Bioinorganic Chemistry
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Lecture - 5
Electron Transport Proteins - I

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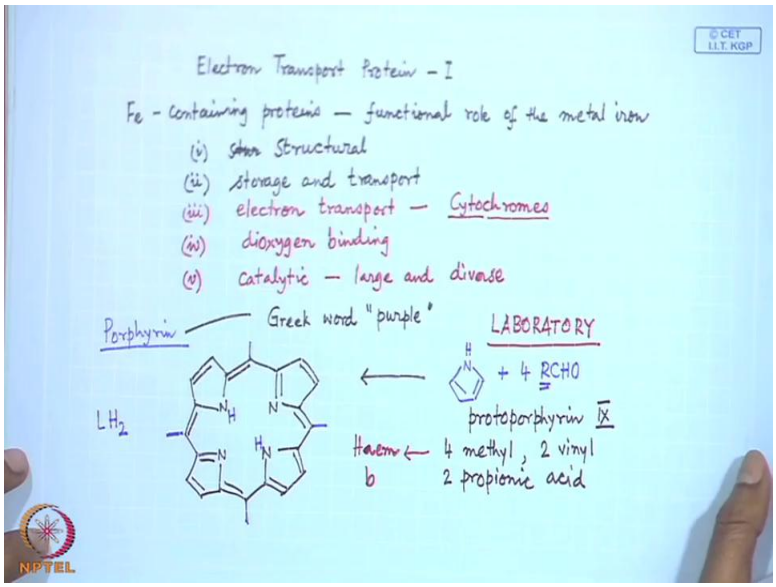

Hello. So, today we will start from electron transport proteins. In the first part we will deal about some of the important molecules, which are basically iron containing proteins. So we will have iron containing proteins, and we will think about the functional role, basically which is very important to know how iron is functioning therefore, a different type of reactions. So we will think about the functional role of the central metal ion; that means the iron.

So, in all these molecules, it can play one part as a structural role, and in some other places what we have discussed earlier that these iron containing proteins also function as, storage and transport. And next is what we will be talking today, is electron transport, which we all know they are very important molecules, cytochromes. So they are present within the cell, which we all know that they are the cytosols, and they are very much colored; that means, they have some chromophoric part, which is responsible for color absorption, so they are our cytochromes. And also we know their function in dioxygen binding, in hemoglobin, and myoglobin molecules. And we will discuss little bit about

their catalytic function, which is also very important; therefore, they are large and diverse in nature.

So, the main backbone of all these molecules, are our prophyrin molecules. So, we will have the porphyrin in the system, so the heme proteins we all know. So, this porphyrin molecules, they are giving rise to a four nitrogen atoms to the iron center, and this particular name has a origin for the Greek word purple; the strongly colored. So, invisible spectroscopy also helps us, the presence of the cytochromosine fat. They have been determined first, by knowing the corresponding characteristics spectra of all these molecules.

So they are all the porphyrin presents, and which is a basic part of it, and this prophyrin as the single unit as the perol, and we have the tetra parole unit. So this tetra parasol unit will get, so it has different substitution positions. So, depending upon the different substitutions, they are of different types, that we will see afterwards, but at the same time, when people discovered these molecules an interesting molecules for the different activities, and one of them has been identified as the protoprophyrin.

They have the typical nomenclature for their different substitution, and some time they have the historical origin also. So, when this particular backbone have four methyl, two vinyl, and two propionic acid; that you should little bit remember, that what are the different substitutions, because these substitutions play some important role, while we talk about some heme proteins, or some heme b proteins in hemoglobin and myoglobin and the cytochromes. So, when these substitutions we have we get a heme b molecule, and when people made this molecules, they are also interested for laboratory synthesis. So, we all the time you can have, the corresponding molecule in the laboratory, you make the molecules and how the meddle complexes in this taking place, in presence of the iron that people can compare.

