Basics of Biology
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Module II – Origin of Life and Evolution
Lecture 8
Evolution (Part I)

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 living organisms. And as far as what we have discussed so far, we have discussed in the module 1 about the classification of the different organisms, we have discussed what is the basis of the classification and then in detail we have discussed about the animal classification as well as the plant classifications.

Based on these classifications we have understood that most of these organisms are being developed from the previous organisms and we have seen that many of, how the, these lower invertebrates or how the unicellular organisms are grown into the higher animals. Then in the previous lecture, we have discussed in detail about their life and how the life was originated onto the earth.

So, in that context, we have discussed about the many theories which were explaining the origin of life onto the earth, we have discussed about the theory of special creations, we discuss about the theory of spontaneous generations, which believes that the nonliving matters are giving rise to the different types of organisms, but that theory was incomplete because it has not been based on experimental evidences.

So, and there were critical experiment which are being performed by the Redi, Spallanzani or the Louis Pasteur to disprove that this is happening in the current environment. And then later on there were many other theories like the theory of catastrophism, theory of cosmozoic, theory of eternity of life and ultimately, there we have also discussed about the theory or modern theory or the chemical theory of the origin of life.

And chemical theory was the first theory which was based on the experimental evidences where the Stanley Miller and Urey has done a very meticulously and very systematic experiment to prove that if you take the bile or if you take the inorganic substances, and if you run them under the primitive earth conditions, which was reducing in nature, then you could be able to develop the biomolecules.

And that was the first evidence that the life could be originated from in primitive environment, because of the chemical interactions or the from the inorganic molecules, and then they have proposed the event of the experiments, how the different event could have happened onto the primitive earth and that is how they have said that, ultimately the inorganic substances are going to react with each other to give you the simple molecules which they have demonstrated by their classical experiments.

And then they have said that these simple molecules are going to react with each other to give you the complex molecules, these complex molecules will then aggregate and give you the coacervates and coacervates are the, they will develop the tendency of a living organism, if you recall, we have discussed that what is the living organism, living organism is the organism which could be able to run its metabolism, which could be able to produce energy and which could be able to repair and that was all the properties were present in the coacervates.

But ultimately the coacervates started acquiring the biomolecule from the primordial oceans, and then the it has acquired the nucleic acids and proteins and lipids and ultimately the coacervates were developed into the first cell and that there is a completely breakage or there is a gap, what will explain that how the coacervates are developed into the first cell which could be able to run its metabolism, which could be able to draw the nutrition and so on.

And one of the questions which they were, we were to solve that why these things are not happening in the current environment and why the theory of spontaneous generation could not be able to be successful? Because the current environment is the oxidizing in nature and because it is oxidizing in nature as soon as these inorganic substances are trying to react spontaneously, trying to react with each other to give you the simple molecule, they are getting oxidized and because of that they are not been able to form the complex molecules.

So, these are the things what we have discussed and we have discussed ultimately that the simple cell is being formed, but, as we know that simple cell gradually been developed into the multicellular organisms and then the multicellular organisms develop into the higher class. So, the question in today's class what we are going to discuss is how and what is the mechanism of the these simple primitive cells been evolved into the multicellular organisms or the higher organisms.

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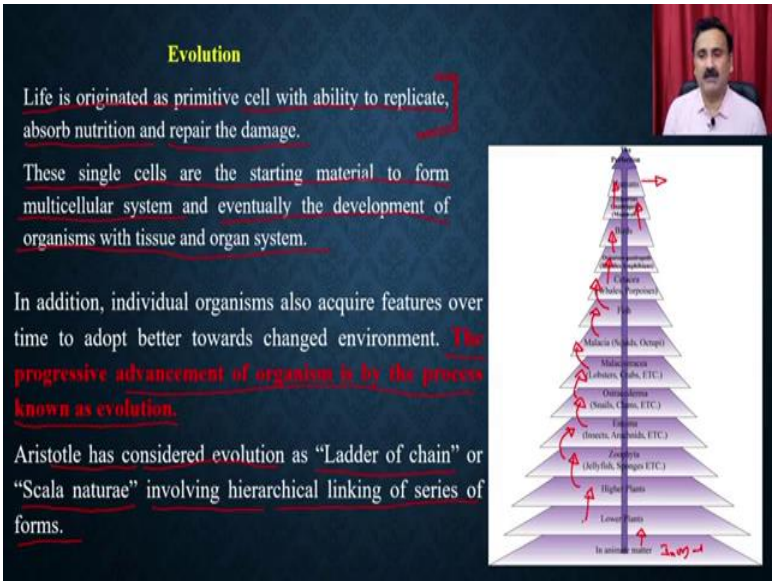

So, that, so what we have discussed? We have discussed that the life is originated as the primitive cell with an ability to replicate, absorb the nutrition and it can be able to repair the damages. Although we are having a very, very big gaps how the coacervates are being developed into the primitive cell, but that is, we still probably have no conclusive answer to that. These single cells are the starting material to form the multicellular system and eventually to develop the organisms with the tissue and organ systems.

So, the changes, the progressive advancement of these organism is by a process to acquire the traits, so that it can be able to adapt to the new environment is known as the evolution. And Aristotle, which was considered to be the father of biology considered the evolution as the ladder of chain, so, where he or the "Scala naturae" involving the hierarchical linking of the series of the forms.

So, what you have seen here is the ladder of chain where the, we know the organic matters are being placed at the bottom. So, what you see here is the inorganic matters which are being placed at the bottom, then the inorganic matters are being developed into the lower plants, that lower plants are going to be developed into the higher plants and then these higher plants are being developed into the lower invertebrates like jellyfish and sponges and all that, and then these jellyfishes are being developed into the Insecta and Arachnida.

Then these insects are being developed into the snails, then snails are being developed into the crab and then crabs are being developed into the squids or octopus and then these octopus are being developed into the fishes, then fishes are being developed into even the more advanced fishes and then the fishes are being developed into the reptiles and the reptiles are

developed into the birds and then it will be developed into the mammals and ultimately it he has kept the humans on the top.

This is simply by not being based on the experiment, these are all simply based on the observation as well as his own personal opinion that this could be the ladder of chain in which the organisms are being evolved. But the question comes, what is the evidence that the evolution is really happening? Because, until unless we cannot have the experimental evidences, we cannot have to believe this particular type of if scheme, we cannot say that lower plants are being developed first and the animals or the plant or humans are being developed at the later on.

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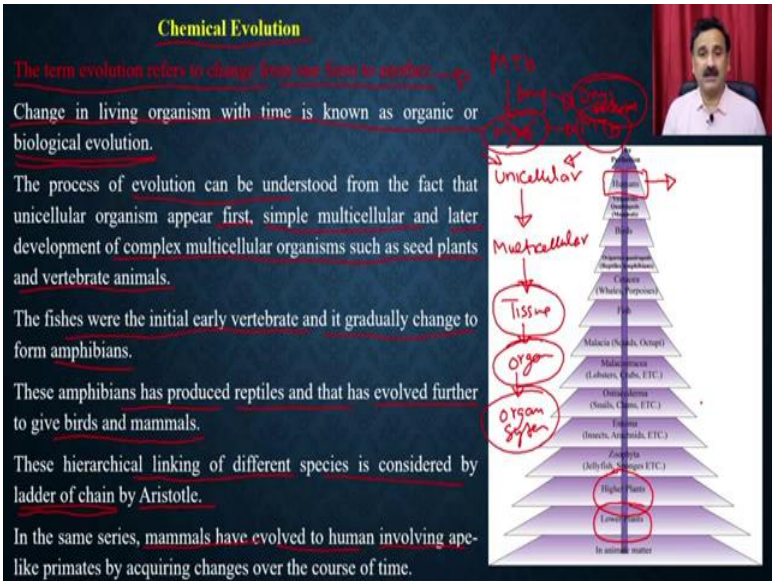

So, the chemical evolution, so, then people came up with the idea of chemical evolution, the term evolution refer to the changes from the one form to another form and that form is always for the advancement. So, the change in living organism with the time to known as the organic or the biological evolutions, the process of evolution can be understood from the fact that the unicellular organisms appear first, the simple multicellular organisms came later and later they were developed into complex multicellular organisms such as the seed plants as well as the vertebrate animals.

