Bioelectricity
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Lecture – 3

Welcome back to the lecture series in NPTEL on Bioelectricity. So, we have introduced the course in the first lecture and in the second lecture we went head and started with the graphical representation of the course the way it will progress. So, in that process we started with inanimate object or inanimate object from the biological origin, we talk about how the thernale regulation is being done will be discussing it can be the following heads, like you know the system identification the biological or electro bioelectrical phenomenon.

And then we will talking about the instrumentation needed and that advanced applications. In that process we finished with that inanimate world what will be dealing in the course, we talked about the insect world, we talk to about the plant world, what we have in talk to yet is about the animal bioelectricity the world, which is most explored among all these where, there are lot of applications for by medical prospective as well as for different form of prostheses and everything. So, today we will start with the graphical representations of the animal electricity or animal bioelectricity what will be dealing.

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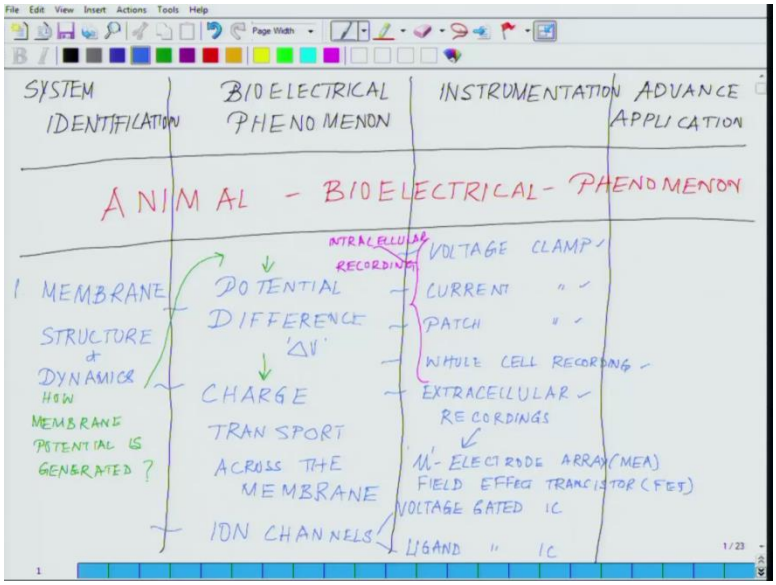

So, one second this coming back the way we started with the other once, so will make four columns, system identification. So, system identification we have first column identification, bioelectrical phenomenon and instrumentation then we talked about the advanced application. And this we are holding under the title of animal bioelectrical phenomenon.

So, again following the same scheme of things, so we will identify the system, we will talk about the phenomenon, we talk about the instrumentation and we will talk about the advanced applications. So, the first questions which we will attempt to answer here is the origin of the bioelectrical phenomenon in other words the cellular electricity at the cellular level how electricity is being generated. So, that needs as to go in depth with the membrane, structure of the membrane, membrane potential and the flow of charges across the membrane, which leads to the generation of electricity ok.

So, start off with we will study about membrane and please ensure to keep this chart in mind all the time. Membrane structure, which leading to potential difference or delta v charge transfer or charge transport across the membrane, across the membrane in the kind of instrumentation, so here they are few more things. So, whenever we talk about the membrane is structure and the charge transport across the membrane, we to realize that these are semi permeable membrane we are talking about. And they regulate the flow of charges especially or exclusively these are ionic charges, which are flowing and they are gated through the membranes using the smallest unit, which helps in the gating that is the ion channels. So, will be starting about the ion channels, which is the smallest known entity which helps in or which regulates the flow of ion across the membrane ok.

So, will be talking about the membrane structure, we talk about structure of the ion channels and within the ion channels will talk about voltage gated ion channels, I am just putting ion channels are I c and ligand gated I c, I just got in other columns do not worry, we will. So, membrane is the most I should say the most primary level where the electrical impulses gets generated and from there it keeps on travelling through from one membrane to another to the third to the fourth likewise ok.

