Bioelectricity

Prof. Mainak Das
Department of Biological Sciences and Bioengineering
Indian Institute of Technology, Kanpur

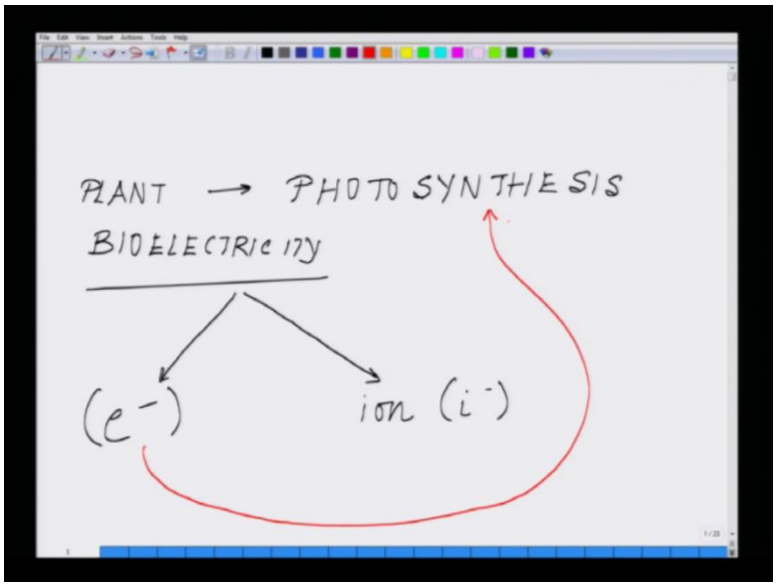
Lecture – 31

Welcome back to the lecture series on bioelectricity. So, we are in the section of plant bioelectricity. So, in the first class in the plant bioelectricity, we talked about the overall scheme of things, it just a brief recap hoping I have just talked in our previous lecture. So, what is being considered is in the whole life cycle or in the food chain is in the solar system, where we all live. Sun is the major form of energy, and this energy is being trapped on the floor of earth by the green plants. The green plants eventually synthesized food. So, these are ate by the herbivores, and the herbivores are being consumed by the carnivores, and carnivores dies and then again all the organic and inorganic matter gets into the soil, and again this whole process continues. So, this is basically the food chain.

From the food chain, we took a deviation telling that during 1970s the discovery of the hydrothermal events, deep under the sea, where there is no sun light is reaching kind of set another paradigm of life forms evolving where most of the bioelectrical phenomena which are taking place are independent of sun light that was one paradigms shift. And apart from it, in our previous class we talked about the anatomy of the plant, the grass anatomy, the leaves, the stem, the flowers. And in the flowers, we talked about will be talking about the dye sensitized solar cells and in terms of the cylum on flowing vessels once will be talking the plant movement with the mimosa and the Venus flytrap will be talking about those structure and their significance.

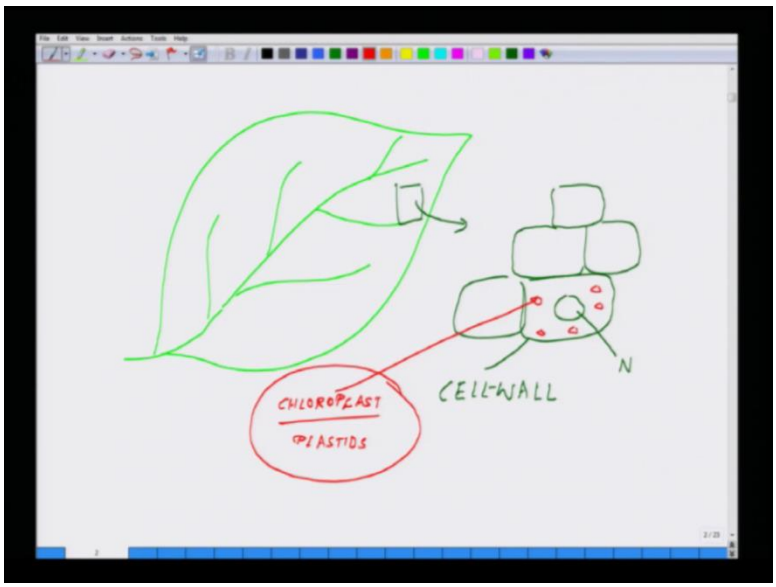
So, in this class, we will start with the basic photosynthetic machinery which is fairly conserved among all the green plants which has evolved on the floor of earth. Of course, they are certain plants, which follow a certain bit of a shortcut, but the overall scheme of things of electron transfer is fairly same. And the bigger molecule, which involved in the electron in trapping the sun light is chlorophyll. So, let us start where we left in the last class; now let us go to the microscopic details of a leaf or the green pigments or the structure, which is involved in trapping the solar energy.

