Bioelectricity

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Lecture – 32

Welcome back to the NP-TEL lecture series on Bioelectricity. So, in the previous class while talking about the photosynthesis we distinguish between the light reaction, and the dark reaction, and I mention that I will be only talking about the light reaction, and the electron transport phenomena which essentially is an inspiration to develop next generation of solar cells where we will be able to replace silicon based panels with some kind of molecules which are much more cheaper much more easy, and much more sustainable.

So, in the light reaction section we I enumerated that there will be six point initially I will be taking care first one will be the structure of the chloroplast which we have discussed in our previous class, and the basic reaction of water plus carbon dioxide making carbohydrates plus oxygen, and in this class we will be discussing two topics one is all those historical landmarks where they simply simple reaction of carbon dioxide, and water forming carbohydrate, and oxygen who are the people who set the ball rolling for us wherever we are today it is, because of those [seminal contribution made by these individuals who ensure that you know follow the track right and.

After that we will be talking about structure of the chlorophyll, and the different types of chlorophyll, and their absorption spectrum, and how the slide structural differences change spectral properties.

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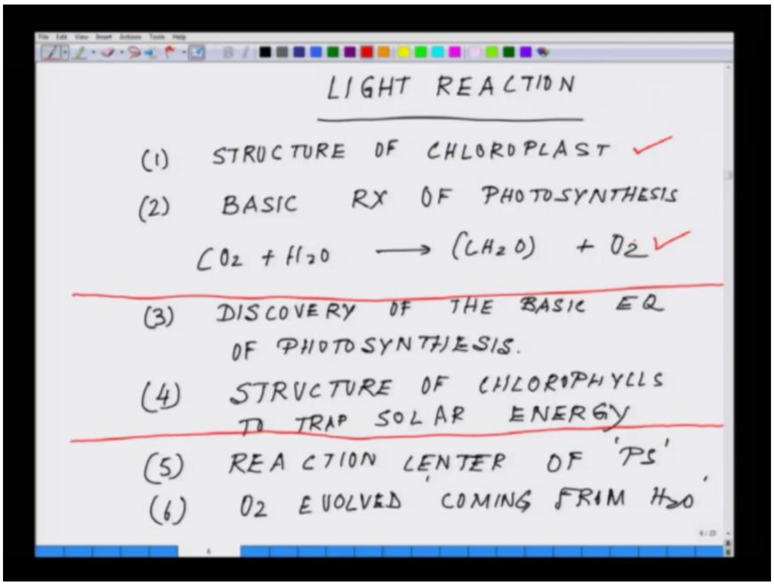

So, let us start with it where. So, our first slide will be the one which we enumerated in the last class, there is we talking about the structure of the chlorophyll which is done we have done with the written with the basic reaction.

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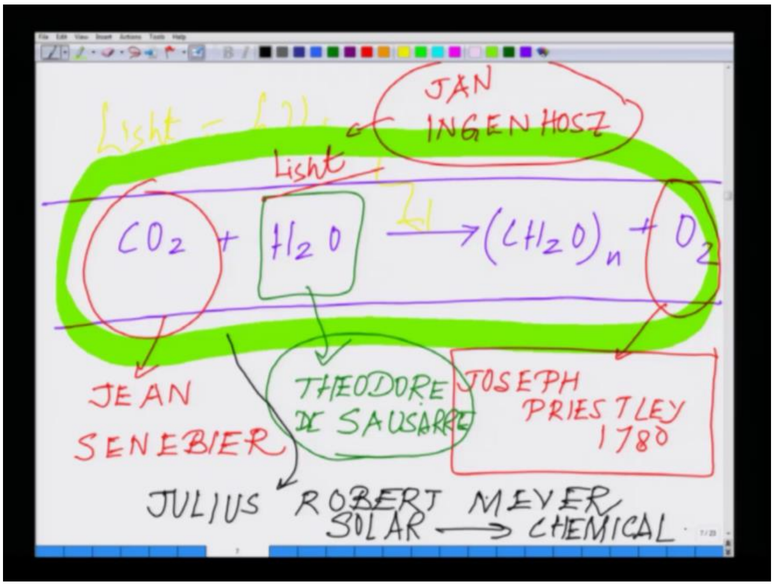

And let us now move on to the discovery of the basic reaction c o two plus h two o forming c h two o n plus oxygen as back as seventeen hundred plant releases oxygen discovered by Joseph Priestley, experiment which was done by Priestley was fairly simple what he did is something like it I will show.