And the major techniques, which have evolved in the study of membranes includes voltage clamp studies, current clamp studies, patch clamp studies, single channel current measurements. So, talking about that instrumentations out here, will talk about voltage

clamp and all come to the exact meaning of all those things, voltage clamp, current clamp, patch clamp within the patch clamp we have whole cell recording, we will talking about. So, that this of all classification, which all be coming to this whole electro chemical or electrophysiological measurements extra cellular, intra cellular, within intra cellular, we have the whole series of patch clamp, voltage clamp, current clamp, where as in the extra cellular also you could have those things, but using extra cellular electrodes ok.

So, then we talking about extra cellular recordings, which will include your micro this is just the sign of micro, micro electrode array MEA or field effect transistors FET ok.

So, there is the, so this section what you see? The voltage clamp, current clamp, patch clamp, whole cell recording extracellular recordings by the way all these others fall under the, most of them falls under the intracellular recording. So, within the membrane structure we will talk about the potential difference and most importantly will apt to talk about is start off with actually will have to talk about the out here, how membrane potential is actually generated? This is the first and foremost question which we need get to answer. And from their so now, have a potential difference this potential difference leads to a charge transport across the membrane and in this whole game of understanding the membrane structure and I should put it more correctly membrane structure and dynamics, because their other event, which are taking place that move on to the next slide, we will be talking about one of the other events, which are involved in this process.

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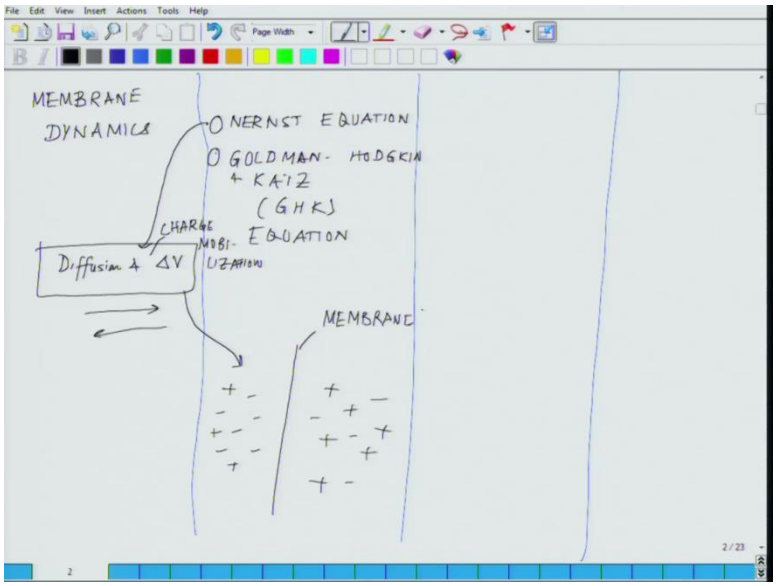

So, will taking about the membrane, so I to verify ok. With the membrane structure, membrane dynamics will be talking about Nernst equation then will be talking about Goldman, Hodgkin and Katz that also called GHK equation, which is nothing but extension of the Nernst equation. So, here will be talking about the counter forces of diffusion and delta v. The potential difference and the diffusion, how, that you know, how these forces are regulating or the reconsider the can also say charge mobilization. In other word what you want, what we want to it say what, what I want to highlight here is that, say for example, you have across the membrane something like this positive charges negative charges. So, and this is the membrane ok.

So, essentially what we are trying to hail will be trying to highlight here is that, under the normal deficiency say for example, you have hundred molecules of Nacl sodium chloride on one side, if ten molecules of sodium chloride of one another side and if you allow the free diffusion it, ensure the what we happen? Hundred on this side, ten on this side, hundred plus ten mixing hundred and ten, hundred and ten divided by two, which makes it fifty five, fifty five one both side. There will be fifty five, fifty five molecules, but think of its situation where you have hundred and ten molecules of Nacl, so which dissociate into Na plus, cl minus charges, in other side also Na plus cl minus charges. And apart from it they are few other charge molecules and the membrane, which is their each semi permeable it would not allow everything to pass through, then how the membrane will balance itself, across across it two sides? That is what we will talking

about the dynamics part of the membrane and because that is those are the governing process is which regulates the flow of ions across the semi permeable membrane and here I will go back to the previous slide.

