

Basics of Biology
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Module II – Origin of Life and Evolution
Lecture 10
Evolution (Part III)

Hello everyone, this is Doctor Vishal Trivedi from Department of Biosciences and Bioengineering, IIT Guwahati. And what we were discussing, we were discussing about the origin of life and its appearance onto the earth. And what we have said is that the life is originated onto the earth in the form of a primitive cell. And that primitive cell is developed into the highly organized organisms either they are belonging to the invertebrate organism or to the vertebrate organisms.

In the case of plants also we have discussed about the different types of plants, whether it is the very simple algae or very, very complicated angiosperms. In the previous lecture, we discuss about the or in this particular module, what we were discussing, we were also discussing about the evolutions and how the very simple organism is getting evolved into a very, very complicated and the advanced organisms.

We have put many types of evidences, we have put the evidences in terms of the morphological or the structural evidences or we have put the embryological or the paleontological evidence and by giving these evidences people have put forward the idea that the evolution was happening and because the evolution a simple organism is getting evolved into a very complex and advanced organism.

In the previous lecture, we discuss about the different types of theories, we said that there are three theories what people have put forward, the theory of inheritance of the acquired characters, the theory of natural selection(2:38) or the mutations theories. In the previous lecture, we discuss about the theory of acquired characters given by the Lamarck.

And we have discussed how the there are many, many points or many points which are being proposed by the Lamarck like the use and disuse of the organs or the natural needs or the theory of acquired characters and so on. All these things are being disproved, because there are huge criticisms of the theory by giving the different types of evidences that which was and ultimately the Weismann's experiments and as well as the Weismann theories where it is saying that the characters could not be, the acquired character cannot be inherited from one

generation to another generation, the modification what is happening into the germ cells, those are only going to be inherited.

And based on these observations, the scientists have also modified the Lamarck theory and they come up with the idea of Neo-Lamarckism. But the Neo-Lamarckism also could not be able to explain many observations and that is how people were looking for a better theory and people were looking for other advanced theory. So, which can be very, very, broad it could be based on the experimental evidences or it could be based on some kind of population study or some kind of, more broader studies. So, they were looking for a theory which was based on the experimental evidences.

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THE THEORY OF NATURAL SELECTION

- The theory of natural selection was proposed by **Charles Darwin** and **Alfred Russel Wallace** in their common publication. Both of them conducted scientific data collection from individual population survey.
- Charles Darwin travelled for 5 yrs expedition around the world on the ship **H.M.S Beagle**.
- During this journey, he made observation of several animals and plants. He keenly observed the similarities among organisms and draw evolutionary relationship.
- In addition, **economist Thomas Malthus's** report on workers recognized that competition between species leads to the struggle for existence.
- Considering Wallace's view and Malthus observations of workers led Charles Darwin to propose the theory of natural selection in his book "**Origin of Species**".

The slide features a small video inset of a presenter in the top right corner. At the bottom, there are four images: portraits of Charles Darwin, Alfred Russel Wallace, and Thomas Malthus, followed by an image of the H.M.S. Beagle. Red checkmarks are placed above the first three portraits, and a red circle with a checkmark is placed above the ship image.

In that context, three people have what, there are three scientists which could come together, and that is how they have proposed the theory of natural selections. So, the theory of natural selection was proposed by the two scientists; one is called as Charles Darwin, and the other one is called at the Alfred Russel Wallace. So, this is the Charles Darwin and this is the Wallace.

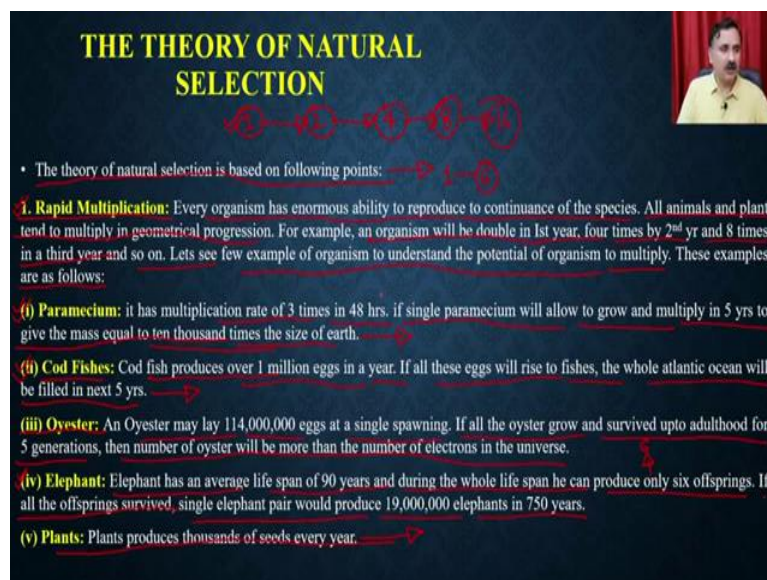
In their common publications, both of them conducted scientific data collections from the individual population survey. So, what they have done is they have collected the data from the population survey. In fact, the Charles Darwin traveled for five-year expedition around the world on to a ship which is called as the H.M.S Beagle. And H.M.S Beagle is a famous ship which the Charles Darwin has used to move, run around different types of, different, run around the world.

And that is how he has collected the different types of animals like he has collected the pigeons, he has collected the other animals like birds and he has studied those animals. And that is how he come up with the idea of theory of natural selections. During this journey, he made observation of the several animals and plants, he keenly observed the similarity among the organism and draw the evolutionary relationship.

In addition, he they also got the help from the economist Thomas Malthus to report on the workers recognize the competition between the species lead to the struggle for the existence. So, this is the Thomas Malthus and this is the famous ship which is called as the H.M.S Beagle. Considering the Wallace view and the Malthus observation of the worker led the Charles Darwin to propose the theory of natural selection in his very famous book, which is called as he “Origin of Species”.

