Molecular Biology
Prof. Vishal Trivedi
Department of Biosciences and Bioengineering
Indian Institute of Technology, Guwahati
Module - 04
Central Dogma of Molecular Biology
Lecture-20 Central Dogma of Molecular Biology

Hello everyone, this is Dr. Vishal Trivedi from Department of biosciences and bioengineering IIT Guwahati. Once we have understood the biomolecules and their structure and functions, it is important for us to understand the how these biomolecules are playing the role in different types of activities. So, let us take an example, right, if I think we have discussed this kind of activity when we were discussing about the carbohydrate metabolism. So, cell is continuously requiring the energy production and that energy production is being done by the burning the food reserves, right. So, one of the major food reserve which can be burned for running the metabolism is the carbohydrates.

And you might have seen that when we were discussing about the glycolysis or the grape cycle, we have discussed about the participation of the different types of biomolecules. Like one is bio, one is carbohydrate which is involved in the going through the different reaction intermediates. And to perform these reactions, you are actually having the coordinated actions of the different types of enzymes. And then apart from that, if there will be a shortage of any intermediate or there will be an access of intermediates, these intermediates can be pulled back to the different biomolecules.

For example, if there will be access of acetyl CoA, then it is actually going to synthesize the different types of lipids exactly. On the other hand, if there will be a shortage of acetyl CoA, then it is actually going to be provided after the beta oxidation and then it is actually going to channelize into the grape cycle. So, there is a coordination among the different biomolecules. And I think if you recall, we have also discussed about the different types of activities, what are happening when you are actually running the life cycle of an intermediate, right. So if you see the life activities, what you see here is that organism is considered to be life, if it actually performing the these four functions, it has the ability of self-growth or the self-renewal, it should have an ability of indigenous ability to produce the energy, then it should also have a movement, right, should have a movement from one place to another place.

In this case, there is an exception that the plants are not moving from one place to another place, otherwise, there are plants also which are moving from one place to another place. And then it should also have the ability to self-relevate. Now if you see

how these events are actually happening, right. For example, if you see the self-renewal, right. So if we take an example of the bacteria, right.

And I think if you remember, we were discussing when we were discussing about the cell division, we discussed how the bacteria is going to replicate and going to provide the more number of bacteria. So if there is a single bacteria, what you have in the bacterial cell is actually a chromosome which is, so it is going to have the cell wall, right. And then it also going to have the chromosome, right. So it is going to have a nuclear content. And if this bacteria has to replicate and give you the two individual bacteria, then it first has to grow in size.

So it is going to grow in size, which means it is actually going to increase the amount of cytosol and then it also going to increase the amount of nuclear content. So what you see here is the nuclear content is going to be double, right. So this is going to be 2x nuclear content, right. And it is also going to have the double the amount of cytosol and then eventually it is actually going to divide into two, right. And it is actually going to give you the two different bacteria.

So now, what you see here is that it is actually going to have the action of the different types of molecules, right. When it wants to grow from one bacteria to a slightly larger in size, it is actually required to synthesize the different types of biomolecules. It requires the synthesis of the proteins. It also requires the synthesis of lipids because it has to synthesize the plasma membrane. And then it also required to synthesize the nuclear content, right.

So it is going to synthesize the nucleus, right. It is going to synthesize the DNA and as well as the RNA. And what you see here is that the synthesis of these biomolecules are going to be essential for this particular bacteria even to go for a simple process of division, right, where it is actually going to give you the two different bacteria. Similarly, we have discussed about how the endogenous ability to produce the energy. So if an organism is having an endogenous ability to produce the energy, it means that the organism is actually going to, you know, have the system, right, has to have a machinery, right.

So in this case, you can have the two different types of example, right. You can have the plants, which are actually going to perform the photosynthesis. And if you remember, when we were discussing about the chloroplast, we have discussed about the complete detail of the photosynthesis where we have the dark reactions and the light reactions. And in both the cases, whether it is a dark reaction or the light reactions, it is actually going to utilize and it is actually going to synthesize the different types of

biomolecules. It is also going to synthesize the different types of proteins, right.

