Bio-energetics of Life Processes
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Lecture – 17
Photosynthesis–VII

Welcome back to the lecture series on Bio-energetics of Life Processes. So, in the last class, I was talking to you about concept of 2 photosynthesis; that mean how it was discovered? I believed when I was kind of closing in, there are a little bit of confusion which was there.

So, let me just reiterate that point before I start this class. So, what we essentially discussed is say for example, so, what was the experiment? Experiment was done like this, at what wavelength for synthetic efficiency is highest; how we measure it? It's very simple say for example; you have a source beam of light.

So, we know if you take a beam of light, you have all these spectrum. So, you take a put a prism or you see a rainbow ok; Violet, Indigo, Blue, Yellow, Orange, Red ok. So, as you go all the way down to Orange or Red or something the wavelength increases; your lambda increases right.

And the frequency of course, decreases because and if the frequency is higher, it will be high energy is equal to h nu right; e energy h is the Planck's constant in you and e is equal to h 1 by lambda right; because energy is inversely proportional to the wavelength.

So, if the wavelength increases, energy decreases right. Similarly, if the frequency increases energy increases. So, at a lower wavelength like wavelengths of Violet, Indigo like where you see something like this; if the light is something like 1 second let me like.

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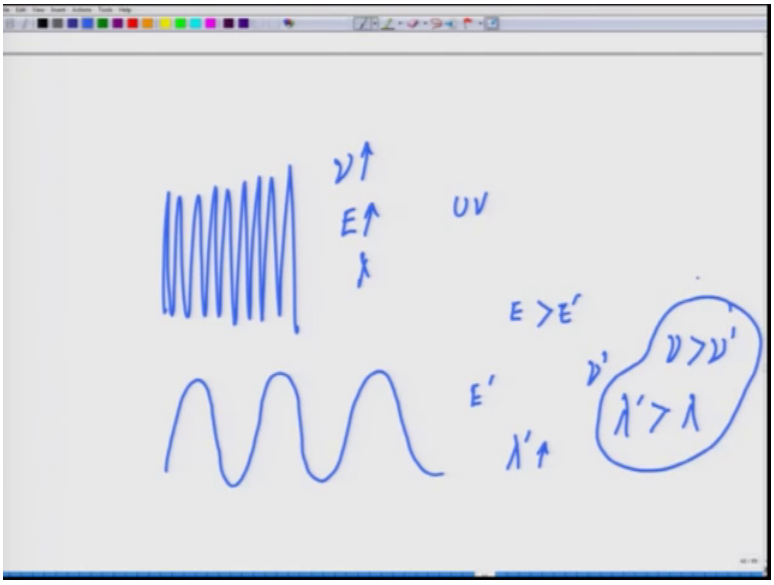

Suppose the light is coming like this. So, these have very high frequencies. So, automatically the energy of such light is very high something like the u v's and all this, whereas, when you talk about wavelength like this ok. As compared to this situation here, e prime energy will be. So, energy e will be more than e prime because here lambda will be higher.

So, if I see the, I say lambda; so lambda which is the wavelength. So, lambda prime will be greater than lambda. Similarly, if we talk about nu and the nu prime; so, you will see nu will be the frequency will be higher then, nu prime. So, there is an inverse relation which continues out here.

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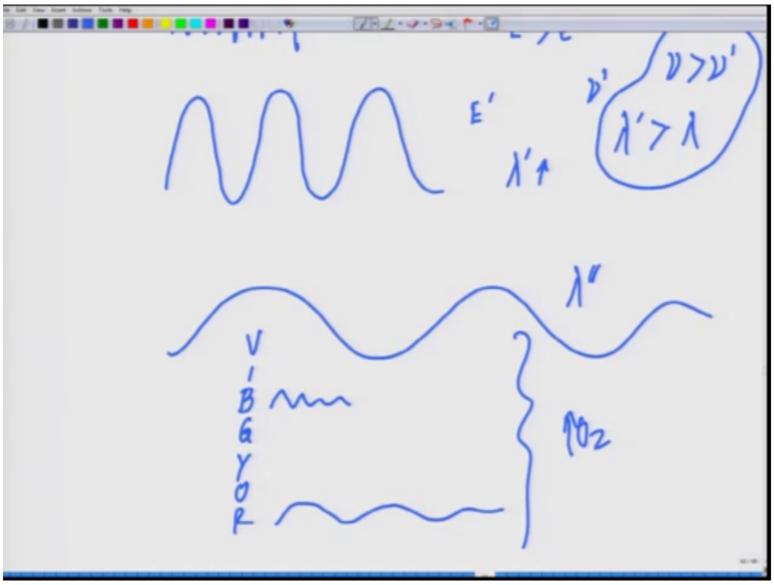

