Biophotonics
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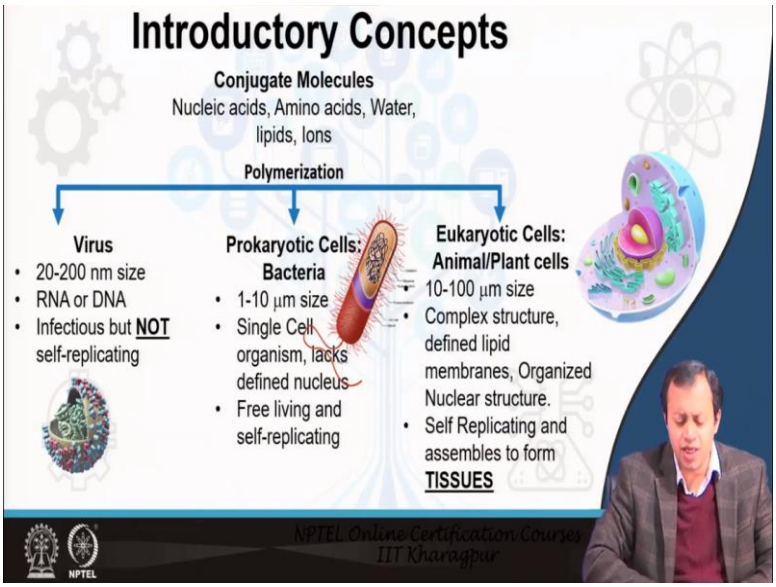
Lecture – 11
The Cell

Hello and welcome. As part of our discussion on Biophotonics, we will continue today with the third module Basics of Biology. Now remember I am not a biologist, I am an electronics engineer. So, this particular module, this entire module number 3 basic of biology is scattered for those of you who have not taken biology from a very, very long time say from your high school days.

This is not a crash course on biology. I will not be able to tell you every aspect of biology obviously that is not possible in a two- and half-hour lecture. Biology is a field, it is an ocean in itself, people specialize in different aspects of biology. So, that is not the aim of this topic anyways this is just to familiarize yourself with some of the very, very common biological terms, some of the very common biological concepts that you may already know, but due to long disuse you have forgotten.

Again, for those of you who comes from a life science background who have spend their most of adult life studying biology. It is perfectly well for you to skip this part, this is simply a revision I have catered just like I have catered previously the light matter interaction for those from a non-physics background, non-electronics engineering background. This time it is just the reverse.

Here the basics of biology will be catered for those from a non-life science, non biology, non medical background. This is specifically for electronics engineers and electrical or mechanical engineers, instrumentation and someone from physics background. Several topics will be simplified and several aspects will be skipped a bit. I will give you details of where to find a more prolong, more elongated, more detailed version of those topics and you are welcome to study those links. However, I will stick myself to simpler concepts, concepts which are most importantly relevant to our course on biophotonics per se. Now, let us start.



Now, all of us know that life begins at cells, but there is bit more to it. So, by this time all of you must know what conjugate molecules are, we discussed conjugate molecules in detail in our previous classes. So, of the several different types of conjugate molecules, of the variety of the conjugate molecules there are few of them such as nucleic acids, amino acids, lipids, ions, etcetera.

They polymerize and create several fantastic, several interesting, several unique biochemical reactions. Conjugate molecules we discussed previously what they are. Conjugate molecule such as nucleic acids, amino acids, lipids, etcetera combined together and create fantastic biochemical reaction of the several different varieties of biochemical reactions that they create one of them is called life.

Yes, you heard me, life is a set of biochemical reactions, a series, a complicated biochemical reaction, but a reaction nonetheless. So, several of these conjugate molecules nucleic acids, amino acids along with some non so conjugate molecules such as waters and some ions polymerize to form three basic complexes, let us call them complexes. One of them being virus.

