Biophotonics
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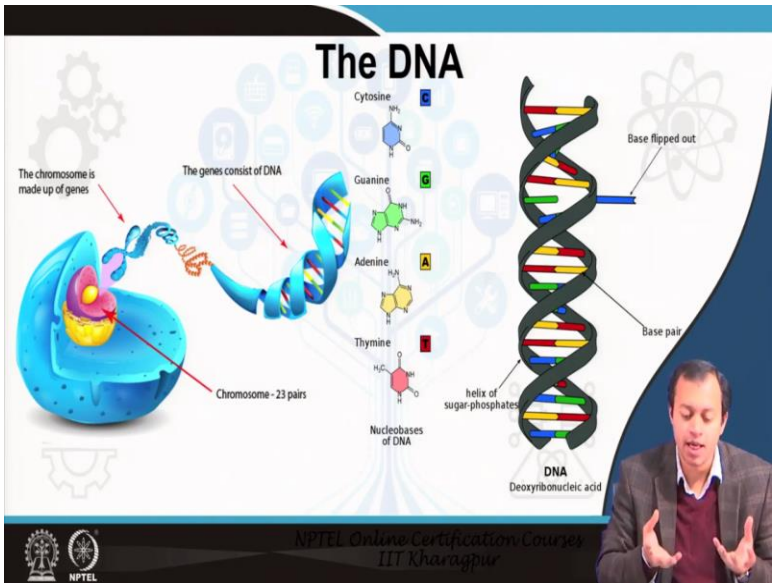
Lecture – 12
The Central Dogma

Welcome back. Let us continue with our discussion on basic biology. Today, we are going to discuss about genetics or how information gets transferred from one cell to another cell and thereby from one organism to another organism and how information can pass from older generation to younger, newer generation.



So, human beings have always been discussing about how information from one particular species or one particular organism get transferred. There were several different myths regarding hereditary like you always be hearing I have got my father's hairline or my mother's eye color, etcetera. So, how an information, how a particular trait, how a particular characteristic, how a particular feature present in a particular generation, in a particular species gets transferred to the newer generation to the off springs.

So, by this time any school going child know about DNA, what DNA is and DNA is the genetic material that helps us, that transfers this genetic information, that transfer information from cell-to-cell, information from older generation to younger generation and so on and so forth, but let us try to understand from a basic point of view what exactly is DNA? DNA stands for deoxyribonucleic acid, but what exactly is a nucleic acid and where it is found.

So, as I told you the eukaryotic cells contains the nucleus, control center of the cell that contains chromatin and this chromatin can be found when this chromatin contains basically

DNA. When DNA wants to replicate they coil themselves into chromosomes. Human being has 23 pairs of chromosomes and chromosomes contains DNAs packaged very tightly using around particular protein.

So, what exactly are DNAs? DNAs contain or what DNAs are made up of, the concept what DNA are will come at a later stage, but let me tell you what DNA contains at first. DNA contains basically a nitrogenous base another conjugate molecule which contains nitrogen such as this cytosine, guanine these are called bases or nitrogen bases, these are nitrogen based biochemical compounds, complex compounds they contain these bases.

These bases come together to form combined with sugar, sugar you can consider as carbohydrates, sugar such as ribose or deoxyribose these are specific types of carbohydrates, specific types of sugars they combine together to form something which we call as nucleoside. So, nitrogenous bases, nitrogenous biochemical compound such as cytosine, guanine, adenine and thymine these are the chemical compounds.

They combine together with carbohydrate sugar let us call it sugar that is more accurate to form nucleoside. They then combine with phosphorous they then combine with phosphate base to give them structural and chemical stability and they form what we call as nucleotide. Nucleotide is the monomer of a polymeric change, large number of these monomer, large number of these nucleotides combine to form nucleic acid.

