

Cell and Molecular Biology

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Week 01

Origin of Life and Evolution

Lecture - 04

Theories of Evolution (Part 1)

Hello everyone, this is Dr. Vishal Trivedi from the Department of Biosciences and Bioengineering, IIT Guwahati. And what we were discussing was the origin of life on Earth, and in that context, we discussed many aspects related to how life originated on Earth and how different theories are being put forward. Following that, we have also discussed how simple organisms, like the primitive cell that formed in the primordial ocean, could develop into very specialized animals or specialized organisms, which could be invertebrate organisms or vertebrate organisms. Apart from that, if you talk about the plants, they have also evolved from very primitive plants like single-celled organisms such as algae, and then they have developed into specialized forms like pteridophytes, bryophytes, gymnosperms, and angiosperms. And that all we have discussed in the previous module, when we were talking about the classifications, and in the previous lecture, we have also discussed how these forms could have evolved.

And we have also understood the different types of experimental evidence that people have put forward and the different theories that have actually explained how evolution could have happened on Earth. So it was certain that evolution had occurred. These complicated or advanced organisms are evolving from primitive organisms. Now, in today's lecture, we are going to discuss the mechanism of how this could have been done and what the different theories and mechanisms are that people have put forward to explain how a primitive cell that formed in the primordial ocean could develop into a very specialized organism.

So with this, I think we will start our lecture. So what we have seen, what we have discussed so far, is that we have collected the scientific evidence that organisms have evolved from previously existing organisms. We have discussed the different types of evidence. We have discussed the morphological evidence. We have discussed the structural evidence and that we have discussed in terms of body organization and homologous organs.

We have discussed the analogous organs, and we have also discussed the gradual modification, where we have taken an example of the heart. Apart from that, we have also discussed the different types of connecting links, and then we also discussed the

embryological evidence as well as the paleontological evidence. Apart from that, we also discuss how fossils are formed and how you can determine the age of a fossil using carbon dating techniques or other dating techniques. Based on that, the different eras are being discussed in the previous lecture as well. So one question is how evolution happened and what the mechanism could be through which evolution is taking place on Earth.

To understand this question and address these questions, the people have put forward different types of theories. So, what are these theories? There are mainly three theories that our people have put forward. One is called the theory of inheritance of acquired characters, which was proposed by Lamarck. Then we have the theory of natural selection, which was proposed by Charles Darwin. And then we have Hugo de Vries or the mutation theories.

So let's start discussing each theory and how these theories explain evolution, the mechanism of evolution, their drawbacks, and what they could not explain. So let's start with the first theory, which is the theory of inheritance of acquired characteristics. The theory of the inheritance of acquired characteristics was proposed by the French biologist Chevalier de Lamarck in his famous book, *The Philosophy of Geology*. He proposed that the organisms are not fixed and that they evolve from pre-existing organisms through modification. He has assumed several types of modifications or several types of assumptions.

The theory is proposed assuming three different assumptions. What are the three assumptions? The three assumptions are that there is a need, a new need, and then we have the acquisition of the characters, and the third is the inheritance of the acquired characters. So, what is the new need? The new need is the variation in the environmental conditions and the overall circumstances that affect the existence of organisms, which need adaptations to survive. And as a result, the organism has to put in special efforts to fulfill its new need for adaptations. In a few cases, it just needs a change in the habits or behaviors of the organisms.

New habits include fresh or extensive use of certain organs or structures of the body or disuse of others. So the assumption of the new need states that there are challenges that people and organisms are going to face from time to time, and according to those challenges, whether these challenges could be environmental or whether their challenges could arise from changes in, you know, the availability of food or other kinds of things. There could be an adaptation. There will be an adaptation in the organisms to survive, and as a result, the organism is going to make modifications to its body, right? Either it is going to start using some organs or it will actually stop using some of the organs, and because of that, there will be changes. Then it is actually going to acquire the characters, so there will be an acquisition of the characters that we are going to discuss in detail, including the different types of acquisition of the character.

