Indian Institute of Technology Kanpur
National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Bioenergy

Lecture-08
Exploration of Photosynthesis Process

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Welcome back to the lecture series on bio energy, so we are in the module two and we have finished first two lectures where we talked about, the overall scheme of, processes which happens in photosynthesis. We describe the light reaction, and the dark reaction, and we talked about for system 1 system 2 and the electron transport, and the proton gradient which is created across the thylakoid membrane. So at this stage all my viewers and listeners have an overall idea of what are the processes which are happening in photosynthesis. Now next two classes what we will do so today, we will be starting our eighth lecture.

Now next to or two three classes our idea will be to explore each one of those processes, in greater detail so that what all the next generation of technologies, which are evolving by getting inspiration from them can be clear to all of you. So let us get back to the slide today.

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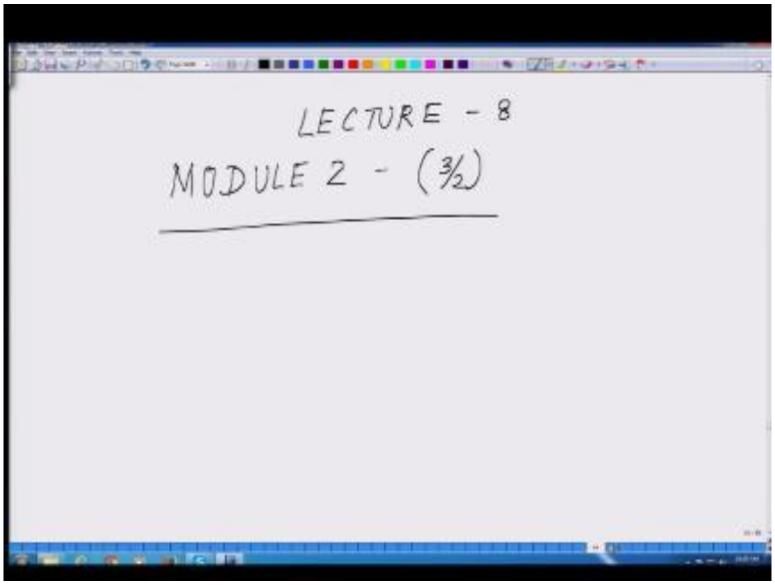

We are in to that lecture 8, so essentially in the module 2 and this is basically the third lecture of module 3 by 2. That is why you did like this okay.

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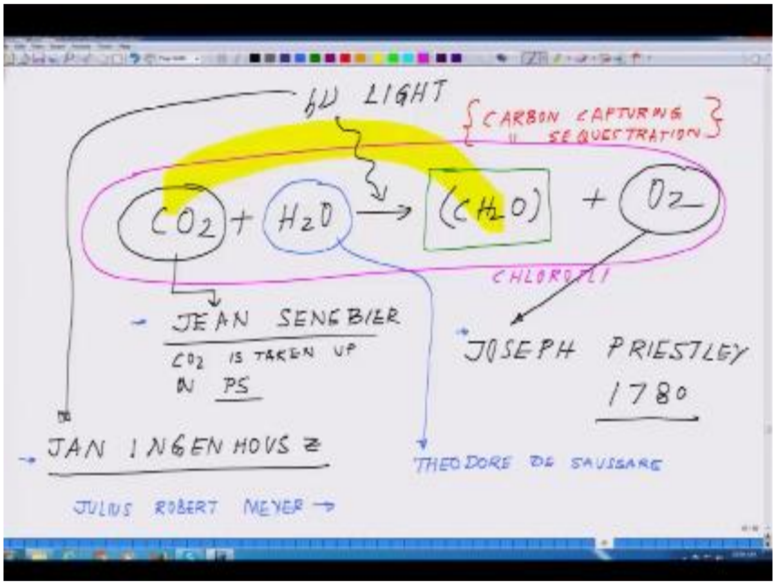

So now if you remember the first very first reaction what we have dealt with was co2 + h2o making ch2o plus oxygen as a by-product. Now fairly early in the 18th century this reaction was discovered but this, this reaction was not discovered in one shot there are few landmark discoveries or you can say landmark events which led to the discovery of the fourth synthesis. So we will just in couple of minutes we will kind of highlight them that will give you an idea of the timeline when this discoveries indeed happen okay.

