Evolution of the Earth and life
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Why Do Groups Change?

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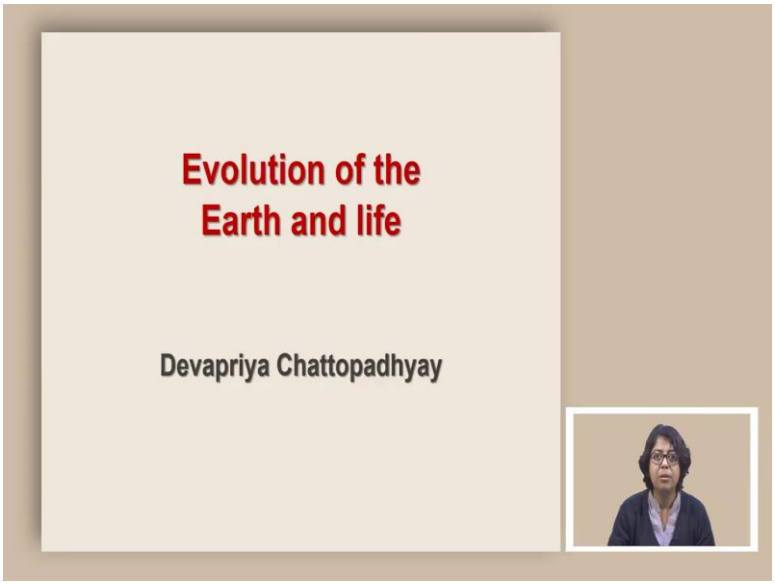

Welcome to the course Evolution of the Earth and Life. Today we are going to talk about evolution and natural selection. The word evolution basically means change. It was a common knowledge that groups change, especially because during 17th and 18th century in England, the dog breeders created 1000s of new breed. And it was very clear to them, that it is possible to create groups, which look quite different from the same ancestral stock.

So what they did was basically looking at different groups of dogs. And in the same population. Also, if they found some dogs, which are really small, and other dogs really big, then they will selectively choose the bigger dogs to breed with another bigger dog of other population to make bigger puppies. And if they continued the process for generation after generation, after 10 generations, they would find that puppies that they are making, or the dogs that finally, they are producing are distinctly different from the ones that they created by breeding very smaller dogs.

And therefore, the product of these breeding of the smaller dogs and breeding of the bigger dogs created completely different looking dogs, which becomes unbelievable that they came from the same stock, even though they observed that in the regular practice, it was not clear how it would happen in nature. It was not just about the dogs, it was also about the pigeons, they were pigeon breeders.

And they also found the same thing that using selected pigeons to breed, they could generate different variety of pigeons, some with very fluffy feather, some with feathers, extending till their limbs, some with different colors, completely white versus some with spotted neck. So all these variations were being created by artificial selection through this breeding process. The question was, how does it happen in nature?

So this was an open question for a very long time. How do people know that life changed over time, because by that time, people also started observing fossil record, which basically captures the history of the earth through time and more importantly, history of life through time. And what they found that many of the organisms that they found in the fossils, some look sort of similar with the living organisms, but they are still different.

And more importantly, if you go through the time wise relationship of fossils, from the bottom to top, you will find that many of the composition of the fossils are actually changing through time. Question is, how do they change and why do they change? And that is one of the open questions during this time in England and for the global scientific community to so many people try to answer this question that why do group change?

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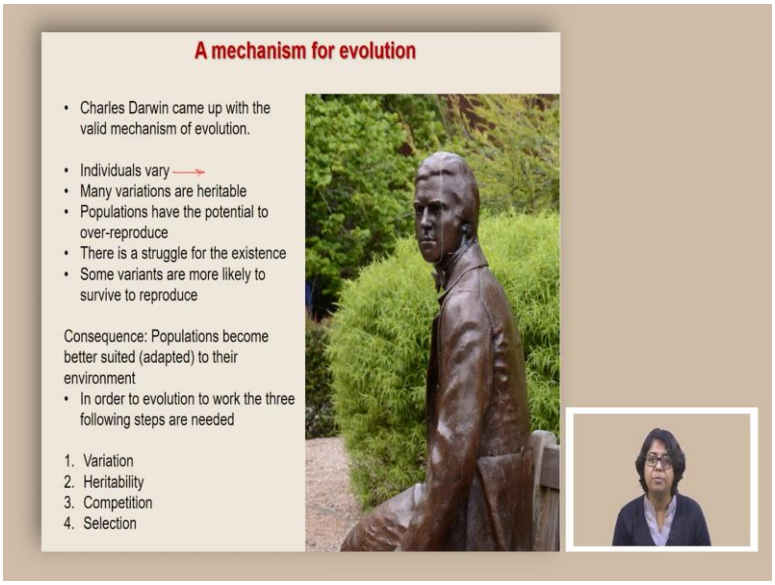