So, this is also very simple reaction of four molecules of petrol with respective aldehydes. So when you use formaldehyde you get CH2 designing; otherwise we can have also some substitutions at these positions, so all these positions can be occupied by this R CHO. So this particular basic unit it will we can have. So, we have the four nitrogen's and these two have hydrogens only. So, basically we get a ligand which is LH2 type, so you have two nitrogens having, where in protons and those two nitrogen's

can go for the deprotonation, while it is complexing with the iron center, when we gave for the good for the corresponding heme protein.

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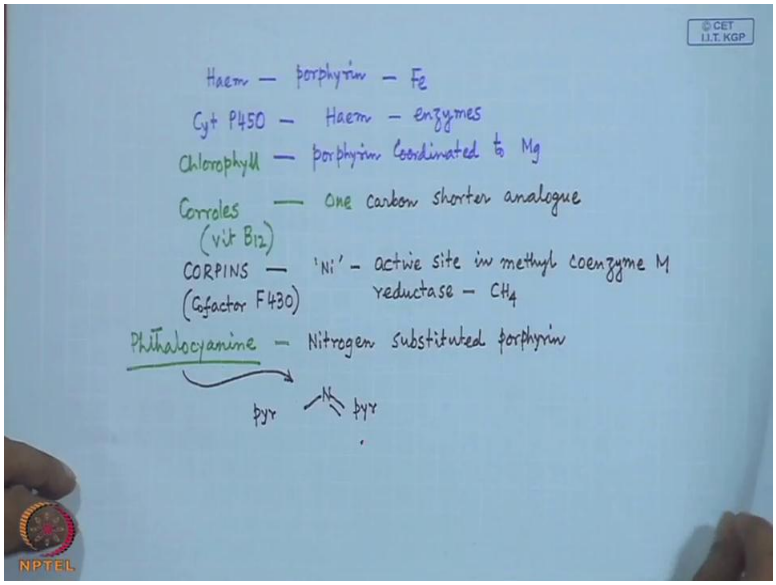

So, this particular unit when we get. So, we know already that, we get the heme proteins when the ligand is here porphyrin. So, it a microcyclic ligand. So, that porphyrin which is coordinated to your iron, then one class of molecules we will talk about which is cytochrome p450. So, they are also heme containing group of enzymes. So, there are some kind of enzymatic reaction they can. So, an enzymes then we all know how the different metal ions can change the molecules. So, the same porphyrin can be used, for coordination to magnesium. So, when porphyrin coordinated to magnesium. So, this particular ligand is very useful to give you chlorophyll. Then for one another type of microcyclic in we get, which is one sort one carbon sort or analog which is known as corroles in vitamin B 12. So, we will have the corroles which is present in vitamin B 12. So, it has one carbon sort of system, so one carbon shorter analog.

Then we have another group of molecules known as corpins c o r p i n s, which is present in cofactor f 4 30. So, which is highly reduced porphyrin, but now it is coordinated to nickel, and nickel is showing presence of this microcyclic ligand corpin. A important reaction which is present in the active site in methyl co enzyme m reductase, which is required in methane producing bacteria, and is the last day for the production of methane. So, in this the background when we have, the four peroll units, and four peroll

units are connected to each other and they give some implant coordination; that means, when it is connected to iron, you have four implant coordination which has satisfied by four nitrogen in it, and another group of molecules people have tried and synthesized in the laboratory, which is known as phthalocyanine, and here we get some of these carbons substituted by nitrogen.

So, they are known as nitrogen substituted porphyrin. How they are substituted in the back bone, what we have we have seen that we have that methelene connector. So, you have the peroll unit on the one hand, and another peroll unit in the other hand. So, basically some time also during the ligand synthesis we can connect two peroll units by a methylene or methine bridge, but when these are substituted by nitrogen. So, nitrogen and this double bond so these molecules are known as therefore, phthalocyanine people have tried to make all these molecules, and their reactivity with the different metal centre people have tried, because all the time when we try to give the compound, until and unless we make the compound nicely and go for the structural determination, we always relay on the spectroscopic thing.