So, whenever we talked about these kind of biological membrane essentially, we are talking about semi permeable membrane. So, will talk about the membrane dynamics and then we will talk about the once second with respect to individual cells, we will have to come and there will be talking about ok fine. We will talk about the nerve cells, which are excitable cells, in the body there are three kinds of excitable cells; nerve cells, cardiac cells and few other cells on of course, that see the excitable cells are electrically excitable cells of the body. Electrically excitable membranes are it called the cells, of its membrane is covering the cells of the body ok.

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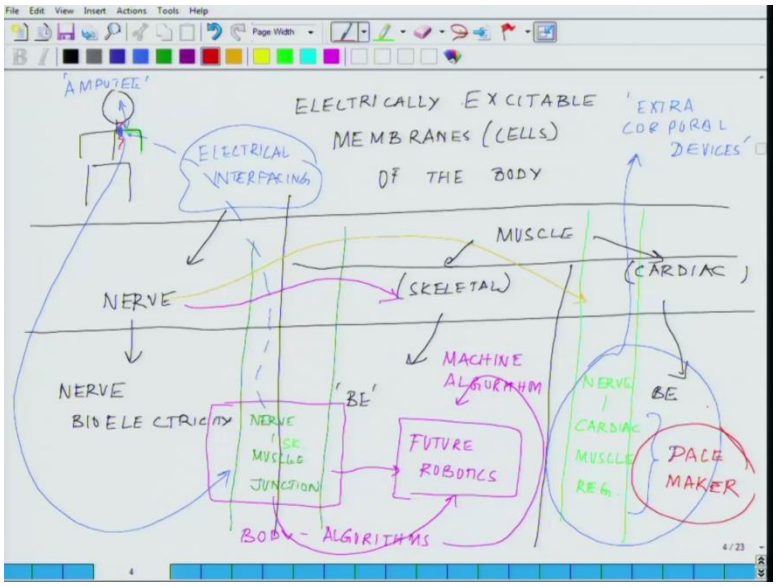

So, there this if the nerve cell, you have muscles mostly skeletal, which is more pronounce and you have other muscle, which is within the muscles in between this. Now, I am trying to write cardiac and skeletal, essentially we will talking about nerve, bioelectricity, skeletal, bioelectricity and cardiac bioelectricity. So, these are on the left most columns. In fact, I talk about the identification of system so this is the broad identification of this system. And mind it, these systems are all interlink. So, for example, this nerve is regulating. So, there is an interaction that falls under the interface zone of this, where we will talking about nerve, muscle, junction and have to study that.

Or say for example, we pick this up the way nerve regulating cardiac muscles and in this situation we are talking about this skeletal muscle of course ok, cardiac muscle regulation. So, while will start with the structure of the membrane that will be originoric structure, while we talk about this is how the membrane looks this is how the potential difference across being maintain and these of the different smallest in it ion channels which are regulating and from that generic introduction we will move on to does specialize are its types, which is nerve cells, take all the three excitable cells, muscle, skeletal muscle into cardiac muscle.

So, coming back to the previous slide to yet we where. So, we were actually started. So, within, so one second within, so this is the overall the outline to start off with this thing and then we talked about the membrane dynamics, what will be the starting in the dynamics part.

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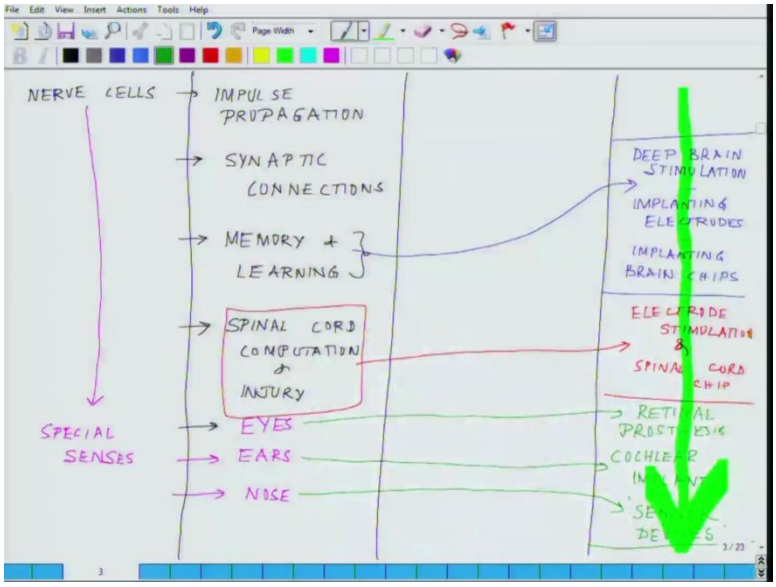

