Bioelectricity

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Lecture - 2

Welcome back to the NPTEL lectures on Bioelectricity. So in the last class, I introduced to the curriculum what I am going to follow, and I talked to you about the five modules under this course to be dealt with, and I also highlighted the fact that each of the modules will be standalone. So you really can pick up any module and go through it. So today what we will do is, I will give you a graphical outline of the way the course will progress, so that will kind of giving an idea where everything fits in because whenever we do a course, kind of you lose track like what is the central theme, how this whole course in its structure.

And especially in a field like bioelectricity which is so diverse from inanimate objects to animate objects, the insect world, the world of plants, and everything. So, where all these things kind of converged, where really why we devote time. So today's class will be kind of giving you an overall outline, the flow diagram – how you are going to progress; of course, your five modules will remain there. Those are the five modules, we will going to follow, but all those five modules can be put under one graphical representation, and that graphical representation is extremely essential for you people to kind of appreciate all other integral theme or I should say the central theme behind this whole exercise of forty lectures. You should be able to correlate each and every component of nature and either you can go on very fundamental research, fundamental studies about it or based on the fundamental findings, you can think of how this could be used for different kind of applications like biosensors or you know prosthetic devices or bio-energy, ((Refer Time: 02:19) application all over the place.

So the way I am going to put the graphical representation just let me give you a verbal idea about it. So first of all, it would be in a tabular fashion depicted. So in the left-most column, we will talk about the system which will be starting, it could be an inanimate system, it could be an insect system, it could be the systems of animals, it could be a plant system then will talk about the examples under those headings. Then will talk about the exact physiology or the exact bioelectrical aspect we are going to study in that aspect and what are the techniques which involved in those kinds of studies. And the result of those studies where we can take it ok, so overall starting from the basic, identifying the system, characterize the system, understanding the mechanism of the system, and the tools employing into the system, and last but not the least is where we can take it from there.

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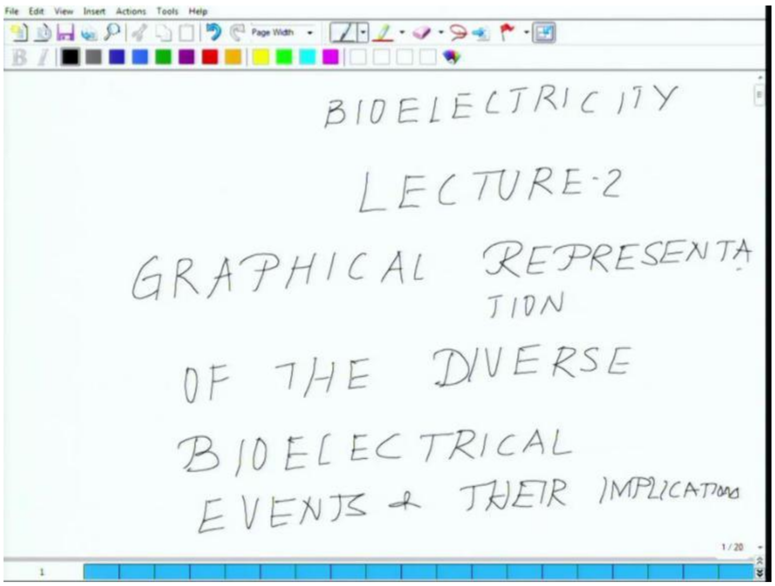

So let me start by slowly drawing the chart with you, at every quarter I will stop, and I will give you my opinion on it and let us get the whole graphical sketch of the whole course. So coming back to the so this is where we are Bioelectricity, this is lecture two and the title of this class will be the Graphical Representation of the Diverse Bioelectrical Events and Their Implications.