The fishes were the initial early vertebrates and it gradually change to form the amphibians and so on. These amphibians have produced reptiles and that evolved further to give the bird and the mammal. This hierarchy linking of different species is considered by, as the ladder of chain by the Aristotle and the same series, in the same series the mammal have evolved to the human, evolving the ape like primate by acquiring the changes over the course of time.

So, the chemical evolution or the normal evolution is the gradual change in the animal forms or the organism form so that it can be able to acquire new and new traits, you might have seen the evolution is either be very slow, where the monkey is being evolved into the humans or it would be very, very fast, you might have seen adaptation in bacteria and the how the you develop a single drug suppose you take bacteria.

For example, the mycobacterium tuberculosis and if you treat it with a drug, the mycobacterium tuberculosis die, but in due course, the mycobacterium tuberculosis does the changes in its cellular body and that is how it comes up with the multidrug resistance MTB or drug resistance MTB. So, because of that, it forms a drug resistance TB and this is called as the evolution because now, this is not going to be killed by this particular drug.

And this is exactly what is happening like, once you are putting a challenge or once you are putting a challenge to a particular organism, it will try to come up with the ways in which it will going to overcome that particular problem. And that is the main basis of the evolution, that it has to overcome, it has to acquire the additional traits. For example, in the primordial oceans, the primitive cells is formed, which is the unicellular cells.

And then the unicellular cell, were having the deficiency because the unicellular cells cannot get the support from the neighboring cells, because it is a unicellular cell. So, what he thought is that, let us have a multicellular cell, if you go to the multicellular system, so in the multicellular system, the advantage is that first of all, you can do division of labor, you can say oh you will do this, I will do this and all that.

And on the other hands, even if the one cell is going to be under the threat or it is going to be died, the organism will still be able to survive, because organism is going to overcome that particular type of problems. Similarly, once the multicellular system, it could develop into the organ or organ system and we know that the as you go along this system, you are acquiring more and more complexity and more and more complexity always comes up with the additional features.

And that is why the people have observed that the organism first appeared as a single unicellular organisms like the protozoa, amoeba, then it goes into the multicellular stage where it has developed the sponges and coelenterates and all those kinds of hydrolyte for example, I think we have discussed all these when we were discussing about the classification and that is why it is, these all these information came because we have classified the organisms and we understood why it is happening so.

And then these multicellular organisms develop into a system where they can have the different types of organs for example, the Platyhelminthes and then the Platyhelminthes eventually developed into more advanced system where you do not have one single organ, but you have the organ system like for example, the humans. So, humans have the different types of organ system like we have the liver, we have the kidney, we have the pancreas, we have the stomach, we have the different types of organ system.

So, every organ system is doing its job, but it also trying to talk to its neighbor, trying to talk its other organs system. For example, if you talk about a digestion, digestion is not happening because of the simple the elementary canal. Digestion is also happening because it is getting the support from the other organs like pancreas, it is getting the support from the liver, it is getting the support from the even the some more other system.

So that is why we know all these, so organ system is the most advanced system what is present in the organism. So, and that helps the, that particular organism to face the different types of the challenges. So that is what it being considered by Aristotle and that is how he has prepared a ladder of chain.

So, what you see here is a ladder of chain which been evolved, which has been designed based on the who can do what, it is not mean the same way in which the organism is being evolved, this is based on the Aristotle's understanding that okay, this particular organism is having these kinds of deficiency, whereas, these deficiencies are not present in the other organ.

So, he has kept that particular organism into the lower level and he has kept up the other organism. For example, he has kept the human on the top, because it believes that the humans have, has all the tools and tech, all sort of systems, so that he can be able to overcome all sorts of problems. Because, so that is why he has kept the humans on the top, whereas, he has kept the lower plants and all those kinds of things at the bottom, because they cannot do many of the things which higher plants or the organism could be able to do.

So, this is all about that chemical evolution and that okay, there is an evolution happening, but once you are talking about the science and when you say that evolution is happening, you always looking for the experimental evidences and you are looking for the some sort of evidences to prove that there is a, actually a system where they switch the lower invertebrates develop into the higher vertebrates and then higher vertebrates develop into the different

types of animals like the mammals and birds and snakes and all that. So, what is the evidence, what is the chemical evidence that the evolution is really happening?

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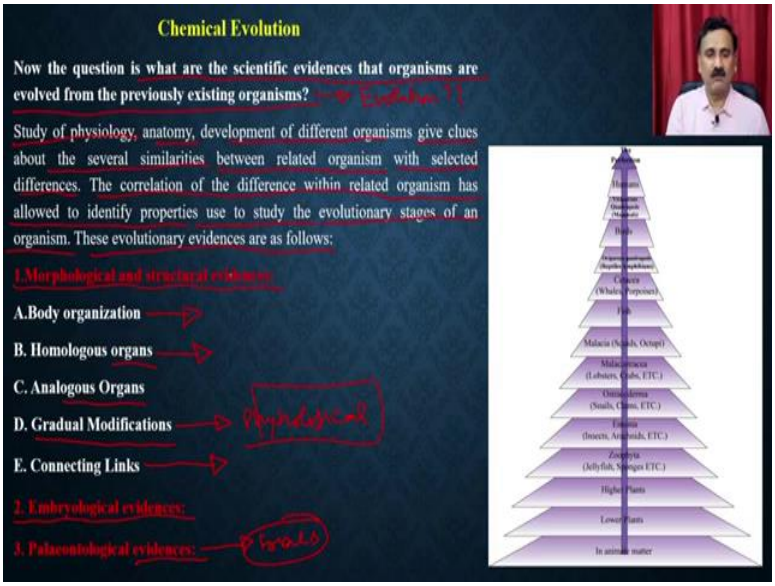

So, now, the question is that what are the scientific evidences that the organisms are evolved from the previously existing organism, which means, whether there is an evolution or not, that we have to answer. So, if you study the physiology, anatomy, development or different organisms, give the clues about the several similarities between the related organisms with the selected differences. So, the correlation of the differences within the related organism has allowed to identify the properties used to study the evolutionary stages of an organisms, these evolutionary evidences are as follows.

So, if you study the physiology, if you have studied the anatomy, if you have studied how the different organisms have the different types of developmental stages, and how they are being similar to the other organism, but they still have their own peculiar features, that all if you correlate, it will going to give you a detail, it will going to give you that in the relationship between a different organism and that is how you can be able to study or you can be able to understand the evolutionary stages of the organisms.

These evolutionary evidences could be classified into the three points, it can be either related to the morphology or the structural evidences, it could be because of the embryological evidences or it could be because of the paleontological evidences which means, where you are going to study the fossils. So, fossils are also a very, very good evidences that is going to prove that who came what time.

Within the morphological and structural evidences, you can have the anatomy, you can have the evidences which are going to say, how the body is being organized. Then you can have the similarity within the physiology. So, you can have the homologous organs or you can have the analogous organs and then you can also be able to study how the physiology is being modified by the gradual modifications.

So, and then you can also be able to study connecting links. So, connecting links are the organisms which are being connected between the two different organisms. So, they have the features which are common to the two different features. So, let us discuss each of these evidences and try to understand that how the scientists have come up with the idea that the evolution is really happening and there is a series or there is an event, there is a scheme through which the these organisms are evolving.

Once scheme is anywhere being proposed by the Aristotle where he has proposed all the linking of all these organism and ladder of species he has proposed, but that was not on the basis of the experimental evidences. So let us first discuss about the morphological and structural evidences.

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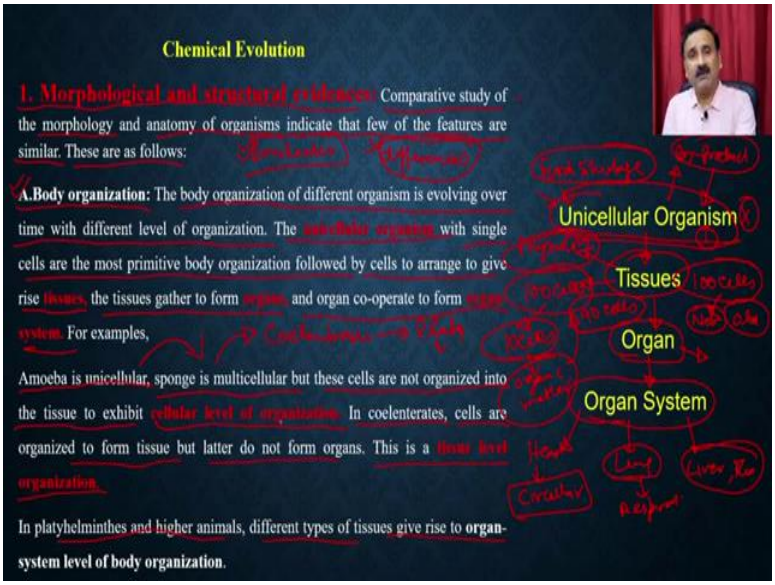

So, as far as the morphological and structural evidences is concerned, you first do the comparative study of the morphology which means and the anatomy of organism indicate that a few of the features are similar these are as follows. So, if you try to see the morphological and structural evidences, what you can see is you can be able to identify the similarities between these features or you can be able to understand the differences.

