Basics of Biology
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Module - 3: Cells in Biology
Lecture 12
Basics of cells (Part 2)

Hello everyone, this is Dr. Vishal Trivedi from Department of Biosciences and Bioengineering IIT, Guwahati. And in this module, we are discussing about the different types of cells. So, cell could be of based on the structure. So, cell could be of two different types, it could be a prokaryotic cell or a eukaryotic cell. In the previous lectures, we have discussed about the prokaryotic cells, we have discussed about the structure of the prokaryotic cell and how the different components are present in the prokaryotic cell.

We have discussed about the cell wall; we have discussed about the different types of analytical barriers what are present in the prokaryotic cells. And then we also discuss about the chromosomal DNA and as well as the plasmids. And in the previous lecture, we have also discussed about how you can be able to isolate the plasmids from the bacterial cell and how you can be able to use them for the different types of applications.

And how the plasmid is actually giving the, spreading the resistance or the different types of properties. So, in today's lecture we are going to discuss about the eukaryotic cells. So, when you talk about the eukaryotic cell, we have discussed, we said we are going to discuss about the two types of eukaryotic cell, one is called as the plant cell, the other one is called as the animal cell. So, let us start our discussion about the eukaryotic cell.

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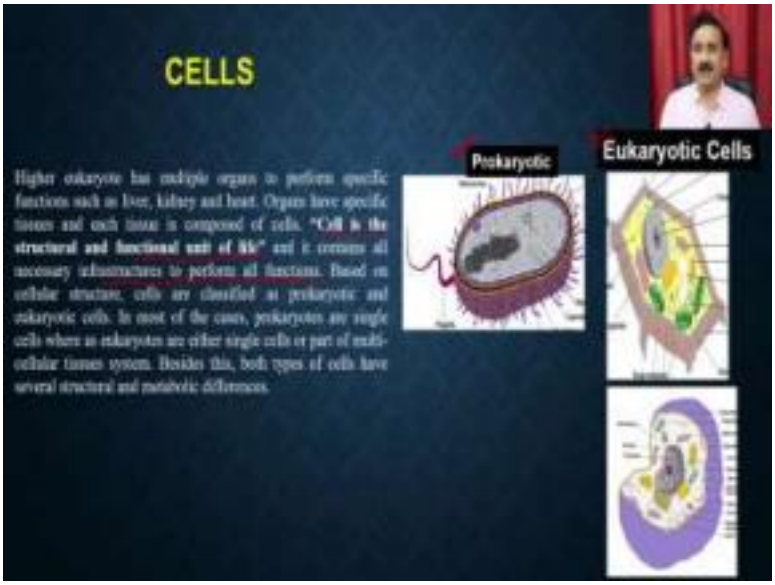

So, the higher animal, higher eukaryotes have the multiple organs to perform the specific functions whereas the cell is the structural as well as the functional unit of the life. And it contains all the

necessary infrastructure to perform the all the functions.

So, besides we have the different types of cells like we have prokaryotic cell, we have the eukaryotic cells, and within the eukaryotic cell, you have the plant cell and the animal cells. So, before getting into the detail of what are the different organelles and what are the structure of the eukaryotic cell, it is important to understand the difference between the plant cell as well as animal cells.

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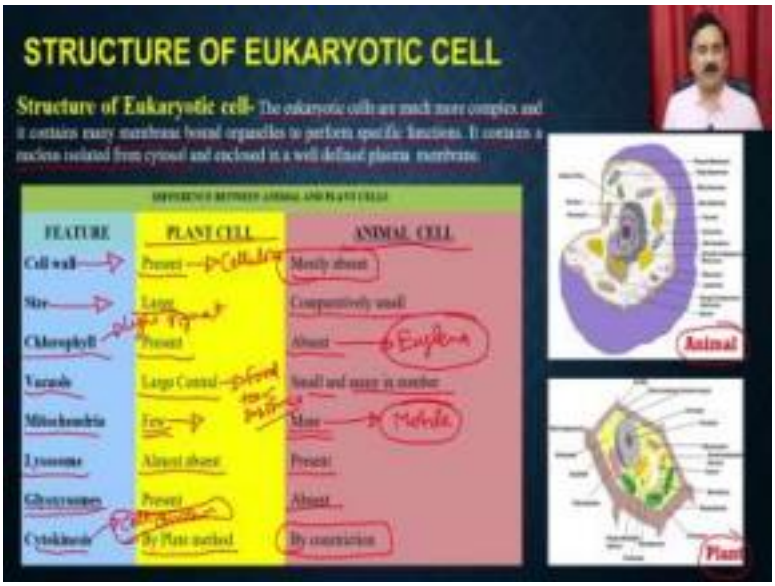

So, the structure of the eukaryotic cell, the eukaryotic cells are much more complex and it contains many membranes bound organelles to perform the specific functions. It contains a nucleus isolated from the cytosol and enclosed in a well-defined plasma membrane. So, one of the classical features is that the eukaryotic cells are actually containing the membrane bound organelles to perform the specific functions.