So, you can further increase it like this ok. So, your lambda will be further higher than lambda prime. So, if we talk about the lower wavelengths; those are the ones which are having higher energy. So, what the experiment which was done is to see at what wavelength of light.

So, I have say Violet wave, Indigo, Blue, Green, Yellow, Orange, Red. At what wavelength of light, you will get a higher quantum efficiency in terms of photosynthesis, oxygen evolution? Now it was observed that if you give if you really see if you see the graph.

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So, you give a 400, you get this much; 520 this much; 600 this much; 680 this much at different level. But if you go all the way out here, you see there is a drop. What was observed is say for example, you couple?

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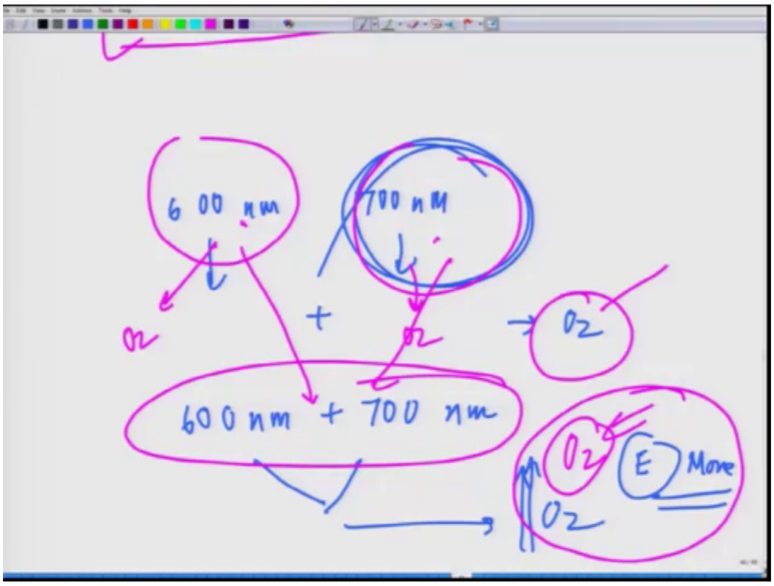

So, if you, if you remember this is what is important for you to understand. If you give it separately, if you give it separately and you see the oxygen evolution here; you see the oxygen evolution here. And you add up say some moles of oxygen what you are getting out here ok. Now what you do? You couple both of them. So, you have a mixture of both these wavelength and you get an oxygen out here, quanta of mole of oxygen.

You would see the oxygen which is evolved here is higher than oxygen evolved in these 2 are given separately and that gives us a concept that possibly there are 2 different kind of sites where light is being absorbed with different quantum efficiencies. And unless the you, the plant is supplied with that kind of light mixture you won't get the complete quantum efficiency of photosynthesis ok. So, this was what was the concept of a Red drop ok; now, coming back a Photo System I and Photo System II.

So, this was the discovery of Photo system I and Photo System II by Emerson.

