The Evolution of the Earth and life
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Appearance of Feathers

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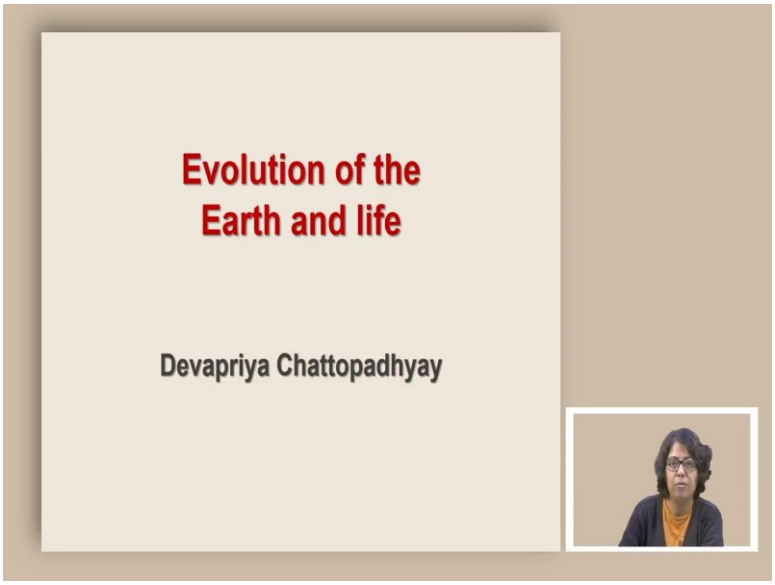

Welcome to the course Evolution of the Earth and Life. Today we are going to learn about feathers.

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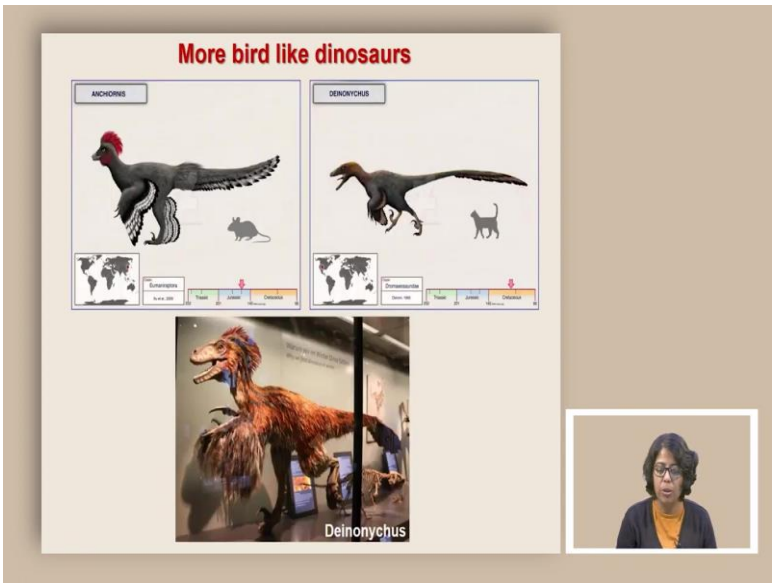

Today's focus is going to be Mesozoic, which runs from 251 million years to 66 million years.

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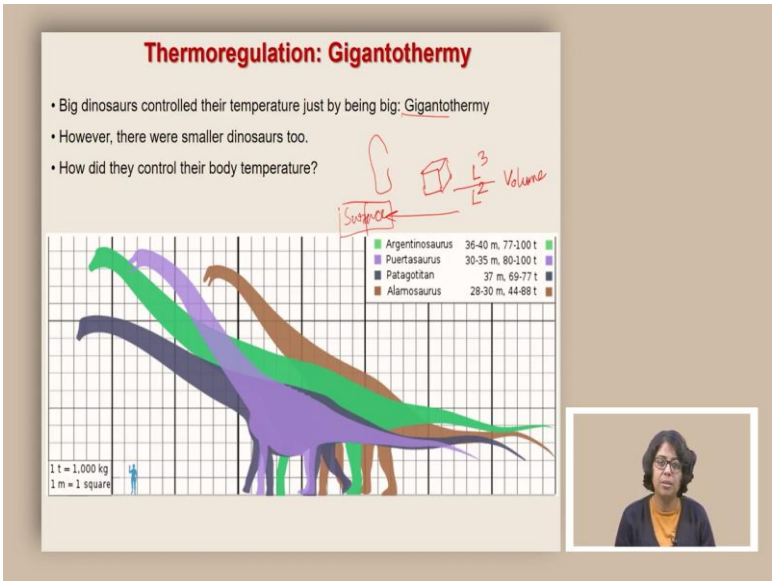

