Bio-energetics of Life Processes
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Lecture - 18
Photosynthesis –VIII

Welcome back, to the lecture series in bioenergetics of life processes. So, in the last class we talked about the photosystems and first time I introduced how at what redox potential water molecule is sitting? And the electron which is ejected by the water molecule is being accepted by a molecule, which is even sitting at a much more higher redox potential in terms of with respect to 0.8, which is for the water, right? Which is we represent by Z, if you go into the slide you will observe it. So, this is the molecule which is involved.

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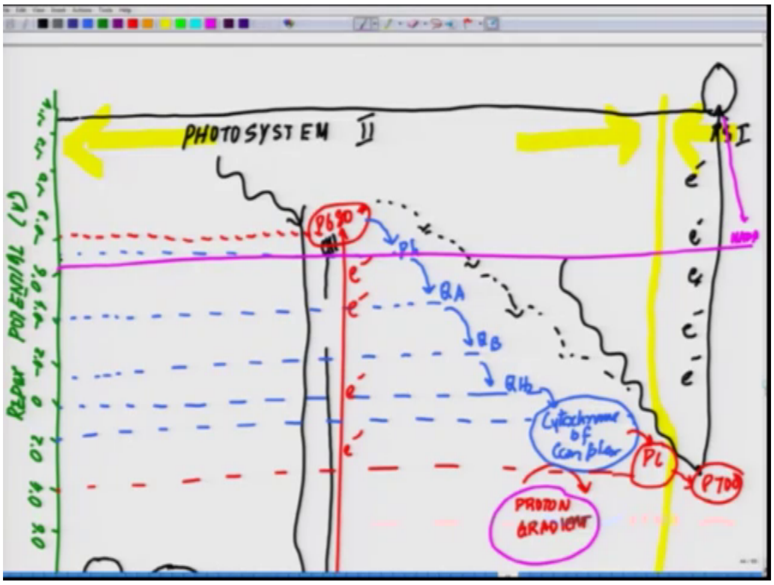

So, if you see if you map it you will see it is sitting at a possibly may be you know 1.0 or something like that ok, some somewhere out here and P 618, which is sitting even at a slightly lower redox potential or slightly higher redox potential in terms of the numbers if you look at it you know maybe 1.2 or something like that.

So, from here there is an electron, which is traveling all the way up. So, before I start today's lecture just eh put it down. So, today we are starting our lecture 18, which is week 4, lecture 3, W4: L3.

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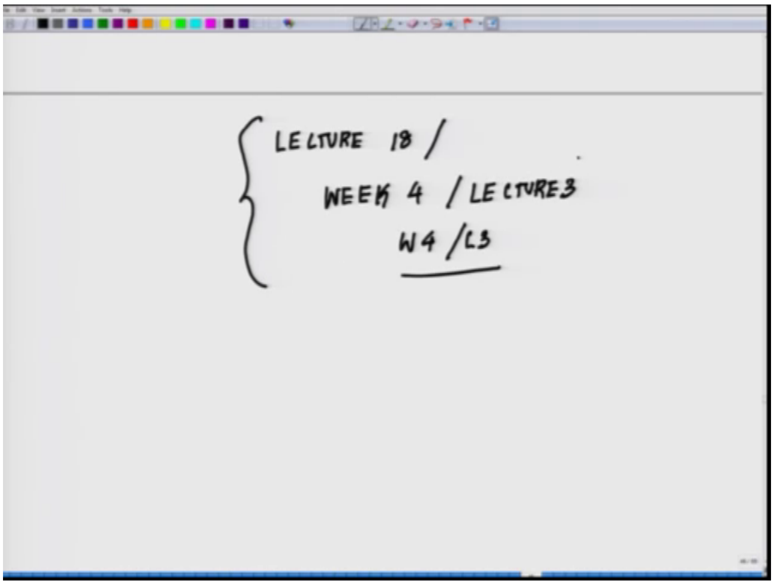

So, this is what we are going to deal today in the last lecture where, I forgot to mention which was our previous lecture which was our lecture 17 where, we talked about the red drop ok, which was week 4, lecture 2, 1617 W4 l2. We talked about it now, coming back to here out here.