And then you have the two different types of eukaryotic cells, you have the plant cell and you have the animal cells. So, let us see what are the difference between the animal and the plant cells? So, these are the properties of the plant cell and these are the properties of the animal cells. So, what you see here is the cell wall. The cell wall is present in the plant cell and plant has a very, very robust and good cell wall, which is made up of mostly the cellulose.

Whereas the cell wall is completely absent in the animal cell, then the size of the plant cells are very, very large compared to the animal cell, and animal cells are comparatively small. Then the chlorophylls the chlorophyll is the light pigment. Chlorophyll is the light pigment, what is present in the plant and it is completely absent in the animal. So, there are exceptions where the animal cells are also having the chlorophyll like for example, the euglena.

So, euglena is an animal cell but it also contains the chlorophyll. Then we have the vacuoles. So,

there are large vacuoles which are present in the plant cells and these, the purpose of these vacuole are that they want to collect the food material or sometime they also collect the toxic substances because the plants are much more exposed to the toxic substances, whereas, in the case of the animal cell it contains the small and in many numbers in the animal cell.

Then we have the mitochondria, the mitochondria are few in the case of plant cell because the plant cells are not very motile. The plant cells are static; like you have seen that the trees are present in the soil. So, they do not move around, that is why they do not require a large quantity of energy for motion. And that is why they do not have the huge number of mitochondrial cells.

Whereas in the animal cell you have the huge amount of animal cell because animal cells are very motile. So, because of the animal cell they are motile, they need more amount of energy, and that is why they have the more number of mitochondria. Tthen lysosomes, the lysosomes are almost absent in the plant cell whereas they are present in the animal cell.

Then we have the glyoxysomes. The glyoxysomes are present in the plant cells, but they are absent in the animal cell. Then you have the cytokinesis, cytokinesis means the cell division, we are going to discuss in due course. So, the cytokinesis is the cell division. Cell division is always by the plate method in the case of plant cells whereas, it is going to be by constriction in the animal cells.

So, these are the some of the notable differences between the animal cell as well as the plant cell. But overall the basic property of these two cells are very, very same actually. They both have the plasma membrane, they both have the many of the organelles what are present. So, let us start discussing about the different types of organelles, what is present in the eukaryotic cell and we are going to then take up the some of the organelles what are exclusively been present in the plant cells and so on.

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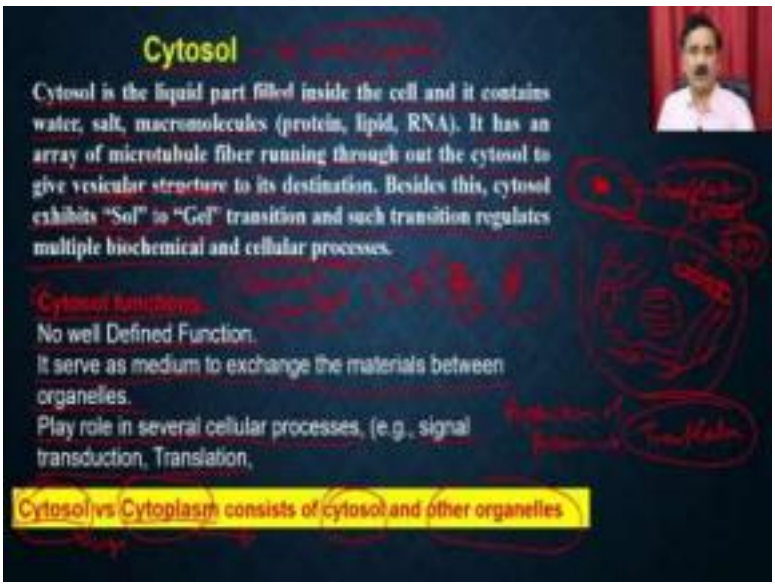

So, let us start our discussion with the first organelle and that organelle is called as the cytosol. Cytosol is nothing but the water or the liquid part what is present inside the cell. So, you see the cell which is there, and it has a nucleus in the center and in between whatever you see is actually are called as liquid part, whatever you see is called as the cytosol.

So, cytosol is the liquid part filled inside the cell and it contains the water, salt, macromolecules, which means it contains proteins, lipids, RNA. It has an array of microtubules fiber running throughout the cytosol to give the vesicular structure to his destinations. So, within cytosol you have the different types of microtubules running. So, these microtubules are actually making the road within this cytosol.

And on these roads, only the vesicles are moving and that is how they are actually delivering their content. Just like as you are ordering the material from the Amazon, or Flipkart. And then the guys are coming to your place. But how they are coming? They are coming because there is a road, there is a road to your home. And that is how they come using these roads. So, these roads are made up of the microtubules which we are going to discuss in our subsequent lecture.

And they will use these roads and that is how these vesicles you can imagine, these vesicles are the courier guys which are coming to your home. And they are actually delivering to your place and how they are delivering that is a part of the very, very extensive vesicular structure system and they are actually having a very, very well-defined vesicular transport system. And vesicular transport system is actually going to help the cells to deliver the material to their destinations.