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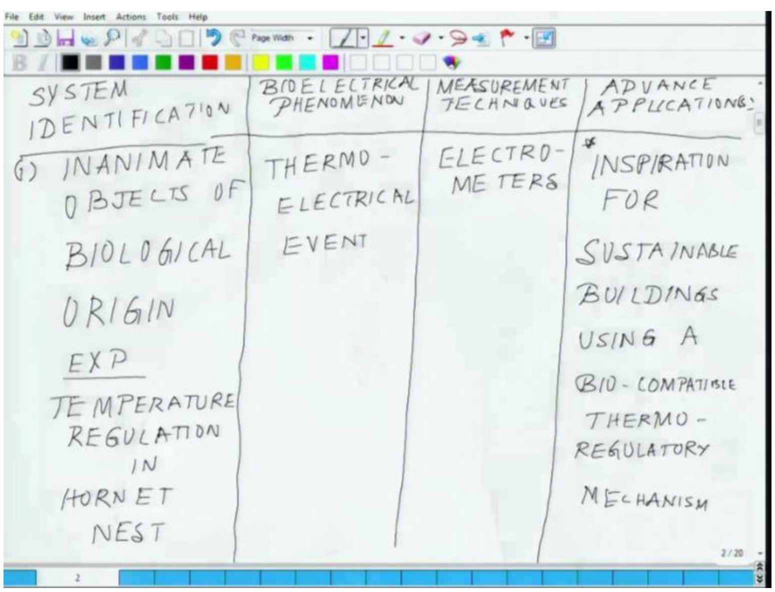

So to start off with as I told you so will be, the system identification that will be our first system identification this is the first step. After the system identification, we will move onto the bioelectrical phenomena of that system. Next, we will talk about the measurement techniques; how we are you know, measurement techniques. And then we will talk about the advanced applications. And I expect you people, to kind of keep this, so what I expect is that I want this to be an act as a guiding principle or should be part of your brain map.

So whatever in the next rest of the classes what I will be teaching, the rest of the course, you should always try to correlate with where exactly all those small pieces of information or puzzles are fitting. So at the end of it, you should have a very holistic picture of nature how nature is surrounded or pretty much bioelectrical phenomena is should say an integral part of the evolution of nature itself. And whatever we studying in basic physics they are all over the place in biology, all over the place. It is just we have to identify the system and kind of you know, quantify the system and establish a link with the existing laws of nature which has been governed in the physical world.

So coming back to the first, system identification part; this is our system one. So, basically, we will be talking about an inanimate object as the first one, inanimate objects of biological origin. So in this context, I will take you back to some of the most fundamental studies which were done

almost I should say forty to forty-five years back, while there are some people who studying the thermal regulation behavior in the hornet nest. So all of you must have seen the hornet nest at someplace or other, you know the hornet nest, it is kind of in the corner of the building or somewhere. And a very intensive study was taking up somewhere in Mediterranean in his rail by Jacob Ishee and other coworkers to figure out, how these different nests of nature maintain regulate their temperature. And in that journeying of last forty years, what all has been discovered, what are the different bioelectrical phenomena.

So in this, the example will be, the first example out here will be, temperature regulation in hornet nest. So the bioelectrical phenomena are out here is the thermo-electrical event, so talking about the thermo-electrical event, so we will be talking about some of the very basic events of nature like sea beck effect, Peltier effect. So these are some of the most fundamental properties where thermal energy is being translated or transforming to electrical energy and vice versa, electrical energy is dissipated in the form of thermal energy. And there are materials which show such behavior and those kinds of materials are been utilize for refrigeration, for active cooling and likewise. There are several other applications of such devices.

Nature indeed has such an interesting mechanism to regulate temperature. So the bioelectrical phenomena which will be dealing in the hornet nest are relevant to that what are the different current and voltage are, how they are regulating temperature and all those things. And one of the instrumentation what will be involved in it basically will be, we talking about the electrometers, which has the ability to so talking about the electrometers. So electrometers are devices, we can measure the current of very very low amplitude, very low magnitude like pico ampere, nano ampere with high-end fidelity ((Refer Time: 11:11)) they can measure it. So we will be talking about electrometers.

So now if you look at it in perspective, so if you look at it that section one falls under all the different phenomena, section two falls under the different events, and section three is about the instrumentation because they are all interlinked with each other. And advanced applications of it, so advance the application of it is one of the applications is an inspiration for sustainable buildings. So this is one of the major inspirations using the bio-compatible thermo-regulatory mechanism. So here I wish to highlight something, so most of us whole eleven ((Refer Time: 12:30)) tropic countries, during

the summer, we are totally dependent on an air conditioner, so which basically essentially does only one thing. It pulls out the air molecules and reduces the collision and between the air molecules within a room using a very strong pump. The sucking out air, and thereby reducing the collision and making the room cooler, that is what an A.C does.