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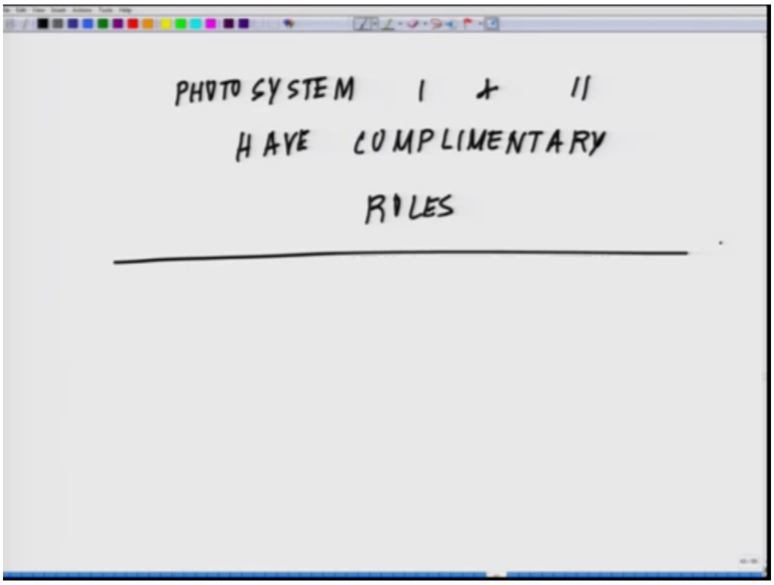

And then, this leads to the concept of Photo system I and II have complimentary roles ; complement tary roles. Now, what are that? Now, it was observed; now, I will come to the photo system I and photo system II's role.

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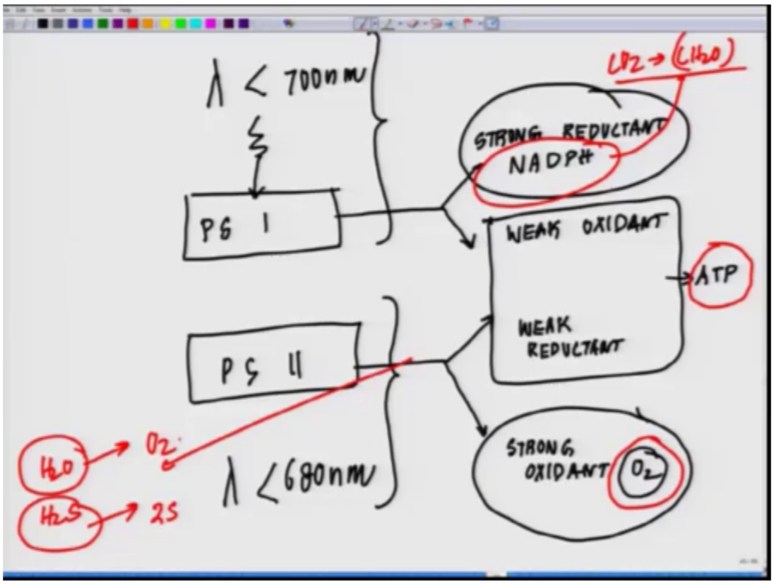

So here, you have photo system I. Say for example, photo system I; here, you have photosystem II and here, you have lambda less than 700 nanometer which I was trying to tell you lambda which is higher which is less than 680 nanometer. So, you have a mixture now right because beyond 680 nanometer, you would not find beyond 700 ideas as you could see, this drop happening. So, you are having a mixture ok. So, this one is kind of less than 700 which includes 680 and this one is less than 680. So, you have 2 different kind of light sources, you are using ok.

Now, this photo system I generates and I will come to that 2 things; one, it generates a Strong Reductant in the form of NADPH. Whereas, photo system II on the country generates a Strong Oxidant in terms of oxygen and both of them generates a weak oxidant and a weak reductant. A weak reductant and a weak oxidant and a weak oxidant which is generated here is weak reductant is your ATP, Adenosine Triphosphate; the real key molecule which is governing it.

Now this is NADPH. So, your byproducts are coming as NADPH, a strong reductant which is involved in CO 2 to CH 2 o strong reductant. You have ATP, which is your energy molecule and you have the oxygen as the byproduct and if photo system II would have contain.

So, you can realize after looking at this, these 2 are complementary and if you realize. So, it seems photo system II is involved in the reaction, what we talked about water splitting or hydrogen sulfur splitting which is generating either 2 S or O 2, if you go back to the previous class where I was, yes look at this one.

