Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning(NPTEL)

Course Title
Bioenergy

Lecture -10
Hill Reaction

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Welcome back to the lecture series on bio energy so we are in the module two let us get back to the slide.

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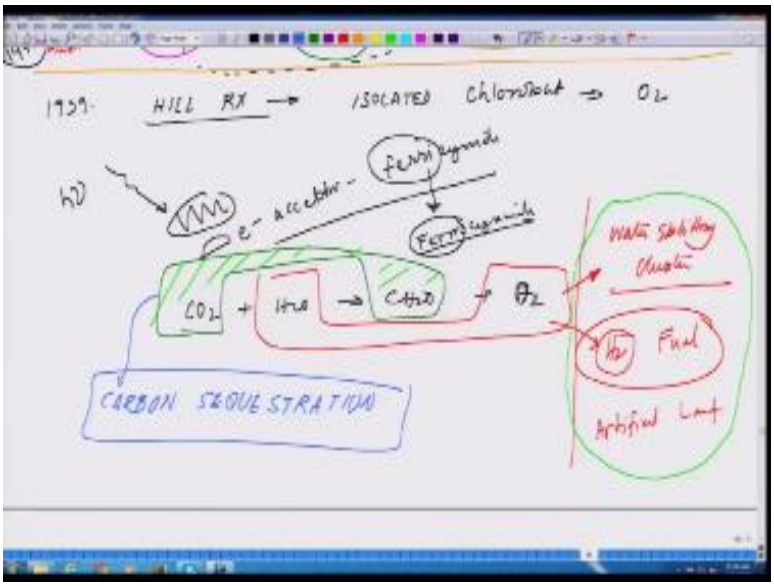

A concept called Hill reaction so what real reaction is all about so this was in 1939 so while this reactions were clear up in 1941 and1950s 1939 Robert Hill discovered that isolated chloroplast so he could manage to isolate the chloroplast isolated chloroplast led to the evolution of oxygen

okay so what he did so what he observed is that when he took an isolated chloroplast like this and illuminated you read light okay in the presence of and what did they he has a suitable electron acceptor in the form of Ferrocyanide and what he found out that Ferrocyanide is reduced to Ferrocyanide Ferro and this is fairy okay.

So there are three points what we detected out they dissected for synthesis by showing that oxygen evolution can occur without reduction of co2 in other words in other word what is important here CO_2+ H_2O CH_2O + H_2 oh sorry plus oxygen this reaction what you see here is independent of the other reaction does it make sense so it means this H_2O to oxygen evolution is totally independent as compared to the reaction of CO_2 forming CH_2 this was one of the landmark thing and that why it is so significant for us to understand is that this one reaction leads to the whole area of in organic chemist who are what pretty much dedicated all their life many of them on developing water splitting cluster.

They are developing different kind of water splitting clusters where they are trying to generate hydrogen as fuel and we will talk later about this some of the works which are done in India as well as abroad by different people on artificial leaves whereas the other fragment so we get back to the slight if you look at it so this is the area where tremendous amount of work is happening across the world in terms of developing what we call as artificial less and some of the landmark discovery is were done in India as well as on a broad and we will highlight about all those things you can those of you are very keen you can go through the website of Daniel Nocera in MIT.

He has done some very seminal work in that area where is the other side which is so if you see the sketch in this part of the reaction this is what falls under another emerging area of carbon sequestration so you see a simple reaction which is happening in nature which is deceptively simple reaction as I am telling you from the beginning opens up some of the most invested areas of research in the modern science.

How to sequester carbon thumb rule has been already shown by nature we are converting carbon dioxide it into carbohydrates whereas the other reaction which is actually supporting this reaction

in unison where the water is getting split and evolving oxygen as a by-product and generating electrons which supports the other reaction of reduction of CO_2 to carbohydrate.

So they are all interlinked and that is one of the reason why a basic fundamental understanding of photosynthesis is critical for understanding the biomass technology now talking about the hill reaction where we started this let us explore a little bit further about hill reaction what are the other areas aspects which will reaction talked about.