One of the young naturalist who started answering this question was Charles Darwin. So, it was not that Charles Darwin was the first person to come up with a mechanism of evolution, he was not even the first person to observe that things change. He was one of the first persons to provide very valid mechanism of how the system can work without human intervention, and he supported his idea through a lot of observational point.

So, what he proposed is that, that the his observation was that groups vary, in fact one of the major sources of his observation was during his voyage on HMS Beagle. It was a ship that was going to South America. And he was a companion to the captain of that ship. And he was a very young person who was going for this big voyage. And when he reached different parts of the world, he saw the diversity of life. And in many places, he realized that, especially in islands, he realized that the groups looked somewhat similar, but they have distinct characters when you go from one island to the other island.

The second important point for his learning during this voyage was the encounter with fossil record. So, he came across the fossil record of large mammals from the South America, which no longer exist. So, he observed that there are organisms, which are really large, which were mammals, which are probably slope like groups, but we do not find them any longer today. And after he returned back to England, he started observing all the changes during an animal's lifetime and how these changes propagate from one generation to the other generation.

He did some experiments to in terms of observational experiments of how long the generation time takes, how long would it take for one generation to the move to the next, and what proportion of groups are actually surviving around the same time he was also influenced by reading some of the literature on economics by Malthus and Malthus basically proposed that in terms of resources, there is always competition, because the number of the population size is always increasing, and therefore, there is always going to be a competition in the population.

Now, this is an idea that Darwin started using for the population that he was observing. Moreover, he also read the writings by Charles Lyell, who was a geologist, who argued that even slow processes, if operated over a very large span of time can create a dramatic effect. And he gave an example, that if there is a large mountain, and every time there are some grains, which are being displaced and broken down because of erosion, if this process operates for millions of years, then the mountain can be flattened out.

Darwin took this idea for the understanding of biological system, and he argued that small changes that we see in biological community may be transferred from one generation to the other. If we continue to do this, for long enough time, we will see major changes and his idea was also supported by the observation from the dog breeders, the PDN breeders, that selective breeding can lead to dramatic changes in the population. And we can find very distinct organisms in the population.

Now, the question is, how does it happen in nature, because for dog breeding or pigeon breeding, it is the organisms which are being selected by human beings and then went for the breeding process. But in nature, there must be a way a natural way, which is guiding this. And to solve this thing. Darwin proposed this mechanism of natural selection. So how does it work?

The first point is that individuals vary that is a very important point, if there is a population and all the individuals are exactly the same, then this mechanism will not work. But in a natural population. Every individual is slightly different, they might be slightly different in size, they might be slightly different in terms of their strength, they might be slightly different in terms of how many offspring they are producing. So there is always going to be some variation in the population. Many of these variations are heritable.

So that means whatever is that strength, or the large body size or the quality of producing larger number of offsprings, these qualities, some of these characters can be heritable, and that means they are going to be passed on from one generation to the other generation.

Populations have the potential to overproduce. And this is a key point that many populations, they basically give birth to a lot of offsprings and depending on the resources, not all the offsprings are going to survive. And because the resource is limited, and the number of offsprings is bigger, there is always going to be a struggle for existence or competition among these offsprings, only some variants are more likely to survive, and because they will survive, they will also reproduce and pass on, they are characters to the next generation.

So, if this goes on, for long enough time, as a consequence, we will see that the populations become better suited or adapted to their environment. Now, in order for this evolution through natural selection to work, there are important steps that need to be followed. Number one, there should be enough variation second, the heritability of the character. Third is competition, and finally, the selection. So, let us take a look at it more closely.