So think of a situation and this process of pulling out air from a room needs an enormous amount of energy, these are all high-powered devices. Now think of a situation, if you can replace an amount of energy which it needs could be replaced by something which is which can maintain the temperature of a room within a very comfortable biological regime. How that room will be, how our life will be, so these are some of the inspiration which we derive from nature and they intensely involved a whole lot of biological phenomena. So this is, this will be our first topic what will be dealing with under the heading of system identification, bioelectrical phenomena, measurement techniques, and the advanced applications – the imaginations. Tomorrow what will happen we do not know, but if we keep on doing this intense research one day the world may be a very different place.

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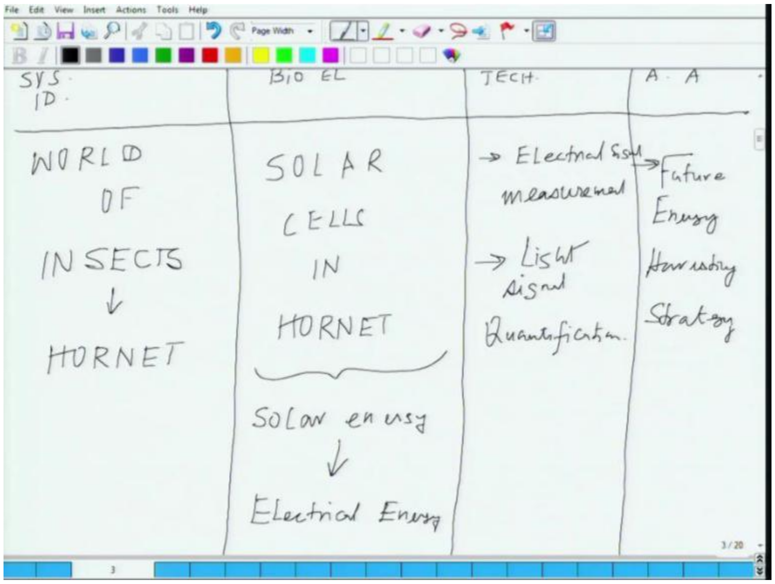

So let us move onto the next one, exactly under the same heading. Again the system identification, I will just put system ID in the first column, then bioelectrical phenomena are the second column, then techniques - I'm just putting the short form and advance application A A. So the second

the thing will be dealing with will be the world of insects. What we learn from them, so talking about insects. Insects have evolved or probably one of the most evolved species on the floor of earth, they have survived millions of years of turbulent weather, turbulent climatic conditions, geological changes, and they still survive. And they have adopted several mechanisms of energy conservation, energy harvesting, and several innumerable known and unknown survival strategies. In order to ensure that they survive on a slot of time, the changing time; so in that process, some of these insects, especially some of the hornets have developed a certain mechanism by which they can ((Refer Time: 15:59)) grab sunlight and convert it into energy. It exactly the same way a plant does.

So in other words, within their body especially in their wings and abdomen, they have certain specific molecules, which functions as solar energy draper. They can drape the solar energy and they can covert that; and in other words, essentially what we are talking about they are living mobile solar cells. So we will be talking about these kinds of solar materials, which are found in nature, which has the ability to convert light energy into electrical energy. So especially will be talking about in hornet and will talking about solar cells in hornet. So in other words here we will be talking about the phenomena that will be solar energy to electrical energy. And of course, the different techniques which would be used will be mostly electrical signal measurement sorry. And apart from it, it will have light signal quantification.

