Nanobiophotonics: Touching Our Daily Life
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Lecture No. 09
The Cell

Hello, and welcome. We are continuing with our discussion on Preliminary Topics. In preliminary topics, this is the second part chapter number 2, where we are discussing the basics of biology and photonics. The previous 3 lectures were basics of photonics and biology. In the remaining 2 lectures, we are going to discuss the very basic of biology by very basic I mean high school stuff. Now, remember I am not a biologist, I am an electronics engineer.

So, I will be teaching you biology from my perspective. And as I said this is going to be high school level. This is for those of you who are from physics or engineering background, who may have not taken biology in their high school class 11 and 12 or after class 12, you have not touched biology. So, these 2 lectures basic as they are, they are targeted for these audience particularly.

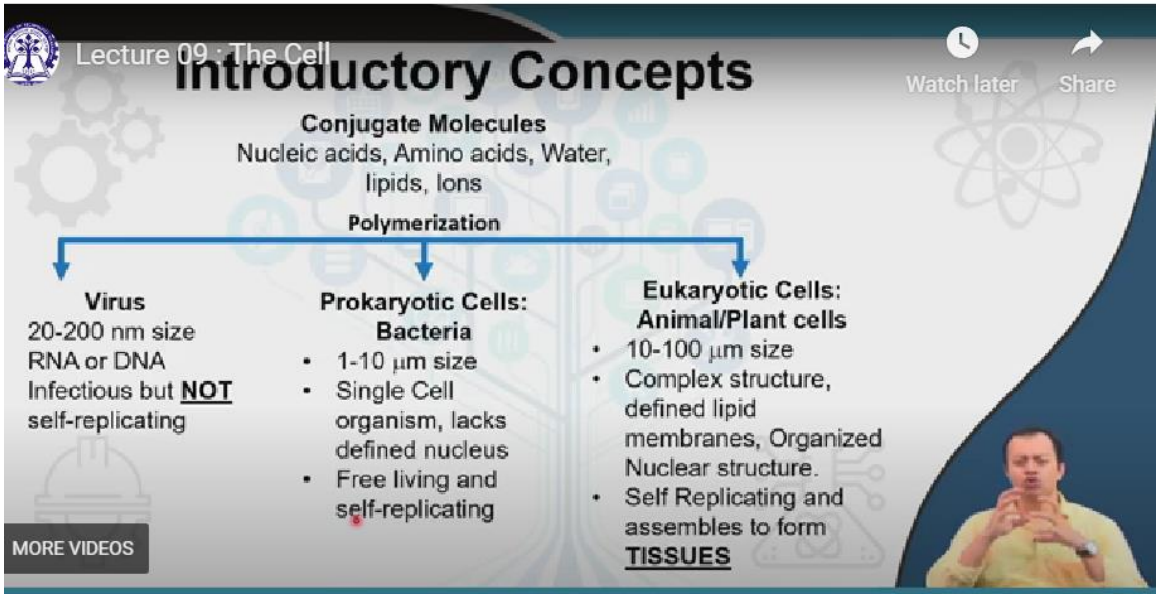
Remember this is preliminary preliminary. So, like in the previous course previous 3 lectures, I had basic of photonics basics of optics, which was scattered mostly towards students from microbiology, medical or other biological fields. And it was not targeted towards students from physics or engineering background quite similarly. These 2 chapters are targeted for students of non biology non medical background. So, just like last time, it is perfectly ok for biologists to skip this lecture and the next and join us from chapter 3 onwards.

What I will be telling you today is something that I understand each one of you know irrespective of your background, but maybe it is long forgotten. So, I am going to reject those memories, reject those concepts that you already know. I would not be telling you anything that you not know. This is preliminary, this is revision. You will see how this takes you to the next level, when we actually starts our course where the actual material comes.

And remember without a revision, without rejogging different concepts for you which might be very easy, it might not be easy for the next person alright. And if it is an interdisciplinary course, where you have both physics and physics engineering and biology medical background students coming, you have to accept this. You have to rather tolerate this. Something that you might consider because of your background is very easy, may not be very easy for the next guy. Ask a physicist or ask an engineer to define the concepts of

biology, you will know and ask a biologist to you know solve you a truth table.

There are several people who do that, but there are also significant number of people who do not do that. So, today we are going to discuss about cell, high school stuff. So, do not worry if you are not from that background, I will be discussing very very generally. So, let us start with conjugate molecules. What exactly are conjugate molecules? Last time we discussed a little bit about conjugate molecules.



So, conjugate molecules comes under the topic of the molecular material. So, conjugate materials conjugate molecules are those molecules that have a monomer like a basic unit cell. A core a basic unit made up of a variety of complex elements, they combine they form a very complicated molecules and that unit that monomer is then linearly combining with other similar monomers, other same monomers or other similar monomers in a polymerized fashion to make a hugely complicated polymeric structure. So, we start from basic monomer, this monomer is made up of a variety of molecules carbon, hydrogen, oxygen, nitrogen, sometimes iron, sometimes metal, sometimes this, sometimes that they form a core structure. Conjugate molecules are having a variety of expressions as in the sense they have a plethora of mostly S and P π bonding is very very common there, recall your high school chemistry π bonding S and P bonds are plentiful and these bonds are usually pretty strong, these bonds in itself in the monomer itself are pretty strong.

