Cell and Molecular Biology
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Week 06
Genetic Material in Cells
Lecture - 21
Genetic Material in Organism

Hello everyone, this is Dr. Vishal Trivedi from the Department of Bio-Science and Bio-Engineering, IIT Guwahati. We would like to ask the questions of how information passes from one generation to another and what the different types of molecules are that could be responsible for passing information from one generation to another. Now what you see is that I'm sure you have noticed that some of your own traits match those of your parents. Similarly, the traits that are present in the plants are also of mixed traits, right? They are also having some information from one parent and some information from the other parent. And on the other hand, you might have seen that some of the diseases are propagating within a particular type of families.

For example, I'm sure you might have noticed traits like height, eye color, and other kinds of phenomena such as hair color, the way you speak, and the way you actually behave, all of which are transferred from the parents to the child. Similarly, you might have seen that the seeds from a red-flowering plant always produce red flowers naturally. And then you might have also seen the different kinds of variations; for example, if you have the crossbreeding of a white flower and a red flower, you will see that they actually produce a pink flower, and so on. And there are classical examples of Haemophilia that actually run in different types of families from generation to generation.

Now the first question is how does it happen, and the answer to this question is that it is all because of heredity. So, what is heredity? So heredity, also called inheritance, is the passing on of traits from the parental generation to the offspring either through asexual reproduction or sexual reproduction. The offspring of the cells obtain the genetic information from their parents. So because of heredity or inheritance, you are acquiring traits, phenomena, or phenotypes from your parents. Definitely, when it is asexual reproduction, the traits are going to be completely 100% intact, but if it is sexual reproduction, then it is actually going to be mixed because you are going to have 50% of the traits from your mother and 50% of the traits from your father.

And depending on which trait is dominant and which trait is recessive, it is actually going to show you the phenotype. So, the first question is whether it is actually true that you are going to acquire the traits from the mother and the father; how is this particular type of phenomenon happening? And who is responsible for that? So who is responsible for carrying the information from one generation to another? And the molecule that is responsible for this particular information or for this particular phenomenon is called the genome, or I will say genetic material, because it is actually passed down from one

generation to another. And because of that, this particular molecule is being called the genetic material, not the genome actually. And I am sure that when we were discussing the cell, and even in the previous lecture when we were talking about the biomolecule, If you see the cell, it is very, very complicated, right? It actually has a nucleus, cytoplasm, and different types of organelles. In the prokaryotic system, you also have all those things, but not the membrane-bound ones, right? So you also have the miniaturized level of or the primitive conditions of the electron transport chains; you also have the other kinds of things.

So basically, if you think about wherever the information can be stored, there are multiple possibilities. One is in a cell; it can be the nucleus, or I will say the genome, or I will say DNA, because we know that the nucleus contains the genome, which is made up of DNA. The second possibility is the cytosol, or I will say, the cytosol, actually. And cytosol mainly contains one molecule, which is called protein. RNA is also present in the cytosol.

Then you also have the membrane-bound organelles, so membrane-bound organelles are also made up of proteins and lipids, right? So we basically have the candidate molecules that are responsible for carrying the information. But because the technique had not evolved, finding out who is actually responsible for carrying the information is a very long journey. So let us first see what the molecules are that we have. We have the DNA, the potential molecules like the DNA, the proteins, and the RNA. And these are the molecules that actually have this stored information.

For example, you know that DNA is made up of nucleotides. So that is actually providing the sequence of nucleotides. So that also can actually carry the enormous amount of information. I'm sure you can calculate, if you have four nucleotides, how many different types of random combinations could be possible to give you the different types of random DNA sequences? Similarly, the protein, which is made up of the 20 amino acids, can provide enormous information through random combinations of these 20 amino acids. So that's how the RNA works, right? The same way as the RNA.

So, these three molecules actually have a similar kind of nature; apart from that, you also have the lipid, but it does not have that kind of flexibility for storing information. So, that is why the lipid is being discarded by the scientists, as they were focusing on the DNA, protein, and RNA. But before that, the people had done the crude experiment because until they discovered DNA and RNA, they did not have the technology. So let's see how we know what the history is of identifying the genetic material, and then we will discuss the different types of classical experiments that show how people figured out whether DNA, protein, or RNA is the genetic material. So the first experiment was done by the Austrian scientist, or I should say the priest Gregor Johann Mendel; he is considered to be the father of genetics.