And among that advance application, future energy harvesting to energy harvesting I should say strategy. So will pick up one example from the insect kingdom and we will talk about how the insect harvest the energy from nature. And this is something which could be a big inspiration further future, whereas all of you have seen in that silicon industry is almost hitting the roof, crystalline silicon efficiency around seventeen percent, and seventeen to twenty percent, maybe maximum in the lab conditions. So there is intern search from molecules, which are much easily available, synthesizable, greener, and more biodegradable ((Refer Time: 18:52)). It does not need the extensive cost of processing silicon. So in that line, one approach I inspiration from nature is what I just now explained is in the lies in the cuticle of the hornets. And if we could synthetically develop those compounds, they may have immense potential to look forward.

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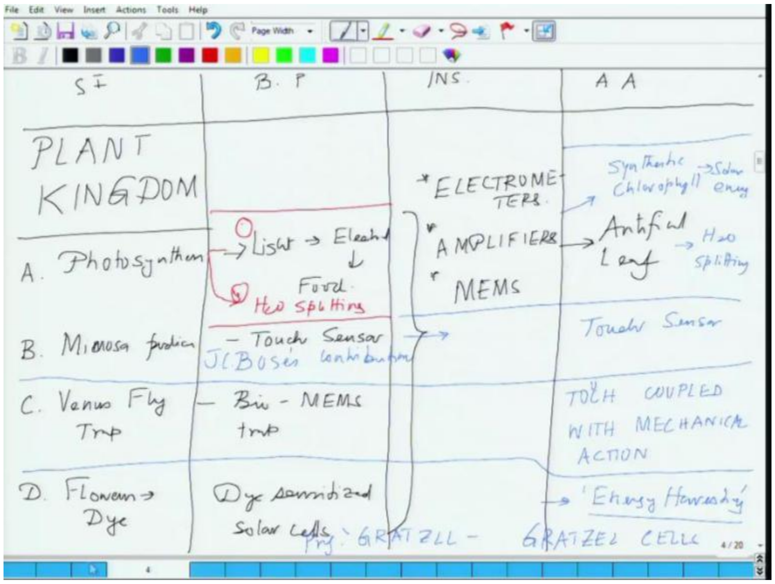

So let us identify the third system from here. Again there are four columns this time again the same thing system identification – the column one, SI – system identification, the biological or bioelectrical phenomena, the instrumentation, and advance applications. So here we will be talking about the world of plants. Another very very diverse kingdom and the only known biological system, which with its fullest ability could harvest sunlight; get the lights, converted into electrical energy in terms of the flow of electron, and helps us to synthesize, helps to synthesize food. In the food chain, they are the autotroph, auto means self, troph means they have the ability to synthesize food and we all depend on these autotrophs for our livelihood.

So they are kind of the pillars of the ecosystem. Based on those pillars, all our the whole food chain is dependent upon. So that is one of their most fundamental contributions. Apart from it, they have a wide range of sensors in their body. They have touch sensors in the form of mimosa pudica, they have touch sensor as well as mechanical you can say touch sensor coordinated with the mechanical door, in terms of Venus Fly Trap, where they could you know to trap an insect. But that whole mechanism, by which biology ensures a fantastic microelectromechanical system, which all of you come in the name of MEMS. Biology already has this kind of MEMS inbuilt in their system, so that's an inspiration for those who are working in the domain of MEMS or miniaturization or mesoscopic devices, it's a big inspiration, so that is the third thing we will be dealing with.

Apart from it, the whole world is so beautiful because of the beautiful flowers all over the place. And these beautiful flowers, there is something very amazing actually. They are the inspiration for dye sensitizes solar cells. Those of you heard ((Refer Time: 22:17)) of the name of grid cells, who has done pioneering work in the field of dye sensitizes solar cells. So what are those different should say different components of nature which contribute to developing a different kind of desensitize solar cells, because that is as I was telling on the previous slide that silicon is silicon technology is hitting the roof. So, we all are looking forward to the next generation. So desensitize solar cells is another one in that line. So different ruthenium dyes, different floral dyes, and all those things, which are derived from nature, basically which is an inspiration to develop the next generation of high-end dyes. So talking about the plant kingdom now.