(Refer Slide Time: 03:05)



So, let us resume the class photosynthesis. Let us get the whole complete basic of photosynthesis - another heading of plant bioelectricity. As we have already discussed some point that whenever we talk about electricity there could be two modes of transport of charges; either it could be through electrons or it could be through ions. These are the two major modes. In this situation, what will we are dealing with is essentially the electron transfers, and the electron transfer change across the membrane and which leads to the energy production eventually.

(Refer Slide Time: 04:12)



So, let us move on to the next slide where we will be talking about basic structure. So, in the last class, we talked about the basic structure of the leaf something like this. Now we will take basically what we will be dealing here is the primary event for synthesis which is taking place across the leaf. So, if you look at the leaf, there will be certainly on top of it there will be a slightly waxy coating and underneath is the epidermal layer, where basically all these machineries are there. So, all the biological structures are consist of cells. So, the plant cells and animal cells, there are some basic differences, the most fundamental difference is the plant cell have something called cell wall, where is the animal cells does not have it.

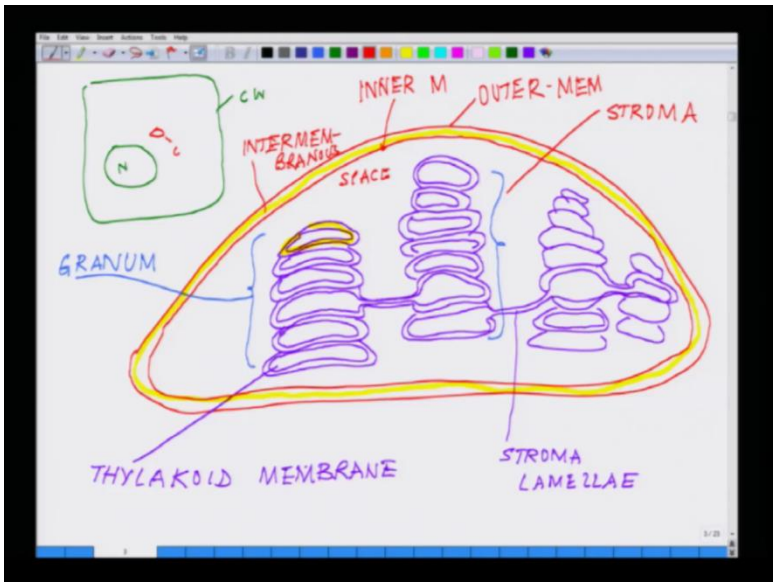
So apart from it, plant cells have a structures called plastids or chloroplast where all this light trapping machinery is being housed, whereas animal cell does not have the any such structure. So, these are the very gross difference between the plant and animal cells. So, if we look at this leaf. So, this leaf essentially consist of series of cells like this. These are the individual cells, if I take a cross section or something like that, so these cells have something called a cell wall; and inside the cell wall, you have the whole machinery of everything. So, the nucleus, this is the nucleus and then you have certain which I am putting in red, those small structures which are called your plastids or the structure, which are basically holding your light trapping machinery.

So what we will be doing now, so from the macro structure of the leaf now we are moving into the cellular structure. Within the cellular structure, now we are moving into the sub-cellular structure. And the sub-cellular structures, so there are I will just take a little backward here. How they have probably evolved, so one of the theories about this particular chloroplast like a structure is this that they were probably at some point of time on the floor of or these were independent microbial specie and some over rather have parasitized on some of these plant like a structures, and they became part of it. The reason why it is hypothesizes likes this is this small chloroplast structure what you see they contain their independent DNA, and where is the other cell itself has it is another set of DNA which ensures that it divides.

So, essentially what we are talking about is that within a individual cell the nucleus has its own DNA and the chloroplast has its own DNA. So, that set people thinking and the current acceptable, mostly acceptable hypothesizes is this that at some point or other those microbes parasitize the plants and become part of it somewhere or other. So, now

the question arises, so how the plants where deriving food before that if that is the situation. So, the answer is we really do not know I mean what was really the I mean how the whole food chain was functioning at that point of time if we really think in that way. They were parasitized and then the plants then acquire the ability to you know synthesize food, so but leaving that debate a side, let us try to exploit this structure of the chloroplast now in what made this structure so very special that it can trap the sun light.