Now, strictly speaking viruses are not alive. Nowadays, this pandemic is going on of Corona virus you will know by this time even in news media they have discussed a lot about what viruses are, strictly speaking viruses comes in the border line between living and non living entities. Viruses are specifically these protein capsules, they contain a protein outer layer and

inner layer there is this nucleic acids, there is this genetic material which can be either RNA or DNA.

Corona virus for example is a RNA virus. It is genetic material is RNA. So, they are infectious, but it does not have the capacity to replicate, to reproduce by itself. So, this is the outer layer, the outer protein layer and this is the genetic material which can be DNA or RNA. When they ask you to wash your hands regularly either the alcohol which is present in sanitizer or the other chemicals present in soaps.

Such as hydrophobic or hydrophilic elements just wash away or dissolve this outer protein layer and as a result this genetic material simply comes out and the virus in itself cease to exist in this particular form and cannot harm you anymore. So, basically what soap is doing, soap is dissolving the outer protein or outer sometimes it may contain lipid as well this outer layer.

So, viruses are one such chemical complexes that these conjugate molecules create, they are having a size of 20 to 200 nanometer, they are infectious, but they cannot reproduce by themselves and we require and they require specific host bodies, host mechanism to reproduce. Then comes prokaryotic cells. This can be considered very well a living. What is the definition of living?

Well, there are several definitions of living, certain criteria need to fulfill, they need to react to stimuli, they need to accept energy from external environment and grow in certain fraction and obviously they had needs to reproduce it. Since viruses fails to reproduce by themselves they are called assembles rather than a live or living entity itself. However, there are debates surrounding that.

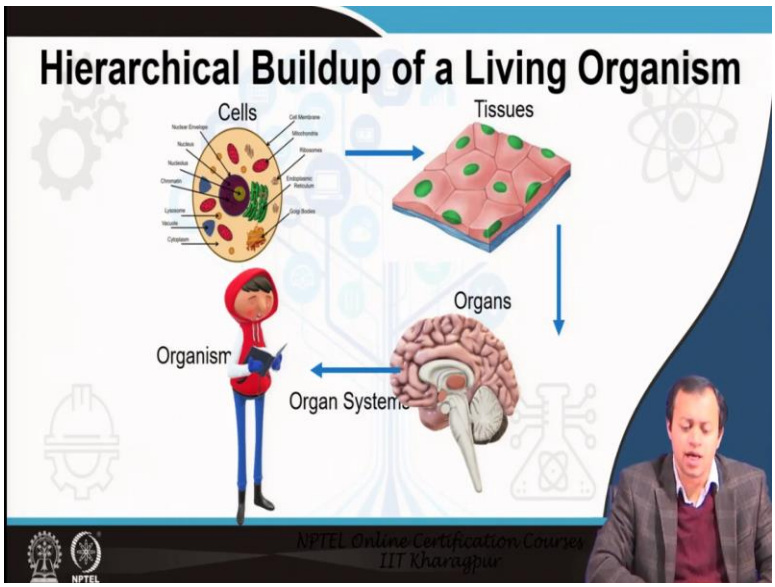
Prokaryotic cells basically are these bacteria. They are 1 to 10 micrometers in size see how the size have immediately changed, they are single cell organisms and they do not have specific compartments inside their cells. I will tell you what exactly compartments mean. So, prokaryotic cells, these are single cellular organisms, they are an entity by itself in their individual cells.

They can reproduce, they can self reproduce, but they do not have specific division inside their cell and they cannot combine together to form tissue. Tissue is quite important for higher organism. Finally, we come to eukaryotic cells which are animals and plant cells much

complex higher life form this is like this and they are of a far greater size 10 to 100 micrometer in size, they have complex structure and defined compartments.