What could be the mechanism through which there will be an acquisition of the characters,

and once there is an acquisition of the character, that acquisition of the character is actually going to be inherited? So, the characteristics acquired by one generation are transmitted to the next generation, and subsequently, new changes or characters are added in the next generation to achieve perfection. This means that when the first generation actually faces these kinds of environmental conditions and changes, they will encounter various challenges. They will actually be going to use some organs, or they will be going to stop using some of the organs, and because of that, they will actually be going to acquire some of the characters. And these acquired characters are then going to be inherited, and that will happen automatically or spontaneously in the second generation; because of that, the second generation is not going to face those problems, and as a result, it will actually survive. Thus, Lamarck proposed that evolution is a slow process where characters are acquired over the course of time in various generations.

So that is a whole soul process, that whole soul method that Lamarck has said, that evolution is a very slow process and it has actually not been done in a single generation. It will be done in multiple generations, and because of that, it is actually going to acquire different types of characters. Now the question is how you can acquire the different types of characters. There are three ways to acquire the character required to adapt to the changing conditions. These changing conditions could be environmental, right? You can have a change in the temperature, or there could be a scarcity of water; there could be a scarcity of food, such as a scarcity of grass, right? And so on, right? So what are the three ways in which you can acquire the characters? There is an innate tendency; innate means there is a spontaneous tendency in each organism to acquire greater complexity and perfection to perform its functions.

In this process of achieving perfection, the organism is better and better adapted to the changing environment. You remember the example of the heart. So, I have discussed when we were discussing how the modifications to the existing organs could be a way to explain that evolution is happening, and that is a very classical example of the heart. The heart was two-chambered in the beginning, and then it was converted into three-chambered, and then it got converted into four-chambered; and why it is so is that if you have a two-chambered heart, there will be a mixing of blood. If it is a three-chambered heart, the mixing of the blood is going to be less, but it is still there, right? Because the auricle and ventricles are still able to mix the blood, the efficiency of the heart is also going to be less.

Because you have a two-chamber heart, it is actually going to cause mixing of the blood as well as affect efficiency. As soon as you acquire the final thing, which is the four-chamber heart, it is actually going to be very precise. You are going to receive the oxygenated blood in one chamber; you are going to supply the oxygenated blood from the other chamber, and so on. So this is why the organism has evolved into this: because they want to acquire better perfection. The same is true for many other things and many other examples.

And then the second point is the use or disuse of the organ. The use and disuse of organs

affect their structure, shape, and efficiency of functioning. More usage of a particular organ brings additional strength, size, and efficiency. In contrast, the disuse or underuse of the organ gradually makes it weaker and smaller, and finally, it may disappear as well. Thus, differential usage of the organ allowed for the additional character in the body during the lifespan of the organ.

So, what it says is that if you utilize the organ, it is actually going to be stronger, more stable, and more efficient. You can imagine that you know many of the bodybuilders; they are still using their organs, and they are using different types of exercises, and because of that, they are actually going to build up their muscles. So, that is a classic example to say that if you use a particular organ, like, for example, when you do weight lifting, you are actually going to strengthen your muscles, like biceps and all those kinds of things. So, that is a classic example of the use and disuse of the organ. Then we have the environmental factors, such as variation in temperature, light, humidity, wind, and enemies affecting living things and bringing changes in their lifestyles and habits.

The combined effect of the use and disuse of the organ and the influence of environmental factors results in changes in the body of the organism, and these characters are known as acquired characters. So what is meant by the acquired character is that it is the character you are going to acquire that you are not going to get from your parents, right? Acquired character means the character that you are going to acquire during your lifespan, and then these acquired characters are going to be inherited by the offspring, and that's how that was the proposal from Lamarck. Now Lamarck has cited many examples, observations, theories, and hypotheses to explain these three phenomena through which organisms are acquiring characters. And how the acquisition of the additional characters is helping them in terms of adapting to the changing conditions, and you know that's how they are succeeding in fulfilling or completing their lifespans, and that's how they are surviving. So he has cited many examples.

One of the classical examples is where he has cited the example of a giraffe. So Lamarck in his books explains the evolution of various animals to elaborate on the proposed hypothesis. Another classical example is the giraffe. So, you know that the giraffe has a very long neck, right? And because of that, it can actually take food from the very tall trees and high trees, right? So, Lamarck uses his hypothesis to explain the appearance of giraffes with long necks and forelimbs. As a theory, the giraffe evolved from short, deer-like ancestors, okay? So, initially, the giraffe was a very short deer-like thing, and because of that, it actually took food from the grass that was there at the bottom right.