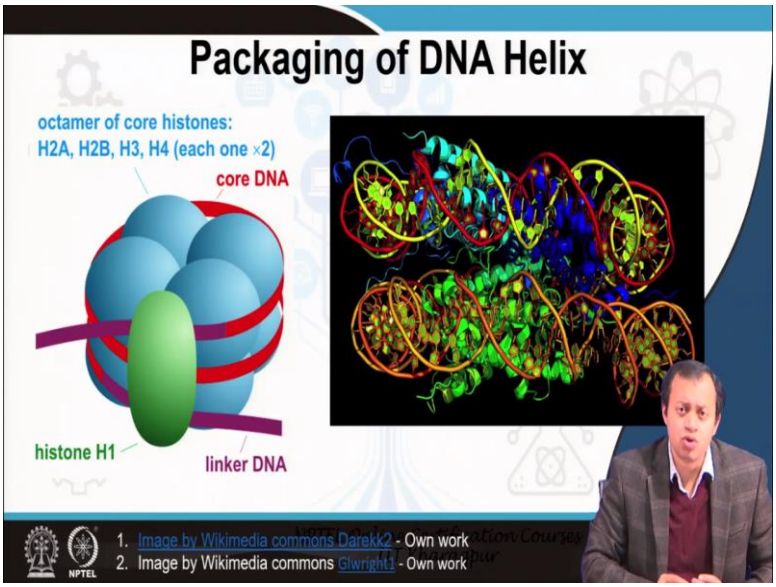
DNA is a type of nucleic acid. DNA is a type of nucleic acid that contains these bases cytosine, guanine, adenine and thymine. These are biochemical compounds, nitrogen based biochemical compounds, they structurally combine with carbohydrates and finally they combine with phosphate. So this double helical structure all of you have seen what DNA looks like this is present from art work to t-shirt to everywhere.

Remember this structural, this double helical structure the skeleton of it is the sugar phosphate. This is the sugar phosphate structure and in between they have this guanine, adenine these base pairs they are combined together like you have a zip, like you have a zipper so the teeth of the zipper are like the bases and the structure and the frame which is holding them are this sugar phosphate base.

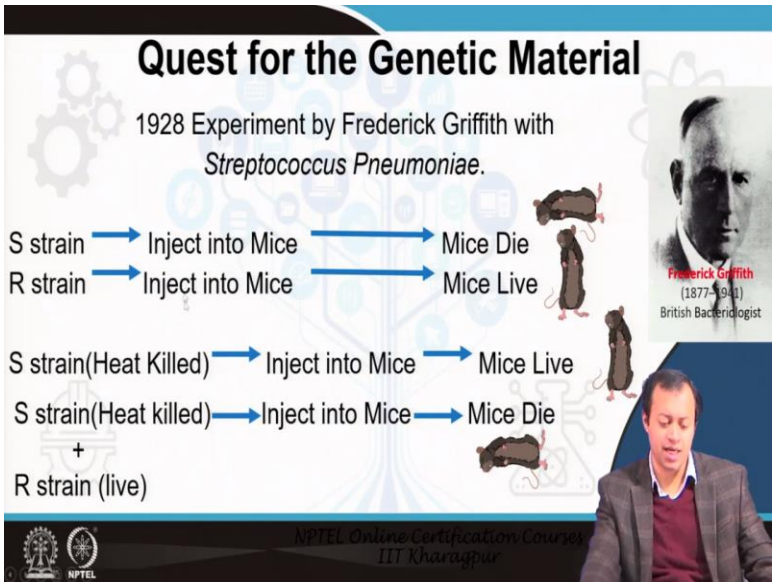
So, that is the DNA and it is known that DNA transfers genetic information from one generation to another generation this is known, but how exactly does it transfer, by what

mechanism can this molecule transfer information genetic information of whether you will be tall or short whether your eye color will be blue or brown or black, whether your hair color will be blonde or jet black.

How does this information or how does this particular molecule transfers that information from one species or another or from one organism to the next its offspring and how are we this certain that DNA it is DNA that is going on because it is not that apparent it did not come out just out of everything.



Before understanding what DNA is or how DNA actually works let us try to understand how we came to know, how we concluded that DNA is the material, DNA is the molecule that transfers information from one generation to another.



So, the very first experiment on that matter was done in the year 1928 by British bacteriologist Frederick Griffith, try to understand this experiment with me. So, Frederick Griffith was working with pneumoniae bacteria. Now pneumoniae bacteria has two strains you can consider it two types, but strain is a better term. One is a smooth strain and one is a rough strain. What does that mean?

It means that when this pneumoniae bacteria was cultured in a petri dish. One strain of bacteria showed made a smooth culture. It was because of the smooth outer layer the smooth coating it produced. Another type of the same bacteria, another strain of the same bacteria was called rough strain R strain because its outer layer was rough in nature and it was not smooth and it was simply in nature.