So, if you go with the similarities and the differences, what you can be able to understand how these(20:40) could be evolved. The first is you can go with the body organizations; the body organization of different organism is evolving over time with a different level of organizations. The unicellular organizations with the single cells are the most primitive body organization followed by the self to arrange to give rise to the tissue, the tissue get gather to form the organs and organ cooperate to form the organ system, for example.

So this is what we are talking about, initially we have our having the unicellular organisms, the unicellular organisms then differentiated and they realized that okay we are being at a danger because as soon as we are getting any kind of scarcity, for example, if there will be a food shortage; food shortage, if there will be a food shortage for a unicellular organism he will die because there is no alternate source, because he cannot.

But once it develops into multicellular organisms or it can be developed into a tissue level organism, so, what will happen? Tissue cell, so here you have the single cells, so, you have one cell, suppose you have developed into a tissue level organization and you have the 100 cells and again you, there will be a food shortage.

So, what will happen, these 100 cells, out of these 100 cells, what will happen if suppose the 10 cells are going to die. These 10 cells are going to die and they will be having the organic matter, this organic matter, that organic matter is going to be utilized by the remaining 90 cells, number 1.

Number 2, since it goes into a stage where it has the 100 cells, and if there is a threat coming like for example, if there is a prey which is trying to kill them, you have the 100 people which are fighting. So you can imagine that if you have single person fighting with the enemy, it is difficult, it is not possible to win, but if you have the 100 people fighting with the same enemy could be, there could be a possibility that you may be able to win. Because you can be able to fight with a fill full strength. So, you can be able to get protected number 1.

Number 3, that is protection, even if the running the physiology also, if you have the 100 cells, they these 100 cells could be able to do things more efficiently because you can be able to do exchange of material for example, if you have a single sale and you cannot be able to even take care of the byproducts of the metabolism, the byproduct is going to ultimately kill the unicellular cells.

If you have the 100 cells, the byproducts could be scavenged, byproduct could be scavenged by the other cells and because when you have the 100 cells, some cells are going to be the new, some cells are going to be old. So, these new cells are going to be more efficient in terms of performing the functions whereas the old cells are going to less efficient. So, these old cells will still survive because they are having a support of the new cells.

Similarly, when tissue is going to develop into the organ, the it was going to come up with the more and more sophistications because the organ is going to be more organized. So it is going to have the different types of tissues and therefore, there will be a further level of division of labor and once the organ is going to develop into the organ system, then you are going to have the support from the different organs.

So, that is going to make the things more and more systematic and sophisticated. For example, in the humans we have the different types of, for example, in a single cell, is the single cell is performing all the functions whether it is respiration, whether it is food intake, whether it is taking care of byproducts, whether it is the water imbalance and so on.

Whereas in the case of humans who have developed the organ system, you have the heart, you have the heart or the circulatory system, which is going to take care of the circulation of the material or distribution, then you have the lungs which is going to do the respiration. Similarly, you can have the liver, you can have the kidneys and all those kinds of things.

So, these all these organ systems have their own dedicated functions, but that does not mean that these organs are not going to talk to each other, heart is always going to listen to the brain and liver is also going to do coordination. So, there will be a coordination between the different organs and that is why it is going to have the organ system. So, that is why the organ system is the highest level of the organization which is present.

Now, let us see the example. So, amoeba is unicellular, sponge is multicellular or the tissue level organizations, but these cells are not organized into the tissue to exhibit the cellular level of organizations. Whereas, in the case of coelenterate like the hydra, cells are organized to form the tissue, but later do not form the organ. This is a tissue level organization.

Similarly, the mean the Platyhelminthes and higher animals, different types of tissue give rise to the organ system of organizations. So, if you go with these kinds of evidences where you have the body organization as a criteria, you understand that the probably the unicellular

organisms if appeared first, then they will be developed into the tissue level organization, then they develop into the organ and then they will develop into the organ system.

So, if I go with these, only this particular evidence, I will say that the amoeba is being evolved into the sponges and then the sponges are being evolved into the coelenterates. And then coelenterates are, so coelenterates, and the coelenterates are going to develop into the Platyhelminthes. And the Platyhelminthes are going to develop into the higher vertebrates and then subsequently into the vertebrates.

Same is also be true for the plant system like the plants, you have a unicellular plant like the algae, then algae is going to develop into the multicellular plants like the fungi, then the fungi is going to develop into the Bryophyta and then the Bryophyta is going to develop into the Pteridophyta and Pteridophyta is going to develop into the gymnosperm, these are the lower plants and then the gymnosperm is going to develop into the angiosperm. So, if you go by the body organizations, you could get the (27:46) scheme through which the organisms are being evolved from the preexisting organisms.

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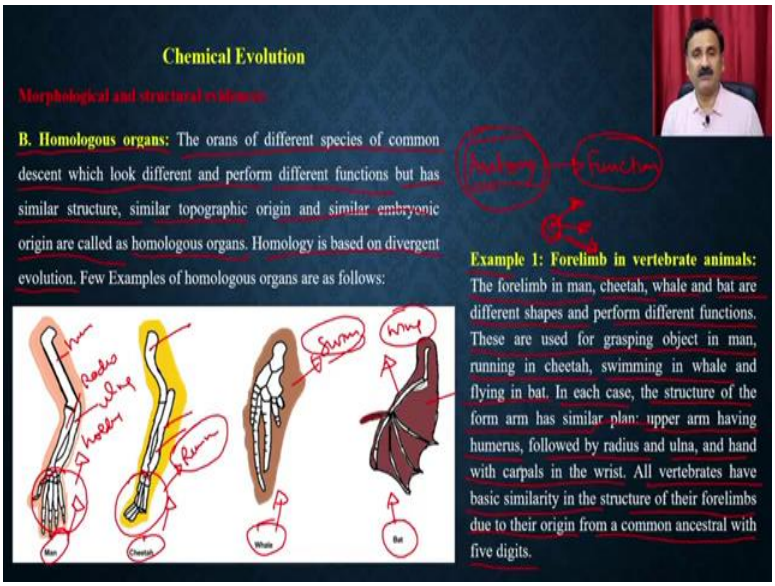

So, then we have the homologous organs. So, that is another advanced evidence the organs of the different species of a common descent which looks different and perform different functions, but has the similar structures, similar topographic origin and similar embryonic origin are called as the homologous origin organs. Homologous organ means the organisms autonomy is going to be identical, but they are going to do different functions. So, they will perform the different functions, but their anatomy is going to be the same.

We have a couple of examples. So, homology is based on the divergent evolution. So, it will be based on the divergent evolution, because of the adaptations, so if this single organism got evolved into these three organs, but it has, he has not changed the anatomy, he has only changed the way these organs are going to be utilized.

One of the classical examples, is the forelimb in the vertebrate animals. So, you have we have the forelimbs in the man, cheetah, whale and the bat and they are of different shapes and perform different functions. For example, these are used for grasping objects, so, in the, so these are the 4 examples, you have the hand in the case of man, then you have the cheetah, so you have the forelimbs in the case of cheetah, then you have the whale and then you have the bat and all these 4 organisms, 4 vertebrate animals are different.

For humans, they are using the hand for holding the objects, so grasping the object, whereas the same forelimb is going to be used for running in the case of cheetah, whereas in the case of whale that particularly forelimbs is going to be converted into these limbs like swimming in the whale. And the same is also being used for the flying in the bat.