But at the same time, it was also trying to take in additional nutrition, so he was using his forelimbs and neck more and more. Because of that, it started developing the neck muscles as well as the health and length of these muscles, and as a result, it started developing these organs. So these ancestors, the deer-like ancestors, are living in the barren place with the leaves on the trees available to them for eating. In order to reach the leaves on the trees,

they stretched their necks and forelegs. As a result, these organs become elongated.

This acquired character in its first generation was passed on to the subsequent generation and continued to stretch and accumulate this character over the course of new generations to evolve the giraffe with the long neck and forelimbs. So, what happened is that the giraffe, as Lamarck proposed, is evolving from a deer-like situation. But these animals do not have adequate food on the earth or on the grass, right? So, they were having the leaves on the higher trees. Because to get the nutrition, they started utilizing their necks. As they started using it more and more, and because of the stretching of the neck as well as the forelimb, it began developing its neck, so in the first generation, it started developing the neck to some extent.

And then that thing continued because in every generation the giraffe has to survive in that particular environment, and because of that it has started developing its neck length as well as its forelimbs. And because of that, it developed into a giraffe with a long neck and forelimbs. Then the second group is the aquatic birds. So other examples of the use and disuse to support Lamarck's theory are blacksmiths and rabbits. Blacksmiths acquired large bicep muscles as they do rigorous hammering for welding, right? I just cited a bodybuilder, as bodybuilders are also doing the same, but a blacksmith is also acquiring very strong biceps because they have to do the hammering for the welding.

Whereas the rabbit develops well-developed pinna muscles to move the ear to receive sound waves from different directions to protect itself from enemies, you might have seen rabbits in a zoo or in your home. That when they can actually rotate their pinna muscles or rotate their ears to such an extent that they can hear sounds from every direction, and why that is so is because the rabbit has to hear the entry of the enemy, and that's how it can actually protect itself from the enemy. Then we have another example of aquatic birds. Aquatic birds such as ducks need to go into the water for food and protection. To achieve this, they spread their toes to float on the water.

As a result of continuous effort, they have developed the web between their fingers. Then we have the snakes. So, you know that snakes do not have limbs, right? And why did snakes lose their limbs? Lamarck explained that the snake is considered to have originated from a lizard-like ancestor with two pairs of fully developed legs. These ancestors need to hide from the mammals, and they prefer to stay in places with dense vegetation, which means there are holes or narrow spaces, and because the dense vegetation, holes, as well as the narrow spaces, are actually obstructing the limbs, right? they have stopped using the limbs and and they started stretching their body to hide in the narrow places and did not use the leg because of they do not use the leg for very very long time like the several generations over the course of time continuous stretching of the body made it cylindrical and they lost the legs. So that is a classic example of how the disuse of a particular organ is actually going to lead to the disappearance of that organ in subsequent generations.

Then we have the deer. It is believed that a deer has acquired speed through continuous running in a process to protect itself from the enemy. So deer have, because deer have to protect themselves from tigers and all other carnivorous animals, developed strong muscles, and that's how they are able to run very fast. Then we have the cave animals. Cave animals do not have well-developed eyes, and they lack well-developed eyes because they stay in a low-light environment and do not use light; as a result, they have lost their vision over the course of time. So these are the pieces of evidence that Lamarck put forward.

But there are, if you have a theory, there are also contradictions; there are criticisms that people have put forth to criticize those kinds of evidence regarding Lamarck's theories of acquired characters. What are these theories? The criticism of the Lamarck theory is that it received initial attention but could not explain several observations. The initial two assumptions are correct. There is a new need to create a change in the environment. So the people agreed that there is a new need because you have to adapt to the changing environment, and whatever changes you make will actually be influenced by the use and disuse of the organ as well as the environment.