When the smooth strain bacteria, pneumoniae bacteria was injected into the mice it was found that the mouse is dying, the mouse dies after getting injected, after getting infected by the smooth strain bacteria. However, when R strain bacteria, the rough strain bacteria the same bacteria, but different strain is injected into the mice, the mice lives. So, the mice lives with R strain, the mice die with S strain, quite simple, quite straightforward.

In the next trip, Frederick Griffith killed all the S strain bacteria by putting them at a high temperature he just burned them, he just heated them so that they all died without losing their outer form, he just heat killed those S strains bacteria. When he injected the S strain bacteria into the mice the mice are living why because the bacteria are dead. Dead bacteria cannot kill a live mouse.

The bacteria are already being killed you are injecting dead bacteria into the mice, the mice lives, but he went one step further. What he did? He combined this dead bacteria S strain heat killed bacteria with live R strain bacteria. Now remember individually S strain bacteria when heat killed does not kill the mouse. At the same time R strain rough strain bacteria also does not kill the mouse.

So, when this and this combines conventional wisdom says that the mouse will live, but unfortunate as it is we are finding that the mouse is dying. He concluded that the R strain bacteria has been transformed, has changed. The R strain bacteria has changed now and this is killing the mice. Moreover, what he did when he dissected the mice he found out that he is getting live S strain bacteria from the mice.

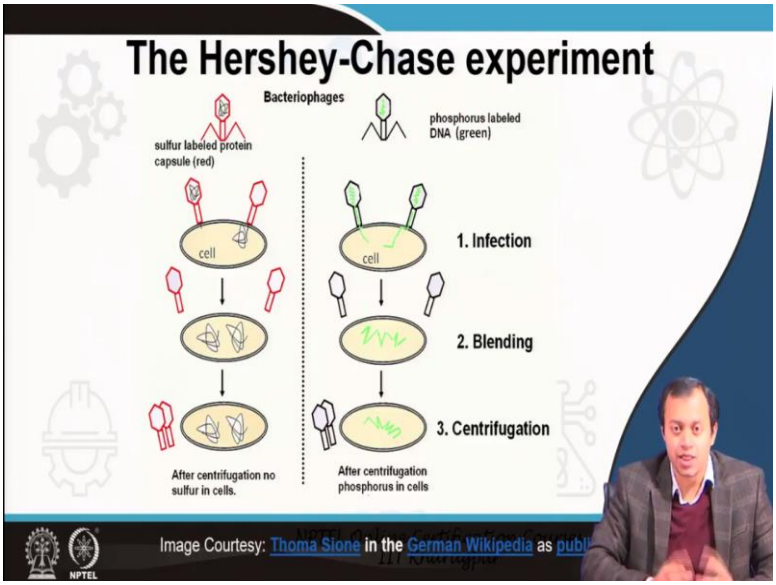
Remember he did not inject any live S strain bacteria inside it, no live S strain bacteria was injected only live R strain bacteria was injected. R strain bacteria does not kill, dead S strain bacteria also does not kill, but a combination of these two is killing the mice. Moreover, you are finding out that R strain bacteria have transformed into S strain. How did that happen or what exactly happened in here?

What exactly is going on why is the mouse dying? Later in 1933 what they did they extracted DNA, RNA and proteins from the S strain bacteria and tried to see that what exactly which part of S strain is actually converting the R strain, transforming the R strain. So, S strain bacteria was divided into RNA, DNA and protein and each individually were put into R strain to say at which point R strain get converted into S strain.

They found out only when the DNA from S strain gets into R strain the R strain converts to S strain protein and RNA are unable to convert or unable to transform R strain bacteria into something else. So, they concluded they knew that DNA, RNA and protein exit, theoretically as well as some experimental proofs have shown them they did not know the exact molecular configuration.

And till 1953 the image etcetera and the proper structure were not properly known, but somewhat information regarding these were available. However, the conventional wisdom was proteins are the most important molecules, proteins are the most important macro molecules, proteins performs a number of cellular functions, metabolism, cell reproduction, energy.

So, protein should also be there to transfer information, genetic should be controlled by proteins. This information, this particular experiments shows that might not be the case. However, several biologist were unsure even when DNA of S strain was extracted and put in R strain bacteria they were saying that errors may happen, we are not convinced etcetera, proteins can be also somehow gets extracted. We need a very, very conclusive proof that DNA is the material that is transforming. DNA is the material that is changing R strain from benign to harmful.