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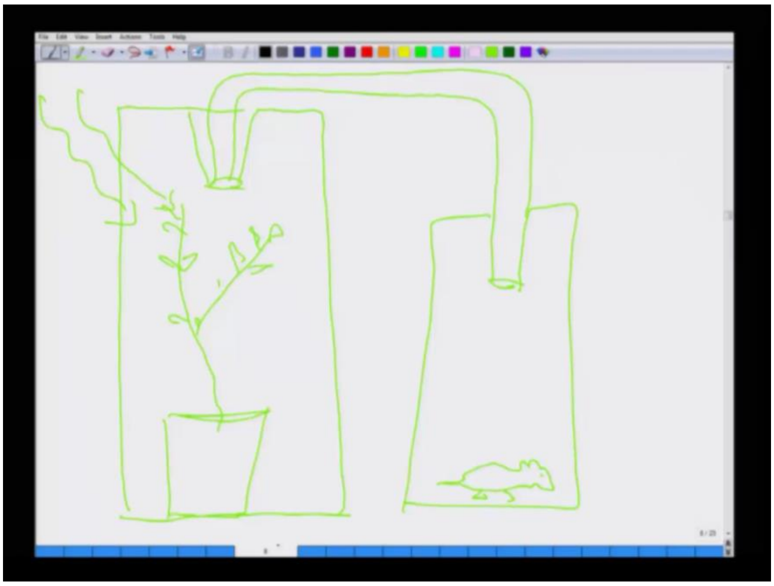

You for example, you have a plant out here some kind of you know indoor plant this and. So, you grow this plant inside a chamber like this. So, at light is falling, and it is connected with what is ever gas is being released you see inside you is another chamber where you have an animal. So, we know that if one individual is confined inside a room without supplying oxygen this individual will eventually dying, because we need continuous supply of oxygen, and that holds through for any animal which survives on earth or it depends on oxygen.

So, this was the experimental set up where it was proved by Joseph Priestley that essentially during the process plant are releasing something called oxygen, and that was the beginning of the journey of understanding what we understand today as the modern photosynthesis. So, let us highlight this. So, this was basically coming back. So, this was this component that it is evolving oxygen was by Joseph Priestley, and this was back in seventeen hundred eighty almost three centuries back, next want to follow was the discovery that this process requires light was by a German called Jan Ingen hose he discovered that this process can only happen in the presence of light.

So, essentially in last class while I was telling you people that photosynthesis could be divided into light reaction, and dark reaction. So, this light reaction is dependent on light was also discovered. So, let us enumerate this point. So, here is the light which is also adding the new component h nu that light, and this discovery was made by Jan Ingen hose that light is involved in it followed by this is the next discovery of carbon dioxide this process is being regulated by carbon dioxide without carbon dioxide some reregulated this the essential component of this or the reactant of this whole machinery is carbon dioxide this was done by another scientist called jean senebier.

so carbon dioxide this credit goes to jean senebier. So, now, we are left with who discovered water that water is an inorganic. So, there was another gentlemen called theodore de sausarre theodore de sausarre is credited with the discovery that that water is involve in this process was theodore theodore de, and this whole reaction that carbon dioxide plus water in the presence of light forming carbon hydrate plus evolving oxygen was completely put in place by mever. So, just this whole thing. So, there is a transformation of light energy into chemical energy was by Julius Robert Mever essentially solar energy to chemical energy.

So, over all if you look at it this is pretty much is the scheme of photosynthesis where there is a carbon dioxide sequestration taking place, and if you currently see this is one of the challenging problem in nature how we could reduce a pollution by in a sequestering carbon dioxide.