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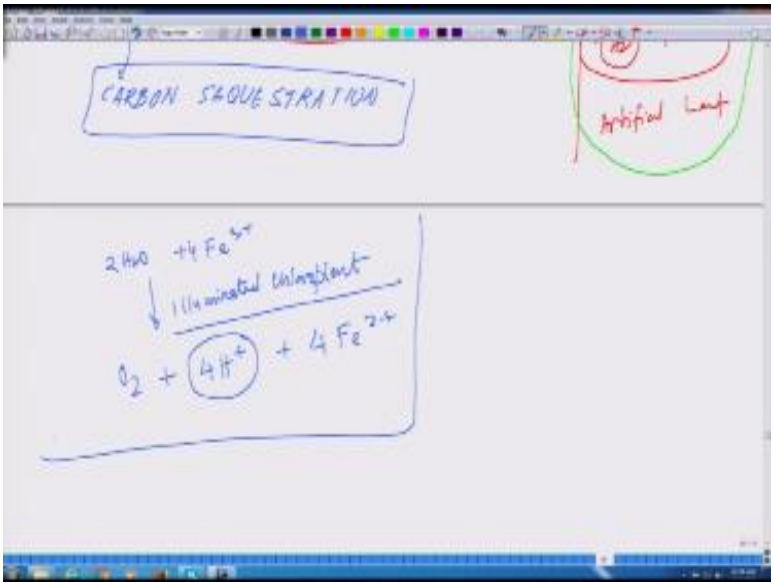

so this is the basic reaction what hill showed us to H_20 + this is where the Ferrocyanide to Ferrocyanide reaction club in the illuminated chloroplast leading to oxygen + 4H + which is the protons + 4 Fe 2+ so here is that reduction reaction what is happening what was shown by health.

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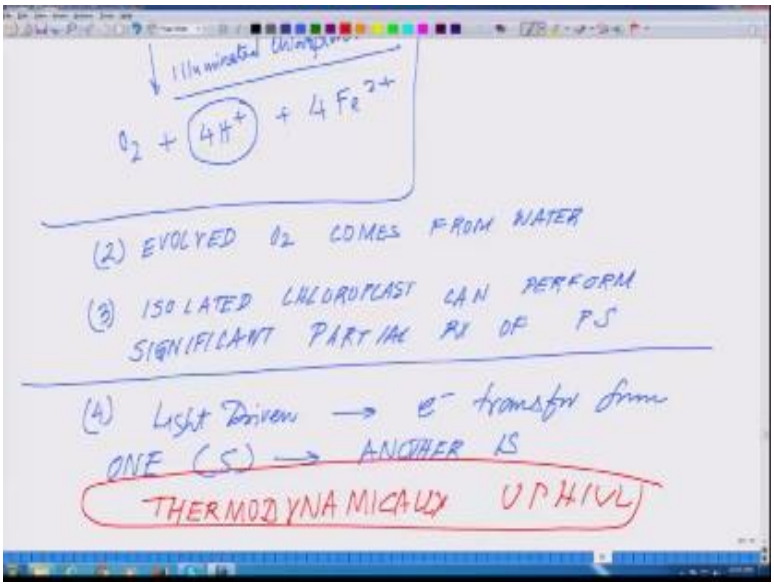

The second aspect this reaction hill reaction confirmed was the Evolved oxygen we have already talked about evolved oxygen comes from water not from carbon dioxide okay third aspect which was shown by a reaction is that isolated chloroplast isolated chloroplast can perform significant partial reaction of photosynthesis partial reaction of I am just showing photosynthesis PS okay and the fourth and most critical point which will be critical for us to look now it revealed that the primary event in photosynthesis is light driven and the transfer of electron transfer from one substrate to another s stands for substrate is thermo dynamically uphill and this is something the gains the gradient.

So it means the electron transfer is happening not down the gradient all the time it happens up the gradient so that needs a lot of energy it is almost like you are pulling a bucket of water all the way uphill that essentially what does that mean a thermodynamic thermodynamically uphill phenomena where you have to invest energy you know to raise the bucket or raise the electron to a higher energy State okay so this is what is very v critical about this whole process of photosynthesis which was very nicely summarized by the hill reaction.