We know that big dinosaurs control their temperature, just by being big. And this phenomena is called Gigantothermy. Giganto means large, very large and thermy basically means heat. So, they were controlling their body temperature, just by being big. Just to recapitulate, remember that, if you have a cube, this cube has a surface area as well as a volume. And as we are making it bigger, in every linear dimension, what we find is the volume grows as a cube of the linear dimension, and the surface area grows as a square of the linear dimension, as a result, as things are growing in size, the cube and the square ratio so, that means the volume versus surface area ratio is going to increase.

So, that means the volume is going to increase as we are increasing the size, maintaining this shape constant. And as we are coming down with size, it is relatively the surface area, that is going to dictate the pattern. And because of these reasons, we find interesting patterns. For example, you will find that the groups which are really large, for example, the elephants, they are really large, and they are also producing heat, and they get overheated. And that is why they have some way of dissipating heat. And the way to dissipate heat, heat loss is by creating large surface area without any volume. And the elephant ears do that.

Similarly, if we look at the distribution of animals, even within mammals, what we will find that as we are going to the polar region, we are not really finding anything which is very small, like a mouse or a rat, we are finding things like polar bears large ones, because it is easier for them to retain the heat. And for the smaller ones, because they have large surface area, they are constantly losing heat. And in order to maintain the heat, they have to eat a lot

just to maintain the heat. And therefore we do not really find small mammals in very cold climate.

Now, when we talk about the dinosaurs, we are still going with the idea that they were probably operating like an ectothermic organism, but a homoeothermic organism because they can control their body temperature. A big problem with this argument is that there were smaller dinosaurs too. There were dinosaurs, which were at the size of a chicken. Now how did they control their body temperature? Because clearly, by this volume and surface area ratio argument, they could not control their body temperature, so they must be using something else.

So, for a very long time, this had been an open question. And people came up with different ideas. One way of thinking of smaller dinosaurs, where that probably those smaller dinosaurs were only restricted to very warm regions. And the climate of the earth has changed over time, and therefore, probably the pools were not as cold as today. Yet, it was still difficult to explain how some of the small dinosaurs even survived in sub polar region or temperate region, because the surface area and volume ratio does not explain it, especially considering that they were not endothermic organism.

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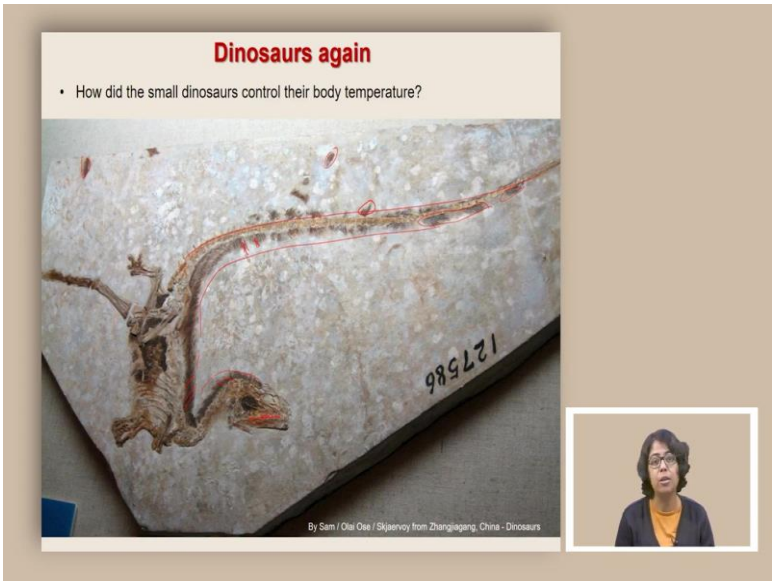