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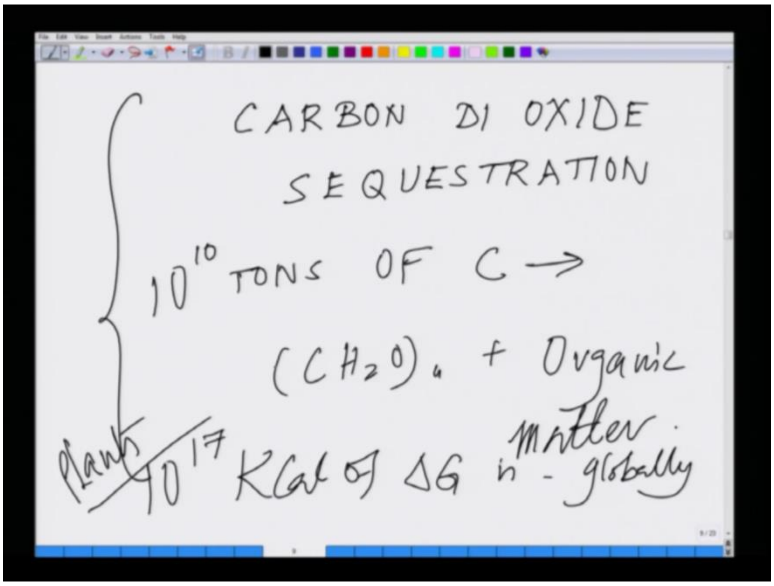

So, the complete vegetative cover of the on the floor of earth essentially. So, let me put that. So, carbon dioxide sequestration. So, during this whole process of photosynthesis almost ten to the power ten tons of carbon is forming plus organic matter now other word ten to the power seventeen kilo calorie of free energy is gain by plants globally.

So, globally the plants are producing that much energy by ensuring the carbon dioxide available along with water in the presence of light transform it into biomass, and even if we could you know mimic part of it this will be big benefit mankind, and there is enormous effort in several countries across the world on carbon dioxide sequestration going on somewhere or other way have reduce the pollution how we can reduce a pollution you could sequester carbon dioxide people are using different kind of algae different kind of a other mechanism to sequester it. So, now coming back up to this. So, with this brief historical perspective about how this simple reaction is evolved since seventeen hundred which is almost now.

So, it is almost 400 years nearing 400 years. So, now, what we will do we will talk about the fundamental molecules. So, if you go back here, if you go back to the structure where we are kind of yeah. So, this is where the light is falling you see this black, and the first molecule which gets activated by it is chlorophyll.

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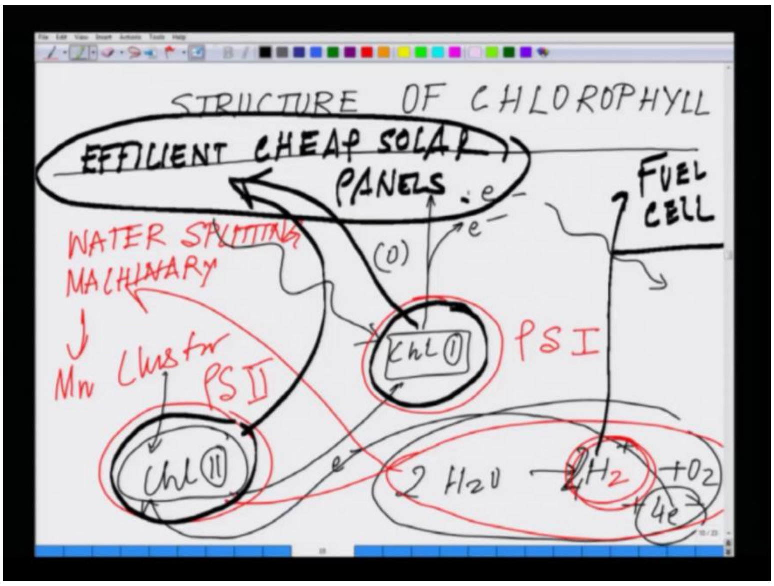

So, now, what we will do is will talk about the structure of chlorophyll. So, before I get into the structure of chlorophyll just for a revision sake I will just go through the electromagnetic gradiation, who is stands where where the I r is standing, and you know all those things I will do that first, but even before that let us give you an overall outline what exactly is happening in photosynthesis.

