Introduction to Cell Biology
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Complexity and Compartmentalization in Cells – Part 1

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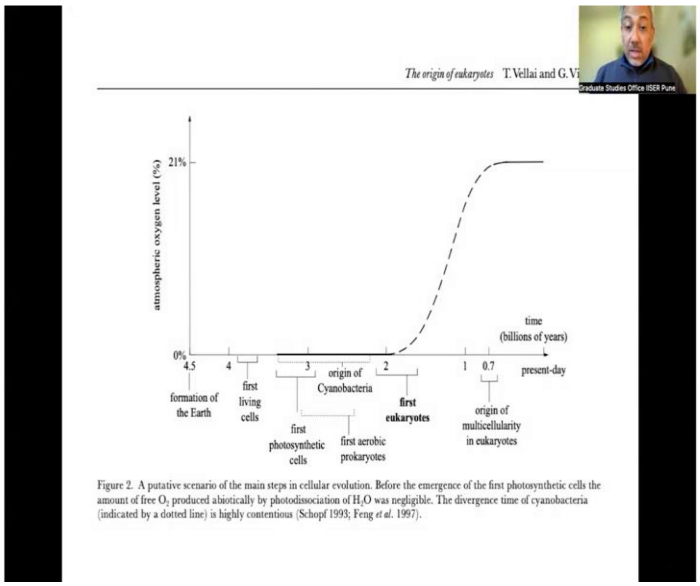

So, what we will do today is that, as I said, the kind of all important question that we wanted to cover is about the complexity and the compartmentalization. That seems to happen as these organisms have evolved. I went back to pull up something that I think will be of interest, which is for many reasons.

And this is a really interesting timeline of the evolution of the early eukaryotes. And this is plotted against the atmospheric oxygen level. And this is an important point to keep in mind as we think about eukaryotes or complex cellular systems evolving, which is that the availability of oxygen had a significant impact on the development of these eukaryotes.

So, you can see the early living organisms, and then you have the first photosynthetic cells, which are very early cell types, you have the origin of the cyanobacteria, the first aerobic prokaryotes, as the oxygen content now started improving on the planet. And that oxygen then led to many changes that were possible for cells to make, including the kind of energy, for example, that they may need. And this allowed for the complexity that we are thinking about to come into play.

There is a really nice video that I am going to share right now, which summarizes some of what we spoke last time, and also talks about this idea of how prokaryotes and eukaryotes could be different. So, we are going to watch that video. We are going to look at the compartmentalization that exists. And briefly remember, we are going to look at each of these components as we go along. This is just an introduction to the fact that there is this kind of compartmentalization. And then we are going to try in this class to talk a little bit about and get your opinion on what that complexity could mean and what that, what and why that compartmentalization exists. So, first let us look at this video.

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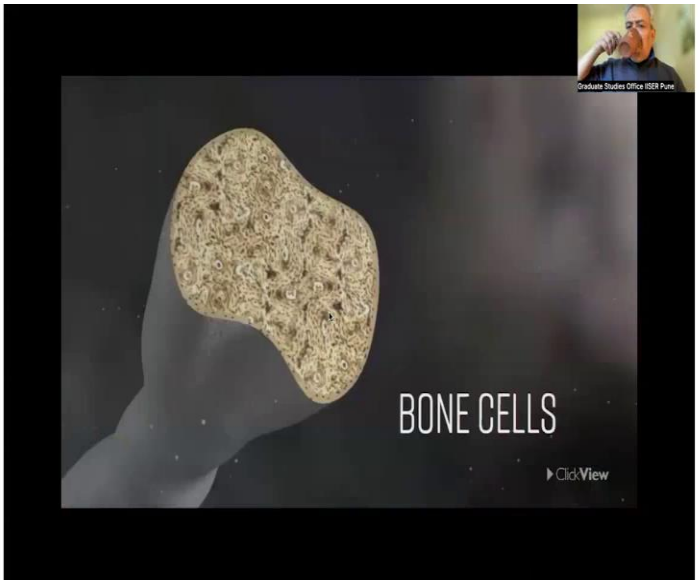