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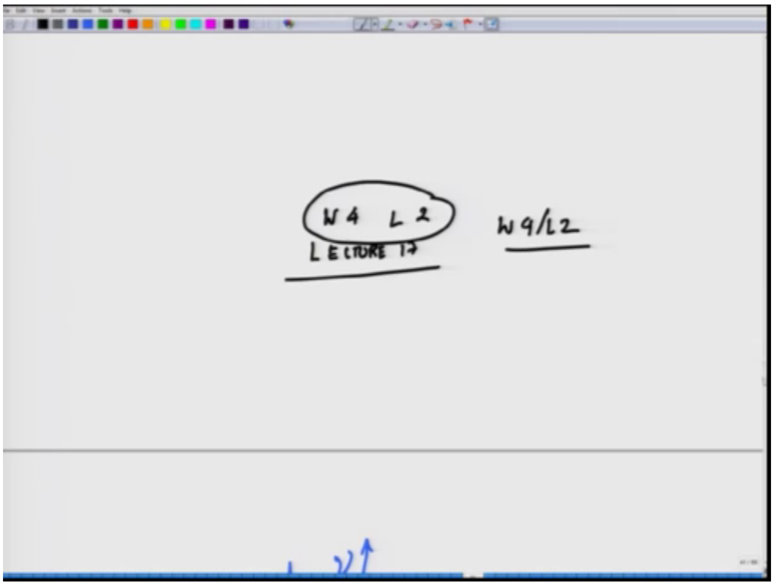

So, water molecule, which is being entrapped in the manganese cluster and the manganese cluster then, donate from the manganese clusters the water getting split up and the oxygen is being evolved, and that leads to a proton gradient and electron is being funneled to P680, which is the photosystem 1, photosystem 2 to bring back that chlorophyll molecule, which is devoid of that electron, and that electron on the contrary which is being ejected out now, transfer its electron to one of the first donor in the field, which is sitting out here, which is called pheophytin Ph; the electron hops like this from pheophytin you have the next redox potential rate is going is 0.4, which is QA which is.

So, here as soon as you see this; so, technically the QA has a higher power to accept an electron, but there is something very interesting especially in terms of space pheophytin is much more close to P680. So, physically if you if I go back to the very first lecture.

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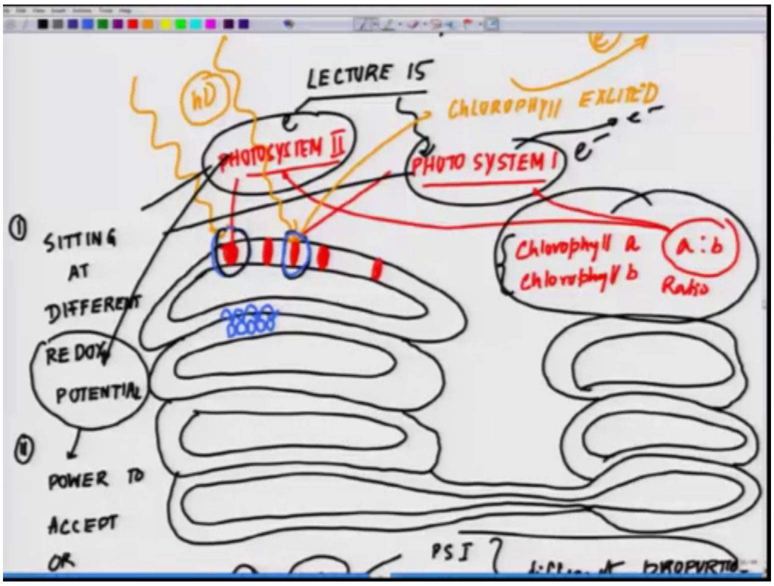

So, the electrons or the electron acceptors are arranged in a special location like this. So, when the electron is hopping; it is hopping like this. So, if the position changes then, electron can directly move if some way or other position changes can directly move from P680 to QA quinone these are all the quinone molecules. Then, the next quinone is sitting at around less than, 2 which is out here the electron coming to quinone B , from quinone B it is sent to QH2 ok, the electron is now, hopping and that QH2 is sitting at close to 0 almost somewhere out here, QH2. From QH2 it moves to something called cytochrome bf complex where, the electron is being funneled cytochrome bf complex ok, from cytochrome.