Beside this the cytosol exhibits the salt to gel transitions and such transitions regulate the multiple biochemical and cellular processes. So, sol and gel transition is actually making either the cytosol more thick or more thin. And because of that the localized sol and gel transitions is actually going to make the substrates more concentrated or less concentrated.

And because of that they can be able to enhance or they can be able to change the rate of these reactions very nicely. So, apart from these functions, the cytosol has many of the functions. So, cytosol has no well-defined functions. It serves as a medium to exchange the material between the different organelles. It play in various processes such as it is actually we are presses they are the signal transduction or the translation is going to take place.

So, cytosol has the cellular machinery which is responsible for the translation or translation means the production of the proteins. So, production of protein if called as the translation and that is happening within the cytosol. Now, one of the things, which people very often use or interchangeably they use the term, which is called as the cytosol or the cytoplasm.

And there is a big difference between the cytosol and the cytoplasm and it is very important that

you should get a clarification. Cytosol is actually the liquid part, this is the liquid part. Whereas, the cytoplasm is actually consists of the cytosol and all other organelles. So, if you take the cell, it has a nucleus outside this nucleus, whatever you have that is called as the cytoplasm; that contains the cytosol and it also contains the different types of organelles.

So, that is a very, very important. And do you understand that you should say cytosol when you are talking about the liquid part and you say about the cytoplasm, when you are talking about the content what is outside the nucleus.

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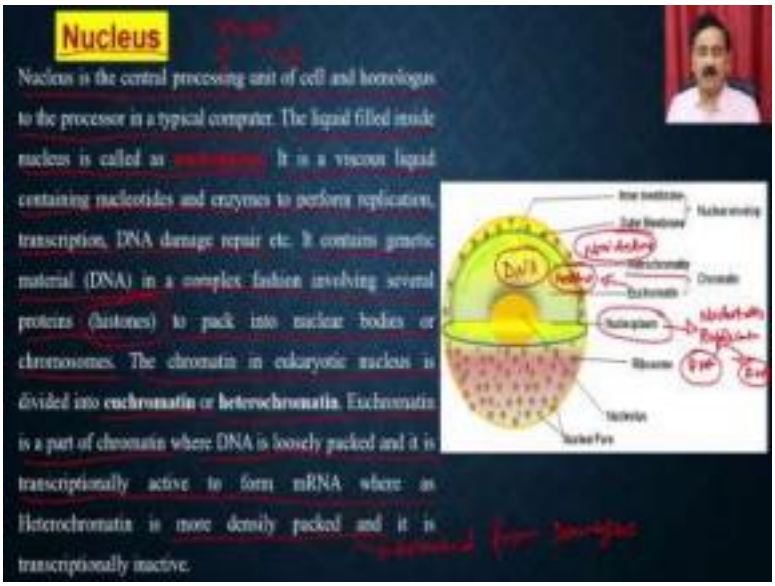

So, let us move on to the next organelles and the next organelle is known as the nucleus. So, nucleus is the central processing unit of the cell and it is homologous to the processor in a typical computer. Nucleus is also called as the master of the cell, because it actually regulates, it actually give the instructions to the cell what it should do actually. So, why it is so because the nucleus is containing the genetic material.

And that genetic material has all the information. And that genetic material is actually going to say what the cell has to do actually. So, nucleus is a very, very well it is present inside double membrane structures. The liquid which is filled inside the nucleus is called as a nucleoplasm. And the nucleoplasm is actually containing the different types of molecules like it is a viscous liquid which contains the nucleotides and enzyme to perform the replication and the transcriptions and as well as the DNA damage repair system.

So, the nucleus contains the nucleotides, which is required for the replication as well as for the transcription and then it has the replication machinery. Replication machinery means, it is actually be going to make the DNA another copy of DNA. So, that will require when the cell is going through with that cell division.

Then it contains genetic material that DNA in a complex fashion involving the cellular protein which are called as the histone proteins. So, compared to the bacterial cell, the DNA is present in a complex with the proteins and that these proteins are called as the histone to pack into a nuclear bodies or to the chromosomes. So, the chromosome when we say about the chromosome, it is an authentic chromosome but is present in the eukaryotic cell.

The chromatin in the eukaryotic nucleus, so chromatin like the DNA content is present in the two forms, either it can be euchromatin or the heterochromatin. So, you can have that chromosome which is going to be either present as the euchromatin or the heterochromatin. So, euchromatin is a part of the chromatin where the DNA is loosely packed and it is transcriptionally active to form the messenger RNA.

So, euchromatin is actually active, whereas, the hetero chromatin is non-active or inactive, which means the eukaryotic cell has the mechanism, so that they can be able to make some portion of their genome active and some portion of their genome inactive. Why it is so, because they do not want to expose their whole DNA for the cellular machinery and as well as for the different types of toxicants and because of that they can be able to protect.

