Bioelectricity
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Lecture - 4

Welcome back to the bioelectricity lecture series in an NPTEL. So, as I told you in the beginning we have divided this course into 5 different modules. And among the first modules and among all these 5 modules, the first module will introduce the course. After introducing the course I gave a graphical representation of the different systems what will be dealing with, system identification. And what are the different bioelectrical phenomena how they are being recorded and what are the advance application of understanding those kind of phenomena. So, after section, after module 1, now we will move on to the module 2. So, just to refer back in order to keep track of the way will be moving. So, what I did? I have on my screen, the first lecture where I talked about all the different kind of module. So, just look at it where we are, so that we can make a move from here.

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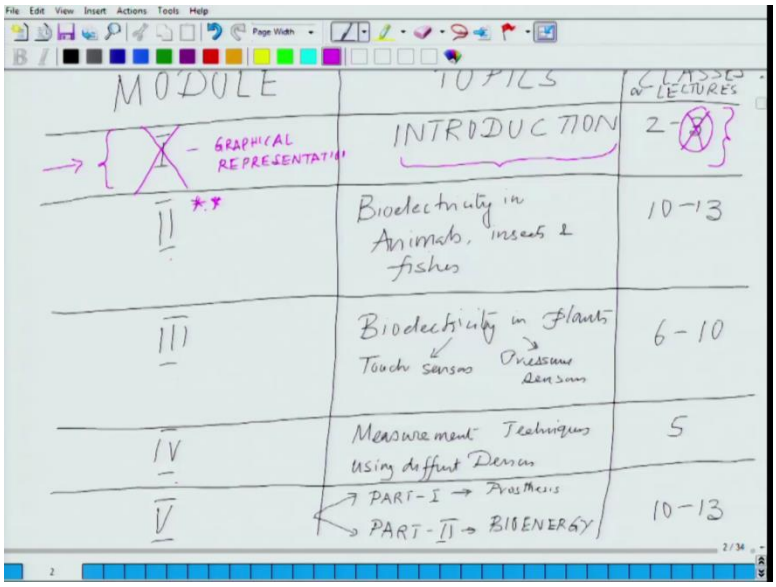

So, going back to the... So, this is the part what we have, this is the part what we have already done and this where we are going to get initiated now module 2. So, now I am moving on to the lecture 4 of the module 2. So, module 2 is under the heading of bioelectrical phenomena in animal plant, sorry animal insects and fishes. So pretty much

all the animal world bioelectrical phenomena, the way I have divided. So, what I will do? First of all I eggnomerate all the different topics am going to deal under this. And then we will pick up the first topic will talk about and likewise we will talk about the individual topics. So, let us enumerate the topics.

So, basically even before I proceed further there are, at the end of the class I will tell you the couple of stuff which I have really sliden properly in the 5 different modules which will come in the end. To tell you which all, in which module those thing will get fit, but at this point for the animal kingdom bioelectrical phenomena. We, I have already discuss with you there are two kind of excitable or three kind of excitable cells in the body which has the potential to produce action potential. So, one of them is nerve cell which constitute the complete nerves mechanism of the body and nerve system of the body.

The second one is the cardiac system which ensures that our heart beats at a specific space in a specific manner and pumps the blood all over the body. And the third section is the muscle or the skeleton muscle on the smooth muscle which ensures that either in the gut the food moves to the gi track properly that is the function of the smooth muscle. And the skeleton muscle which ensures all our physical moment, mechanical moment which offcourse driven by the nerves systems. Under these 3 classes, we are going to study the animal kingdom electricity and initial fields what will do is that we will be referring most of the time in the beginning with the nerve cells. So, let us enumerate all the different topics we are going to deal in the section.

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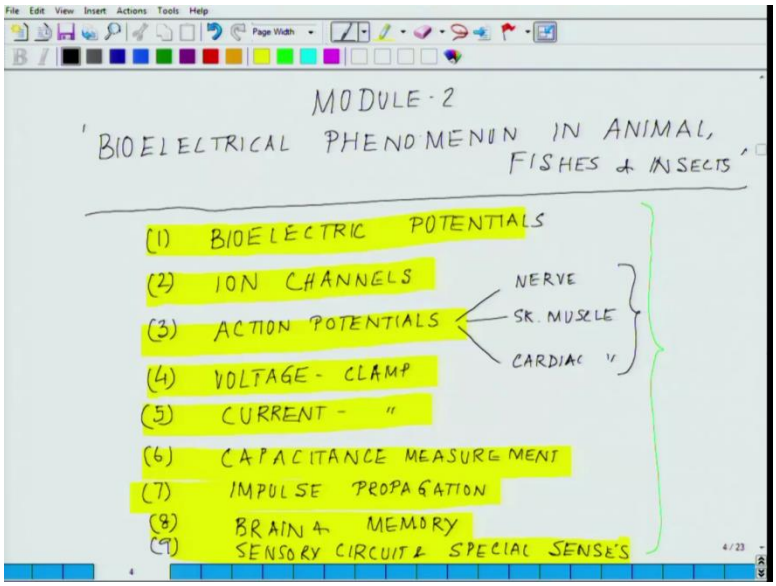