So, the unit itself is pretty strong. So, if electronic students are asking how it is different from lattice of a semiconductor, lattice of a semiconductor is made up of you know very similar types of atoms maybe 1 or maybe 2 silicon and oxygen, gallium or arsenide etcetera etcetera. Here you have a combination a variety and they form chain, they form bonds this monomers, they form monomeric bonds with other such monomers and make a polymer and these bonds one monomer to another monomer is generally generally weak. One lattice

of silicon dioxide or one lattice of silicon or one lattice of gallium arsenide is very strongly bonded with the neighbor lattice, they are not weakly bonded. Here you have it is like beads in a necklace or something like that in a garland for say.

So, the monomer is there made up of complex molecules, they are very strongly bonded together, but they are bonded with the next monomer of similar types relatively weak usually van der Waal forces or hydrogen bonds or things like that and hence we are these materials are softer, we are conjugated molecules, we are made up of conjugated molecules and hence these materials are pretty soft. The internal bond the inter bond can easily be broken with temperature, pressure other kind of energy. So, this conjugated molecules combine together and form further you know basic building blocks which can be considered as macromolecules biological macromolecules. Macromolecules are in the sense they are large molecules, variety of molecules large molecules polymers nucleic acids are one of them, then you have amino acids which forms proteins lipids and few other which are not exactly conjugate molecules waters and ion they polymerized together. One of the major advantage of this conjugate molecules is that not only they form a variety of bonds among themselves, they can form a variety of bonds with non conjugated molecules as well and hence you see variety in organic material organic matter.

They polymerize they polymerize and form what we call as the basic building block of life, they form biochemical reactions and they form a basic building block of life. So, polymerization of conjugate molecules complex conjugate molecules combine together and they start giving you the hint, they start giving you the trailer, they start giving you the advent of something that can be roughly considered as life . We first start with virus now strictly speaking virus are at the boundary between living and non living materials viruses are very small \ 20 to 200 nanometer size. It has basically a genetic material and it is a genetic material such as this genetic materials RNA or DNA nucleic acids and that is covered in a protein plus lipid shell. So, there is a envelope which is protein and lipid and it has a genetic material as such.

They cannot replicate they cannot reproduce by themselves and thereby they are called organic assembles organic assembles. They infect or they hijack the reproductive mechanism of a host say a particular cell a cell can reproduce by itself the reproductive mechanism of the cell is hijacked by virus. So, cell do not reproduce itself instead cell starts reproducing more viruses. So, technically a virus reproduce only inside a host outside the host it is as good as a non living material. So, they are called basically organic assembles large number of organic molecule complex organic molecules are assembled together are brought in close together.

What they do afterwards is something that is that can be debated. The genetic material

could be RNA or DNA deoxyribonucleic acid and ribonucleic acids. We will be discussing it in moderately detail in the next chapter, but they are containing genetic material these are genetic materials genetic materials covered with protein and envelopes protein and lipid envelope. So, these spikes that you see these are proteins these are the spikes by which they attach themselves they attach themselves to a particular cell and insert through drill it and insert this genetic material these genetic material hijack the cellular reproductive mechanism of the cell and start reproducing this rather than it is own type. Now, before we are going to this further let us first understand because these are so called life what exactly is the difference between life and non life.

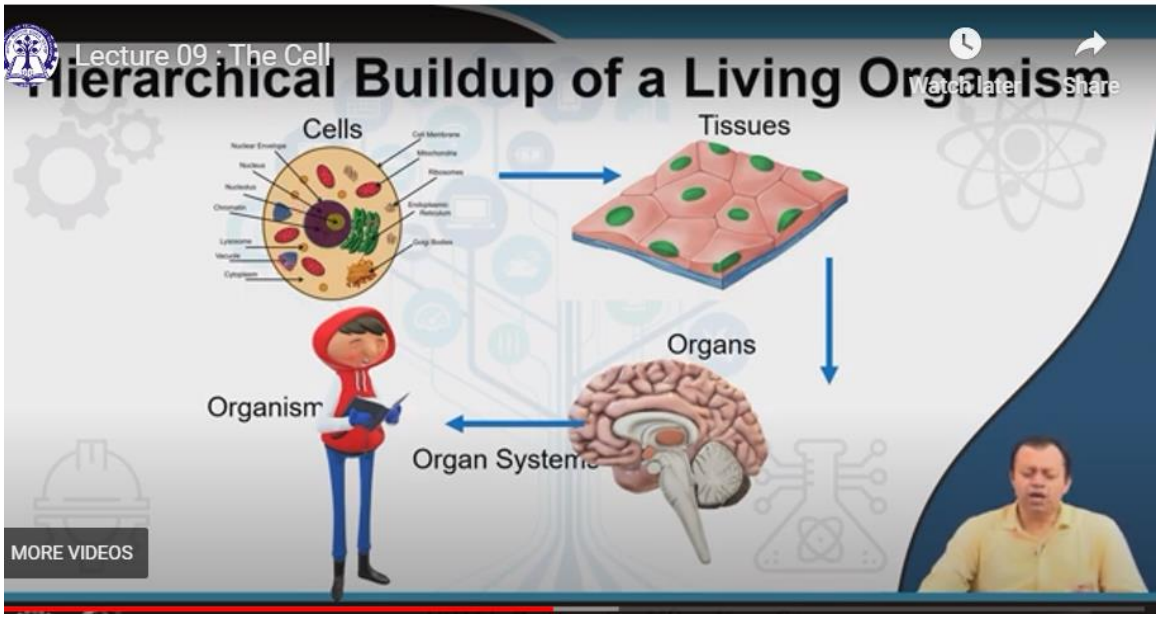
How do you differentiate a living organism with respect to something that is non living? Well previously we thought that three major criterias are there for a material to fulfill if we consider it as living or not three major criteria. First one that material that object that thing has to accept energy from external environment that object gets energy and sustain itself continues to stay in more or less in its present state by accepting by consuming energy from external sources. The external source could be heat, light, sunlight or it could be protein food which could be broken down into carbohydrates and glucose thereby producing energy. So, it needs to consume energy living thing it needs to consume energy second it needs to react towards external stimulus. So, if you have done something to it some kind of environmental change has happened something has taken place which is sudden which is fast which is rapid it is going to react to it.