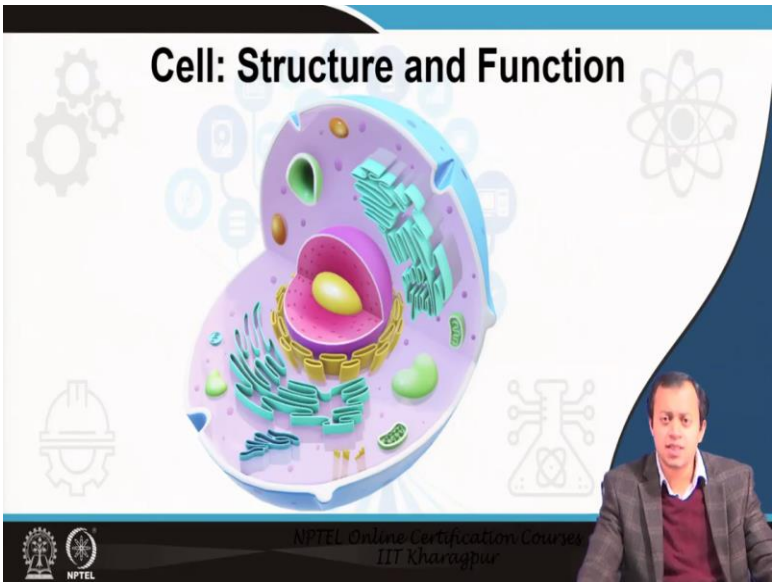
Specific parts defined within the cell structure that performs specific function. Prokaryotic cells do not have specific compartments, specific boundaries. They just have the nucleus floating around, nuclear material floating around inside the cell. Here, every different part has a boundary and perform a specific function. They can replicate themselves and they can assemble to form tissues.

We will see how tissue finally forms organs from organ system. Organ systems perform much more complicated task and finally an organism is created. So, almost all higher life forms are eukaryotic cells, the lower life forms bacteria are prokaryotic cells and below that in the border between living and non living are the viruses. I assume you know it already from your high school there was nothing new that I taught you here. It just helps to revise certain types.



So, as I was saying the hierarchical build up of a living organism is simply like this you have a eukaryotic cell this cell has a different compartment, different compartments perform different functions they combine cells combine to form tissues, several of these different types of tissues combine to form organs, several organs combine to form organ systems and when you have a complex network of organ systems you have an organism.

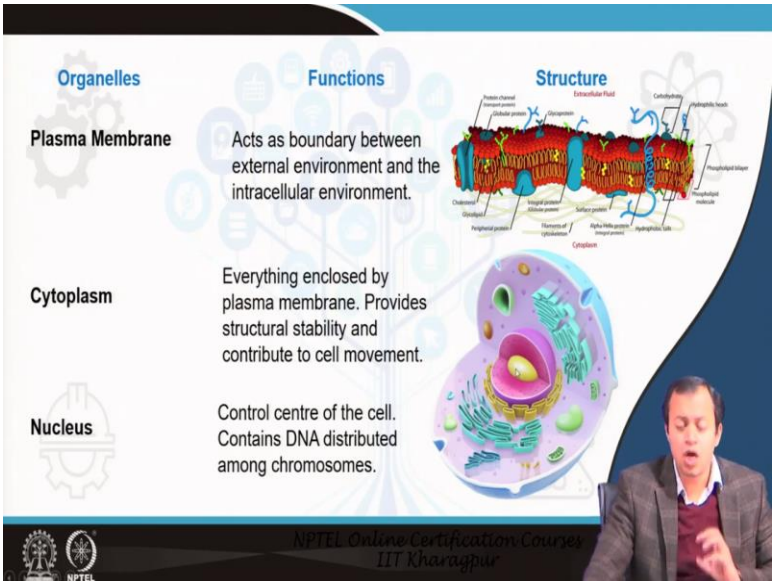
We are all organism lower to higher. Human beings are one of the most complicated organisms as such and all of us have this specific hierarchy that is going on. Though, there are different types of cells, different types of tissues and different types of organs and obviously there are several different types or organisms. The fact of matter remains that eukaryotic cells have something very, very specific any eukaryotic cells have some very, very specific details. We are going to discuss that.



Now, this is a representation of your cellular structure, eukaryotic cellular structure and there are these different compartments. These different compartments are called organelles. Organelle simply means small organ. So, the idea was when they were discovering this they were, they already knew what organs in human body do like you have a brain which performs a specific function, you have a lung which perform a specific function.