So, I can. So, we are into module 2; module 2 is essentially bioelectrical phenomenon in animal, fishes and insects. So, this is the broad title all these module, under which will be studying bioelectric potentials that is a first topic are the stepping on to this world bioelectric potentials. An off course will be referring to the nerve cells for that, talk about the ion channels a briefly told you about the different kind of ion channels which are presents. Third topic will be action potentials, again will be referring mostly to the nerves system will talking about some of the techniques here which will come into clear without this techniques the kind of a material.

So, here I will just interrupt so, essentially the reason why to push the technique here itself, some of the techniques. Because without realizing the technique, without appreciating the technique it is really it becomes really drape to see how those different potentials had been measured, how those different current had been measured, how the current flux is been determine. So, that is why I introduce part of the instrumentation here again in a instrumentation section, we will kind of cover those parts which I cannot cover here under the broad spectrum and that will short learn.

So, that we can devote little bit more time on these sections as well as cut short some of the classes on that sections, so that way we can adjust everything So, voltage clamps studies then talking about that current clamp, current clamp studies. And then you have capacitance measurement and the significance will comes capacitance measurement for a

wealth. Impulse propagation then we have in that same line we could introduce the brain and the memory. This is we will get an opportunity to introduce the brain chip an all those things sensory circuits and special senses. So, all these nine topics what I have just now talked about I just put a colour codes all these 9 topics will be essentially will be dealing with the nerve using nerve as a module system. Apart from here this one out here we can talk about the two, one actually the three, one the nerves the skeletal muscle action potential and cardiac muscle. We can talk this, because already we have talked about the ion channels.

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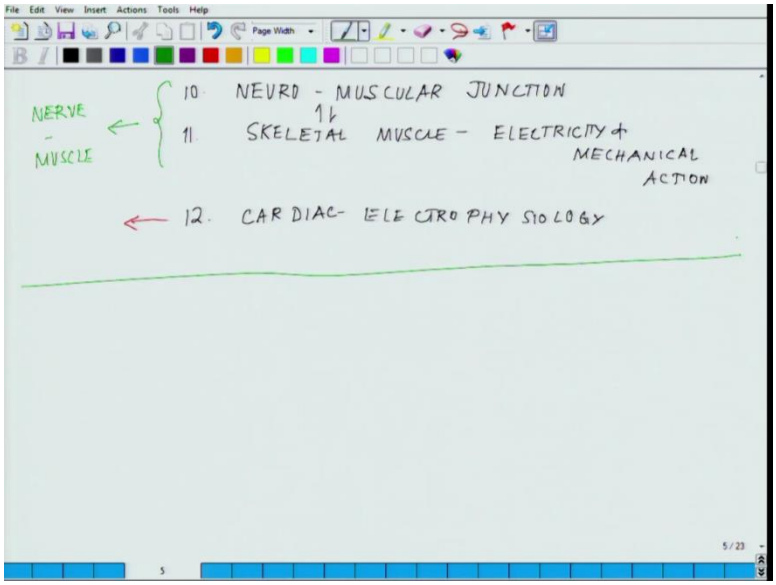

And as tenth topic what will be dealing here will be a Neuro muscular junction. And eleventh one will be off course they will be going handle hand actually skeletal muscle; skeletal muscle electricity and mechanical action and in the same line will happen cardiac electrophysiology. So, this is where you see the cardiac concern triplay and this is where the nerve and muscle will come to clay. This is the overall layout of the section two are the module 2 of this course. So, to start of, so if you go back to will be starting with this part bioelectric potentials.