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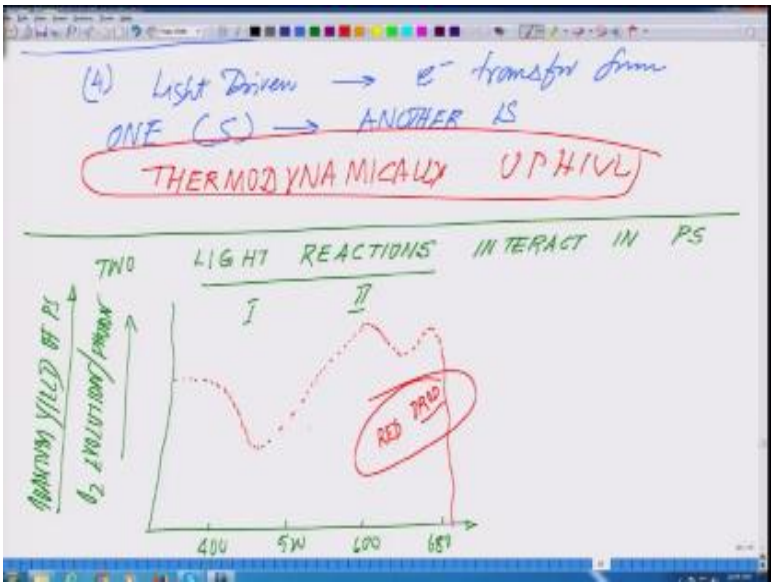

Now from here we will move on to the next aspect what we talked about was two light reactions interact so now this is so what we talked about is two light reaction interacting photosynthesis we have talked about two light reactions remember we talked about 1 for system one and for two system two so how this was being figured out is something like this I am drawing it so here you have the wavelength on the x-axis 400 520 600 680 okay and on the other side we will be talking about the oxygen evolution or the quantum yield or oxygen evolved per photon or in other words this is also called the quantum yield of photosynthesis okay.

So what you observed in this is a very interesting aspect init so what you see out here and something called a red drop why is it so now what does this red drop why is it so signifies so what it says is that for synthesis require interaction of two light reactions as we have already mentioned okay for system one and two system two and both of them can be driven by light of wavelength less than 680 nanometer but only one of them by light of longer wavelengths and interestingly the one which is driven by light of longer wavelength is the one which is involved in what we call as the dark reaction driving the dark reaction which is for system 1.

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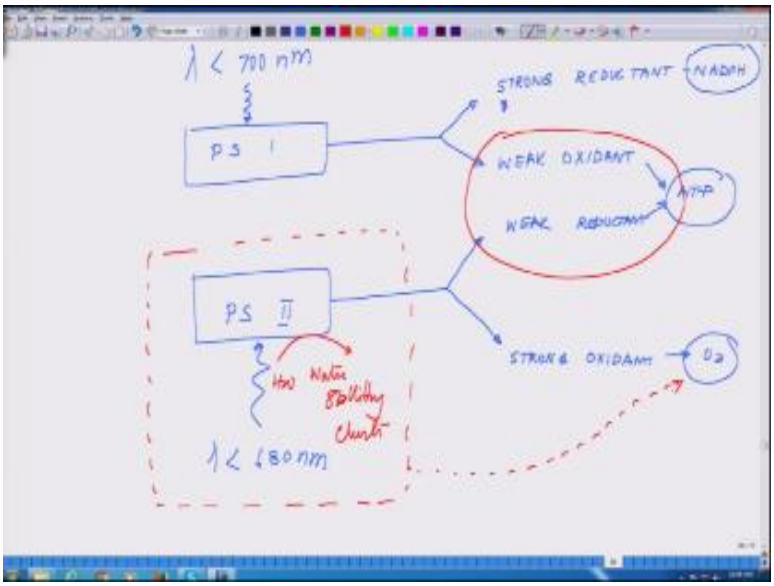

So in the next slide this why you see this red drop will be very clear to you if I draw the next just go down on the next slide so to summarize what does that mean or not this will make everything clear to you so here you have photo system 1 PS 1 shining light on it which is wavelength less than 700 nanometers okay and you have another photo system PS 2 which is getting light less than 680 nanometer corrected nanometer okay now what is generated out here is a strong reductant in the form of NADPH which is NADPH and one second and a weak oxidant in the form of ATP where the for system two you have a weak reductant in the form of ATP again.

Whereas there is a strong oxidant in the form of oxygen so these weak oxidant and weekly distant is an ATP now if you look at this reaction very carefully you realize so coming back to the slight and let me add one more point to this which will make you understand so out here underneath it is the water splitting cluster now this part functions at less than 680 nanometers which is directly involved in evolution of oxygen now if you see the previous red drop graph.

