Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title

Bioenergy

Lecture – 07

Basics of Mechanism of Light Reaction

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Welcome back to the lecture series in bio energy, so the first terminology which I am introducing here is photo system 1, photo system 1 or 2 system to and which is out here a colony of there is another colony of chlorophyll molecules which is sitting out here, which is called photo system 1 okay? what exactly happens is in both the cases the light falls both in photo system 1 as well as for the system 2, now in both the places electron is being ejected out, here also here also okay, now the electron which is generated in photo system 1 is involved in generates a reducing power because it's an electron, so it can reduce, generates reducing power in the form of NADPH in the form of NADPH okay.

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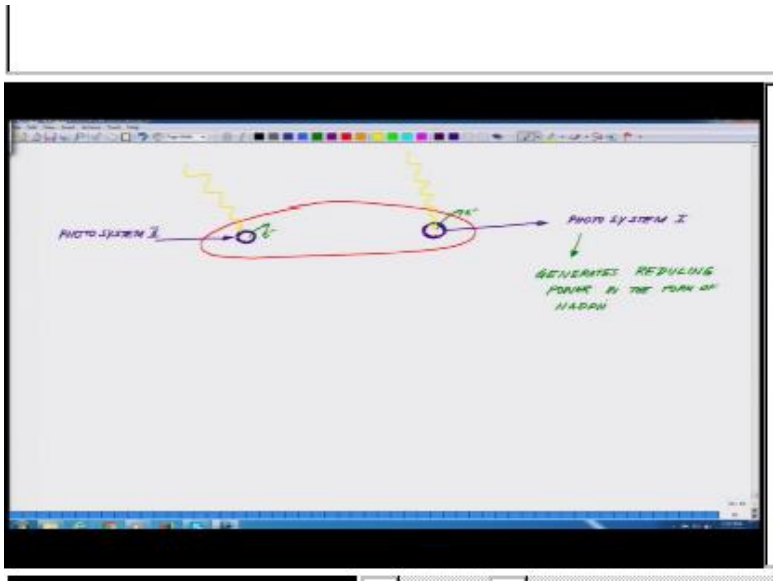

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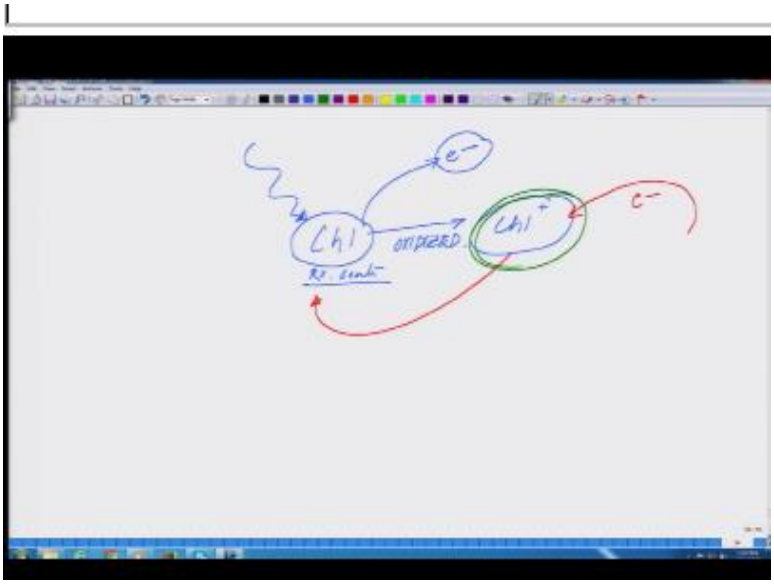

Now having said this so now for system one has rejected an electron because of the light so, it means there is a chlorophyll molecule which is oxidized so that has to be brought back to the ground state just follow my previous slide I showed you one second, here this has to be brought back to its ground state. So just now getting back to the slide so, here the electron which is ejected this has to be brought back, the electron for the photo system 1 is varied from photo system 2 through a series of mechanism which will be coming later.