And Origin of Species was so famous that it was the bestselling book on that particular year. In fact, the number of copies what are being sell for the Origin of Species were much more than the number of copies which people are buying for the Bible also. So that is how the, it says that the theory of natural selection, what has been proposed by the Darwin was actually been very, very, interesting and exciting to explain the evolutions.

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THE THEORY OF NATURAL SELECTION

• The theory of natural selection is based on following points:

- Rapid Multiplication:** Every organism has enormous ability to reproduce to continuance of the species. All animals and plant tend to multiply in geometrical progression. For example, an organism will be double in 1st year, four times by 2nd yr and 8 times in a third year and so on. Lets see few example of organism to understand the potential of organism to multiply. These examples are as follows:
 - Paramecium:** it has multiplication rate of 3 times in 48 hrs. if single paramecium will allow to grow and multiply in 5 yrs to give the mass equal to ten thousand times the size of earth.
 - Cod Fishes:** Cod fish produces over 1 million eggs in a year. If all these eggs will rise to fishes, the whole atlantic ocean will be filled in next 5 yrs.
 - Oyster:** An Oyster may lay 114,000,000 eggs at a single spawning. If all the oyster grow and survived upto adulthood for 5 generations, then number of oyster will be more than the number of electrons in the universe.
 - Elephant:** Elephant has an average life span of 90 years and during the whole life span he can produce only six offsprings. If all the offsprings survived, single elephant pair would produce 19,000,000 elephants in 750 years.
 - Plants:** Plants produces thousands of seeds every year.

So let us see, what are the assumptions what Darwin has made. The theory of the natural selection. The theory of natural selections is based on the following point; the first point is the rapid multiplication, so it has multiple points it has and the first point is the rapid multiplication. So what the Darwin says that every organism has the enormous ability to reproduce to continue its species.

All animals and plants tend to multiply in geometrical progression, for example, an organism will be doubled in first year, four times in second year, and eight times in a third year, and so on. So this means the production is on a logarithm, on the geometrical progressions. So you can if you start even with the one organism, it is going to be doubled within 1 year or after the first generation, then it is going to be 4, then it is going to be 8, then it is going to be 16.

So this is when you started with the single plant, like if you started with single plant, it will become 16 plant in four generations. So let us see the examples of the organism to understand the potential of the organism to multiply, these examples are as follows. So we have first example of paramecium. It is multiplication rate of three times in 48 hours, which means in two days, it is going to be get tripled.

So if the single paramecium will allow to grow and multiply in five years, it will give a mass equal to the 10,000 times to the size of the earth, which means if you allow a paramecium, which is going to be multiplied three times, in 48 hours, a single paramecium will grow and multiply, if you allow the grow and multiply for five years, it will going to give you the total mass, which is equivalent to the 10,000 times to the size of the earth.

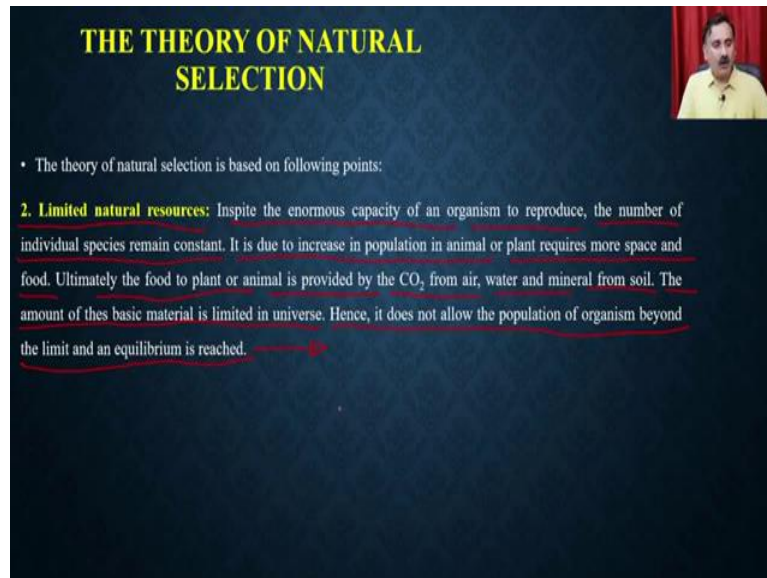
Then we have fish, so if you have the cod fish, the cod fish produces 1 million eggs in a year. If all these eggs will give rise to the fishes the whole Atlantic Ocean will be filled in five years. You can calculate how many fishes are going to be produced if you allow these and all these million, fishes are also going to produce. So if you try to calculate it is going to be very, very huge number.

Similarly, we have the oysters, an oyster may lay these many eggs at a single spawning. But if all the oysters grow and survive up to the adulthood for five generation; then the number of oyster will more than the number of electrons into the universe. Similarly, even for the bigger animals like the elephants, elephant has an average lifespan of 90 years and during the whole lifespan he can produce only six offsprings. So, it even it is a big animal, it has the reproduction rate is very low which means, a single animal elephant is going to give you the six offsprings.

If all the offspring survived and single elephant pair would produce one, this many elephants in 750 years. This means, even if the bigger animals like elephant if they grow, if you allow them to grow for the reproduction, they will be going to be very, very high number. Plants also, plant produces 1000s of seeds every year. So, plant every organism. So, what the point what the Darwin was putting an emphasis is that every organism has the enormous ability to

produce, to maintain every species. But you know that the number of, number of these species or their number is also not very high, they will be remained under constant. So, how it is so?

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THE THEORY OF NATURAL SELECTION

- The theory of natural selection is based on following points:

2. Limited natural resources: In spite of the enormous capacity of an organism to reproduce, the number of individual species remain constant. It is due to increase in population in animal or plant requires more space and food. Ultimately the food to plant or animal is provided by the CO₂ from air, water and mineral from soil. The amount of this basic material is limited in universe. Hence, it does not allow the population of organism beyond the limit and an equilibrium is reached.

It is so, because you have the limited natural resources. In spite of the enormous capacity of our organism to reproduce, the number of individual species remained constant, you do not see the elephants everywhere, you see a few elephants, but you do not see that number what we have just discussed. It is happening it is because there is a natural, there is limited natural resources and all the elephants required the food, they require water, they require oxygen and so on.