It is requiring, you know, for light, for example, for light reaction, it requires the ATP synthase to produce the amount of ATP. And then it for the dark reactions, it requires the different types of enzymes like rubisco and all other enzymes. So even if you see the photosynthesis, for photosynthesis also the plant has to synthesize the proteins. And it also requires the different types of receptors and channels to receive the atmospheric oxygens and then also requires the stomata, right. So it is opening and closing of the stomata is also going to be governed by the different types of biomolecules.

As far as the animal is concerned, right, animal, for example, if the animal is concerned, animal is also going to utilize the preformed food, right. For example, if you talk about the humans, they are actually going to utilize a very well developed system where they are actually going to digest the food material and into the elementary canal and then they are actually going to have the constituent molecules and then these constituent molecules are going to be channelized into the different types of metabolic pathways. We have also discussed about the glycolysis and Krebs cycles and how the different types of enzyme, lipids and you know, the carbohydrates are participating into the energy productions. And then it also has the ability to self replicate. So self replication is also where it is actually going to produce from the one person to, so one organism is going to produce the two different organisms.

So these are the few of the classical and the basic pathways which actually are essential and what you see here is that the synthesis of the new biomolecule or the synthesis of the different types of protein, lipids and nuclear content is essential for performing these functions. Apart from these functions, we have several more examples where also the life activities are involving the different types of production of the different types of biomolecule. For example, the adaptations. Adaptation is a very, very important phenomena for the survival of that particular organism. Remember that when we were discussing about the evolution, we discussed the different types of theories and whether you go with the Lammock's theory or whether you go with the Darwin's theory, both of these theories were heavily been dependent on the adaptations.

Like the process by which they have been explained the adaptation is different, but the adaptation is a very, very successful or where adaptation is an essential phenomena for an organism to succeed in their life cycle or to complete their life cycle so that they can be able to produce their offspring. So that adaptation is a multidimensional event. The second option is where you are actually going to get protection from the prey. So you can get the protection from the prey. You might have seen the example of the deer, how the deer has developed the strong muscles.

And because of that, the deer can be able to run very fast. And it happens because the deer has to get protection or get has to be remain safe from the tigers and other carnivores. So that is a classical example where the deer has developed the muscle cells. So if it is developed the muscle cells, this means it actually has produced the large amount of muscular proteins, the proteins which are responsible for making the muscle cells. And these proteins are actually being responsible for providing the extra power into the muscles of the deer and that's how it is actually getting protection.

Similarly, we can also have the different types of, for example, the adaptation also needs that you can have some kind of phenotypic changes. Like for example, if you can have the color of the skin change, so if there will be a skin color change, that may actually also going to do the similar kind of function that can also be able to protect the organism from the prey. And then it also can actually allow the organisms to go for the better choice for the sexual partner. So that is also very important because when you are actually going to have the better coloring patterns and when you have a better way of attracting your sexual partner, you can actually have the higher chances of going for the sexual activities and that's how you can be able to have the higher chances of producing the more number of offspring. And this also is requiring the production of the different types of biomolecules.

So different production of the molecules or biomolecules and eventually all these biomolecules are end up in one molecule which is the protein and the protein is because the protein is responsible for the providing the colors to the skin protein is responsible for making a different types of metabolites so that they can be able to give the patterns into the skin color and so on. So eventually what you see here is that whether we are actually going with the basic activities like the sexual reproductions or the running its own metabolism and all those kind of things or whether we are going with the specific activities where you are actually requiring the adaptations or phenotypic changes or running its own your own metabolism, the ends comes when there you are actually going to produce the different types of proteins and the protein production is directly linked to the generation of the amino acid. Which means if you have to synthesize a protein you also have to synthesize the amino acids and then you have to connect these amino acid in a specific order. Remember when we were discussing about the proteins we said that the protein is a polymer of the amino acids where the amino acids are combined to each other by a peptide bond and these amino acid has to be put in a systematic or in a sequence which is actually going to be defined the secondary structures and then the secondary structures are going to define the tertiary structures and the tertiary structures is eventually going to define the function of that particular protein. So what you see here is that if a protein production is actually being essential then the protein is going to be

provided or thus going to be synthesized by synthesizing the different types of amino acids and then combining them in a particular sequence and that is being done by a systematic series of the reactions.

