Bioelectricity

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Lecture – 1

Welcome to the NPTEL lecture series. So today, we are introducing a new course on Bioelectricity. So the course consists of forty lectures and the course has been divided into five different modules and each module is purely independent of each other. I will try to treat each module as a independent cluster, so that at one point which one module you want to really go through first, may help you, (( )) site very fundamental basics. The basic requirement what I kind of expect from this that up to your high school, you have gone through some of the very very basics of electricity, that the charges has been carried in different forms. It could be ionic charge; it could be flow of electrons. So the way, and this much fundamental understanding of Ohms law – V is equal to I R, any point of time voltage is equal to product of current and resistance. As long as these simple concept or concept of capacitor, what is the capacitor and what is an amplifier, there is good enough for you to you know appreciate this course.

What is the philosophy of this course? Today, what I will do, I will give you some basic idea about the philosophy of this course and then I will move onto the overall layout of this course. Why bioelectricity? There is electricity all over the place. So all of you are aware of that your, I am taking because sound energy is converted into electrical signals and electrical pulses. I am standing in this room, this completely lighted, because the source of electricity which is taken care of it. So, this is the origin of the electricity. Electricity is very much ((Refer Time: 02:14)) of the biological system. If you look all around you, say for example, think of the nerve impulses, those are nothing but electrical impulses, which are flowing in your body. The way your cardiac beat, cardiac cells beat, the way your heart beats that is nothing but flow of electrical impulses, which regulate the flow of blood all over your body.

The memory acquisition phenomena, it is an electrical phenomena. The moderactions, the propagation of nerve impulse, the way your muscles respond to some kind of a stretch, some kind of a strain, there is a translation of mechanical energy into electrical signals. Or say for example, in case of touch me not leaf, you touch the leaf, it folds. It is the electrical phenomena, it is a bioelectrical phenomena. Think of the situation of Venus

flytrap, which catches the insects. These are the plants, which catch the insects. So, basically the insects comes, touches on certain surfaces of the flower and the flower starts closing. It is another electrical phenomena. So they are some touch senses, which senses that impulse and translate that impulse into electrical signals and in result is the trap gets closed and the insects gets trapped inside that whole flower. And it is being finally digested and used for food. So these are the carnivorous plants.

Similarly, they are several in ((Refer Time: 04:21)) objects, which exhibit electrical phenomena something like back in a hornet nest, this is back in nineteen seventies, there was significant research which was done. It is in the hornet nest, it has been observed that hornet nest has a thermo regulatory property and that thermo regulation is driven by the hornet cell cap, which is presented. In other words, the hornet cap is a thermoelectric membrane, those of you from your basics high school if you remember something like Peltier effect, Seebeck effect, where which are thermoelectric. So you give thermal energy, it is translated into electrical energy or vice versa. If you give electrical energy to a material, it is converted into thermal energy. So these kind of thermoelectric materials are being seen across nature.

Apart from it, you will see the examples of fireflies… Or think of situation of photosynthesis, where solar energy is leading to the emission of an electron and that electron eventually, basically a photon is being absorbed and electron is being emitted and that electrons hops through inside the plant cells and leads to the generation of food, which is under photosynthesis. Photo means light, synthesis is a process by which bigger molecules are being synthesized. So all these phenomena what you look across nature are bioelectrical phenomena. And they have been exploited or they have been understood from different perspective. So, bioelectricity is a very very broad term first to start off with.

The whole body is governed by bioelectrical phenomena and understanding of this individual bioelectrical phenomena has profound implications in understanding our whole existence. So if you look the way it has progressed in last two centuries, I would say definitely one and half centuries, the progress in measurement of charges, electrical impulses leads to the development of the whole field of the bioelectricity. Look back at the time of Volta, look back at time of when the impulse were recorded from the frog's muscle, the twitch which was recorded. So these are long back Volta, galvanic – these

are some of the like ((Refer Time: 07:13)) or you can say the founder, father of the whole field of electricity.

So it is, it deeds back to that time, from the time actually I ((Refer Time: 07:24)) electricity was initially being very correctly observed in biological systems. It is long back. And then of course, the whole field of electrical engineering develop and parallely the progress of bioelectrical phenomena or understanding bioelectricity became a function of the different devices we have developed in the domain of electricity and electronics. Especially in the later ((Refer Time: 07:49)), in the last century, post nineteen fifties with a discovery of silicon based electronics, they are happened tremendous improvement in the development of amplifier circuits, or in the development of different electronics electrometer, which could major current on the equal nano ampere level with decent amount of accuracy. So if we look at one side is all these phenomena, which is taken place.