And he has actually done extensive experiments with the pea plants, where he has taken the combination of traits, and that is how he has come up with the classical rules of genetics. So, what is the history of genetic material? So it is well known that qualities are

passed down from one generation to the next. The offspring share certain characteristics with both of its parents. But the question is, who is responsible for this? It was the first time that, based on its interest in plant hybridization studies on the sweet pea, the Pisum sativum, monk in a monastery in Austria, Gregor John Mendel, tried to find out this answer. He proposed that some factors were involved when Gregor John Mendel was doing the experiment.

There was no technological evolution, there were no techniques available to say whether DNA, RNA, or protein were involved, but he said that there are factors, and he used the term factors that carry the information on the manifestation of a characteristic or phenotype and how the traits are passed from one generation to another. Since he gave the clue about this particular factor and said that this factor could be a dominant factor and recessive factors and so on, and all these laws of genetics, you might have studied in some of the textbooks. So then people have started, you know, identifying this particular factor. So in the late 90s, three biologists, Humboldt DeVries, Karl Kornis, and Eric Vaughan, worked on Mendel's works and proposed that different characters have individual hereditary carriers, and the inheritance of specific traits in an organism is called particles. So DeVries actually called these units pangenes.

And he actually came up with some of the theories as well, discovering that the factors Mendel was talking about are nothing but pangenes, which, if they can move from one generation to another, will carry that particular characteristic or quality. But in the almost 20 years later, when Wilhelm Johannson and William Bateson actually proposed the terms gene and genetics respectively, Edward Strasberger and others continued to refer to the basic physical and functional unit of heredity as the pangene. So basically, from the pangene, it becomes a gene, and the gene was considered to be a responsible factor, right? So genes are present in chromosomes which are evenly distributed between the two daughter cells during cell division, and the biochemical study showed that the chromosomes consist of protein and DNA. So it is clear that the gene is present in the chromosome, and we are going to discuss this nuclear packing and all that when we talk about the genetic material. And the chromosome is made up of two parts, right? The protein part or the DNA part.

So the first question is whether the genetic material is proteins or DNA, which means, out of this chromosome, which one is more responsible: the protein part or the DNA part, because it has both components, right? So until the 1940s, proteins were thought of as genetic material because proteins are polymers made up of 20 different types of amino acids, which are abundant and encode diverse information. And you can easily calculate; in fact, you can actually go with that activity, right? How many different types of amino acid compositions or amino acid combinations could be possible if you have the 20 different types of amino acids? For example, you have a very small protein of 100 amino acids. If you have a small protein of 100 amino acids and you can have 20 different random combinations, you can actually calculate that number. That number is going to be very, very, very big, actually. However, based on certain experiments that have been conducted from time to time, it was finally shown that the DNA, not the protein, actually carries the genetic material.

But we are actually going to discuss in detail these particular experiments, and the conclusion is that it is DNA which is the molecule present within the chromosome and is going to carry the information from one generation to another. Now the first question is, what could the properties of the genetic material be? What could be the possible or probable properties that a molecule should have; then only can you say this is the genetic material? So, the properties of the genetic material are. So for a molecule to be considered the genetic material, it must have some requisite parameters to accomplish its task. What is the task? The task is to carry the information from one generation to the next generation. That is the task of genetic material, and that is why it should have the prerequisite conditions.

What are the conditions? Number one is stability, number two is that it should be heritable and expressed, number three is that it should have mutations, and number four is that it should be replicated. So, stability must contain all the biologically useful information in a stable form, which means it should be stable; it should be, you know, resistant to any kind of damage, and if there is damage, it should have a mechanism to recover from that particular damage. Then it should have the heritability and the expression. So it should process hereditary units that follow Mendelian inheritance and control the expression of a particular phenotype. So it should have the components, and I think all these you are going to understand when we talk about transcription and translation, how there are different components present within the genetic material that actually control the expression of a particular gene.

And so you should have these kinds of switches. You can have these kinds of switches so that you can actually be able to modulate the expression of the particular gene, and that is how you are actually going to modulate the overall phenotype of that particular organism. I am sure you might have noticed that when you go into the sun and it is very hot outside, you always start sweating. So sweating occurs because there are expression profiling changes within your body, and that is how it started, you know, throwing the sweat. The same is true when you are entering, you know, into a cold room or entering into a place where you have AC, and then you actually, you know, all your sweat disappears, and then you also feel cold, right? And when you feel cold, you find that the skin is actually, you know, becoming more, you know, contracted, actually.