And then we talk about the yah, so in this classification what we are going to studying in the nerve cells. So, within the nerve cells, we will talked about impulse propagation, this is exception important then we will talk about the one second, we will talk about the synaptic connections and in that whole process with the nerve system we will talk about memory and learning. It was there are some of most important bioelectrical phenomenon; here we will talk about the spinal card computation and injury. Then we will among this nerve cells will talk about some of the special senses, becomes a special

senses, we will talk about the eyes, the ears then nose and these have very straight output. Whenever we talk about the eyes, ears and nose, because these are the organs, which has opened up the, should say opened up the scope for the prostheses right, because the first prostheses which was done was the cochlear implant.

So, from here will move one to essentially to from here will talk about that among the advanced applications about cochlear implant, which is an eight electrode system then among the eyes will talk about retinal prostheses. This is in the case of nose in human being that is not as a strong as on road ends, it is more of a research interest of understanding what are the different odors and they have of course, perform implication in perfume industries and all other places. So, they are more like a inspiration for a odor and sensors. So, for the sensor devices and within this parts spinal card injury, we will talk about among that advanced application, we will talk about different electrode stimulation or and sorry, spinal card chip likewise. Then in the case of memory and learning this is one of the most challenging frontier, word we will talking about different debrain stimulation techniques different research is currently going on to replace a part of the brain with the chip to you know handle situations of like also cymas or some other new diseases or we will talked about how a brain can cross talk with the robot now those kind of things.

So, it will start with stimulation is one of the areas then implanting electrodes then you have this implanting brain chips. These are the futuristic dream of mankind. So, what essentially transfer out of all these things is this that, we have to understand the very basic fundamental ideas first, specially interms if you go back to the previous slide have to understand the membrane potential, we have to understand the charge transport across the membrane, we have to understand the dynamics of the ion channels. And we have to understand the how the Nernst equation, Goldman Hodgkin and Katz equation and other all of the things a regulating the whole process, but then the next phase, which is the most challenging phase of all these game is something if you look here. So, if, you look very concentrate on this side right, if you really look very carefully to this side, this whole part is taking us to a different zone that is basically what we talking about is your implanting or your introducing something inside your body in the form of electrode or in the form of a chip, but mostly at the form of a electrode form of an electrode ok.

So, that requires at different kinds of explicates. So, we will just a numerate bit of it. So, let you appreciate that why these areas are so very challenging. So, I will do. So, I will try to do it more on a diagrammatic position.

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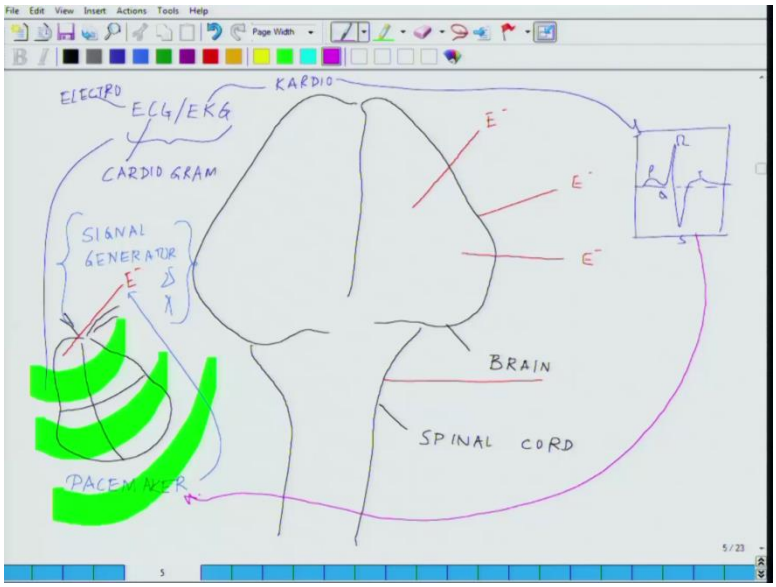