So, essentially what happens is when the light falls on the plants, and it hits upon the chlorophyll molecule chlorophyll molecule ejects an electron [FL] as soon as a molecular specie ejects an electron it gets oxidized now this electron which is getting ejected travels through a cascade of molecules. So, what it does this electron goes, and attack another molecule. So, as soon as that molecule accept the electron it gets reduced, and then it comes back to its ground state by donating that electron to the next molecule, and from there it donates to the next molecule. So, likewise this electron travels or how through a series of such molecules, and then eventually in that process it creates a proton gradient across the thylakoid membrane.

This proton gradient essentially leads to the synthesis of a energy rich molecule called arinocine tri-phosphate, and n a d p which further acts in generating glucose molecules which is part of the dark reaction, but you remember when I started I told you when the light falls on the chlorophyll it ejects an electrons. So, that chlorophyll molecule becomes oxidized so, but if that is the case in no time all the chlorophyll molecules will become oxidized eventually the plant will die, because the machinery cannot function further, but that does not happen this molecule which gets oxidized is put back into its ground state how it is being done.

So, what happens this is supplied with another electron this electron comes from another part of the photo system which is called photo system two. So, the part what I just now describe it for system one I will be coming into the real molecular details. So, do not worry about it I am just telling you global scheme of things now from photo system two exactly the same event happens light falls electron gets ejected that electron through a cascade goes, and brings back the oxidized electron into its reduced state or its in to its ground state, but in that process there is another photo system another chlorophyll molecule which is getting oxidized, because it has donated the electron.

So, now that second molecule of chlorophyll. So, say for example, we just draw it for your understanding sake say for example, this is one chlorophyll molecule c h l now the light falls on it as soon as the light falls it ejects an electron once it ejects an electron. So, this is the oxidation reaction o. So, then of course, I told you the electron travels through a cascade, and does its job do not worry about it how to bring back this chlorophyll back to its ground state. So, this is supplied with another electron out here from another chlorophyll molecule if I call this as chlorophyll one, then this is chlorophyll two, now as soon as this chlorophyll two donates this electron this chlorophyll two also gets oxidized.

So, it has to be brought back to its ground state. Now how it is being brought back to its ground state what nature has design is something most abundant electron donor, and the most abundant molecule on earth is water. So, it is there the water molecule gets split up. So, what essentially happens is something like this you have the water molecule plus four electron o h plus. So, this is pretty much what is happening these electrons what you are seeing are the once eventually bring that chlorophyll back to its ground state.

So, essentially a photosynthesis what will be talking about we will be talking about three things will be talking about this chlorophyll which forming photo system one this chlorophyll which, and this chlorophyll molecule is coupled with this wonderful water splitting machinery water splitting machinery is essentially manganese cluster this is the sum total of this thing, and very interestingly this manganese cluster which is splitting the water is fairly conserved all over the photosynthetic specie which are which has evolved on the floor of earth it its fairly very well conserved, and one by one we will take up all these things, but in order to understand this whole process we have to first of all understand the structure of the chlorophyll.

So, this is the whole thing, and you might wonder that why there are what are the catches of this game? So, just to again to give you a global perspective on this thing if we could essentially split water the way a plant does which is probably the most efficient means by which a plant does it, then we can produce a lot of hydrogen out here, and we can use this hydrogen, because this is one of the challenging problem this hydrogen could be used for plus enumerate where all we get could be used for fuel cell, this is what we are going to study once will finish the manganese cluster fuel cell the… If we understand these, if we could really mimic these kind of structure we can make efficient cheap solar panels, and coupling this with these kind of machineries we can really have a sustainable energy sources.

So, this is overall the scheme of things what we are trying to understand that is the. So, reason why we are trying to understand each one of these electron transfer which are happening in biological machines which if we could emulate even one or two percent of it of course, maintaining the efficiency we can really solve some of the major energy related issues across the world. So, now, coming back where I took the detour try to you know give you a global perspective of this whole subject why we are kind of you know intensely across the world people are trying to understand these some of these bioelectrical phenomena, and the chemicals involved in it.

