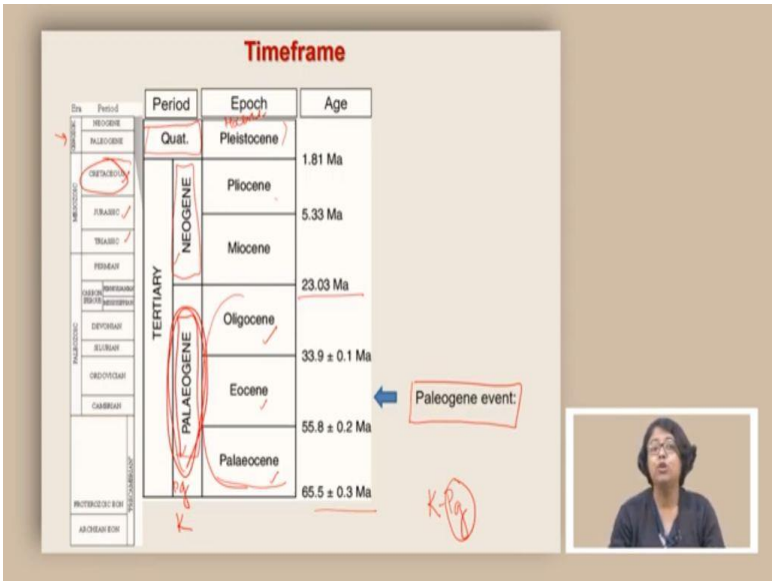
Evolution of the Earth and Life
Professor Doctor Devpriya Chattopadhyay
Department of Earth and Climate Science
Indian Institutes of Science Education and Research, Pune
Recovery from K-Pg: Paleogene Event

Welcome to the course Evolution of the Earth and Life. Today we are going to talk about the life after the K-Pg mass extinction.

(Refer Slide Time: 00:27)



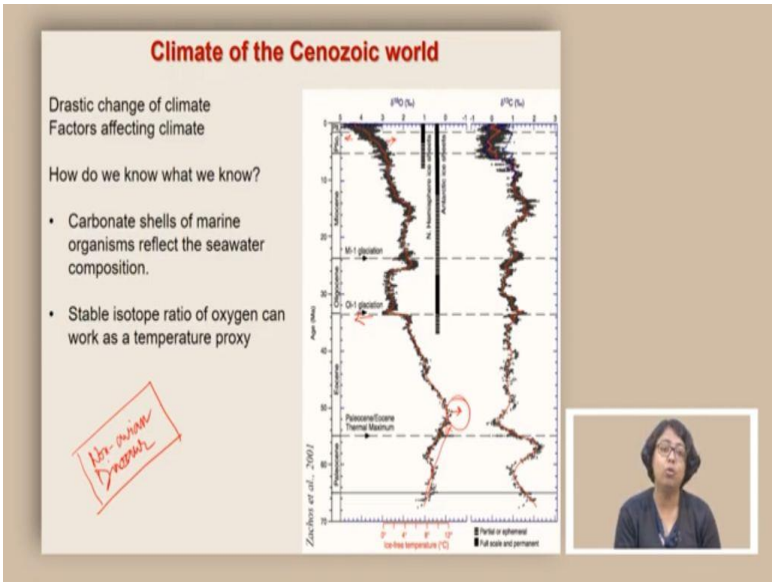
The timeframe that we are going to be talking about would be in Cenozoic. Now, unlike the other parts of the geologic timescale, where we only divided them in terms of periods, such as within Mesozoic there are three periods, Triassic, Jurassic and Cretaceous. In Cenozoic, we have a much higher resolution.

So in Cenozoic, we divide them into periods, which is Paleogene and Neogene. But within these, we can also divide them in epochs, and these epochs become very important for certain types of geologic events. So, there are different epochs within the Cenozoic and they start with Palaeocene, going to Eocene, Oligocene. And these three epochs define what we call Paleogene in terms of period.