So, in 1933 I am forgetting the exact date look it up Alfred Hershey and Martha Chase did this very, very famous Hershey Chase experiment. Just look at this experiment and you will see how beautiful it is, it found places in one of the 100 most beautiful experiments in science the other beings Young Double Slits Experiment, all Physics student or electronic engineer student must by this time now Young's experiment.

So, Hershey Chase experiment is one of those experiments it happens I think around 1952, but I might be wrong. Just figure out the exact date when Hershey Chase did this experiment. So, by the time virus was developed by the time they knew about radioactivity, by that time they knew about isotope 1952. So, I think that is 1950s and not 1930s. So, what they did they were working on viruses, viruses like bacteriophages.

Bacteriophage are a particular virus that affects bacteria. So, previously Frederick if it only worked with bacteria, but 1952 and so they started working with viruses and they were working with specific viruses that infect bacteria, viruses can infect bacteria. So,

bacteriophages are one of those viruses that infect bacteria. So, as I said the outer layer is the protein layer is the virus and the inner layer is the genetic material.

So, what they did they used radioisotopes. Radioisotopes to level different parts of the same virus. So, they took a set of bacteriophages in which they used radioactive sulfur. Sulfur is part of the outer protein layer of the virus, they just coated the outer protein layer of the virus with sulfur, radioactive sulfur and infected the bacterial cell with sulfur radioactive virus.

Another set of experiment same bacteriophage, but this time they used phosphorus. Radioactive phosphorus to label the genetic material which was present inside the bacteriophage, inside the virus and this virus was made to infect similar types of bacteria. So again, virus is an assemble outer layer protein, inner layer genetic material. In the first experiment the outer layer was made radioactive.

In the second experiment the inner material was made radioactive. Two different material sulfur and phosphorous the DNA which is the inner genetic material does not contain any sulfur it contains phosphorous I told you phosphate base. So, phosphate base was made radioactive so that they could trace it. The outer layer protein layer contain sulfur so the outer layer was coated with radioactive sulfur so that they can trace it.

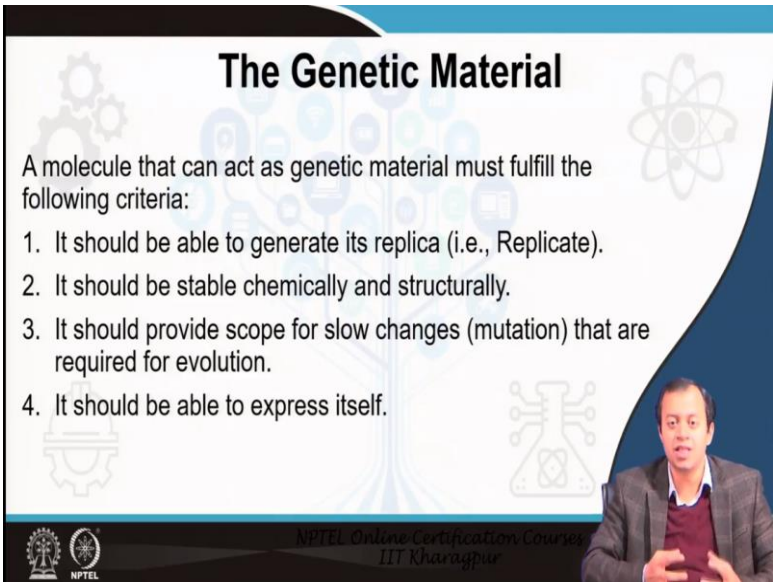
The two separate experiments same bacteria, same types of bacteria, same types of viruses. One has outer layer radioactive, one has inner material radioactive. They infected the cells, they infected the bacterial cells and then after centrifugation, after filtration process they separated the viruses with the bacteria. After centrifugation, they found out that those viruses whose outer layer were radioactive are simply going out.

There is no sulfur present inside the bacterial cell. On the other hand, when they separated the infected bacteria with respect to infected virus and the viruses they found out that phosphorus is present in the bacterial cell meaning the inner material, inner nucleic acid material is getting inside the cell and transforming the cell itself. It is not the outer protein layer that is transferring information.

The information get transferred from inner material, nucleic acids material and not the protein they figured it out that every time they did this experiment, the inner level, inner material is what is present inside the cell in which the bacteria is injected, in which the bacteria is transmitted. So, it was the DNA of the S strain bacteria that was converting, that was

mutating that was changing the DNA of the R strain bacteria converting the R strain bacteria from harmless to harmful.