A living organism has to react to an external threat external change external modification external stimulation sudden change in temperature pressure sudden change in threat perception the more complicated the organism goes the more complicated the threat surrounding it becomes. And thirdly the material the thing the object should be able to reproduce these are the three things. So, viruses fulfill two of those criterias they do consume energy from outside and they do require well consumption of energy depends where it is and they do react to external stimuli, but they do not reproduce just by themselves they require something else to reproduce for of them they cannot reproduce themselves. So, two out of three it depends on you whether you will particularly consider there as living or not living. So, there is a debate going on about this it is still it is still debatable.

However, the next case there is no doubt is those prokaryotic cells bacteria basically they are single cell organism a cell itself is sufficient the cell itself is the organism it lacks defined nucleus or any different compartment inside the cell and it is free living and self replicating it replicate among itself it consumes energy from external sources and divide itself into 2 3 8 10 etcetera. 1 to 10 micrometer size single cell, the cell itself is the organism it do not have any definite compartment or definite structures within the cell that perform

specific functions and it itself itself replicating itself replicates it takes energy and its replicates. These are bacteria single cell organisms prokaryotic cells bacteria I have to be mindful of the Freudian slips. The third category most definitely are eukaryotic cells these are animal or plant cells this eukaryotic cells are something that we are made up of. They are 10 to 100 micrometer size they are very very complicated structures they have specific specific compartments within those cellular structures specific compartment within those cellular structures that each perform individual task the performance of one particular compartment cannot be taken by another compartment these compartment are called organelles organelles have specific function these specific functions are specific to a particular organelle and the organelle will not do anything other than what it is assigned to it in 99 percent of cases in biology there will always be an exception there will always be something or else that is new and coming up and that will break the boundary, but this is as I said high school biology you do not need to at this present moment worry about the exceptions. Let us understand the rules first and then when we and have understood or more or less grasp the concept the rules we go to the exceptions. The fantastic thing about eukaryotic cells animal cells plant cells are they can combine all several of them can combine together to perform a larger function in itself.

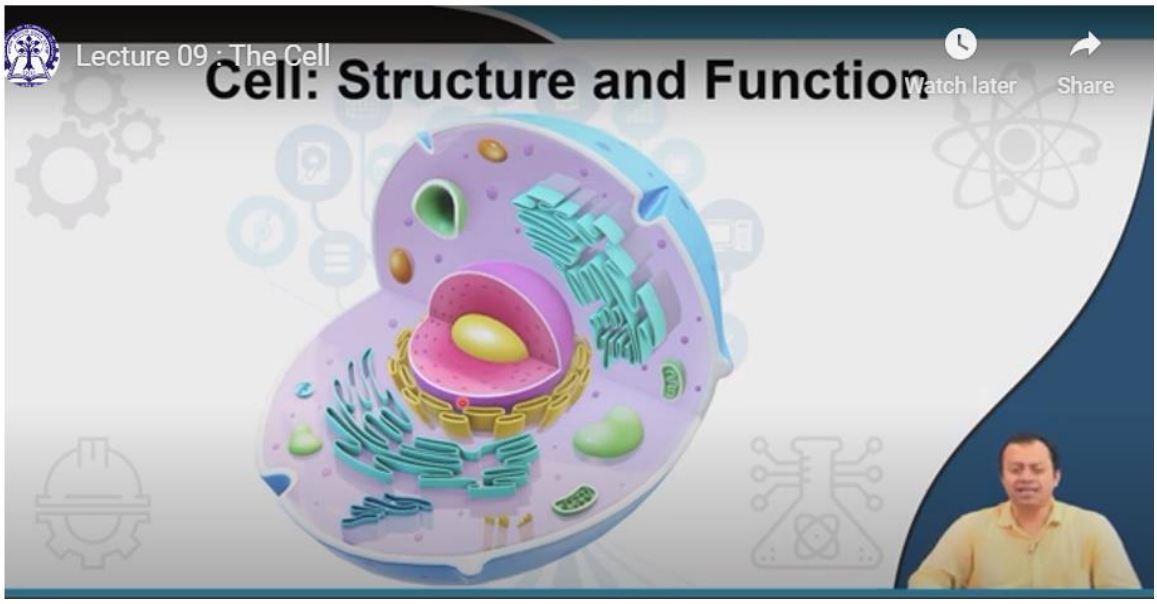
So, a combination of several cells of similar type for a particular purpose is the this assembly are called tissues. So, you have viruses boundary living non living prokaryotic cells, cell itself is the organism and then eukaryotic cells for complex they can combine together they can combine together to perform a particular function. So, this is the complicated structure of eukaryotic cells it has nucleus and different these compartments each compartments perform a specific function. So, the there is a hierarchical build up. So, each of these eukaryotic cells I am talking about eukaryotic cells generally by themselves they have difficulty living just by themselves like unlike the prokaryotic cells prokaryotic cells they themselves are self sufficient.