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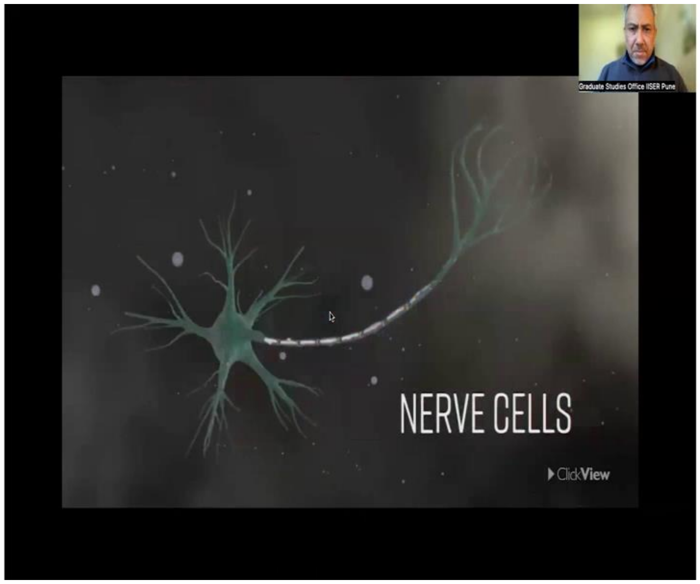
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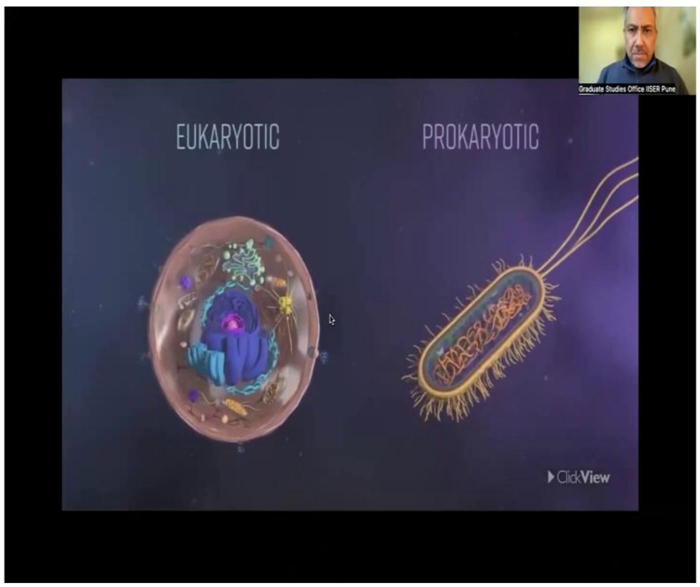
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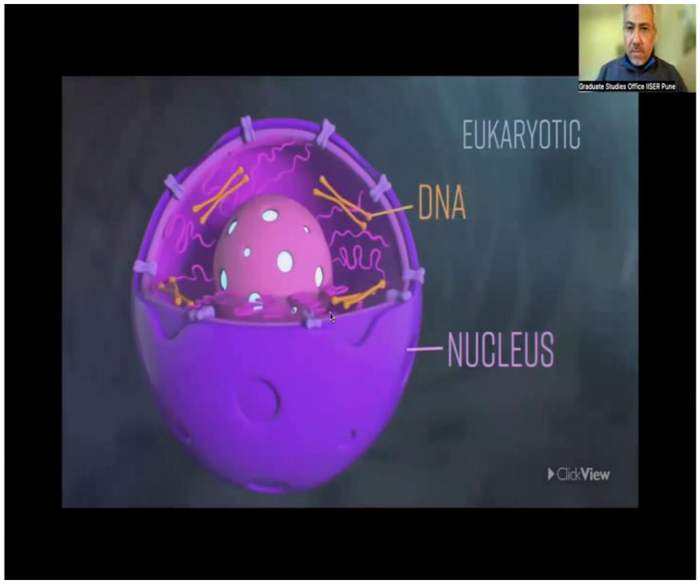
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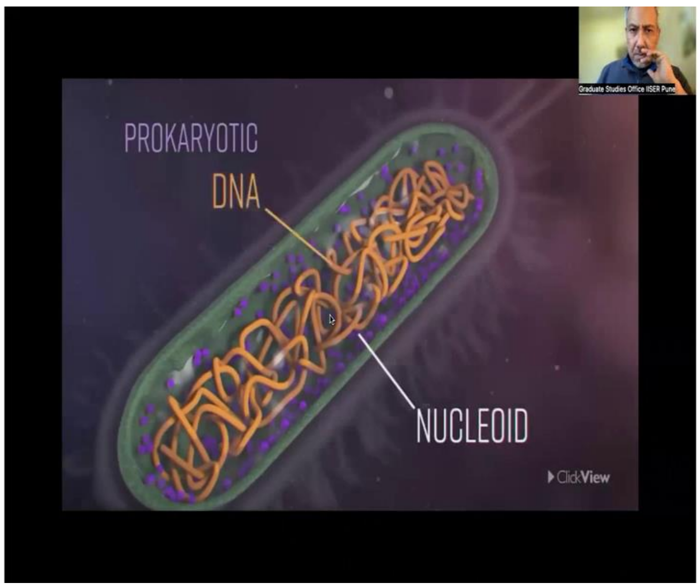
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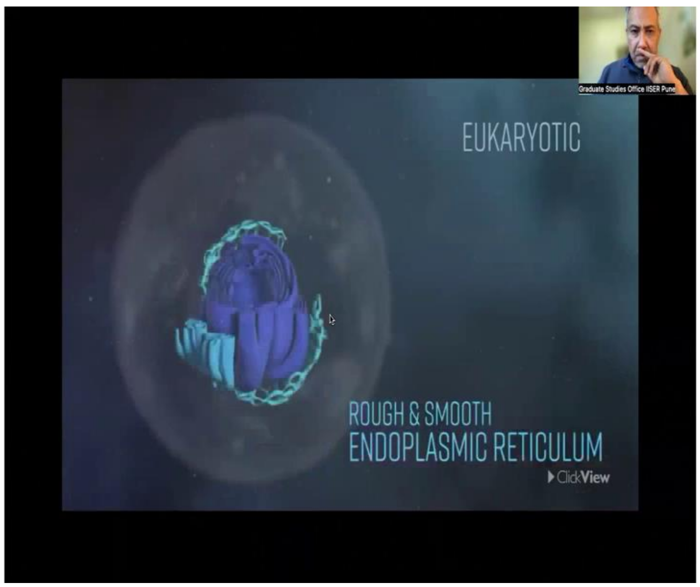
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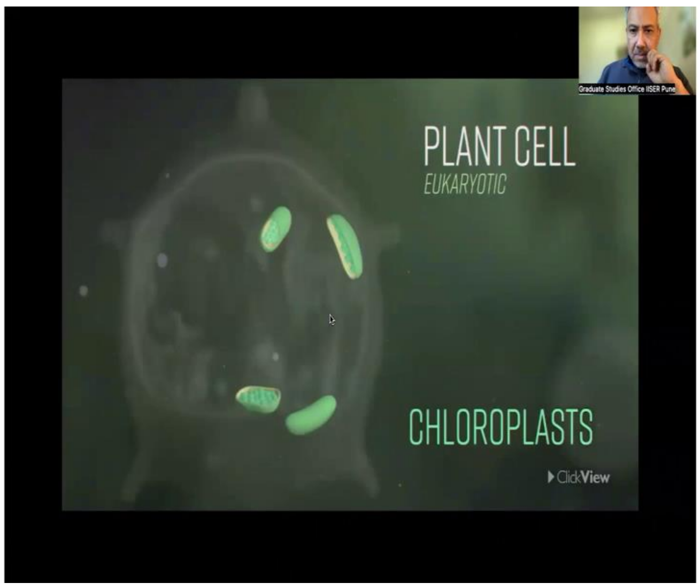