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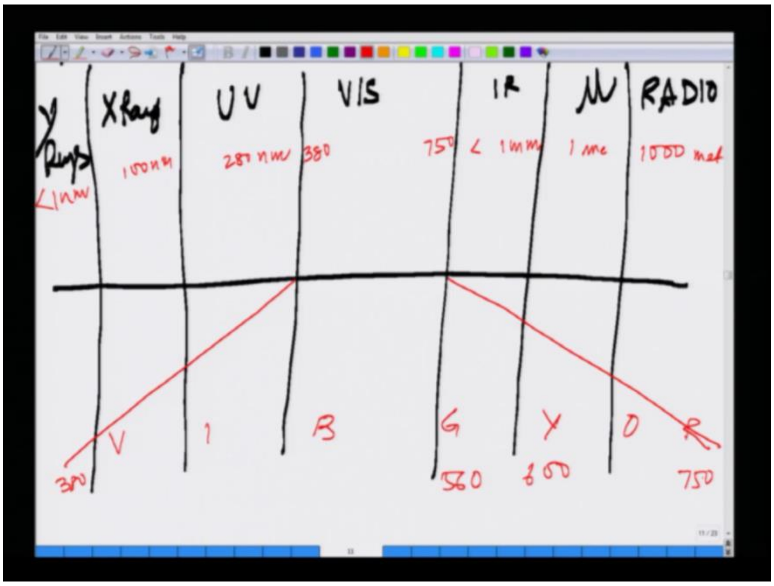

So, next what we will do I will just give you an overall outline of the spectrum just draw it for recap, and then we will move on to the structure of the chlorophyll molecules now coming back to the spectrum structure of the spectrum where what lies where . So, just put it like this visible you have the visible, then you have the IR, then you have the microwave, and you have the radio wave on the other side you have u v x-rays, and gamma rays.

So, if you look at zone we are talking about the visible spectrum is around three eighty nano meter to this is all in nano meter three eighty nano meter to seven fifty nano meter you have here u v’s around two eighty nano meter x-rays hundred, and these are less than one nano meter, this is all in nano meter whereas. So, you cannot see the values let me draw the values again. So, basically spectrum we are talking about.

So, this is spectrum into three eighty nano meter to seven fifty nano meter in the I r spectrum you have more than one milli meter, then in the radio you have sorry in the microwave you have more than meter, and in the radio waves which are around thousand meters, and the u v we are talking about two eighty nano meter range of two eighty nano meters, and then you have x-rays which are around hundred nano meter, and gamma rays which are less than one nano meter. So, this is the kind of spectrum, and what is ever we will be talking about we will be talking about the visible spectrum. So, within the visible spectrum starts with three eighty.

So, you have violet indigo blue green yellow orange, and in the green you are around five sixty, and yellow around six hundred orange, and of course, red, and red around seven fifty. So, this is pretty much is the spectrum where will be talking about the absorption of the chlorophyll molecules. So, now, coming back to a structure of the chlorophyll molecule. So, if you remember the structure of the hemoglobin molecule which is involved in carrying blood all over your body carrying oxygen in the blood all over your body. So, it has a polyp role ring, and in the center you have a iron in the case of chlorophyll the molecular architecture is fairly the same almost the same if not exactly, but only difference is that in the center there is a magnesium instead of iron there is a magnesium.

So, I will draw the structure will, and the chlorophyll are of two types type a, and type b, and type a, and type b has some small molecular differences I will highlight that, and that molecular differences leads to the difference in their spectral properties let us draw the structure of the chlorophyll now.