So, see for example, this think of it, if this is your brain and this is the spinal card moving it. Now, we are introducing and electrode into the system like this, or say for example, electrodes are may be a self as electrode like this. So, the very moments and these are I am just putting the sign E minus as the electrode and this is of course, the brain and the spinal card ok.

So, the very moment, your introducing something into the brain or into the spinal card your introducing the foreign object into the system. And essentially and how this individual cells all going to interact with that for an object is the most fundamental challenging problem.

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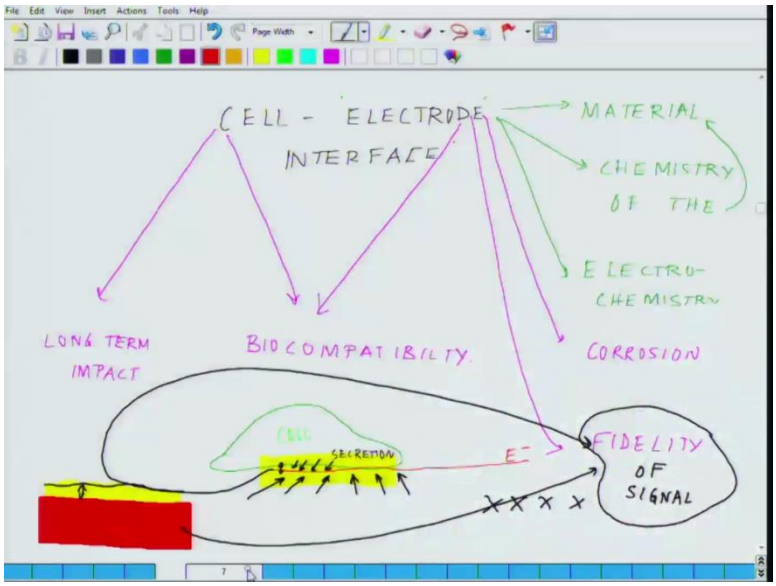

And that falls under them the feel of cell electrode interface, cell electrode one second, one second, cell electrode interface. This interface is extreme important, because electrode this is the zone, where we look how diverts the feel becomes, this is the zone which needs your understanding of materials, chemistry of the material then we have to understand electro chemistry then we have to understand the, which is the interface idea out here, that interaction which is the biocompatibility and then long term impact. So, this whole feel of cell electrode interface is exceptionally challenging and that is where lies the catch what are the newer and newer electro materials, which mankind to develop which could have pass in progressing into the feel of man machine interface or Nero prostheses and Nero electric interface much more easily it should, it should seen in very easily without any problem.

So, that is the whole feel in its in merit and that needs different kind of training to understand. So, this is one thing which will be highlighting as we will be talking about micro electrode daring is we will talking about different electro material which having use. So, that is the part where will be talking about the whole instrumentation in everything. And talking about this implication if you look at it we have already talk to about if will you go back or out here one second yah, so deep brain stimulation implanting. So, there are all material things, electrode stimulation, spinal card, retinal, prosthesis, cochlear implant, sensor devices. So, if it look at all of them they all need electrode materials. So, an one hand we are dealing with the biological system, but on

other hand you we need at deep in depth understanding of material science otherwise it is exceptionally challenging even to handle a single problem in this field.

So, now what we will do will talk about few more other areas. So, this, so talking about nerve muscles junction, understanding nerve muscles junction. So, this could have performed impact in understanding the field of robotics could you have a robot, which make the movement of the arms, so gently it could to like this, it could walls through, it could moves through, it could do like this all these different degree of freedom. This privilege we have because we are under the continuous control of the nervous system which helps us.