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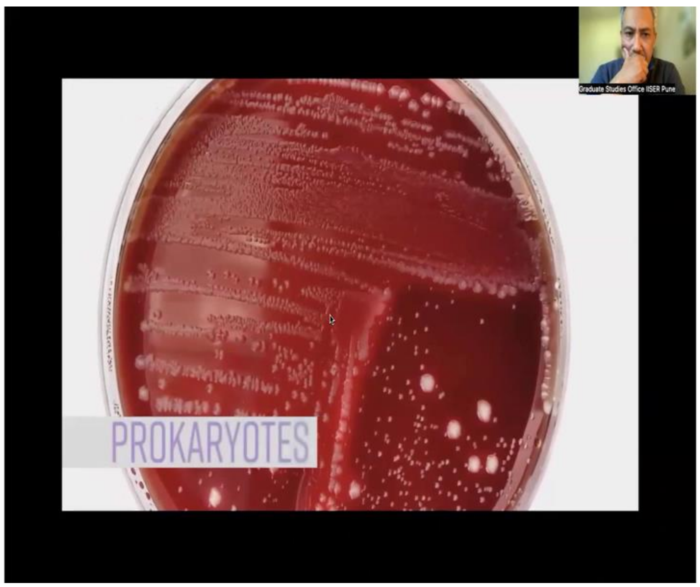
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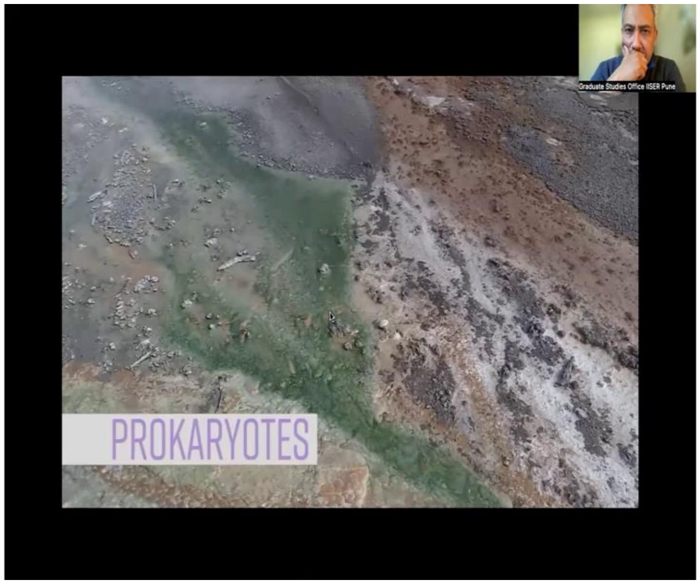
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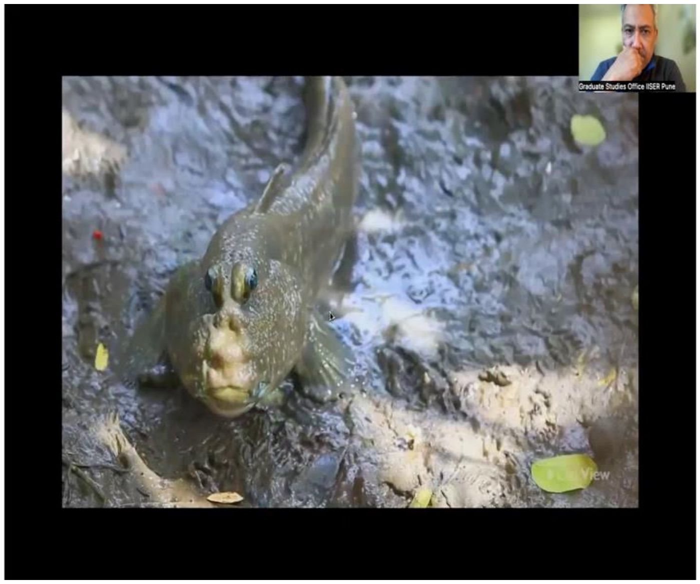
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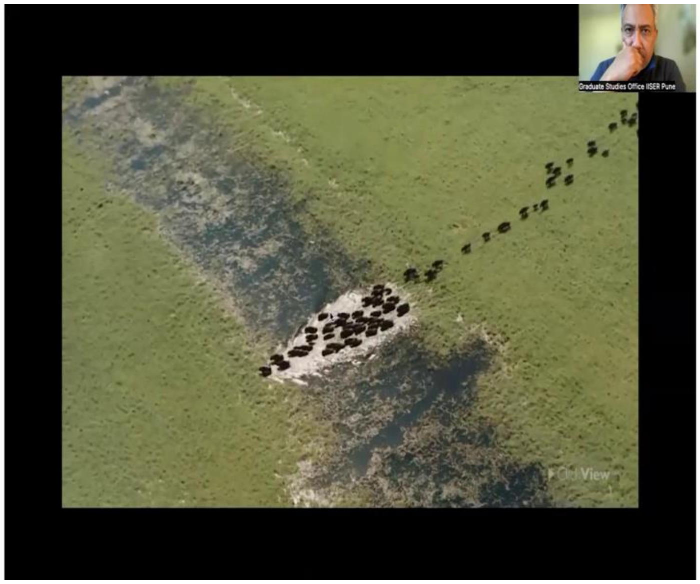
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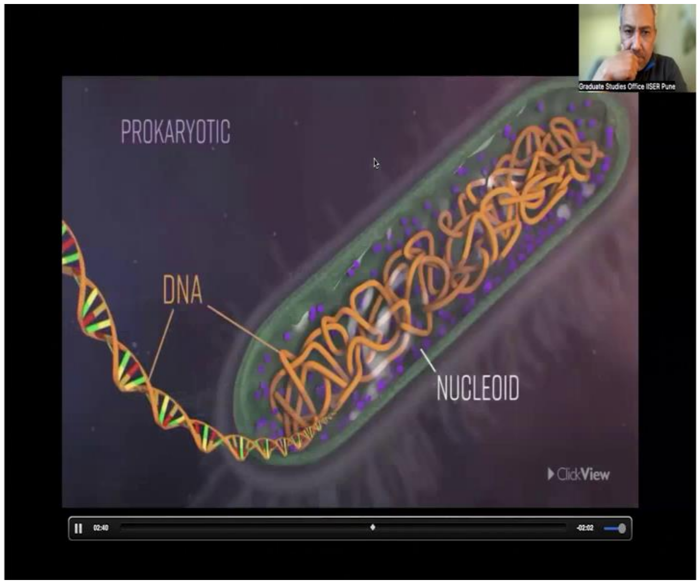
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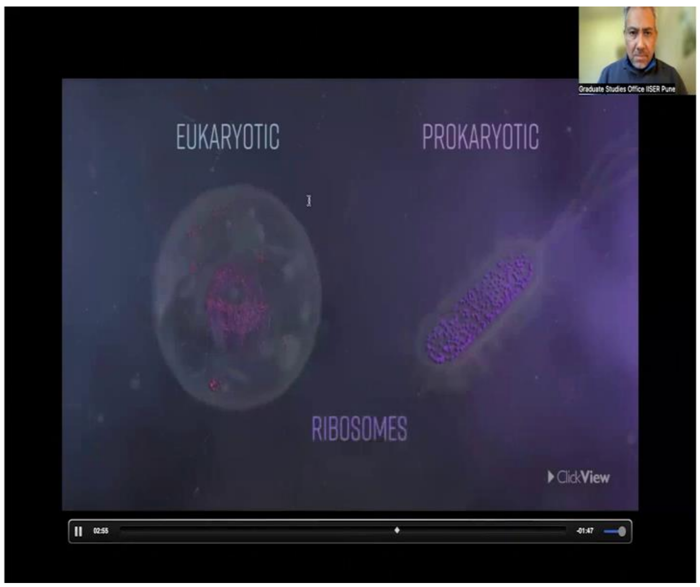
