you follow it the venus flytrap one to forty seconds electrical signals activate the a t p hydrolysis starting fast proton transport initially. So, basically the whole proton transport when we are talking about out here this place become very very acidic, because there is a huge amount of protons which are moving out there h plus ion concentration is really gearing out the fast proton transport induces transport of the water, and change in the turgor pressure the leaves of the venus flytrap actively employs turgor pressure, and hydrodynamic flow for the fast movement, and catching insect.

In these processes upper, and the lower surface of the leaf behaves quite differently, this is exactly the same situation as you saw in mimosa pudica during the trap closure the loss of turger by parenchyma lying beneath the upper epidermis accompanied by the active expansion of the tissue of the lower layers of parenchyma near the under epidermis closes the trap the cells on the inner face of the trap jettison their cargos of water shrink, and allow the trap lobe to fold over the cells of the lower epidermis expands rapidly folding the trap lobe over the minimum elastic energy of the leaf including mean, and gaussian curvature corresponds to the closed state. So, this is what is the what I was telling about the hydro elastic curvature model.

So, there is several other models which are involved in this whole process please go through them and… So, this is the overall what I wanted that there are mechanical events just like you know what happens in the nervous system there are mechanical event which are translated into electrical event, and the mechanical event could be simulated by inducing charges into those tissues, and that is exactly what this experiment was all about. So, one second yeah this is the one which all about where you are injecting the charges to it. So, overall if you look at it. So, by the action, and reaction it looks very fairly similar that what is there in the animal system is pretty much followed by the plant world, but unlike the animal world plant do not have a very specialized nervous system will de-marketed nervous system that is why back in 1926.

So, J C bose came with his idea that nervous system of plant are rudimentary or the probably the very you know the kind of you know the most under development nervous system before as animal king the animal evolved they developed much more you know higher organized structure. So, I will close here, and I will try to you know give few other held out which may help you know to appreciate this whole process.

Thank you.