So, this is another site where, we have a proton gradient. So, you saw a proton gradient site at water splitting cluster. So, here is another proton gradient site and we will talk later about it, what is this proton gradient site is doing? From here the electron shifts to 0.4 there is something called DC plus to sign in where, the electron hops.

So, if you see from plus to sign in and just close to plus to sign in is sitting P700. Now, this is the location of your so, this is where, we are drawing the line between photosystem 1 and photosystem 2. So, this is where, you have the photosystem 2 and here you have photosystem 1. So, now the electron has reached photosystem 700 you know interesting now, this is the point I want to make, I told you the electron ejected it reaches minus 0.8 redox potential. Now, P700 there is an electron, which is ejected out because, when the light falls here.

So, light has fall I have showed you it has fall oh sorry light has fall here. So, now, from here the electron, which is ejected reaches all the way between 1.2 and 1.3 somewhere out here, is where the electron reached. And this chlorophyll, which get excited is brought back to its ground state by the electron which has hopped here.

Now, while observing this try to realize a very interesting phenomena what biology is doing. We always talk about the speed of electron transfer governs, how fast the signal can be transmitted from one spot to another? Interestingly here, as if it looks like biological system does it in a very different way. it slows down the electron transfer. Because, when the electron is hopping like this if you think of it for a minute if it is hopping like this hopping like this hopping like this hopping like this.

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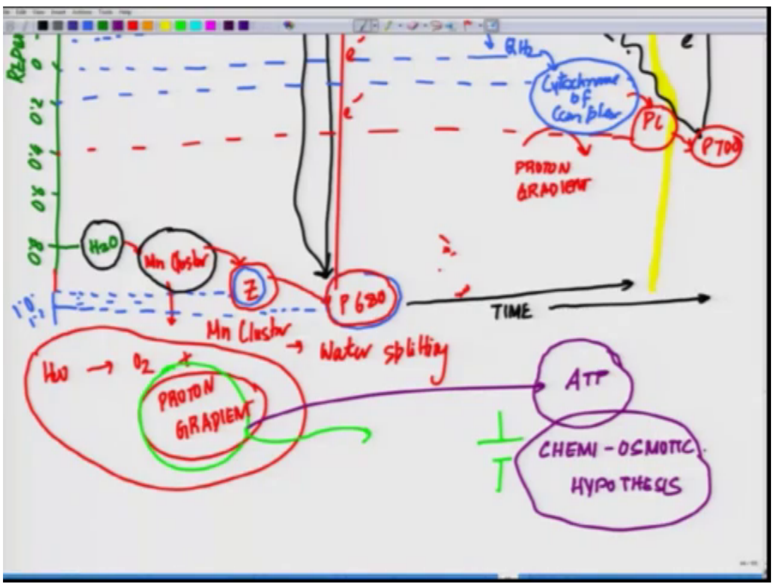

So, on the x axis what is increasing is the time? But what is the utility of this time? Why this process biology does in a very different way than a normal information transfer? Did it ever wander? Did it ever strike you? Possibly during that process say for example, I say that you know I have say for example, I have a battery and this battery is getting charged and getting discharged.

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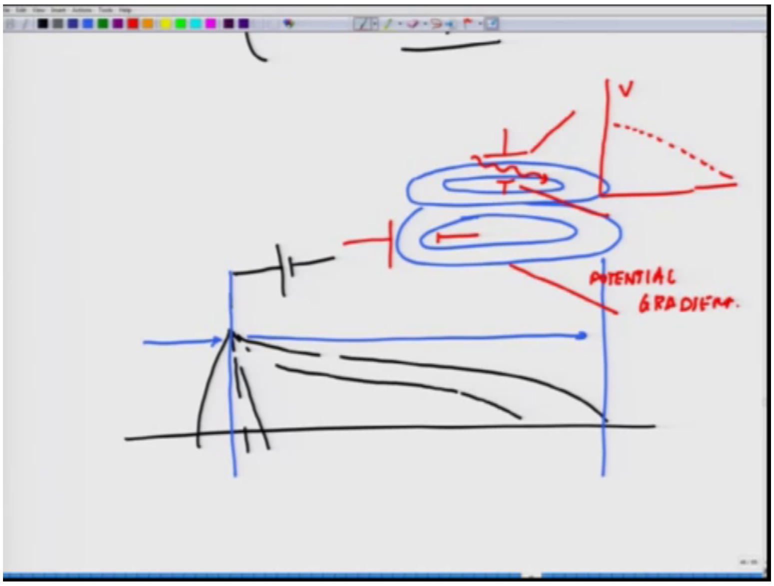

So, how I want the battery to get discharged? It can get discharged like this, it can get discharged like this, it can get discharged over a period of time like this or it can take longer time ok. So, biology is almost like if this is my charging curve this is the side, which is showing the charging time. So, I want the discharging time to be longer exactly something like this, analogy biology is falling as if its chloroplast is like a battery charge of the electron and electron is slowly coming down and while it is doing so, across the membrane.