And all these reactions are coming under the big umbrella of the central dogma of life. So what is central dogma of life? So what central dogma of life is that the protein is made up of the amino acid and every protein has the unique amino acid arrangement in a specific sequence. But we have seen the many examples where the protein is important for the particular activity of that particular organism. The information to synthesize the protein with a unique amino acid sequence is provided by the nucleic acid present within the nucleus. In a preset sequence the DNA present in the nucleus give rise to the specific RNA sequence and in that in turn guide the cellular machinery to synthesize the protein.

So what will happen is that the DNA what is present into the nucleus or whether it is present into the cytosol like in the case of prokaryotic cell it is actually going to synthesize the RNA and then this RNA is actually going to have the sequence information to synthesize the different types of amino acids and then these amino acids are going to combine to give you the specific proteins. That is why if you see if you want to have the proteins you first have to synthesize the RNA and then you have to synthesize the DNA which means it has to first synthesize the RNA from the DNA and then from the RNA it is going to synthesize the DNA. Scientists consider this as the fundamental event to run the life and considered as the central dogma of life which means it is actually going to be the central theme of any kind of life related activities. We have seen the many types of life related activities and where the everywhere you have to have some kind of production of the protein and if you want to see the production of the protein you might have to synthesize the RNA and that RNA has to be synthesized from the DNA. In another word the Francis communicated to the journal Nature state that the central dogma of the molecular biology deals with the detail residue by residue transfer of sequential information states that the such information cannot be transferred back from the protein to either protein or to the nucleic acid which means that the central dogma of life is also been called also been known as the central dogma of molecular biology and that is going to as well the you know the statement given by the Francis it says that it is actually going to deal with the residue by residue transfer of the sequential information which means you are going to have a residue of DNA which are going to synthesize the RNA and then it is also going to synthesize the protein.

What he also says is that the reversal is not possible which means from the protein you cannot synthesize the RNA and from the RNA you cannot synthesize the DNA which is we know now that it is not true right in the under the special circumstances you can be able to synthesize from the RNA to DNA and as well as from the protein to RNA as well

or from the protein to DNA as well that you are going to see when we are going to discuss more about the central dogma of life. So, what you are going to see is that if we have to follow the central dogma of life we have to run the multiple reactions. So, the central dogma of life is the basis of life on the earth and it is required to control the biological processes. Following this, hypergial flow of information from the DNA to protein allow the nucleus to control the all biological activity in a cell. The normal condition the flow of information sequence to sequence requires the three processes.

Now the question is why there is a requirement of the central dogma of life or the central dogma of molecular biology. It is required because then you can have the full control over the all the activities of a particular cell because you cannot have the that particular type of biological process started or ending until you have the particular protein to be produced. Like for example, if we want to start the glycolysis, we have to have a synthesis of hexokinase or the glucokinase, but you cannot have the synthesis of the hexokinase or the glucokinase spontaneously. It has to be governed from the DNA and that is why it says that if since everything will depend on the DNA to first synthesize the RNA and then the RNA is going to synthesize the DNA, the RNA is going to synthesize the protein, it is actually going to allow the DNA what is sitting inside the nucleus to control all these processes and because of that the nucleus can be able to control all the biological processes. The three processes which are required for the flow of information is as follows.

You can have the sequence dependent synthesis of DNA from the pre-existing DNA. So you can have a DNA and that DNA also has to be synthesized. Remember that mean there will be a duplication of organism, the organism want to go for the division whether it is a bacterial cell or the eukaryotic cell, it has to have the duplication of the DNA. So you can have the DNA dependent DNA synthesis and that is actually going to be performed by an enzyme which is called as the DNA polymerase and the process which is by which you are going to do this is called as the replications. Then you can have the sequence dependent synthesis of RNA from the DNA.

So once the DNA is synthesized then you can also have the DNA dependent RNA synthesis and that is also going to perform by the enzyme which is called as the DNA polymerase, RNA polymerase. So once the RNA is and this process is called as the transcription. Then we have the sequence dependent synthesis of DNA from the pre-existing DNA. So once you have the RNA then RNA is going to be have the synthesis of the protein from the RNA molecule and that process is called as the translation. And this process is called as the translation.