So there is a electron transport which takes place along the membrane which we call as a thylakoid membrane, now I'm drawing the membrane out here where same time well light has fall on both for system one and system two the electrons have been ejected from the chlorophyll molecule in photo system 1 as well as photo system 2. The electron which is rejected from the photo system one helps in forming the reducing power of NADPH, what you have talked about if you will see the slide generates the reducing power in the form of NADPH.

So at this stage 1 chlorophyll molecule or a population of chlorophyll molecule present at photo system one needs to be reduced or brought back to their ground state, because they are all oxidized so, these electrons which are ejected at for system one say, for example these chlorophyll molecule CHL + CHL which are devoid of, are being brought down to their ground state why the electrons supplied from photo system 2 okay, so these are the electron traveling from photo system 2.

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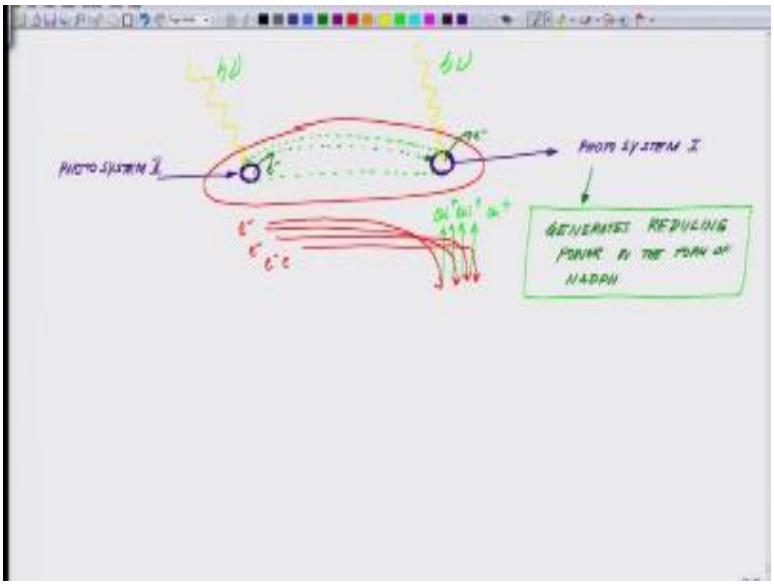

Now there is another situation, if the electron has been supplied by photo system 2, so all the chlorophyll molecules which are present now think of it think of the situation out here there are

series of chlorophyll molecule which are now at a higher state, we all have lost electrons and they are all again they are also oxidized, now who is going to bring them back into their ground state. This nature does with an amazing efficiency and which is a challenge for mankind to understand just underneath photo system 2, now I am just highlighting that zone see I'm highlighting a zone you see this, this is where there is a nano or atomic machine sitting there which is called manganese cluster.

This nano machine or atomic machines takes up the water molecule and it just drips out the water molecules and becomes a perennial source of electron and as a byproduct it gives out oxygen, making sense so this is that electron or the family of electron which is coming by ejected out by the water splitting are the ones which brings the chlorophyll molecule of photo system to to their ground state. So this is how so this is ps2 and here you have ps1 okay, so you see the whole thing is nothing but oxidation and reduction, oxidation and reduction but end of the day you need one perennial electron donor in this case that electron donor is nothing but water which is abundant on the floor of earth.