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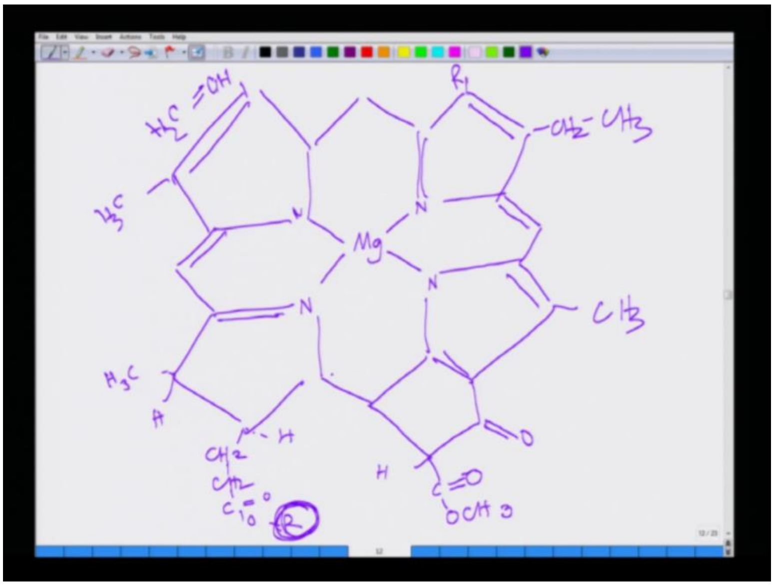

So, I told you there is a manganese magnesium cluster out here it. So, you have the manganese in the center which is all fine nitrogen nitrogen nitrogen, and nitrogen, then up to this this was alright, and the mistake what I did was out here. So, basically is another bonding which is taking place out here which....

So, here you have oxygen out here you have hydrogen here you have o c h two c h three, and then out here you have slightly more modify it hydrogen here is c h two, there is a c h two, and you have this r this r is important, because this is the r where the difference are starting will come back to this wait this is c h three this was h here you have c h three you have f c h c h two, and then you have r group out here the two r groups. So, I will tell you which one is the actually the causes, the one second you have to read was again there was r group out here you have c h two c h three, and you have another c h three molecule out here, and it is almost like this.

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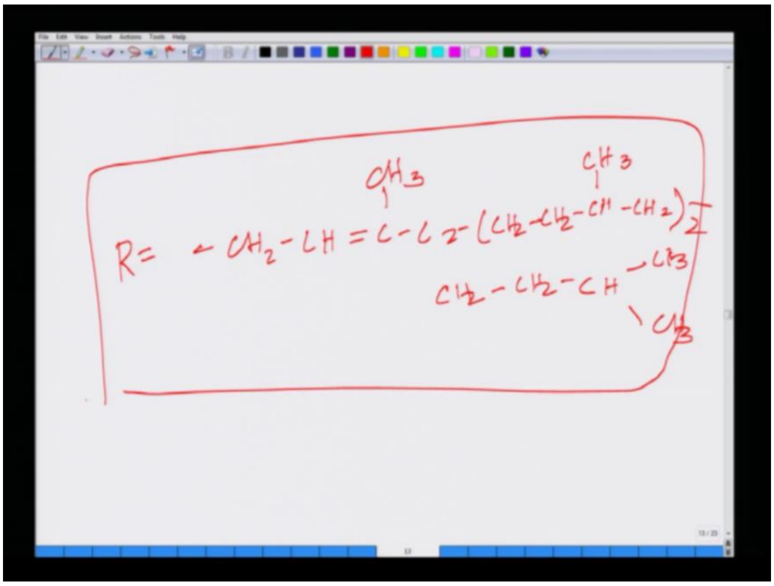

Then the double bond here double bond here. So, this r group, let me just highlight this r group, what you see this r group is actually you have to go to the next slide. So, this r group is equal to c h two c h c c h c is long side chain out there two c h two c h, and c h three c h three it is this r group, which is attached there what I showed you another r group which is out here which is be in green this r group is very important now coming back to the. So, if you have seen this structure this is very, very, very symmetrical structure its really remember this structure all the time, and kind of have to refer to this structure.

But its really easy to draw this structure as long as you do not have to write those huge structures which are there, but with this basic structure there are there are two forms of chlorophyll which are formed, and that change in that form comes in that other r group go back to the structure.