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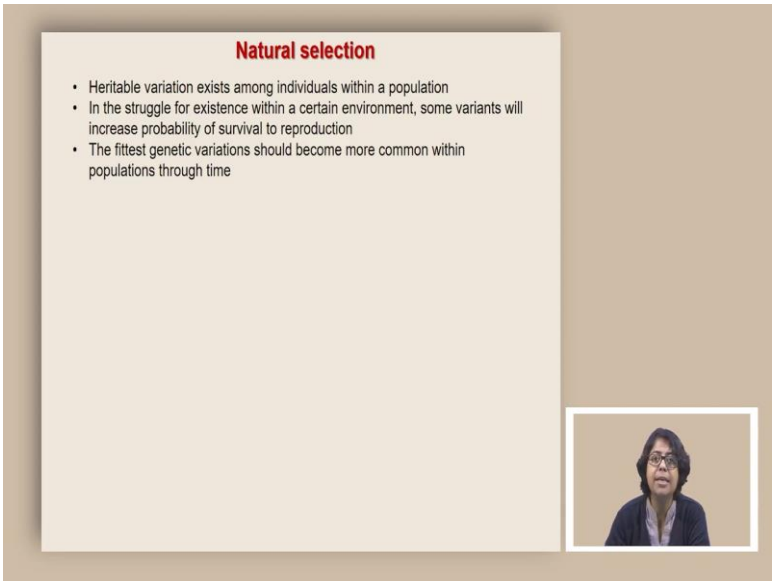

The heritable variation exists among individuals within a population. And in the struggle for existence within a certain environment, some variants will increase probability of survival to reproduction, the fittest genetic variation in that particular environment should become more common within population through time. So, let us take an example of how it actually works.

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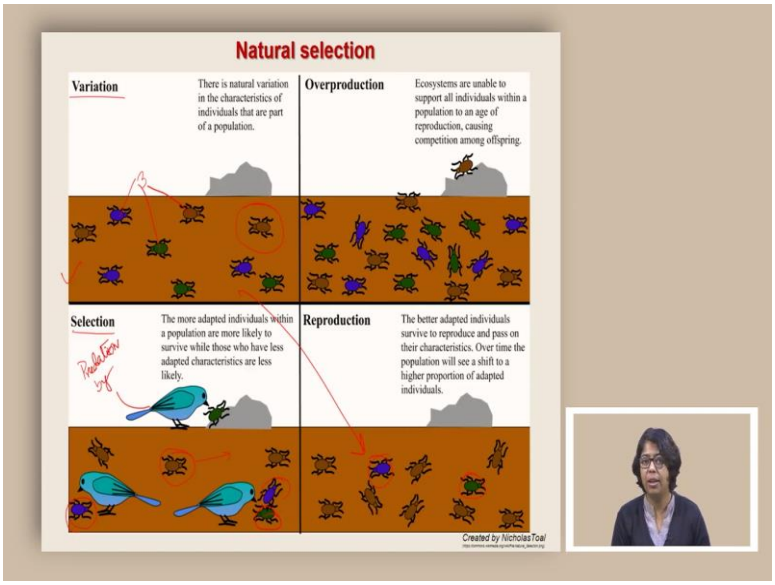

So, let us take a look at this particular system, where there are different types of beetles, these insects and these are living on the ground. And sometimes they are also on the inside the sediments. But for now, for simplicity sake, we are considering that they are basically on the ground. Now, they have different colors, some of them are blue, some of them are green, some of them are brown, the brown ones are hard to detect, because they basically camouflage well with the surrounding things. So, this one is hard to detect.

Now, because of this inherent variation, and let us say that this particular variation is also heritable over time, we will simply see that the total number is increasing, and that is the overproduction. So, what we are saying is that to start with, there is a natural variation in the character of the individuals, that is a normal process. And that is what we meant by variation where we see three variations one is this one is this and the other one is this.

Now we are saying about the overproduction, what it means is basically ecosystems are unable to support all individuals within the population. So, there is so many, only a some of them are going to survive. So, there is an immense amount of competition among them. And then there can be selection. So in this particular case, the selection comes by the mechanism of predation. So these beetles are eaten by birds. So in this case, the selective agent is the predation by birds.

The birds choose some Beatles and not others. How do they choose? Well, they can choose the Beatles which have the maximum contrast because it is easy to pick. If they do that, then selectively all these blue and green beetles will be eaten, because they are eaten, they are not

really reaching to the reproductive age. On the other hand, these brown beetles are basically getting a selective advantage and they are not being eaten. And because there is a competition, they are finally reaching to the reproduction age.