The inheritance of acquired characters to subsequent generations is actually arguable because there is no mechanism through which Lamarck proposed or explained acquired characters, as we said acquired characters are those that one acquires during their lifespan, but one does not inherit these acquired characters from their parents. So because you cannot get the acquired character from your parents, how can the acquired character go into the next generation? So that mechanism Lamarck could not be able to explain or Lamarck could not be able to verify. Then there is additional evidence that is actually against the inheritance of acquired characters. The major objection is gathered from the experiment performed by August Weismann. So, August Weismann proposed that Weismann's theory of the continuity of the germplasm states that the animal is made up of two types of cells.

Animals are made up of two types of cells. One is called somatic cells and the other is called germ cells. The germ cells, the nuclei present in the germ cell, are responsible for the inheritance of the character, whereas the somatic cells contain nuclei that respond to environmental factors or use and disuse, which means that according to Weismann's theory of the continuity of germplasm, you have the germ cells and you have the somatic cells. So somatic cells are actually the, one of the classical examples is the muscle cell. Somatic cells are all the other cells except the germ cells. In the case of humans, there are two different types of germ cells.

One is called sperm, the other is called ovum. These germ cells, the nuclei present in the germ cells, are actually responsible for carrying genetic information. The sperm you are going to get from the father and the ovum you are going to get from the mother fuse with each other to create the zygote and the offspring. So, these germ cells are actually going to carry the genetic information from one generation to the next generation, whereas the

somatic cells, which are classical examples like muscle cells, are actually going to respond to your habits. If you are using the muscles, they will become stronger because you are going to use them every day. So they will actually acquire mass, and that's how they will become stronger and stronger.

But that information will not get into the germ cells because germ cells are very, very far away from the somatic cells. So the acquired character, these somatic cells are actually going to be responding to the acquired character, whatever you acquired. For example, when we study in our classes, that information goes into our somatic cells, which goes into our brain. That does not mean that if I have done the PhD and have acquired that much information, I will be able to pass on that information to my next generation, and that is not possible because it is not being transcribed or it is not going to be passed into my germ cells, and because of that, every generation has to study; every generation has to learn how to make the alphabets. When you are born, you actually go through those learning experiences.

So the acquired characteristics remain within the somatic cell. As a result, this theory supports the idea that the acquired characters are not inheritable, which means the basic idea of Lamarck is that Lamarck's theory is mostly dependent on the inheritance of acquired characters. So people are not having any objections, people are not having any problems with that, there is a new need for organisms to survive in the changing environment, and it is actually going to use or disuse the different types of organs, which is also going to develop that particular organ. The only problem was the third assumption that there would be an inheritance of these acquired characteristics, and that's how it has been categorized and performed; even Weismann has done several types of experiments to prove that if you make changes to the somatic cells, those cells are only going to be modified, but the germ cells are not going to be modified in the second generation. In fact, what he has done is conduct a conclusive experiment on rats where he cut their tails for 80 generations, and that did not produce rats without tails, which means Weismann cut the tails of the rats.

So, once you cut the tail of a rat, the rat cannot use that particular tail, right? Because there is no tail available, right? So, that is actually mimicking the condition that you are forcing the organism to disuse that particular organ, right? But even then, when the newborns are being produced, they are not being produced without a tail; they will be produced with the tail only. So that has conclusively been proved that there is no inheritance of acquired characters. So there is much evidence from human civilization. There is much evidence from what people have observed in other animals as well. For example, the boring of the ear has been practiced in women for thousands of years, but this characteristic has never been inherited.

You know that in every civilization, women as well as men have been piercing their ear pinna for some time so that they can wear different types of ornaments. But these piercings, which are actually a kind of practice passed down from generation to generation, do not

result in a newborn being born with the pierce, nor does a newborn have a hole. Then we have the European women's, so European women wear tight garments to maintain a slender waist, but their children have normal waists at birth. So that is another example where the women are actually wearing tight garments so that they can look slim and smart, but the information that is acquired and collected does not go to their children.

Then we have the Chinese women. Chinese women wear tight shoes to have small feet. So that is a misuse of that particular organ, right? So they will be trying to constrict that particular use, and because of that, they want to develop small feet, but their children have normal feet. Then we have the children of the athletes who are not born with powerful muscles. The same is true for the blacksmith and the weightlifters. Weightlifters are acquiring huge power in their muscles, but that muscle power is not being transmitted to their offspring.