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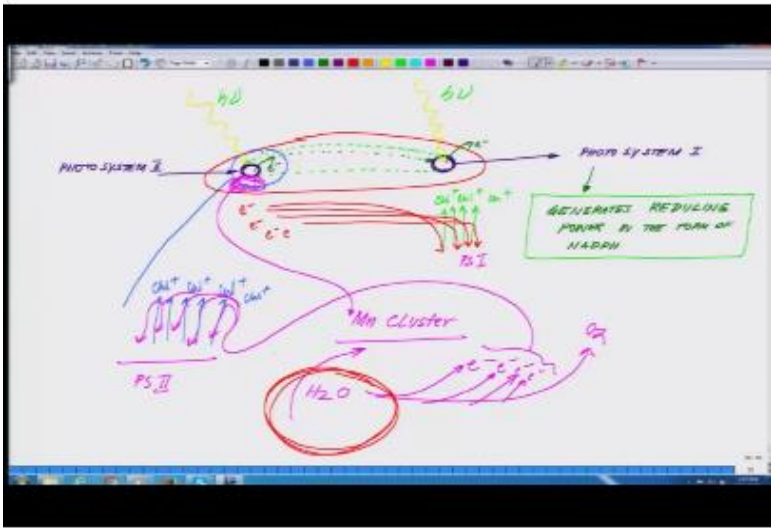

And in that process it generates hydrogen, so there are a lot of research and we will talk about this manganese cluster we will in-depth about it, there are a lot of research which are going on in the field of inorganic chemistry where they are people who are trying to emulate the manganese cluster. If you could emulate the manganese cluster and get spit water then we can generate hydrogen and this hydrogen could be the source of infinite energy, but as of now we haven't been really successful to match the efficiency with which nature is continuously breaking a hydro; water into oxygen and being the Fountain head of electron.

So this is that unique zone underneath photo system 2, but then is this electron transfer which is happening from photo system 2 to photo system 1, what I have drawn out here if you follow this thing like I'm just putting it in the paint now this is this a straightforward process actually, it is not as straightforward process this electron which is generated out here is, so there are series of proteins which are present out there which are taking part in a phenomena called electron transport chain.

So electron transport chain, so this electron transport chain for those of you have read about mitochondria and biology as we knowing this similar electron transport chains are being seen in mitochondria too only difference between chloroplasts and mitochondria is that the source of the high potential electron in the case of mitochondria, the high potential electron source is the burning of the fuels and in the case of photosynthesis which takes place in chloroplast, the high energy electron source is the photo excitation of the chlorophyll molecule, this is the most fundamental difference between the that high energy electron which is generated in chloroplast as well as in mitochondria, okay.

Coming back another electron transport chain, so in the electron transport chain the first molecule which takes place and we'll talk in later in depth about all of the is the Queen own molecule there is something called a queue and just represented by Q so, what is happening is that these electron these proteins which, are present in the electron transport chain or which are facilitating the electron transport are standing at different reduction potential, we'll come later into that what does that mean a different reduction potential, different.

So what is happening is like a staircase so it is sitting here, it is accepting an electron getting reduced then throwing the electron to the next one, now this one is getting reduced showing the electron to the next one, and again coming back to the ground state this one is getting reduced, showing the electrons so, it's something like though I have drawn these protein like this but they are actually sitting, something like this or something like this in a staircase model and during this phase this process.

If you talk about the speed by which electron is getting transported in biological membranes that speed is very less as compared to the electron transport in a conductors what we talked about, but this slow transfer has its own slip site this stepwise transferred through the different proteins which are present along the electron transport chain helps the membrane to maintain a proton motive force across it will come later into that, how that proton motive force is generated so, what you see out here coming back to the slide across this membrane what you see is something called a proton gradient.

And this proton gradient is critical in generation of ATP or adenosine triphosphate the other molecules so, you have talked about one molecule which is NADPH the other molecule what we talked about is called the ATP. So let's summarize photo system 1, photo system 2 the two colonies of chlorophyll molecules present on the thylakoid membrane, okay. Now the light falls on both of them, photo system 1 and photo system 2 not only are in a space they are sitting at different location these two colonies, they are sitting at a different reduction potential, will come later into that.

So in other words their power or their energy to eject electron is different so not only they are located different position of the thylakoid membrane, the power with which the throws an electron out is different the reduction potentials are different. Now when for system one throws out one electron it helps in reducing creating the reducing force of NADPH which further, will come to that what is the use of that, whereas those photo system 1 electrons or chlorophyll which are devoid of electrons are in oxidized state, so they have to be brought back to their ground ground state we are being brought back to their ground state by supplying the electrons or transferring the electrons from photo system 2 to photo system.