So, these things have actually been done simply by the information that is present inside the genetic material. Then the third property is about the mutations, right? So genetic material is also going to acquire mutations. Some of the mutations might be beneficial. Some of the mutations might be incorrect. And that's how the accumulation of mutations is actually going to result in changes in the phenotype.

And that will be responsible for evolution, right? So mutation is the random change that may occur and could actually be a chance for evolution. And the number four is replication because, as I said, you know genetic material is going to have only one copy, so that genetic material has to be replicated. And that's why you're going to have two copies of genetic material. And then you can actually be in a situation where you can

share. Remember that when we were talking about the cell cycle, we said that during the S phase, the DNA is actually duplicated.

And then only it will actually be shared between the cells. And the same is true for the relationship between the parents and the offspring as well. Then you're going to have two copies of the genome, and when you share one copy with your offspring, and so on. So that should have the ability to synthesize its own copy. So this replication is actually what we are going to discuss in our subsequent modules.

We are going to talk about replication, transcription, and translation. Now there is some direct evidence or experimental evidence, and there is some indirect evidence that proves that DNA is the genetic material. So, there is direct as well as indirect evidence which has ruled out protein or RNA as genetic material and has proved that DNA is actually the most acceptable genetic material present from prokaryotes to mammals. There are exceptions, and these exceptions we are also going to discuss. So, in 1928, Frederick Griffith actually performed an experiment on bacterial transformation, and by doing these experiments, he proved that the information present in the DNA is carried from one bacterium to another.

And that is how it is actually going to change its phenotype, and that is how it is actually going to be responsible for the death of the mice. Then in 1944, Oswald, Avery, McCloy, and McCarty actually did the experiment on the transformations, which also proved that it is actually going to be the DNA that is the responsible factor. And then we have the Alfred Hershey and Chase experiment on the T-even bacteriophage, which also proved that DNA is the genetic material. So if you go by the timeline, in 1869, Frederick Matcher actually isolated the nucleic acid, or I would say the genetic material, from white blood cells. Then in 1928, almost 50 or 60 years later, Frederick Griffith actually demonstrated that genetic information from one bacterium is transferred to another bacterium through a phenomenon known as transformation.

Then, in the year 1944, McLeod and McCarty actually identified that DNA is a transforming agent. It actually carries the genetic information and can then change the phenotype of the other bacteria. Then, in the case of 1952, Hershey and Chase actually confirmed that DNA is a genetic material with the help of the viruses. And then in 1952, Watson and Crick and all those people got the Nobel Prize because they discovered the structure of DNA. So let us first discuss the Griffiths experiment to understand that DNA is the genetic material, and then we will talk about McLeod and McCarty's experiment, and at the end, we are going to discuss the Hershey and Chase experiments.

So in Griffith's experiment, he used a bacterium called pneumococcus. He has used the bacteria called streptococcus pneumoniae, and he has used two different types of strains: the S-strain and the R-strain. The S-strain, which is a virulent pathogenic strain, is called the smooth strain or the S-third strain, while the R strain is a recessive strain. So, the R strain is an avirulent strain, and it is a non-pathogenic strain known as the r-virulent, the rough strain, or the R2. So, the S strain is actually going to cause the disease, whereas the R strain is not going to cause a disease.

So, if the S is going to cause a disease, S is actually going to kill the mice, whereas R is not going to kill the mice. So, the S strain has a smooth outer coat made up of polysaccharides, and the R strain lacks this polysaccharide coat; therefore, its surface appears rough. S3 strain was virulent, possessed a lipopolysaccharide capsule, could kill mice by causing pneumonia, and formed round colonies on a culture plate. Whereas the R2 strain was avirulent and lacked a lipopolysaccharide capsule, it gave rise to rough-shaped colonies on the culture plate. So these are some of the properties given, right? So stereotypically, it can be R2 or the S3, and morphologically, the R strain is a rough strain, whereas the S strain is a smooth strain.