So, the DNA what is present in the heterochromatin is actually going to be more densely packed and because of that, it is getting protected from the any kind of damages. So, they will be protected from the damages and it is transcriptionally inactive. So, the portion what you are going with, what you require for example, if there will be a record requirement of the insulin molecule.

For example, if we require insulin, then that insulin gene is actually going to be present in the euchromatin. And that is how the insulin is going to be transcribed within the nucleus. And that is how the insulin production is going to start in the cytosol. Since the nucleus is present inside this particular double membrane structure, it is actually well protected from the cytosol or well separated from the cytosol by the very, very complex structure and that complex structure is called as the nuclear membrane.

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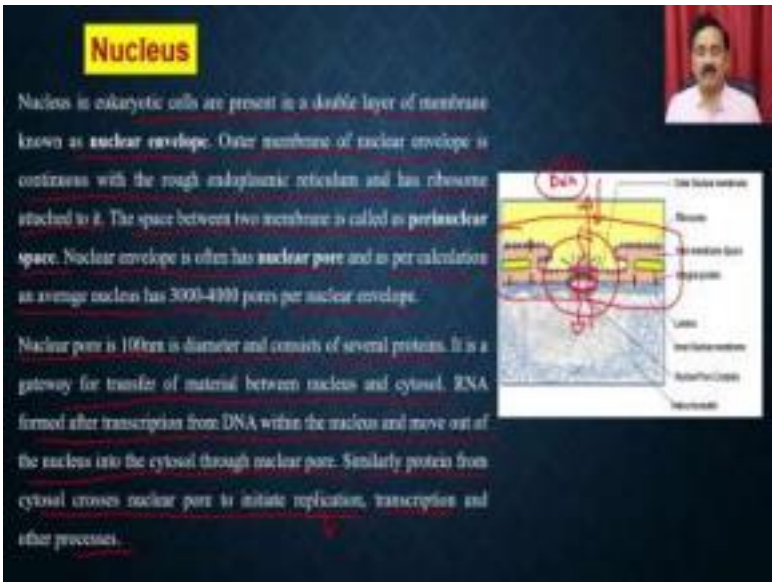

So, the nucleus in eukaryotes are present in a double layer of membrane known as the nuclear envelope. So, what you see here is, this is the nuclear envelope, where you have the nuclear pore, and this is the only portion through which the molecules can come in or the synthesized molecule can go out. The outer membrane of the nuclear envelope is continuous with the rough endoplasmic reticulum and has the ribosome attached to it.

The space between the two membrane is called as the perinuclear space and the in nuclear envelope is often has the nuclear pore. And has and as per the calculation and average nucleus has the 3000 to 4000 per nuclear envelope. So, you have these type of nuclear pore and the nuclear pore is 100 nanometer diameter and it contains of different types, several types of protein. It is a gateway for the transfer of material between the nucleus as well as the cytosol.

So, you cannot just get anything into the nucleus because then that will in that that is the case there are many DNA damaging agents what are present in the cytosol. So, they will not get into because the nuclear pore is actually going to have a mechanism, so that they can be able to discriminate between who will be allowed to get in and who will be allowed to go out of this DNA.

The RNA formed after the transcription from the DNA within the nucleus and it will move out from the nucleus into the cytosol through the nuclear pore. Similarly, the protein from the cytosol process the nuclear pore to start or initiate the replications, transcription and other processes, because you require the signal from the cell also, you require the cellular machinery from the cell with you, so that you can be able to perform the different types of function.

For example, that replications in transcriptions and that is also been governed or that is also been completely been controlled by the nuclear pore.

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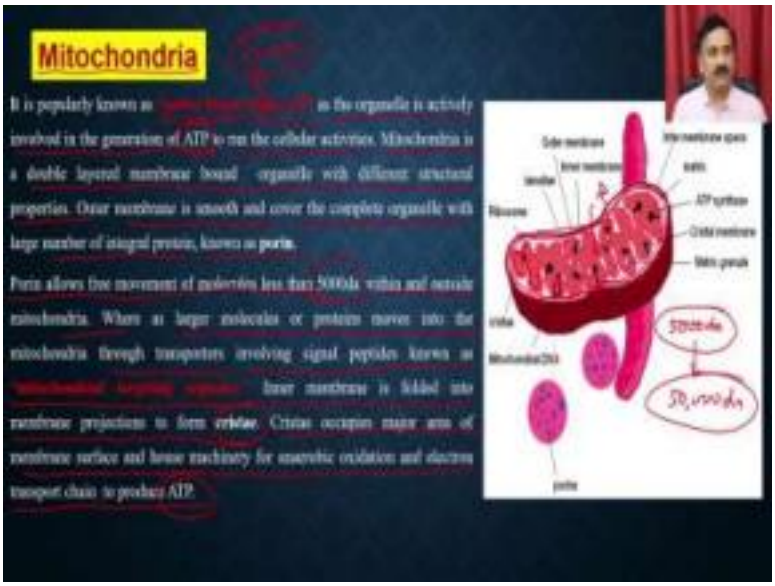

Now, let us move on to the next organelle and the next organelle is called as the mitochondria. And the mitochondria is also called as the powerhouse of the cell because it is responsible for energy production. So, and that is why, if you recall, when we were talking about the plant versus the animal, the animal is having the more number of mitochondria because they require more energy compared to the plant cell.

