

Cell and Molecular Biology

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Week 01

Origin of Life and Evolution

Lecture - 05

Theories of Evolution (Part 2)

Hello, everyone. This is Dr. Vishal Tevedi from the Department of Biosciences and Bioneering, IIT Guwahati. And what we were discussing was the origin of life and its appearance on the Earth. And what we have said is that life originated on the earth in the form of a primitive cell and that primitive cell developed into highly organized organisms, whether they belong to invertebrate organisms or vertebrate organisms. In the case of plants, we have discussed the different types of plants, whether they are the very simple algae or very complicated angiosperms.

In the previous lecture or in this particular module, what we were discussing, we were also discussing the evolutions and how very simple organisms are evolving into very complicated and advanced organisms. We have put many types of evidence. We have put the evidence in terms of the morphological or structural evidence, or we have put the embryological or paleontological evidence. By giving this evidence, people have put forward the idea that evolution is happening because a simple organism is evolving into very complex and advanced organisms.

In the previous lecture, we discussed the different types of theories. We said that there are three theories that people have put forward: the theory of inheritance of acquired characteristics, the theory of natural selection, and the theories of Hugo de Vries or the theories of mutations. In the previous lecture, we discussed the theory of acquired characters given by Lamarck, and we discussed how there are many points proposed by Lamarck, such as the use and disuse of organs, natural needs, the theory of acquired characters, and so on. All these things are being disproved because there is huge criticism of the theory by providing different types of evidence, including the Weismann experiments and the Weismann theories. Where it is saying that the acquired character cannot be inherited from one generation to other generations, the modifications that are happening in the germ cells are the only ones that will be inherited.

Based on these observations, the scientists have also modified the Lamarck theory and come up with the idea of neo-Lamarckism, but neo-Lamarckism could also not explain many

observations. And that's how people were looking for a better theory, and people were looking for an advanced theory. So which can actually be very, very broad; it could be based on experimental evidence, or it could be based on some kind of population study or some kind of broader studies. So they were looking for a theory that was based on the experimental evidence. In that context, there are three scientists who could come together, and that's how they have proposed the theory of natural selection.

So, the theory of natural selection was proposed by two scientists. One is called Charles Darwin and the other one is called Alfred Russel Wallace. So, this is Charles Darwin and this is Wallace. In their common publications, both of them conducted scientific data collections from the individual population survey. So what they have done is collect the data from the population survey.

In fact, Charles Darwin traveled for five years on an expedition around the world on a ship called the HMS Beagle, which is a famous ship that Charles Darwin used to travel around the world. And that's how he has collected the different types of animals, right? He has collected the pigeons, he has collected other animals like birds, and he has studied those animals, and that's how he came up with the idea of the theory of natural selection. During this journey, he made observations of several animals and plants. He keenly observed the similarity among the organisms and drew the evolutionary relationship. In addition, they also got help from the economist Thomas Malthus.

The report on the workers recognized that the competition between the species leads to the struggle for existence. So this is Thomas Malthus, and this is the famous ship called the HMS Beagle. Considering the Wallace view and the Malthus observation of the worker led Charles Darwin to propose the theory of natural selection in his very famous book called *The Origin of Species*, which was so famous that it actually became the best-selling book that year. In fact, the number of copies that are being sold for the original species is much greater than the number of copies that people are buying for the Bible as well. So that's how it says that the theory of natural selection, which is being proposed by Darwin, has actually been very, very interesting and exciting in explaining evolution.

So let's see what assumptions Darwin has made. The theory of natural selection is based on the following point. The first point is rapid multiplication. So what Darwin says is that every organism has the enormous ability to reproduce to continue its species, right? All animals and plants tend to multiply in geometric progression. For example, an organism will double in the first year, four times in the second year, and eight times in the third year, and so on.

So this means the production is actually on the geometrical progressions, right? So you can, if you start even with one organism, it is going to be double, right, within one year, or after the first generation. Then it is going to be four, then it is going to be eight, then it is going to be sixteen. So this is when you started with a single plant; if you started with a single plant, it will become 16 plants in four generations. So let's see examples of the organism to

understand its potential to multiply. These examples are as follows: So we have the first example of paramecium.