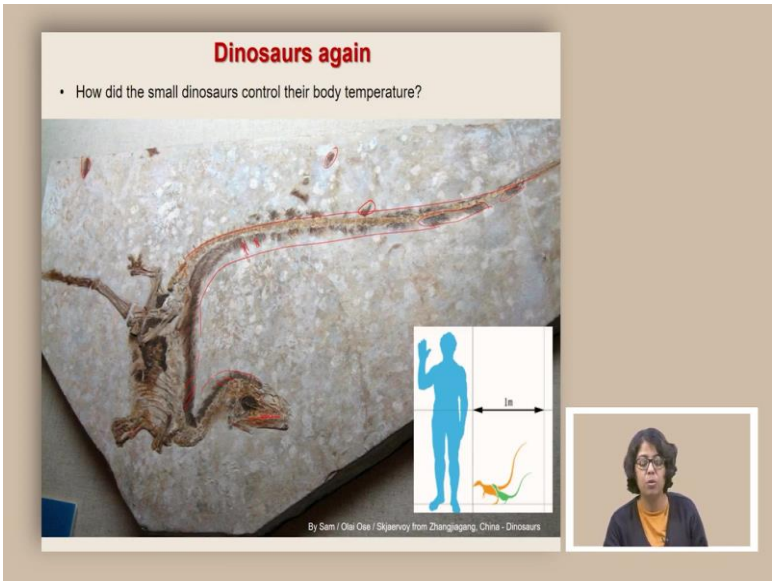

And then we started finding interesting fossil specimens. So, this is one of the very small dinosaurs, and this was found in China. And this small dinosaur comes with excellent preservation. And therefore we can find all the little details of the small dinosaur. What is quite interesting are these patches. If you look at these patches, they are also part of the dinosaur body, some of them have been scattered. But if you look at these regions, it is attached to the body, and it goes all the way from the head to the end of the tail.

Now, if we zoom in, what we are going to find is they have a pattern like this. And interestingly, they are very, very similar to what we call feathers. So, it was one of a kind of a dinosaur. And people started questioning whether this was just one of a kind, where there was a dinosaur, and there were feathers.

Now how did we know that this was not a bird? Well, because there are typical dinosaur features that we are seeing here that are not possible in the birds, for example, we have a jaw, which has teeth in it, then it has a very long bony tail. If you look at the birds of today, we do not really see this bony tail which also has feathers. So, this was definitely a dinosaur. But this actually has feathers.

And then all over the world when people started discovering newer fossil specimens of dinosaurs with feathers, it became quite clear that many of the smaller dinosaurs actually had feathers. And we are talking about the size of this, where it is really small. So, all the really small dinosaurs mostly started showing the signature of feathers from the fossil record.

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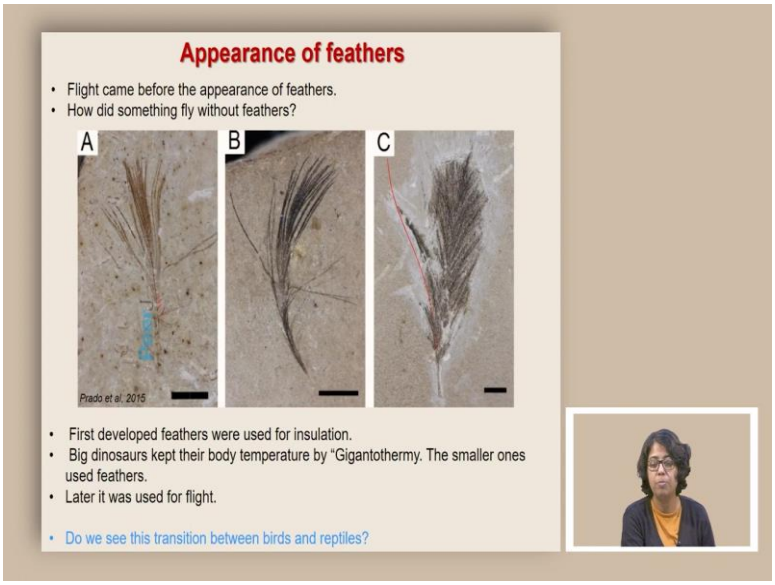