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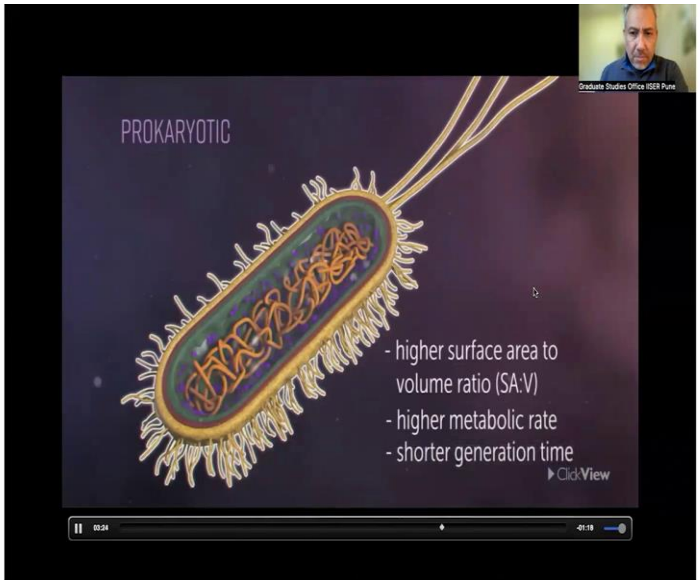
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- higher surface area to volume ratio (SA:V)
- higher metabolic rate
- shorter generation time
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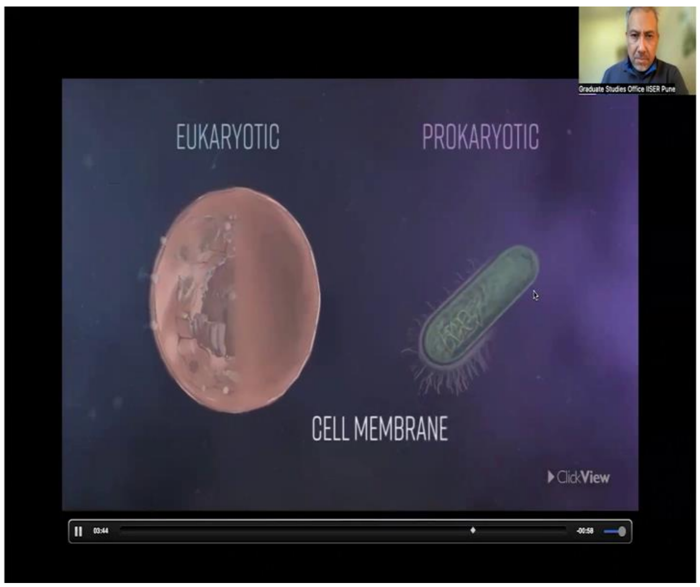
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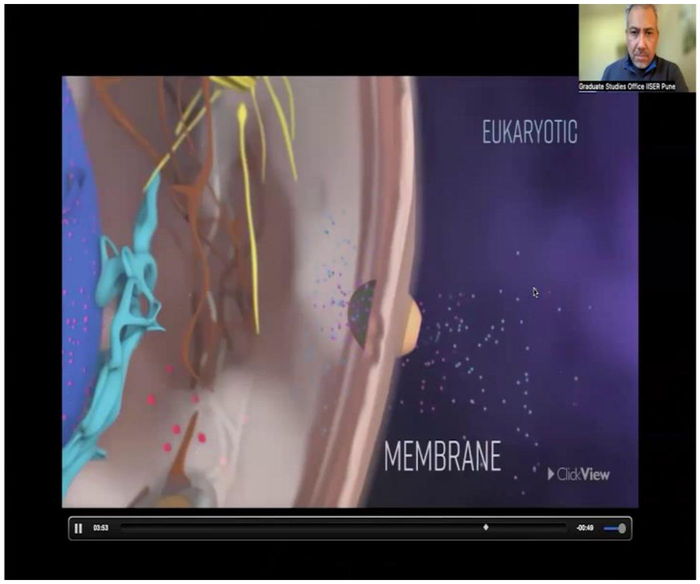
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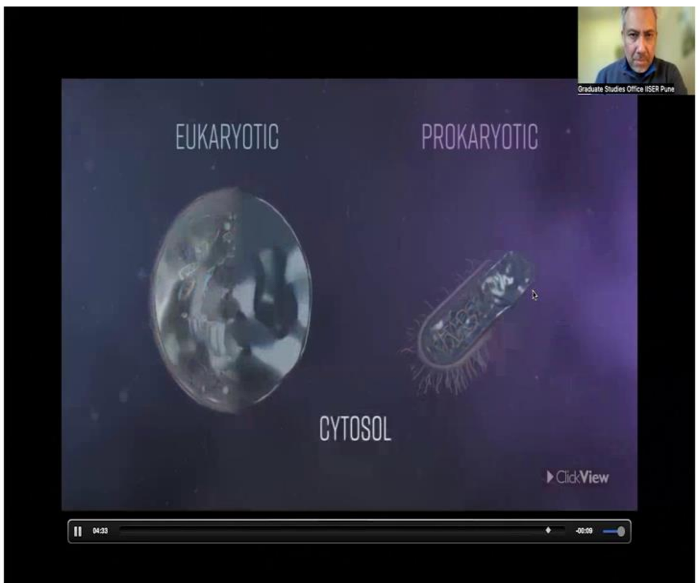