So, if you remember there is chloroplasts membranes you remember? This is how I was drawing the thylakoid membrane. Now, I am introducing a very interesting thing across the membrane, it is generating a kind of a polarity something like this, do not worry about the sign, which side I am putting positive and negative it does not matter that is irrespective of it, but while the voltage is dropping like this.

So, here as if I had to put a voltage graph. So, the voltage is dropping like this, while the voltage is dropping like this across this membrane; it maintains a potential gradient and this potential gradient is what? We were talking about in out here, as proton gradient. This proton gradient of what I am trying to bring an analogy of a battery or a cell or something like that is the one, which is the governing force for synthesis of the biggest energy rich molecule, which biology is being utilizing in the current stage of evolution called ATP.

A weak reductant and a weak oxidant adenosine triphosphate, adenosine triphosphate is governed by proton gradient and we will talk about it, how this is being postulated based on the chemi osmotic hypothesis? Which is essentially will be our next class or some of the concluding class will talk about the chemi osmotic hypothesis. So, what is important for you to appreciate out here, that biology buys time unlike a straightforward transfer it does not do it like that, it does it in a very interesting way, but it has its own significance and the significance is out here.

So, you realize. So, it created a proton gradient here, it created a proton gradient here and there is another place where, it will create a proton gradient. So, we have reached this far where, from photosystem 1. Now, the chlorophyll is being brought back, but what is the fate of that electron? Interestingly that electron will donate through series of customers and eventually it will reach to the strongest reductant, which is sitting which is NADPH in ADP which is becoming NADPH NADP plus. So, this journey from I will redo this journey from minus 0.6 and 1.3 volt minus 1.3 volt. So, I will do it in another graph now ok, what is happening to that? This is in continuation with what I have already done?

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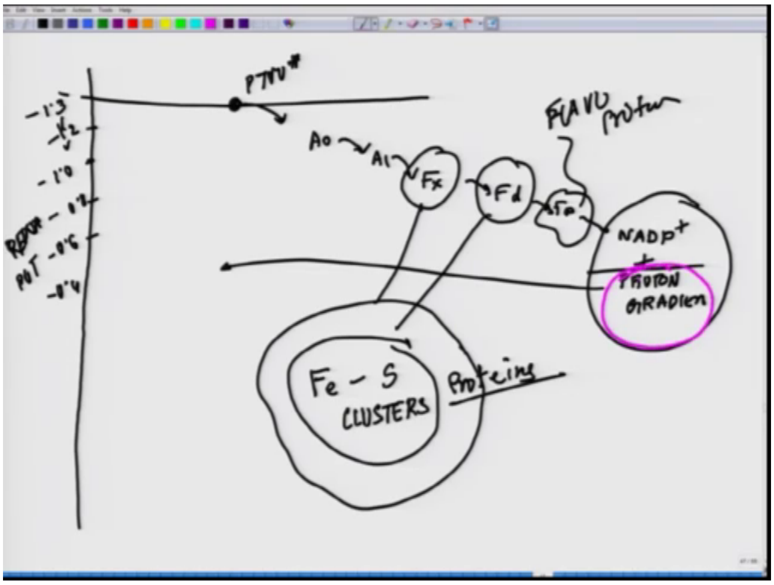

So, photosystem 1 out here, it is sitting at around 1.3 minus 1.3 volt of redox potential a redox pot ok. So, out here you have minus 1.2, 1, 0.8, 0.6 and. So, the electron reaches at 1.3 from here, from P70 electron this electron transfer it to acceptor called A 0 from A 0 it is transmitted and these are all mostly A 0, A1 an acceptor of electron from P700 and from A0 it is moved to A1 and it one second let me just mark it 0.4 and 0.4 where, essentially your NADPH is sitting ok, A1 from A1 it goes to Fx. Now, is what is very important for you to realize, which will take you back to the very first lecture NADP plus proton gradient. Now, if you look at these compounds these are all iron, sulfur, clusters embedded on proteins and this is precisely is the reason.