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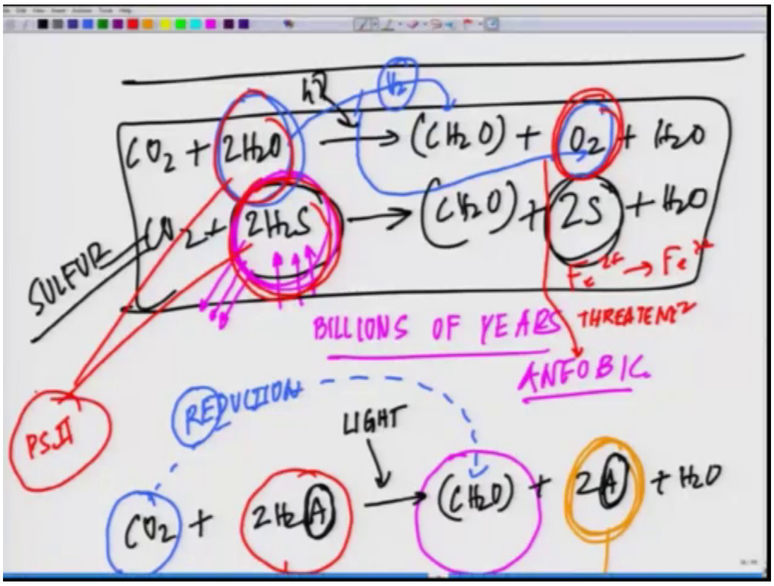

So, it is out here for probably photo system II ; where, that kind of water splitting is happening or a hydrogen sulfide splitting is happening at photo system II ok. Of course, both of them produce a weak oxidant as well as a weak reductant in the form of ATP molecule ok.

Now, coming back to what happened? Photosystem; now, we will talk about the whole architecture of photosys and if you remember in the very beginning I talked about the reduction potential or REDOX potential. I told you that the REDOX potential is basically the ability of x molecule to donate or accept electron of course, if you are going by the accepting electron series; then, it is called a reduction potential and if you go by the ability of oxidation or donation of electron; then, oxidation potential. And we are only dealing with the reduction potential because you have to.

So, if I am comparing say a to z the different molecules. Then either I can compare by all of them on the basis of oxidation potential or all of them on the basis of the reduction potential because you have you cannot interchange it ok. So, we will be dealing with all of them in terms of the reduction potential. In other word, what is the energy it needed to generate an electron ok? How much energy?

And that's what essentially distinguishes the different REDOX potential of different x y z elements which are present ok. So, talking about the redox; so, what we will do now is if you go back when I was drawing this. What I will be trying to do now, ok.

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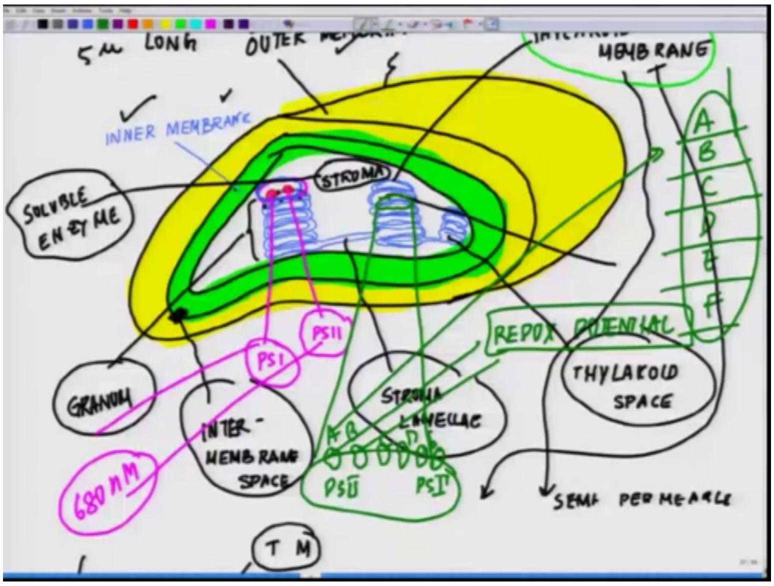

Now, here. So, there are series of, series of molecules which are involved in photosynthesis. In which are lying at photo system II, photo system I and these are different membrane bound proteins which are there and they are arranged something like this and I will draw it further.