Narrator: Living things are made up of cells. There are many different types of cells in our bodies, including bone cells, cartilage cells, blood cells, muscle cells, and nerve cells. Broadest classification of cells is into two groups, eukaryotic and prokaryotic. There are a number of differences between these two types of cells. The main difference is that eukaryotic cells have a double membrane bound nucleus, which contains the cell's DNA. Prokaryotic cells do not have a nucleus, only a nucleoid, which is the central open part of the cell where the DNA is found.

Eukaryotic cells also have other large complex membrane bound organelles, which prokaryotic cells lack. These include mitochondria, rough and smooth endoplasmic reticulum, the Golgi complex, and in the case of plant cells, the chloroplasts. Organisms with eukaryotic cells are called eukaryotes, and they include all animals, plants, protozoa, and fungi. Organisms with prokaryotic cells are called prokaryotes, and they include bacteria and archaea.

For millions of years prokaryotes were the only form of life on this planet. Eukaryotes came later as a result of the process of evolution. Another difference between eukaryotic and prokaryotic cells is their size. Eukaryotic cells are generally larger than prokaryotic cells. Eukaryotes are mostly although not entirely multi-cellular organisms, whereas prokaryotes are always single celled or unicellular organisms. Examples of unicellular eukaryotes include amoebas, paramecium, and yeast.

The structure of the DNA in eukaryotic cells is different from that in prokaryotic cells. In the nucleus of eukaryotic cells, DNA forms tightly bound and organized chromosomes. Prokaryotic cells contain just a single loop of stable chromosomal DNA stored in the nucleoid. The nucleoid is not a structure, but the area where the DNA is found. Both types contain ribosomes. But in eukaryotic cells, they are bigger and more complex and bound by a membrane. Most eukaryotes reproduce sexually. The offspring have genetic material that is a combination of the parents' genome. Prokaryotes, however, reproduce asexually. Their offspring are clones of the parents cell, which come about through binary fission.

Finally, prokaryotic cells have a larger surface area to volume ratio than eukaryotic cells, which results in a higher metabolic rate, and therefore, increased growth rate and shorter generation time. While eukaryotic and prokaryotic cells are quite different in their structure and processes, they do share similarities. Ribosomes are one feature they have in common, but both also have a cell membrane composed of phospholipids and proteins. The membrane provides a barrier between the external and internal environments of the cell, and selectively allows certain materials to pass through.

Both types of cell have DNA as the basis for their genes. Although the structure is different, the genetic material regulates cell function and contains the coded information that is passed on to offspring. Both also contain cytoplasm. But in eukaryotic cells, it is defined as everything within the cell outside of the nucleus. In prokaryotic cells, the cytoplasm refers to everything contained inside the cell membrane. The gel like cytosol is a major part of the cytoplasm in both types of cell. This solution is the site of many of the cell's metabolic processes, such as the synthesis of protein.

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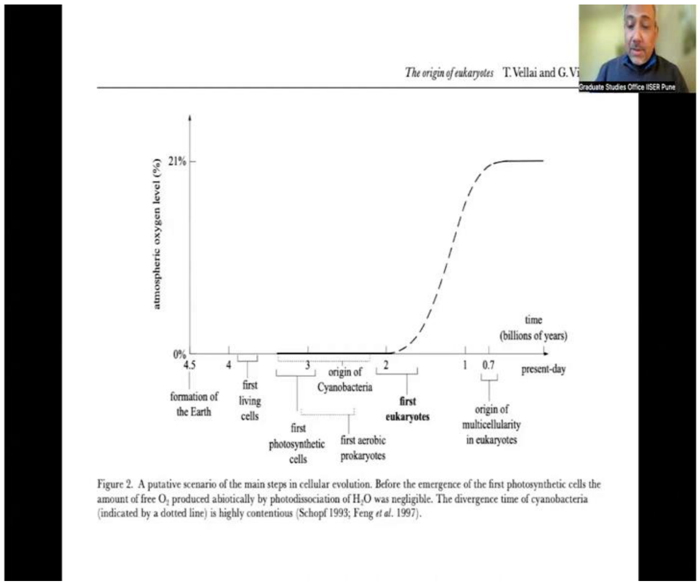

Professor: So, one of the things that strikes you is how, and we alluded to this earlier, is that there is indeed this change in complexity that happens as cells go from being prokaryotic to eukaryotic this timeline that we were looking at, and everything on the y-axis that you see in the lower access is in billions of years. And so it takes a long period of time for these changes to happen. The increases that you are seeing, for example, in oxygen levels are very gradual.

And remember that for many organisms, for us, we need significantly higher percentage of oxygen to live. A lot of these cellular systems do not actually need a lot of oxygen and can survive even at the bottom end of that curve, so to speak.

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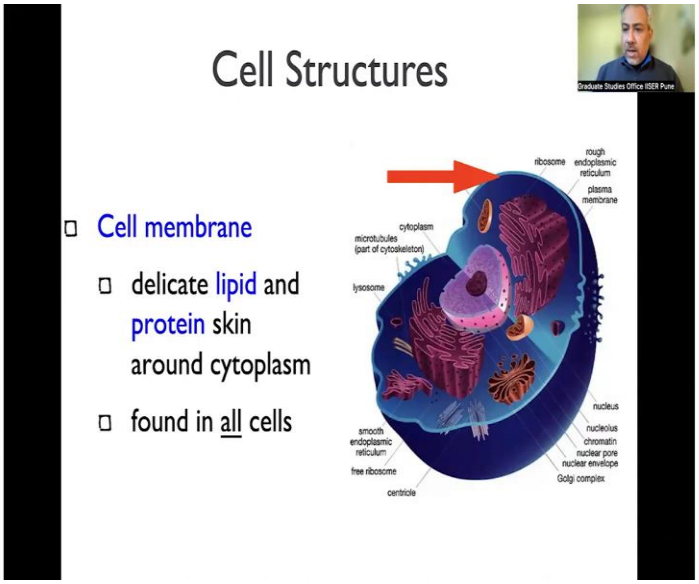

So, clearly, there is this evolution of structure. Some things are however common, and be prokaryotes or eukaryotes. And one of the things for early life to have evolved that is vital, like with complex eukaryotes as well is the presence of this boundary, so the cell membrane, and remember each of these structures we are going to pick up and discuss.

So, be patient to learn more about them. This is just to introduce you to what structures that the cell carries, is this boundary to be formed, something that would define what is outside and inside and such a boundary can do many interesting things for the creation of a cell. It could change, for example, the composition inside versus outside, it could regulate what moves in and out, and these are largely made up of lipids. And we will come to when we discuss the cell membrane on why lipids were chosen.