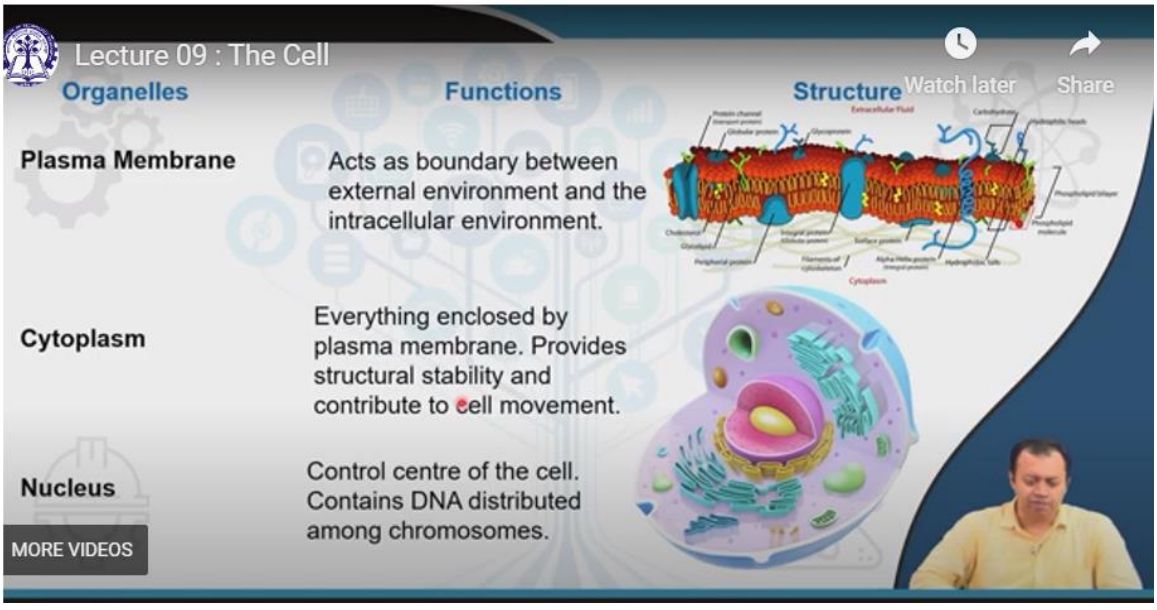
I would not say eukaryotic cell is not self sufficient, but its properties or its complexities or its beauty is manifested when it is combining itself with several other similar type of cells which can also bond with dissimilar type of cells. So, the actual manifestation of what a cell can do is us rather than a bacteria a bacteria by itself is self sufficient, but a bacteria can do probably less than 1000 of a function or one millionth of a function that we can do though maybe our one single eukaryotic cell is not as self sufficient as a prokaryotic cell is. So, combination of cells doing similar type of works can be considered as tissues several different type of tissues combine together to form organ, organ performs several 1000 order more complicated functions compare this with brain the type of function your human brain can do we will learn brain slightly in more detail in the last 3 or 4 chapters and this combination of different organs all acting in coherence with each other produces the organism produces the organism we are the final product. So, we start from this end up in this. So, cells are basic unit of life every high school student knows this it has been drilled, but understand what it is coming from a cell is a basic unit of life you combine similar types of cells tissues different types of tissues organs different types of organs into organ systems different types of organ systems combining together to form organism.

Thus far we are good physics student good engineering students good do not run away I know like vampires get afraid by the cross physics or engineering students get afraid by biology the moment you use the term biology or DNA or RNA it is the same effect of cross kept in front of a vampire I do not know why surprisingly it is not that if complicated for biology students I am I myself I am an engineer, but when you talk about truth table or algorithm or machine learning all those concepts to biologists frankly speaking they are relatively more forthcoming to accept that that is just couple of examples that I have seen I am sure there are exceptions, but what I have seen is that physicist or engineers are more

reluctant to accept biology than biologists are reluctant to accept physics or engineering concept I do not know why is this there is disparity, but both hate each other no doubt about it you can tell me later.