So, each one of them have different REDOX potential. In other word, these proteins are arranged in such a way that each one of them have a different work function of donating electron or accepting electron ok. They can accept electron with very different efficiencies. So, say for example, if I have A, which has more power to accept electron than B. So, if I have a source of electron; then, A will be catching the electron faster as compared to B because A has more pull for the electron, more power to get reduced.

Keep this basic, basic concept in mind that if I have 20 players and if you arrange them in order that you know A B C D E F G H and assume that a has the highest power to accept electron. So, what will happen if I start dropping the electrons like this? So, A will be the one which will grab the maximum number of electrons till it is completely filled; then, B; then, C; then, D; then, E; then although it is Z. So, z will be the least one. So, that helps them to arrange.

So, you know in a way if I name this proteins at A B C D E. So, what I can do is I can arrange them with a different REDOX potential. I can arrange them like this. So, we can I can say that A has the highest power to accept an electron, B is the next, C is the third, D is the E and F likewise. And of course, there is another aspect which is in space how they are located ok. So, keep this concept in mind while I will be drawing a very interesting aspect of explaining photosynthesis in terms of the REDOX potential or the ability.

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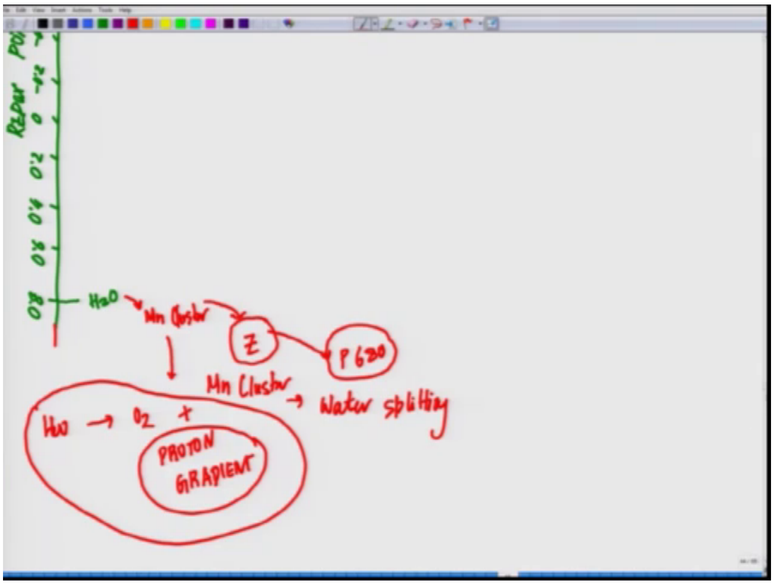

So, in terms of the REDOX potential, on my left hand, I will be drawing the REDOX potential in terms of the voltage. REDOX potential in terms of voltage ok. Now, I will start with 0.8 ok; 0.6, 0.4, 0.2 0, minus 0.2, minus 0.4, minus 0.6, minus 0.8, minus 1, minus 1.2, 1 minus 1.4 likewise. If I could really take of this scale, fine. This is this is good enough for us to study ok.

So, water if I onceagain, get the scale ok. So, water is sitting at 0.8 REDOX potential H 2 O ok. So, now, out here the. So, the way it works, before I kind of get into this graph; let me tell you how the whole thing works.