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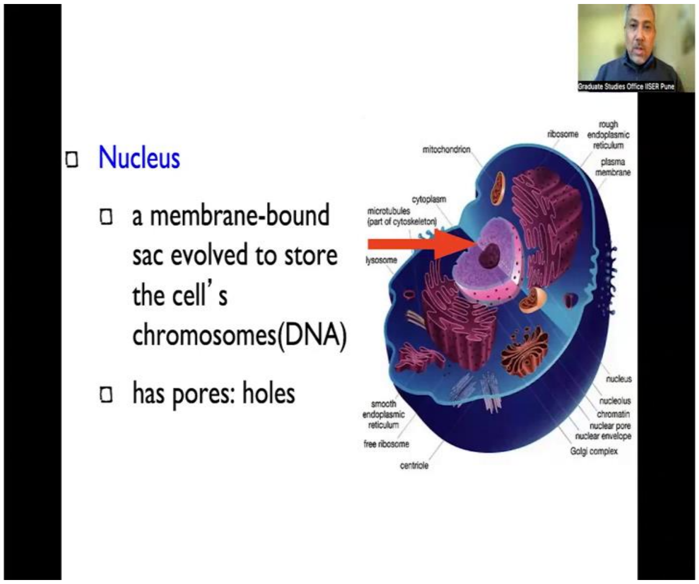

We obviously have the nucleus. And in eukaryotic cells the nucleus is a much more organized structure as compared to prokaryotes. And so is the DNA within the nucleus, which is kind of wrapped around histones to make these chromosomes, which are very distinct structures which carry a lot more content of DNA, of course, but also their organization, regulation, the fact that there are introns, exons, all these things happen to the DNA when it is part of these complex structures in chromosomes.

The nuclear membrane again talks to the cytosol. So, the nuclear, nucleus also has a membrane. And like with the cell membrane, where the purpose is essentially to be able to separate what is outside and inside, the nuclear membrane also has this function of being able to segregate what is outside and inside the cell, inside the nucleus. And that segregation allows for a lot of control, which is something that is a common theme you will see as we talk about how organelles have evolved, and what this compartmentalization means for these organelles.

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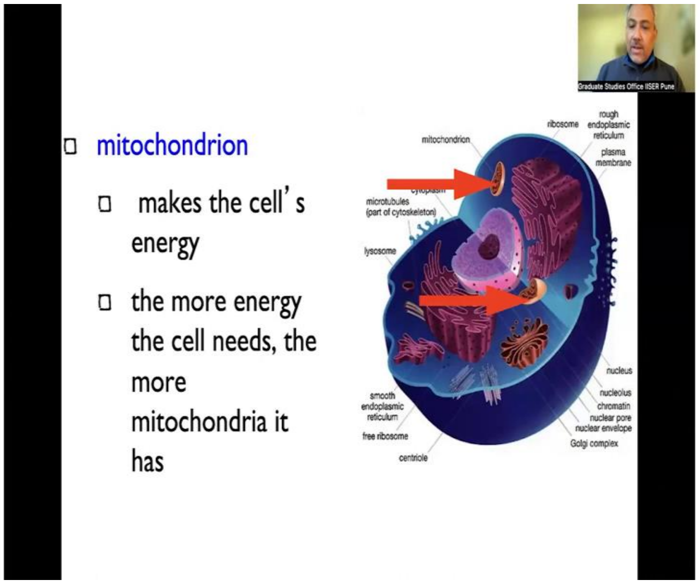

We have the energy centers of the cell, which are mitochondria, which actually also form a very interesting basis of the theory of how complexity may have evolved. And we will come to that theory at the end of this particular class, and we will discuss that at length in the next class as well. So, the mitochondria are another important players.

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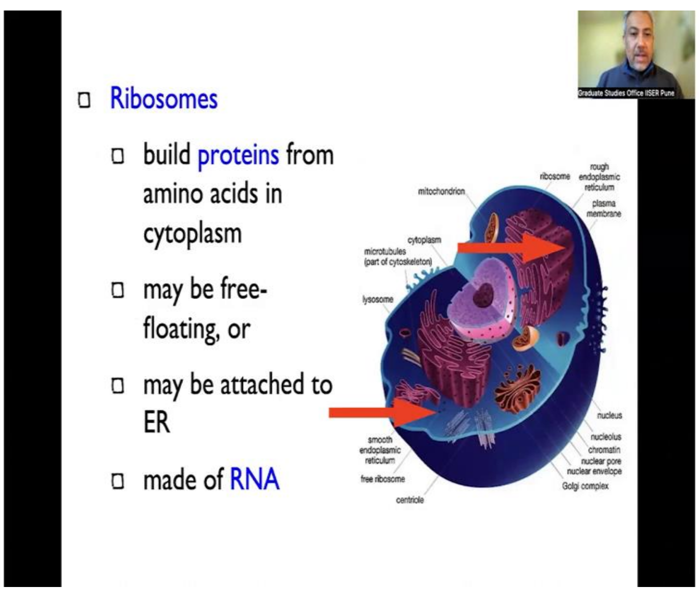

Then we have ribosomes, which build proteins and are associated with RNA, and use the information that is coming in the RNA to make the proteins that the cells need.

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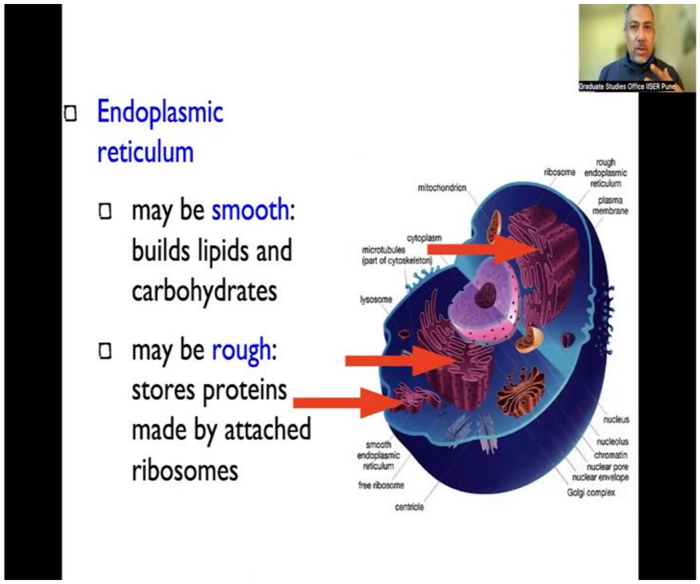

We have endoplasmic reticulum. And the endoplasmic reticulum again is a network of membranes that talks to the nucleus, has two versions smooth and rough, and we will come to both of them. And the presence of the ribosomes on the rough endoplasmic reticulum is what allows for protein synthesis to take place.