And because they are going to the reproduction age, they are going to pass on their heritable character, which is the brown color to the next generation. And therefore, the next generation is going to be mostly brown, because all the blue ones and green ones are probably already eaten, and therefore only a few survives and passes their character to the next generation. So over time, this better adapted brown beetle is going to dominate the scenario.

And this can change the moment, let us say the predator changes, or there is a change in the environmental condition, which can make the life difficult for maybe the brown beetle. And in that case, things will change on the other direction. But for this particular pattern, the brown beetle is getting adapted to the environment, and they are surviving better. On the other hand, the blue one and the green one, over time, is declining in terms of their proportion in the population. So now if we look at the original population that we started with, we will see that the original population has changed significantly, where we find more blue and more green at the beginning. Now we find very low proportion of blue and green, it is primarily dominated by the brown. And that is a proportional change in the population through the natural selection.

It is very important to recognize at this point that evolution through natural selection is a process that operates on the population level, it really does not work on an individual level individuals do not evolve, they can change. If you exercise a lot, it may change your body shape, you can have strong muscles, but unless it is already a heritable character, what you achieved in your life will not be passed on to the next generation and therefore, it will not be working in terms of evolution. At a level of population on the other hand, if these variations are heritable, selection makes a different population and changes the population structure. So, therefore, the evolution through natural selection is primarily a population level phenomena and it does not really work at individual level.

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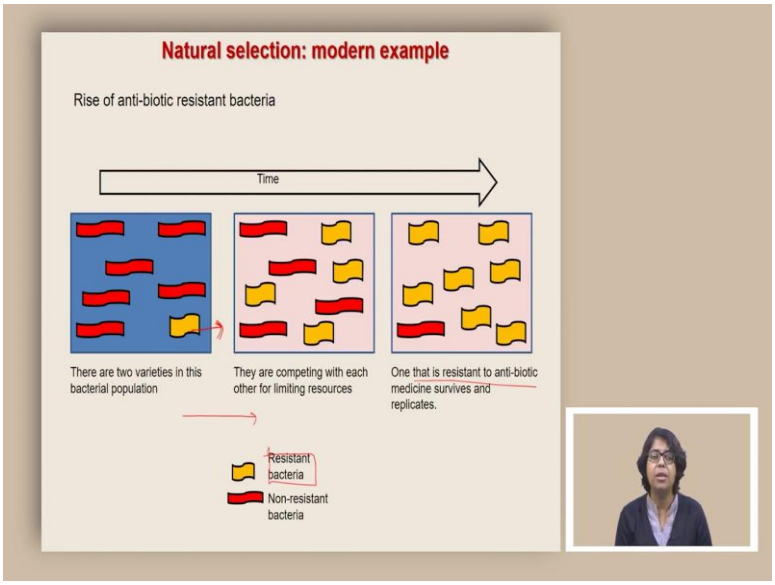

Another example, which are very relevant today is the development of rise of antibiotic resistant bacteria. What I mean by that is today in the hospitals often there is a scare because there are increasing level of antibiotic tolerance, it also works through the process of evolution. So, if we think about it, that initially there are 2 different variants in the bacterial population, some are resistant bacteria, that means they will not die, even if you are giving the anti bacterial, antibiotic therapy.

With time what is going to happen if the especially if this antibiotic medicines are not continued for during the entire time, not all the bacteria will die, some of them will die, and some of them are going to survive. Once these ones survive, because they are resistant, they are going to increase in number through adapting in the population because they are the fittest in this situation. And they are they also have this heritable trait and therefore, they are the surviving ones and they are going to dominate the population.

So, they are competing with each other with limited resources and which one is going to survive till the reproductive age or which is going to reproduce faster, the one which is more adapted, which is not being impacted by the antibiotic therapy. As a result, eventually we are going to find the increase in antibiotic or resistant bacterial strain in the entire bacterial population. If that is the case, eventually with time we are going to encounter a bacterial strain, which is not going to be affected by the antibiotic therapy.

So this is also a modern example of how the evolution through natural selection works. But so far, we have primarily talked about how a population changes. If we look into the fossil

record or the deep time record, what we see is it is not just changes in the population, it is also the development of species, new species. And by species, we mean 2 groups of organisms which cannot breed among themselves and create viable offspring, that is the biological definition of species. Now, how do we create species?