You have heart which perform a specific function. They figured out that there is somewhat of an analogous to those organs inside the cells. The specific compartment thereby was called organelles or small organs. Small organs which are inside the cells that perform various specific and distinct function. So, again eukaryotic cells have specific compartments inside them, these specific compartments are called organelles.

They have specific boundaries, specific shape, specific structure and they perform a very, very specific function. Now, let us understand some of these organelles and what are the different functions that we are going they perform?



So, the first being the plasma membrane, this is also called cell membrane, this is the outer layer. This is basically the boundary you know the fence, the wall that protects or that separates cell from outside world. They contain basically phospholipid membrane. Lipids are basically lipids and fats are mostly use synonymously, but actually fats are a type of lipids. Lipids is the bigger set, subset of that is fat.

But if you are having difficulty you can consider lipids as fats no problem and sugars as carbohydrate that will be gone we will be discussing about sugar and carbohydrates at a later stage. So, plasma membrane mostly contains this membranous structure, this lipid bilayer lipid membranous structure which has hydrophobic and hydrophilic end and they also contain several protein channels.

This is semipermeable. Semipermeable means it allows certain material to pass through them and then it disallows certain material to pass through them. Some materials from the cell needs to go out, it goes out through channels inside them just like you have gates in your fences., just like you have gates in your wall from which people get in and out. Similarly, there are doors or there are gates inside that plasma membrane also called cell membrane through which ions, proteins, etcetera pass through, cellular mechanism happens through.

Curiously enough if you are following the news you will know there is a lot of question going on about how Corona virus enters the cell and there is a certain enzymatic receptor, certain protein gate you can call it that is called ACE2 receptor look about it a bit. This is just trivial information that I am giving not part of the course just to increase your knowledge. So, ACE2

is one of those gates, a specific gate, a specific enzyme through which the hook of the Corona virus attaches and then it enters.

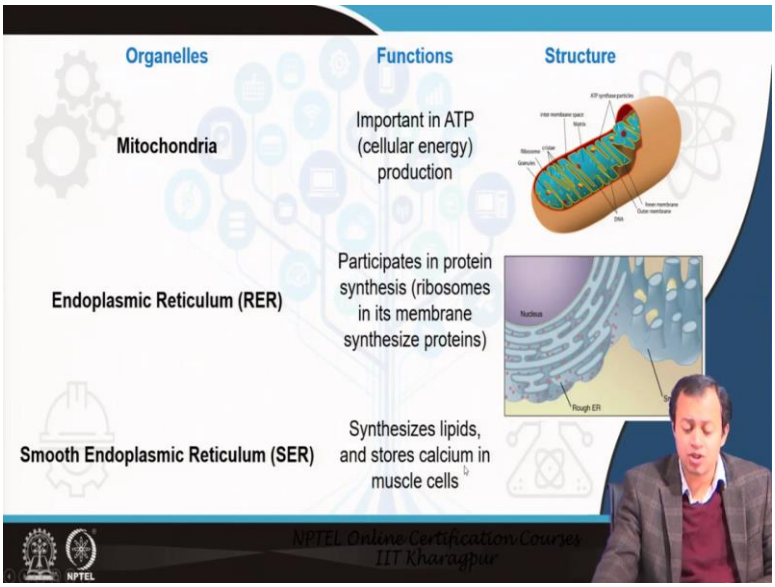
So, there is a lot of talk that if we disable the ACE2 receptor or those people whose ACE2 receptors are either genetically disabled or who constantly reproduce their cells. For example, young children their ACE2 receptors are completely changing Corona virus cannot affect them that much. You might have heard that children are less susceptible to Corona virus. It is simply because one of these gates in their cell membrane are disabled or constantly getting changed so something to know about it.