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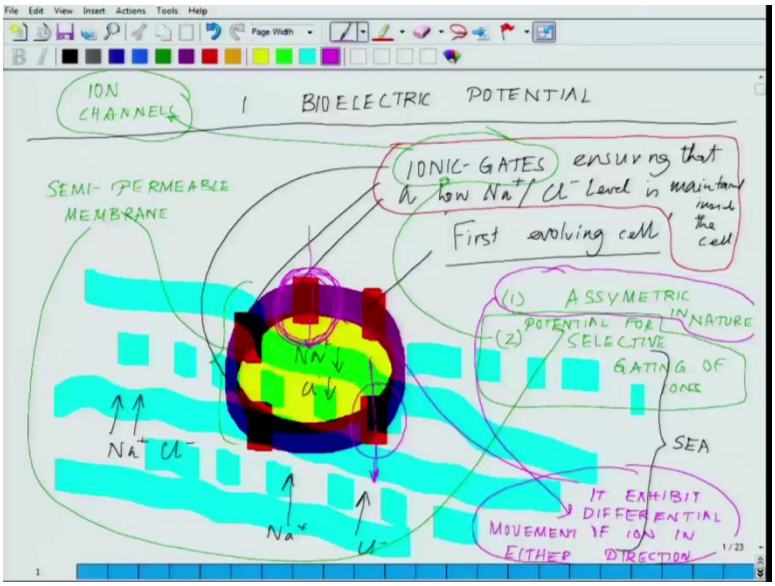

So, let us get back to the bioelectric potentials what bioelectric potentials I am why how they arrives first start with first. So, talking about bioelectric potentials there is always flow of energy from higher potential to lower potential. This much you all know say something is at higher potential some if water is higher altitude lower altitude they will right to move on the height know balanced it out. So, potential is essentially word of difference of energy of 2 systems. So, any kind of flow of energy will take place when there is a potential difference without potential difference they cannot be any flow of information from one system to another.

It is that very important an as a matter of fact the biological systems which are evolve they have evolve it is believe they have evolve from sea which is rich in sodium chloride in all this kind of things. And the way the first cell was formed it is believe somewhere are there from that harsh environment of the sea. A confirm a structure was formed which ensures that the sodium concentration inside the confirm the structure is significantly low and there should be away to pump out the excess sodium. So, that life can evolve with because that very, very high salt concentration, it is really challenging for life to evolve not very many life can evolve. So, it is being believe that the first cell which has formed as evolve from water and the first membrane the story is very more clear out there.

Nobody can really say with 100 percent guaranteed that this is how the first membrane was formed. But what will know for sure is there is a membrane all over the biological system there are membrane solve a biological systems. And these membranes are semi permeable nature and they are made up of bio lipid layer. We can refer to some of the books which I will recommend you at the end of the class which will help you to brush a basics. We can go through trials bio chemistry; we can go through lenenger bio chemistry which will help you to understand the bio lipid structure of the moment a briefly deal with. But again all the different kinds of the lipids which are involve in. Let in all those other finite details you kindly need to look into it or you can refer to the course and physiology where you will see how the first membrane has evolve and what are the different components of it.

So, coming back to it somewhere other the when the first in closes structure which evolve it ensure the, that structure has lower sodium concentration. So, in other word if I graphically show it you, so for example, so imagine this is the water firm the life is evolving. So, now, on the first cell must evolved at some distant past somewhere at some point, so for a say thank you. This is extremely high in sodium and chloride exceptionally high and when the first cell must evolve. It must have taken a very different kind of rule while it has self assemble to form ionic closes structure. It ensure that inside the, encloses structure the ionic concentration of sodium is low something like this.

So, inside this as well as chloride is low first evolving cell now when the, when how you have enclose the structure whose sodium is low and chloride is low an. If somewhere are there you have mechanism by which this membrane can ensure that it can get rid of the sodium and always maintain lower concentration from the surrounding. Then it can lead to generation of bioelectric potential. So, for example, what I mean by that is. So, for example, I have mechanism by which I ensure that enough I ensure that enough different kind of gates. So, these are the different kind of ionic gates and these ionic gates ensuring that a low sodium and chloride level is maintained inside the cell. If one can does this kind of situations somewhere are there you have this ionic gates which ensures that the sodium and chloride inside is maintain at a lower concentration. As compare to the concentration of sodium and chloride which is outside into the system.

Then we are talking about generating the first bioelectric potential and this kind of membranes at on the technical term for this kind of membranes these are called semi permeable membrane. And they are semi permeable membrane and these membranes are asymmetric in nature. The first thing they have an they have selective gating of ion potential for actually the word potential for selective gatings of ions. And which is been regulated essentially be by this ionic gates which in the modern world we call then as which will be our next topic actually to the ion channels and it has a semi permeable membrane.