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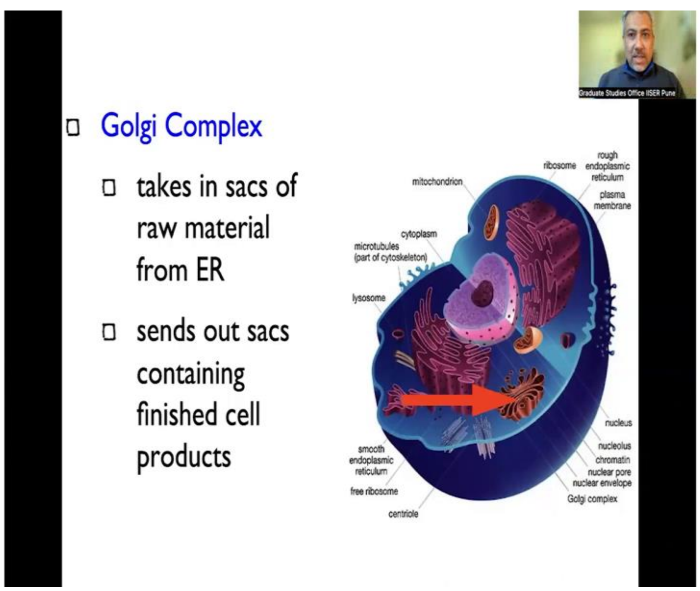

We have the Golgi complex, which is, again, something that is a network of membranes that is present inside the cell, which we will discover, works as a packaging and processing center inside the cell, and now allows things that are synthesized from the ER. Proteins that are synthesized from the ER to go be processed in such a way that before they can be delivered to different parts inside the cell, including the cell membrane.

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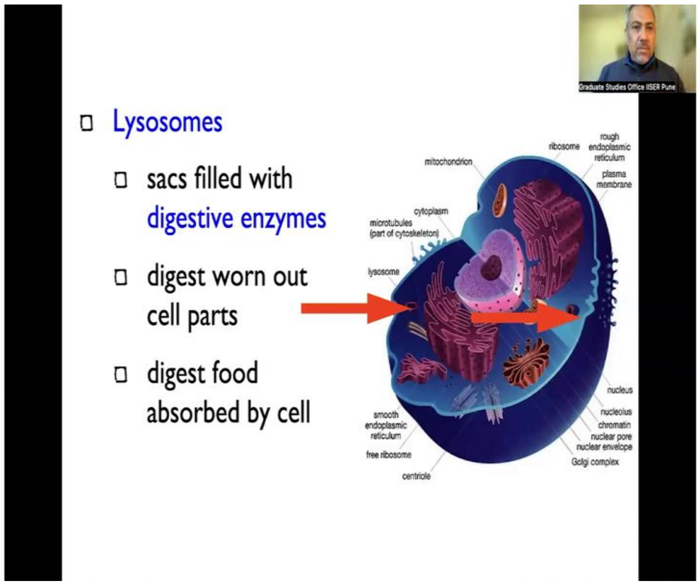

We have things like lysosomes, which are very unique structures that are filled with digestive enzymes that are able to digest things, break them down when required.

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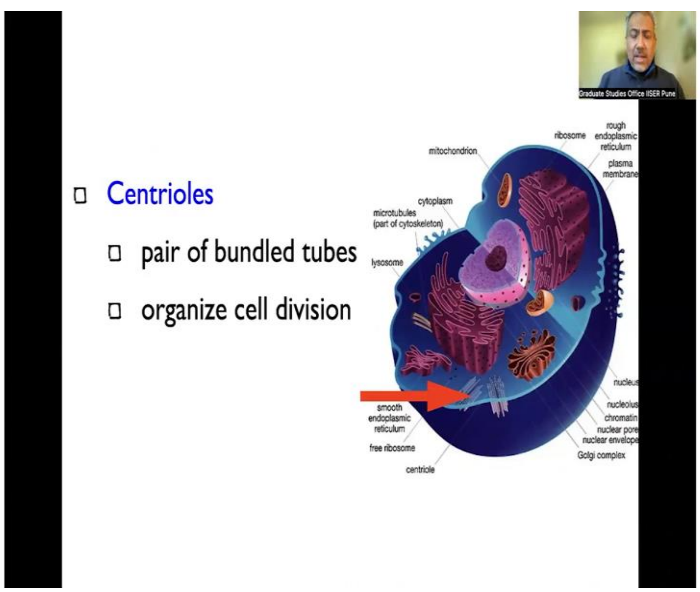

We have structures like the centrioles from which cytoskeleton components like the mitochondria originate, sorry, the microtubules originate and distribute throughout the cell.

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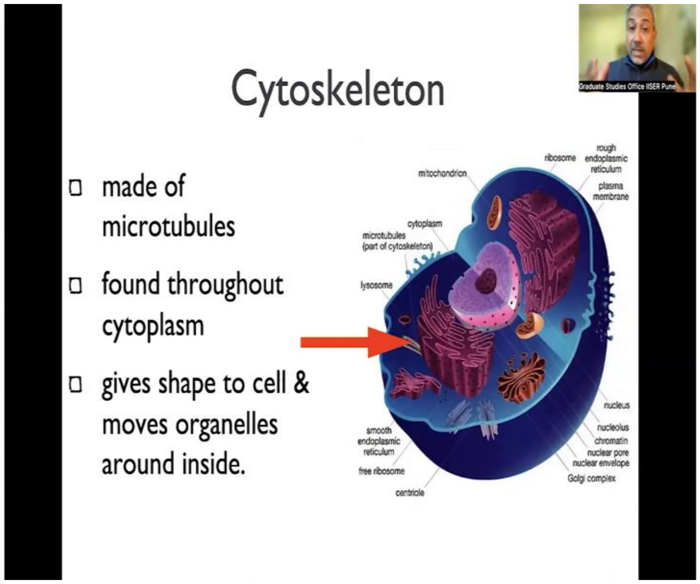

We have the cytoskeleton itself that is made up of multiple components. Again, all of this we will come to when we talk about the cytoskeleton later. But the cytoskeleton is again an integral part. It is also integral in keeping many of these organelles and structures in very distinct locations inside their cell, inside the cell.