So, this is the area, the nerve muscle junction what I try to highlight out here have performing impact in future robotics. Future robots may use some of the algorithms what are be in. So, basically first of all you have to understand you have to understand cross leads this algorithms of body, body algorithms have to translated into a for a machine algorithm to execute the chart. So, this is how the understanding of nerve muscle junction could be out the calve, other than that there is another side of this old field that is the keys of patient with amputation, say for example, a person has say amputate hand or amputate legs could we, so say for example, here is the situation is difference occur here is an human being ok.

This is the indirect human being. Now, there is an amputation, this is gone. Now, we can put an artificial, artificial limb, but how this limb will cross talk with the brain, what will be the signals which will be put here, that all falls under understanding these algorithms have nerve cells are controlling the muscles, could we have could we translate this in terms of some kind of electrical gaga tear. After understanding the algorithms are electrical interfacing could you do that for an amputeephation. So, these are some of the fundamental things, which we needed to understand, while we will talking about the nerve muscle interaction from a very application oriented point of you.

We will do the very floral biology, but will more concerned about how those signals could be translated interms of computer algorithm that we could design something, which could execute, if not to the level of a fishing so fee normal human being, but you know to some degree, so that the life of the individual, but comes much more easier. So, there is one re area we will be kind of highlighting here is an advanced application, while

talking about this part the story nerve cardiac muscles. So, these are some of the understanding, which has performed impact in extra corporal devices for those of few for not affair the extra corporal devices these are devices to check the spelling from thus spelling is wrong here. These are the devices, which are use outside the body. So, for example, somebody the best example is this, somebody is having kidney, kidney problem fine, the kidney is unable to purify the blood. So, what they do they put in artificial kidney outside the body and the bypass the flu it which moves through that devices and purifies the blood in put in back in your body. So, it preedy much carry the devices with you are when your line down. So, in depending on how fast it has to be talking here.

So, this extra corporal device, devices are fairly prominent in before even we have a very ready prostheses out here. So, this is one of the routes. So, these nerve cardiac interaction could have such scope apart from it understanding is could help us to develop the zenith artificial heart, which currently only of course, only one company in the world which is doing, so but there is lot of room lot of understanding apart from it. There is another area which is the most prominent area currently is, the area of pace makers, one second where basically, so the pace makers, pace makers is nothing but the heart of the rhythm, by we the electrical impulses are been transmitted from one part like from one side of the heart to the other end from one I should say from corner to other corner ok.

So, that pace is set by the specific cells or the specific circuit within the heart and those are called pace maker cells. So, say for example, for some reason or than the pace maker cells goes, they were, they were bad, they were not functioning. So, what to do? How to bypass the problem? Knoll the way to bypass the problem is that input as synthetic pace maker on the surface of skin out here, which said the tone for the conduction to take place and there is the technical term though for it. So, basically heart is divided into two system, which functions in complement in each other one is called the conduction system, which is basically the pace maker system and other one is called the contraction system, which actually executes all this you know the heart beat in all those kind of things ok.

So, is the conduction system goes bad how to you know ensure that we get were fine. So, that where comes the whole field of pace maker and pace maker implantation is the very common process currently, but there is lot of room for an improvement of a pace maker,

because this is another thing, which is very similar to what I drew for you something like this. So, where your putting electrode like this. So, here essentially what you are doing, if this is your, this is the heart with four chambers. So, essentially what you are doing at the surface of the skin you are putting and something like this. So, this is essentially is the story of pace makers, which is nothing, but a signal generator. So, here the electrode is not really picking up signal it is generating signal at a certain frequency and a certain wavelength. So, that is the other area where there is the normalizes scope of understanding an apart from it, the way this rhythm are moving across the heart the way this waves are moving out here the propagation of the wave.

So, this propagation could be adult and the field of ECG or EKG. So, will talk more on this on C stands for cardio, electro cardio gram, or K is original kardio gram. So, this something, which all of you must of seen that this is the kind of traces. Whenever you see a screen and that based on that they are an intervals like you know p q r s t likewise you know. So, we will be talking about those electro cardio grams and all those electro cardio grams are being interpreted and what are they significance and how that helps the doctor to decide with it this individual needs a pace maker or not.