Let us what I just narrated you, so plant kingdom. So within the plant kingdom, we will have A, we will be talking about photosynthesis. Then we will be talking about the mimosa pudica or touch me not or touch sensor. This is for light to electrical to food. Then you have Venus flytrap, which is basically a Bio-MEMS trap. And then will be talking about dye sensitize, so the flowers – flower dyeing or dye-sensitized solar cells. So the instruments here, there are multiple instruments, which are being used, which are fairly common' of course, you need electrometers, amplifiers. You need a whole lot of biochemical techniques to study photosynthesis and you need a high-end MEMS – microelectromechanical systems, and likewise several other instrumentations, which is needed. And among the advance application, in terms of photosynthesis, we are talking about artificial leaves, I am coming to this, what does it does that means.

So say for example, we talked about photosynthesis. Essentially what is happening, on the leaf surface light is falling, and this light energy ejects an electron, a photon is remaining absorbed, ejects an electron and this electron through the cascade of to the pathway along the chloroplast leads to the formation of glucose molecules, which is being consumed by our body. And of course, it goes for system one, for system two and the output of this is you are splitting a water molecule to oxygen as a byproduct, and you are evolving hydrogen. So there is two inspiration, the first inspiration is that making synthetic chlorophyll molecules, which could be used for trapping solar energy and ejecting an electron, that is one approach.

The second approach is that so coming back, let me the second approach is that whatever we get inspiration in terms of the manganese cluster for splitting water. So let me talk about at this line let me make one correction here, and this is one aspect of it, this is another aspect of it, which is water splitting. And this is all taking place within the domain of photosynthesis. And artificial leaf or we can add something else here also synthetic chlorophyll for solar energy. Artificial leaf for water splitting. So understanding photosynthesis and emanating photosynthesis could have a profound impact on our understanding of nature. And this is one of the most fundamental reactions of energy conservation, which is being followed by nature. So we will go in-depth in photosynthesis and we will talk about it, and from there we will move onto the water splitting cluster which is part of the photosynthetic machinery.

So, then we talked about mimosa pudica or the touch sensors. So these touch sensors, have been a study for almost the last hundred years, and some of the pioneering studies were done by Sir J. C Bose. – Jagadesh Chandra bose. And he made some very very pioneering contribution and we will talk about his contribution where he talked about with the plants have nervous system or not, as [FL] matter of fact in some of his fellow's tropical transactions he has kind of hinted upon the these are rudimentary nervous systems of plants, which could sense touch. And we will talk in-depth and what are the different devices which are being used, and what is the current status of the field, and which could be an inspiration for developing touch sensor for the future.

So we will talk about J. C Bose's contribution and talking about touch sensors. And while talking about the touch sensors, I wish to highlight one more point that he is among those very first people, Bose is among those first people who could show a functional semiconductor device in the form of galvanic. We'll talk about it a little bit more. So now coming back to the Venus flytrap ok, Venus flytrap is a kind of a device where which has an inbuilt touch sensor as well as a mechanical event. So, whenever insects come and sit there, it stimulates some part of the flower, and there is a hood that closes in like this. So in other words, these touch sensors coupled with a mechanical door, touch to the mechanical door, and this whole connection are could be a big inspiration feature for developing MEMS-based devices, and which is purely an electrical and mechanical phenomenon.

So we talking about clear touch coupled with mechanical action, this is what Venus flytrap will be starting. Then we will be talking about some of the contributions made by Professor Gratzell who among the pioneer in developing dye-sensitized solar cells or Gratzel cells which is commonly known. So we will be talking about some of those dye-sensitized solar cells and basically talking about some of the contributions of Professor Gratzell and his Gratzel cells one second sorry and will be talking about energy harvesting.

And in the previous slide, while I was talking previously to the previous slide where we are talking about inanimate objects of biological origin. I will have one more column which I have mentioned, so if this one is the first one, so we talk about this will the second one which is the world of insects. And we talk about the third one, plant kingdom.

So there are two more which are left actually, I have not talked to about the kingdom of an animal, which will be anywhere I will be talking in the next class. There will be one more section, which I will be introducing which is not very clearly highlighted in the course part is about some of the very primitive inorganic molecules, which has some amazing electrical characteristic which has a wide range of implication in biological process and we will talk about those. So I will close in here today, we will continue here with the same graphical scheme of things in the next class and then we will move onto different steps of the course.

Thanks a lot.