So, spectra will always compare. So, if you have the model compound, and some of this cytochromes or hemoglobin or cytochrome p, p for pitied type of molecules. We always try to compare those spectra with the molecules compounds, and then try to say that this has this environment and that is giving some important reactions, related to that iron centre, because we are not going away further or far away from the iron centre. So, what are our cytochromes.

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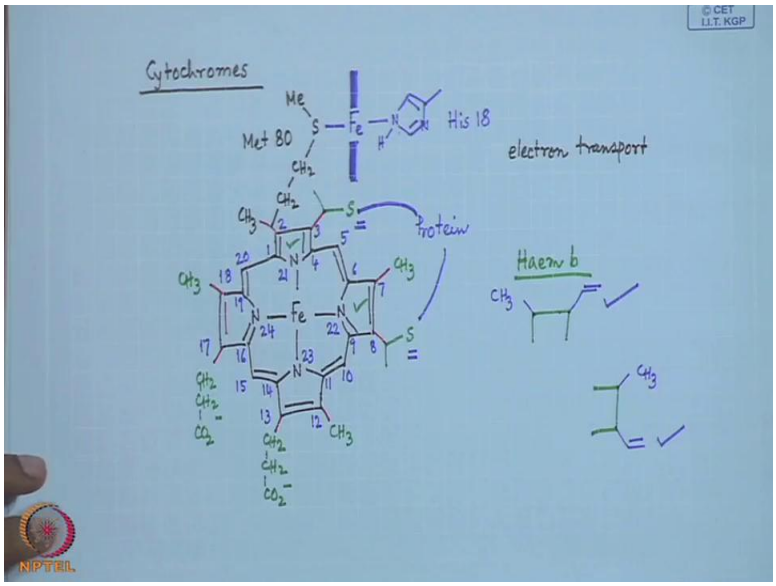

So, ligand has been defined, or identified that we have this particular ligand environment, and within that ligand environment, as we know from our knowledge form hemoglobin or myoglobin type of molecule, that we have the iron centre, and in most of these drawings we will see that this is your porphyrin plane. So, here heam the other form the plane of this porphyrin rings, only this particular part is available, and then we have the fifth coordination site, and the six coordination site. So, when we have these, then here it is connected to some emmiter jole side chain, emmiter jole side chain of some of the long protein chain, which is in this particular case is histidin 18. So, this particular environment we all know that this was present in the myoglobin molecules. So, you have four coordination sides coming from the microcyclic porphyrin ring, and the fifth form the histidine emitter jolie ring and this particular side six side was available for binding to dioxygen molecule, but in this particular case this is also connected by methylene sulphur.

So, metheninin group we known that, amine acid residue from the metheonine is s methyl group then you have the c h two and c h two function. So, this is methonine 80. So, all this six coordination sides are fulfilled. So, you have a nice octahedral iron centre, and that iron centre will be responsible for our electron transport. This will be responsible for electron transport, but what is the difference between these, with that of our heme protein which is present, or the heme is group is present in that myoglobin or hemoglobin molecule that we can see, that in this particular case, we have that iron

center, and this iron center is bound to four nitrogen's of the porphyrin ring. It is very easy to draw, because we draw the four porphyrin ring, and then we connect it, so have the unsaturation the positions. So, you have no choice for the different substitutions what we have seen, that we can have the substitutions.

So, these are the positions. So, you have one two three four five six seven eight, eight positions for the different substitutions, and we basically number it, starting from this carbon. So, if this is one, the next is two, this is three. Then four five six seven eight nine ten eleven twelve thirteen fourteen fifteen sixteen seventeen eighteen this is nineteen twenty, after this point twenty, then this nitrogen is numbered as twenty one, second nitrogen is numbered as twenty two, third is twenty three, and then twenty four. So, all the positions we have numbered. So, numbering is very important, because most of the cases, because the different types of cytochromes if we say the a cytochrome a cytochrome b cytochrome c d etcetera. So, we will talk about only the substitutions, because all these substitutions play some important roll, particularly their (()) how they bind and their corresponding shapes also.