But while doing this process of transferring the electrons from photo system 2 to photo system 1 it, follows a casket from one electron transport protein to another to the third one to the fourth one, likewise when and so forth the reason for following such a slow transport processes that during that process it generates a proton gradient across the thylakoid membrane and that proton gradient generates sufficient energy which is essential for synthesizing what we talked about here in the slide is the ATP molecule which is adenosine, adenosine triphosphate.

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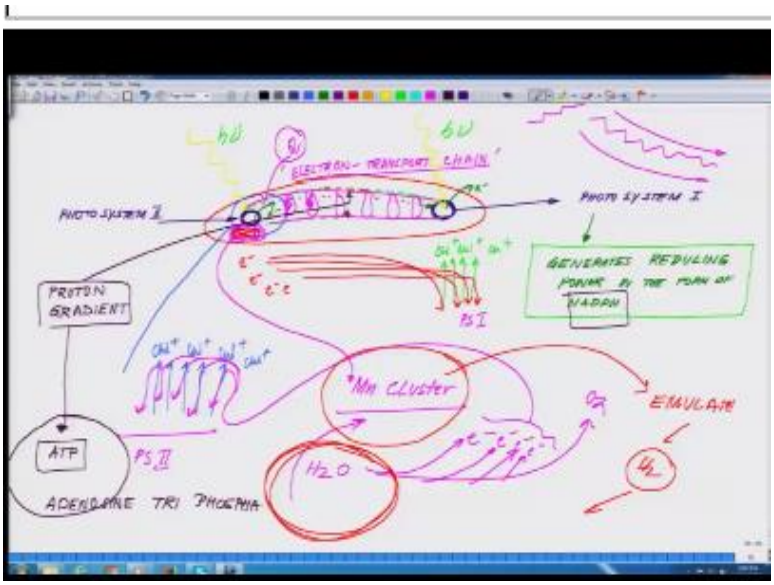

The major currency for all the cells to function adenosine triphosphate (ATP),AMP and ATP okay, so now what this any NADPH is doing so, there is two there are two more terminologies which I wish to introduce in this roadmap, so the roadmap is by far it's clear to you guys? So you have photo system 1 you have photo system 2 and you have something called a network or protein wearing, using different protein sitting at different reduction potential and underneath for system to you have what we call as the manganese cluster or water splitting clusters which is the perennial source of electron.

Now we will add two more terminologies before we wind up the whole Road map okay, so this reaction could be divided also into two parts one is called light reaction or light dependent reaction and the other part is called dark reaction. What is the difference between the two? So if you recall the first reaction what we talked about, we talked about co_2 + h_2o forming ch_2o + oxygen right, now this conversion of co_2 or this reduction reaction what is happening between from co_2 to ch_2o or to the carbo hydrates, this is what we termed as and this for this this you need our series of electrons to take care of this in the form of the reduction potential.

That reduction potential is supplied by what we talked about the NADPH and the reaction in which this whole thing takes place is called dark reaction or calvin cycle okay, so the calvin cycle is essentially so, if basically what is happening is that co_2 is getting converted into will come in depth of all these things later just address a stage have an idea of phosphoglycerate and all these things are happening within that organelle what we talked about as the chloroplast, so within the chloroplast there are we will talk about this structure see of this thylacoid membrane but essentially this kind of reaction the dark reaction is taking place outside it which is also called the Struma of the chloroplast.