(Refer Slide Time: 09:11)



So, now the next slide what I will be doing is that I will be getting the cross section of this structure how it looks like. So, this is where structure, so this is the nucleus with N, this is cell wall and this is the chloroplast. The chloroplast structure essentially is something like this; it is a double membrane structure like this, so they are. So this is how the structure apparently look like in a regular microscope. So, inside this, what you will observe is something like a very interesting membranous network like this. Many of them out here, and these are connected with each other at different level like this.

I would just highlight all the names and everything. These may be connected to another set of structures like this at multiple levels these are connected. I am just simplifying the diagram. So, this kind of structure what I have just now drawn is basically called thylakoid membrane and this thylakoid membranes are also double structured. So, one of the beauty of most of these structures are these are all you know double membranous structure something like this. So, this is how the structure looks like, and there are empty

spaces what you people are seeing in this picture is empty spaces essentially called the stromal space, something like this ok.

So, this is your stromal space, and this structure is called thylakoid membranous structure, and this connecting link are called stroma lamellae, and this whole pile what you see this piled up structure like this, this is called granum. So, this is the outer membrane of the chloroplast, and this is the inner membrane of chloroplast; outer membrane, inner membrane, the granum, the stroma, stroma is the space - the blank space out there, then you have inter membranous space in between. So, this is the what I am drawing now is a inter membranous space and always there is one very interesting thing in all this structure, there are lot of inter membranous space between all these membranes. These are the inter membranous space. So, this is the inter membranous space.

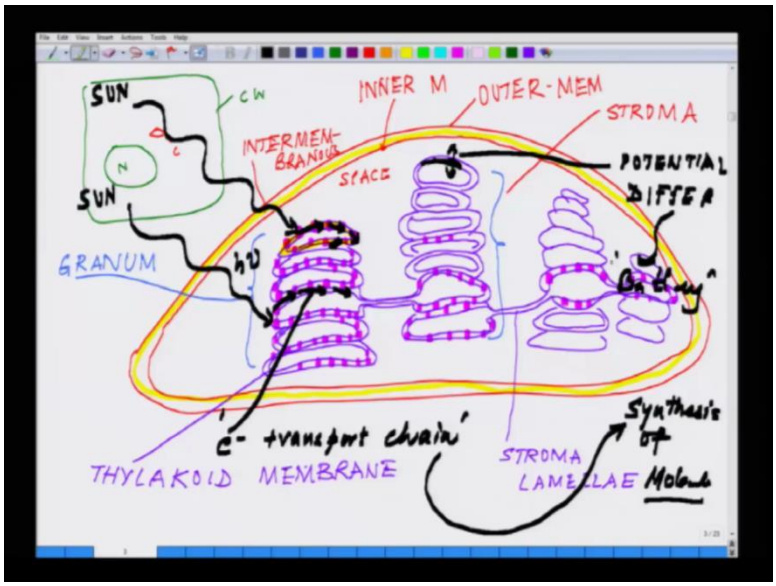
So, this is essentially the whole structure of the chloroplast, which is involved in trapping the cell like. Now the question arises where exactly is trapping the cell like, this is very important. So, I have drawn the gross geometry. So, as of now what we have done I am going very slowly because you have to understand this structure otherwise things will become kind of you know confusing. So, we talked about the whole structure of the leaf then we moved onto the structure of the individual cells. We talked about the different organ cell wall, chloroplast, nucleus and we highlighted the fact that this chloroplast structure, it is also called plastid actually - synonymous. So, they have their own set of genome or DNA in them. Then from there we moved onto the molecular architecture of the chloroplast, and now we will be getting into the exact chemical architecture, where all these different molecules sun trapping molecules which are sitting.

So, one thing you all has to remember in this kind of structures, most of these membranes or all these membranes are a symmetric that is why I continuously highlighting which one is the outer membrane which is the inner membrane. Essentially whenever I am talking about that they are a symmetric, it means the property of the membrane is suppose this is the membrane this my hand is a membrane. So, this side has a different texture as compared to this side. So, just imagine, if this is the membrane, the property of this side is different from this side that is what we meant by a symmetry of a membrane. There are certain molecules, which could bind here; there are certain

molecules, which cannot bind here. The electron transport may takes place from one direction whereas some molecule may be synthesized on the other direction.

So, slightly highlighting this structure what I have drawn for you the stroma. This stromal what you see the vacant space spot that is not really a vacant spot. There are lot of molecules which are present there which are involved in synthesis of energy rich molecule and carbohydrates and all other things. So, basically, the empty space what you see is rich in organic molecules, which will help for a synthesis of wide range of molecule and they are coupled with several other structures within this micro architecture of the chloroplast.