There is other side, where we are talking about all the different measurement techniques, because whenever we talk about biological systems essentially we are measuring currents of pico ampere, nano ampere, femto likewise very low currents, we are talking about. We are not talking about a grid where huge huge amount of currents are flowing through. We are talking about something which is a fairly look, in order to major such currents you need different kinds of devices. You cannot afford to use your regular multi meter to do those recordings. So you need very high impedance devices, which can measure those.

So if you look back since nineteen or from seventeen hundred, I would say, the field has take quantum jumps with the discovery of newer and newer measuring techniques. And currently with the advancement of amplifiers, high end amplifiers we are able to measure extremely low electrical potentials in all different forms of systems or different systems which are existing in nature. So a part of the course, will concentrate on all these different kinds of devices what will be dealing with. We will be dealing with any electrical phenomena has a direct link then this could be used for energy harvesting. So we will talk in detail of different energy harvesting modules which are being currently under in developments, specially you have to realize that more and more we are heading for sustainable energy. And our biggest hope is learning from biology, the sustainable root to harvest energy.

So we will be talking in depth about different modules like artificial leaf, how from the leaf there are people who are trying to emulate the photosynthetic power of the leaf to harvest energy, one of the topics which will be going to go through extensively. Apart from it will be talking about the examples where the different dyes, different color dyes of nature are being used like Hibiscus, are being used to develop dye sensitize solar cells. So, these are the molecules which are all across the nature. And they have a tendency to absorb light and eject a electron and that electron could be funneled and could be used for running any kind of low power electronics devices at this stage.

So we will be talking about those small dye sensitize solar cells, will be talking about back-back based systems, where mechanical energy is being translated into electrical energy which has been, it is in progress for a long time. Because those of you grandfather or you know great grandfather riding a bicycle which has a dynamo attached it. So basically while the bicycle they are riding, so the mechanical energy which is generated well the bicycle is moving. It is translated into electrical energy using the dynamo. And you could see that without any source of battery or anything, the light is glowing in the night. So if you look back and go online or ask your great grandfather or grandfather, they will tell on that is how they used to travel with a bicycle when in the evenings. When there is no street light or something like that. So there are several examples where electrical phenomena has been extensively used for harvesting energy.

Apart from it, we will be talking about man machine interface, where will be taking about how the, say for example a person is having a blindness. So basically that means the image plate or the retina of the individual is not functioning. Is there a way, we could implant and synthetic or electronic camera in front of the eyes so that the image which is formed in eyes could be interfaced with the brain. So we totally bypass the sensory mortality, because this has been successful in ((Refer Time: 13:31)) implant in the ears. So those are cannot hear, so they put the synthetic cochlear or bioelectronics cochlear or basically an electronic gajet, which could sense, in other words, you are a (( )) putting a mike out in your ear. In that mike is being connected to your brain, so what is your hearing is bypassing your ear, because your eardrum is, your eardrum and the cochlear structure is no more early fractural, so you bypass everything and you interface it with the brain, so that is possible another way. Or say for example, is there a way for spinal cord injury patient, we could implant some electronic devices with at this zone or at the

site of a injury which could help this person to you know get back some of the last degree of freedom in terms of movement, is it possible?

We will be talking about here some of this seminal experiments, which have been done by the people or scientist across the world, where could dictate among the using a computer or vice versa. So basically, in other words, how man is interacting with the machine, so that is another area which you would be highlighting. So this course encompasses a wide range of different topics, which has been put under five different headings. And the goal is to give a flavor of bioelectricity and inspire you to exploit this subject for the future, because future lies in all form of sustainable growth, sustainable development, sustainable energy, because we cannot rampantly misuse the natural resources for our goods. We have to very careful and critical, because you have seen places like Tukushema or you know places like Janoval a kind of nuclear disaster have taken place or several other places which are not really reported that.

So we need different other sources of energy and some of our hopes are lying in using biological system for energy harvesting, in the field of solar energy where we are pretty much heading the roof with the silicon based crystalline, silicon based electronics. Because, currently in the lab conditions, the maximum efficiency you could get it is around seventeen percent. And the cost recovery is the very challenging problem because the amount of intense investment, which is being done in developing silicon based electronic system, silicon manufacturing system is enormous, could be really you know by pass that could they have be newer and newer material. So we will talking about some of these newer and newer materials, which are there in the radar but needs lot more research from you people.

Apart from it, the another area, which people are trying to explore is the way biological system which is the byproduct of photosynthesis. How there is splitting water, because this is the way how hydrogen can be generated and eventually hydrogen could be used as the source of energy. So what are the different techniques by which water could be split, what are the different molecules which could be developed very cheap. So in case of biology, the leaves contains, something called a manganese cluster. It is the cluster of manganese which remain in different oxidation state and the water molecules get strapped, it is mean stripped off and you get the oxygen and as the byproduct and this

whole process people are trying to emulate using different kind of complexes which will emulate the manganese cluster.