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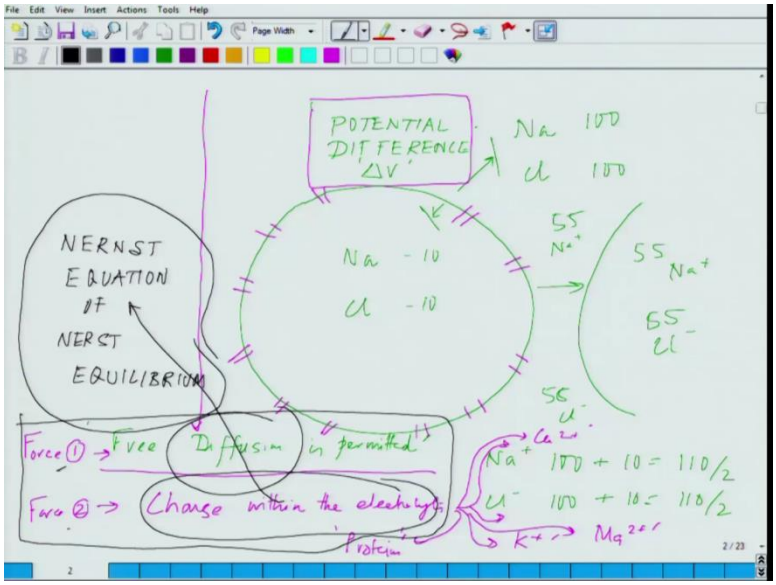

So, as soon as you have say for example, on the words coming back. So, say for example, if this is the cell what we just now kind of develop. And say for example, sodium has a 10 molecules inside, chloride has 10 molecules inside and sodium outside has 100 molecules and chloride outside has 100 molecules. So, what essentially we are doing across this by like this across this what we have showing there is a potential difference. And this potential difference could be represented by delta V, V is a voltage will come into all this details. And what essentially will happen in a normal condition if this membrane is non selected it allows the free diffusion to take place. So, the free diffusion happens and what we will get out here is after point of time.

So, if you add up this 100 plus 110, 100 plus 10 next is 110 and same a for chloride 100 plus 10 110 divided by 2 divided by 2. So, eventually there will be a time come and

became 55, 55 for sodium and for chloride 55, 55 for chloride eventually if free diffusion is permitted. But bioelectricity is not the first membrane about I told you just in the previous slide, it is asymmetric. In other word for does that mean is if you go back where I showed you this; this word when I used this critical word it is asymmetric and it exhibit differential gating differential movement of ions in either.

What does that essentially means? That means, this membrane which is present may allow the sodium to get in or allow the sodium to move out or allow the chloride to move in or move out. But it can only do the particular gate can only open in one direction in other word. If this is the gates say for example, I take example of this gate; this is the gate out here in red, this gate may either allow sodium to get in. But this very same gate this very same gate is not going to allow sodium to go out mind it. So, it is in essentially this is what; that means, understand to explain you that it exhibit differential moment of ion in either direction. Or say for example, this gate if it allows chloride to move out it will not allow chloride to move in.

These are some of the very, very fundamental concept with needed to be grass before we understand the animal kingdom bioelectricity. And this will be dealing with in the next section next class in ion channels, but, before that. So, this is essentially is where potential difference is been created and this potential difference is being maintain all throughout our life. Because there are channels all over the place which will not allow the ions to move freely they are being regulated they are being governed. And flow of ion is being is a function which will be coming in the next to next class where will be talk about the, there are two counted forces which are functioning here.

One is off course a force of diffusion this is force 1 and there is another force 2 which is the charge within the electrolyte. And where the electrolyte are could be sodium could be chloride could be potassium could be magnesium could be even proteins. Because they also have full lot of charge in that the summations that they are summated charges on them apart from it a which I forgot is calcium and a mostly calcium sodium magnesium sodium chloride magnesium proteins a likewise. So, they are four range of electrolyte which are present an apart from it there are 4 non electrolyte. Their diffusion is totally different, we are not going to deal at this time how they are diffusing I will briefly touch up on it.

Well, I will be talking about the Nernst equation and the balancing act a between this two forces look at this force 1 and force 2 free diffusion force and the charge within the electrolyte the balancing act is given by Nernst equation or Nernst equilibrium. So, I will devote atleast half a class on this Nernst equilibrium before I move on to the ion channels at this point. But I want to highlight is this ions can move freely from this side to this side if only diffusion is allowed. So, that one allow as to maintain a membrane potential, but, ate there is a membrane potential. So, if you look at it, if we just give a idea about that membrane potential which are presents.