So, when this particular cytochromes are there. So, you have one is the methyl substitution at number two, then you get something, what is that sulphur. This is methyl, this also sulphur, this is this is CH2 CH2; that means, the propionic acid function we all know, form the hemoglobin and the myoglobin molecules. So, this is also a propionic acid, and this is CH3, see if we just simply recall that what is our heme b system? In heme b system the upper porphyrin ring, these two are different; the upper one, this one and this one, those were having methyl, as well as on the right hand side you have the final substitution. Here it was methyl but this your final substitution. So, what is happening they are now, this is the only difference with that of hemoglobin and myoglobin molecules; that now you have a protein chain. So, protein chain is coming close to the porphyrin ring, and it has two cystenal residuals, and those cystenal residuals are attaching, or attacking rather to the final ring, so final substitution.

So, you have a thioether linkage direct thioether linkage with the protein chain. So, now your porphyrin ring in your hand and that is now embedded within the protein chain, how the protein has only the castle residuals. So, correctly disposed cystenalsulphur residues what they are, and those are reacting with this final group and this final group . So, these two final groups are attacked and you get a strong protein chain, and that

protein chain attached to the porphyrin ring. So, what is the difference with that molecule, is that cytochromes, the protein varying two sulphur ends now covalently attached to the microcyclic ring, which is your porphyrin ring; that means, it is the activity pattern and all the other things will be completely different to that of your myoglobin and hemoglobin molecules. So, this particular one; that means, you have these four groups from these, and you have the fifth and the sixth positions from the hystedine as well as the mythelene sulphur. Now you have a typical octahydral molecules in your hand, and that octahedral molecules will basically give to us some electron transport chain in mitochondria. So we have mitochondrial electron transfer chain.

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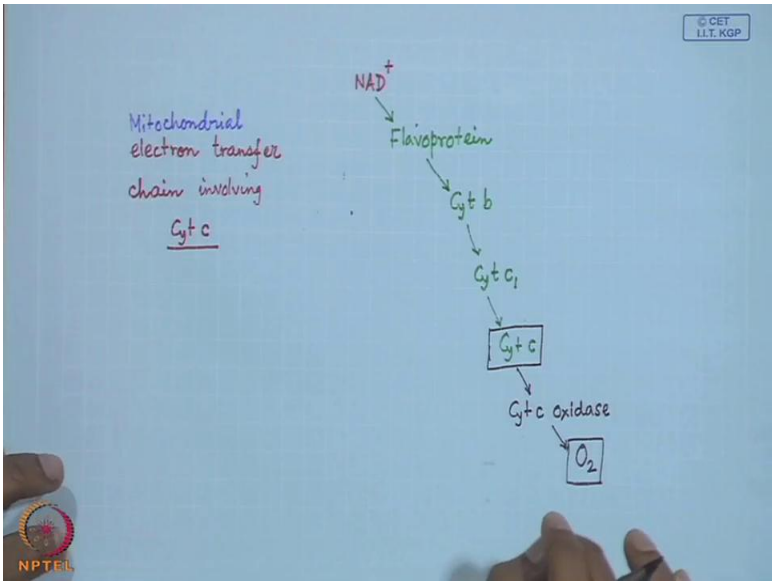

So mitochondrial electron transfer chaininvolving our cytochrome. One molecule will study is your cytochrome c. So, there are large number of molecules. That basically the difference between these is only in the porphyrin chain. So, basically this is very important chain, will start from some biological using agent nicotenamyde and nelucotide in the oxidized form. So, you have n a d plus we write, and the other form is n a d h it is a reduced form. So, so at one end you have this then you have flavoprotein. These are all biological reductance, so this flavoprotein will then transfer the electron to cytochrome b, then to cytochrome c 1 to cytochrome c. So, there we have the cytochrome c, where it is. So, these up to this point we get that cytochrome. So, cytochrome c what will use it has some important role to play in the electron transfer

chain in the mitochondria; that it accepts electron form cytochrome C 1 and donate the electron to some other molecule which have known as cytochrome c oxidase, why these are known as oxidase, because these are the responsible for oxidizing your cytochrome c. So, on the right hand side what we get. So, it has high potential.