Then we move on to Miocene, Pliocene and Pleistocene. So Miocene and Pliocene are part of this Neogene epoch, Neogene period, and then there is another period called quaternary. This quaternary is the most recent one, and we can go from Pleistocene to Holocene. So, these are some of the division of the geologic timescale when we look at the Cenozoic.

Today, we are going to be primarily focusing on the Paleogene event. So, the timeline for that would be between 65 million years and 23 million years. Now, we know that right before this, there was a major mass extinction, what we know as K-Pg mass extinction. K stands for Cretaceous and Pg stands for Paleogene, and this is the reason it is called Cretaceous Paleogene transition. And this is the mass extinction we have learned about. And today we are going to see how right after the mass extinction, the earth starts to see development of new groups and dominance of other groups.

(Refer Slide Time: 03:01)



This is also a time where the climate actually changed drastically, and there has been multiple changes after that. So, before Cenozoic, the climate our understanding about the climate is fairly poor, because the climatic record is not so well preserved before this Cenozoic. But, within Cenozoic through multi-proxy approach using different paleoclimatic reconstruction, we can have a very good understanding of how the climate of the Cenozoic world looked like. And these are some of the reconstruction, so you will see that there are times when the climate actually changed for the colder period.

This is where the colder period is, and then there were times when it went to really hot climate. So, we see variation between very hot versus very cold, and this changed throughout the Cenozoic. As we come to closer to the present day, we actually see a lot of variation, and it actually moved from colder to warmer phases, maybe not as warm as this point with a very high frequency. So, the climate kept on changing back and forth between more glacial dominated area, more glacial environment to more warm environment within a very short time.

And all of these changes also affect the land, because it also affects the land plants, and how much plants you are going to get, what kind of plants you are going to get. All of these are often determined by both temperature, but temperature also affects precipitation, rain versus snow. So, all of these put together finally determined what kind of land plant diversity is there going to be. So, at the beginning of Cenozoic, we are talking about Palaeocene, the warm the climate was generally warming up and it had a much warmer temperature compared to today. And one of the other things that we should expect in this generally warming temperature, is a lot of forests on the planet if it has a high precipitation.

The next thing that we have to understand is during the K-Pg extinction, especially on the land, there were major animal group which went extinct, and we are talking about the non-avian dinosaurs. And after the demise of the non-avian dinosaurs, it is really important to understand which where the group that basically appeared during this time. So for a very long time, a historically long time, people thought that we started seeing mammals during Cenozoic, and the time before was primarily the time of dinosaurs, and therefore it must have been a competitive exclusion.

What that means is during Mesozoic, it was the domination of dinosaurs. And because the dinosaurs went extinct at the K-Pg boundary, it was the it started with the time of the mammals, because they out competed. But, now we understand that the demise or the extinction of non-avian dinosaurs had nothing to do with competition or any biological change. It was actually caused by major changes in the physical environment, by the (con) volcanism, by the impact of asteroids, so, it was not really a competition scenario. The second point of this is mammals did not really take over the place of the dinosaur's right after the K-Pg extinction.

So, we have seen that the dinosaur size was really varying, there were small chicken sized dinosaurs, and also dinosaurs which were really big, the size of the whales. But, the mammals throughout Mesozoic were extremely small. They were smaller than a regular rodent, a mouse or a rat that we see today. So, it is they were not really competing for the same resources, and therefore, the entire idea of competition is probably not valid for the interaction between the two groups. The second point is right after the extinction of the non-avian dinosaurs, right after Mesozoic, it was not really the mammals which dominated.

So, in an ecosystem, once the predictor which was primarily the non-avian dinosaurs on land were gone, this predictor position will never be vacant, there would be other groups which

will take over that position. And that position was not really taken over by the mammals, it was actually taken over by birds.

(Refer Slide Time: 08:50)

So, the entire history of birds, as we know started from Mesozoic, and it was a very interesting point of the transition from dinosaur to birds. In fact, the transition is so smooth, it is very difficult to draw a line between real dinosaur and a real bird. But, after the extinction of the non-avian dinosaurs, the avian group started to dominate. And these were the groups which became the apex predator, so they became the top predator of the land. They were huge flightless birds, they had clawed feet and slicing beaks, and they basically were the most powerful animal group on land, and therefore, they started to act as an epics predictor.