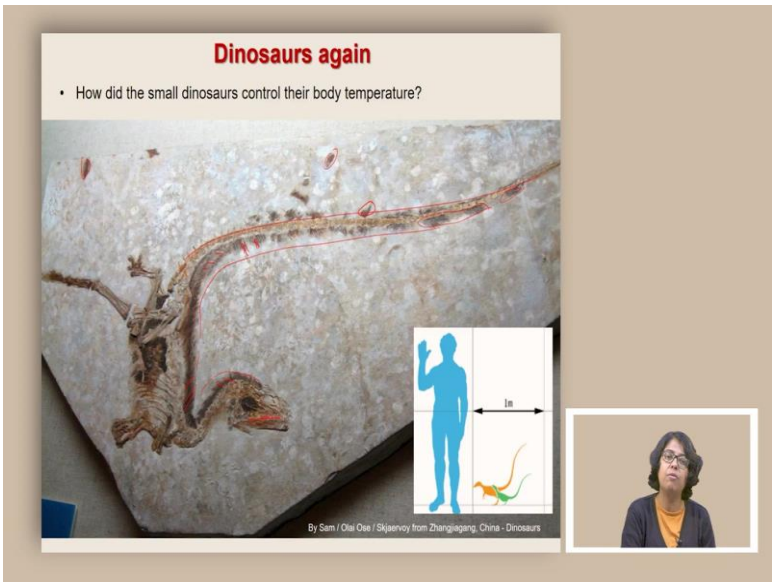

Now what can we talk about the feathers? Now flight came before the appearance of feathers. So, flight is not the reason for the appearance of feathers because the flight can actually appear even without the feathers. If you recall, we also talked about animals which did not require feathers to fly, such as bat such as insects, such as pterosaurs, many of the fossil organisms flew without the feathers, so feathers are not the primary reason for flying.

And the second problem is, if you look at the feathers in this particular dinosaurs, they are so small, they could not contribute to anything about flight. It is simply a tiny layer of feathers which covered the entire body. And when we started looking at the feathers, there are different kinds of feathers, especially for birds that we see today. When we look at their feathers, their feathers are long. And many of these feathers have extended patterns. And they

are very different from feathers which are small and which has only a few threads among them.

And comparing the modern bird feathers, and there are some feathers which are called downs, which are just covering the entire body but very small, so small that they cannot be used for flying, it was quite clear that the function of the feathers is not for flying, at least at the beginning.

At the beginning, the feathers were first used for insulation. So, if a group has a large surface area, and it has a coat, which can cover the entire surface area and insulates it from outside, then two things happen. First of all, when the climate outside gets very cold, the body is insulated, it does not really experience that cold temperature from outside.

Secondly, because of the coat of the feather, the heat loss of the body is much reduced, so they are not losing heat as fast as the other groups without the feathers. So, the big dinosaurs kept the body temperature by Gigantothermy but probably the small dinosaurs used feathers, and once the feathers started to grow, initially, the groups will be selected if they have a thick coat feathers, because they are just going to keep their temperature constant. And that has a lot of advantages.

One advantage is that they can be agile, they can have more strength, because many of the biochemical reactions require a specific temperature. So, if the temperature is maintained, they can be more agile. But then, as groups get selected for thicker coats of feathers, probably some groups also started developing larger feathers, longer feathers, and those feathers could be used for flight. So, this idea also helps to understand how the feathers evolved, and why some of the early feathered creatures were selected for through natural selection.