So, the cytochromes c oxidize can function as an oxidizing agent, for your cytochrome c, and it is a very complex molecules, little bit we will see afterwards, that how cytochromes see bearing iron beaingprophorineplay some important role to oxidize cytochrome c. And lastly this will end up in dumping electron to O2 for our respiration. So, the mitochondrial respiration what we use, and we bond our glucose material or any other food material. So, you bond this material; that means, the glucose material, with the help of your dioxygen molecules. So, ultimately these dioxygen molecule is accepting four electrons, and dioxygen molecule will be converted to water molecule. So, this is a long chain, and this particular long chain, will see the different steps, depending upon the difference in the corresponding e zero values; the redox potential values. So, all these molecules will have a typical e half values. So, we have a characteristic e half values for all these biological molecules.

So, those who are on the right hand side, should be able to oxidize the species on the left, because you know that this is the strongest possible oxidant in your hand, and some where here above this N A D plus, we have the glucose molecule. So, glucose is getting oxidized by your dioxygen molecule, but we are not allowing this dioxygen molecule directly, to react with the glucose molecule; otherwise that will be a binding process, so in a stepwise manner, depending upon this electrons transfer chain.

So, this chain is required, such that you can have in a stepwise fashion oxidation of these glucose molecules or any other food material by the dioxygen molecule, and depending upon the difference in your differ e zero values, we have the corresponding required amount of free energy change at these reactions, and those free energy change for this different reactions, will be utilized for our A T P synthesis. So, the basic goal for getting all these things that how we use the cytochrome c, and how this cytochrome c is useful for all these reactions, to produce our different amount of A T P molecules for our energy purpose.

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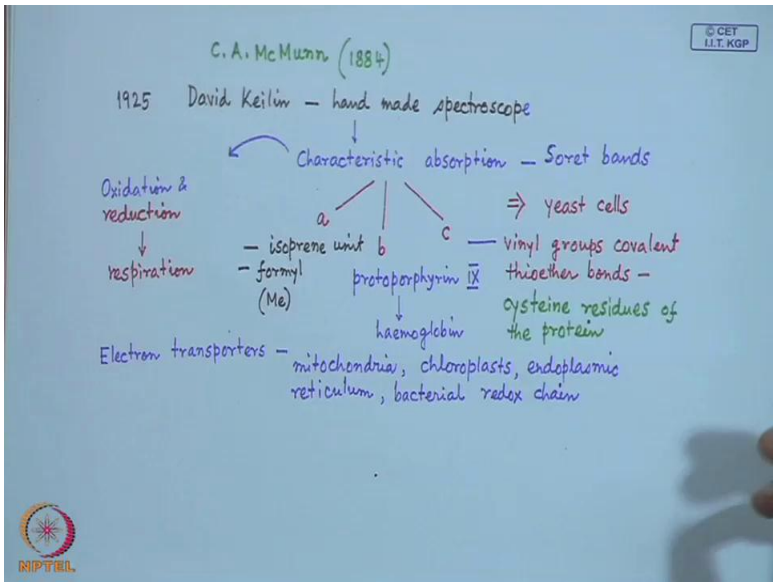

So, this interesting class of molecule, the cytochromes are first discovered by a man which is C A McMunn, you should know little bit about the history, it is not very old molecule, it was discovered in 1884 only. Then the total characterization was made, and people proposed that it has a corresponding porphyrin ring or the iron ring, is done by another man who is David Keilin, what he did. He has a handmade spectroscope. So, here has to relay on , the determination of the spectral behavior, or the spectral property of all this molecules. So, porphyrin rings what we have seen, they have a very strong and characteristic absorption spectrum, and that characteristic absorption if we are able to monitor. So, we have through these handmade microscope, sorry microscope we have the characteristic absorption, and these characteristic absorption are known as soret bands.