In its multiplication rate of three times in 48 hours, which means in two days it is actually going to get tripled. So if a single paramecium is allowed to grow and multiply for five years, it will give a mass equal to 10,000 times the size of the Earth. Which means if you allow a paramecium, which is actually going to be multiplied three times, 48 hours a single paramecium will grow and multiply; if you allow it to grow and multiply for five years, it will actually give you a total mass equivalent to 10,000 times the size of the Earth. Then we have fish. So, if you have the codfish, the codfish produces 1 million eggs in a year.

If all these eggs give rise to the fish, the whole Atlantic Ocean will be filled in five years. You can actually calculate how many fish are going to be produced if you allow these million fish to also be produced. So if you try to calculate, it is going to be a very, very huge number. Similarly, we have the oysters, and oysters may lay many eggs in a single spawning. But if all the oysters grow and survive to adulthood for five generations, then the number of oysters will be greater than the number of electrons in the universe.

Similarly, even for the bigger animals like elephants, an elephant has an average lifespan of 90 years, and during its whole lifespan, it can produce only six offspring. So even though it is a big animal, its production rate is very low, which means a single elephant is actually going to give you six offspring. If all the offspring survived, a single elephant pair would produce this many elephants in 750 years. This means that even if the larger animals, like elephants, are allowed to grow for reproduction, they will produce a very high number. The plants also produce thousands of seeds every year, so the point that Darwin was emphasizing is that every organism has the enormous ability to produce and maintain its species.

But you know that the number of these species is also not very high. They will remain constant. So how is it so? It is so because you have limited natural resources. In spite of the enormous capacity of our organism to reproduce, the number of individual species remains constant. You don't see the elephants everywhere, right? You see a few elephants, but you don't see that number that we just discussed, right? It is happening because there are limited natural resources.

All the elephants require food, water, oxygen, and so on. It is due to the increase in population of animals or plants that they require more space and food, and ultimately, the food for the plants or animals is provided by the carbon dioxide from the air, and water and minerals from the soil. So the amount of these basic materials is limited in the universe, right? You have limited natural resources. You have a limited amount of water, a limited amount of oxygen, a limited amount of carbon dioxide, and even sunlight is also limited. So, it does not allow the population of the organism to grow beyond the limit, and an equilibrium is reached.

An equilibrium is reached where there is the production of a few organisms and then the death of the same organisms. So, because of that, there is a complete balance. How is that balance happening? That balance is happening because there is a struggle for existence. Due to the shortage of food, water, and space, there is severe competition among the offspring for existence. For example, if you start with the elephant, the elephant has produced six offspring.

All six offspring actually require one thing: they require food, they require water, and they require space. So, if all six are requiring the same thing, they will actually fight with each other for all these natural resources, and because of that, some of the offspring are actually going to get the food, while some of the offspring are not going to get the food. So, every individual has a few basic requirements such as food, space, and water. They are also looking for partners so that they can reproduce, and they also require protection from enemies. And if anything goes wrong, for example, if they cannot get food, space, or water, or if they cannot find a place to hide to protect themselves from the animal that is actually going to end their lives.

So because of this, there will be a competition, and because of that, not all six are going to survive, right? There could be some of the offspring that are going to die. The same is true for this elephant as well. This elephant could also die in due course, right? Because it may not be able to get the food, water, or space, or it cannot get protection from the enemy as well. So in order to achieve basic needs, the organisms compete with each other, and it is known as the struggle for existence. The struggle for an individual can be of three types, so you can have three different types of struggles.

What is the struggle? Struggle is intraspecific; the competition of individuals of the same species is called intraspecific struggle. For example, the fight between two dogs for a piece of meat is one example, and war is another example of intraspecific struggle among different humans, right? So, you might have seen the fight between the two dogs for a piece of meat. You might have seen around the butcher's shop, there are a lot of dogs which are sitting and waiting for their piece to get. But as soon as he throws the piece of meat, there are multiple dogs which fight for that particular piece of meat. So, who will get it? That is going to be the winner.