Clearly, they were not getting any advantages from the feathers in terms of their flying, but they were getting advantages, because those feathers helped them to keep their body warm. And so, the primary function of the feathers at the initial stage was to keep the body warm, was to keep the body insulated.

Now once we come up with this idea, then we should also think of transitional form. A transitional form that has all the characters of reptiles, or more importantly dinosaurs, but also has characters which are bird like. And although we showed some of the feather dinosaurs, initially, that was not the organism that people came across.

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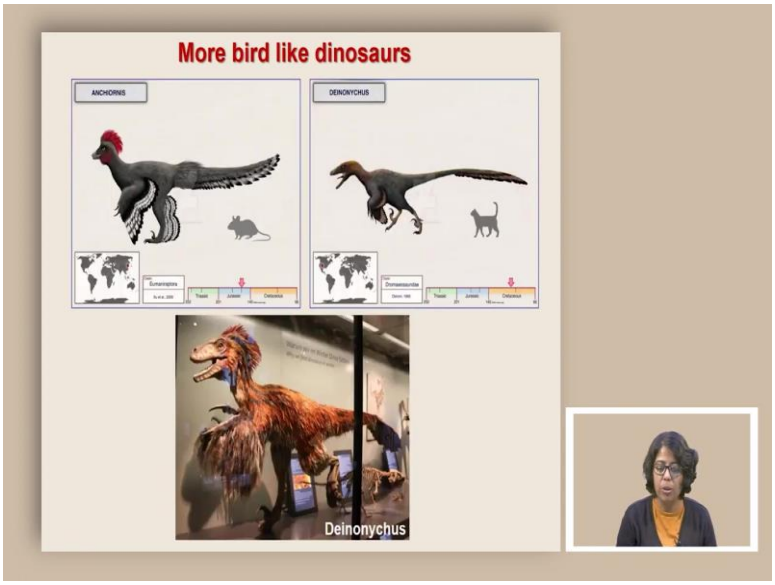

So, today, we know that there are multiple feather dinosaurs that are found from all over the body. So, this one is in comparison with a rat. So, it is still a very small creature, and it is found from China. Then there are other organisms, which are found from North America. And this is a comparison with a cat. So, it is slightly larger, but still, it is not a very large dinosaur. And this is artist's reconstruction of these feathered dinosaur. And it is not a very large creature like the other dinosaurs like sauropods, but it is not as small as chicken, so somewhere mid-range.

And it also shows us the different patterns of dinosaurs sizes, which had feathers, and every day, people are finding different fossils, which are showing this pattern again and again. But these are relatively newer discoveries. A much older discovery, which showed a clear relationship between reptiles and birds, came from Germany, from a limestone quarry called Solnhofen.

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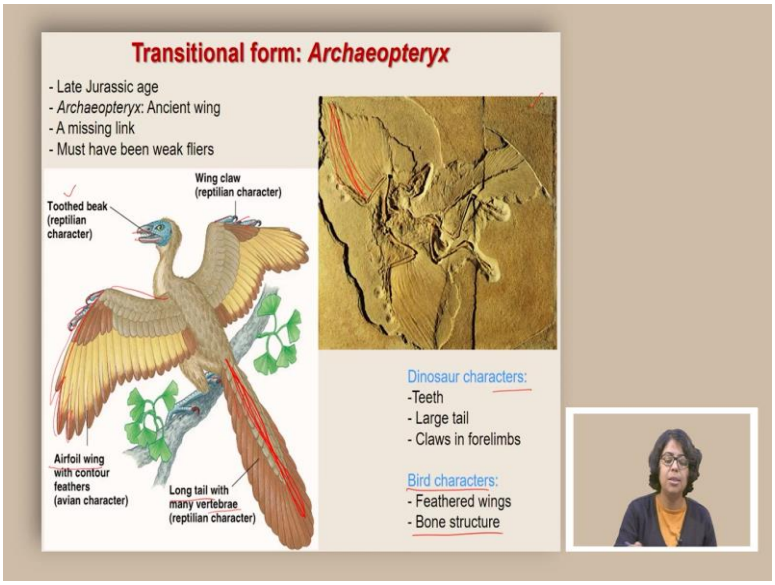

And the transitional form is called Archaeopteryx. So, this is an Archaeopteryx fossil which is discovered from Solnhofen limestone. Solnhofen limestone had this unique quality of being extremely fine grained, because they are extremely fine grained. Once that carbonate covered the body when these organisms just died. It did not allow any water or air to go inside and therefore the preservation is very good. And these are primarily lead Jurassic age.