And as the organelle is actively involved in the generation of a molecule, which is called as the ATP to run the cellular activities. Mitochondria is a double layer membrane bound organelles with a different structural properties, outer membrane is smooth. So, this is what you see here, this is a double membrane structure and the outer membrane is smooth. So, this is the outer membrane, what you see here is a smooth membrane.

And it covers the complete organelle with a large number of integral protein which are known as porins. So on this outer membrane, you have the proteins which are called as the porins. And the porin allows the free movement of molecules less than 5000 Dalton within an outside the mitochondria whereas the large molecules are all the protein moves into the mitochondria through the transporter involving the signal peptides known as the mitochondrial targeting sequences.

So, it is not like just like the nucleus, it is not like that anything will be allowed to get in or anything will be allowed to go out. There is a small size like if it is a size of 5000 Dalton that is the molecule which is going to be allowed getting through the porins. But if it is bigger than this, suppose you have the 50,000 Dalton then that protein has to be go through with a well-defined mechanism.

Which means it should have a signal peptide, so that and that signal peptide should be of a mitochondrial targeting sequence. So, do not worry about these targeting sequence and all this kind

of terminology because that we are going to discuss. Inner membrane is folded into membrane projection which are called as the cristae, so what you see here is the inner membrane which has been folded in the form of the cristae.

And cristae occupies a major portion of the membrane and house machinery for the anaerobic oxidation as well as the electron transport chain to produce the ATP.

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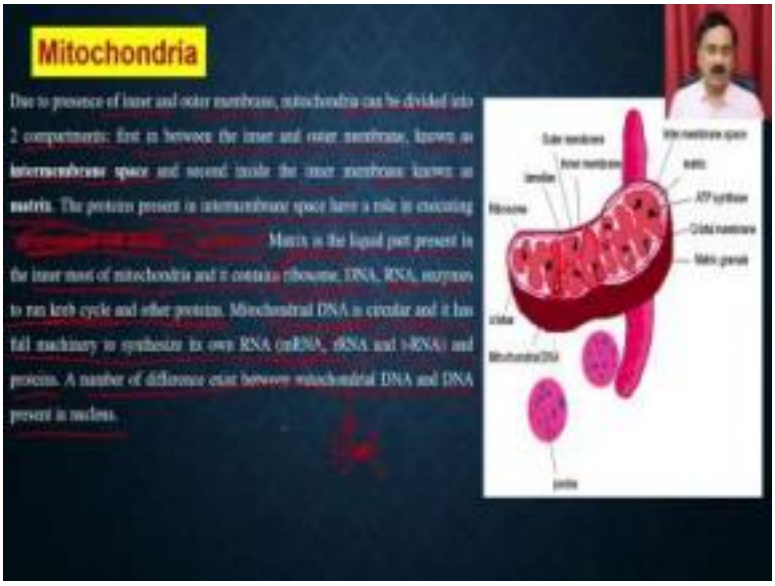

Due to the presence of the inner and the outer membrane, the mitochondria can be divided into the two compartment; first in between the inner and the outer membrane. So, this is the compartment and known as the inter membrane space and the second inside the inner membrane known as the matrix. So, this is the matrix what you see here this is the matrix. The protein present in the intermembrane space have a role in executing the program cell death or apoptosis, which we are going to discuss in a subsequent module.

Matrix is the liquid part present in the inner most of the mitochondria and it contains ribosomes, RNA, DNA enzymes to run the Krebs cycles and the other protein. So, this protein what, this portion what you see here is called as the matrix. And the matrix is actually going to have all the cellular machinery it contains the ribosomes so that you can have the protein production because you know that the nucleus, mitochondria has its own mitochondrial DNA.

So, it can be able to do the transcription and translation and that is how it can be able to produce the proteins. Then it also has the RNA, DNA and it also has the enzyme for the running the Krebs cycles and all other proteins. Mitochondrial DNA is a circular DNA it has a full machinery to synthesize its own RNA which means it can have the ability to synthesize messenger RNA, ribosomal RNA and as well as the transfer RNA and the proteins.

A number of differences exist between the mitochondrial DNA and difference and the DNA what

is present in the nucleus. One of the classical difference is that the mitochondrial DNA does not contain the introns. So, it does not contain the intron compared to the DNA what is present in the nucleus.

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Now, let us talk about the cellular the ATP generation machinery. So, this is the ATP generation machinery which is called as the, which is present in the micro which is present in the plasma membrane. And the system what produces the energy is called as the electron transport chain, which is actually a very, very huge complex. And that is why these are labeled as the complex 1 to complex 5 and these are all complexes are the integral proteins.

And they are present in the inner membrane of the mitochondria. During the metabolic reactions such as glycolysis Krebs cycle produces large amount of reducing equivalent in the form of the NADH2 and as well as the FADH2. Electron transport chain processes the reversing equivalent and the flow of electrons through the different complexes. So, what happened is that the electrons are moving from the complex 1 to the complex 4.