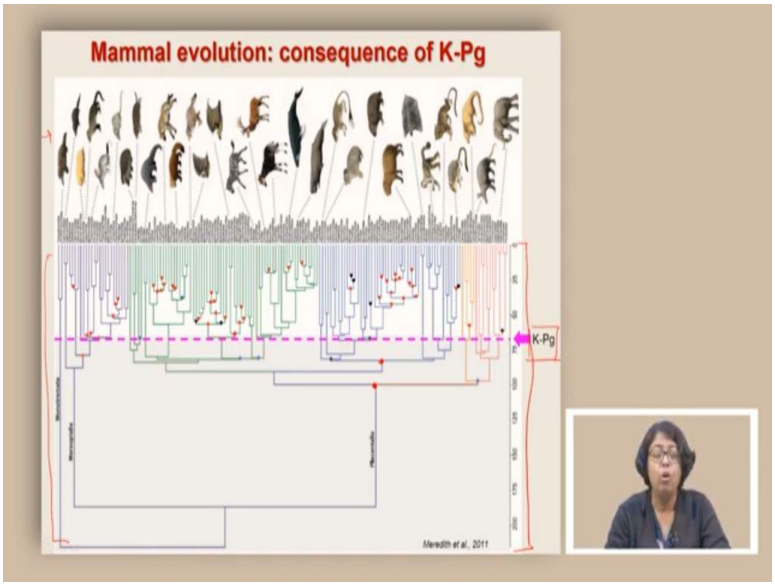
This particular example of Gastornis is a type of this large, flightless, extinct bird, which we find from the records of Palaeocene, Eocene. This particular picture is from the Eocene record of the United States, and these birds were really powerful. The most important part of it is they had all the predatory apparatus, they had a very strong beak, they had extremely powerful claws. They also had extremely powerful muscle structure in their feet, which indicates that they could run and chase their prey.

This is an artist's reconstruction of Gastornis during Eocene, and it is also interesting because what it is hunting is actually the ancestor of horse. Very interestingly, ancestors of the horses were much smaller compared to the modern horses. And in contrast, the Gastornis was much bigger than a regular modern bird that we see. So, the Gastornis in some sense were much similar to ostrich or emu, and much more powerful than that. And they could chase, they could hunt their prey, and they were completely carnivorous. Apart from these predatory

birds, they were only a very few birds with flight. Majority of these birds were so heavily structured that they could not fly, they could not effectively fly.

And we find no songbirds during this time. So, the more modern type of bird that we see today which can fly, which have various niche partitioning started to appear much later. But, the initial birds, even within Cenozoic were primarily the type of this large flightless predatory birds. The other important transition that we start to see is among the mammals.

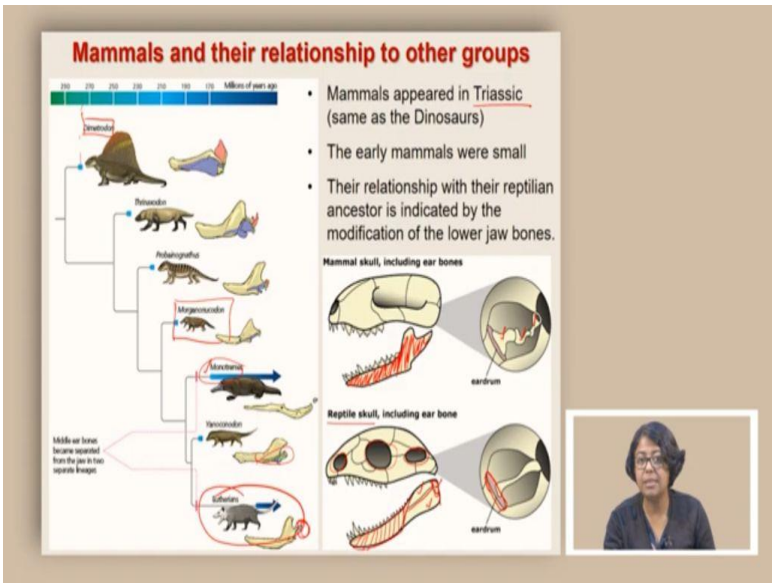
(Refer Slide Time: 12:15)