The capsule was absent in the case of R strain, whereas it is present in the case of S strain, and R strain is avirulent. What is meant by avirulent is that it is not going to cause the disease. Whereas in the case of acid strain, it is virulent. So it is actually going to cause the disease, and what disease is it going to cause? It is going to cause pneumonia and ultimately it is actually going to cause the death of mice.

So this is the experiment that he has done. So he has conducted the experiment using four different types of conditions. So, case 1, case 2, case 3, case 4. So in case 1, what he has done is take the S type of bacteria and inject it into a healthy mouse. And after some time, the LD mice was gone, right? Because he developed the disease, right? Pneumonia, he developed pneumonia, and that is how he actually died. In case 2, he has injected the R type of bacteria.

So, R type bacteria are avirulent bacteria. So, it is actually not going to cause any kind of disease, and that is how this particular mouse is actually going to grow, and that is how the mice are actually going to live. Then, in the third experiment, what he has done is actually denatured the S type of bacteria. So he has heat-killed the S type of bacteria and then he injected that into healthy mice, and that also has not caused any disease, and that's how the mice have survived. Then the third is he has taken a heat killed S type of bacteria, so virulent bacteria he has heat killed, so this is not live bacteria. And then he added the R-type bacteria, which are live; so this is live, and this is dead.

Dead bacteria, and then he mixed them together in a case, and then he injected them into healthy mice. When he had done that, he actually found that the mice had developed the disease, and they also died. So this was very interesting that something which was not infective because in case two you see that the R strain is not killing, but in case four, the R strain is killing the mice if it is mixed with the heat-killed S3, actually. So, these are the four different types of conditions.

And then what he has done is isolate the blood. He isolated the blood from case number four. What he found was that there were no R bacteria present. It was all the S type of bacteria that has been isolated. So all the R type of bacteria is actually being converted into the S type bacteria in case 4, and that is how he said that the material, or the material which actually carries the information from this bacterial material, has gone from the heat-killed bacteria into R-type bacteria, and that is how the R-type bacteria got

converted into S-type bacteria. So there is a term, and that is how he actually pointed out that this phenomenon is going to be called Thal-formations.

When Griffith injected a mixture of heat-killed and live bacteria, the mice died, and live S bacteria were recovered from the dead mice. So remember that he has actually injected heat-killed S-type bacteria, and that the genetic material present in the S-type bacteria has gone into the R-type bacteria, which has converted or started expressing its own genome, and that is how it is actually going to cause the generation of S-type bacteria. So Griffith concluded that the R-type bacteria had somehow been transformed by the heat-killed strain bacteria. Some transforming principle transferred from the heat-killed S strain had enabled the R strain to synthesize a smooth polysaccharide coat and become the S strain. This must be due to the transfer of genetic material from the S-type bacteria to the R-type bacteria.

However, the biochemical nature of genetic material was not defined by this particular type of experiment, right? So, we still do not know what is actually being transferred, whether it is DNA, protein, or RNA, right? So, then they did further experiments. So, in the meantime, The Oswald, McCarty, and McLeod actually did a more specific experiment to ask whether the factors that actually converted the R-type bacteria into S-type bacteria were DNA, protein, or RNA. So, it was believed that the genetic material was made up of proteins. They worked on the transforming principle in the fifth experiment to investigate its biochemical makeup. So, to determine the biochemicals from the heat-killed S-type bacteria that could convert the live R-type bacteria into S cells, they isolated the biochemicals as they isolated the proteins, DNA, and RNA.

From the S-cell bacteria, it was finally found that the DNA from the S-bacteria was needed to convert the R-type bacteria. So, what they have done and what they have used for this particular type of experiment is that they have used three different types of enzymes. They have used a DNase. So the function of DNA is that it actually digests DNA.

It actually destroys DNA. So if you take the DNA and any reactions, it is actually going to destroy the DNA. So it is actually going to remove the DNA component. Similarly, they have the RNA. So RNAs function to digest the DNA, which means they will actually destroy the RNA part, or I would say they will actually remove the RNA from the reactions. Similarly, you have another enzyme called proteases, and the target substrate for the proteases is that they actually digest proteins.

And it is actually going to destroy the proteins because it is going to convert the protein into amino acids. This means it is actually going to remove the protein components. This means that if you have a reaction, for example, if you treat this with the protease, then this reaction is going to be a reaction minus protein because you have treated it with the protease and removed the protein. So, these are some handy enzymes that these people have used to answer the question of which biomolecule is actually the genetic material.