And that causes degeneration of the proton gradient across the membrane. So, what happened is, it is actually going to accumulate the large quantity of the proton. Then the proton expelled in the intermembrane space returned back to the matrix through complex 5. And this is what you see here the complex 5 which is called as the ATP synthase. And what happened is that the big,
when the electrons are moving from the complex 1 to complex 4 they are throwing the proton from the this side to this side.

And that is how there will be accumulation of the proton and then when this proton comes back to the metrics part, metric side, it is utilizing this complex or this ATP synthase and because of that ATP synthase is coupling the ATP plus PI to generate the ATP. And that is because ATP synthase

is a very, very big complex it has the F1 unit and as well as the Fo unit. And it is actually, so ATP synthase is a mushroom shaped multimeric protein complex.

Mainly composed of two proteins Fo and F1, Fo is a membrane bound portion. So, this is the Fo, which is a membrane bound portion and F1 is a complex present into the lumen towards a matrix. FoF1 complex of mitochondria harvest the protein motive forces to catalyze the phosphorylation reaction in responsible for generating the ATP. Now, what are the what are the different reactions what are the different function of the mitochondria?

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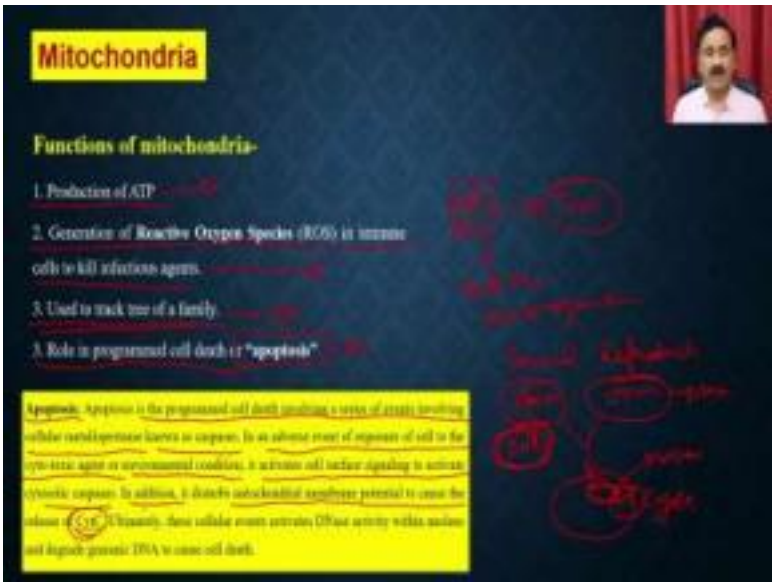

So, the first and the most important function of the mitochondria is that it is involved in the ATP productions. Then the second is it is actually responsible for the generation of the reactive oxygen species to kill the infectious organism. So, when there is the entry of the infectious organism within the mitochondria or within the cell, it actually induces the production of the reactive oxygen species, oxygen species means any molecule which actually contains the single electron.

So, because of this single electron, they are very, very toxic. So, because they are toxic, they are actually been used as a weapon to kill the microorganisms. Then the mitochondria is used to track the tray of a family, you know that the mitochondria, if you see the production of or the how the sexual reproduction occurs, during the sexual reproduction, the you have the two species you have the sperm and you have the ovum. Ovum is actually a complete cell.

It contains all other organelles, so it contains the mitochondrial also, whereas the sperm is only containing all other augments, but it only contains the DNA. So, when there is a fusion of the sperm and ovum, it takes the DNA part from the sperm, whereas it contains all other organelles from the ovum. So, because of that, when the zygote is being developed, it actually contains the mitochondria.

And that mitochondria is from the mother side; that mitochondria remain constant because even if this particular individual will again go for the sexual reproduction, that mitochondria is actually going to carry forward. And that is how you can be able to use the mitochondria to track the family tree. Then the mitochondria is also having a role in the programmed cell death or apoptosis. So, apoptosis is what we are going to discuss in the subsequent modules.

But I have given a very short write up so that it will actually help you to understand what is apoptosis. So, apoptosis is the program cell death involving the series of events involving cellular metalloprotease known as caspases. In an adverse event of exposure of the cell to the cytotoxic agent or to the environmental conditions it activates the cell surface signaling to activate the cytosolic proteases.

In addition, it disturbs the mitochondrial membrane potential to cause the release of a protein which is called as the cytochrome C. As you remember when we are talking about the transport of material within the cytosol and outside, we said that the porin is only allowing the 5000 Dalton proteins. But if there will be a membrane potential problem, if there will be a drop in the potential, then that will allow the leakage of the proteinaceous substances from the mitochondria.