So, whenever there is a porphyrin in a system, so in all the biological fluid or in the biological liquid sample. If we suspect that there is a cytochrome molecule; that means, the porphyrin ring is there. So, we must detect the corresponding solid band in to the system, because in all these electron transfer molecules involving there, they are responsible for different types of oxidation, and reduction reactions, because those reactions are responsible for our very survival; that means, respiration, how we utilize dioxygen molecules for this respiration. So, this particular system has, when we are getting the characteristic absorption band. So, we will get three different types basically

in that nature of the heme group. So, cytochrome a we can have, cytochrome b we can have, and as well as cytochrome c, and they are first characterized in yeast cells.

So, these nature of these corresponding porphyrin ring will tell us, that if we have a b type cytochrome present, which is nothing but a protoporphyrin nine. Just now I told you that it would be protoporphyrin some numbers is also tagged with it protoporphyrin nine, and which is also present in hemoglobin, same porphyrin, the porphyrin is also present in our hemoglobin molecules. Then a type cytochrome is a different one, with regard to that of our substitution, and in this particular case, we have a hydrophibic tail of isoprene group. So, we have the isoprene tail is present, plus a formyl group, in place of our originally present methyl substitutions. So, nothing is changing there, only the substitution is changing from one to the other. Then we have the final group attached porphyrin nine for cytochrome c, and we have a covalent.

Now the difference is that already we have seen, that it has the final groups found, present in the ring covalent bond, covalent thioether bonds, with whom, with cysteine residues of the protein. cysteine residues of the protein. So, they all present, and everywhere, not only in the mitochondria, so they are known as basically the electron transporters, who are responsible for transporting electrons. So, they are basically electron transporters, have already seen that they are present in mitochondria, they are also present in chloroplasts, then endoplasmic reticulum, and different bacterial redoxchain as well. So it is not only present in the human system, is present in plant origin, it is present in bacterial origin also. So, in bacteria also they play the redox transfer, so in bacterial, redox chain. So, we have now iron centre, which is satisfied from its all coordination demand; that means, they are all hexa coordinated. So, all six positions are attached, to the ligand as well as the other groups, coming from the protein chain.

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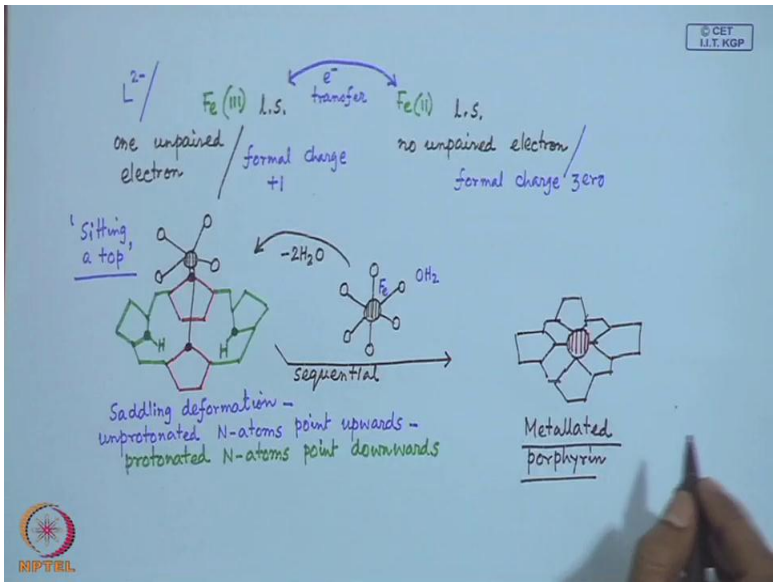