(Refer Slide Time: 17:42)

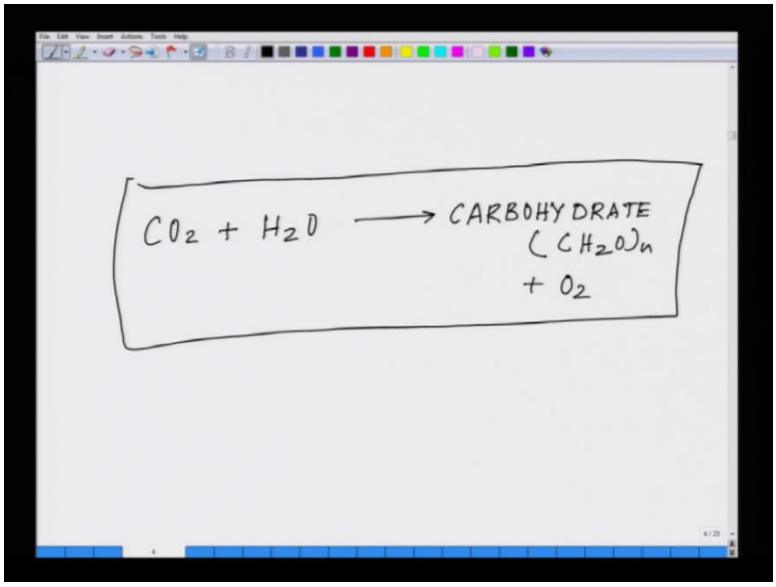


So, now coming back that where these molecules are sitting, so most of these molecules which are taking part in the photosynthetic events they are all sitting somewhere like this. So, they are kind of sitting like this out here. See, I am drawing those pink color dots. So, these are imagine, these are series of different molecules, which involved in electron transfer, and they are all membrane bound. So, they are all membrane bound, there structure really integrity is maintained when they are in the membrane. As soon as we take them out from the membrane, they are structurally integrity will be lost and that is why they are so many challenging to crystallize and their understanding their exact structural details. So, this is where all these molecules are sitting and will be talking

about these individual molecule one by one as we will be highlighting the whole process of electron transfer along this group.

So, for a layman understanding what exactly is happening is overall thing is this is. I will use the black and mark. So, light falls out here like this, and through a series of oxidation reduction reaction, the electrons flows along this. If you follow my arrow or something say for example like this let us do it. And in that process of electron flow, so this is h nu or this is sun. So, this is where the electron transport chain is moving. This electron transport chain eventually leading to synthesis of molecules, essentially what is happening here this electron transport chain out there is creating a potential difference across that a symmetric membrane. So, across this membrane what you see out here, there is a potential difference. It almost functions like a battery or something like a device which can you know generate sufficient energy to synthesize molecules.

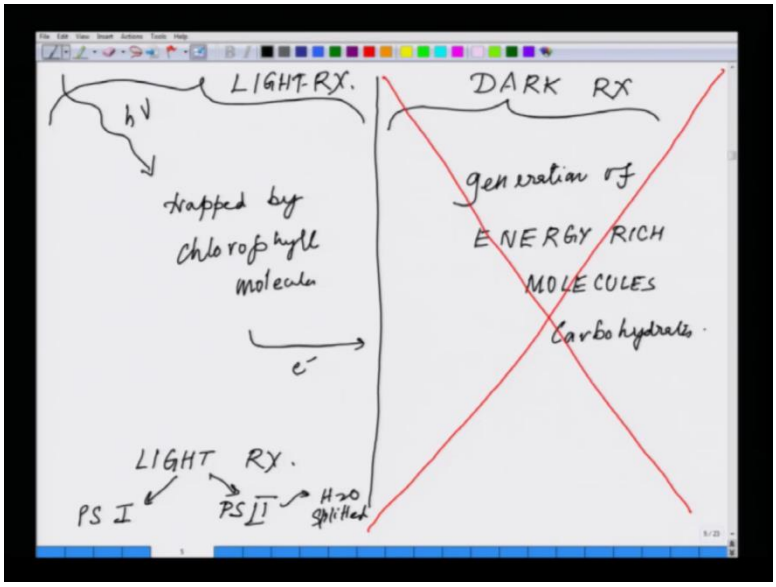
(Refer Slide Time: 20:48)



So, now, we have to go one by one to figure out the molecules which are involved in this game, before we do that let us revisit the basic reaction of photosynthesis. So, which is essentially your C O 2 plus H 2 O forming carbohydrate plus oxygen. So, which is essentially what you are talking about is C H 2 O whole n. So, your raw material is carbon dioxide and water, which is abundant; water is very abundant and carbon dioxide is also very abundant, and your output is carbohydrate - a glucose. The major source of energy and oxygen, which ensures that we all breath.