Cytoplasm on the other hand is this part. Cytoplasm is this jelly like substance that is bound inside it is semisolid, a jelly like viscous material that is bound inside the cell cytoplasm. So, every other compartment or every other organelle float inside this cytoplasm. Cytoplasm is this main material which is inside the cell that produced structural stability and contribute to the cell movement this is the semi viscous, this is the viscous material, semi solid jell like material that is enclosed inside the cell.

And everything in between, every other compartment, every other organelle inside float in this cytoplasm in this cytoplasmic cellular matrix. Nucleus just like you know about atoms. Atom has a nucleus which is the main part which contains protons and neutrons along with several other things. Nucleus is the largest organelle and that is the control center of the cell. This contains chromatin, chromosomes.

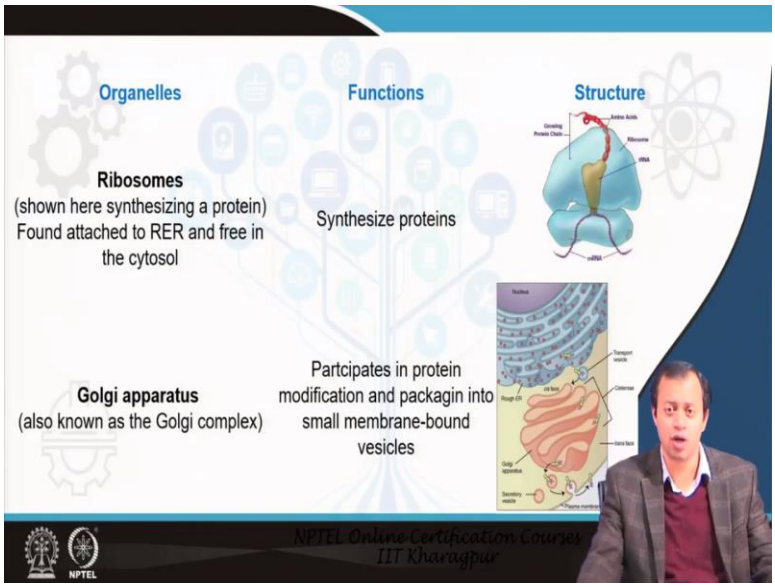
And the chromosomes contain obviously DNAs, RNAs and some amount of well chromosome does not contain RNA, but nucleus contains DNA and RNA and maybe little bit of nuclear proteins are present though huge amount of proteins are outside. So, basically nucleus contains the genetic material. Nucleus contains the information, nucleus contains the code, nucleus contains the control sticks of how this particular cell will behave.

How it will replicate, how the energy will be transported, how it will defend itself all of these things this is the center, this is the nucleus, well not necessary center this is the nucleus and this nucleus controls the very essence of the cell.



Then we have mitochondria. Mitochondria is this tubular structure I imagined it or I recognized it because it looks a battery or a cell and like a battery it is there for cellular energy production, it creates ATP Adenosine triphosphate these are the energetic molecules, they generate energy and well the energy environment, the energy of the cell is generated in mitochondria.

Mitochondria is considered the battery of the cell. Similarly, we have endoplasmic reticulum which is both rough as well as smooth. The rough endoplasmic reticulum creates proteins and the smooth endoplasmic reticulum creates lipids basically fats as well as stores calcium and muscles.



So, you see that each different organelles of the cell have very, very specific function analogous to different organs of our body. Just like lung of our body has a specific function as compared to heart as compared to kidney, as compared to liver. Similarly, all these structures microscopic as they are having very, very specific function. All of them combine together inside a cell for the cell to move about, for the cell to propagate.