The winner is actually going to get the ability to survive, whereas the losers are not going to get food for a very long time, and that's how they are going to die. Then we have the interspecific struggle, the competition between individuals of different species, which means if you have a bird and a frog, for example, or suppose you have a snake, right? So in that case, the frog is actually going to require protection from the snake, right? It has to have the ability to take up food and nutrition and all that, and it also could get protection from the snake. The same is that the snake should also get protection from the bird. So that's how the struggle or competition among individuals of different species occurs; for example, the tiger attacks the deer for food, right? So, the tiger should attack the deer to gain food; the

deer should be protected from the tiger; then only it can survive. So, that competition is called the interspecific struggles.

And then the third is the environmental struggle. Every individual struggles against the changes in the environment, such as changes in temperature, humidity, water levels, rainfall, and climate. So these three kinds of different types of changes could actually be responsible for the struggle for existence. And once you struggle, you are actually going to change yourself, right? You are going to be intelligent; only then can you get protected. For example, the deer, right? Deer has to adopt new and new schemes, a new way so that it can hide from the tiger.

Similarly, the frog should actually be intelligent enough to hide in some bushes or deeper places so that it does not get caught by the snake. The same is true for the snake as well. Snake should also have better and better abilities so that it would be able to catch the frog, and then it can actually get the food. So, if you actually keep developing these kinds of strategies, you are going to pick varying yourself from your offspring and your other partner and other members of that particular species. And because of that, there will be a variation, as each individual varies in several aspects from other individuals, as we have just discussed.

A frog that has to survive from the snake will probably change many things; it may change its skin color, it may change its size, and it may change some of its other features, and that's how it is going to be very different from the other individuals. Even the offspring produced by the parents differ in their aspects. The two individuals can be different from each other in their behavior, color, size, and strength, right? You might have seen, right? You and your brother or your sister may not be identical. They have been different from each other from the beginning. They are different from each other by birth.

They are different in terms of their intelligence and their various types of skills. Your sister could be very good at drawing. Your brother could be very good at cricket. You might be very good at hockey, and so on. So those kinds of behaviors and those kinds of changes are happening from birth itself, right? And by training and through these struggles, you are actually improving those abilities.

And then there will be natural selection. So, due to the variation among different individuals, they struggle for their existence with different potentials. For example, there could be two individuals: Individual A and Individual B. This guy is not good, right? So if you have two different types of frogs and if this guy is not very good at getting protection from the snake, this guy is going to be killed in due course, whereas this guy is going to survive, and that's how the lineage of this B guy's lineage is actually going to continue, whereas the A guy's lineage is actually going to be removed from the population. So that's how this A is actually going to be a new species; the B is also going to be a new species. The variation in an individual may allow it to survive and complete its life cycle comfortably.

Whereas if the variations are unfavorable, the individual will struggle against every odd, and as a result, it may not be able to complete its life cycle. For example, fast-running deer have a better chance of escaping from the tiger compared to the slow runner. This is another example: you have two deer, Deer 1 and Deer 2. Deer 1 is very fast, so whenever the tiger comes, it will run away, whereas Deer 2 is slow, so whenever the tiger comes, it will actually catch this deer. This means the population of B will go down, whereas the population of A will go up, and that's how Deer 1 is actually going to capture that particular place.

Another factor is the ability to adapt to the changing environment. Both Darwin and Wallace recognize the environment as the principal factor in natural selection. So there are many times when you are even very, very powerful and very strong, but you cannot adapt to the changing environment. One of the classical examples is the dinosaur, right? Dinosaurs, as per the latest theory, if they were cold-blooded animals, what is meant by cold-blooded animals? Cold-blooded animals are the animals that cannot regulate their body temperature, which means they will adopt the same temperature as the environment, so they will not be able to regulate their body temperature. For example, humans are not cold-blooded animals.

They are the other kind of animal right they could not be able to regulate the body temperature so if there will be cold they will actually going to feel the cold if they will be hot they are actually going to feel the hot So, because of this kind of variation, dinosaurs could not adapt to this changed environment. If there is a low temperature, they will not be able to survive because they cannot regulate their body temperature, and that's how the dinosaurs could not survive; they will vanish or become extinct. For example, the plants at the end with the ability to hold more water and reduce water loss will ultimately survive despite their physical strength, height, and other connectors. So this is another example: if you have a plant that can actually hold more water and reduce water loss, for example, a cactus. So cacti survive even in hot weather because cacti are converting their leaves into spines.