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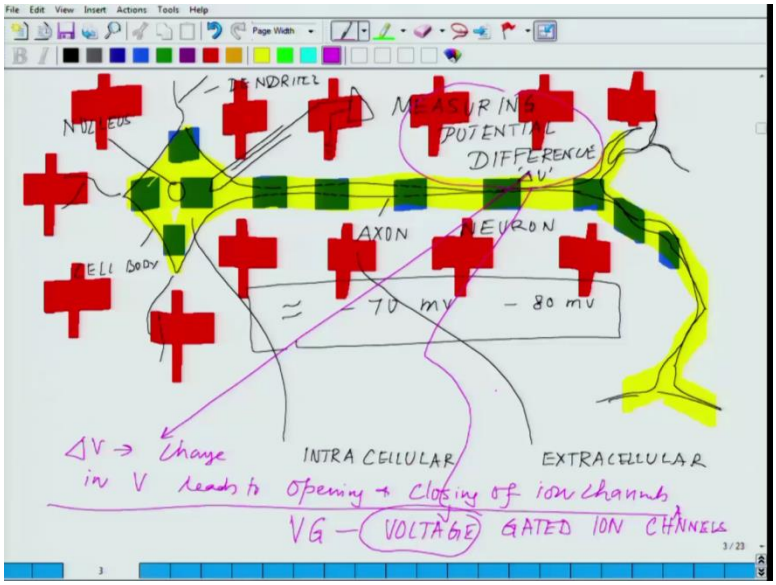

So, those of you are goes to see for example, I will be taking the example of neuron. This is the neuron which is sitting and this is the cell body. These are the dendroids; this is the axon and this is the cell body this is the nucleus and this are dendroids. So, if you impole an electrode here like this and measure the potential with respect to outside. You will find that this electrode anode actually here what essentially doing are measuring potential across measuring potential difference are delta v neuron. So, what will essentially you recording delta V will see approximately minus seventy mille volt. Sometime it may evolve minus eighty volt, in other word whenever we talk about membrane potential of the electron. What we are talking about is that with respect to outside the inside is more negative.

So, essentially what does the mean is here it is more negative with respect to the outside where is going out. But that is essentially means is that this are positive with respect to the outside where as inside it is this are all negative, negative, negative, negative. So, with respect to the outside inside is more negative, why is that more negative? Now, what we will do last 100 years, all the different concentration of the electrolytes which have been discovered. We will I will give you the complete list of it then give you an idea why with respect to inside, the outside is more positive about with respect to outside inside is more negative. So, what will essentially do here will talk about the exosphere concentration of the two different the two major a cells.

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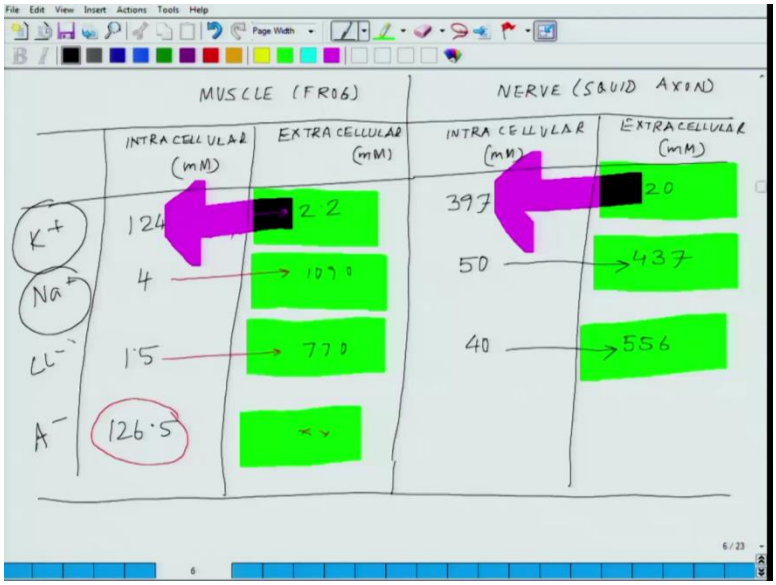

Especially will take about muscle of frog and will take more which is another. So, this two more of squid will talk little bit more about the script once again done with this. And these are the two substance will be looking at and what will be looking at here will be the intra cellular are, am coming to this intracellular in milli molar. I think I am mistake here will write this intracellular milli molar and extra cellular in mill molar. So, if you go back to the diagram what I was drawing free. So, out here this is intracellular that is inside the cell and this is all extracellular which is outside the cell. Coming back the intracellular and extracellular an here we are enumerating the different ions or electrolytes. We talking about chloride and this are the anions which could be protein are works other.

So, in case of muscility 124 milli molar intracellular 4 milli molar intracellular sodium chloride is 1.5 milli molar and other anions 126.5. Whereas in the extracellular potassium is exceptionally low if you compare this 2 values out here look at the two values compare the two values will see potassium is very low outside where a sodium philicate sodium it goes up out here it is almost 109.0. Whereas chloride is very high outside 77.0 and there are none nine outside because all the proteins are inside the cell. Now, talking about the nerves, if you look at the nerves now again the same are dividing intra cellular in terms of milli molar extra cellular in terms of milli molar.