And one such protein is called as the cytochrome C. And once the cytochrome c is going to be released from the mitochondria, it is actually going to activate the different types of DNAs, and that is how the DNA is are actually going to destroy the DNA what is present inside the nucleus. And ultimately it is going to destroy that particular cell. And this is actually a very, very programmed death, and that is why this is called as the apoptosis. Now, let us understand the first process how the mitochondria is actually synthesizing the ATP.

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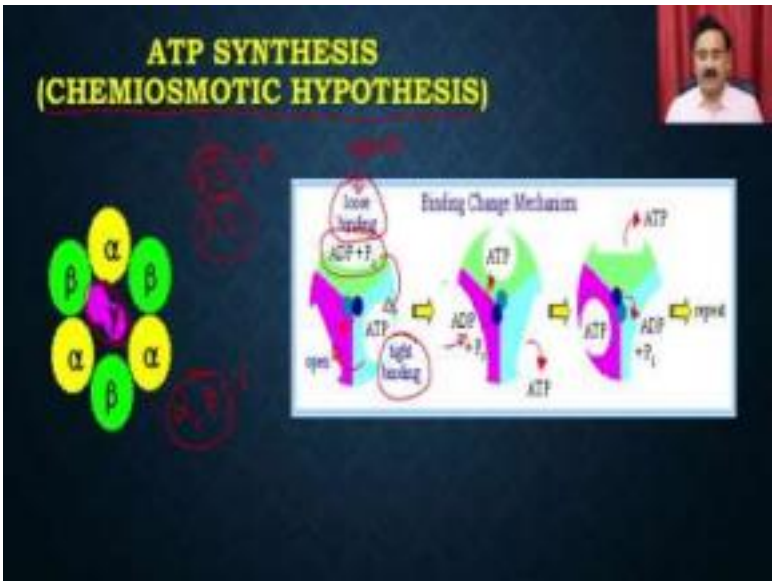

So, to understand and to explain this process, the people have put forward a theory which is called as the chemiosmotic hypothesis. So, what it says is that the F1 particle, so you remember it has

two particles, one is Fo particle other one is F1 particle. Fo is the integral membrane protein, which is only responsible for holding the F1 and it also gives the path for the protons to enter, whereas the F1 is actually a multi medic protein complex.

And it contains the three different proteins. It contains a protein which is called alpha subunit, it contains the beta subunit, and it calls the gamma subunit. So, this is the gamma subunit what is present in the center. And the function of the gamma subunit is that it actually only transfers complexes from the alpha to beta. So, what you see here is that these alpha and beta proteins are or the subunits could be present in two different confirmations, either it could be present in the loose binding confirmations or the tight binding confirmations.

So, when they are present in that tight bind configurations, they will bind that particular molecule and very tightly. So, what will happen in the beginning? In the beginning the ADP and Pi is actually going to come and bind to the loose binding site. So, once they will bind to the loose binding site, the gamma subunit is actually going to take these molecules and put it into the another subunit. And once they will reach to another subunit, they ADP and Pi are actually going to mixed with each other and that is how they are actually going to form the ATP.
As soon as it forms the ATP, it will again been flipped to another subunit. And that subunit is open complexes. And that is how it is actually going to, it is going to release the ADP and then it is actually going to take up the new molecules of ADP and Pi. So, this, this cycling event is going to continue for many rounds, and that is how it is actually going to keep giving you the ATP synthesis.

So, I have requested the one of the professor in MRC and based on my request he has shared a movie which actually explain these processes very nicely So, Professor Walcker is, we should be very grateful to him that he has shared this very good animated schemes. So, in this scheme they have shown how the ATP synthase is actually synthesizing the ATP utilizing the different types of complexes.