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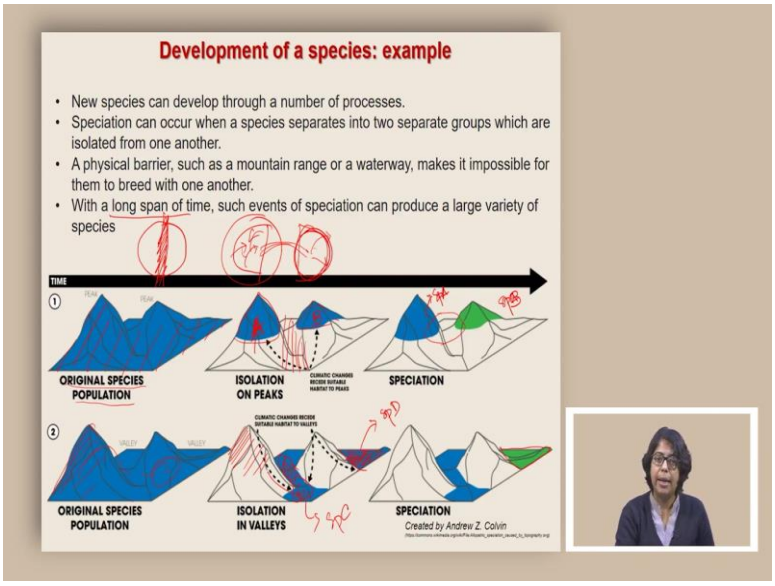

So, development of a species is a more complex phenomena, and new species can develop through a number of processes. We are going to talk about one specific example. Speciation can occur when a species separates into 2 separate groups, which are isolated from each other. So you start with a single population, but then you break it apart, and one part is isolated from the other part. And therefore they are not interbreeding for a very long time, they are interbreeding among themselves.

And depending on the changes in the environment in that particular area, they are going to change over time, the same is true for this one, that they are also going to change in time. And these changes do not have to be exactly the same. As a result, after times, these groups will look very different and because they have not interbreeded, they will have very different genetic composition, which stops them from interbreeding further and therefore, there will be a development of a new group, which we call a species.

So, how does this separation happens? So, one way the separation can happen is through a physical barrier, such as a mountain range, or a waterway, which makes it impossible for them to breed with each other. And with a long span of time such events of speciation can produce a large variety of species and this is important probably, because of which we do not

see development of new species every day, it requires a long span of time, where they have to be separated, and that time is much larger than the human timescale.

So therefore, when we look at the fossil record, we do find development of new species. But when we look at the recent record, we very rarely do see development of new species happening right now. Let us take a look at this example once more. Let us say this situation where the original species population was basically distributed all the way around, let us say we are talking about a particular animal, let us say a small rabbit, which was living all the way in this mountainous region.

Now, there can be a situation where the climate changed. So, let us say the climate change was very warm, and these rabbits are surviving only in cold areas. If that means the cold areas are only at the mountain peak, then the groups which can go to the mountain peaks are going to survive, but that means that the entire population which used to live in the entire region, they have now changed and they have gone one population has gone to peak A and the other one has gone to Peak B.

And because they are not interbreeding because they have they are separated by this valley, which is very warm, and therefore they cannot really cross this they are surviving here and also changing here depending on the local environment for a very long time. Now, after some time, even if you bring some from here and some from here, what is possible that they cannot interbreed, and therefore, they have become completely new species, species A and species B, starting from the same population, which was present throughout the mountain. And opposite situation can happen where let us say that temperature.

In the first one we talked about warming of the climate, let us say the climate actually cooled down. So cooling down means these places are so cold that the rabbit cannot live there. So it basically goes down and lives in the valleys. But once it lost the connectivity, the ones which are living here in one side of the mountain cannot really breed with the other side of the mountain, because there is this entire mountain region, which is too cold for them to pass and too high for them to pass.

In that situation, this becomes a completely different species over time, and they cannot interbreed with another species which is separated by the mountains. Again, one more point that we should keep in mind that these processes these process of allopatric speciation, it takes a really long time. And with time, they can be separated, they can live their develop

their own identity, in terms of their genetic composition, which makes it impossible for them to breed with the separated community where they have not exchanged genetic material for quite some time. So these are some of the ways that species can develop in natural condition.