You might have seen cacti with spines. These spines are nothing but modified leaves. If you change the leaf to a spine, what you are doing is actually reducing the loss of water because the leaf is actually losing water from the stomata. So if there is a loss of water from the leaf, that is actually a problem. When you convert these leaves into a spine, a leaf has a very big surface area, and because of that, the evaporation is going to be fast; whereas when you convert that leaf into a spine, the surface area is going to be reduced, and because of that, it is actually going to reduce the evaporation. So that's how these are the modifications; any plant that will make this kind of modification is actually going to survive in a harsh and low-water area, whereas the other plants are actually going to die.

Another example we have discussed is about the dinosaur as well. Now, once you have

these kinds of things, then you have to have an inheritance of the useful variations. The individual survives due to unique variations made and produced in their offspring to complete their life cycle. As a result, they transfer the useful variations to the next generation and allow the individual to multiply. Darwin believed that any variation which can help the individual to survive and is favorable for struggle will be inherited.

It's considered the variation that may be acquired or inherited. For example, just now we discussed, right, if the elephant or frog, for instance, if the frog has to hide from the snake, suppose you have two different types of frogs, right? Frog number one, frog number two. This frog has changed its skin color, right? It has the ability to change its skin color, whereas the other one cannot do so. This means this guy is not going to survive, whereas this guy is going to survive. And if it survives, it is actually going to mate with another individual, and that's how the number of this particular frog will increase, and that's how it is actually going to be present in the environment.

And if it is present in the environment, it is actually going to form a new species. So as a result of struggle and natural selection, only the individuals that fit the environmental conditions will survive and complete their life cycles. As a result, the number of these individuals will increase over time compared to the less favorable organisms. In addition, the variation favoring will be inherited by the next generation, whereas unfavorable variation will be discarded. Due to continuous selection, a new organism will appear that will be different from its ancestral form.

This means if you started with a frog that cannot change its skin color, you might have one frog that actually can change its skin color; the other will be a normal frog, so you have a normal frog and a frog that can actually change its skin color. So if it can change its skin color, it can disappear into the bushes; it can blend into the green grass, and that's how it cannot be caught by the snake. Now this guy is actually going to be caught, right? So if this guy is actually going to keep reproducing, then another generation is also going to have the same thing happen again. It is going to produce two different types of frogs. It may produce a frog that may not be able to change its skin, but it will actually produce a frog that is going to change its skin.

So this frog will survive again, and if this continues for several generations, what will happen is that it is actually going to evolve into a separate species. It will be changed from the frog not only in terms of skin color, but it may also acquire different types of additional characteristics. So these good variations are actually going to be selected by nature, and these good selections will eventually form a new species. So, we will say, "Oh, there is a new frog; the frogs could be ones that can change their skin color, or they can actually make their skin so slippery that the snake cannot catch them, along with all other kinds of characters."

So, because of that, it is actually going to form a new species.

And that's how Darwin explained the development, production, or generation of new

species. So let's understand this through a classical example of the giraffe. So what Darwin has proposed is his theory on these points. One is the rapid multiplication; then you have the limited natural resources, the struggle for existence, variation, natural selection, inheritance of the useful variations, and the formation of new species. Now see here, so what Darwin has said is that you have two different types of giraffes.

You have a giraffe that looked like a deer, so you have the giraffe that was deer-like, and there was a giraffe that was a natural giraffe that we can see nowadays. This is the giraffe and this is the deer-like giraffe. So this deer is like a giraffe when it was present in the environment; initially, there was grass, so both of these species were surviving. But then there was a scarcity of grass and the leaves were only available on the trees. So when the leaves were only available on the tree, this particular deer-like giraffe could not get the nutrition because his neck was small.

So he cannot reach these trees. Because of that, they actually start dying. And this guy was only surviving, so he started mating with another giraffe, and that's how their numbers are increasing, and that's how we could be able to see a new species. So this is what is written here: that you have the two different types of giraffes present on the earth: the deer-like short height and the long neck, and the forelimbs, which are the current giraffes that you see. So until the grass was available on the land, both of these species were surviving and able to compete with their life cycle. With changes in the climate and a reduction in the grass, there might be a struggle for food, right? So that was said, right? There will be a scarcity of natural resources, which means in this case, there will be a scarcity of grass.