So, these are the different electron acceptors, which are iron sulfur centers then you have Fp as the fiber proteins, you have ferredoxin, NADP plus reductase and series of them it is not important that you know all the names, what is important is Fp is your essentially your, Fx is your iron sulfur center, Fp is the fibro protein, once again this (Refer Time: 15:07), which is the fiber protein and these are the ones, which are involved in hop making the electron hop and reach the NADP.

So, what I wanted to highlight here is, as the electron hops through there are at three different location a proton gradient is formed as electron flow through cytochrome bf from photosystem 2 to 1. So, there are three locations of proton gradient out here, one gradient and if I go back on the second-place spot proton gradient, third spot where your proton gradient. So, these are the three spots where, proton gradient is being created and photosystem 1 generates NADPH by forming reduced ferredoxin, which is a powerful reductant.

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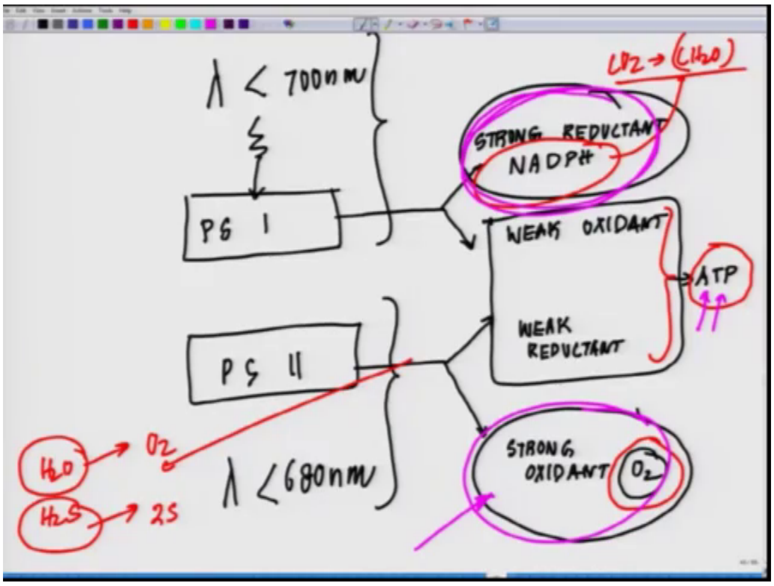

So, that brings us to this concept a very powerful reductant, which is formed here and a strong oxidant which is coming from photosystem 2. So, photosystem 2 is involved introducing a strong oxidant photosystem 1 is involved introducing a strong reductant and both this system generates at three different spots known proton gradient, which is involved in the synthesis of ATP. So, now, if you see this whole thing in one spectrum then, you will see the whole energetics kind of clubs down here, is your energy rich molecule called ATP synthesized by a proton gradient.

So, these are some of the most fundamental bioenergetic reactions, which dictates the evolving life on the floor of earth. So, if any of these one can mimic now, if you talk about the manganese cluster this is one beautiful situation where, if you look at the cluster the it looks like it is something like, a manganese let me just give you a bit of overview manganese iron plays a key role in extracting electrons from water, so manganese ions plays a key role in extracting electron from water, in other word they are water splitting they are splitting the water molecule and while splitting the water molecule the way it works manganese stays at different oxidation state as you know from oxidation state 2 to 6 manganese can stay in different oxidation state and a different oxidation state it maintain itself a different oxidation state, and in that process it generates a certain amount of force which is still till this date it is not known. So, here is the water is entering the manganese cluster and at different stage it rolls through and ejects the electrons, which here is oxygen coming out and here is the proton, which is coming out which can become H2 of course, but it can also use for creating the proton gradient.