So, what they have done is repeat the same experiment. What Griffith did was take heat-

killed S-type bacteria and live R-type bacteria, and then he treated the heat-killed bacteria with protease. So they have either treated it with the protease, treated it with the RNase, or treated it with JNase, okay. So in these cases, what you have done is remove the protein; in this reaction, you have removed the protein, in this reaction, you have removed the RNA, and in this reaction, you remove the DNA. This means that in this reaction you have the protein and RNA present, and in this reaction you have the DNA and protein present. So what are the things that are present? You have the DNA and RNA present.

because the protein has already been removed because you have treated it with protease. Then in this one, since you are removing the RNA, you are going to have the DNA and proteins. And in this one, you are going to have the RNA and the protein because you have removed the DNA. And then he tested under which condition the mouse is actually going to die. So in this case, when you have no protein, you have no protein; mice are dying.

This means that the protein is not responsible for converting the R bacteria into virulent S bacteria. Similarly, when you have no RNA, the bacteria mice are dying because the R type bacteria can still be transformed into S type bacteria. The third point is that when you don't have DNA, removing the DNA actually results in healthy mice, right? This means that in this case, you have the RNA and protein, but the mouse is still not getting the disease, which means the R strain is not being converted into the S strain. And that's how the mouse is actually healthy. And what you see, even at the cultural level, is that when they cultured the bacteria, they found that they could recover the live S bacteria in the absence of protein and RNA, but they could not isolate the live S bacteria; instead, they were actually getting the R type bacteria R2 in the case of the third condition when their DNA was not present.

So this actually confirmatively proved that DNA is the genetic material. Now let us talk about the conclusions: they found that both RNA and protein-digesting enzymes had no effect on the transformation, proving that the molecules undergoing transformation were either proteins or RNA. were neither a protein nor RNA. Transformation was prevented by DNA digestion, indicating that the DNA was the transforming agent. So they came to the conclusion that DNA is the genetic material, but not all biologists agreed with that.

And then the further experiments were done by Alfred Hershey and the Hershey and Chase experiment. So in the Hershey-Chase experiment, the researchers on the virus that infects the E. coli provided additional evidence for the genetic importance of the DNA. The DNA core of the T2 bacteriophage is encased in a protein coat. Alfred Hershey and Chase put this theory to the test in the following manner.

The radioactively labeled T2 phase in either the protein, which means the 35S, or they have labeled the DNA with the help of the 32P component before injecting them into the bacteria, which means they are going to have the bacteriophage where they have labeled the protein or where they have labeled the DNA by the radioactivity. Specifically, they infected the non-radioactive E. coli with the radio-labeled T2 bacteriophage. So in a T2

bacteriophage, you can have the protein, which is 35S, meaning sulfur-labeled, or you can have the DNA, which is actually going to be the 32P, right, or the phosphate-labeled, okay. And that is how they have asked where or which molecule is going from one generation to another generation.

So, they injected the bacteria with the T2 phage that has been radio-labeled either in the DNA component or in a protein component. The infected bacteria were agitated in a blender, and the two fractions were separated by centrifugation. One fraction contains the empty fast coat that was released from the surface of the bacteria, which consists of the protein and therefore carries the 35S radiolabel. The other fraction consists of the infected bacteria themselves. Most of the 32p label was found in the infected bacteria, which means that when they were doing the agitation, what they found is that the protein, which is a part of the coat, was always extracellular and was not being carried within the bacteria; it was not getting into the bacteria.

So, when the virus is infecting it, its port remains outside, and that is how it is actually going to be present outside. This means that the radiolabeled protein remains outside, whereas the radiolabeled DNA remains inside. So, that is why there was no sulfur, which has been associated with the bacterial cell, whereas in the case of DNA, all the DNA was present inside, and that is why, after certification, the radioactivity was associated with the bacteria. So by doing this experiment where they performed the infection followed by blending and centrifugation, what they found is that the protein is extracellular whereas the DNA was associated with the bacterial system. And by doing this experiment, Hershey and Chase concluded that DNA is the genetic material.