And it is due to the increase in population in animal or plant require more space and food and ultimately the food to the plant or animal is provided by the carbon dioxide from the air, water and mineral from the soil. So, the amount of these basic material is limited in universe you have a limited natural resources, you have a limited number of water, you have a limited amount of oxygen, you have a limited amount of carbon dioxide and even the sunlight is also limited.

So, hence, it does not allow the population of the organism grow beyond the limit and an equilibrium is reached. An equilibrium is reached where you have the production of few organisms and then you have the death of the same organism. So, because of that, there is a (12:32) complete balance. How that balance is happening?

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THE THEORY OF NATURAL SELECTION

• The theory of natural selection is based on following points:

3. Struggle for existence: Due to shortage of food, water and space, there is severe competition among the off spring for existence. Every individual has few basic requirements, such as food, space, water, mate to reproduce and protection from enemies. In order to achieve basic needs, organisms compete with each other and it is known as struggle for existence. The struggle for an individual can be of 3 types: →

(i) **Intraspecific Struggle:** The competition of the individuals of the same species. For example, fight between two dogs for a piece of meat. War is another example of intraspecific struggle among different human. → **Winner** **Loser**

(ii) **Interspecific Struggle:** The competition of the individuals of the different species. For example, tiger attacks on deer for food. → **Food** **Space** **Survive**

(iii) **Environmental Struggle:** Every individual struggle against the change in environment such as temperature, humidity, level of water, rain, climate etc.

That balance is happening because there is a struggle for the existence. Due to the shortage of the food, water and space, there is a severe competition among the offspring for the existence, for example, if you start with the elephant and the elephant has produced the 6 offspring, all these 6 offsprings require one thing, they require the food, they require water and they require the space.

So, if all the 6 are requiring the same thing, they will be going to fight with each other for all these natural resources and because of that, some of the offsprings are going to get the food, some of the offsprings are not going to get the food. So, every individual has a few basic requirements such as the food, space water, they also looking for their partners to so that they can be able to reproduce, and then they also require the protection from the enemy.

And if anything goes wrong, for example, if they could not get the food or space or water or they could not get a space to hide, so that they can get protected from the animal that is going to end their life. So, because of this there will be a competition and because of that, they will, all the 6 are not going to survive, there could be some of the offspring which are going to die.

Same is true for this elephant also, this elephant also could die in due course. Because it may not be able to get the food, water or space or it cannot get the protection from the animal, enemy as well. So in order to achieve basic need, the organism compete with each other and it is known as the struggle for the existence. The struggle for an individual can be of three types. So you have the three different types of struggles.

What is the struggle? Struggle is intraspecific struggles. The competition of the individual of the same species is called as intraspecific struggles, for example, the fight between the two dogs for a piece of meat. War is another example of intraspecific struggles among the different humans. So if you, what, you might have seen the fight between the two dog for a piece of meat, you might have seen, around a butcher shop, there is a lot of dogs which are sitting and waiting for their piece to get.

But as soon as he throws a piece of meat, there are multiple dogs which will fight for that particular piece of meat. So who will get it, that is going to be the winner, so winner is going to get the ability to survive, whereas the losers are going to not get the food for a very, very long time and that is how they are going to die.

Then we have the interspecific struggle, the competition of the individual of the different species, which means if you have bird and if you have the frog, for example, or suppose you have the snake, so in that case, the frog is going to require a protection from the snake, it has to have the ability so that it can take up the food and nutrition and all that thing, and it also could get the protection from the snake, same is that snake also should get protection from the bird.

So that is how if the struggle or the competition among the individual of the different species, for example, the tiger attacks on the deer for the food. So, tiger has to be, tiger should attack onto the deer to gain the food, deer should be get protected from the tiger then only it can be able to survive. So, that competition is called as the interspecific struggles and then the third is the environmental struggle.

So, every individual struggle against the change in the environment such as change in the temperature, humidity, level of water, rain and climate etc. So, these three kinds of different types of changes could be responsible for the struggle of the existence. And once you struggle, you are going to change yourself, you are going to be intelligent, then only you can get protected for example the deer; deer have to adopt the new and new schemes, and new and new ways so that it could get hide from the tiger.

Similarly, the frog, frog should be able to intelligent enough so that it would have hide into some bushes or some deep deeper places, so that it should not get caught by the snake. Same is true for the snake also, snake should also have the better and better abilities, so that it could be able to catch the frog and then only it can be able to get the food. So, if you keep

For example, there could be to individual, there could be to individual; individual A, individual B, this guy is not good. So is there, if you have two different types of frogs and if this guy is not very good from getting the protection from the snake, this guy is going to be killed in due course, whereas this guy is going to survive and that is how this the lineage of this, B guy's lineage is going to continue whereas the A guy's lineage is going to remove from the information. So that is how this A is going to be a new species, the B is another going to be a new species.

The variation in an individual may allow him to survive and complete its lifecycle 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 lifecycle. For example, fast running deer has better chance of escaping from the tiger compared to the slow runner. This is another example, you have two deer; one is, so you have two deer, deer 1, deer 2; this deer is very fast.

So, he will whenever the tiger will come, he will run away, whereas this one is slow. So whenever the tiger will come, he will catch this deer. So it means the population of the B will go down, whereas the population of A will go up. And that is how the deer 1 is going to capture that particular place.

Another factor is the ability to adopt into the changed environment. Both Darwin and Wallace recognized the environment as the principal factor for the natural selections. So, there are many times when you are even very, very powerful, you are very strong, but you cannot be able to adopt due to the change environment, one of the classical examples is the dinosaur. Dinosaur as per the latest theory is could not be able, they were cold blooded animal. They were cold blooded animals, what is meant by the cold-blooded animal?