Then we have the child of the Nobel laureates or the child of the professors. They are not as intelligent as the parents because, as I said, you know when you are studying, you are actually collecting information in the brain, and the brain is nothing but a somatic cell, right? The brain is a somatic cell, so if you are acquiring and making changes in the somatic cell, those changes are not going to go into the subsequent generations. Then Pavlov also did so. Pavlov was a scientist; he trained the mice to come for food when the bell rang. So when he was ringing the bell, the mice would come, and they were being trained that when the bell rang, there would be food.

But what he found is that training is necessary even for the subsequent generation. You are not going to get the kids automatically trained because training is also a part of brain activity or spinal cord activity, and both of these organs are composed of somatic cells. Then we have the eyes of a voracious reader that do not grow in size, nor do they acquire improved eyesight with increasing age, right? What did Lamarck say? Lamarck said that if you use a particular organ, that organ is actually going to be more and more efficient. It will be stronger and stronger, right? But that is not the case, right? When you see that many people are actually reading novels after novels, or they are actually going to read the novels at night, it does not allow their eyesight to be improved, nor does it allow their eyes to grow in size, and that character is also not being transmitted to the new generations. So, to address these criticisms, Lamarck has utilized the latest information, and that's how he came up with the idea of the revised hypothesis or revised theory of inheritance of acquired characteristics.

What is this new theory? This new theory was called Neo-Lamarckism. So, there are evidences to support the inheritance of the acquired character. For example, the effect of radiation and chemicals on the germ cells and the resulting change in the phenotype of the cell, along with the evidence for the inheritance of the acquired character, revived Lamarck's theory as Neo-Lamarckism. The modified Neo-Lamarckism has the following postulates: So what people have observed is that if you are actually going to be exposed to

any kind of radiation that is going to make changes in the germ cells, then those changes will actually go into subsequent generations. And that has actually given a clue to the people who are supporting the Lamarck theory that this could be the reason; this could be the way in which the acquired character can be transmitted to the next generation.

And that's how they have proposed a new theory called neo-Lamarckism or the new theory of Lamarckism. This new Lamarckian theory or neo-Lamarckism has the following postulates. The germ cells are not always immune to the effects of the environment. So, what it means is that when there is a change in the environment, it is actually going to change both. It is actually going to change the somatic cells; it is also going to change the germ cells.

So if there is radiation, it is actually going to affect the germ cells; it is also going to affect the somatic cells. Or if there is any change in the environment, that is actually going to affect the somatic as well as the germ cells. The germ cells may affect it directly by the environment without any effect on the somatic cells. So whatever effects are happening to the germ cells may or may not affect the somatic cells. The germ cells may carry the acquired characteristics to the next generation.

So that's how they have explained, you know, how the inheritance of acquired characteristics could be possible. But even considering these points, Lamarckism could not provide a satisfactory mechanism for evolution. They still had questions and objections that they could not explain, and that's how people dropped the idea of the inheritance of acquired characteristics as the best solution to explain the mechanism of evolution. So what we have discussed is the theory of inheritance of acquired characteristics, where Lamarck stated that the organism is actually being forced to change its needs. It has actually been trying to evolve, trying to make the system more and more efficient, and because of this tendency or because of this habit, the organism has to evolve.

Why it is so and how it is doing so is because it is using or disusing its organs. If it is using the organs, it is making them stronger and more developed; if it does not use that particular organ, then it is actually going to shrink that particular organ. Or it is actually going to disappear with the classical example that it has cited, which is the snake example, where the snake has to go through the bushes, and when it had legs, they were actually interfering while going through those bushes. So what it has done is started sliding onto these bushes without using its limbs, and because of that, during the course of a few generations, there was a disappearance of the legs.

And the third is the inheritance of acquired characters. So if you can actually make changes to the body that will be inherited, that character is going to be passed on to the next generations, and that's how you can develop a new species and a new organism that is going to be more advanced compared to the previous organisms. And that's how if you keep going with those particular modifications, you can be able to develop new organisms. So, these are

the few points that Lamarck put forward, and that's how he actually explained the theory of the mechanism of evolution. So with this, I would like to conclude my lecture here, and in the subsequent lecture, we are going to discuss a few more theories where people have put in their efforts to explain the mechanism of evolution. Thank you.