So, we have the iron centre. So, it has only option now, that it can settle between a oxidation state of F e III and F e II, and at the same time, will just talk about the corresponding spin state, weather this iron center is in the high spin state, or the low spin state, and those spin states will be dictated by the ethical binding donors; that means, the donor atoms which are coming from the fifth side, as well as from the sixth sides. So, this thioether binding, the thioether sulphur binding is a strong binding. So, that gives us only the option for low spin. So, we will just settle between the iron three that is the ferric iron, as well as the ferrous iron, but both of them are in low spin state. So, in this particular case what we it have, it will have one unpaired electron. So, it has one paired electron. And at the same time it has no unpaired electron.

And the porphyrin ring is given a charge of l 2 minus from the deformation, because two of the nitrogen atoms are barring the hydrogen atoms. So, it has the l 2 minus in this particular case, it has a formal charge of plus one, and in this particular case the formal charge would be zero. So, by settling between these two, it will felicitate the electron transfer. So it will be responsible for, until and unless some modification is taking place, it will not go for a five coordinated species, what we get for our myoglobin or hemoglobin molecule; that means. One position is vacant which is occupied by water molecule. So, until and unless something you do for these; that means, you take out the thioether molecule or the hysterine residue, you cannot transfer this particular centre to a

five coordinate at one. So, until and unless you make it five coordinated, it cannot bind to dioxygen molecule.

So, that will see afterwards for some other type of molecules, that how you can make this tetraperol nucleus to a five coordinated one, which will be useful for binding the dioxygen molecules. So, regarding the structure of this porphyrin ring it is a basic structure. I am just coming back again from one structure to the another. So, if we just simply able to draw in this form, the three dimensional structure, bearing four petrol unit which is a little bit different one, what I have drawn right now. So you have these nitrogen bearing rings here, then have other two rings; that means, the petrol ring which are bearing hydrogen. Similarly the other one is also like this, they are connected. So, what we have from just now is different. So, it has a (( )) structure. So, two of these terserinitrogen's divide of hydrogen atoms are pointing upward, and two N H groups are pointing downwards, in a three dimensional structure.

So, which is going to accept our iron centre, which is supposed to be octahydral one in the bear form also, when it is attached to six water molecules. So, this is our OH2, this is our iron. So, what will happen, so this particular structure, which is known as a corresponding out of plane structure. So, is also known as a deform structure, as a seddling deformation, what is that, how it is known as this is then; that unprotonated nitrogen atom, these are all unprotonated nitrogen atoms. So, unprotonated nitrogen atoms point up wards, and next the protonated nitrogen atoms points downwards. So, the protonated atoms point downwards. So, what will happen next, that you bring this iron above it.

So, these two nitrogens will be available from the top only, so your iron will come over here. So, we are bringing this on this. So, this is your iron, so it will form two bonds; one with this nitrogen, and another with the second nitrogen. So, it will have four remaining water molecules, so this is a very week interaction. So, iron centre is forming by losing two water molecules. So, it will immediately loose, two water molecules and will sit above the particular porphyrin seddle structure, and this particular structure is also known and considered as this iron is sitting atop complex, is known as sitting atop complex. Then what will happen, this next step is the important step; that means, you can go for sequential depotonation of the two (( )) nitrogen atoms; that means, this hydrogen

and this hydrogen one after another will go. So is not a immediate one, but a sequence, so sequential (( )) of the two petrol nitrogen groups.

So, when they are depotonated, they will start interacting with this iron centre, and ultimately you get a metallated porphyrin, so all four bonds are formed. So, it is not only true for iron, but is also true for other useful metal irons, which is giving rise to some important molecules like chlorophyll, or vitamin B12 in case of corine molecule where we get . So, now, the porphyrin is sitting comfortably, within the cavity of the petrol ring. So, within the ring, we get the corresponding metallated porphyrin. So, this is the way how these molecules are forming, the corresponding complex with iron, with nickel, with cobalt, and this will give rise to your cytochrome molecule at the same time. So, we have with this molecule 2 HCL ligands.