Cold blooded animals are the animal which cannot regulate their body temperature, regulate body temperature, which means they have to go, they will adopt the same temperature of the environment. So, if there will be cold, so, they will not be able to regulate the body temperature, for example, humans are not cold-blooded animals, they are the other kind of animal.

So, they could not be able to regulate the body temperature. So, if there will be cold, they will going to feel the cold, if they will be hot, they are going to feel the hot. So, because of this kind of variations dinosaur could not be able to adapt to this changed environment. So, there will be a, if there will be a lower temperature, they will not be able to survive because they

cannot regulate the body temperature and that is how the dinosaur could not be able to survive and they will be get vanished or they will be get extinct.

For example, the L plants with ability to hold more water and can be able to reduce the loss of water will ultimately survive despite the physical strength, height and the other characters. So, this is another example, if you have a plant which can have the ability to hold more water and can be able to reproduce, reduce the loss of water for example, you have a plant like cactus.

So cactus survive even in a hot weather because cactus is converting its leaves into spine, you might have seen cactus with the spine, these spines are nothing but they are modified leaf these if you change the leaf to a spine, what you are doing is you are reducing the loss of water, because the leaf is leaving the water from the stomata. So, if there will be a loss of water from the leaf that is a problem, but when you convert these leaves into a spine, because a leaf, you might have seen leaf is very, very big.

So, that has a very large 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 going to reduce the evaporation. So that is how that is these are the modification, any plant, who will do this kind of modification is going to survive into a hot and the low water area whereas other plants are going to die. Another example we have discussed about the dinosaur as well.

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THE THEORY OF NATURAL SELECTION

• The theory of natural selection is based on following points:

6. Inheritance of useful variations: The individual survived due to unique variation, mate and produces their off spring to complete their life-cycle. As a result, they transfer the useful variations to the next generations and allow the individual to multiply. Darwin believed that any variation which can help the individual to survive and help to favorable for struggle will be inherited. He considered the variation which may be acquired or inheritable.

7. Formation of new Species: As a result of struggle and natural selection, only the individual fits to the environmental conditions will survive and complete its life-cycle. As a result, the number of these individual will increase over the course of time compared to the less favorable organism. In addition, the variation favoring will be inherited to the next generation whereas unfavorable variation will be discarded. Due to continuous selection, a new organism will appear which will be different from their ancestral form.

Diagram: A branching tree structure starting from 'Foss' on the left. It branches into two paths. The upper path leads to a box labeled 'New Species'. The lower path leads to a box labeled 'Extinct'.

Now, once you have these kinds of things, then you will have to have an inheritance of the useful variations. The individual survives due to unique variations, mate and produce of their offspring to complete their lifecycle. As a result, they transfer the useful variation to the next generation and allow the individual to multiply. Darwin believes that any variation which can help the individual to survive and help to favorable for struggle will be inherited.

He has considered the variation which may be acquired or to inheritable. For example, just now we discussed if the elephant is or frog for example, if the frog has to hide from the snake, it, suppose you have two different types of frogs; frog number 1, frog number 2, this frog has changed its skin color. It has an inherent, it has the ability to change your skin color, whereas this cannot.

So this means this guy is not going to survive, whereas this guy is going to survive. And when if it survives, it is going to mate to the another individual and that is how the number of this particular frog will go up. And that is how it is going to be present in the environment. And if it is present in the environment, it is going to form a new species. So as a result of struggle and natural selection, only the individual fits to the environmental condition will survive and complete its lifecycle.

As a result, the number of these individual will increase over the course of time compared to the less favorable organisms. In addition, the variation favoring will be inherited to the next generation, whereas, unfavorable variation will be discarded. Due to continuous selection a new organism will appear which will be different from their ancestral form. This means, if you started with a frog, which cannot change its skin color, you might have, one frog which can change the skin color, the other will be another frog which is normal, so, you have normal frog, you have the frog, which can be able to change its skin color.

So, if it can be able to change the skin color, it can get disappeared into the bushes, it can disappear into the green grass and that is how it cannot be get caught by the snake. Now, this guy is going to caught. So, if this guy will going to be keep reproducing and so another generation also, again the same thing is going to happen, it is going to produce the two different types of frog it may produce the frog which may not be able to change the skin, but it will going to produce the frog which is going to be changed the skin.

So, this frog again will survive and if this will continue for several generation, what will happen is this is going to be evolved as a separate species, it will get change from the frog, not only in terms of skin color, it may also acquire the different types of additional characters.

So these good variations are going to be get selected by the natural, by the nature. And these good selections are eventually will form a new species.

So we will say, Oh, there is a new frog, the frogs could be which can change its skin color or it can make the skin so slippery that snake cannot be able to catch him and all other kinds of characters. So because of that it is going to form the new species. And that is how the Darwin has explained the development or the production or the generation of the new species. So, let us understand this by a classical example of the giraffe.

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THE THEORY OF NATURAL SELECTION

- The theory of natural selection is based on following points:
 1. **Rapid Multiplication**
 2. **Limited Natural Resources**
 3. **Struggle for existence**
 4. **Variation**
 5. **Natural Selection**
 6. **Inheritance of useful variations**
 7. **Formation of new Species**

According to the theory of natural selection, in the beginning there were two different types of giraffe present on earth; **1) Deer like short neck** and **2) Long neck and forearms**. Until the grass was available on land, both of these species were surviving and be able to complete their life cycle. With change in climate and reduction of grass, there might be a struggle for food. The giraffe with long neck and forearms can still be able to eat leaves on the trees but the deer like giraffe could not be able to reach there and died due to starvation. In due course, several round of the natural selection led the giraffe with long neck and forearms dominated the region and be present as new species.

The diagram illustrates the process of natural selection in giraffes. It shows two initial types: a 'Deer' (short neck) and a 'Giraffe' (long neck). Both are shown eating grass from the ground. A change in the environment is depicted with a tree and a bird. The 'Deer' is shown unable to reach the leaves and is marked with a red 'X', indicating it died. The 'Giraffe' is shown reaching the leaves and is marked with a red checkmark, indicating it survived. The final stage shows a population of giraffes with long necks and forearms, representing the new species that survived due to natural selection.