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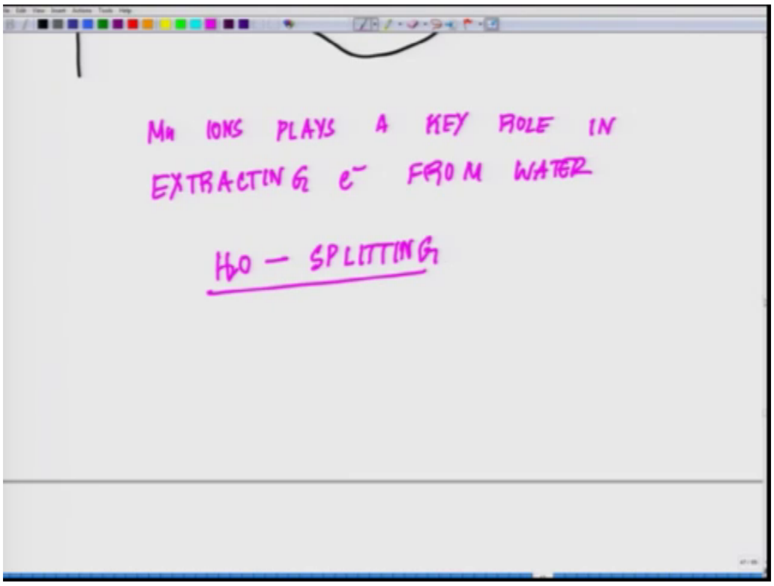

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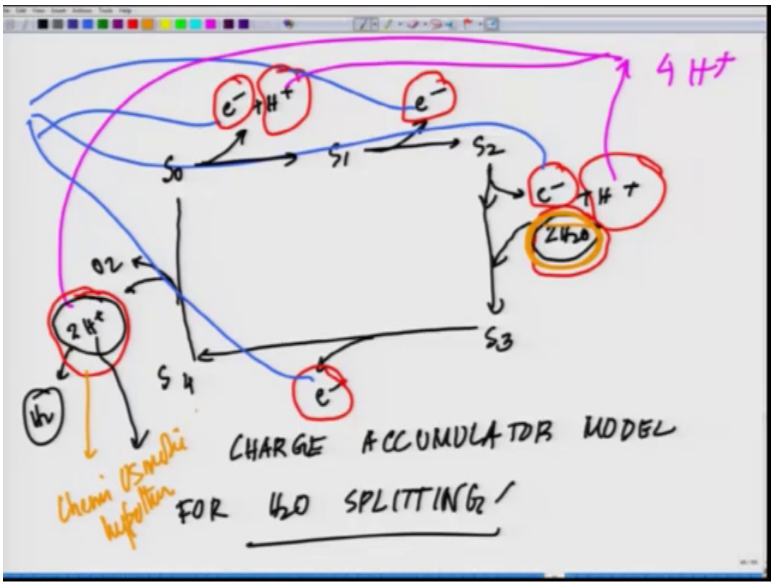

So, this is how the charge accumulator model for splitting water by manganese center or photosystem 2. So, this is basically called the charge accumulator model for water splitting. So, this charge accumulator model for water splitting is the sequential withdrawal of four electrons.

So, this is what is happening here, sequential withdrawal of four electrons electron 1, electron 2, electron 3, electron 4, these are the four electrons sequential withdrawal of four electrons by P680, which is P680 plus drives the formation of oxygen from two water molecules here, are the two water molecules which are entering into the cycle which are getting trapped and four protons are released, which are two protons are released here one proton is released here, one two and the third proton is released here. So, in terms of the proton economy these are the four protons, these are the electrons and yes, and input you have two water molecules which are entering and this is the input.

So, the weight charge accumulation model works is the manganese remains in multiple oxidation state 2, 3, 4, 5, 6 likewise. So, at it is said there are at least 4 manganese atoms sitting in the cluster with different oxidation state and they could change their.

It has been designed in such a way they could change their state only one like in that they can and they can come back to their own state it can do a flip flop it is kind of a bi stable switch like from 2 it can go to one or it can go to 3 the one standing at 4 can become 3 and 4 the one standing at 5, can become 6 or 4 likewise and its peculiar it is not known I mean the day this whole mechanism will be clear, based on high in crystallography or cryo em electron microscopy will be a d day this if you want can.

But as of now what we know is that, two water molecules get trapped four protons are being released four electrons are being released and this way the global energetics is being governed and those protons will lead us to what we talked about chemi osmotic hypothesis ok.

So, I will close in here, and in the next class we will move on to the chemi osmotic or the proton gradient.

Thank you.