Then there will be a struggle, right? Because some guy could not get the food, he went hungry. So the giraffe with the long neck and the forearms can still eat the leaf from the tree, but the deer-like giraffe could not reach it and died due to starvation. In due course, the several rounds of natural selection led to the giraffe with the long neck and forearms dominating the region and being present as a new species. So that's how Darwin has explained the generation of the giraffe that we see in the present time.

There are other examples as well. Another example is natural artificial selection. From ancient times, man has been selecting good breed animals and plants for his use. In addition, they are performing the crossbreeding of these species to develop a new breed with desirable characteristics. The scientists supporting Darwin's theory explained evolution through natural selection to give rise to new species, just like following a similar mechanism to artificial selection by man. They further added that natural selection is a slow process, but much more complex compared to artificial selection.

For example, you can see these are the sheep, right? So the people were developing the sheep, which had a low height, right? So if they have a low height, they cannot run away from their barricades, and that's how they would be preferred, right? Then we have mimicry and protective coloration. The mimicry and the protective coloration are very

common in several organisms as the product of natural selection. Most of these organisms acquire their pattern of coloration by gradually changing color at each stage. So that was also another example that states that because of the forced conditions, due to the conditions that are forcing them, you have to change the conditions.

Then you have the correlation between the nectarines and the proboscis. The position of the nectarines and proboscis in insects correlates as well and matches well to facilitate pollination. This relation does not develop in single days but eventually emerges gradually through the process of natural selection. So you know that the nectarines contain the food, right? It contains the food for the insects, right? And that's why you have a very specific pair of flowers, you have a very specific pair of insects, and this proboscis and the nectarines combination match with each other. That does not happen in a single day; it happens because there is natural selection. These insects are only going to come and take the nutrition or the food from the nectar of these nectarines, and that's how they will do the pollination for these plants.

So these are a few examples, but these examples are not enough because people were coming up with different types of objections. So there were objections to the theory of natural selection as well. What is this evidence? The evidence, one of which is the perpetuation of vestigial organs. We know that vestigial organs are non-functional but are still present in new generations.

Those are called vestigial organs. Their classical example is the wisdom tooth in the case of humans. So you have a wisdom tooth which is considered to be a vestigial organ. Or there are other things as well, right? You have the caudal tail and something like that. So vestigial organs are selected despite the fact that they are not useful for animals, but even then they are preserved generation after generation.

So you know that we all have different types of vestigial organs. Then there is no explanation for the variation. Darwin could not explain the source and the mechanism of variation in organisms. So he could not explain why there could be a variation or what the mechanism of the variation is. So he is still having the same kind of issue that Lamarck had. Lamarck could not even explain how the acquired characters would be inherited, how the acquired characters would go into the germ cells, and the same kind of problem was there for Darwin as well.

Then the distinction between the continuous and the discontinuous variations. So, according to the theory, Darwin assumed that any variation essential for animal survival would be carried forward to the next generation. We know that it is not true according to the current knowledge of genetics. So, any character that you acquire for your own existence will not be passed down to the next generations. Then we have the disapproval of Darwin's pangenesis theory. So, Darwin put forward the theory of pangenesis to explain the process of inheritance.

It was disapproved by the experiment performed by August Wiesmann in 1892. So, these are the few objections that people have put forward against the theory of natural selection, and that's why people have been looking for some explanations. They were looking for the explanation for the variation, and then they would also be looking for what the different characters were that would actually be carried forward from one generation to the next generation. To explain those phenomena, Hugo de Vries actually proposed a new theory called the mutation theory or the Hugo de Vries theory. So what the Hugo de Vries theory is that the theory of Lamarck or Darwin is based on population study, but both theories could not explain the origin of the variation and their mode of transmission from one generation to the next generation. So that was the major objection that was present in both theories, the Lamarck theory and the Darwin theory, that they could not explain the origin of variation and its mode of transmission from one generation to the next.