So, what the Darwin has produced, Darwin has proposed? The Darwin has proposed its theory on the these points; one is the rapid multiplications, then you have the natural selections, then you have the struggle for the existence, then you have the variation, then you have the natural selections, and then you have the inheritance of the useful variations and then you have the formation of new species.

Now see here, you have so what Darwin has said is that you have two different types of giraffes, you have a giraffe, which was look like a deer. So you have the giraffe which was deer like giraffe and there was the giraffe which was a natural giraffe, what we could see nowadays.

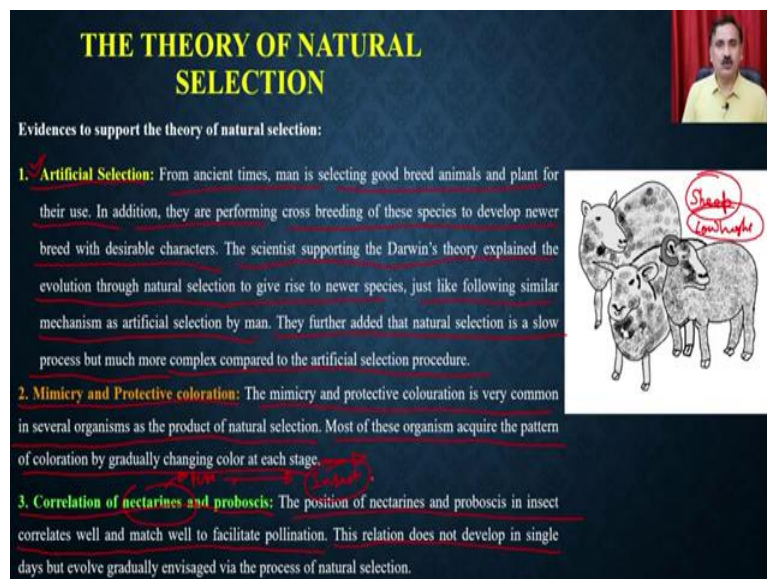
So you have, this is the giraffe and this is the deer like giraffe. So this deer like giraffe when it was present into the environment and so initially there was this grass, so the both of these species were surviving, but then there was a scarcity of grass and the leaves were only available onto the trees.

So, when the leaves were only available on the tree, this particular deer like giraffe could not be able to get the nutrition because his neck was a small. So he cannot reach to these trees. So because of that they start dying and this guy was only surviving. And this guy was surviving, so he started mating with another giraffe and that so their number is increasing and that is 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 giraffe present onto that, deer like short height and the long neck and the forelimb, which is the current giraffe what you see. So until the grass was available on the land, both of these species were surviving and be able to complete with their lifecycle. With change in the climate and reduction of grass there might be a struggle for the food. So that was it said you there will be a scarcity of the natural resources which means in this case, there will be a scarcity of grass.

Then there will be a struggle because some guy could not get the food. So the giraffe with long neck and the forearms can still be able to eat the leaf from the tree but the deer like giraffe could not be able to reach there and died due to the starvation. In due course, the several rounds of the natural selection led to the giraffe with a long neck and the forearm dominated the region and be present as a new species. So that is how the Darwin has explained the generation of the giraffe what we see in the present time.

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THE THEORY OF NATURAL SELECTION

Evidences to support the theory of natural selection:

- 1. Artificial Selection:** From ancient times, man is selecting good breed animals and plant for their use. In addition, they are performing cross breeding of these species to develop newer breed with desirable characters. The scientist supporting the Darwin's theory explained the evolution through natural selection to give rise to newer species, just like following similar mechanism as artificial selection by man. They further added that natural selection is a slow process but much more complex compared to the artificial selection procedure.
- 2. Mimicry and Protective coloration:** The mimicry and protective colouration is very common in several organisms as the product of natural selection. Most of these organism acquire the pattern of coloration by gradually changing color at each stage.
- 3. Correlation of nectarines and proboscis:** The position of nectarines and proboscis in insect correlates well and match well to facilitate pollination. This relation does not develop in single days but evolve gradually envisaged via the process of natural selection.

Handwritten notes on the slide:
- A red circle around the word 'Sheep' in the drawing.
- A red circle around 'nectarines' in point 3.
- A red circle around 'proboscis' in point 3.
- A red circle around 'single days' in point 3.

There are other examples also, another example is the natural artificial selections. From ancient time the man is selecting good breed animals and plant for their use. In addition, they are performing the cross breeding of the species to develop the newer breed with a desirable character. The scientists supporting the Darwin's theory explain the evolution through the

natural selection to give rise to the new species, just like following similar mechanism as the artificial selection by the men.

They further added that the natural selection is a slow process, but much more complex compared to the artificial selection. For example, you can see these are the sheep. So the people were developing the sheep which was having a low height. So if they are having a low height, they cannot be able to run away from their barricades. And that is how they would be preferred.

Then we have the mimicry and the protective coloration, the mimicry and the protective coloration is a very common in several organism as the product of the natural selection, most of these organisms acquired the pattern of coloration by gradually changing the color at each stage. So that was the also natural, another example which says that, because of the forced conditions, because of the condition which are forcing them you have to change the conditions.

Then you have the correlation of the nectarines and the proboscis. The position of the nectarine and proboscis in insects correlates well and match well to the facilitate pollination. This relation does not develop in single days, but eventually gradually envisaged through the process of natural selection. So that the nectarines are containing the food, it contains a food for the animal, for the insects. And that is why you have a very set pair of flowers, you have a very set pair of insects, and this proboscis and the nectarines combination is matching with each other.

And that does not happen in the single day, it happens because there is a natural selection. These insects are only going to come and take the nutrition or the food, the nectar from these nectarines and that is how they will be only going to do the pollination for these plants. So that is these are the few examples. But these examples are not enough because the people were coming up with different types of objections. So, there were objections against the theory of natural selection as well.