The name Archaeopteryx means ancient wing and when we look at the artist's reconstruction based on this fossil, we find interesting characters. The first character that we find is this toothed beak. So, if you look at the beak, you will find that it has a number of tooth, which is something which do not find today in the modern birds, generally birds do not have toothed. The second very interesting point which is a dinosaur like point, similar to this toothed beak is the winged claws.

Now when we look at a bird, we generally do not find any claws in the front limb. The front limb has been converted to the wings in the birds, and we do not have these digits in the modern birds generally. We only find the claws in the back limb, which is the legs. That is where we find these claws. But in this Archaeopteryx, we have these wings, which is definitely converted form of the arm. But this still retains these digits, which has claws. And that is a very telltale signature of dinosaur character.

The third point is the long tail. Now this tail, I mean, you may think that there are birds, which also has long tails. For example, if we look at the peacock, it actually has a long tail. But those tails only has feathers. Here, for Archaeopteryx, this long tail is supported by many

vertebra, so it actually has a bone. So, it is more important rather than saying long tail, it is actually a bony thing. And on this bony tail, there are feathers. But then we come and look at the bird like character, the first character that we find is it has actually has a wing, and this wing has long feathers.

So, unlike those feathered dinosaurs, that I showed at the first picture, where the feathers were very small, this one had really large feathers, and these feathers had airfoil wing, which means that it actually contributed to flight, those small feathers could not have contributed to flight. But for Archaeopteryx, the feathers were long enough and the shape was ideal for flying. So, this clearly shows that this also has some bird character.

The second bird character is the bone structure. So, in birds, because it helps them to fly, they make their body light. In fact, loss of tooth also aids to this making the body light because tooth's are heavy. Then we look at the bones of the birds, the bones of the birds are hollow, and they have numerous pores, that is also reduces the body weight, and therefore it helps them to fly.

When we look at Archaeopteryx bone, we also find these kind of hollow bones, which is a bird character. So, here is that organism, where we are finding all kinds of characters between two groups, one set of characters, which are very similar to dinosaurs, and another set of characters which are very similar to bird, and therefore this is a truly unique transitional form.

Now the question is, among modern birds do we see something similar? Do we also see some patterns that we see among Archaeopteryx?

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In modern example, also, we find some interesting character. So, this is a picture of an Amazonian bird called Hoatzin. This Hoatzin looks like a common bird, it has a tail, it has these unique spiky feathers at the head. What is interesting is they live in near the water bodies. And often they have these branches on which they hold on to. Now their chicks have very interesting pattern in their wings.

Now, this is a reconstruction. But you can also see them in photographs, that the wings of these young individuals of Hoatzin actually have claws. And as they grow bigger, they lose those claws. So, in a grown, Hoatzin we do not find these claws attached with the wings. But in chicks, we do find the attached claws. This is exactly what we were finding in the Archaeopteryx. So, it is not only the ancient fossil record, which shows this transition between dinosaurs and birds. But even in modern examples, also we find some characters, which are very reptile like and we do find them in the birds.