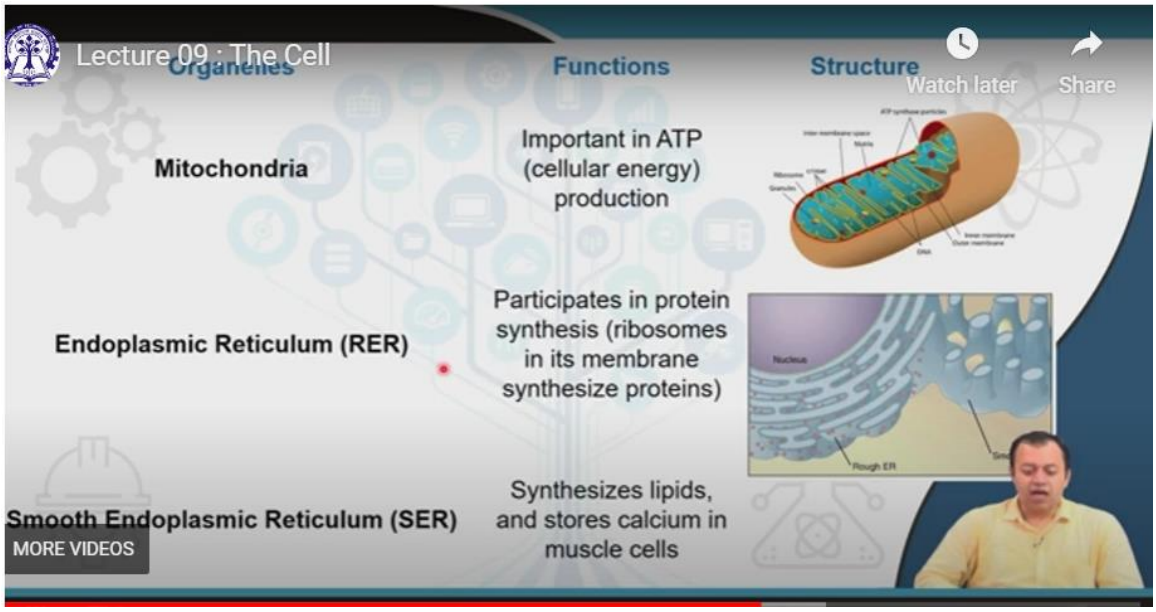


So, let us try to understand the eukaryotic cells we will be mostly dealing with eukaryotic cells if and when prokaryotic or viruses come I will be discussing that more in the coming chapters, but let us understand the cell function. So, this is the cell it has several different compartments within itself these compartments perform specific specific function and these compartments these specific weird looking compartments are called organelles not organelles organelles organelles repeat after me organelles and these organelles have specific specific function.



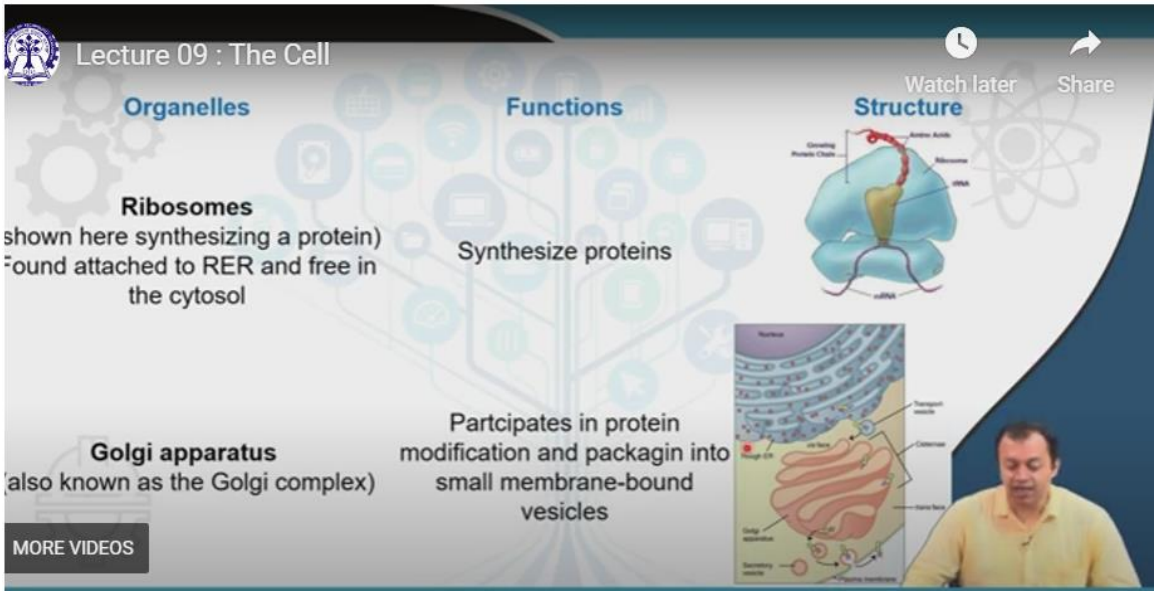
So, the first one is the plasma membrane plasma membrane is the boundary the boundary the outermost periphery the outermost boundary of the cell it is a semi permeable membrane just like you, if you put a fence around your house in around your property it is the same thing it is a wall that prevents unwanted things to come inside it is semi permeable it has gates ion channel gates which allows certain materials to come inside and you need to allow something to come inside and pass through otherwise it will simply die without getting anything from outside without interacting with outside without combining itself with other cell of similar types and then make a tissue. So, plasma membrane is just this outer membrane a fence a defense defensive thing that is there to allow or disallow materials to pass through.