Now, this is a picture which shows the mammal diversity that we see today, and this is what it shows. So, the top part of it is showing all kinds of mammals that we see today, and the bottom of it shows their relationship, and also when did they start to originate? So, if you look at this side of the diagram, this has ages, and these ages can be derived by looking at their genetic structure, and finally looking into their fossil record to calibrate. Using both of these data, it is possible to relate them through a branching diagram, and also to say, when did these branchings appeared.

And what we see is majority of these branching nodes, which finally led to the different modern groups that we see today. All happened majority of them happened right after K-Pg, very few of these nodes you will find within the Mesozoic. So, it says that within Mesozoic, although the mammals were there, their diversity was very low. And the majority of the modern mammals actually started after K-Pg extinction. Now, what kind of mammals are we talking about? And also, where did they originate from?

(Refer Slide Time: 13:52)



Mammals appeared at the same time when the dinosaurs appeared. So, we are not really talking about reptiles, because the reptiles appeared much earlier as we know that reptiles actually started to appear in Permian even before that, when we started to see amniotic eggs, development of amniotic eggs, so Dimetrodon was one of the Permian reptiles, which we have a very good fossil record of. But, when we are talking about dinosaurs, they appeared only in Triassic, and interestingly, mammals also appeared in Triassic. Although for the entire Mesozoic, the dinosaurs started to diversify, and we see various groups of dinosaurs.

When it comes to mammals, we see only a very few groups. The question is how do we know it is a mammal? And that leads us to the understanding of how do we think the mammals originated? As I mentioned that the Dimetrodon was a reptile. But, then we start to get other groups which are more like mammal like reptiles. Now, the major difference that we can use to understand who mammals are and how do we recognize a mammal through their skeletal structure?

One important transition is the development of the jaws. As we know that reptilian skull, be it Dimetrodon on or other reptiles, they have first of all, they have these different holes. And these holes are quite distinct, and it can be used to identify things, and whether something is reptile or not. But, another part of it is their jaws. Now, if we look at the lower jaw, we will see that they have many components, they have many parts. On the other hand, if we look at the mammal jaw, it has only one part. Now the question is if all of them have a reptilian ancestors, then where did these bones go to?

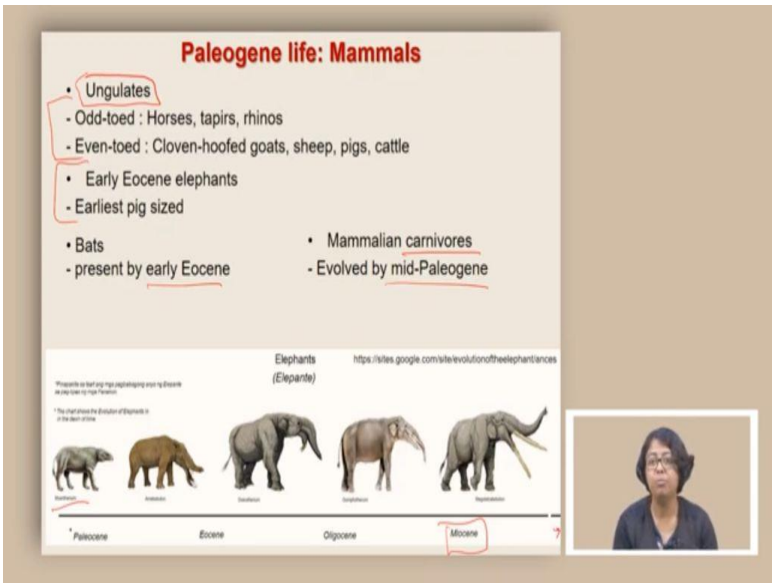
Because right now we have only one bone that we see in the mammals. And the answer is in the ear region of the mammals. As it turns out, if you look at the reptilian ear, you will find only one bone, sometimes, this structure is quite primitive. Whereas, when we look at the mammal bones and mammal ear, what we find is there are three distinct bones. And one idea is that these extra bones that we see in reptilian jaw, the lower jaw, those have actually converted into the bones in the middle ear. And that is what shows the transition from mammal like reptiles to original mammals.