This was one of the specific proofs that DNA can transform information, they carry information, they carry character, they carry information on how to change characteristics, how to change features per se. Read a little bit about Hershey Chase experiment in detail I did not describe you fully what happened, but this is one of the most beautiful experiment in science in the past three or four decades if not more.

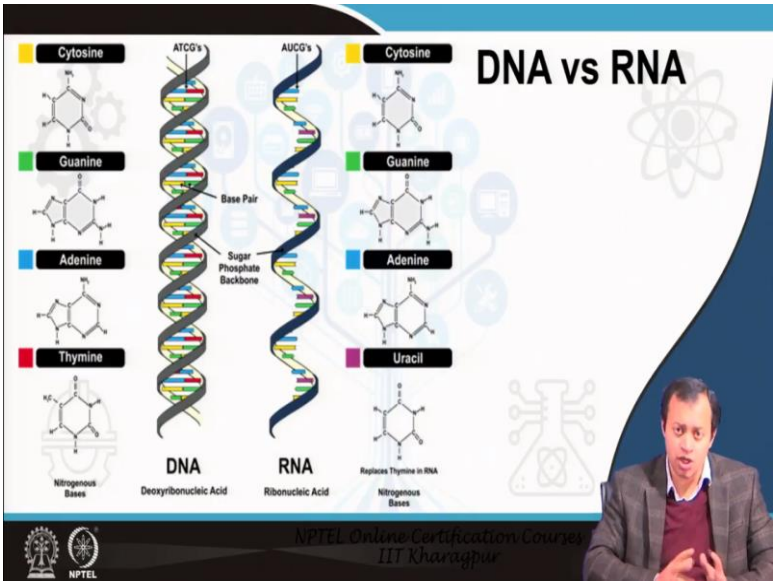


So, what the genetic material needs to be? When you need to transfer information from one species to another species, one organism to another organism, one generation to another generation certain criteria needs to be fulfilled. The criteria the genetic material should be able to replicate itself, should make a copy, several copy so that it can go into different cells, it can replicate, it has to be chemically stable, chemically and structurally stable.

If it is an unstable material obviously it would not be able to carry information quite far. It should provide scopes for slow changes, as the external environment changes this genetic material must be able to change or adapt itself, it should have some sort of adaptability and it should be able to express itself, what does this means? Expression simply does not mean it will go into a song and dance sequence.

It should be able to generate or synthesize proteins out of it. It should have information to create or synthesize proteins from the information that is encoding. So, genetic material,

stable, self replicating, adaptable as well as it should create or synthesize proteins that is the characteristics of any required genetic material per se.



Now, there were two candidates they figured out that there are two types of nucleic acids that are available in most cells, most eukaryotic cells, one being DNA and another being RNA. There are quite similar to one another it is just that in DNA one of the nitrogenous bases is thymine whereas in RNA one of the nitrogenous basis is uracil, rest of them are common as it is.

DNA on the other hand is double helical structure RNA on the other hand is single strand. You can say the sugar is little bit different it has DNA has deoxyribose whereas RNA has ribose, but overall other than these minor modifications there are not much of a difference in DNA and RNA. One base pair is different, the sugar have oxygen group and it has a double strand whereas as a single strand.

So, now it has been found out that both DNA and RNA can carry genetic information not just simply DNA or only DNA that can carry genetic codes or genetic information to pass on from one generation to another. RNA also carries similar information. The main fundamental difference from DNA to RNA you can see from structural point of view as from a chemical point of view there is CH_3 to CH. DNA is bit more structurally and chemically stable.