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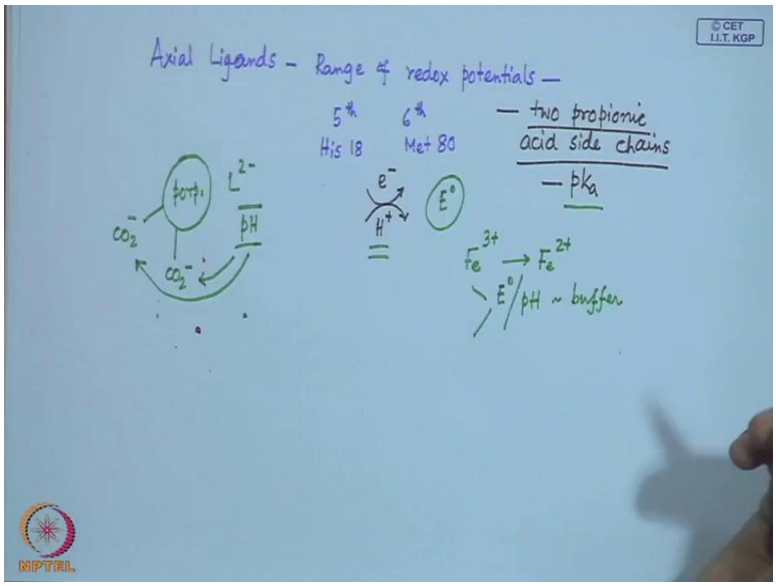

So, these axial ligands, play some important roll that means form the position number 5 and 6, they basically control the corresponding range of redox potentials. So, the binding of these two groups; that means, the binding form the fifth side, as well as the sixth sides, which one is your histadin 18 and metheonin 80, this two you should remember nicely. So, these two groups basically control our ferrox potential, at the same time, if we control the ionization of the propionic acid side chain, because you still have two propionic acid side chain, which have a typical values for the p k a's. So, in all these cases what we will see, in all these electron transfer chain, will just see the detail of

these; that means, whenever there is transfer of electron from one side to the other; that means, in the biological system, we have the membrane, and along these membrane electron coming from one side to the other, at the same time we will see the proton is also going from one side to the other.

So, proton is always playing some important role to play, not only that in which direction the electron is going, and how the proton is of moving, in the opposite direction or some time both of them are going together; that means, the electron is moving, as well as the proton is going for your deprotonation and from the periphery of these porphyrin ring. You have the two propionic acid side chain, and those two propionic acid side chains will go for the different deprotonation. So, you have the microcyclic ring, and here you have this chain, and here you have the chain for the propionic acid groups. So, this particular ligand, which is functioning as l 2 minus to the deprotonation of the nitrogen atoms only. So, we are not considering the corresponding protonation as well as the deprotonation of the propionic acid side chain, by depending upon the availablethe p H value of the system; that means, in which particular part of the cell, or in the biological system where you have a typical p H.

So this particular p H will control this corresponding protonation level, of these protonic acid side chain, so this is nothing but your porphyrin. So, that particular protonation will control our different e zero values. So, this particular proton will also behaving as a valve for your electron transfer, because sometimes if it is a metal centre electron transfer ,will see that iron 3 plus is reducing to iron 2 plus, and we can have a typical e zero value, and in the biological system, if we are able to determine, the corresponding p H, we all the time if it is dependent on the corresponding proton gradient or the p H. So, the e zero value we have to report, against the different p H values. So, this p H value you should also know the corresponding buffered medium. So, if you have a acidic buffered medium and if you can have a basic buffered medium, you will get two different e zero values. So, basically the p H, the proton in the system will control the corresponding e zero value, whether you that cytochrome will accept the electron, or whether that cytochrome will donate the electron, within the environment you can have the corresponding protein chain and all other thing as well as you have the corresponding proton gradient, that will control the different e zero values.

Thank you.