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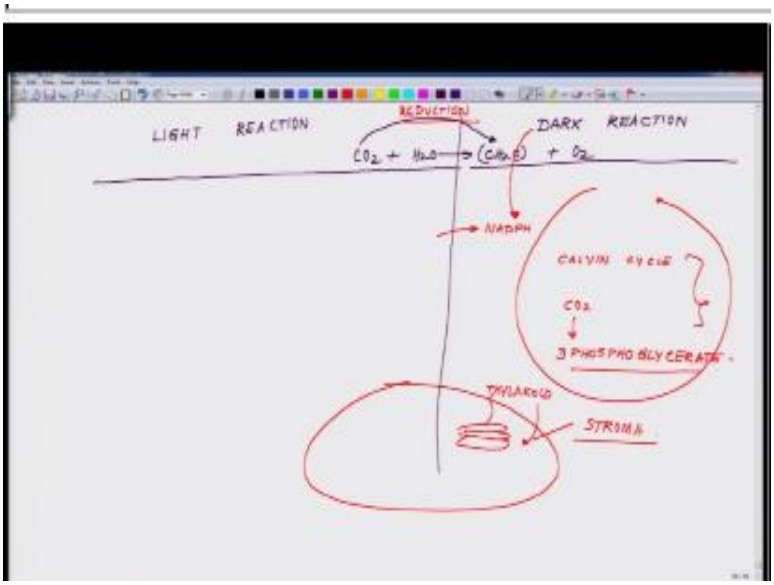

On the Struma of the chloroplast this set of reactions takes place, whereas the light reaction what you are observing is happening here where you have photo system 2, photo system 1 which is generating an electron this electron is the driving force for formation of NADPH and whereas through electron transport chain, electron is traveling from photo system 2 to photo system 1 to bring back the photo system 1 to it from, here to its ground state. Similarly for photo system 2 once it goes up it is being brought back push down state by the water splitting clusters.

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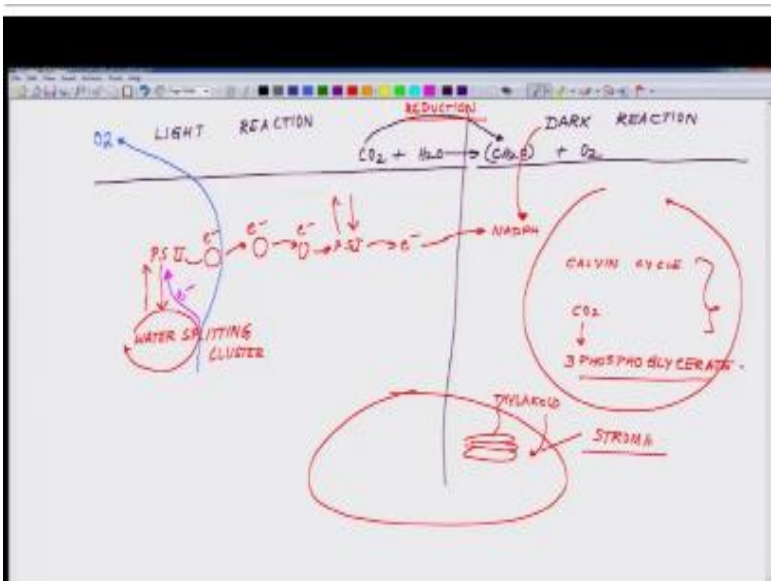

So out here what you are seeing is this is what is leading to the generation of oxygen and second thing what is coming out of this is the electrons okay, so if we have to summarize what all new terminologies today we in the roadmap we talked about, we talked about photo system 1, now I'm circling all of them we talked about photo system 2, we talked about water splitting cluster, we talked about this part which is generation of ATP because of proton motive force across that membrane, so if you remember in the beginning I was telling this if you just go back to the very first slide.

At such reaction center the energy of the excited electron is converted into a separation of charge in a sense light energy used to create a reducing potential, so that's exactly what is happening

proton motive force which leads to the generation of ATP of course, the part of a calvin cycle essentially out here and on the other side this NADPH which is formed is running the calvin cycle and this is where we talked about the whole biomass formation. So if you kind of drag your imagination a little further you will realize the efficiency with which light is being trapped by the chlorophyll pigment present in the chloroplast will decide how efficient the reaction will take this.