In each case, the structure of the forearm has similar plans like upper arm having the humerus, followed by the radius and ulna and the hand with the carpals in the wrist. So, if you see the anatomy, the anatomy remains the same, you have the humerus, you have the radio ulna, so, you have the radio ulna and then you have the hands. So, here also you have the humerus, you have the radio ulna and then you have the hands, but the functions are different.

Functions are that in the case of human it is for holding the object whereas in the case of cheetah, it is for running. So, it has been adopted accordingly, it has been adopted to give of that particular type of functions, whereas in the case of whale it is for the swimming and in this bat, this got membrane. So, in this last part is getting the membrane and because of that it got converted into a wing and that is why it has been used for the flying.

All vertebrates have the basic similarity in the structure of their forelimb due to their origin from a common ancestor with the five digits. So, that is why these all these organisms are, all these animals are being originated from the single ancestor and that ancestor is a having a pentadactyly feature. So, pentadactyly means the organism which will going to have the five fingers.

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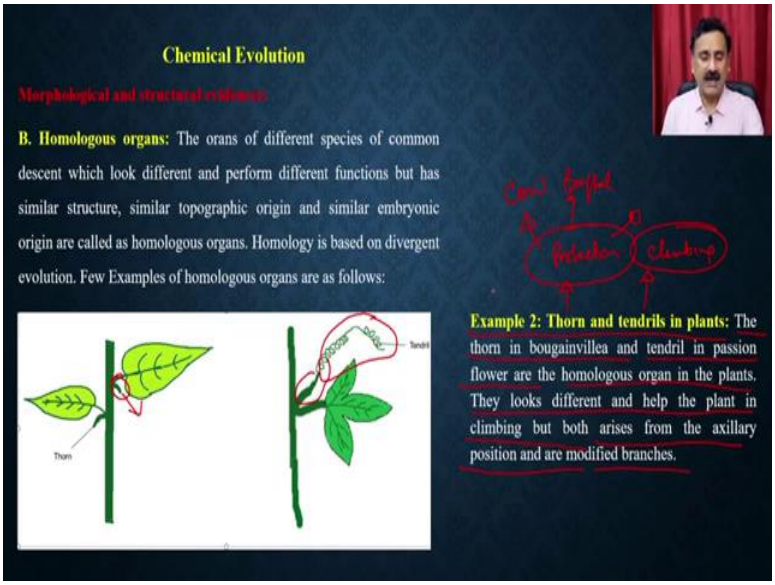

Then we have another example. So, another example is the you have seen the thorn and the tendrils; thorn is being used for the protection in the plant because it protects the plant from the, from the herbivorous like for example, cow or buffalo or all these grass eating plants. So, they will be having the thorns, so that when they try to eat, these thorns are causing the injury and that is how they will be get protected.

Whereas, the tendrils are being used for the climbing. So, there will be found in the creepers and they will be used for the climbing. So, the thorn in bougainvillea and the tendril in the passion flowers are the homologous organ in the plant, because they are having the similar kind of anatomy except that here you have the pointed knobs, whereas, in the case of this it got converted into a spiral spring like structures.

They look different and they help in the plant in the climbing, but both arise from the auxiliary position and our modified branches. So, these are been modified branches, some; one is used for the climbing, the other one is used for the protection from the herbivorous or protection from the cattle.

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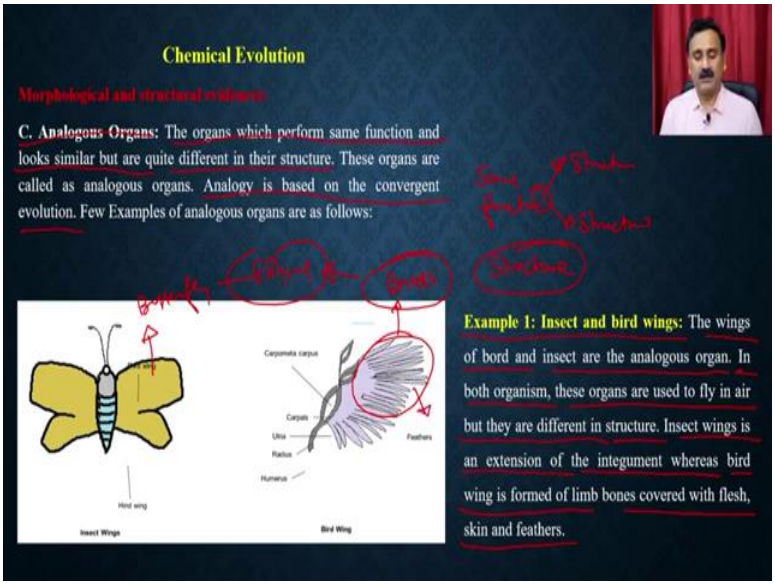

Then we have the analogous organs, the organs which performs same function and look similar, but are quite different in their structure. So this analogous is very is exactly opposite, so they do the same function, so they have the same function but they are different in terms of structure. Which means if you remember, in case of the homologous organ, it was telling us the divergent evolutions, whereas the analogous organs are going to tell us convergent evolution, which means these two are been convergent evolutions.

So if you see an analogous organ, it is going to tell you the convergent evolution. Because the structure is more important than the function, because the function is very, very can be based on the adaptation into a particular environment. So the example is, there are several examples like for example, the insects and the wings of the bird.

So you have seen the wings in the butterfly, so this is the butterfly and you might have seen the wings in case of birds, both are the analogous organs. Because they both are being used for one function that is the flying. They both are being used for the same function like the flying, but their anatomy is different, you see the anatomy of the bird wings and you see the anatomy of the flies. So, they are very different.

So, the wings of the bird and the insects are the analogous organs in both organisms, these organs are used to fly in air, but they are different in terms of their structures, insect wing is an extension of the integuments, whereas, the bird wing is formed of the limb bones converted with the flesh, skin and the feathers.

So, they are different in terms of their origin, they are, this is coming from the integuments whereas, this is a extension of the forelimb. So, where you have the feathers and all those kinds of things and that is how you get the ability to fly. So, it can be able to be change the air and that is how it be able to uplift the birds.

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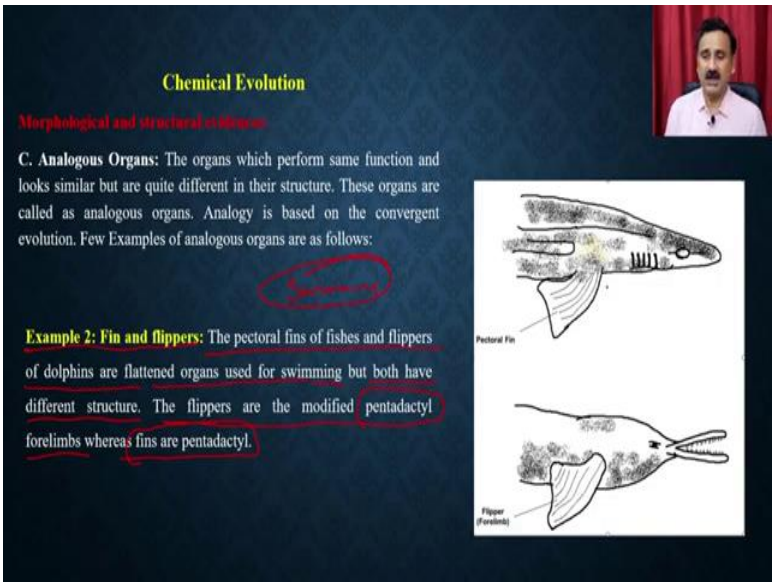

Then we have another example, where you have the fin and the flippers. The pectoral fin or the fishes and the flippers of dolphins are flattened organ use for the swimming, but both, so here in this case, we have the one function which is the swimming. So, for swimming these two, these two fishes are using their fins and they have the fins and the flippers.

So, they are doing the same function, but their anatomy is different. So, but their structure is different. The flippers are the modified pentadactyly forelimb, whereas fins are the pentadactyly. So, the these two are been formed from the different origins and different structures, but their function is same.