So, for potassium intracellular potassium 397 milli molar whereas, it is 20 milli molar in extra cellular. So, essentially there is a there is of the direction is something like this whereas, out here it was direction was just a same out here also where is in terms of potassium sorry in terms of sodium 50 intra cellular an 437 extra cellular very, very high chloride 40 intra cellular and 556 extra cellular. And most of this extra cellular is with respect better much, you can they are comparable with sea water and that is one of the clues which says that life is evolve from sea life is evolve from water. So, all these values are see to find to 109 all these. So, just like go back to the slides I like that. So, if you compare this values which I am putting in green now here are.

So, all these values are kind of similar to the sea water and now, if I go back to the slide which I wanted to show you in the, which I was showing in the beginning, in the first slide out here. So, essentially this was the, I was trying to explain in the in the first slide to start of with that sodium and pota in chloride is low in out inside. Whereas sodium and chloride is high outside and will find out the potassium is low some hiding on these diagram. Potassium is high inside and there are lot of proteins which is say a negative inside it which we call as a negative. All the anions which are present there which are jointly present as all the proteins.

So, now the challenge for biology comes how it maintains these potentials. So, neatly over appear of time and how that is getting regulated. So, coming back to where I was yeah. So, so this is the concentration which is currently accepted on the may be few number here and there which varies. So, from here we will take two parts what we will do in the next class from here will drive the Nernst equation will talk about how the Nernst equation regulates. So, if you look at this picture itself that will tell you the whole

the story. So, look at this picture you see this are the electrolytes which are present out here.

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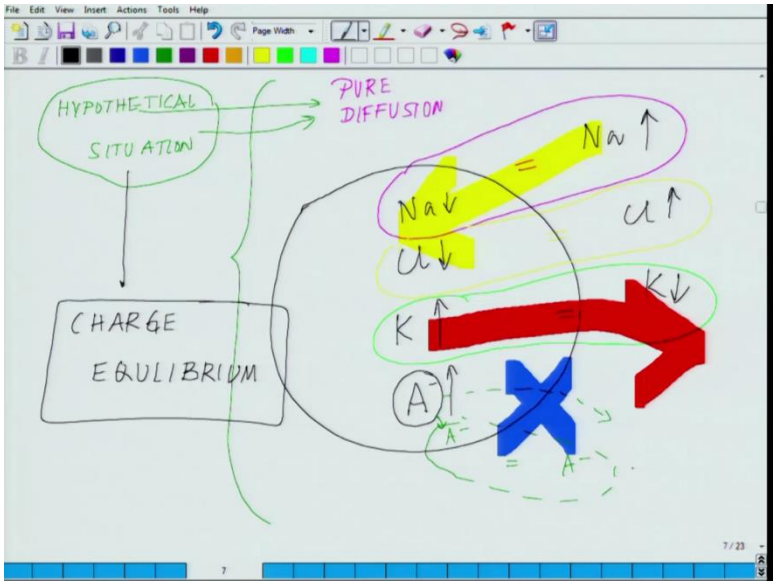

So, if I draw this in terms of just for your visualization say if this, the cell. And you have sodium which is very high chloride, very high potassium, very low potassium, very high chloride, low sodium low and you have an anion in terms of proteins which is very high. Now, going by the simple diffusion you can appreciate it here going by the simple diffusion, what will happen if I take case by case? This should if going by pure diffusion this should be come equal. Similarly if I take this 2 chloride and this chloride should be come equal. Similarly potassium and potassium will become equal and part of this protein well move out like this to outside to make a new concentration a negative a negative equal.

This is the pure diffusion of hypothetical situation this is basically an hypothetical situation for your understanding sake. This is a pure diffusion; a pure diffusion is allowed what is going to happen, but, I put an condition here the condition which I put is that those each proteins which are present inside the cell cannot really move out. So, essentially what I am trying to tell you now this transfer is not allowed, first not allowed. So, the very moment I say I want allow one of the components out of the four not to come out. So, automatically the charge inside it is not confined more charge. So,

whenever there is a more charge inside it, its generates a potential around that small confined area accept it.

Now, comes I say I start I am now start it putting conditions am putting like an up I am, what should be I am introducing limitations on the flow of electrolyte. Now, I put the next limitation; the next limitation is this, this particular thing that sodium can only move from here to here through the sodium charge second limitations. I put third limitations I put is this one; this potassium can only move out like this. So, I am just putting limitations after limitations into the game I am not doing anything I am just putting limitations. So, in the light of these limitations, we will be talking about two aspects what will be going to talk about one will be the, this is the pure hypothetical pure diffusion situation. I give you another situation in that same line another hypothetical situation charge equilibrium.