And this we started to find in different groups independently. So, there are monotremes which are an out group of the mammals. That means it is a mammal, however, it has certain characters which are more similar to the reptiles. So, monotremes are groups which has a mammary gland, but it also lays eggs. So, egg line is a character which is more similar to the reptiles, but they have mammary gland and the young suckles the milk. And that means it is a more mammal like character. So, this is a group which sits somewhere between these mammal like reptiles and an original mammal.

There are other fossil evidences where we start to see these kinds of transition, where we see this ear bones development of proper ear bones, which are characters of mammals. So, this middle ear bone became separated from the jaw in two separate lineages, one is monotreme, and one is in this group. And both of these are showing the development of mammals, and these developments of the jaw region of the ear region, sometimes of the tooth. These started to appear in Triassic and that is how we know that the mammals were there in Triassic.

And the early mammals were definitely small. An important transition of Morganoncodon, this is one of the very early mammal like organism, probably a true mammal. These organisms were much smaller than a mouse or a rat, so they were really small organisms. Now, we will look at how the diversity changed over the Paleogene, because the entire Mesozoic, we are still talking about these small (rep), small mammals. And these small mammals have only one niche where they basically lived on a jungle, and probably hide in the bark of a tree. And they are primarily eating insects.

(Refer Slide Time: 19:45)



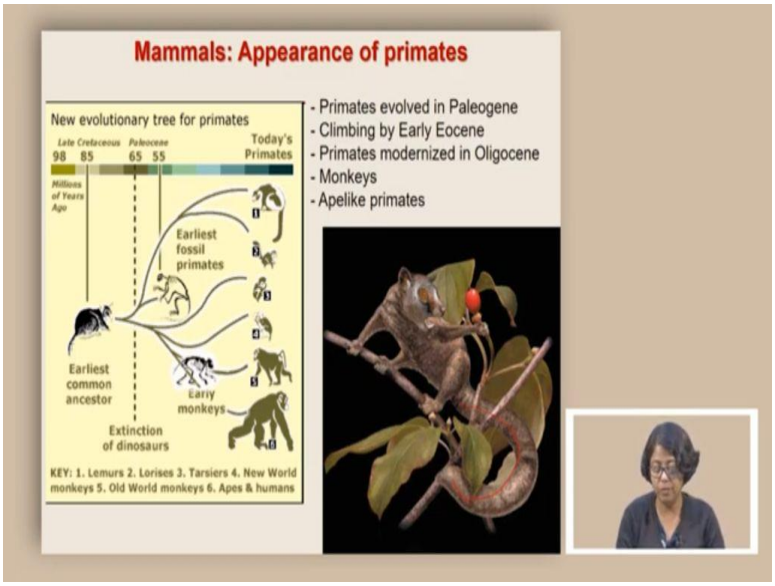
When we come to the Paleogene, we started to see development and diversification of various mammal groups, which started to take care of different environmental niches. The most important development was the development of Ungulates. So, these Ungulates, means it is the hoofed animal, the groups which have hoops, and it can be divided into two types. One is odd-toed, some things like horses, tapirs, rhinos. And the other one is even-toed, like goats, sheep, pigs, any kind of cattle that we can think of. Now, this very important group of ungulates which we are so familiar with, whenever we think of animals of today we think of these animals.