Now add one more component to this was the role of light which is light given reaction so if we look at it, it was the evolving of oxygen this part this was by Joseph Priestley just putting the name you can cross-check you can go online, and you can figure it out, and around 1700 80 the next major discovery which happens was the role of light. Which was described by a Dutch scientist his name was Jan Ingen Hous so who discovered the rule of light. The third one was Jean Sengbier so his discovery was with this carbon dioxide what he essentially says let me just put the name Jean Sengbier showed that co2 is taken up in photosynthesis.

I am just putting PSS photosynthesis not putting the whole name, then came the role of water out here you seem just in a different color code for your understanding role of water was basically shown by a guy called Theodore De Saussare. What he said that he demonstrated that some of the weights of the organic matter produced by plant and of the oxygen evolved is much more than the weight of co2 consumed. And based on the law of conservation of mass by lavish or It predicted that this is nothing but the water okay.

And all these so you see Joseph Presley here this is around 1780 very similar Jan Ingen Hous worked at the same time Jean Sengbier just soon after that and the Theodore De Saussare who talked about the role of water and the final contribution was made by Julius Robert Meyer, Julius Robert Meyers. So what Meyer says was the plant take in one form of power that is light and produce another form of power called chemical molecules. So essentially it was completely summarized by Robert Myer who said that it is a light energy is converted into a chemical energy.

And if you will see it very clearly this is what is happening out here this is the chemical molecule which is generated and in other words this is also a process, natural process of carbon sequestration or carbon capturing because in the environment there are lot of carbon layer. So what you are essentially doing you are capturing the carbon dioxide or the carbon molecules and converting them into baked carbohydrate molecules in other words you can call this whole process. Let me okay, this whole process could fall under carbon capturing or carbon sequestration which is one of the very emerging challenging field currently that how we can sequester lot of this carbon dioxide in the form of air pollutant which are present there.

But this brings us to a very different tab perspective to this whole thing if there is a way one can emulate the photosynthetic apparatus then essentially one can think of making food in an artificial chamber. Think of it you have carbon dioxide is in abundance your water in abundance in the sea of the ocean and what you need and you have light in abundance all your three commodities are in abundance. Now if you can push them in one apparatus which will make carbohydrate as the way a chloroplast does. And what we are talking about is that you do not need to grow food in the field you actually can grow food in a small chamber.

So these are the kind of dream what mankind is seen in other words, you can actually form biomass if you know what really photosynthesis is doing. So think of it why I am putting trust on this whole area is that the whole biomass formation is directly related to the photosynthetic output which is happening on the floor of Earth as long as the solar energy is available to us. That is why now what we will do from this point on our next journey will take us talking about the architecture of the organelle which is chloroplast.

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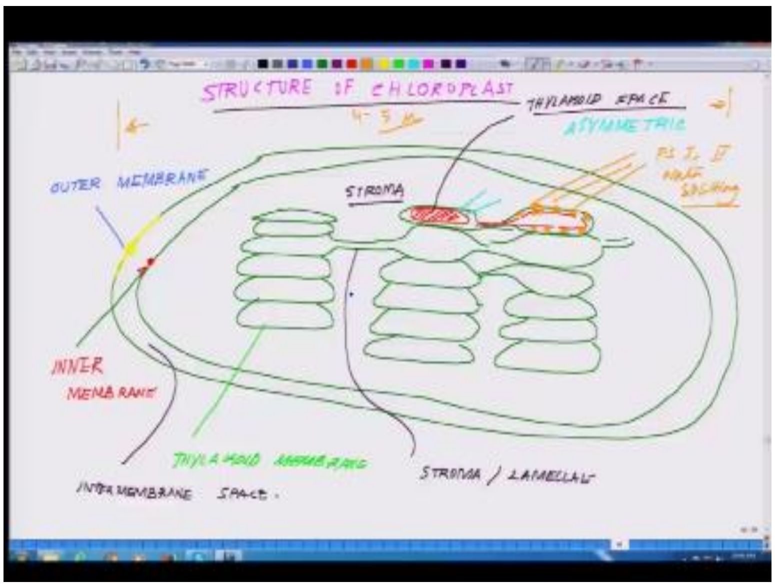