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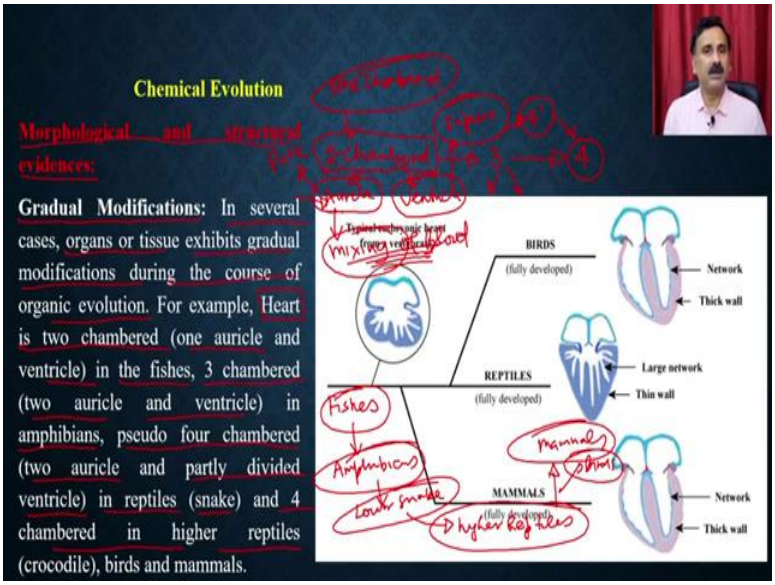

So, other evidence for the within the category of the morphological and structural evidence is the gradual modifications. In several cases the organs or the tissue exhibits the gradual modification during the course of the organic evolution. For example, the heart, heart is the classical example, because heart was initially being two chambered, then that got converted into three chambered and then that got converted into four chambered.

Within the two chambers, you have the auricle and ventricle; within the three chambered, you also have the auricle and ventricle and so on. So, you have, see here, if you have the two chambered, it will be one auricle and one ventricle which is be present in the fishes. If you have three chambered it is two auricles and one ventricle, which is been present in the amphibians.

And then there is a pseudo four chambered heart which is present, which is having the two auricles and partly divided ventricles, which is in the reptiles or the snakes. And then you have completely well-developed four chambered heart in the case of the higher reptiles like crocodile, birds and as well as the mammals. So, between this, you also have the four which is partially coated. So, this is what you said, this is going to be an intermediate stage. And there are two chambers, so this is having only two auricle and as well as the ventricle.

And before this, there would be one chambered heart which was formed, which was the primitive heart probably be formed. And that got split into two chambered and that is how, so if you see like cockroach or lower invertebrates, they do not have the heart, but they have a pumping system and that is not having a chamber. So, this is not, so there is no one

chambered heart is present in the any animal but the system what is present in the lower invertebrates are like they have a pumping system but that is not having a chamber.

So you can imagine that two chambered heart, two chambered heart has auricle and ventricle. Now what is the disadvantage? Disadvantage is that it is not going to avoid the mixing of the blood, you know that the ventricle is having the pure blood, whereas auricle is having the pure blood, whereas the ventricle is having the impure blood.

So if you do not have the chambers, you are going to mix this blood later on, because the auricle is going to receive the pure blood from the lungs. But and then it is going to pump that blood into the body whereas, so once you go from the two chambered to three chambered or three chambered to four chambered and so on, that is who you are going to increase the efficiency of the working, you can be able to very precisely control which chamber is going to accept the deoxygenated blood, which chamber is going to give you the oxygenated blood and so on, and that is how you can avoid the mixing of the blood.

And that is how you can be able to perform the functions properly. So, if you see the gradual modifications, this is just one example where we have taken an example of heart, it says that initially the fishes are being narrow developed. So fishes, then that fishes are given rise to amphibians, then amphibians are being developed into the lower snakes or the lower reptiles, then the lower reptiles are going developed into the higher reptiles like higher reptiles, where you have the crocodiles and all those kinds of thing. And then the higher reptiles got into the into the mammals or birds.

So, if you see all these evidences clearly says that the ladder of species what has been proposed by the Aristotle was not completely correct, it was based on some assumptions, but here you see that the, if you see the ladder of the species, this is not a sequence in which it has been placed. It has been placed in a different sequence, where the birds are placed lower to the reptiles.

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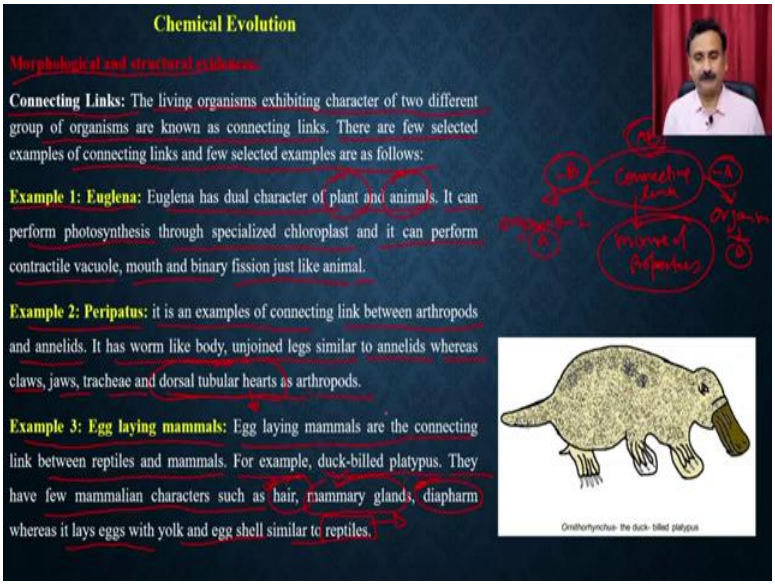

Then we have the another advantage. The other example other advantage is the connecting links. So, what is a connecting link? Connecting links are the (())(41:46). So, you have, for example, you have two any, two, three organisms. So, you have organism 1, you have the organism 2 and you have the connecting links. Now, this connecting link is going to diverged into these two species. So, it is going to have the mixture of properties what are being present so, if this is suppose this is A, this is B, it is going to be AB.

So, this during the course of this can be first of all this organism is being evolved. And then depending on the conditions, depending upon the environment, depending upon the other kinds of adaptations, this particular thing has given up the B. So, if there will be a given up of the B character, it will develop into organism A, if there will be a giving up of the A, it is going to develop into the organism B and that is how the connecting link is going to tell you that okay, these A organisms and the B organisms are related to each other, they are going to have their common ancestors.

You might have seen that kind of common ancestor is also exist even within the different races within the humans also. The living organism exhibit character of the two different groups of organisms and known as the connecting links. There are few selected examples of connecting links and few examples are as follows, few example is euglena. Euglena has the dual character of the plant and animal. So euglena is going to be a connecting link between the plants and animal.

And it is considered that probably the euglena like molecules is being evolved which was having the chloroplasts at the one side and they also have the system, so that they can be able

to catch the prey. It can perform the photosynthesis through the specialized chloroplasts and it can perform the contractile vacuole, mouth and binary fission and it can be able to eat just like the animal and that is why this is considered to be a connecting link between the plants and animals.

Then we have an example 2 which is a Peripatus. So, it is an example of connecting link between the Arthropoda and the annelids. It has warm like body so that is a character of unjointed legs, which is similar to the annelids, whereas it has claw, jaws, tracheae and the dorsal tubular heart as Arthropoda.

So this is what I was talking about dorsal tubular heart, which was present in a cockroach and which is pumping the blood but that is a single chambered organ, the tissue and it does not have the well-defined muscles and other things to pump, but it is distributing and that is considered to be heart like structure. So this is what so peripatus is an example of connecting link between the arthropoda and annelida.

Similarly, you have the egg laying mammals, you know that the mammals are giving rise to the babies. But in this case, we have the egg laying mammals. So, egg laying mammals are the connecting link between the reptiles and the mammals. For example, you have the duck-billed platypus. So this is a duck-billed platypus. They have a few mammalian characters such as hair, mammary glands, we have the diaphragms whereas it lay eggs with yolk and egg which is similar to the reptiles.

So, if you, well if you recall when we were talking about declassification of the living organism, and we were talking about the features of the mammalian system, we said that there are seven characters which are, which should be present onto the mammal like one of the characters was the hair, the mammary glands and the well-developed the respiratory system. So these are the three characters which are present in the duck-billed platypus. But they were also going to lay the eggs with yolk and egg shell which is similar to the reptiles.