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THE THEORY OF NATURAL SELECTION

Evidences Against the theory of natural selection:

- 1. Perpetuation of Vestigial Organs:** Vestigial organs are selected despite the fact that they are not useful for animals but even then they are preserved generation over generation.
- 2. No explanation for variation:** Darwin could not be able to explain the source and mechanism of generation of variation in organisms.
- 3. Distinction between continuous and discontinuous variations:** According to theory, Darwin assumed that any variation essential for animal survival will be carried forward to next generation. We know that it is not true as per present knowledge of genetics.
- 4. Disapproval of Pangenesis theory of Darwin:** Darwin put forward the theory of Pangenesis to explain the process of inheritance. It was disapproved by the experiments performed by August Weismann in 1892.

What are these evidences? The evidences, one of these it is the perpetuation of the vestigial organs. We know that the vestigial organs the organs which are nonfunctional, but they are still be present in the new generations, those are called as the vestigial organs. The classical example is the wisdom teeth in the case of the human.

So, you have wisdom teeth, which is considered to be a vestigial organ or there are other things also like you have the chordal tail and something like that. So, vestigial organs are selected despite the fact they are not useful for animal, but even then they are preserved generation over generation. So, you know that we have, all have the different types of vestigial organs.

Then there is no explanation for the variation, Darwin could not be able to explain the source and the mechanism of variation in the organism. But he so he could not be able to explain why there could be a variation, what is the mechanism of the variation? So he is still having the same kind of issue what Lamarck was having, Lamarck could not be able to even explain how the acquired character will be inherent, how the acquired character will go into the germ cells and same kind of problem was there for the Darwin also.

Then the distinction between the continuous and discontinuous variations. So, according to the theory, Darwin assumed that any variation essential for animal survival will be carry forward to the next generation, we know that it is not true and as per the current knowledge of the genetics. So any character which are acquired for your own existence will not be going to go into the next generations.

Then we have the disapproval of the pangenesis theory of Darwin. So Darwin put forward the theory of pangenesis to explain the process of inheritance. It was disapproved by the experiment performed by the August Weismann in the August 1892. So, these are the few objections that people have put forward against the theory of natural selections.

And so that is why the people have looking for some of the explanation, they were looking for the explanation for the variation and then they will be also looking for how the different way, what are the different character which are going to be carry forward from the single generation to the next generation.

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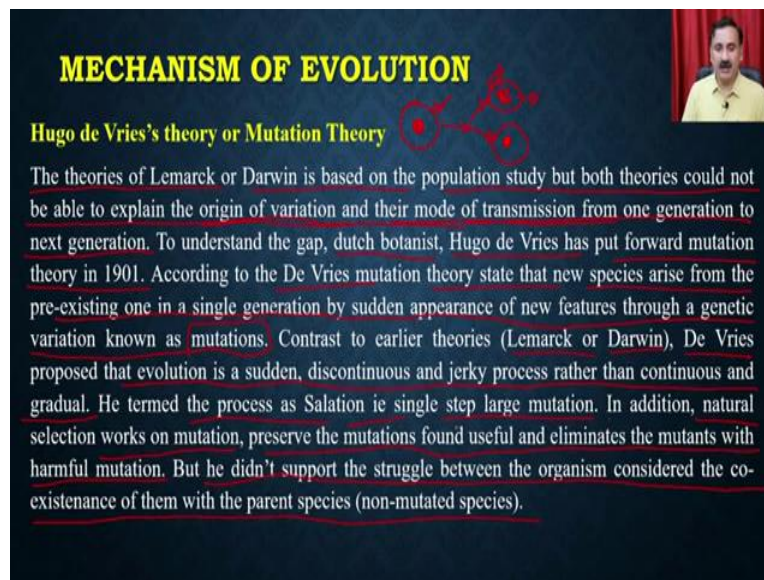
MECHANISM OF EVOLUTION

The mechanism of evolution is not known and several theories have been put forward to explain the process of evolution. These theories are as follows:

1. Theory of inheritance of acquired characters.
2. The theory of natural selection
3. Hugo de Vries's theory or Mutation Theory

To explain those phenomena, the Hugo de Vries proposed the new theory and that theory is called as the mutation theory or the Hugo de Vries's theories.

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MECHANISM OF EVOLUTION

Hugo de Vries's theory or Mutation Theory

The theories of Lamarck or Darwin is based on the population study but both theories could not be able to explain the origin of variation and their mode of transmission from one generation to next generation. To understand the gap, dutch botanist, Hugo de Vries has put forward mutation theory in 1901. According to the De Vries mutation theory state that new species arise from the pre-existing one in a single generation by sudden appearance of new features through a genetic variation known as mutations. Contrast to earlier theories (Lamarck or Darwin), De Vries proposed that evolution is a sudden, discontinuous and jerky process rather than continuous and gradual. He termed the process as Salation ie single step large mutation. In addition, natural selection works on mutation, preserve the mutations found useful and eliminates the mutants with harmful mutation. But he didn't support the struggle between the organism considered the co-existence of them with the parent species (non-mutated species).

So what is Hugo de Vries theory is that, the theory of Lamarck or the Darwin is based on the population study, but both theory could not be able to explain the origin of the variation and their mode of transmission from the one generation to the next generation. So, that was a major objection, what was there in the both the theories, the Lamarck theory or the Darwin theory that they could not be able to explain the origin of the variation and as well as their mode of transmission from one generation to the next generation.

To understand the gap, the Dutch botanist Hugo de Vries has put forward the mutation theory in the 1901. And according to the De Vries, mutation theory state that that new species arise from the pre-existing one in a single generation by the sudden disappearance of the new feature through a genetic variation known as the mutations. So what he said is that evolution is not a slow process, it happens all of sudden, because of some kind of environmental changes, it causes a mutation into the germplasm.

And because of that, it allows the appearance of the new species. So contrast to the earlier theories, whether it is a Lamarck theory or the Darwin theory, De Vries proposed that evolution is a sudden discontinuous and jerky process rather than the continuous and the gradual process. He termed the process as Saltation that is a single step large mutation.