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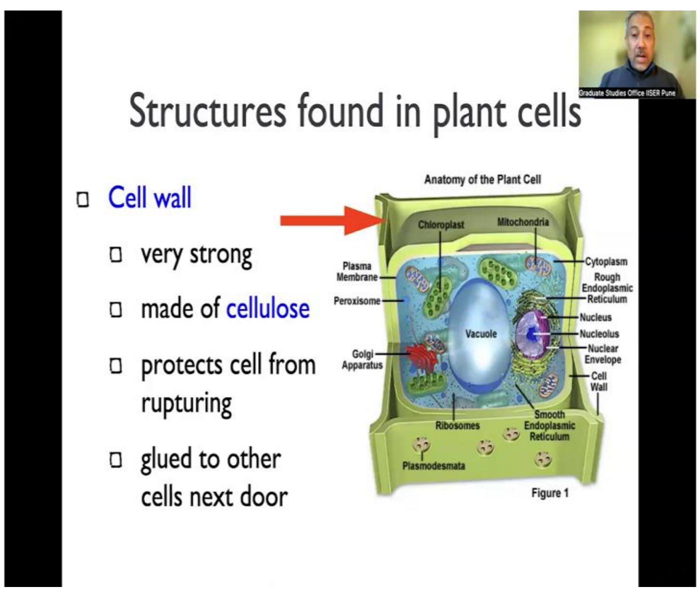

And along with this, there are distinct structures that are found in the plant cell as well. Along with the cell membrane, the plant cell has a cell wall that is made up of cellulose, which adds an important layer of protection and structure to the plant cell which is distinctly different from animal cells.

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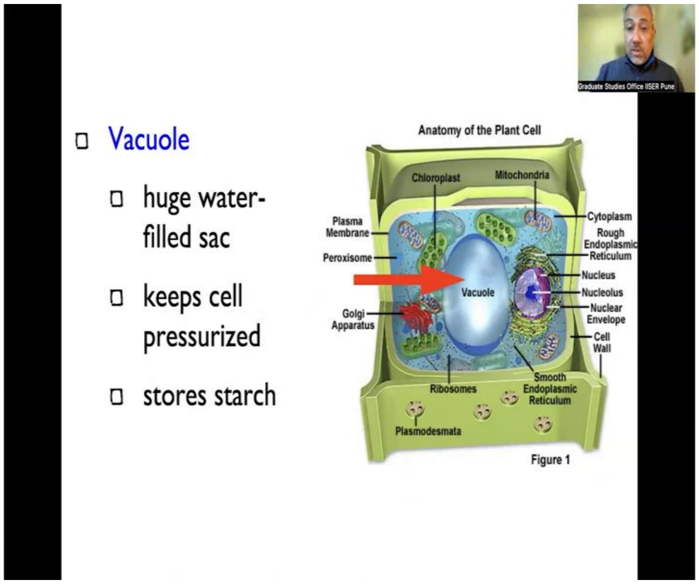

Plant cells also have this big vacuole which stores water and plays an important role, and stores starch as well and plays an important role in keeping the cell pressurized, which is again a big distinction between animal cells and plant cells.

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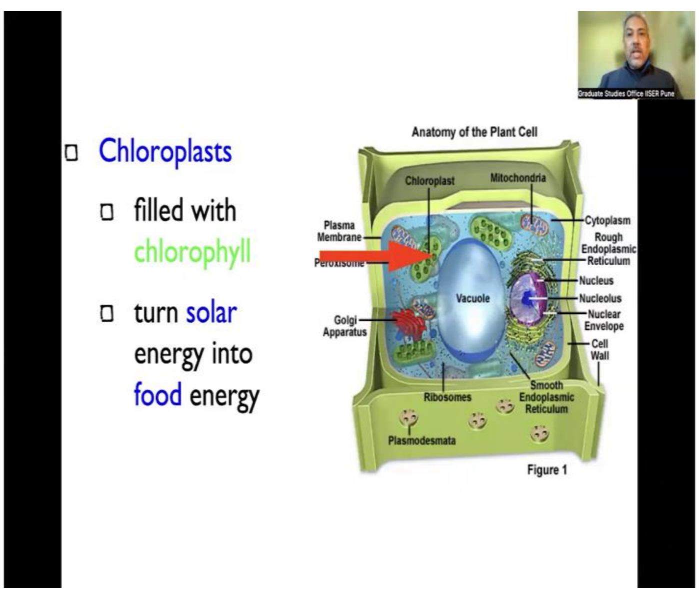

And they also have unlike cells, eukaryotic cells, these carry chloroplasts which are distinctly different from the mitochondria, but functionally may be similar in what they do for the cell. And this theory, which is called the endosymbiont theory, which we will come to, essentially suggests how chloroplasts and mitochondria might be examples of things that got integrated into cells, allowing for the development of the complexity as we know it.

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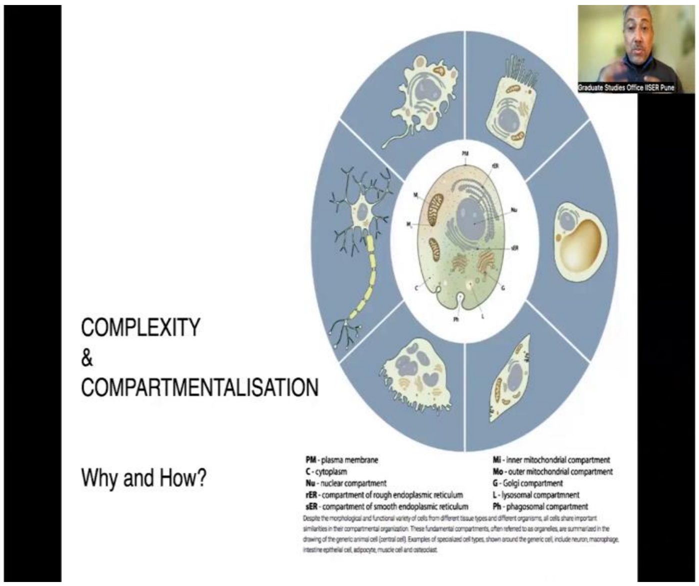

So, it is this complexity that we are talking about in terms of how things are built, and the fact that there is compartmentalization that is taking place, which are two inherent properties that distinguish eukaryotic cells from prokaryotic cells. Now, one of the things we already looked at and has been suggested on more than one occasion is the size of eukaryotes and so that is again an important distinguishing characteristic or property that they have. But along with that, we will see how complexity and compartmentalization both happen in very prominent ways in eukaryotes as compared to prokaryotes.