So, this is the first thing that the virus tries to invade these are some of the gates that it tries to break it is like invading a castle you attack certain gates then you have cytoplasm cytoplasm is the jelly like thing inside the cell everything is enclosed in plasma membrane it is provide the stability and contribute to cell movement it is that semi fluidic viscous medium in which everything floats or everything it is viscous. So, float probably is not the one here it is embedded inside them and it has a particular polarity it allows it maintains a particular chemical balance pH pressure temperature etcetera also it provides the structural stability and cell movement or everything else is embedded inside them. The nucleus is the center of the cell the nucleus is the center of the cell and it contains the DNA distributed among chromosomes do not worry I have a fantastic prop to tell you exactly what it is. So, the DNA contains all the information that is required to create an organism DNA is the code DNA is the sets of 0s and sets of 0s and 1s that is the that basically comes out together to a beautiful movie or a picture something like that that you basically see code get translated into something else. So, the DNA is put inside nucleus nucleus is the control center of the cell and I will be dealing with that in a moment.



Then there are mitochondria. So, organelles came from the term that people were when they anatomically they opened up a human being they found out there are organs liver heart etcetera. Similarly, when they opened up a cell they found out many such smaller compartments inside a cell which has its own function like our liver our lungs our brain everything has a different function similarly the organelles also have different functions and since they were like organs they were called as organelles smaller organs. Mitochondria, mitochondria is the battery of the cell mitochondria produces this ATP adenosine triphosphate these are basically the molecules that breakdowns and produces energy this is the energy currency. So, more mitochondria inside a particular cell the cell is more energetic especially our rod cells, cone cells etcetera. Mitochondria are the compartment or the organelles inside the cell that produces most of its energy it is the battery part of a large circuit a circuit contains I am electronics engineering it for you a circuit contains diode, inductor, capacitor, resistor, wire this this this, but then you need to have a source or a battery or a bias this is it this is it do not use the term bias that goes in a different direction.

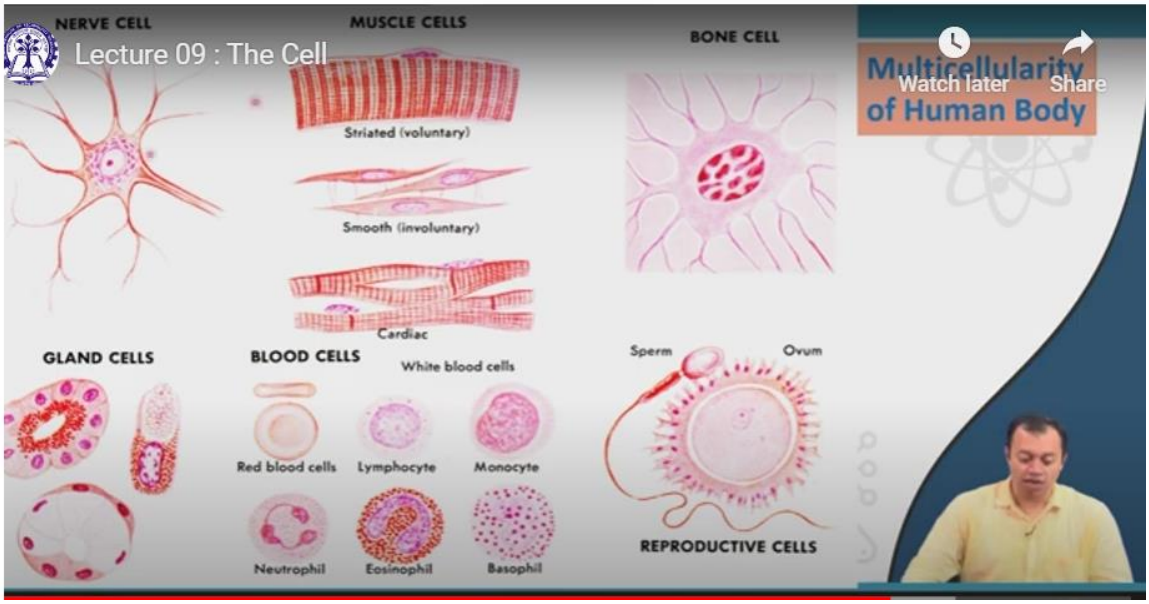
Then you have endoplasmic reticulum RER and SCR they are divided into smooth and rough endoplasmic reticulum and they creates well they precipitates in protein synthesis they helps in protein synthesis they have ribosomes in them ribosomes convert RNA into proteins or packs them I know biology students are already ripping their hair apart, but we are engineers at the end of the day smooth endoplasmic reticulum synthesizes lipids and stores calciums and muscles .