So, by observation, they found that the most radioactive protein was released into the serpentine, whereas 32P DNA remained within the bacteria. Since genetic material was injected and T2 progeny were produced, DNA must have been carrying the genetic information for the T2. This means not only that when the bacteria were sliced, it produced an enormous amount of viruses. This means the genetic information was there inside the bacteria to produce the viruses, and that was nothing but the DNA, right? As the ghost or the coat of the bacteriophage was not labeled with 32P and only with 32S, the result of the experiment clearly indicates that only DNA and not the proteins enter the bacterial cell. The protein coat is left outside, and all of the genetic data necessary for the creation of a new phage particle is carried by the DNA that entered the host cell.

This undoubtedly demonstrated that the DNA, not the protein, serves as the genetic material of the bacteriophage. And that's how they concluded that the genetic material is DNA, not protein. Then there is several indirect evidences for DNA to be the genetic material. The first evidence is that the DNA is regularly present in the nuclei of all set types.

It is equal to the amount of DNA present in all cells of an organism. The amount of DNA is proportional to the ploidy of the cell. Haploid cells have half the amount of DNA of diploid cells. Nuclear division occurs only after the DNA duplication during the S phase of interphase. This is anyway we have discussed when we were discussing cell division.

Then the different species have different amounts of deployed DNA. Out of all macromolecules, DNA is the most metabolically stable molecule, and that is the first criterion that the genetic material should be very stable. An indefinite number of combinations is possible with the four sub-bases like ATGC. DNA has the same physical and chemical properties in all organisms yet allows for great diversity among them. So, it was clear that DNA is the genetic material, right? But this has been challenged when people have discovered that there is a phenomenon called reverse transcriptase or reverse transcription.

When the people have discovered a phenomenon which is called reverse transcription. So, what is meant by the reverse transcription is that the RNA is actually going to give rise to the DNA, okay. So, this reverse transcription was against the central dogma of molecular biology, right? It says that RNA can produce DNA. And by doing so, there were people who said that RNA is also made up of, it's very stable, right? RNA is also stable and can provide diversity. And since RNA can be converted into DNA, there is a possibility that RNA could also behave like genetic material. Right, and then the same, uh, in exceptional cases or some other kinds of cases, right? So then again the same debate started: whether RNA could be genetic material or not.

To prove that, people have started doing experiments. Okay, so RNA as genetic material. So, according to the RNA world hypothesis, RNA was the first genetic material that stored all genetic information, and it is believed that the first life arose from it. RNA is thought to catalyze a number of chemical reactions in primitive cells. The presence of the two hydroxyl groups in the ribose group increased their reactivity. But this reactivity makes them unstable, which makes the RNA unfavorable as genetic material.

As genetic material, it should be chemically and structurally stable. So that was one of the drawbacks of RNA as a genetic material, as it actually contains the two-prime hydroxyl group, and because of that, it has more reactivity compared to DNA. So ultimately, these unstable molecules are replaced by the more stable genetic molecules. During this stage of evolution, the DNA molecule emerged. They have replaced RNA's role as both a genetic material and a structural component. The unstable and degraded nature of RNA has led to the development of double-stranded DNA genetic material that is both chemically and structurally more stable.

So, according to the hypothesis, it is found that RNA is actually the preferred material for genetic material in the primitive cell. During evolution, the cell has found that RNA is good as genetic material because it reduces the steps. You don't have to go for the transcription. You can directly use that information to produce the protein.

But, on the other hand, it is unstable. So, what they have done is convert the RNA into double-stranded DNA, and that is how you are actually bringing more stability, both chemically and structurally, into the structure. However, RNA is not completely animated. They still serve as genetic material in some systems, like viruses, and they catalyze a few essential biochemical reactions in the cell. Also, the complex machinery of

protein synthesis from DNA is still proceeding through RNA.

So, RNA is very important in relaying the information from the DNA. And that is why it is not excluded from the complete picture of protein synthesis. Still, the protein is being synthesized from the RNA itself. So, even if you see that the DNA actually stored the information, it is RNA that actually dictates the production of the protein, and that is how RNA is actually responsible for the particular type of phenotype. So, RNA is present as genetic material in some of the viruses, right? So, a virus consists of two parts: nucleic acid and the protein coat, sometimes with additional envelopes.