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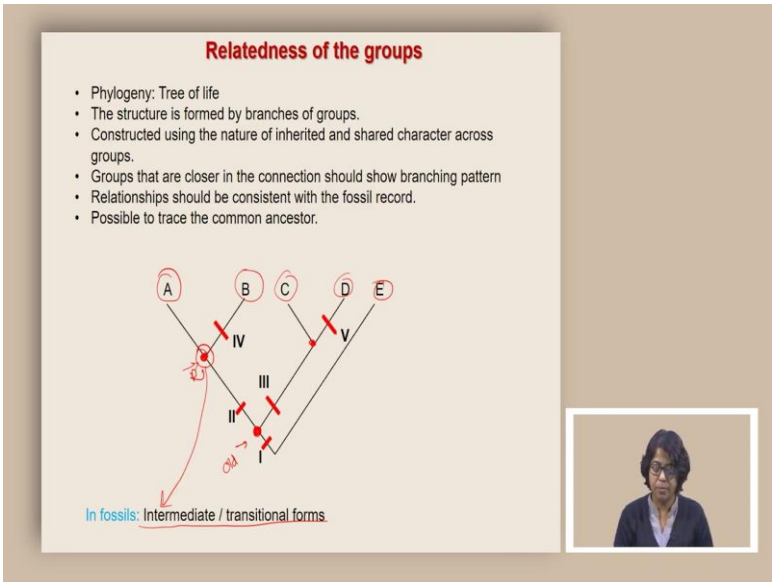

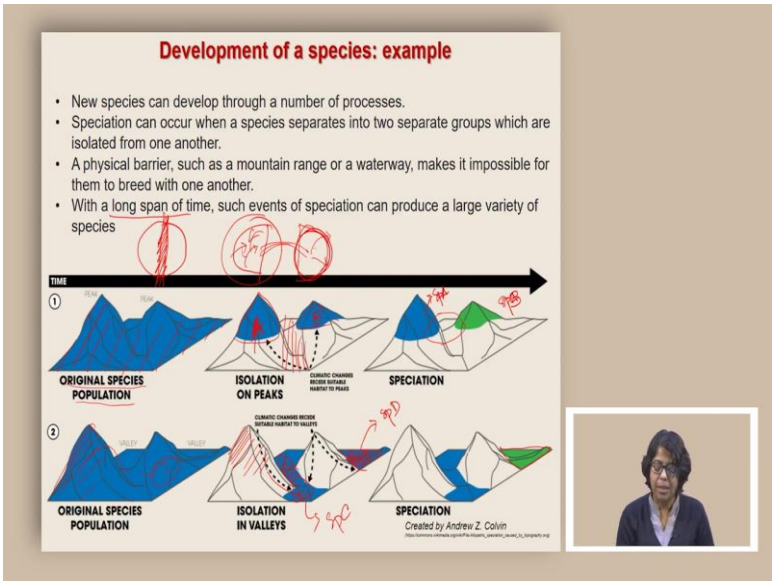

Now, one species developed, we understood that often the species are developing from the same stock. So in the previous case, we said that initially, they were all the same. So now, if we look at species C, and D, they should not say they should give us some indication that they actually split from the same stock. So they had a common ancestor, which was living all the way in the mountain and the valley some time ago.

To capture that essence, people try to look at their characters and try to plot it in terms of a tree diagram. And that is what is called a phylogenetic tree or tree of life. The structure is

formed by the branches of the group. It is constructed using the nature of inherited and shared characters across the groups, the groups that are closer in the connection should show branching pattern. And relationships should be consistent with the fossil record. And this is possible to even trace common ancestor. So for example, let us take a look at this branch. What it means is, species A and species B are relatively closely connected, and they had recent common ancestor at this node.

Species C and species D are closely connected. And they also have a common ancestor, the most recent common ancestor at this node. A, B, C and D, also have some characters, which indicate that they actually branched out from a recent common ancestor at this node now have to compare this common ancestor and this common ancestor, we know that this common ancestor is much more recent, compared to this common ancestor, which must have been old.

So even though we really do not have a common ancestor, in terms of fossils, we can look at the characters of them and how characters are shared across we can talk about their relatedness. And these trees are constructed using the characters such as this character means C and D shares, this character 5, this character can be presence of tail, this character number 4 can be the presence of canine and things like that.