Then you have ribosomes as I shown they are here to synthesize a protein they are connected with rough endoplasmic reticulum and they synthesize the protein they create the amino acids. Golgi apparatus are the post office of a cell different types of so, all the

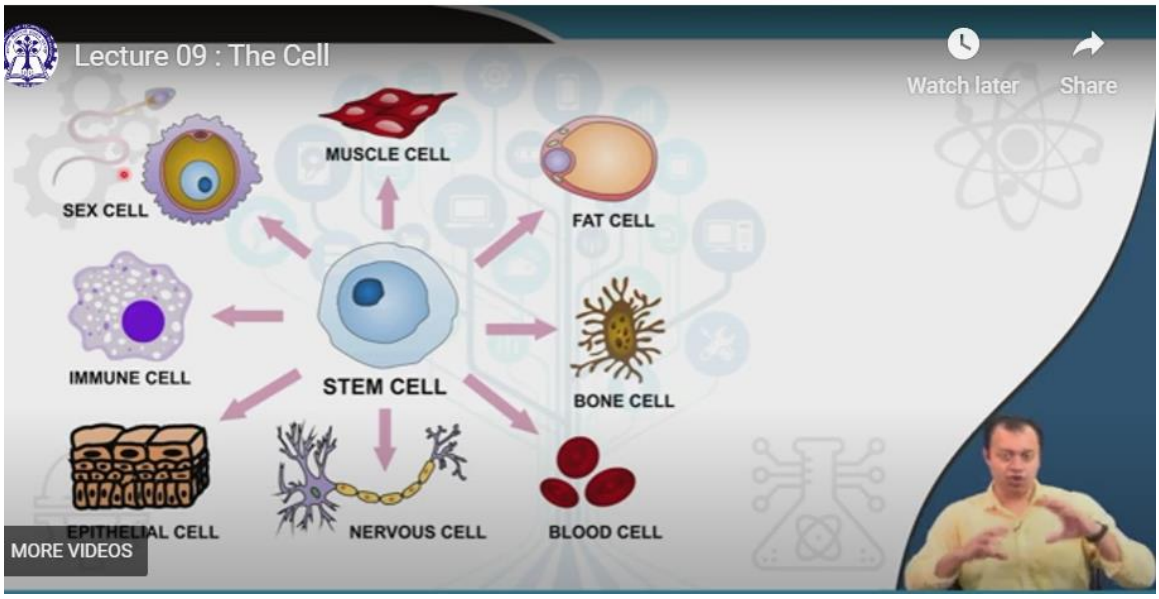
functions in our body are because of certain types of proteins I am talking to you because of a protein my skin color is a particular tone because of a particular protein I am susceptible to diabetes because of particular protein which is because of a gene which is part of a DNA, but at the end of the day it is the protein that functions. So, cells produce proteins well DNA produces RNA, RNA produces proteins. So, the cell which contains the DNA inside it nucleus produces the protein in search as such and there are different types of proteins.

So, where a particular protein will go outside the cell is determined by the Golgi apparatus it participates in protein modification packaging into small membrane bond vesicles they then take the protein out of the cell to a particular location. So, as I said in post office thousands of letters come the postman short sets out one is for particular city one is for a particular village one is for a particular town and then those individual letters which all come to a particular post office get sorted out get distributed out into different areas different locations is basically what Golgi apparatus do. All the proteins that a cell is creating yes cell is creating because the nucleus is creating the DNA is creating which is inside the cell it is not outside the cell comes finally, to the sorting session to this distributing session Golgi apparatus and then they distribute it and that is it.



When you have large number of cells different types you have you know different well these are example of different types of cells nerve cells gland cells muscle cells etcetera they combine all of them combined together and to make a particular complex life form such as ourselves such as ourselves this is exactly what cell basically do. So, see not that hard is it physics people not that hard you can simply go through without converting yourself into a biologist.

So, that is it needless to say there is people make their career out of just studying a single nerve cell. So, I cannot give you crash course of biology in half an hour, but as we evolve as we go further into the course we will be adding more and more biology concepts with it and if you are sufficiently imaginative enough and not scared of the unknown this is something that we are going to do.



One more thing that you need to know there is something called stem cells I think you have all heard in 2012 they got the Nobel prize stem cells are the cells that are between progenitor cells progenitor cells are the cells from which everything else comes up and they can they cannot reproduce indefinitely, but stem cells can reproduce indefinitely stem cells can differentiate into any cell. So, here a muscle cell will divide and replicate into another muscle cell nerve cell will divide and replicate into another nerve cell a nerve cell will not divide and become a muscle cell. A muscle cell will not divide and become blood cell.