We will talk about the structure of the chloroplast, on next slide we will move on to the structure of chloroplast shirt off okay before I draw the structure try to visualize those of you have seen Food Corporation of India godowns or something. You must have seen that there are gunny bag filled with grains they are stacked over one another like this at some point or other all of you have seen this if not in real life or at least in a picture you have seen it okay. We are stacked over one another and there is a closed room inside which these green serving cape exactly visualize a similar structure chloroplast is a double membrane structure before I draw this try to visualize in your brain is a double membrane structure. In which you will see stacking of those something like a gunny bags all over and there are connected between them so now let me draw it what I was trying to tell you.

It will be something like this, so the structure is this is outer layer something like this a structure which dimension is around 2 to 3 micron and on 80 we will see something like this these are those granny bags which are present the connector liked it okay. So now that is was telling you try to imagine where the grains are kept in gunny bags and these are those gunny bags that will kind of help you to visualize how the structure really looks like, like this now if we label this a structure let us put the labeling to them.

So this is the this is the inner membrane and putting the inner membrane then the yellow shading what I am doing this is the outer membrane so two envelopes in a membrane and the outer membrane then you have something these structures are called thylakoid membranes. So if you see the cross section of the thylakoid membrane so you must have seen a pillow. So imagine you have the cover of the pillow cover and you remove the cotton from it or any kind of cushioning agent.

So it is something like this so if I had to know coming back to the slide if you see this structure very carefully this is structure will be something like so there is a hollow part out here this part is follow okay. So thylakoid membrane is kind of inflicted it is kind of you can say it is a saucer-like inflated structure there are saucers like this and underneath it is hollow. So and they have a different function that is one and all these structures area symmetric in other words if you look at the outer periphery so that is why I am putting different colors.

So if this power and this part inner and outer they have a different property in property in the sense they are molecular arrangement of the different kind of proteins which are present there is entirely different so most of the biological membrane. What we know off till this day are a symmetric in nature and this asymmetry helps most of them to achieve some very unique functions okay. So now coming back to the slides out here so there are a few other things what we have to mark here so we talked about the thylakoid membrane and this is spacing between what you see is called thylakoid space okay.

Then these kind of connectors are called stoma or lamellae okay and then there is a space in between these two which is called inter membrane space okay and this empty space was you see is called trauma so overall this is the whole architecture of the chloroplast where these reactions are taking place and if you guys the number so where this photo system one and four system to is located now just let me point out in so forth system one and four system to is kind of suppose this is the inner membrane like this is connecting like this.

So now this is where the four system 1 system 2 what is fitting cluster all these things are decorated around so what you see essentially is that so this is where all the, the is 12 water-splitting and all these things are located so if you see it is essentially a energy transforming membrane where the lighter energy is falling and electrons are ejected and all the phenomena what we have talked in the last two classes it is all happening at that site so this is and that of course if we look at the dimension.

So we are talking about a dimension of around you know 5 4 to 5 micron and the max or maybe less and within that for 25 micron much, much smaller are these the smaller units where these kind of reactions are taking place so that was telling you that if one can emulate even ten percent of this kind of structure and make energy harvesting then pretty much all our global energy problem will be solved this is the kind of challenge when mankind is heading could we emulate a chloroplast or could you emulate thylakoid membrane is it really possible maybe someday somewhere okay.