So if you want to run the central dogma of life or if you want to continue the all the

biological activities within the cell, you have to follow these three events. You have to synthesize the DNA from the existing pre-existing DNA and that process is called as the replications. Then you can have the sequence dependent synthesis of RNA from the DNA that process is called as the transcription and then you can also have the sequence dependent synthesis of DNA from the pre-existing DNA, sequence dependent synthesis of the proteins from the pre-existing RNA and that process is called as the translation. Now we can have the more detail about these processes. So replications, so genomic content in an organism need to be duplicated from the S phase of the cell cycle.

Transcription of DNA is done by the replication utilizing the sequence information of the parent DNA. The enzyme used in this process is called as the DNA dependent DNA polymerase. Then we can have the transcription. So the DNA is present in the nucleus whereas the protein synthesis machinery is present in the cytosol. Whereas in the case of prokaryote the both the transcription and the translational machinery is both present inside the cell so because there is no nucleus.

Hence the information present in DNA is used to synthesize the RNA which has the ability to transport outside the nucleus to participate into the protein synthesis. Synthesis of RNA from DNA is done by the transcription utilizing the sequence information of the DNA. The enzyme used in this process is called as the DNA dependent RNA polymerase. Then we can also have the translation. The RNA present in the cytosol is utilized by the translational machinery to synthesize the protein in a sequence dependent manner through a process known as the translations.

So these are the things which we have depicted here. The DNA dependent DNA polymerase synthesis which is going to be done by the DNA polymerase. The process is called as the replication. Then you can have the transcription and then you also have the translations. But as I said you know although the Francis has said that these processes cannot be reversed or the sequence of information can be only from the DNA to RNA and then RNA to protein it cannot be reversed.

But under the specific conditions biological system does not follow the usual pathway to replay the information which means it also can have the reverse directions. So under the normal circumstances what you have is you have the DNA dependent DNA synthesis. This is called as the replication. Then you can have the DNA dependent RNA synthesis.

This is called as the transcription. And then you can also have the RNA dependent protein synthesis which is also called as the translation. So these are the normal circumstances which are happening in every cell. But there are an exceptional or special cases where you can have the other activities. For example the RNA dependent DNA

synthesis which is called as the reverse transcription.

So this is actually a reversal of this. This is reversal of this. So it is also called as the RNA dependent DNA synthesis. So that is called as the reverse transcriptions. In most of the organism the genomic content is present in the form of DNA. But in few organisms such as viruses RNA is also present as the genomic content.

And in these cases RNA need to be converted into DNA and replicate using the host machinery cycles. It is done by reverse transcription utilizing the sequence information of the parent DNA. The enzyme used in this purpose is called as the RNA dependent DNA polymerase or it is also called as the reverse transcriptase. So this is what is shown here. You can have the normal circumstances where the DNA is actually going to be synthesized by the DNA and is going to give you the by the replications.

Then the DNA is going to give you the RNA by the process of transcription. And then the RNA is going to give you the protein which is called as the translations. Or you can have the special circumstances where the RNA is actually going to give you the DNA and that process is called as a reverse transcription or the and the enzyme is called as the reverse transcriptase. Then we have another example where you can have the RNA dependent RNA synthesis and that is called as the RNA replications. In most of the organism the genomic content is present in the form of DNA but in some organisms such as viruses RNA is present as the genomic content and done by the replication utilizing the sequence information of the parent RNA.

The enzyme used for this purpose is called as the RNA dependent RNA polymerase. And then you can also have the DNA directly synthesizing the protein. So there will be a complete absence of this particular RNA species. So you can also have the DNA dependent protein synthesis. So in that case the DNA directly giving you the protein under the in vitro cell free system.

So it is not possible in the in the in an organism but it is also possible under the in vitro cell free system. So in a cell free system it is possible to translate the DNA directly into the protein in the presence of ribosome. It is not precisely controlled and it is not known whether it is synthesized the protein in a sequence dependent manner which means this is possible but it is not precisely controlled. It is not precisely going to give you the specific protein molecules.

It may actually give you the protein molecule. It may give you a random amino acids combined with each other. Then we also have another example where we can have the additional possibilities. So there we have an additional possibility like the protein is

giving rise to DNA or protein is giving rise to RNA or protein is giving rise to protein without going to the normal second chances of the central term of life. So we have a protein to protein.