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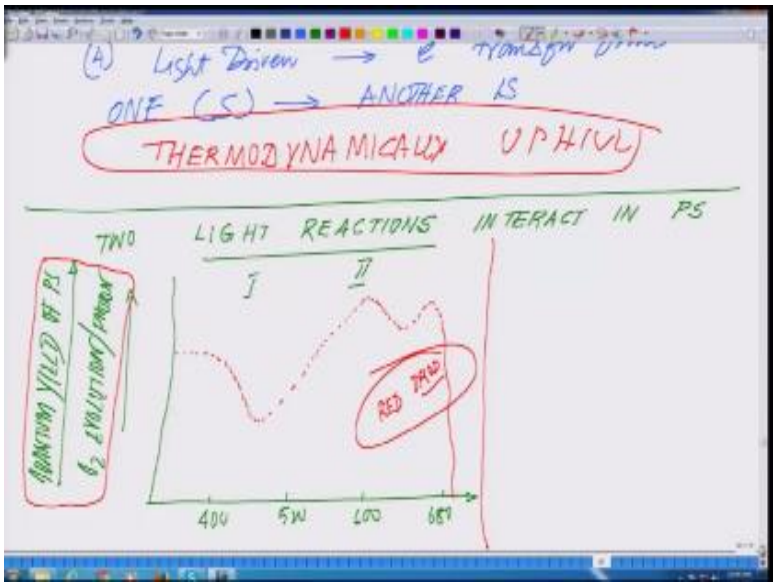

Now you observe what you are how you are quantifying you are quantifying based on oxygen evolution so beyond 680 the oxygen evolution is going to go down there will be a red drop yet the photo system absorbs light white is absorbing light now coming back to this picture.

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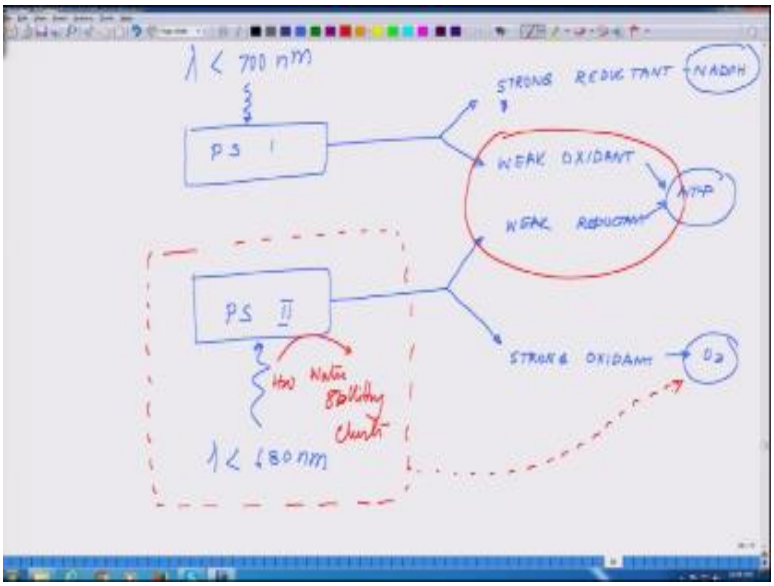

Because between 68 t + 700 682 704 to system one is functional so what you see a red drop you see a red drop out here because of this one out here photo system 2 only functions at 680 and less and for system to the oxygen evolution is what we use as a quantifying or scale for measuring that quantum efficiency or photosynthetic efficiency but try to understand the two points here.

But that does not rule out that the chloroplasts not going to absorb light it is going to absorb light because between 680 and700 nanometer for system one is absorbing light where it is producing a very strong reductant in the form of NADPH which is eventually taking part into the CALVIN cycle which will be coming later where the real biomass formation is taking place where CO2 the sequestration is taking place now this brings us to a point three aspects what we will be dealing.