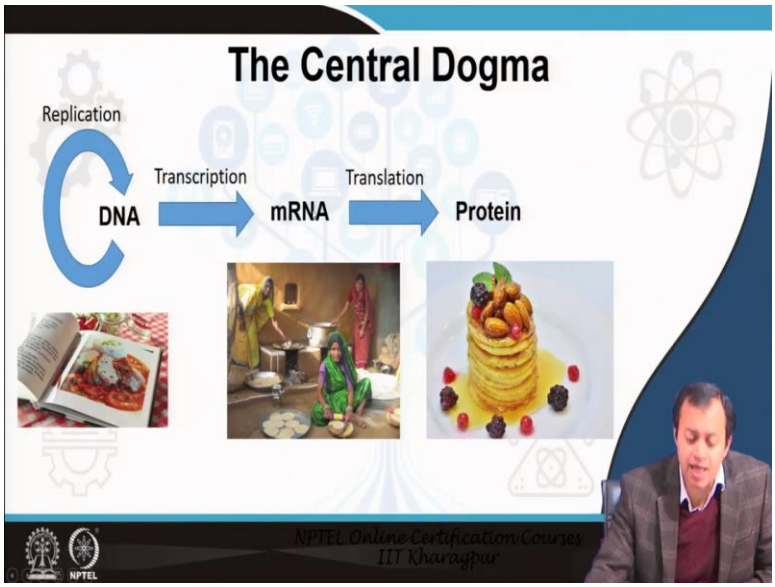
DNA is more stable than RNA. RNA is not as stable as DNA. RNA can be considered as unstable. However, RNA therefore is prone to changes. Since, it is unstable it tries to form different bonds, it tries to mute it, it tries to change, it tries to modify and thereby RNA is

much quicker to change much quicker to adapt. However, at long term it is not structurally as well as chemically stable even after mutations.

Now, it has been found that the primitive life forms almost all contained RNA based most life forms were RNA based, but as life becomes more and more complicated more generation needs to live from single cell to multi cellular organism came up, prokaryotic to eukaryotic formed RNA could get converted into DNA which is much more structurally and chemically stable.

Hence little less prone to adaption, little less prone to mutation. Virus some people considered viruses as one of old organisms or old life forms though the term life is debatable in it, but the genetic material present inside viruses could be both DNA as well as RNA in fact Corona virus is an RNA virus meaning the outer shell of its protein and lipid and what not, but inside it is RNA that is the genetic material it is carrying.

And as I said that RNA is much more prone, much quick to mute it, much quick to change, much quick to adapt because of its inherent instability you must have heard this is the end of the year 2020 that Corona virus have mutated and particularly in South Africa and United Kingdom at the end of the year 2020 they are finding mutated versions of Corona virus. So, RNA viruses, viruses that contains RNA as a genetic material are much prone. Much quicker to mute it, much quicker to change, much quicker to modify themselves as compared to DNA viruses. Though as we know DNA is also muted DNA also changes.



So, overall all of these things, all of this genetic information can be simply put into this so-called central dogma meaning DNA gets converted into RNA. DNA creates RNA, RNA creates protein that is how genetic information is passed from one generation to another generation and this whole process DNA creates RNA, RNA creates protein can be considered or is called the central dogma.

Now, you have to understand this for the sake of it. Central dogma is the bases of molecular biology. For those of you who are not from biological background consider this as Schrodinger wave equations, theory of relativity and Maxwell equation all rolled into one. The very basic of molecular biology is given in central dogma not necessarily for this particular course, but I want you to learn more about central dogma.

And I will give you more information on where you can learn. We will just touch upon the central dogma. Central dogma describes how genetic information, how information from one organism to another organism passes via DNA, RNA and protein. DNA creates RNA synthesizes RNA. RNA creates synthesizes proteins. The easiest analogy you must be wondering what this picture below it is?ok.

The easiest analogy for those of you who are not from a biological background or those of you who are not from a biological background I will give you like this, this is how I have tried to understand it when I was studying it. I am not from a biological background so this helped me. Biologist do not require it, biologist may find fault in it no analog is perfect, but

in order to understand what exactly is how information is processed, how information is passed from one generation to another generation consider it like this.