In addition, the natural selection works on the mutation, preserve the mutation found useful and eliminate the mutation with the harmful mutations, but he did not support the struggle between the organism considered coexistence of them with a parent species. So what the Hugo de Vries brief normally said is that if you have a cell, okay, then all of a sudden they will be a mutation.

So what will happen is its genome is going to get mutated and that is how you are going to have two different types of cells one which is having the original cell, the other one is going to have the changed mutated one. So this mutated one is going to survive, if these mutations are helping this particular organism to grow. But if it is not, then it is going to, but will not allow this particular organism to replicate or go further and that is how it is going to die.

So, what he said is that a mutation which are useful are going to be preserved, whereas the mutations which are going to be harmful for the organism, they are going to be eliminated. He did the several experiments to prove that.

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MECHANISM OF EVOLUTION

De Vries Experiment: To test the proposed mechanism of evolution, Hugo De Vries conducted experiment on plant called as Evening Primrose (*Oenothera lamarckiana*).

He observed the subtle but significant difference between different wild type variants. He took normal plant and collected the seeds through self pollination. He found that majority of seeds were normal like their parents except few one. These seeds were quite different from their parents. The plants with variants were true to give rise to plants with similar characteristics. In 2nd generation, it breeds to give plants with majority of plants similar to their parents but few plants with different variants. Hence, he observed that in each generation, majority of the offsprings are similar to their parents but it gives few off springs with variants. In addition, he found that mutations appeared suddenly and were inherited by off-springs. De Vries found 4 different types of plants:

- (i) **Progressive**, with newer traits.
- (ii) **Retrgressive**, that had reduced or lost traits compared to their parents.
- (iii) **Degrressive**, plants with weak with low survival.
- (iv) **Inconstant**, these plants are unstable and they resembles parents as well as at times produced variants.

So what are the experiment? To test the proposed mechanism Hugo de Vries conducted the experiment on the plant called as the Evening Primrose or the *Oenothera Lamarckiana*. He observed the subtle but the significant change between the different wildlife varieties. So what he has done is he has taken up the Evening Primrose plant and then he breed them. And once he done the breeding like the self-pollination after that he got the seeds and then he started growing them.

So, what happened is he could find that the majority of the plants are giving the normal plants, but there are some plants which are having the different plants. So different he was getting the different plants, if it is, even if it is getting the different plant which is he termed as the mutant plants. If you even have to do the self-pollination you are going to get the different plants like you are going to get some different plants and you are going to get the more different plants.

So this means in every generation what it says is that if you do the event the self-pollination, in every generation they will be a normal plants and then they will be a mutant plant. For example, if you go to the second generation, again there will be a normal plant or the different plants, whereas in the mutated plant, so this will continue and any mutant which is allowing the survival, will going to propagate any mutant, which is going to be lethal, which is going to this 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 offsprings and De Vries find the four different types of plants; progressive, it means, the plan with the new traits, retro-progressive, which means that has reduced of lots of traits compared to the plant, which means, it has gone to the one generation back then it has a degressive plant with the weak or the low survival and then it got inconstant, these plants are unstable and they resemble plant, they resemble the parents as well as at times have produced the variations. So, you are getting the four different types of plants progressive, retro-progressive, degressive, and inconsistent.

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MECHANISM OF EVOLUTION

Important conclusions from Hugo De Vries Mutation Theory are as follows:

1. Mutations are the initiator factor for evolution.
2. Mutants are non-predictable, occur suddenly and produce their effect instantly.
3. No intermediate stage between appearance of mutant form and parent plants.
4. Mutations are cumulative in nature and occurs on multiple occasion to increase the frequency of mutant in the population.
5. A single mutation may give rise to new species.
6. At last, environmental factors work as selective pressure to allow growth of beneficial mutants and eliminates lethal or not useful mutations.

The flowchart on the right shows the following progression:

- Normal Plant (Oenothera lamarckiana) - About 10,000 specimens (Self-pollination)
- ↓ Seeds
- Normal Plants (Mutants) | Different Plants (Fewer-Mutant) - About 800 (self-pollination)
- ↓
- Different Plant (Mutant) | More different Plants (Fewer-Mutant)

Handwritten red annotations include 'Progressive' and 'Retrogressive' with arrows pointing to the flowchart, and 'Degressive' with an arrow pointing to the text 'More different Plants (Fewer-Mutant)'.

So, important conclusion from the De Vries's mutation theory are as follows. So, based on that experiment, he has made the conclusions. What are the conclusions? The mutations are the initial factor for evolutions, then the mutants are non-predictable, occur suddenly and produce their effect instantly. So, there is a no delay, no delay in evolution, that is a major point from the Hugo de Vries the theory of mutation.

Which means, it says that the mutants are non-predictable, they occur suddenly and they produce their effect within the next generations. So, within the single generation, you would

be able to see a change phenotype. So, no intermediate state between the appearance of the mutant form and the parent plants, then the mutations are cumulative in nature and occurs on multiple occasions to increase the frequency of mutation into the populations.

So, mutations which are good, were useful, which are good, they are going to be accumulate even if they are getting into even if that is happening onto the multiple occasions and that will increase the frequency of these mutant organism into the organism, the mutated organism into the populations.

Is because the mutation is making the organism more strong? So, if the, so the strong mutation is going to be accumulated in the populations. A single mutation may give rise to the 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-lead useful mutations. So, what it says is that you start with the parents and there will be a mutation, after the mutations, you are going to have the multiple types of offsprings.

And all the offsprings are going to face the environment. Once they will change the environment, this is going to be like for example, if you have three, four different types of mutations, this all these 1 2 3 4 are going to face the environmental conditions and those who are going to survive the environmental conditions, for example, the if the mutation number 1 is going to survive, that is going to result into the formation of the new species.

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MECHANISM OF EVOLUTION

Important conclusions from Huger De Vries Mutation Theory are as follows:

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3. No intermediate stage between appearance of mutant form and parent plants.
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5. A single mutation may give rise to new species.
6. At last, environmental factors work as selective pressure to allow growth of beneficial mutants and eliminates lethal or not useful mutations.