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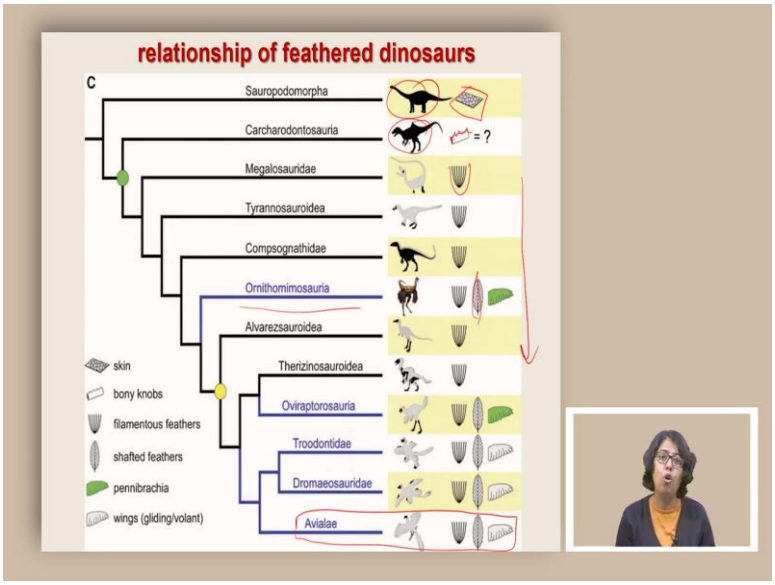

Now if we look at the relationship of these different groups, we find progressional pattern. So, we find these sauropods, this large dinosaurs, which definitely had skins. Then there are some dinosaurs where sometimes we find a bones which has these patterns. And then another dinosaurs very closely related to these dinosaurs, we started finding feathers. And these feathers are different. These feathers are mostly small feathers. They primarily kept the body insulated. And then as we go down in terms of their related groups, we started encountering some groups where we also find feathers. And these are shafted feathers. Some of them are pennibrachia, some of them's are basically wing feathers, and these wing feathers we started getting towards the end.

Finally, we come to a point where it has all the characters of a bird, but it also shares some of the characters of the dinosaurs. So, now is the time when if we actually have to classify dinosaurs, and we will see that bird automatically comes within this Dinosauria group. So, there is no way of removing the birds from the Dinosauria groups. So, birds are a type of dinosaurs. So, which dinosaurs went extinct? It is the known avian type of dinosaurs that went extinct. But some of the dinosaurs still exist. And we are simply calling them birds. They are the avian dinosaurs, because in this classification, we could not isolate birds without isolating some of the other dinosaurs. So, birds are an integral part of the dinosaurs.

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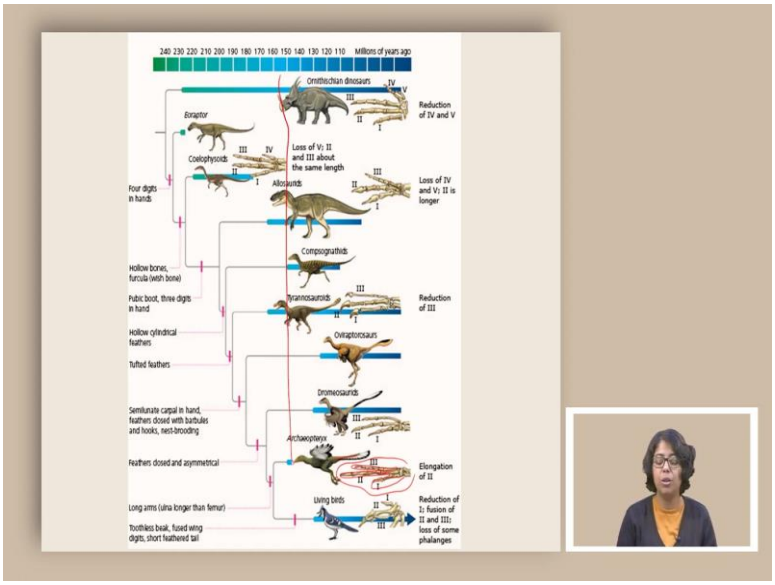

How are these modern birds different? The modern birds, we see some more changes from things like Archaeopteryx. So, from Archaeopteryx, if we look at their arm, we already saw that they lost the claws in the modern birds, for the arms for the front limb. Then, we also found that in modern birds, often this some of the limbs or some of the digits within the limbs, they are either connected together, joined together or altogether lost. And these are some of the patterns which we started finding in modern birds, which were different from Archaeopteryx.