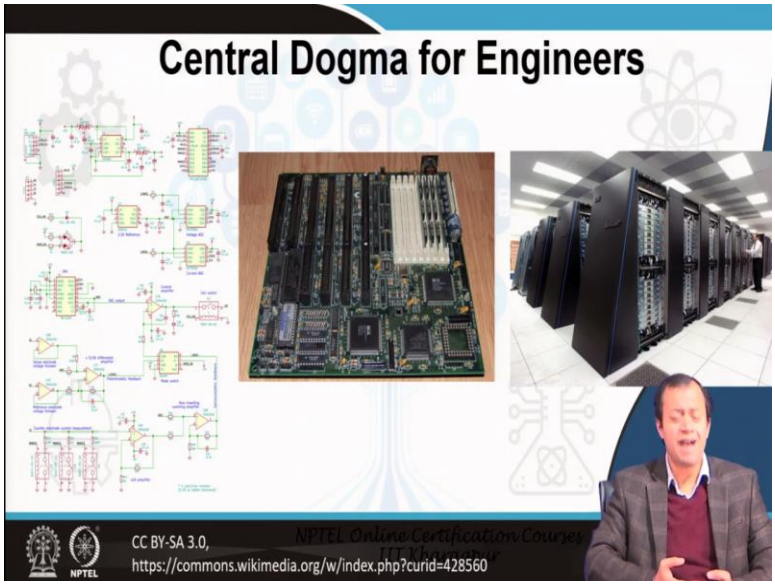
The DNA is like your recipe book it contains information, it contains information on how to say prepare a particular dish, how to prepare a particular meal. RNA is the entire complicated process of cooking. This process is very complicated and this is based on the information that is present in DNA, this is RNA, this is DNA. DNA contains information, RNA is actually the process of churning, running or analyzing that information, utilizing that information.

RNA is the process of cooking and the final product which you get is the proteins, information is passing from one generation to another generation like this the DNA is present in the nucleus it contains information, it contain information about the organism every information how tall you will be, whether you will be prone to diabetes, whether you can run faster or not, whether you will be susceptible to heart diseases or not etcetera, etcetera.

All this information is present in DNA. DNA is synthesizing into RNA the process of conversion of DNA into RNA messenger RNA I will describe it in next class is called transcription. This process of converting what is an idea into something conjugate, into something concrete not a correct analogy I know biologist will shout at me, but this is the best way I can explain to a completely non biological person is that the idea is getting transferred.

The idea is getting modified, the idea is getting actually analyzed as computer science student say run this is being run, this is being synthesized in this particular process. The final product of mRNA the final product of all these mRNA forming, going into ribosomes, ribosomes are creating the information from here translates into proteins. The proteins then takes part in almost all cellular activities and metabolism cell replication.

Cell death all of these things is done by protein, but how the protein is going to behave depends on how it has been created by the translation process you are using RNA. RNA on the other hand how RNA will be is how RNA is synthesized is by DNA transcripting it on to. Another example by which the central dogma, the process by which information flows in an organism for electronic engineers out there. Since I am an electronic engineer I have a soft corner for those of you who are studying electronics, electrical instrumentation is that consider the central dogma as this.



The DNA bad analogy, wrong analogy, no analogy is perfect, but try to understand it like this. DNA is the circuit diagram that contains all these informations which you then add, subtract, like in cooking you require so many different things you require the heat, you require the big oven, you require the big tumbler, you require the big spatula spoons etcetera. In this particular case you require ICs.

You require resistors, you require capacitors, all of these combine together to form the so called motherboard. Combination of all of these mother boards together gives rise to the final product which is the main frame computer. This is protein, this is RNA, this is DNA, not perfect analogy I am accepting it, but this is the best way for me to describe central dogma to a non biology someone who has not touched biology from a high school level.

Cut me some slackbiologist. This is how I described Schrodinger wave equation to you. So, if I can simply Schrodinger wave equation I can also simply a central dogma. Remember central dogma is the Schrodinger wave equation for biologists this is the bases of molecular biology, how information get transferred from one point to another, one organism to another organism.

Now, please do me a favor I am requesting you all whoever is watching this video try to invest bit more time in understanding central dogma. Central dogma is not required for this biophotonics course. If you look at Paras Prasad's book central dogma is not even touched at least the edition 2003 edition in which I am discussing, Central dogma simply should be known by almost every single human being.

This is the essence of our life and this is so fascinating. Now I would not be describing you the central dogma in full detail, I would not be describing you transcription and translation in full detail for three main reasons. First and foremost I am not comfortable the same way I am not comfortable in writing you a prescription of medicine if you are suffering from fever. I might know that this is common cold and give you some disprin.

But I would not like to write it in a prescription why because I am not qualified. So, central dogma needs to be taught to you whosoever you are interested by far more qualified people, people who actually have a degree. Secondly, there are beautiful, beautiful animated videos of how this DNA replication, DNA transcription, RNA translation protein these are forming in YouTube free of cost.