To understand the gap, the Dutch botanist Hugo de Vries actually put forward the mutation theory in 1901, and according to the De Vries mutation theory, new species arise from pre-existing ones in a single generation by the sudden emergence of new features through a genetic variation known as mutations. So what he said is that evolution is not a slow process; it happens all of a sudden because of some kind of environmental change. It actually causes a mutation in the germ plasm, and because of that, it allows the appearance of new species. In contrast to the earlier theories, whether it is Lamarck's theory or Darwin's theory, De Vries proposed that evolution is a sudden, discontinuous, and jerky process rather than a continuous and gradual process.

He termed the process salation, which is a single step involving large mutations. In addition, natural selection works on mutations, preserving those that are useful and eliminating the harmful ones. But he did not support the struggle between the organisms considered coexistent with a parent species. So what Hugo de Vries normally said is that if you have a cell, okay, then all of a sudden there will be a mutation. So what will happen is its genome is actually going to get mutated, and that's how you are actually going to have the two different types of cells. One has the original cell, and the other one is actually going to have the changed mutated one.

So this mutated one is actually going to survive if these mutations are helping this particular organism to grow, but if it is not, then it will not allow this particular organism to replicate or go further, and that's how it is actually going to die. So, what he said is that the mutations which are useful are actually going to be preserved, whereas the mutations which are actually going to be harmful for the organism are actually going to be eliminated.

He did several experiments to prove that. So what are the experiments? To test the proposed mechanism, Hugo de Vries conducted the experiment on the plant called the evening primrose.

He observed the subtle but significant change between the different wildlife varieties. So

what he has done is that he has taken the evening primrose plant, and then he actually bred them, and once he had done the breeding, like the self-pollinations, after that he got the seeds and then he started growing them. So what happened is that you could find that the majority of the plants are producing normal plants, but there are some plants that actually have different characteristics. He was getting different plants, even if he is getting a different plant, which is actually termed as the mutant plant. Even due to self-pollination, you are going to get different plants, and you are going to get more different plants. So this means that in every generation, what it says is that if you do even the self-pollinations, there will be normal plants and then there will be a mutant plant.

For example, if you go to the second generation, again there will be a normal plant or different plants, whereas in the mutated plant. so this will continue and any mutant which is allowing the survival will actually going to propagate any mutant which is actually going to be lethal it is actually going to does not allow the running of that particular mutant. So what he said is that he found that the mutations appeared suddenly and were inherited by the offspring, and De Vries found the four different types of plants. Progressive, which means the plant has new traits; retrogressive, which means it has reduced or lost traits compared to the plant, which indicates it has gone back one generation; then it has a degressive plant with weak or low survival, and then it became inconsistent. These plants are unstable, and they resemble the parents as well as, at times, produce the variations.

So you are getting the four different types of plants: progressive, retrogressive, degressive, and inconsistent. Some important conclusions from the De Vries mutation theory are as follows. So, based on that experiment, he has actually made the conclusions. What are the conclusions? The mutations are the initial factors for evolution.

Then the mutants are unpredictable, occur suddenly, and produce their effect instantly. So there is no delay in evolution. That is a major point from Hugo de Vries's theory of mutations, which means it states that the mutants are non-predictable; they occur suddenly and produce their effects in the next generations. So, within a single generation, you would be able to see a change in phenotype. So, there is no intermediate stage between the appearance of the mutant form and the parent plant. Then the mutations are cumulative in nature and occur on multiple occasions to increase the frequency of mutation in the populations.

So mutations that are useful and good will actually accumulate even if that happens on multiple occasions. And that will increase the frequency of these mutants, the mutated organisms in the populations because the mutation is making the organism stronger, right? So the strong mutation is going to accumulate in the populations. A single mutation may give rise to a new species. And at last, the environmental factor works as a selection pressure to allow the growth of the beneficial mutant and eliminate the leader or the non-useful mutation. So, what it says is that you start with the parents and there will be a mutation, right? After the mutations, you are going to have multiple types of offspring,

right? And all these offspring are actually going to face the environment.