Apart from it mind it this is not one standalone phenomena happening, happening in the chloroplast so, whenever such thing happens there are other things which are also happening say, for example well the biomass formation is taking place if there is an energy molecule synthesis, similarly there is another thing which is happening which is energy molecule consumption. So energy molecule consumption which is also a process called respiration, okay it well plant or any other life-form is using this process to you know generate energy for its livelihood, apart from it and this energy molecule synthesis which is a light dependent process unless otherwise we are talking about hydrothermal vent this leads to whole sort of photo damage.

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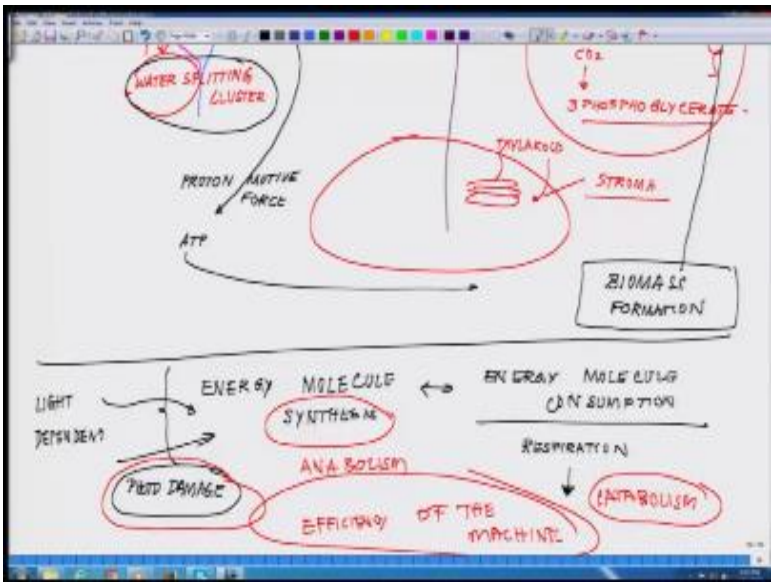

So it's always a very trade-off of three words synthesis or anabolism or making something respiration or a process of catabolism, breaking of the molecule and the efficiency of the machinery; efficiency of machine and why this is so important that efficiency of the machine has to be kept in mind, because of the simple reason that the any of the atomic or molecular machine has a finite life, if there is excess damage then definitely it's like we shorten and if there is too much solar radiation it is continuously exposed to there will be more damage.

So how we balanced it out and based on that in the latter half of this section we will talk about c3 c4 plants and how they vary, so what you overall see the biomass production, now if I had to pull everything together what we have talked about, the biomass production process which is governed by the process of photosynthesis and photosynthesis in itself is divided into light reaction and doubt reaction. Dark reaction is the process where the biomass formation takes place and the light reaction is the array of reactions which leads to the electron transfer through electron transport chains in the chloroplast by creating at proton motive force which eventually makes it happen the whole process of biomass formation.

So with this brief overview we will kind of moved on to this pretty much covered, our first two lectures what we talked about in this section and the next two lectures what we will be talking about is the whole process of how each one of these steps were discovered say, for example whenever we if you see this reaction out there on the slide out here if you see this reaction which is placed, so how we discovered that we will talk about chloroplast, structure of the chloroplast next segment is our chloroplast structure a, then we will talk about the basic discoveries which leads to our understanding of then we will talk about reaction center and the discoveries which leads to the discovery of reaction centers.

Then we'll talk about photo system 1, photo system 2 and in between rules we have few points here and there then we will talk about manganese cluster or water splitting, so each one of these segments what we'll be dealing with and then from there we will talk about this biomass formation in terms of c3 c4 plants and evolving technologies after that we'll talk about evolving technologies for increasing chlorophyll and photosynthesis rate and of course, eventually we will talk about maybe another section we'll talk about the research towards artificial leaves.

So in summary if you look at it it's basically the process of trapping sunlight and convert it into energy-rich molecules, so I will close in here with this and we will take up each part of it in our subsequent lecture. Thank you

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