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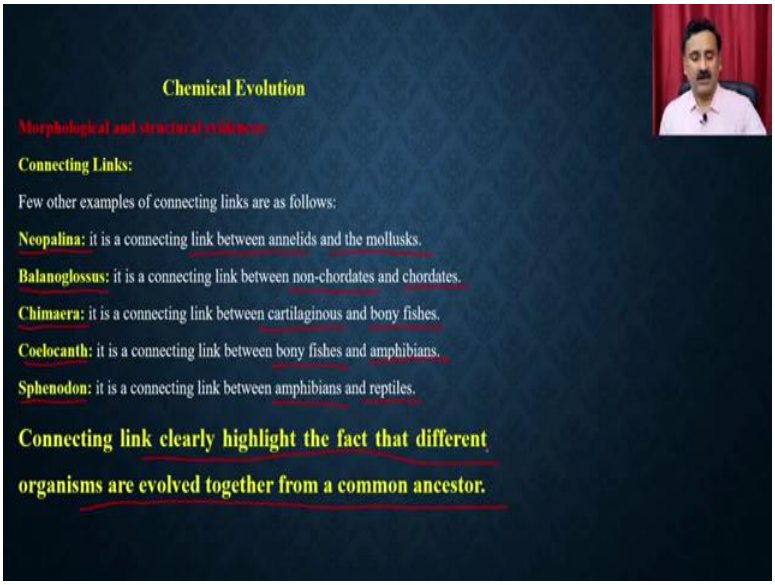

Then we have the several more examples also of the connecting links. For example, we have the Neopalina, which is a connecting link between the annelids and the mollusks. Then we have the Balanoglossus, which is the connecting link between the non-chordates and the chordates. So I am not going to discuss about multiple features, the only idea was to just to give you that the connecting links are a very, very crucial evolutionary evidence that the two organism been evolved from that particular organisms.

Then you have a chimaera, it is a link between the cartilaginous and the bony fishes. Then we have Coelocanth, which is a link between the bony fishes and the amphibians. And then you have sphenodon which is a connecting link between the amphibians and reptiles. So connecting links clearly highlights the fact that the different organisms are evolved together from a common ancestor and that is a very, very strong evidence that the evolution is happening from the earlier primitive form of these organisms.

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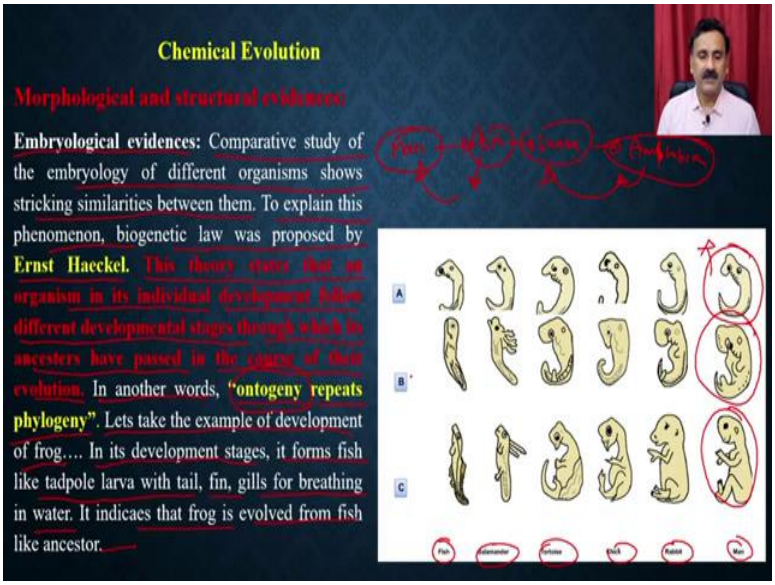

Then we have the embryological evidences. So embryological evidences, the comparative study of the embryology of different organisms shows that the striking similarity between them to explain this phenomenon, the biogenetic law was proposed by the Ernest Haeckel. And what this law says, this law says that an organism it is an individual developmental follow, in its individual development follow the different developmental stages through which its ancestor has passed in the course of their evolution.

What this mean says is that if the man is the best organism, which is as per the ladder of species from the Aristotle, and if it is suppose has the, fishes, it has the snake, it has the amphibians, like for example, if all these are mean this the sequence in which it has followed, so, when the baby is going to born, it is going to first be amphibians than it is going to be a fish and then it is going to be have, it will show the features like a bird and then it will eventually be developed into the man.

So, what it says the what the Ernest Haeckel is saying is that the organism, its individual development follows the different developmental stages through which its ancestor have passed. So, man has passed through multiple stages by which it has reached to this final stage, but when the baby is going to born and that is what is exactly happened when the fetus is born, they are swimming into the into the womb, into the that water and then that they will behave like a fish and eventually they will develop like amphibians, then fishes and then eventually they will develop into the man.

So, this is what example is what is showing here it will be showing the example of fishes, salamanders, tortoise, chicken, rabbits and the man. So what you see here is initially it is

going to have the fetus which is going to form, it looks like as the amphibians and then it will going to develop into the fish like and then eventually it is going to form the baby in the case of man.

So, in another word that this law what it is also says is that ontogeny repeats the phylogeny, which means if you want to go with the development it is going to follow the phylogenetic tree, the phylogenetic means what are the different organism through which you have been evolved. So, let us take an example of the development of frog for example, in its developmental stages, it forms a fish like tadpole larva with tail, then fin and gill for breathing in water. It indicates that the frog is evolved from the fish like ancestors.

So, that is a classic example where the tadpole or the frog is forming the species like that the frog is initially giving rise to the eggs then those eggs are being fertilized and these fertilized eggs are then going with the, they are swimming into the water like a fish and then eventually they will develop all the other kinds of appendages and other things. And then they will develop into the frog.

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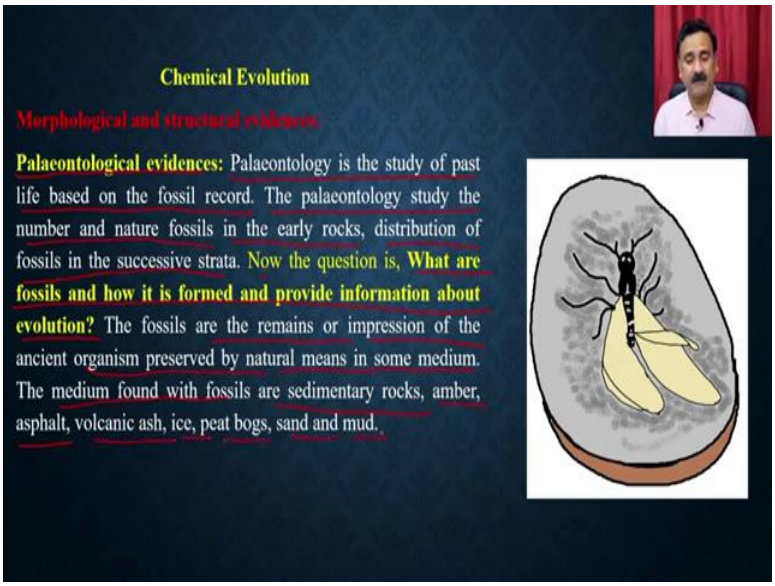

Then we have the paleontological evidences. So, what is a paleontology? Paleontology is the study of past life based on the fossil record, the paleontology studied the number and the nature fossil in the early rock distribution of the fossil in the successive strata. Now, the question is what are the fossils and how it is formed and provide the information about the evolution?

The fossils are the remain or the impression of the ancestral organism preserved by the natural need in some medium, for example, this is a fossil of insects into the amber. So, the medium found with fossils are like sedimentary rocks, it could be amber, it could be as asphalt, it could be volcanic ash, ice, peat bogs, sand and the muds.