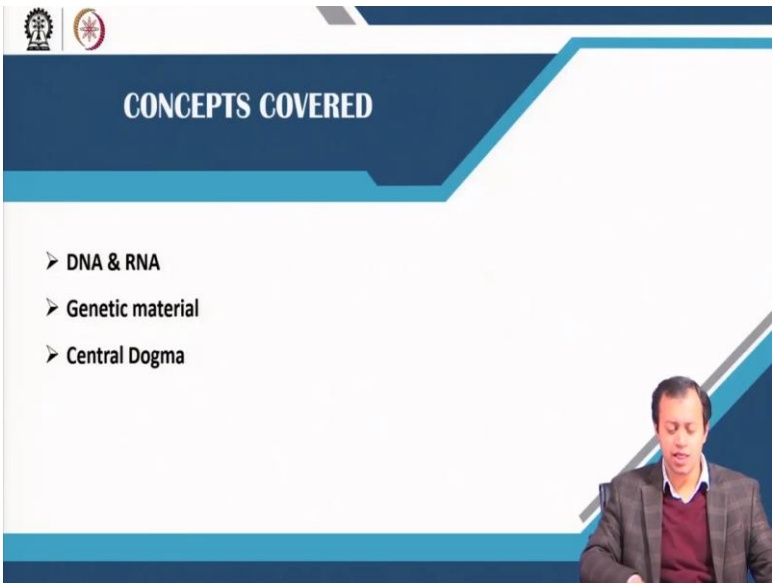
Khan academy, Your genome, Professor Dave Explains, nucleus medical groups these are some of the name of the channels just that I took, they have beautiful animations in YouTube far, far better than I would ever be able to teach you. So, this is full confession. This is not my specialty area, if you want to learn central dogma which I think you should please just type central dogma of biology or DNA translation any of these keywords into your YouTube search engine.

And you will see beautiful animations and you can see how fascinating, how beautiful information, genetic information is carried from it. There is a topic of called codons, codons are these codes made of these bits three base pair and it is very, very similar to how software engineer writes codes. In fact, much more sophisticated than the present day programming, strictly speaking they do not form part of biophotonics course.

I am interested and I think you should be interested to it. So, if there is huge enough demand I may try to touch on it, but I would rather have you learn from actual biologist, there are other NPTEL course specifically discussing central dogma, so I am reluctant. Secondly, the animations are much better in other YouTube channels. No doubt about it. So, if you look at them, you will learn better than what I am telling.

And thirdly and this is the most crucial part central dogma will take me a huge amount of time to discuss, just like I was reluctant to discuss quantum mechanics in detail because that will take away the focus from what biophotonics is. Similarly, discussing too much on central dogma will take away the focus from biophotonics says. I told you in the beginning the first three chapters light metal interaction, light and this basics of biology are simply revision.

These are the minimum requirement you need to go into your biophotonics course, this course after all is on biophotonics. So try to read bit about central dogma and see how fascinating it is, how life gets transferred from one generation to another generation.



So, these are the topics that I covered today.

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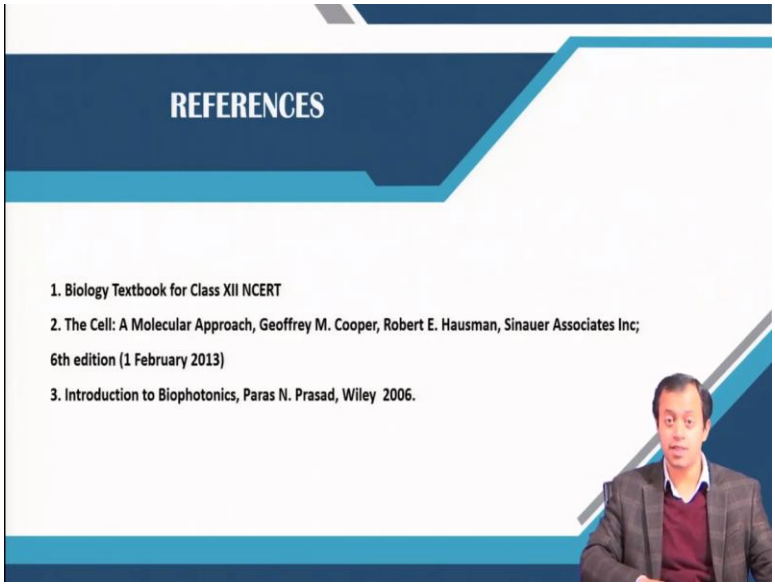

And these are my references. I will give you one more reference on genes and genetics and I shall see you on your next class. Thank you very much.