Once they change the environment, it will be like, for example, if you have four different types of mutations, all these one, two, three, and four are going to face the environmental conditions, and those that survive the environmental conditions, for example, mutation number one, are going to result in the formation of a new species. This is what he has done, right? If you start with the parents, okay, you are going to do the self pollinations. Then you are going to produce the offspring, right? So the mutations are actually going to create the variations. You see that this is the wild type. This is mutant number one, and this is mutant number two because this mutant, mutant zero, is actually not good, right? Unfavourable mutations will actually be selected against, so if there is an unfavourable mutation, it is not going to survive, and there will be no survival.

Whereas these two mutants are actually going to be selected, they will undergo another round of mutations, another round of reproduction, and further mutation. That mutation will continue, and that's how another generation will be generated; the mutations like A and B, and both of these A and B mutations are not useful, then they are actually not going to survive. whereas the favorable mutations are likely to survive. For example, in this case, you have first generated a single mutation in the first generation; then in the second generation, there will be mutations again.

So it has generated the third generation, and the third generation again got a mutation, and that's all. That's how you see the population of this particular mutant; the mutant 2 has now overtaken the whole population, and that is what Hugo de Vries proved by doing multiple experiments. Because it was very well defined based on the experiments, people have come up with different types of evidence to prove that. The evidence to prove the Hugo de Vries theory was that the experiment performed by De Vries was reproduced by several other scientists, and they came to a similar conclusion. So that was the first thing that was positive for the Hugo de Vries mutation theory. The mutations found spontaneously in nature and the sudden appearance of mutation variation have strengthened the mutation theory.

These mutations found in nature are as follows: For example, the Ancon sheep was produced from an ordinary sheep in a single step in 1891. The mutated sheep was short in height, and it was useful for farmers as they could not jump over the low stone fences. Then we have the hornless or polled Hereford cattle, which was produced in a single step in 1889 from normal parents, meaning that with a single mutation or a single mutation, you can develop a particularly different species. The hairless cattle, dogs, and mice were produced from normal parents in a single step. Then we have the different types of experiments in the plant, like *Oenothera Lamarckiana*, which has 14 chromosomes, but the mutations were only in this kind of 30 chromosomes.

We have mutations that are genetically linked and inheritable, so what we can count is that the mutations being produced in these animals are genetically linked and inheritable. The

single large mutations can produce new species in plants; for example, the delicious apples. So, what people have found is that there is a single mutation that is actually producing the new species. But despite this experimental evidence and a foolproof theory, people are coming up with objections.

So there is evidence against the theory. There is evidence against the mutation theory proposed by Hugo de Vries. What are the objections? The mutations are of rare occurrence, and it is difficult to assume that all the animals or plant species could appear solely by mutation. So mutation is a very, very rare phenomenon. It could happen, and it could be inducing factors, but it could not be explained that only the mutation is the responsible factor for the development of so many species. The relationship between the flower and the insects, such as the length of the proboscis in insects and the position of the nectaries in flowers, cannot be explained by the mutation theory.

The relationship between the two intersecting species, such as those that help each other, cannot be explained by the mutation theory. How is the insect evolving in such a way that it has a well-defined or suited proboscis, allowing it to take up nutrition from the flower while also helping the plant with pollination? The mutations are recessive, whereas it is generally the dominant mutation that brings out the evolutions. So there are mutations that are recessive, and there are mutations that are dominant. So Hugo de Vries could not explain these particular types of aspects, and that's how the mechanism of evolution, or the theory of mutation, was also unable to explain each and every phenomenon that is happening.

So what we have discussed is the different types of theories we have covered. We started with Lamarck's theory, and then we also discussed the theory of natural selection, as well as Hugo de Vries's theories of mutation. Every theory has some positives and some negatives, and in the end, what you could see is that probably all the theories were not complete and all the theories were not conclusive in explaining how evolution could have happened. But if you summarize them and try to conclude something, you will understand that Hugo de Vries said there could be a generation of mutations; there could be a mutation generation, and the environmental factor could have been playing a crucial role. Because you know that solar radiation, as well as UV radiation, could actually cause mutations, and these mutations could be helpful for the organism or lethal for the organisms, that is how it is making variation within the species.

So, you see, if you mix Darwin's theory and Hugo de Vries' theory, you could be able to understand the full picture. But as I said, none of these theories were conclusive in terms of explaining the mechanism of evolution. So, with this, I would like to conclude my lecture here. Thank you.