So, once you know all the characters, which are shared between them, and also inherited characters, then we can try to reconstruct such trees. And once we have done that, we can also try to understand in the fossil record, if we find some creature, which is not present today, how to place them, where to place them, how connected they are, between them. So it may so happen that we find something like this in the fossil record. And that is going to tell us about the real form of the most common recent ancestor.

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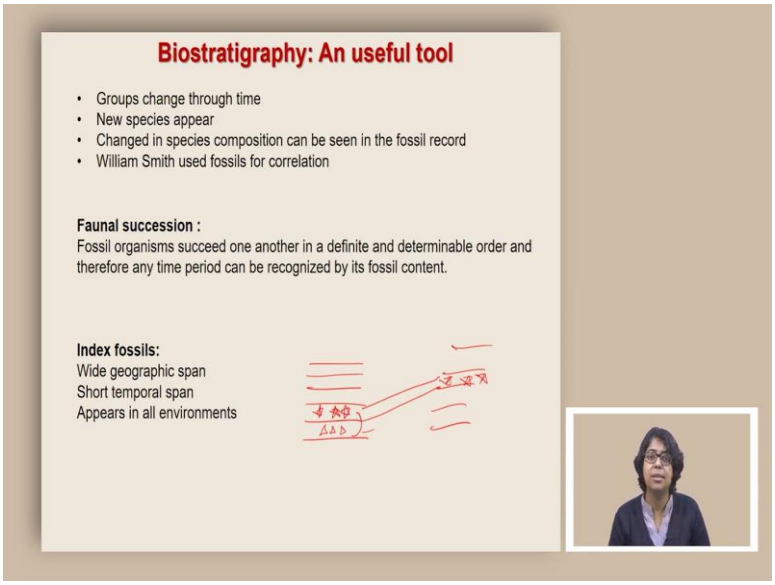

And using this idea, we can actually try to look at the record the rock record and try to guess the time. So groups change through time, new species appear and changed in the species composition can be seen in the fossil record. This is the idea that William Smith, a geologist from England used for correlation. So if you look at different layers of rock, and if you see that the compositions of fossils are different between different layers.

He did not know anything about evolution, but he observed that things are changing with time. And if you see consistent changes between different layers across region, you can actually correlate them using the fossil composition, because things are actually changing. And you can connect them saying that they represent the same time. And that is the whole idea of faunal succession.

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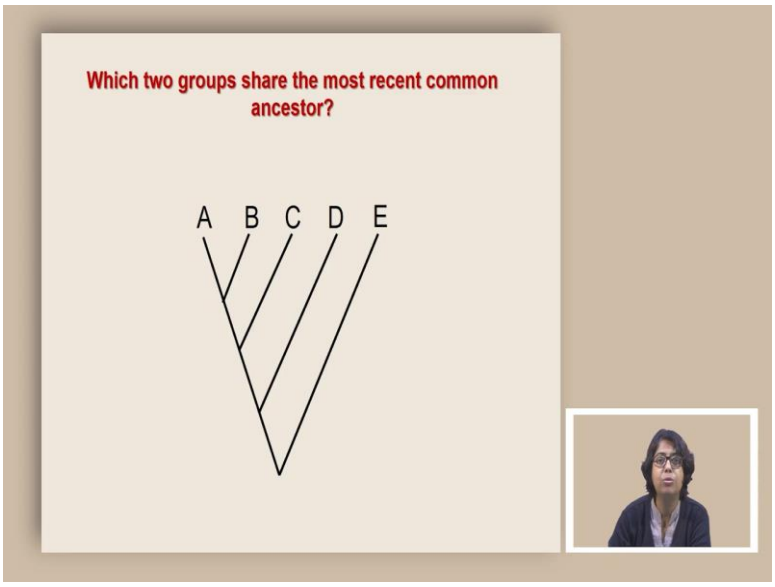

In summary, today, we learned why groups change, we also learned about the basic idea of evolution through natural selection, why it is a population level phenomenon and not an individual change. We also learned some of the ways species can be created from the same stock. We also understood how to represent the relatedness of the species. And if we look at the phylogenetic tree or the tree of life, how do we comment on the most common recent ancestor versus groups which are not related or distantly related? Here are some of the resources for you to think about. And this is a question for you to think about. Thank you.