So this is the wide range of bioelectrical phenomena and the other side is where people are developing the different kind of super capacitor, biological materials. We will be talking about this some of the most recent advances where people have developed super capacitors from biological systems. People are trying to develop bio batteries using different kind of sources. So these are, these all like whenever you pick up a textbook on this, there is hardly any textbooks, which exclusively deal with all these things. So it is very broad subject. So, this forty brief forty lectures is basically to give you a flavor of the broadness of the field and the beauty of this whole field, it is a standalone subject, and it is a very passionate subject, if you look at it. I mean there are so many things, what you can do, so many product which can develop so many fundamental studies which could be done, but it needs different kind of flavor to appreciate all these things.

So with this introduction what I will do, I will give you the outline of this, what are the different modules I am do, I have pretty much talked it out, but I have given you on systematic layout that how will be dealing with this different modules and what are the different things will be dealing with. So let me give you on overall outline of the different modules, and from there, we will talk about how we are going to deal with this individual modules.

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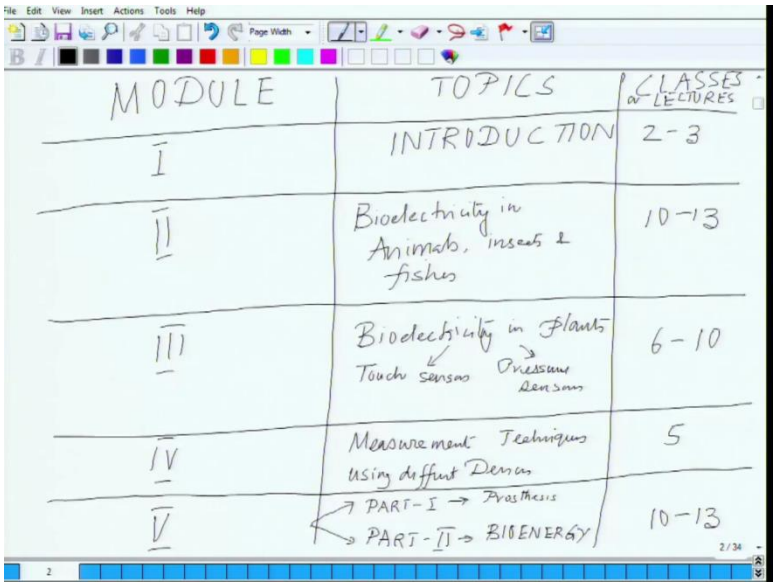

So welcome again, so the course title is Bioelectricity. So, I told you there are five different modules we are dealing with. So let me, the module and for the topics. What are the different topics we are dealing with. So module one that is essentially introduction to the subject, so coming to a module one, coming back to one, so here basically what we will do, in module one we will have three lectures, two or three lectures, you know this kind of flexible. I will introduce you with some of the different examples of nature, what is happening in diagrammatic manner. And based on what I am drawing now ok, and we will try to get a formal definition of bioelectricity and from there we will lay the course, how we are going to follow in the subject and section.

So coming back, so let me put another column here, which is classes or lectures. So there will be two to three lectures out here in a module one, which is the introduction. Module two will be dealing with bioelectricity in animals, insects and fishes; so pretty much all in animal kingdom. So here, I am keeping it very broad, we will talk about the, we will introduce ourselves with the membrane potential in the animal world. Then will talk about the nerve propagation, which is taking place in the animal world. After that will be talking about the action potentials, will talk about memory acquisition processes, then we will talk about the reflux circuits; will talk about vision, how the image is being formed. Then we will talk about the hearing, and mind it all this will again come back. So parallel what I will do, what are the cochlear implant and all these things I will include, both of them simultaneously. And will be talking about the different situations how spinal cord

injury situations could be you know could be bypassed. So this is all about the bioelectrical phenomena, so you will have a approximately ten to thirteen lectures devoted to this area.

And from here, we will move onto the bioelectricity in plants. So here we will talk about some of the plants like you know touch sensors or pressure sensors likewise; especially plants like mimosa pudica, touch me not and the insectivorous plants like you know those which traps the insects and will partly introduce you to the whole photosynthetic machinery here. How the photosynthesis taking place, how the electrical events within the plant leads to the generation of energy. So this is where we will be devoting around six to ten lectures.

So then from there, we will move onto module four. Module four is measurements of electrical impulse, measurement techniques using different devices. This is the section which will cover around approximately around five lectures. So in this section, we will be talking about electrometers, those of you remember during your school days may be standard seventh or eighth, we introduced to ((Refer Time: 25:12)) electrometer. If you remember, the charge wrap something, and you see the charge moment; so currently those old electrometers have become electronic devices, now it has translated into electronic kind of ion. They are very high end devices in terms of their measuring capacity, they can measure around you know nano ampere, pico ampere currents with highest vitality.