And the other point was that if you look at the bony tail, in modern birds, you do not see it. But again, it is a continuation of the large dinosaur family. And we started finding the modern birds only in a relatively newer time, but if we look at when were their ancestors there, we will find that it actually goes back all the way in Jurassic.

So, during Jurassic we start finding groups, which are representing both dinosaurs as well as birds. And dinosaurs are the groups which got extinct, but only they are known avian group of it. The avian group still continues, and we call them birds.

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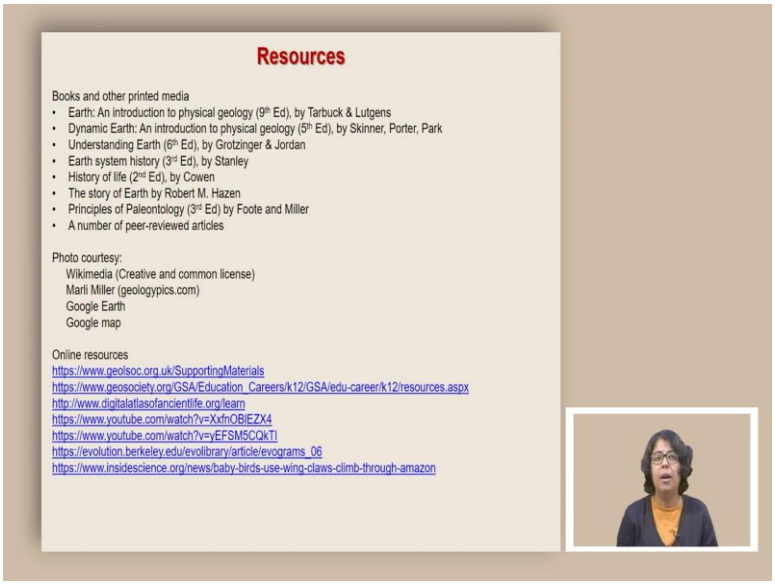

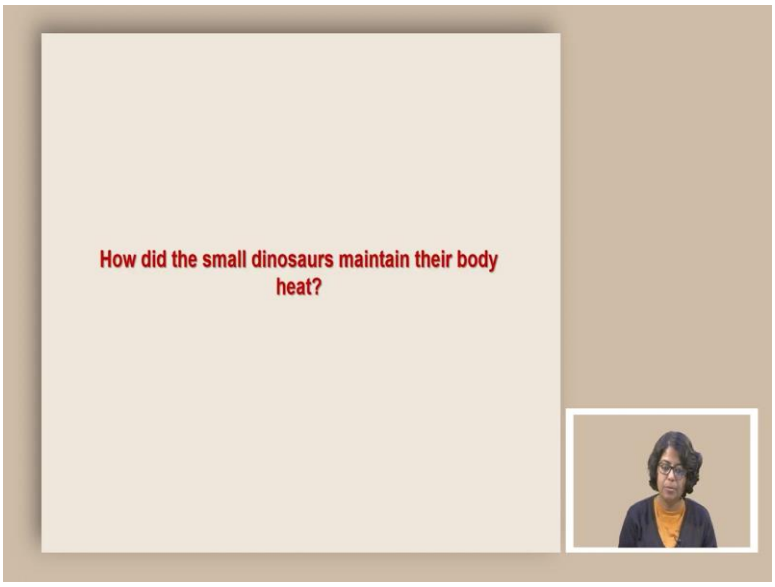

So, in summary, today, we learned how feathers appeared, and what was the primary function of the feathers. They did not contribute much at the early stage in flight, but they were the in solitary mechanism. They helped the small dinosaurs to control their body heat. We also learned how the feathers changed over time, and how they contributed to flight. We learned about Archaeopteryx a transitional form between the dinosaurs and the birds. And finally, we understood that the birds are an integral part of the Dinosauria and therefore, only the non-avian dinosaurs went extinct.

Some component of the Dinosauria group still exists today in the form of the birds. Here are some resources that I have used for making the slides and here is a question for you to think about. Thank you.