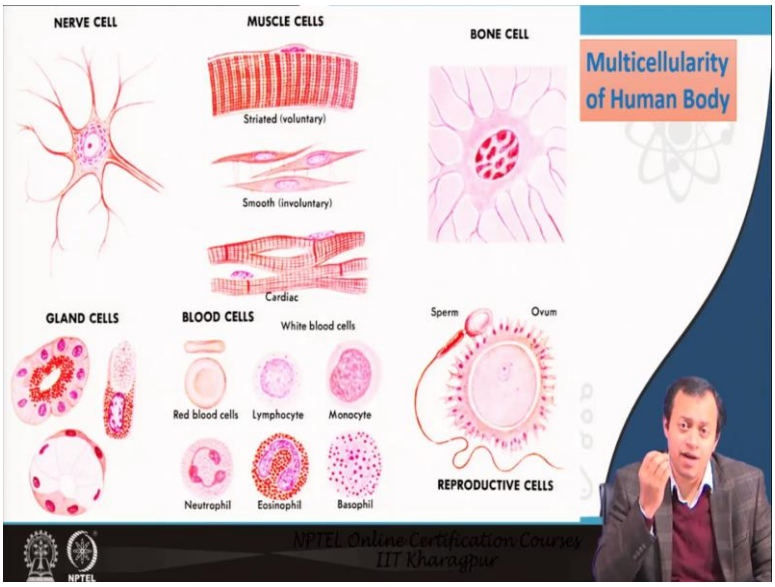
For the cell to reproduce and thereby the very essence of life is formed. We have ribosomes that synthesize proteins. Proteins has the most important molecules, proteins are the most important macro molecules of the body almost all function metabolism, reproduction everything happens because of proteins, amino acids and then we have Golgi apparatus. When I first learned about Golgi apparatus I was fascinated.

And I will tell you why? Golgi apparatus is like the post office of your cell. What do you do in a post office? You bring in your letters which you fold in an envelope then you give it to the post office. The post office sort it out to be send at a specific destination, at a specific address. Golgi apparatus just think about it does the exact thing with cellular proteins. The nucleus helps in creation of proteins.

These proteins come to Golgi apparatus where it packs them into small membrane bound vesicles. Envelope it packs the protein and send these specific proteins into specific location just like a post office. People use the term shipping container or some kind of sorting facility, but for me this is the post office of a cell. This is the place where proteins come, proteins get folded into three dimensional structure for a particular function to be carried out.

They get covered, they get enveloped in vesicles and then these vesicles these entire envelopes are transported at a specific address just like a post office and you have that inside your cell think about it and then see how complex it gets from just a tiny cell to tissues to organs how different mechanism is going on. Protein sorting or protein targeting is a very strong field that is coming up and maybe it will have a significant overlap with biophotonics at some period of time.

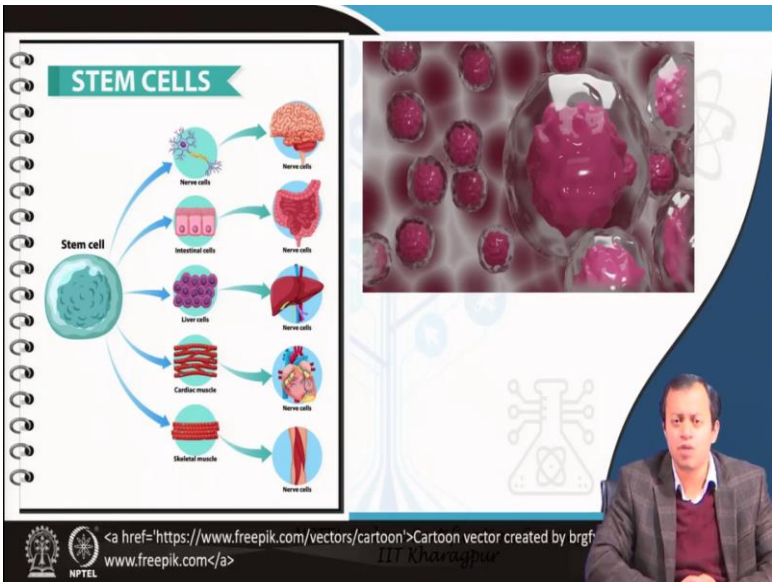
So, I would like you to read a bit about Golgi apparatus if not directly for this course, but for some kind of future trend that may come up, but Golgi apparatus is a fascinating thing just read about protein sorting or it is just like post office and it is quite interesting at least for me.