So, these are the things, which will be studying in the cardiac system. So, we are talked about, so the way we started is go back. So, we talked about they will be talking about the membrane structure and dynamics and how the potential is generated the potential difference leading to the charge transport across the membrane, we talk about the voltage gated ion channels, will talk about the ligand gated ion channels and in this whole section of techniques will talk about all the major techniques will be dealing out here. I will thus I told you that we have a section on the techniques one second yah, then we will talking about the dynamics part where I highlighted that will be talking mostly about nernst equation and how this is being the governing, the governing dynamics for this whole process. Then will be talking about the nerve, when in the nerve cells will talk about the nerve propagation, synaptic connection, learning and memory, spinal card computation and injury and the special sensors, which are exceptionally important for our survival the eyes, ears and nose and simultaneously return process this cochlear implant and then sensor devices respectively.

From here we will talk about the electrical within this classification we have this nerve cells out here this skeletal muscles into cardiac and we will talk about individually and

how those could be used for amputation patient amputee patience and or in robotics. And then will talked about the electrode implant and especially within the cardiac and how the EKG traces could be used to understand the pace maker with it the too person needs the pace maker or not.

And here I highlighted that how the cell electrode interface demands your understanding of a material its biocompatibility, its long term impact and the electro chemistry of the material and in that same line there is something core the corrosion and then they are the fidelity of signal how long the signal they are because the thing is whenever there. So, it do realize here in this diagram whenever this electrode is inside. So, essentially what is happening for redraw the situations like this? So, if I representing the cell by a green color like this, we have the electrode as red color like this. So, this is electrode and this is your cell. So, at this interface zone, at this interface zone it is a very dynamics zone, this is the zone where this cell what is see out here is secreting a lot of things. And the surrounding flue it is acting with this electrode and because of this gap first of all there is a gap you could see there is the gap this gap influences the signal the fidelity of signal is one thing this gap is very good at doing.

Apart from it what happens over the period of time this cell is secreting as the these arrows are saying the secretion these secretion could, if you kind of makeup slightly more bigger image of this privilege this gap this is the electrode over the period of time what will see is out here what will essentially see that they will be coating of something like this. And still the cell is out here and this gap make keep on increasing and the definitely reduce the fidelity of the signal what is reaching to the electrode. So, these are the some of the stuff what we are going to deal with in the cell electrode interface, which is exclusively it is a very challenging area and continuously there is research going on our try to if give we the feel of the different research, which has been done. Apart from it we will talk about some of them, so I told that we will talk about the lot about the bio energy. So, what we will do this is one area which I have in really highlighted well shine in the scheme of things.

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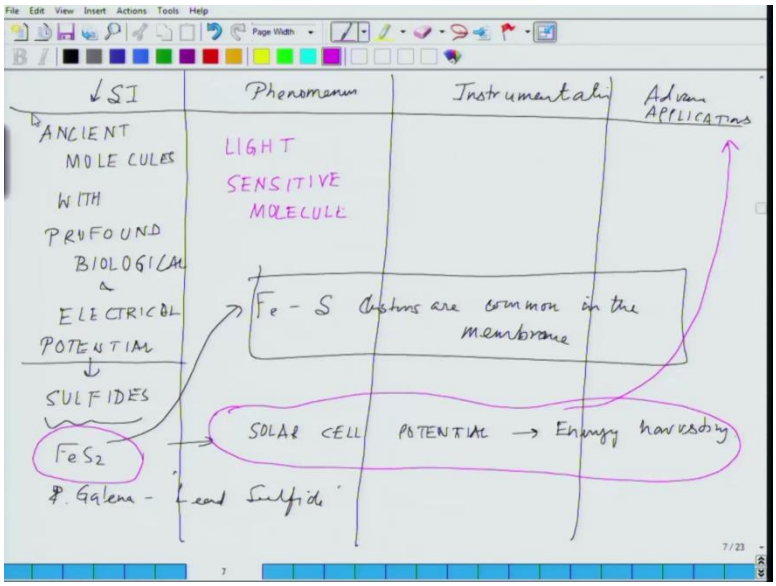