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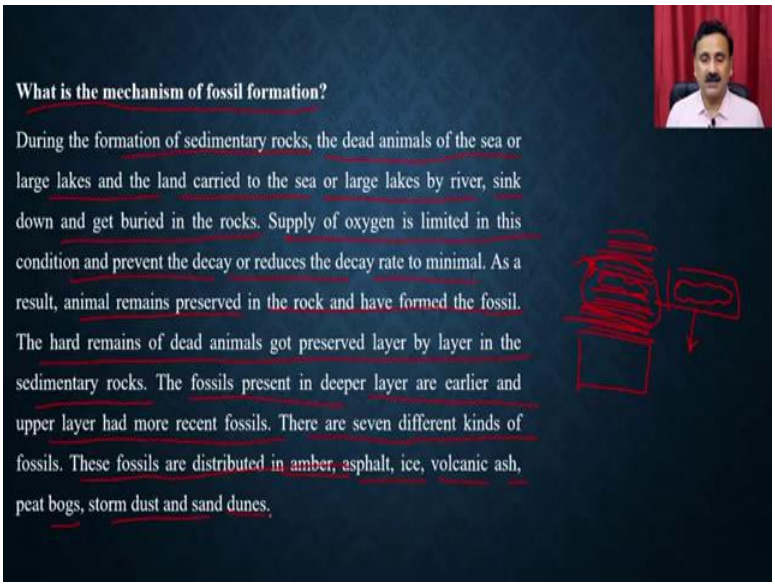

What is the mechanism of the fossil formation? So, during the formation of the sedimentary rock, dead animals of the sea or the large lakes and the land carried out to the sea or large by the rivers sink down and get buried into the rock. So, when there will be a rock is forming. So, for example, this is a rock and it is accumulating the soil, it could possible that one dead animal is going to fall and then it is going to again covered with that particulars soil, soil particle.

And because of that, it is, and since there will be no entry of oxygen, this particular organism is going to be preserved. Supply of oxygen is limited in this condition and prevent the decay or reduce the decay rate to minimal. So, because it will not allow the decaying at a faster rate compared to what we could see in the open, it is going to give you an impression. So, when you take out it is going to give you an impression of that particular animal or and if you take out the soil, it will be going to give you the molds.

So as a result, the animal remains preserved in the rock and have the have formed the fossils. The hard remains of the dead got preserved layer by layer in the sedimentary rocks. The fossil present in the deeper layers is earlier and the upper layer had more recent works. There are several different kinds of fossils, the fossils are distributed in amber, asphalt, ice, volcanic ash, peat bogs, storm dust and the sand dunes.

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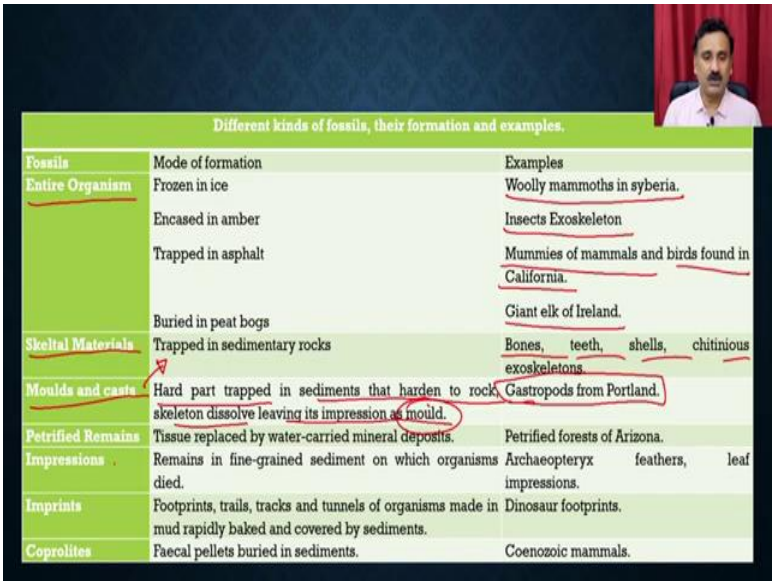

So this is the table where I have shown all different types of fossils, their formation and examples. For example, there are fossils where the entire organism is being preserved. The example is the woolly mammoth in the Siberia, insect's exoskeleton, mummies of the mammals and birds found in the California and the Giant elk of Ireland. So, these are the different fossils(53:54).

The other example is the skeleton material, so in this case, you cannot develop, you cannot have the entire organisms but you can have the sub part like the bones, teeth, shells and all those kinds of things. Then you have the molds and the casts, so here you will not get even the skeleton or the entire organism, but you will going to have the negative impression. So in this the hard part trapped in the sediment and that harden to rock, skeleton dissolve leaving its impression as the mold. So this is gastropods from the Poland. So that is the example of the fossil and this is what is other examples of the fossils what has been present.

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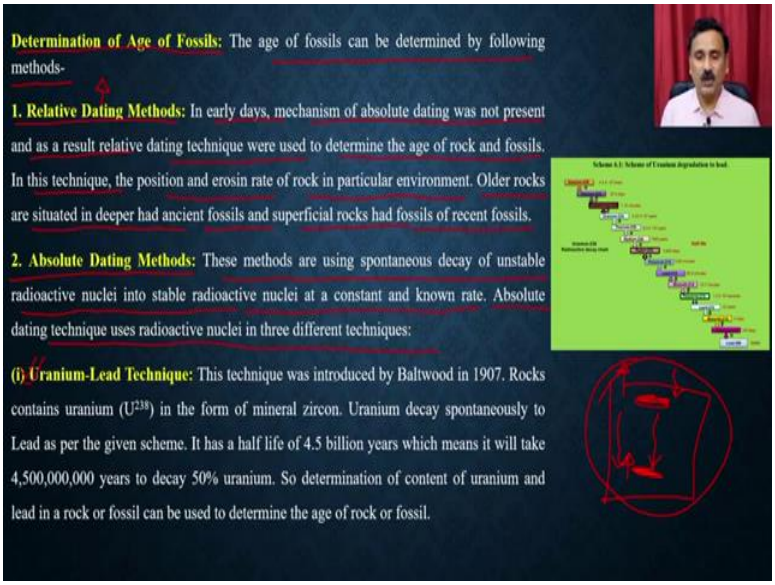

So how, the question is how you can determine the age of the fossil? The age of the fossil can be determined by the following method. So in the past, people were using the relative dating methods, so in the early days, the mechanism of absolute dating was not present. And as a result, the relative dating technique were used to determine the age of rock and the fossils. In these techniques, the position and the erosion rate of rock in particular environment. So older rocks are situated in deeper, had ancient fossils and superficial rock had the fossil of the recent one.

So this relative dating technique is a very, it is like you say that if you have a rock and if you find a fossil here, if you find the fossil here, since this is in a deeper portion, and this is a shallow portion, this is going to be earlier fossil, this is going to be late fossil, but this is all based on relativity, this is going to be a relative. So that is why the people were looking for the absolute dating data and they have developed a multiple absolute dating method.

These methods are using the spontaneous decay of unstable radioactive nuclei into the stable radioactive nuclei at a constant and known rate. Absolute dating technique uses radioactive nuclei in three different techniques. So, you have the uranium lead technique, so, this is the uranium decay, what has been shown.

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So, if you see the very clearly, in the uranium lead technique, this technique was introduced by the Baltwood in 1907. So, rock contains the uranium which is the uranium 238 in the form of mineral zircon. So uranium decays spontaneously to lead as per the given scheme. So you have the uranium 238, then it will going to form the thorium 234, then it is going to form the protonium and so on. And ultimately what you are going to form is you are going to form the lead.

So, depending on the amount of lead, depending upon the amount of uranium, you can be able to identify how many lifecycles, how many half-lives are being crossed, for example, if one half-life, the uranium is going to develop into thorium, but the difference is the 4.5 in 10 power 4 years. So, if you count the number of half-lives, you can be able to count the age of that particular fossil.

So, it has the half-life of 4.5 billion year, which means it will take these many years to decay 50 percent uranium, so determine, determination of the content of uranium and the lead in a rock or fossil can be used to determine the age of rock. For example, if I got like 40 percent or if I got the 50 percent decay. So, suppose I got the total amount and suppose I got 10 mg of uranium and 10 mg of lead, that means that there is a 50 percent decay, and that means that the age of that particular fossil or age of that particular rock is 4.5 billion years.

You can easily calculate accordingly the same way. If you got like for example, if you got 2 mg of uranium, and you got 8 mg of lead, then also you can be able to calculate, you can be able to calculate, so there will be 80 percent decay. So that is how you can be able to calculate the age of that particular rock using these kinds of equations.