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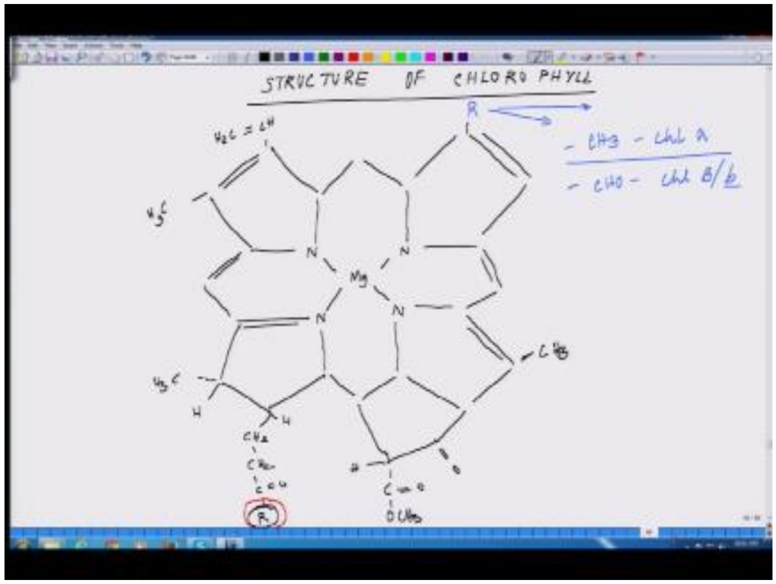

So this is the overall architecture which what I want you guys to know kind of you know keep in mind and if you see wanted to know the composition of it the composition is something like this they nearly have equal amount of lipids and proteins okay almost equal amount of equal amounts of lipids and proteins and most of the lipids and the total lipids if you look at it so there are Galacto lipid you have sulfa lipid and you have phospholipids. These are the different kind of lipids which are present there so this is overall and of course I have already mentioned you that one second this structure also has its own genetic material have already mentioned, and that is one of the reason why people say, let this at some point in evolution was and stand alone organelles which for some XYZ reason parasitized and other animals.

And today what we see is the plant evolved the cause of that okay so coming back so the next thing what we will be dealing with is once we are done with it so this is what you have talked about now we will talk about the structure of the chlorophyll so, so the chlorophyll molecules how they look like so I told you that there are similarities between chlorophyll and hemoglobin told you that if you remove the iron from the Centers of the poor fire injuring or then it becomes CEO low because the whole profile is zero similarly if you remove the magnesium which makes the chlorophyll then it remains as yellow the very moment you put magnesium it retains the green color the very moment you put iron it attains the red color okay.

So now let us see the structure of the chlorophylls the light trapping pigment structure of chlorophyll so the structure of chlorophyll is something like this you have a coordination out here you have the magnesium sitting out here like this and this is the poor fire in structure it is a complex of structure but just follow it, it will you see a lot of symmetrical features in the structure okay. Similarly you have okay, okay, okay, and in this corner you will see a CH and a methyl group present here than the methyl group present here and there is something called an R.

I am just putting it R here that are essentially stand for one second bit that are essentially stand for two situation if it is one second if it is ch3 then it is so there are two kind of chlorophyll then it is chlorophyll a and if it is CH 0 then it is chlorophyll b okay. So these are the two chlorophyll generally used in very small letter just correct that colorful be out here another methyl group present here at this point you have complex structure out here where you see carbon and ch3 and out here you have an oxygen attached to it on the other side okay.

So of the plane you have a methyl group hydrogen out here under hydrogen and out here this is where the second level of modification comes and there is something called an R this R is again very important for you guys to keep tap and I will talk about the arch just in few minutes and it is one small this, this bond is wrongly placed here actually this should happen here. So now you see this complex structure and I have not explained you about our what that are it stands for now what I will do just follow up this pictures.