So, the scheme of thing I told you that you know, I have these another four columns in the graphical representation. So, we will talk about in that in among the system identification some of the ancient molecules, some of the very ancient molecules with profound biological and electrical potential. So, some of the molecules will be dealing here will be some of semi conductor molecules like sulfides. So, we will talk about them, will about them will pick up one different section something like will talk to about to FeS2 and major one, will be talk to about it is a solar cell potential. And the reason while pick up FeS2, because these are iron sulfide clusters are common in the membrane, they are paretic much integral part of the membrane. And we will talk in depth about what will that advanced, which has been made, because mind it among the first semi conductor material, which were develop, which was kind of discovered was galena, which was nothing but lead sulfide.

So, sulfide has remain very much an integral part of our development. So, this is one section, which will separate out, so here of course, again another same classification we will talk about system identification the phenomenon and instrumentation what will be leading for that will remain between the same instrumentation and advanced application. And within the advanced application is our this section, which I actually they denote, this is pass part which will be in that advanced application and phenomenon is of course, the light sensitive molecules. And as will moves through this you realize that why I picked

up this particular molecule, it has some very unique, unique properties, which is forbidden than the silicon based electronics what we are currently so much involved in it.

So, this is the overall layout the first three classes what you told you that all been you introducing you to the intro to the course. So, these are the first one minute yet to let me just, just like do you are favor with me open up my first lecture to here yah. So, this is what I want to show you guys here yeah, so this is the introductory part of a module, which I just I now finished with you people that first three class two to three class what I devoted on introducing you to the whole subject. So, this is where all those three graphical representation in everything comes introduction and graphical representation of the subject.

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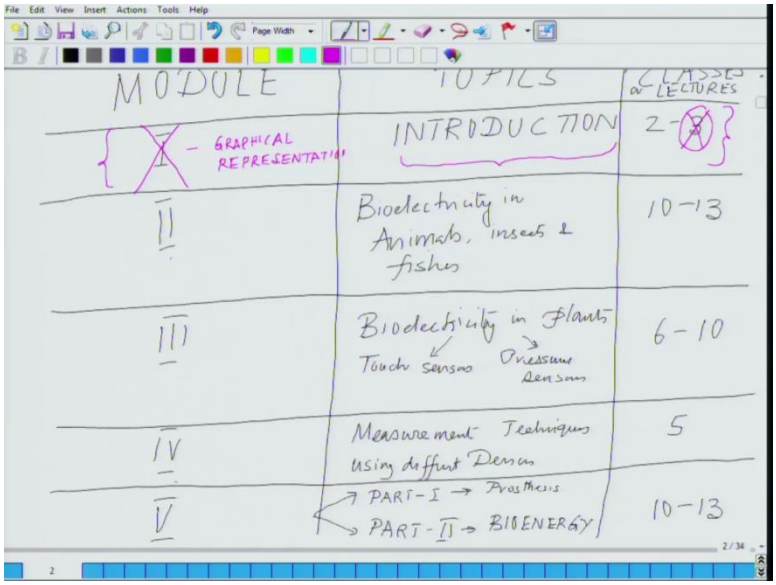

Now, we will move on to, so this part is all take in care now. Now, we will pick up one by one, all this what you are seeing instructions two second and every time I will come back, I will just see, how for a have reached in the whole scheme of things what you seeing front view now, the first three lectures are gone. So, now, you move on to, so will make a call weather we moving to sections, because I have told you, we can pick up this, this, this, this, anything at any point, we can again comeback. So, we will, will keep it very lose it, very simple and my expectation is very clear here.

Just your basic high school or whatever it is and we will stick their, we will not go anywhere beyond at, because the whole idea is to appreciate electricity across nature. It

is not about you know knowing highest equations out here or you know very intricate phenomenon, it about first of all what it needed in that we look love the subject if to appreciate and once you start loving the subject then you get in depth into it you like this part ok. You will gave get in to it.

So, the whole further of this course is appreciated, appreciate all over nature they are so many beautiful things, which are happening, easiest you have to try to look at it ok. So, now I will end my module one, where I basically introduce you to wide range of bioelectrical phenomenon. And now I will pick up one by one and I will explosive to the different events.

Thanks a lot.