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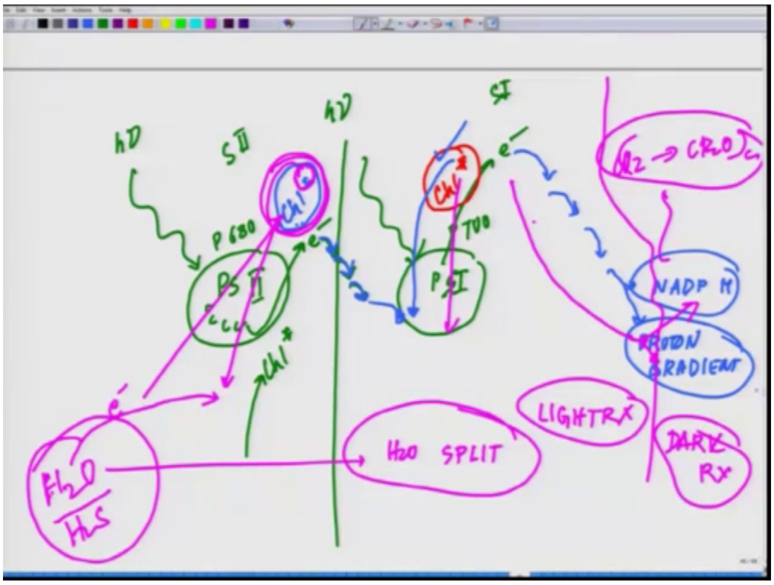

So, you have photo system I, photo system II and photo system I. So, light falls on both these photosystems ok. And these photosystems are what we talked about p 680 and p 700 ok. This is the one which is activated at p 680 and this is the photosystem I which is getting activated at p 700. Now, what happens is that? From here, from the reaction center of chlorophyll, 1 electron is getting ejected out ok.

Once, there is an electron which is ejected out the chlorophyll out here becomes devoid of an electron. Now this electron is funneled through series of those proteins what am trying to tell you reach is. So, let's again, rehash this light falls at 2 photosystems h nu h nu. From here an electron is ejected; from here an electron is ejected.

So, at this site, site II and site I, once the electron is ejected; there are 2 chlorophyll molecules out here which are devoid of, which are devoid of electrons. Now, once they are devoid of electrons; they are almost like free radical. Now the electron from here from this side too is funneled out here, all the way to photo system I and that electron which photo system where it reaches photo system I brings this chlorophyll back to its ground state ok. Whereas, this electron is further utilized and it channels through to make what we talked about NADPH and this is used to create a Proton Gradient. We will come later into that.

Now on the contrary, so, now, you have already balanced out this chlorophyll. So, it is now back to its ground state; it went and it donated the electron and then it received an electron from photosystem II. Now what happens? Out here, still there is an electron which is left high and dry. Who takes care of that electron? Because that electron which is devoid of.

So, this chlorophyll molecule needs an electron to comes back, comes back to its ground state. Who helps it? That is helped by this wonderful molecule which is water or it could be H 2 S which supplies the electron to this chlorophyll to bring it back to its ground state. So, essentially you observe there is what I was trying to tell from the beginning that there only 1 molecule who will be a perennial electron donor.

So, this whole potential drop will only be maintained, when you have 1 donor that 1 poor fellow will be continuously donating electron and through billions of years. The history is all about the chemical evolution is all about, who is that player who will be an electron donor. It is believed there was an earth where that key player was hydrogen sulfide. And today, we live in a world where that key player is water who is that perennial source of electron.

So, to summarize or empty, before I put the REDOX potential in place. So, you have 2 photosystems light falling on both the photosystems; photosystem I and photosystem II both have reaction centers of chlorophyll what I have explained in the previous class. The chlorophyll energy is funneled to the reaction center. So, 1 chlorophyll molecule gives away the electrons.

So once, it gives away the electron; they are a 2 chlorophyll which are left high and dry out there, who has to be brought back to their ground state. Now, the electron which has been given out by photosystem I is being brought back by the electron which travels through or not travels through which kind of hops through from photosystem II to photosystem I and brings it back.

So, photosystem I is now quite, but what will happen to photosystem II. It also has a chlorophyll molecule which has to be brought back to its ground state. So, that needs an electron because finally, that electron energy is being utilized to synthesize your NADPH and creating a proton gradient. How you work out that logic? And that logic is being worked out by that perennial electron donor.