In other word what I am essentially trying to tell you is that if I am not allowing this process to take place a negatives cannot go out an have to ensure in the first place. The charge or the positive or the negative charge generated by sodium or chloride respectively and the potassium and few are ions which are presents like calcium I will talked about the calcium. So, you have the calcium also here which are which is contributing two positive charges out there. So, the charge has the equillibriated on both sides. So, we have two opposing or two forces which are governing which I just mentioning in the previous, if I if I go back to my one of my previous slides are as telling yes.

So, this is what essentially our trying to highlight diffusion charge and that is is a stage where I will be introducing you to the, this two forces in the light of this values. All sense you know this values will introduce Nernst just disc about by volt and Nernst and the earlier half of the last centuries somewhere 1900. So, at this point what are you do I am not introducing Nernst immediately I will highlight. Or I will take you retention to another aspect of electricity which will be helpful for your understanding whenever you will being taught electricity we talked about along a conducted if you look back.

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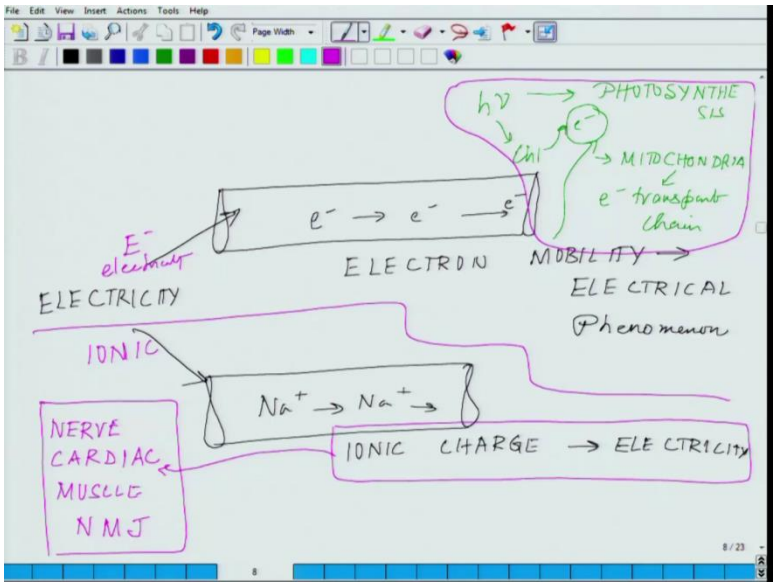

So, we say if this is the conductor through a charge is being hollows there is electron which are in motion. So, those are electron mobility which governs a electrical phenomena this is what we are allow is goes to. But simultaneously say for example, along a channel you have ions moving along the gradient these are called ionic movement or ionic charge movement an ionic charge movement is also an electricity. So, in other word in the light of this slide am dividing electricity into 2 parts; one is ionic electricity and the other one is electron electricity an in biological system.

Both this phenomena are being same it is not that we only see one phenomena. So, what are we do just with this brief introduction I will just highlight some of the areas where we will talking about the electron. And some of the areas will be talking about ion and an some of the areas will be talking about the interface of the ions and the electrons. So, let us see why all we see ionic electricity sorry electron mobility in biological system. The classic example is photosynthesis by basically when a light falls h mu when a light falls it from the chlorophyll molecule a electron is actually generated.

So, essentially see a electron movement and second place where we see is mitochondria an as whole term is electron transport chain. So, these are the two example and will come many more such examples where we will say electron transport an as will be studying about all this things in the photosynthetic biology will talk about it. Apart from that we talking about ionic charge electricity out here. This is seen all over the place in the nerve

cardiac system in the muscle in neuro muscular junction am just putting as N M J. So, all over the place you see ionic charge mobility. So, these are the two forms of electricity which will be dealing continuously. There we interplay of electron as well as ion and this is what I wanted to highlight that I proceed through please brush up some of the basics especially. So, I have introduce you to this.

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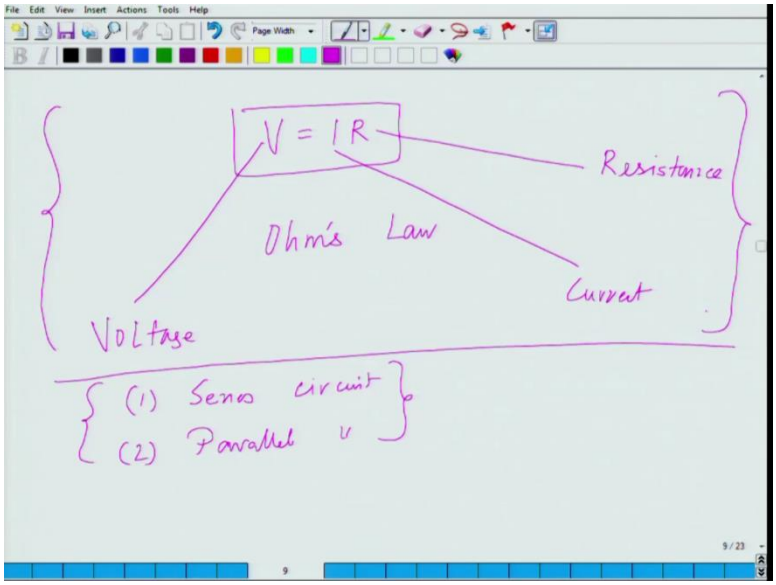