These are considered as the infectious protein. They are also called as the prions. So in a prions what you have is that the protein is replicating from the protein itself. So in this these are considered as the infectious protein which replicates to form the identical copies on themselves. These proteins are known as the prions although it is represent the transfer of information but it is not the usual pathway and considered to be exception of the central dogma of life. So what we have discussed we have discussed about the importance of the central dogma of life or the central dogma of molecular biology and how and why there is a requirement of such a pathway.

Do we require that pathway so that the DNA can be able to precisely be able to control the production of RNA and in turn it also can actually have the full control over the protein molecule. Not only that the DNA is actually going to have the information which is going to be more stable. However that mean we are discussing about the DNA and RNA and as well as the protein what we said is that the DNA is a very stable molecule compared to the RNA because the DNA is having the double helix structures. DNA is having the deoxyribose sugar and it also has the more stability and that and because it is protected inside the nucleus and it is protected by the you know the some of the binding proteins it is very very preserved. So that is why the information what you have in the DNA is not having the not going to give you the any kind of alterations whereas the information what is present into the RNA is very susceptible for the any kind of damages and same is true for the protein.

The protein also can get modified and it can also get altered and all that. And on the other hand the RNA is very very you know not stable right RNA is less stable compared to the DNA because RNA is single standard, RNA is susceptible for the different types of RNases what are present in the cytosol and so on. So because of that the biology or the life has decided that okay I will going to utilize the information what is given into the DNA. But since the DNA cannot participate directly and give you the protein because if that is the case the DNA is actually not been able to synthesize the different types of proteins right because if suppose the DNA has to synthesize the thousandth of the proteins and then the DNA molecule is going to be remain open right and it has to keep synthesizing the protein. So because of that purpose the DNA has decided that okay I will take the help of the RNA.

So what it will doing is it is actually making its own copies in the form of RNA and that is how it is actually distributing the work right just like any remember that the if any for

example the prime minister of the country right prime minister of the country can is his have a is has the ability to perform the different types of task right. But it cannot do all those tasks on its own because it has a limited resources right. So because of that what it is doing is it is actually making the different types of portfolios and then he is distributing those portfolios to different types of ministers. So these are actually going to be the ministers for the DNA and that is how it is they are actually going to do the their special function. For example if DNA has to synthesize the actin, myosin, beta, beta ATP synthase you know some described of different types of proteins it cannot do this function on a timely manner it cannot do that because it cannot channelize into the multiple types of activities.

So what it can do is it can synthesize the RNA which is for the actin molecule it can synthesize the RNA which is for the myosin it can synthesize the RNA for the ATP synthase and that is how these different RNA molecules are now going to taken up by the protein synthesis machinery and that is how these RNA molecules are going to give you the corresponding proteins. On the other hand because the DNA is stable you cannot modulate the expression level of this particular protein right. But at the same time if the function of that particular process is over and suppose you want to degrade the myosin or ATP synthase then you cannot degrade that region of the DNA right. What you can do is you can just simply degrade that amount or that particular RNA. If you degrade the RNA you are eventually going to degrade the protein because the protein have a definite half life or definite age right after that their protein is going to be removed from the system right.

So that is also another aspect why the biology has decided to go for these you know these kind of sequential transfer of information from the DNA to RNA and RNA to protein. So central dogma of life is very important for us to understand the different types of activities what is happening into the cell. So this is all about the central dogma of life and what we have discussed we have discussed about the many events what is happening inside the cell and what is responsible and what are the different types of you know moly molecules are going to be produced. And what we have understood is that the protein is actually been responsible for making the different types of activities within the cell and the protein synthesis is always been governed by the sequence dependent synthesis of the RNA and the sequence dependent RNA synthesis is being done by the DNA. All these events are actually been coming together under the central dogma of life or to the central dogma of molecular biology as it is been stated by the Francis.

What we have discussed we have discussed about the applications like the DNA dependent DNA synthesis which is been done by the DNA polymerase and we have discussed about the different events where we have discussed about the origin of

applications. We have discussed about the initiation, elongation and terminations. So with this I would like to conclude my lecture here in our subsequent lecture we are going to discuss some more aspects related to the central dogma of life where we are going to discuss about the transcriptions. So with this I would like to conclude my lecture here. Thank you.