So, multicellularity of human body though there are certain common functions of all those cells, all those cells contain similar types of organelles, more energetic cells will have more mitochondria, less energetic cell will have less mitochondria of these different cells that are present can you tell me which one of them will be more energetic, which one of them will be less energetic?

Anyways, what I am telling you is that different types, several different types of cell exist performing different function, but there are few common factors that is common in all cells we have nerve cell, we have muscle cells, blood cells, reproductive cells, bones cells, but several of them almost all of them will have a nucleus. The nucleus have a DNA, there will be RNA, there will be protein synthesis, there will be Golgi apparatus.

There will be mitochondria the battery of the cell and so on and so forth. Not all organelles were discussed in my lecture because I discussed some of the most important ones and well human body is a museum or human body is an exhibition of this different types of cells. All different types of cells perform different functions as a result we are alive and biophotonics allows you to prove this cell non-destructively using light to understand what is happening even at the basic molecular level we will come to that.



Now, some very interesting thing came up recently by 10, 15 years which are called stem cells almost all of you have heard what stem cells are. This got noble prize in physiology and medicine in the year 2012. Stem cells are these so called I would not like to use the term protocells, but these cells can differentiate, can convert depending on circumstances to any different type of cells.

Now, when I say that human body has different cells, multicellularity like you saw in the previous lecture a blood cell will divide, will reproduce into more number of blood cells and nerve cell will divide into nerve cell, skin cell will divide into skin cell. A skin cell does not convert into blood cell or a blood cell does not convert into neural cells, a neuron or a nerve cell under ordinary day-to-day circumstances you can do whatsoever you want in lab, but that is not real life.

Stem cells on the other hand can be differentiated, can be converted into any type of cell of your choice. Stem cells can be customize to convert the same stem cell could be used to convert it into nerve cell, the same stem cell could be tweaked, could be controlled, could be

manipulated, could be customized to convert it into blood cell. So, stem cells are these pluripotent cells that can get converted into any different types of cells.

So, immediately people thought of it as some kind of therapeutic of medicinal value. They tried to put so where you have a cellular damage some kind of breakdown has happened, you have organ damage or like for example in cancer you have leukemia blood cancer etcetera. There was this stem cell therapy that became quite popular. Though there are miles to go to actually customize this.

Actually get to know what stem cells can actually do and how perfectly control them. Stem cells has shown huge potential in showing the actual capacity in cure and therapy for various different ailments. Now, at the very beginning stem cells were mostly embryonic stem cells generated from embryos and immediately it became controversial that in order to generate stem cells you have to do something to embryo, but later it was found out that any human somatic cells.

Somatic cells are basically cells any human cells other than reproductive cell other than germ cells, lung cell, blood cell, brain cells. Any human somatic cells could be induced any of these cells could be induced, could be reversed engineered to go back to stem cell meaning this is not a one-way traffic. It is not that stem cell well in real life in biology it is a one way traffic.

Stem cells it converts it to nerve cells, but in laboratory you can convert potentially a nerve cell or intestinal cell or liver cell back to stem cell and then that stem cell will be converted to something completely different understand this. You take a nerve cell, do some kind of lab based manipulation, bring it to stem cell and that stem cell gets converted into skeletal cell or cardiac cell that is possible that is induced stem cells.