So, that is what I am trying to highlight from the beginning of the course that it is all about that 1 perennial electron donor and as long as you have that perennial electron donor at your disposal and you have a way to extract the electron from that perennial donor; you do not have to worry. That 1 electron donor will always be sitting somewhere out here who will be you know giving the electrons and as long as that perennial electron donor keep on giving the electron, your energetics of life machinery will run. And in this case that perennial electron donor is your water. So, this electron; so, water getting split. So, photosystem II is where water is getting a split.

So, essentially photosystem II has 2 functions. The first function is it absorbs light and led to the evolution of of an electron from the reaction center of chlorophyll. The second reaction what happens it is its water and brings back that chlorophyll molecule which is away from its ground state at higher energy state upon losing an electron. On the other hand, photosystem I does the job of producing NADPH, a very powerful reductant which is involved in CO 2 to CH 2 o reaction, which is more of a biochemical reaction of the dark reaction what we talked about.

So, this part of photosynthesis is all about light reaction and that part of photosynthesis is all about the dark reaction or the Calvin cycle. So, now, in the light of this, I will draw the REDOX graph which will help you to appreciate photosynthesis from, yes this was the reason why I was waiting for it ok. So, this is where water is sitting. So, photosystem II has a unique cluster called Manganese cluster and we will talk more about it soon.

These manganese cluster is the one which traps the water molecule in its belly and split it up into oxygen and creates a proton gradient and that proton gradient has its own significance. So, what this manganese cluster is doing? This manganese cluster is involved in evolving oxygen. So, it is taking the water molecule and creating an oxygen plus it leads to a proton gradient.

So, this is where the whole manganese cluster is involved in water splitting reaction. And this manganese cluster donate it to another molecule which is something like a Z which is 1 good electron acceptor which can accept electron even at a much more efficiency than water and that Z molecule actually donates it’s into that reaction center which is P 680.

So, I told you that there are 2 reaction centers in photosynthesis. This is the 1, which is P 680 which is photosystem II and P 700 which is photosystem I. So, P 680 is that first center from where an electron is being ejected out whose REDOX potential is very interestingly stand somewhere; look at this picture this is very interesting it is almost almost hitting out here.

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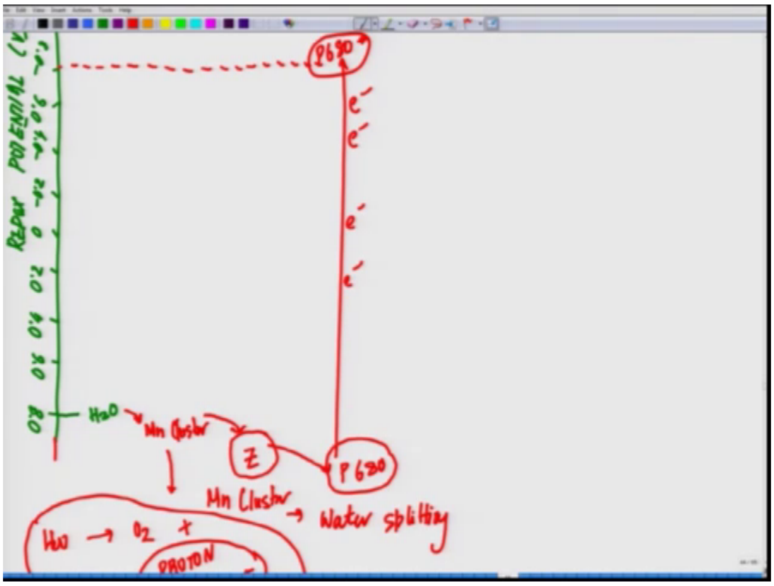

This is where P 680 chlorophyll molecules electron is indicated throughout. So, this is where the electron is being raised. It has a different REDOX potential and what is very important as I will come through you will realize; electrons are all same. They belong to the same class called Electrons.

Yet, they had different REDOX potential and that is what the most beautiful part of Biology and they belong to the same route; same cast of molecules called Electrons. Yet, yet they have a different REDOX potential. How is it so? And we will come to that in the next lecture where will be kind of completing this REDOX potential map. They will kind of realize how electrons emitted out from different photosystems behaves differently.

Thank you.