So will talk about the electrometers, will talk about the high gain amplifiers; will talk about patch clamp setup, where which are used for measuring the electrical impulses or the flow of current through a single channels. So in that context will talk about the single channel recording, will talk about the development of different fluorescent molecules, which could help to image electrical phenomena something like calcium imaging or there are molecule, which have been developed. And some really very intense research has been done in developing some of these fluorescent molecules, which changes their color with the change in the potential. So we will talk about some of those techniques. Apart from it, we will talk about the voltage clamp and current clamp under the patch clamp. And then we will talk about if time premise will talk about little bit about the electrochemical measurement techniques, which have in the bioelectrical process. So this is our module four.

So from here, we will move onto module five. Module five is a very interesting module, this module will take you from one end to the other end. This is the module where we will be talking about man-machine interface; we will talk about prosthetic retina in terms of putting a camera in front of the eyes and interfacing it with the brain. We will talk about cocklier implant, here we will talk about the different electronic gadgets, which are been used for deep brain stimulation and the idea of brain chip, idea of spinal cord chip, what is the current status of research. And here I will introduce you to some really very good materials and I will introduce you to some of the stalvods in this field whose work you can read and kind of get an idea about how the progresses I been made in this phenomenally beautiful area. And very very challenging area, because the very moment we talk about, so here I will highlight something.

The very moment we talk about man-machine interface; in other word, we are talking about, you have to engage an electrode inside your system. And electrode is a foreign material, so that needs intense understanding of material properties of the material, which you are introducing into the body and that is the whole field in its own authority. Because when we talk about like you know, you put a deep brain stimulator or electro ring inside your brain, it is a totally totally foreign material which is entering. How do you handle that it is not easy, it is not easy really even to think in that way like you know what a big deal. It is really challenging. And that is where lies the major challenge of prosthetic bioelectronics. The prosthetic area of bioelectronics where people are really at developing, so there is one there are groups which are developing newer and newer by compatible electrode materials, which could be put inside the body without much immune reaction. Because you have to realize that you cannot pull that electrode or gadget time to time, and you know clean up and put it back; it is there, and it has to be there for a vial, it is just like you putting a pacemaker.

It is the another area, which will be dealing with. A pacemaker out here, so ((Refer Time: 29:58)) the pacemaker does not have a immune reaction or something of that sort. So, these are the things will be talking about in this section part one of it.

So essentially, I can divide this into two parts; here is part one. This part one will be dealing with prosthesis mostly and in the most of the animal kingdom. I will be dealing the another part, so the part two will be dealing with, how energy could be harvested from the biological systems that falls under bio-energy and that is where will be talking

about as I was mentioning in the earlier half of the this lecture. In that, there will be talking about the dye sensitize solar cells, artificial leafs, bat back energies and deriving energy from inanimate objects. And in possible we will talk about the fire flies and will talk about other different dyes which are found all across nature, which has potential to be exploited for electronics applications. So that will be essentially our part two, where we will be talking about bio-energy. And this is the part which will be dealing in another ten to thirteen lectures.

So this is in as a summary I could say how the course will progress will talk about, I have partly introduce due to the subject. I will probably take one more class to introduce in depth of these different aspects, how you are going to move on. The whole graphical understanding of it that how the whole things are happening, then I will be moving onto the individual module and as I have told you already, you can study the individual module as standalone module, I will try to keep it as independent as possible, so that you do not need to follow as sequence really. If you know the introduction, and the broad outline of the course, you can pick up any of the module and do a complete in-depth study of it without any problem.

So apart from it, what I will request you people that in every class, I will try to give you some of the references which because of of course because of copy right reasons and everything, I cannot really handout like that, but you people can independently download them. I will give the link and will try to go through those ok that will be extremely essential. If you invest little bit of your time to go through them, so that will help you to understand some of these process and that is the reason why I am not even giving you some of these handout, because there are copyright ((Refer Time: 33:17)), and I don't want to do that.

So there will be a material, which I will be providing, I will be providing the link we will have to go online and search or download. If the link is function with you system and definitely you will be download some of these materials, which will be really helpful in this course. And just while concluding this first lecture, I will tell you just brush-up some of the basics of electricity that will help you to appreciate this course in greater detail. And you have to be bit more imaginative for this course, this is not really a information based course that. There are information I have you know transferring information to you, it is more of an imagination. This course needs bit of a, so high imaginative power

to think in a very global perspective that how things are going to change in next hundred years; thinks are in the phase of changing. It is just we are not seeing them, but thinks are changing across the world. So I will expect you to be slightly more imaginative you know visualize the changes what are coming on our way, so the way we see life, it is going to change in next hundred years – big time. So with this whole, different five modules of the course how you are going to progress so I will closing here, and we will come back with our second lecture, which is part of the introduction and there will be talking about the graphical layout of the course.

Thank you.