So, please brush up the most central line to the game physical to ion wishes basically the ohm's law where V is your voltage and I is the current and R is the resistance. These are some of the basics which will be it is bring the essential and go through the simple series circuit and the parallel circuit wherever needed. I will just introduce the wherever it will be essential, but, I just expect you people to kind of brush all this basic. Because that will help you to appreciate some of this things much better as compare to just me very briefly touching upon and going to the phenomena. So, this is what I expect you people kind of go through some of the fundamentals. So, coming back where we where we the bio electric potential.

So, this potential as I told you that and next we will talking about the Nernst equation how these are been covered. And then what we will do will move on to the membrane structure to introduce you to the ion channels exactly this ion channels are gated should I told you there asymmetric. They open only in one direction either they will ensure an specific ion to move out. Or they would not they will allow to move in and this is for the

their opening and closing is further regulated by the voltage across the membrane as you remember while I was drawing should see this picture. So, I told you that the across this there is a. So, essentially there is a potential difference out here delta v and the change in this change in v lead to opening and closing of ion channels.

In other word this gives rise to something called v g or voltage gated ion conducting channel or ion channels where voltage is ensuring a change delta v out here is ensuring whether the channel will be an open state or will be an closes state. And this are all pico nano fermterm fermto second phenomena there are very, very interns phenomena which takes place in a scroll of the movement and with pretty much regulates and ensure that we are kicking alive and kicking. So, with the pre background of bio electric potential I will close on this class and I told I promised that I will pluge it pluge in some of the things which I missed upon. So, something which I missed in the first lecture which I will just come back.

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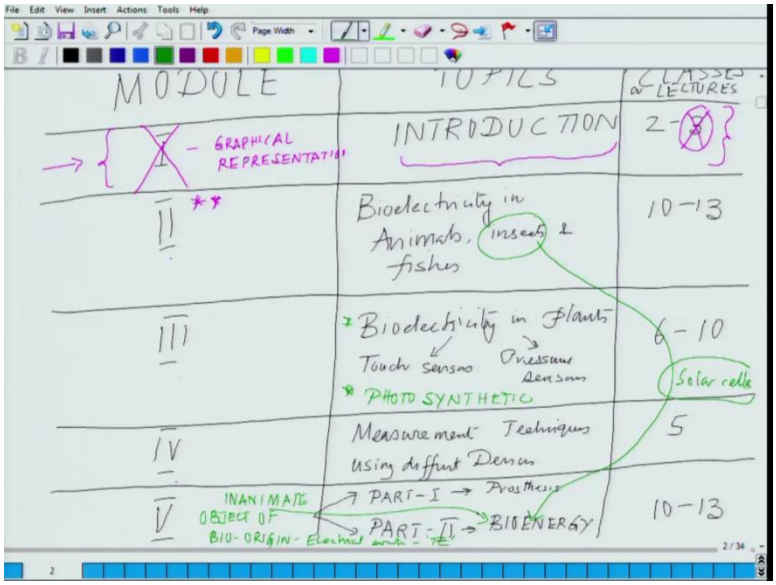

So, what where I am going to? So, I told you that I will be talking about this inanimate objects of biological origin and their electrical phenomena which in the second lecture I was telling with the regulation all those things. So, what I decided is this sensitive is not exclusively mention here, what we will I will do is I will include them in this section out here in the bio energy section. So, basically out here we will talk about in animate object of bio origin and that is it electrical event. So, that is where will we talking about t e

electric events and out here in the bio electricity of plants all this things will introduce actually the photosynthesis. These are the two things which were are this is sorry, there is on more thing which is and in this section itself we will introduce the some of this insect based solar cell I told you.

Solar cell; this is this are the three thing which are not very clearly I was coming out while I was kind of highlighting the course that where those will fat. Those will fat as under the bio energy section where will deal with those things all go on this. In the next class will talk about the Nernst equation and we will talk about the action potential followed by that. And in while will sorry will be talking about the ion channels and then the action potentials and in the mid in between this will sliden the exact picture of the membrane how it looks like, and how the ion channels three dimensionally matrix are...

So, thanks a lot.