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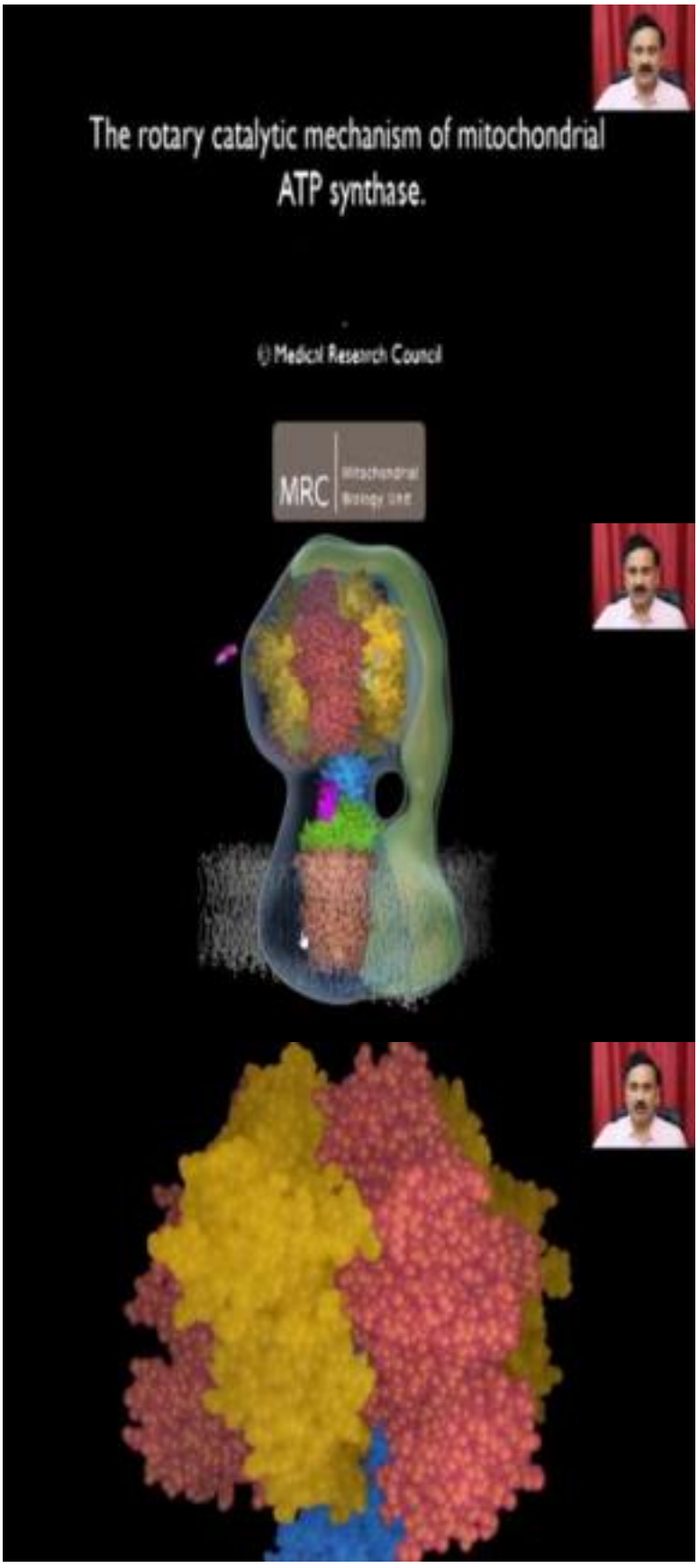
The rotary catalytic mechanism of mitochondrial ATP synthase.
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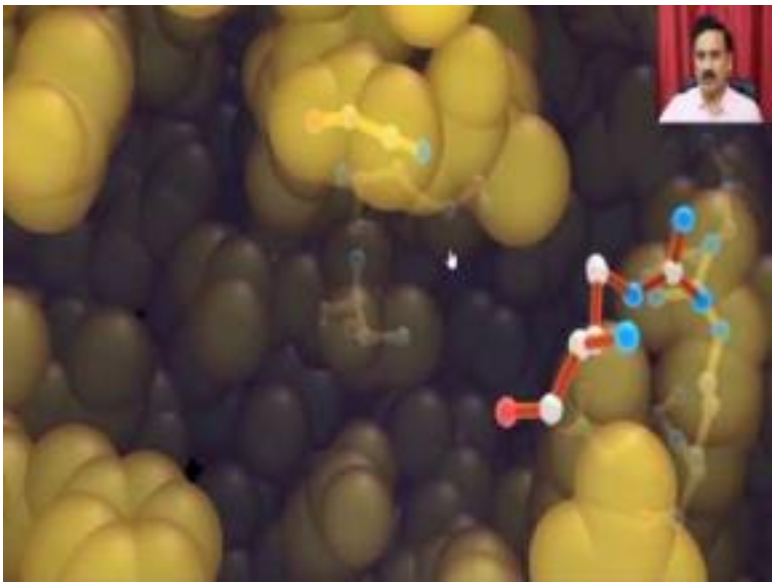

So, what you see here in this movie that this cyan color portion is actually the Fo particle and all these what you see is a F1 particle. This is what you see is the gamma chain, whereas this blue, yellow is the alpha chain and this is the beta chain. So, what when you will see that when the it is actually utilizing the proton motive force, it is actually rotating and when it is rotating, it is actually accepting the ADP Pi which is in the loop binding site.

And once the binding site is rotating, it is converting into a tight binding site and that is how the ADP and Pi mixed together and it generate the ATP again, there is a rotation and because of that the it was getting converted into the lose binding site and that is how the ATP which is formed in the previous cycle is going to be released. So, this is a very, very, good movie to understand the whole process and that is how you will be able to you know, appreciate how these events are actually been happening.

So, what you see here is actually it is showing how the ADP and Pi are combining with each other. So, you see these are these are different bonds with through which the ATP is combining with the PI and that is how the ATP is formed. And that is how it is actually been released from the system. So, this is all about the ATP synthesis and its mechanism by the ATP synthase.

And what we have discussed so far, we have discussed about the eukaryotic cell and within the eukaryotic cell we have discussed about that if the differences of the eukaryotic cell with the plant cells and then we have discussed about nucleus, we have discussed about the cytosol and we have also discussed about mitochondria. Now, in our subsequent lecture, we are going to discuss about some more organelles from the eukaryotic cell.

And then we also going to discuss some more interesting aspects related to the cell. So, with this I would like to conclude my lecture here. Thank you.