A blood cell will not divide and become a reproductive cell, but a stem cell can divide into any number of cells or it can still stay divide into just a stem cell. So, stem cells forms a middle ground between progenitor cells that is the proto cell something that gives rise to everything else as well as you know differentiated cells this will only differentiate into fat cell, bone cell will only differentiate into bone cell, but stem cells can either differentiate into any one of them or can simply keep on differentiating itself it depends on several factors. We have been able to control to a large extent several properties of stem cells previously stem cells were found in embryos. So, there was a huge controversy that whether we should be extracting embryos and doing this research, but now we have found out that any of these cells have the capacity to return back to reverse engineer itself into stem cell in a lab inside a natural organism a stem cells breaks down or differentiate into

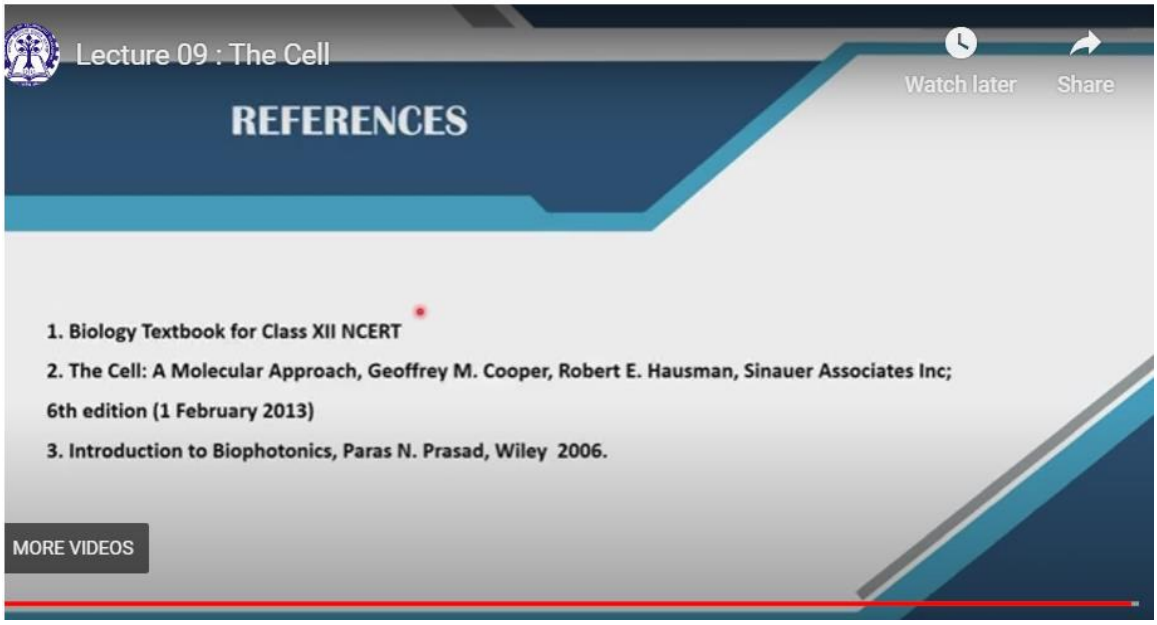
either this or by itself there is no reverse process. So, the arrow is only in one direction, but in lab you can convert fat cell or bone cell or blood cell into stem cell in a lab and thereby the controversy has basically died down yes stem cells have also different types and different categories I am not going into that I know biology student will scoff, but I am not going into that because that has very little to do with what we have started to study.

We look you know cellular structure from a organic molecules conjugate molecules viewpoint rather than we break it down into a biological viewpoint let us we try to see it into different viewpoints. So, I know you are reaching to tell us about mesenchymal cells stem cells etcetera somatic stem cells etcetera, but I do not see the point of discussing it at this present moment for benefit of physics people. So, stem cells stem cells are those cells that can be broken down or that can divide into anything else this has found application in therapy we have a bone damage cartilage damage cancer etcetera those stem cells from your own body can be made to you know recreate replace the damaged part stem cell therapy perhaps you have heard, but the therapy still has some complications we are still not able to control it fully meaning probably a bone section has fragmented and you have inserted stem cell into it. Some of the stem cells divide into bones and then bones start healing, but then another part of the stem cell do not divide or create muscle cells in the same area and that cause further complication you do not need muscles inside your bone inside your bone.
So, that that causes problem. So, stem cell therapy is still going on.

So, that basically ends it, but here I have brought in a prop for you I have brought in a prop for you I hope this will help you understand what a cell or a DNA is. So, yeah so what do

I have with me is a CD this is a prop this is a CD all of you have seen this the code that is written inside this CD sets of 0s and 1s which basically runs a particular program particular software say suppose I have put a movie inside it or a music inside it it is in sets of 0s and 1s in those structures in those in those CD structures. So, these codes are the genetic sequence yeah the code is this genetic sequence and this genetic sequence are each track the CDs have tracks. So, the tracks could be of the CDs could be considered as DNA the codes genetic sequence is written in DNA just like your sets of 0s and 1s are in those tracks.

This tracks are combined together into this compact disk this disk is the chromosome we have 23 pairs of chromosome we have 23 pairs of chromosome this chromosome goes inside this packet this chromosome goes inside this particular packet this packet is this packet is the nucleus and this along with several other packing materials several other packing materials is inside the envelope the envelope is protecting the entire thing. So, this entire thing this entire thing is cell of course, there are so many things inside which has its own performance which has its own work, but this overall is the cell no analogy is perfect this is also not perfect, but this is something I need to give you a first glimpse of genetic materials or gene what are genes as to the non medical background students. This is not the perfect analogy no analogy is perfect, but use this as your imagination.



So, these are the topics that we have discussed and these are some very basic you can start your biology class with as you increase your knowledge go back to something that is far important and I will see you in the next class. Thank you very much.