So a virus contains only one type of nucleic acid, either DNA or RNA. Viruses that have RNA are called riboviruses. They vary in the structures of their nucleic acids. Most of the plant viruses are RNA viruses, either single-stranded or double-stranded. So you can have animal viruses, you can have plant viruses, you can have single-stranded RNA viruses, you can have double-stranded RNA viruses. And even in plant viruses, you can have single-stranded viruses like the TMV, or you can have double-stranded viruses like the Oriya viruses.

Then we have the evidence in favor of RNA as genetic material. The first evidence that RNA also has the capacity to carry genetic information came from the experiment conducted on the tobacco mosaic or TMV viruses. So, Kriger and Schumann demonstrated in 1956 that the tobacco plant can contract a mosaic disease when exposed directly to pure RNA from TMV. RNA speed treatment rendered the pure RNA incapable of inducing TMV lesions. Then Franklin, Conhart, and Singer demonstrated in 1957 that the progeny viruses from the TMV infection with viruses have RNA from one strain and protein from another strain, but invariably of a kind determined by the RNA, not the protein.

So this is exactly what they have done. They have taken a TMV virus, and what they have done is remove the capsid protein. So they have removed and fragmented it into a protein and RNA. And then they degraded the RNA with the help of enzymes. So these are the four components. So when they take the TMV virus and infect the new cells, new leaves, they could find that the infection is happening.

When they remove the capsid, okay, when they remove the capsid part, right? So, it is still actually having the RNA right. So, if they remove the fragmented fractionated material from a capsid and the RNA when they take the capsid protein and infect that into the protein, there is no infection. So, there is no infection right now, but if you take the RNA and then infect the protein and the leaf, what they found is that there is an infection. So basically, the genetic information that was present in the RNA is good enough to produce the virus, and that is how it actually causes the disease. When they degraded the RNA with the help of the enzyme RNase, there was no RNA, right? They found that there was no infection.

So there is no infection in this case also. So, Brigger and Schumann correctly concluded that the viral genome of TMV is composed of RNA. So, if there is no RNA, then there

will be no infection. And then Franklin, Conhart, and Singer use the type anti-BTMV virus in this investigation. The RNAs were isolated from the protein coating, and then, in order to create hybrid viruses, Singer concluded the RNA of the strain with the protein of another. So, the phenotypically and genotypically identical progeny virus was similar to the parental type from which the RNA had been recovered after rubbing the hybridization or reconstituted viruses onto the living organism.

So, what these people have done is exclude the RNA; they have isolated the RNA from the two different types of TMV viruses, like TMV A and TMV B, and when they mix them together, they found that they are actually producing hybrid viruses. In conclusion, Franklin Conhart therefore comes to the conclusion that both DNA and RNA can carry kinetic information; as a result of all these investigations, research has established that the genetic material for TMV is stored in RNA rather than protein. However, while DNA may always serve as genetic material, RNA is typically non-genetic. RNA only serves as genetic material in a few instances when DNA is not present. So in summary, what we have discussed is that the gene carries the data for phenotypic expression, and these genes are referred to as factors in the case of Mendel.

And the chromosomes have the genes on them. They are made up of 60% protein, 40% DNA, and stable genetic material that can replicate, store information for expression, and undergo mutations as required. And experiments by Griffith, Avery, Hershey, and Chase have produced results that directly support DNA as the genetic material. There are also some circumstantial arguments in favor of DNA as a genetic material. So the experiment on TMV by Griger and Schumann demonstrated in 1956 that it is the RNA that is actually carrying the information from one generation to another, and that is how wherever you have the RNA, it is actually going to be responsible for the generation of or causing the disease. Even when they have mixed the two different types of viruses, what they found is that they are actually generating hybrid viruses, and the protein has no role in carrying the information from one generation to another.

So by doing all these experiments, it is concluded that RNA is not preferred as the genetic material when DNA is present; but if DNA is absent, RNA is also taken up as a substitute for carrying genetic information from one generation to another. Or I will say that RNA is preferred by primitive organisms such as viruses. And whereas DNA is more evolved, it is then taken up by the higher organisms. And that's why, very categorically, you can see that RNA is one of the most preferred genomes in the case of viruses, whereas DNA is more preferred in the case of higher animals.

So, with this brief discussion about genetic material, we would like to conclude our lecture here. In our subsequent lecture, we are going to discuss some more properties of the genetic material and how it actually has a role in synthesizing protein, and we are also going to discuss the central dogma of molecular biology. So, with this, I would like to conclude my lecture. Thank you.