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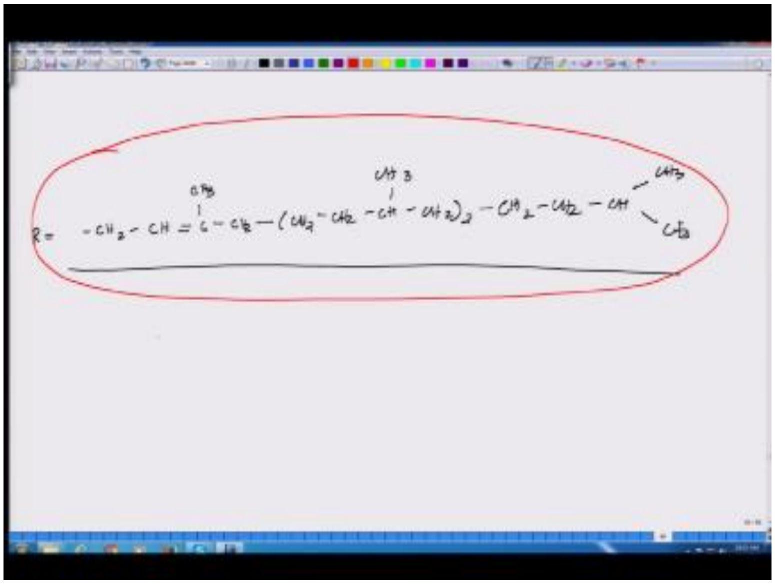

And let us put what that are means in the next slide so that r is equal to CH 2 CH another CH 3 CH 2, CH 2, CH 2, CH then of the ch3, ch2 twice and here you have ch2, ch2, ch3, ch3 so this is what the R group stand for so what you have talked about is there is a chlorophyll a and a chlorophyll b based on that particular position. Where we talked about where whether it will be CH0 or it will be a ch3 now we will talk about what distinguishes a chlorophyll a and chlorophyll b let us coming back to the slide so this is the second our group. What we have talked about so there are two zones one our group I told you out here the box top and the other our group out here which I shown in all right okay.

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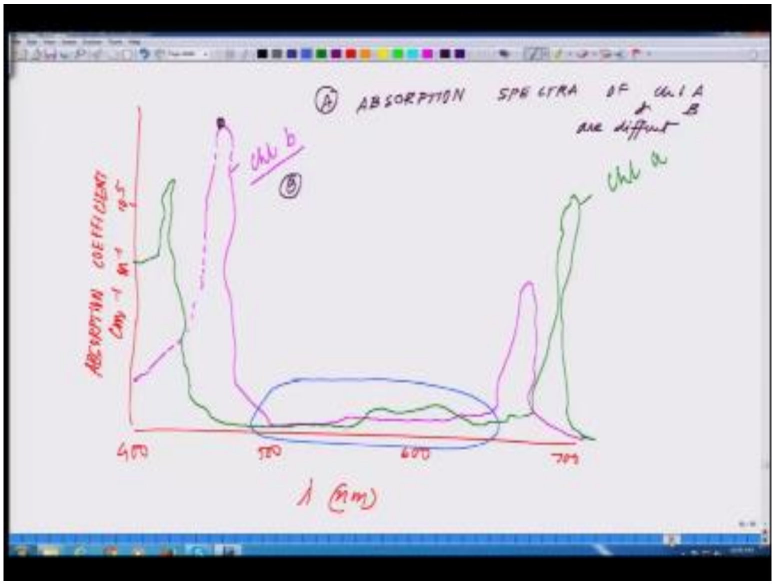

Now so what you see is the absorption spectra so if you if I draw the absorption spectra it will be it will look like something like this okay. So here you have absorption coefficient which is shown in mole and say around out here 10 to the power 5 and absorption 400, 500, 600 and ending at 700 these are in wave length in nanometers okay. So for chlorophyll a if you look at it we put it in green so for the chlorophyll a the absorption peak is something like this if you see this is what is the chlorophyll is absorption is going okay.

Now if you look at chlorophyll b which I am so let me just this so this is chlorophyll a and for chlorophyll b you see the absorption it is something different it will be something like this it is slightly shifting and so one second business today Lotus will be okay. So what you observe is that and there is a slight staggering and the wavelength at where chlorophyll a and chlorophyll b are absorbing but what is interesting to know that there are a huge vast part of the spectrum where there are no absorption.