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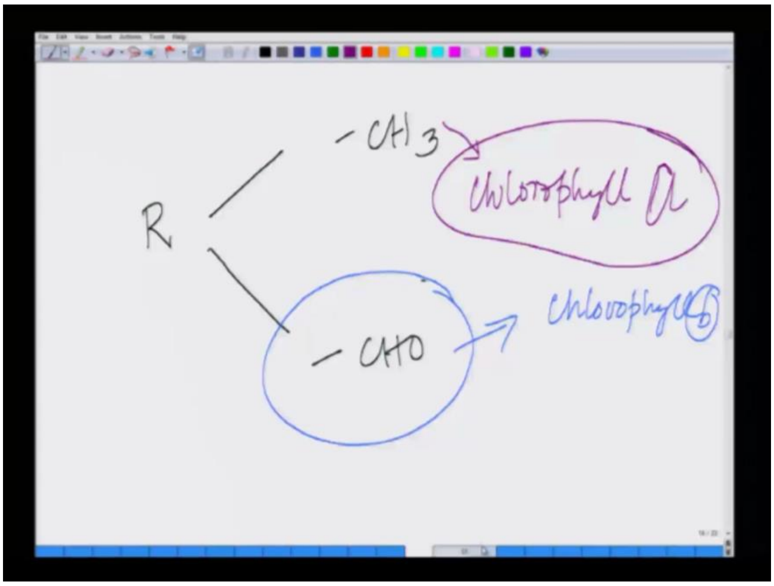

Now if you look at this out here sorry this one kind of circling this r group this r group varies what happens is this that r group what is there could be two types either that r group could be c h three group methyl group or c h o group, and if it is c h o group, then this is called chlorophyll b, and if it is a methyl group this is called chlorophyll a.

This is the basic difference between chlorophyll a, and chlorophyll b, and, because as I was telling, because of that one simple change at one of the r groups it is a spectral properties slightly varies, and that is really helpful, because that way there is no rigid single spectrum there are staggered spectrum which happens, because of this in terms of the absorption.

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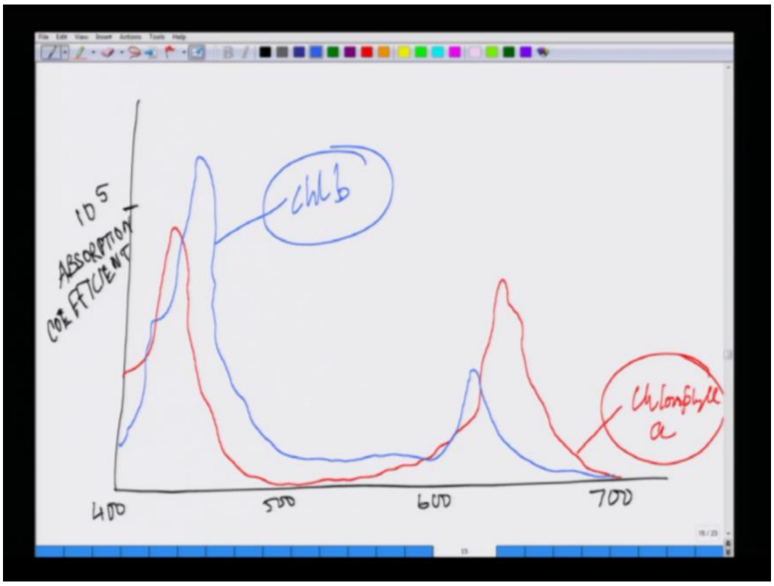

Now let us look at the absorption spectrum of chlorophyll a, and chlorophyll b back to the spectrum part. Now let us give the axis right ok absorption coefficient absorption coefficient which is. So, as a matter of fact the absorption coefficient of chlorophyll molecule is among the highest found in nature, and that is why nature has probably selected chlorophyll as the molecule of choice for its functions now chlorophyll b let us a chlorophyll b with chlorophyll a with red.

So, chlorophyll a is something like this or let us draw it like this. So, chlorophyll a. So, a spectrum which starts to take a down like this and. So, again starts to pick up, and it have another peak out here, and then it take a slight. So, this is chlorophyll a which is in red now chlorophyll b I will be drawing it in blue chlorophyll is slightly staggered, and picks up have its peak out here, and then again it also triples down like this, and then starts to take up somewhere out here, and one second let me just one second let me let me draw this spectrum again. So, chlorophyll b starting like this out here, and it comes back, and somewhere out here.