Mutation creates variation

Unfavorable mutations selected against

Reproduction and mutation occur

Favorable mutations more likely to survive

... and reproduce

This is what he has done. If you start with the parents, you are going to do the self-pollination, then you are going to produce the offsprings. So the mutation are going to create

the variations, you will see that this is the wild type, this is the mutant number 1, and this is the mutant number 2. Because this mutant, the mutant 0 is not good, because unfavorable mutations you will going to select against.

So if there will be an unfavorable mutation, it is going to not going to survive, so there will be no survival. Whereas these two mutants are be, going to be selected. And again, they will go with another round of mutations, another round of reproduction and the mutation, that mutation will continue. And that is how if the other generation, they will be generated the mutation which is like A and B, and both of these A and B mutations are not useful, then they are going to not going to survive

Whereas the favorable mutations may likely to survive, for example, in this case you have first generated a single mutation in the first generation. Then in the second generation again there will be mutations, so it has generated the third generation and third generation again got mutation and that is how, that is how you see the population of this particular mutant, the mutant 2 is now has overtaken the whole population. That is what Hugo de Vries has proved by doing the multiple mutation multiple experiments. And because it was very, very well defined based on the experiments, people are come up with the different types of evidences to prove that.

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MECHANISM OF EVOLUTION

Evidence for the theory: There are experimental evidences to support the Hugo De Vries mutation theory.

These evidences are as follows:

1. The experiment performed by De Vries was reproduced by several other scientist and they came to similar conclusions.
2. Mutations found spontaneously in nature and these sudden appearance of mutant varieties has strengthen the mutation theory. These evidences found in nature are as follows:
 - The Ancon sheep was produced from an ordinary sheep in single step in 1891. The mutaed sheep was short height and it was useful for farmers as they could not be able to jump from low stone fences.
 - Hornless or polled Hereford cattle were produced in single step in 1889 from normal parents. → Mutations
 - The hairless cats, dog and mice were produced from normal parents in single step. →
3. *Oenothera lamarckiana* has 14 chromosomes but the mutants were having 16,20,22,24,28 and 30 chromosomes.
4. Mutations are genetically linked and inheritable. →
5. A single large mutation can produce new species in plant. For example, Delicious apple.

These the evidences to prove the Hugo de Vries theory was as, the experiment performed by Hugo de Vries was reproduced by the several other scientists and they came to the similar conclusion. So that was the first thing which was positive for the Hugo de Vries mutation

theory. The mutations found spontaneously in nature and this sudden appearance of mutation variation has strengthened the mutation theory. These evidences found in nature are as follows.

For example, the Ancon sheep was produced by an ordinary sheep in a single step in 1891. The mutated sheep was short height, and it was useful for farmers and they could not be able to jump from the low stone fences. Then we have the hornless or the polled Hereford cattle was produced in a single step in 1889 from the normal parents, which means when a single mutations or single mutations, you can be able to develop a particular different species. The hairless cattle dog and mice were produced from the normal parents in a single step.

Then we have the different types of experiments in the plant like *Oenothera Lamarckiana* has 14 chromosomes, but the mutations were having only in, were in this kind of 30 chromosomes. Then we have mutations are genetically linked and inheritable. So we could found is that the genetic mutations what are being produced in these animals are genetically linked and inheritable.

And single large mutations can produce new species in plants, for example, the delicious apple. So what people have found is that there is a single mutation and that is producing the new species. But despite these experimental evidences and a full proof theory, that people are coming up with the objections.

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MECHANISM OF EVOLUTION

Evidence against the theory: There are evidences against the mutation theory proposed by Hugo De Vries.

These objections are as follows:

- (i) The mutation are of rare occurrence. Hence it is difficult to assume that if all animal or plant species could appear solely by mutation.
- (ii) The relationship between flower and the insect (such as length of proboscis in insect and position of nectariesd in flower) can not be explained by mutation theory.
- (iii) Mutations are recessive where as it is generally the dominant mutations that brings about evolution.

So, there are evidences against the theory, there are evidences against the mutation theory proposed by the Hugo de Vries. What are the objections? The mutations are of the rare occurrence; hence it is difficult to assume that all the animals or plants species could appear

solely by the 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 the 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 insect and the position of the nectarines in flowers cannot be explained by the mutation theory. So, the relationship between the two intersecting species like the species which are helping to each other, cannot be explained by the mutation theory. How the two, how insect is been evolved in such a way that it is having the well and well-defined or suited proboscis so that it can be able to take up the nutrition from the flower and at the same time, it also can be able to help the plant to the go for the pollination.

The mutations are resistive, whereas it is generally the dominant mutation that bring out the evolutions. So, there are mutations which are recessive, there are mutations which are dominant. So, the Hugo de Vries could not be able to explain this particular type of aspects and that is how the mechanism of evolution or the theory of the, mutation theory was also not could not be able to explain each and every phenomenon what is happening.

So, what we have discussed, we have discussed about the different types of theories we have discussed, we started with the Lamarck theory. And then we have also discussed about the theory of natural selection and as well as the Hugo de Vries theories of mutation theory. Every theory has some positives and some negatives.

And at the end, what you could see is there is a probably, all the theories were not complete, and all the theories were not conclusive to explain the how the evolution could have happened. But if you summarize them, and you could, try to conclude something you will understand that the Hugo, what Hugo De Vries has done, he said is that there could be a generation of mutations, there could be a mutation generation, and in that the environmental factor could have been playing a crucial role.

Because you know that the solar radiation and as well as the UV radiation could have made them mutations. And these mutations could be helpful for the organism or could be lethal for the organisms. And that is how it is making the variation within the species. So you see, if you mix the theory of Darwin's theory, and if you make the Hugo de Vries theory, you could be able to understand the full pictures.

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. In our subsequent lecture, we are going to discuss some more aspects related to the living organisms.

Thank you.