These are the peak absorbed them which are taking place at that particular wavelength now to summarize this particular slide it is so what we are observing is that the absorption spectra of chlorophyll a b and b are different. So absorption these are the take-home message absorption spectra of chlorophyll a and b are different this is the first conclusion you have to draw from this and secondly light is not appreciably absorbed by chlorophyll-a at 460 nanometer that you can see at 460 nanometers light is not appreciably absorbed by chlorophyll-a whereas it is captured by chlorophyll b which has intense absorption at that wavelength.

That you can see out here so if you see it around 460 nanometer so there is a better absorption of chlorophyll, chlorophyll b as kind of to as compared to chlorophyll a and these two kinds of chlorophyll complement each other in absorbing incident light okay. So this is the major take-home message and the spectral region from 500 to 600 nanometer is only weakly absorbed by this chlorophyll that you can see out here as far as trying to tell you in the beginning. So if you look at this zone there is hardly any kind of absorbance which is happening at that region okay.

But this does not pose a problem for most green plants okay by contrast light is often limiting factor for cyano bacteria or blue-green algae red algae the poses accessory so for such blue-green algae or the red algae for them there are other accessory molecules which Nature has devised which ensures that they absorb light at those kind of different kind of wavelengths. So having said this let us summarize this so what we have observed is that there are two kind of chlorophyll, chlorophyll a and chlorophyll b and their absorption spectra is slightly started but there is a huge shown between 500 and 600.

Where there is hardly any kind of absorbance which is taking place but apart from it there are several accessory molecules which are available to different species whether it is a blue-green alga cyano bacteria read by red algae or whatever they are supplemented with a series of such different dyes which absorbs wavelengths at different wave which absorbs light of different wavelengths. So in other words if you have to can you imagine it, it is to be something like this as if there are different kind of say you know.

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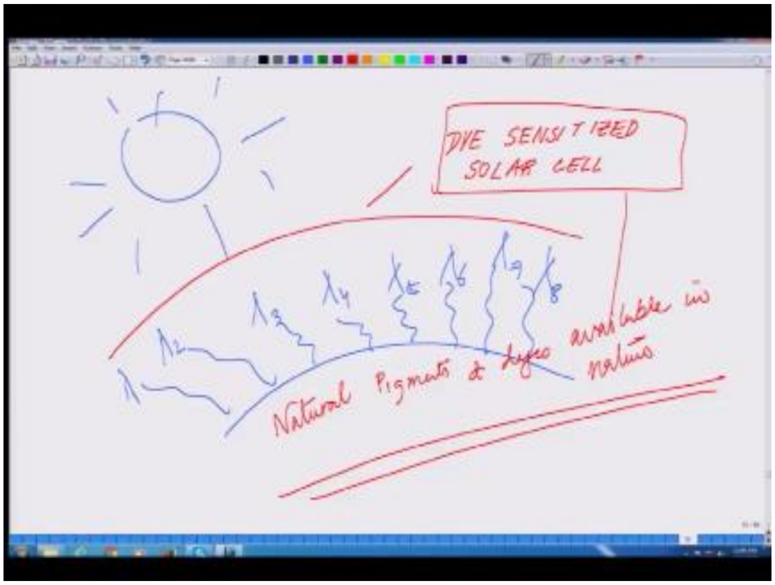

So this is the solar energy which is falling on different kind of life form and they have a different kind of you know so wave length one wave length two wave length three wave lengths 45. So Nature has equipped most of the light form with wide array or spectrum of light harvesting pigment by virtue of which it complements the existing panels of chlorophyll a and chlorophyll b but this particular aspect is an inspiration for one of the advanced topic. What we will be dealing with is called dye-sensitized solar cells we will be right in so tight solar cell we talk about this later but at this stage just remember there are wide array of such pigments available in nature.

So these are the if I these are the different pigments or natural pigments and dyes available in nature which otherwise have a role to support the living systems which are there but those could be an inspiration to develop different kind of another series of solar cells okay we will come later into this so this is the overall understanding what I wanted for you whistles for chlorophyll a and chlorophyll b but what is the significance of this chlorophyll a and chlorophyll b. So I will close in here thank you.

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