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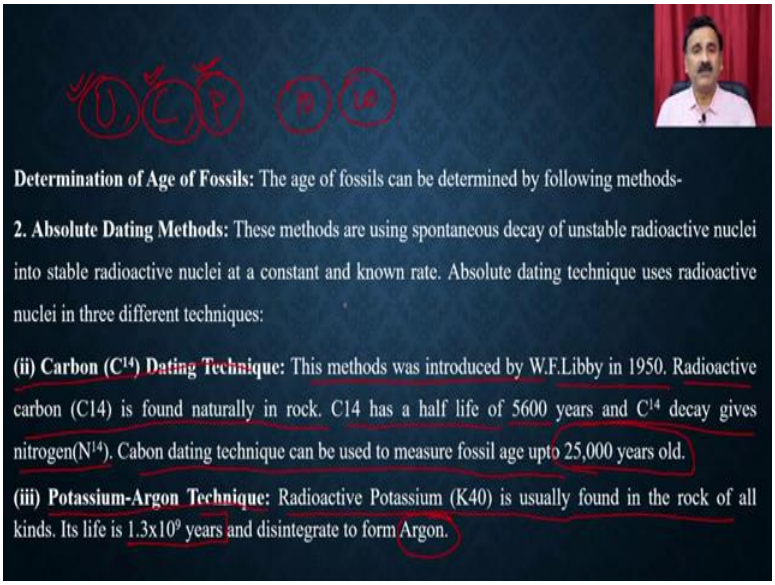

Then we have the carbon dating method. So carbon method is also being introduced by the WF Libby in 1950. The radioactive carbon C14 is found naturally in rock and C14 has a half-life of 5600 years and C14 decay give rise to the nitrogen 14. Carbon dating method can be used to whether the fossil age up to the 25 years age. So you can see that, you have the uranium method, you have the carbon method and you have the potassium method. And all these methods are having the multiple range in which you can be able to use.

Then we have the potassium-argon method. So radioactive potassium is easily found the rock of all kinds. It has a half-life of 13.9 years and it disintegrate to form the organ. So you can be able to use all these three methods to calculate absolutely, there will be no relative dating methods. So these are absolute methods that will going to tell you what is the age, age is 10, 20, whatever.

And that is how you can be able to correlate the different fossils, what is being found even in the different areas or different regions within the world. Now utilizing what is the, what is the utility of determining the age of the fossil, that they if you determine the age of the fossil, you can be able to utilize that information to calculate when that particular organism is being appeared and based on these people have come up with the geographical scale or the geological timescale.

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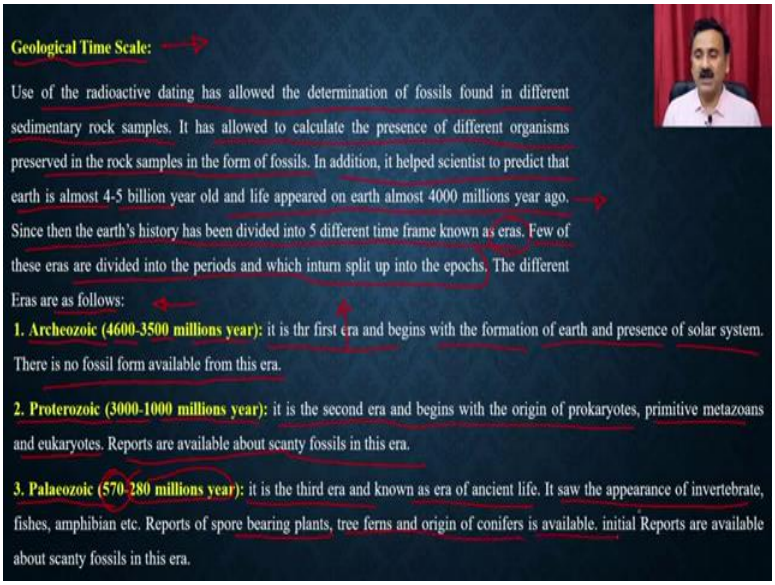

Geological time scale is going to tell you the appearances of the different animals and so use of the radioactive dating method has allowed the determination of fossils found in the different sedimentary rock sample. It has allowed to calculate the presence of different organism preserved in the rock sample in the form of fossils.

In addition, it helped the scientists to predict that the earth is approximately 4.5-billion-year-old and life appeared on earth almost 400 million hours ago. So these two information came because of the carbon dating or the absolute dating techniques. Since then, the earth's history has been divided into five different timeframes known as the eras.

Few of these eras are divided into periods and which turn is splits into the epochs. The different eras are as follows. So, you have the Archeozoic era. So, that Archeozoic era is starting from the 4600 to 3500 million years. Remember that it is always been done in the reverse order, you see the higher number and then you see the lower number. So, this means we are talking about from the reverse.

So, it is the first era and begun with the formation of earth and presence of the solar system, there is no fossil form available during this era. This means this is the era when the earth is actually being formed. Then we have the Proterozoic era, which is starting from the 3000 to 1000 million years. It is the second era and began with the origin of the prokaryotes, the primitive metazoans and the eukaryotes, reports are available about the scanty fossils in this era.

Then we have the Paleozoic era which starts from the 570 to 280 million years, see there is a gap and these gaps, still there are no fossil found between this and this age, we cannot have any idea what is happening. So it is the third era and known as the era of ancient life, it saw the appearance of invertebrates, fishes, amphibians and reports of spore bearing plants like which is trees, ferns and origin of conifers is available. Initial reports are also available about the scanty fossils in this particular era.

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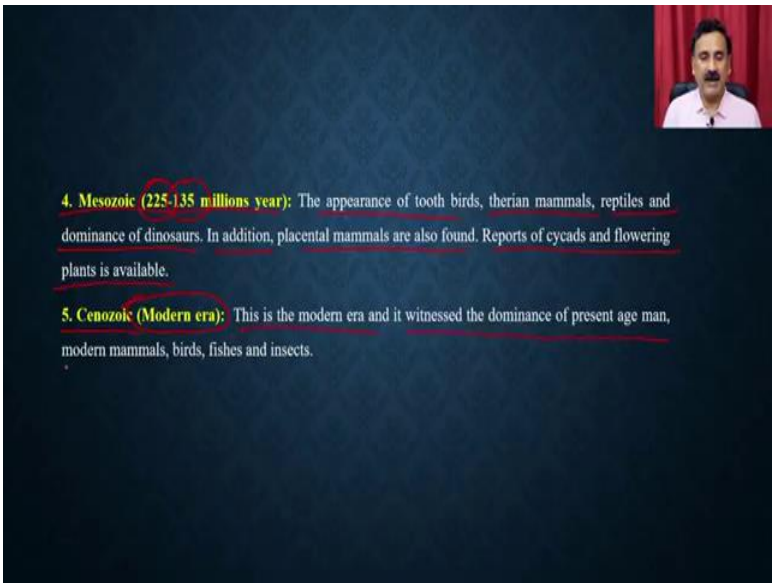

Then we have the Mesozoic era and the Mesozoic era is from the 235 to 135 million eras. This appearance of the tooth birds; therian animals, reptiles and the dominance of dinosaurs. In addition, the placental mammals are also found, the reports of cycads and the flowering plant is also available. And then you have the Cenozoic era or the modern era, where which is starting from the 135 million years. This is the modern era and it witnessed the dominance of present age man, modern mammals, birds, fishes and insects. So, this is what we have discussed so far.

What we have discussed? We have discussed about the evolutions; we have discussed about what are the different evidences what we have produced for which support that there is an evolution. So, we have discussed about the morphological and structural evidences, we discussed about how the body organization is giving you the idea about the how the different organisms are evolving from the preexisting environment.

You have initially you have the cellular level organizations, then you are having the tissue level organizations and then you are having the organ or the organ system organizations and

you know and we have discussed also the many advantages as well as disadvantage of these systems.

Then, we have also talked about the homologous as well as the analogous organs and we have said that the homologous organs is going to give you the idea about the diverge evolutions, whereas the analogous organs is going to give you the evolution about the converge evolutions. So, if you could study the homologous as well as the analogous organs, you can be able to make the very clear and crystal pictures who appeared when.

And then we also talk about the gradual modification, how the different organisms or different organisms have adopted to the change environment and because of that, they have changed the physiology, they have changed the organs, we have taken an example of heart and we have discussed about how the heart is being converted from the two chambers to the four chambers.

And then we also discussed about the connecting links and connecting link is a very, very crucial features or crucial evidence that proves that these two organisms are coming from that particular ancestor connecting links. And then we also discussed about the embryological evidences as well as the paleontological evidences.

And at the end, we have also discussed about the different eras (65:13). We have also discussed about the geological timescales and we have discussed about the different types of eras what are present. So, with this I would like to conclude my lecture here in the subsequent lecture, we are going to discuss about the how the evolution is happening.

So, till then, goodbye. Thank you.