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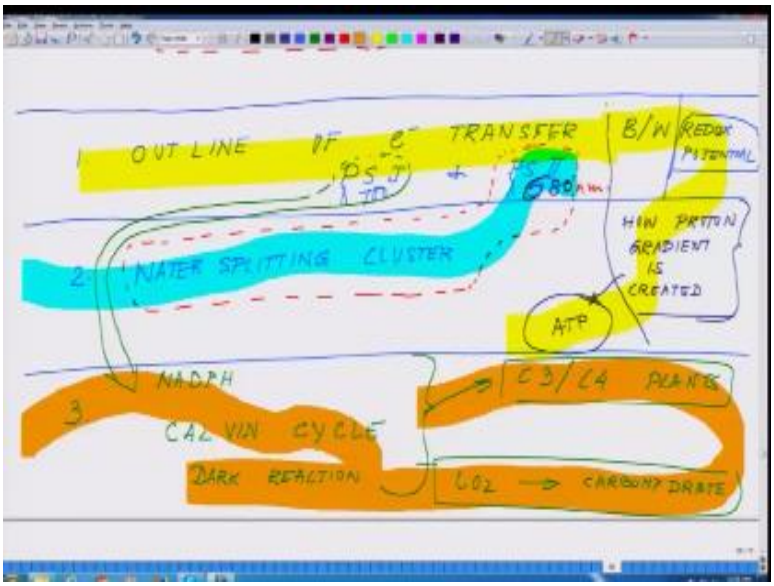

Now what we will be dealing now is one second so now at this stage let us draw the three more aspects what we will be dealing our next goal will be to 1 outline of electron transfer between photo system 1and photo system 2 which of course you can also mention as 680 and 700 sorry let us take a once again 700 or 680 the outline of electron transport with respect to the radix potential this is one aspect what we will be dealing with now second thing we will talk about water splitting cluster involved in out here at underneath for system to at 680 okay.

Then we will talk about the third which is this part and how this one is governing the CALVIN Cycle for the dark reaction of photosynthesis where CO2 to carbohydrate or the carbon sequestration which is happening and from here we will talk about C3 and C4 plants and what we learn from them so after crossing through this whole thing now we have reached to a point where we will I have already highlighted what always we are going to discuss we will discuss about next two classes.

That will be our target area we will discuss about the transfer of electrons along the cluster we will talk about the water cluster process which is happening underneath for systems too and we will talk about the CALVIN cycle and that will summarize our this module so after this these are

the three points so please go through what all we have covered just to summarize for example so we talked about the basic architecture of a leaf where the or of plant cells we have not still talk show in the plant cell we talked about the basic architecture of the chloroplast we talked about the arrangement of thethylakoid membrane and within thethylakoid membrane okay.

Let me just coming back to the slide once again and here also we will talk about a little bit more out here just as the part of this how proton gradient is created this is very important we just slipped out so this is another thing which will be talked about which actually leads to generation of the ATP so we talked about the architecture of the chloroplast we talked about the how it was discovered that there are four system one and photo system 2 it is further how it was discovered that there are two different kind of chlorophyll molecule chlorophyll A and chlorophyll B we talked about in depth about the reaction center and how it was observed that after this match is illumination you only get this much oxygen.

So it means all the chlorophyll molecules are not involved post excitation into oxygen evolution then we talked about the hill reaction where we kind of you know split that whole reaction of CO_2 + H_2O into two parts and showed that they are two independent events where carbon dioxide is converted into carbohydrate is one part whereas water is splitting and it will evolving oxygen is another part which is part two of it.

So there are two separate events which are happening altogether which are not interlinked with each other or quick with each other two separate events and from there we talked about the overall scheme of things where we talked about for system one where it is producing a very potentially very strong reductant in the form of NADPH whereas for system two which is forming a very strong oxidant in the form of oxygen whereas both of them are generating a mutually a week reductant and a weak oxidant in the form of adenosine triphosphate or ATP molecules.

That got generated because of the proton gradient which is formed there and in between how you talked about the red drop why because the quantum efficiency or the for synthetic efficiency is a function of oxygen evolution so if you kind of you know shine light beyond 680 nanometer there

would not be any further evolution of oxygen instead there were the only absorption of light and that will only reduce the photosynthetic efficiency so what you will be observing is that there will be red drop in terms of oxygen evolution we talked about it so based on that we put this outline for the next couple of classes.

This is what we are going to deal with the outline of the electron transfer between for system one and for system two this is what we will be dealing are part 1 and follow-up it with respect to the redox potential and how the gradient is created and out ATP is generated so again what we will be dealing what will be the water splitting cluster which is present underneath photo system 2 or at PS 680 and the third thing what we will be dealing with will be NADPH as a strong reductant driving the CALVIN cycle or the dark reaction where carbon sequestration taking place and followed by c3 and c4 plant so these are the three aspects what we will be dealing with so I will close in here and we will take up these three topics in the subsequent two lectures where we will wind up the module thank you.

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