So, if you look at both the spectrum very carefully will observe something as if chlorophyll b is in between the two extremes of chlorophyll a. So, that way it is happening is that this if the total number say for example, if a cluster has say five chlorophyll b molecule, and five chlorophyll a molecule they will be absorbing a certain amount of light within the certain a, but if I keep on changing the numbers its chlorophyll a's number is higher than chlorophyll b or something. So, a total absorption is going to change. So, that is what gives it in edge by having not having a single chlorophyll molecule, but instead having two chlorophyll molecules which ensures that you can you know tweak or play around with the absorption of the molecule at a specific case ok.

So, this is about the structure of the chlorophyll molecule now next pertaining question what we are going to answer or go going to kind of you know try to understand is something called a reaction center. So, if I take your back to the some of the previous slides. So, again coming back to this slide well light is falling, and you could see that sun light is falling, and then thylakoid membrane there are chlorophyll molecules which are getting oxidized, and then again coming back to its ground state, let me come back here .

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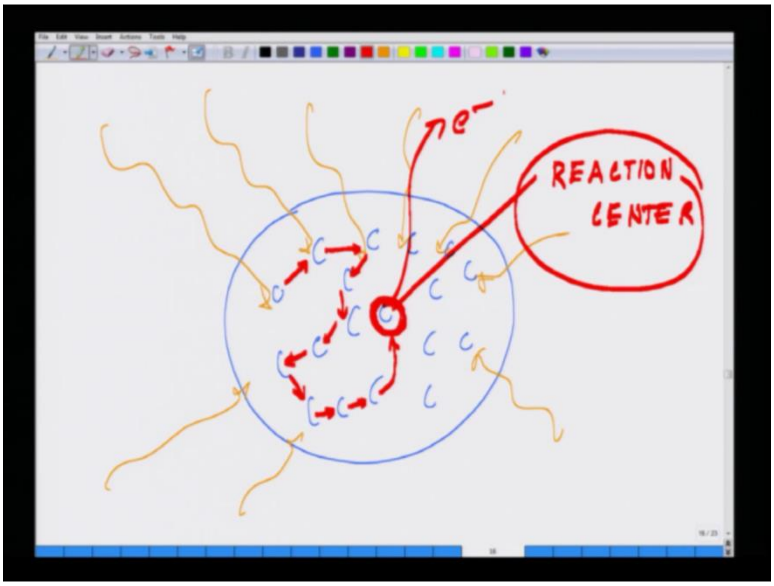

So, now, does. So, next imagine a situation. So, suppose this is a part of the leaf, and there are lot of chlorophyll molecules. So, these are all the c's stand for the chlorophyll molecules.

When the light falls here or does all of them simultaneously start ejecting electron, and gets activated it has been observed that the story is really not like that what happens is that. So, within a pool of chlorophyll molecules there are some very specific centers called the reaction centers. So, say for example, this one say for example, this is the reaction center which I am circling with ka with red. So, what happens when the light falls. So, there is a transfer of electron like this taking place vibrational energy transfer they getting excited eventually they reach to that unique center which is called a reaction center where this whole process of electron emission starts other than that this whole energy is being transferred.

What we do not know is that who determines the reaction center, and does the reaction center changes as the plant is leaving its life we do not know this, but this is one of the very unsolved mysteries, because I will come to that how how it has been discovered, because in the next class that is what we are going to do how this reaction center that self was discovered, but it is not all the chlorophyll molecules are taking part in you know this whole cascade one of the thing which you could speculate is that probably, because of this reaction center concept the longevity of the leaf is increasing, because it is not all the molecules are at excited state just, because of the light. So, with this concept I will closing on this class.

In the next class what we will do is let us go back where we were. So, we have done with the discovery of the basic reactions we are done with the structure of chlorophyll to trap solar energy, and now we have just initiated with the reaction center, and from the reaction center we will talk about the different experiments which have been performed, and from there we will move on to the next part of it, and how these will be translated in terms energy production.

Thanks a lot.