The first challenging question in this equation, which haunted for a while was who is supplying the oxygen is it the carbon dioxide or is it the water? It was found out that it is the water, which contributes in the generation of oxygen, and that discovery helps us to figure out that photosynthesis could be divided into two stages - one stage where water is getting split, the other stage is where energy rich molecules are synthesize through a process. So, broadly speaking the whole photosynthesis event could be classified into two parts - one part is purely electron transfer.

(Refer Slide Time: 22:55)

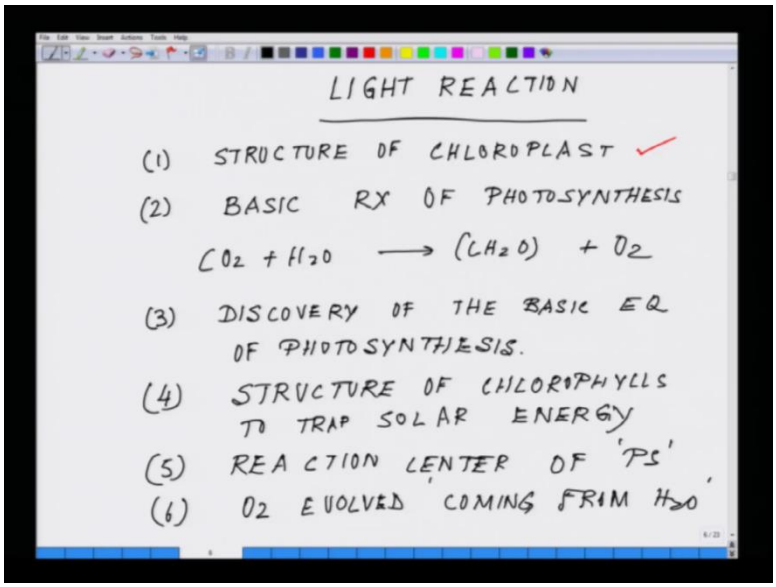


So, let us find put it like this. The sun rays are falling, ray been trapped by will be talking about the details of this structure, chlorophyll molecules, and this leads to a series of electron motion, this whole process falls under light reaction. And within light reaction are existence for the reaction, there are two stages one is called photo system one PS 1 other one is called PS 2, and in the PS 2 where water is getting splitted, and this whole electron transfer leading to generation of energy rich molecules, which is essentially the carbohydrates.

This part falls under something called dark reaction is not dependent on sunlight as said. This part falls under light reaction, which is essentially dependent on sunlight. There is no sunlight the light reaction would not proceed any further. So, under the broad umbrella for synthesis you have light reaction and dark reaction. So, in this course, we are not dealing with the dark reaction. I will just give you one example of dark reaction

just in terms of the C 3 and C 4 plants about their efficiency and why some plants are efficient and some plants or not in terms of photosynthetic output. But I will be what we will be doing we will be mostly talking about will be talking about the light reaction.

(Refer Slide Time: 25:17)



So, within a light reaction, let us enumerate what all we are going to cover. The first thing we have already covered is light reaction. The first thing is structure of chloroplast, which we have already dealt with this particular. The second thing will be dealing with basic history of photosynthesis or rather first of all the basic reaction of photosynthesis which we have already kind of highlighted C O 2 plus H 2 O forming C H 2 O plus oxygen. Now third thing will be dealing with the discovery of the basic equation of photosynthesis. All the reactions we led to the point where we are now, and that will take you from the point of lavisour all the way up to the 19th century when photo systems where been discovered.

So, next thing what we will be dealing with is the structure of chlorophyll and how they trap energy. Structure chlorophylls to trap solar energy, and followed by that we will be talking about the very interesting unsolved concept called reaction center of just putting P S for photosynthesis, reaction center of photosynthesis. And sixth will be dealing this phase will be oxygen evolved coming from water. This is the next thing what we are going to deal with how the oxygen is coming. After this once we gone this part in this,

we will be talking about the actual physical electron transfer how the electron transfer is taking place.

So, essentially next two to three classes that is what we are going to deal with and before I moving to that I will be taking two classes where I will be dealing with how you the very basic concept of your reduction potential. Because this reduction potential concept will be very essential for you to understand, how the electron transport is taking place. So, we have done with the structure of the chloroplast, we are done with the basic reaction of it. Next what we will be doing in your next lecture will be the discovery of the basic equation of photosynthesis and the structure of the chlorophyll which are there to trap the sun light. So, we will closing here; in the next class, will resume these two.

Thank you.