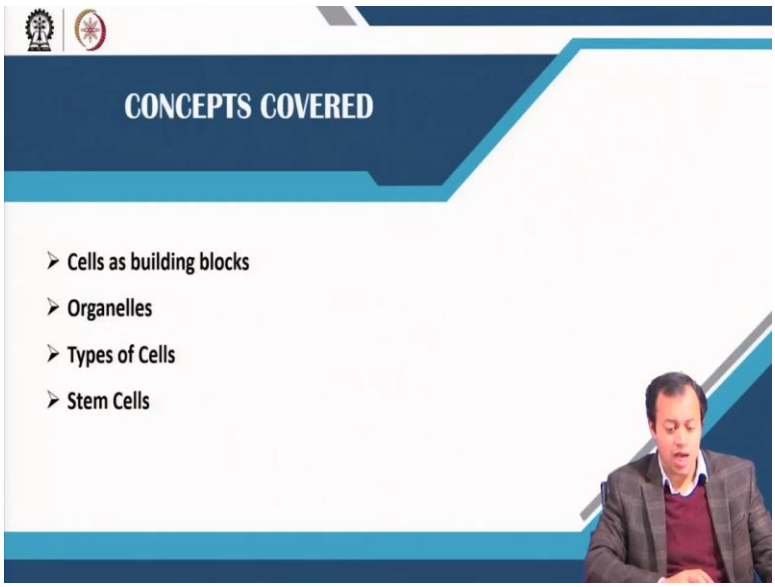
Induced stem cells, induced pluripotent stem cells iPSC then there already exits some mesenchymal stem cells. These are the stem cells that are present in bone marrows in adult, human these kind of stem cells are also produced when we were first looking at stem cells we are thinking that these could only be found in embryos because embryos are forming different organ so they need something protocell which gets divided.

And differentiated and specialized into specific cells. But now it was found that even adult human bodies contain some amount of stem cells in different parts like bone marrow etcetera

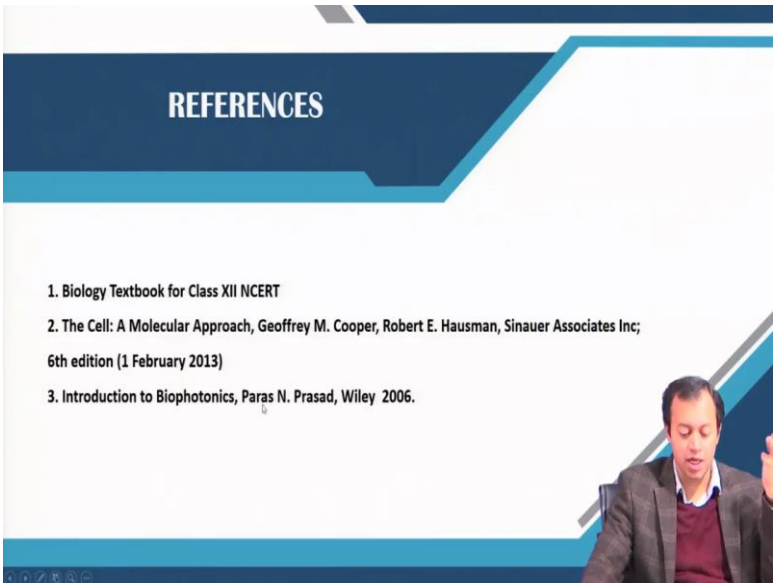
you could take them and you could differentiate them, you could manipulate them to form different types of cells which can then be put into different organs. So, think about it, think about stem cells.

If you have a brain damage or if you have some kind of they should not all be nerve cell, but what I am telling you is that if you have some kind of damage here, if you have some kind of damage in intestine or in liver instead of some other kind of therapy you can possibly use stem cell therapy to rebuild or repair the damaged area, the damaged region and since stem cells contains your own genetic material it will not be like transplant from another donor.

So, your body has much more capacity to accept it. So, this was the very basic of biology I believe none of what I told you here is something you do not know already it was just me revising old concept, old high school concepts, but now that you have it under your belt let us move to the next part and that is nucleic acid. We need to know hereditary or how information transfers from one cell to another cell, one organism to another organism.



These are the concepts that I just covered.



And these are my references you can see I have taken a high school textbook to refresh my biology part which I myself have not studied for a pretty long period of time, but if you want to go detail on to it this is a very good book a molecular approach by Geoffrey Cooper and Hausman the cell. This is a very good book to give you much more detail than this course requires for on understanding the various cell from a molecular standpoint.

And of course, Professor Prasad's book on biophotonics is my constant companion. So, thank you very much I shall see you in your next class where we will discuss genetics. Thank you very much.