They appeared only in Paleogene. We also started to see early Eocene elephants, and these elephants were very different from the modern day elephants. These elephants were much smaller and their tasks were different from the modern day elephants. This is not even a modern day elephant, modern day elephant could be somewhere here. And this is only in Miocene, where we see this kind of changed elephants. But, what is very important to recognize is the early elephants were only big sized, so they were small.

So, we have animals which lived in the grassland, those were the ungulates. Then, we have animals like elephants, or ancestors of elephants which lived in the jungle. We have bats which started to appear in early Eocene which were primarily found in places near lakes, in shallow jungles. We also started to see carnivores. So, now, before this the apex predator was only the birds, in fact, predictors were only the birds on land. And around this time, we started to see major carnivorous mammals around with Paleogene things like cat family and the bears, all of these started to appear around this time.

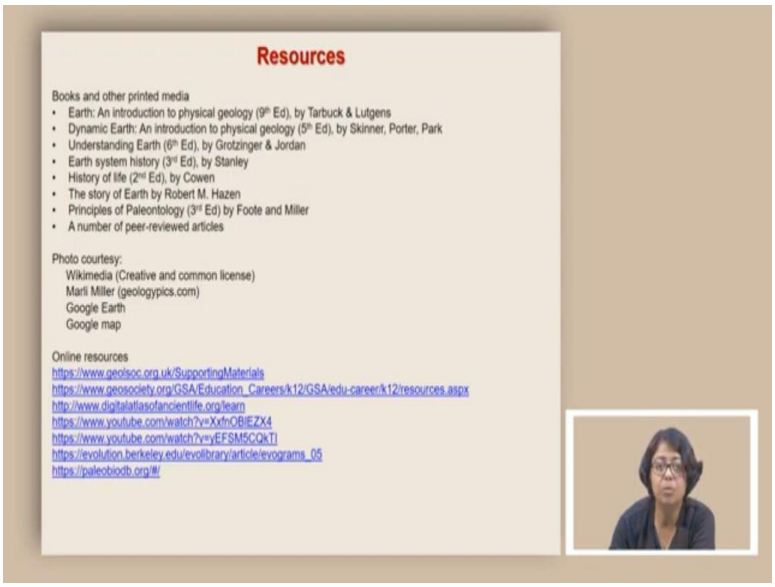
So, this is a time when we started to see a diversification of mammals and occupying different niche, occupying different areas of the ecosystem and performing different roles. So, this started to appear more of a modern day organisms that we are familiar with.

(Refer Slide Time: 22:35)



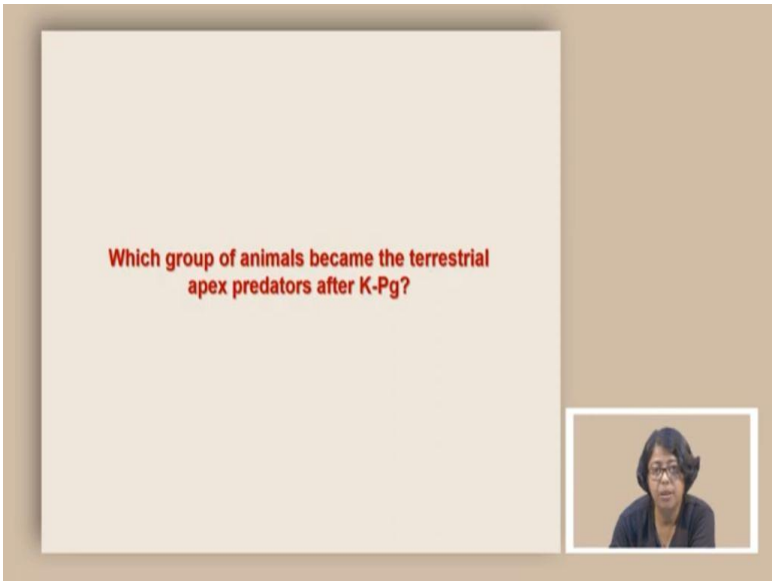
One more important group appeared around this time, and those are the primates. These are the groups which have opposable thumbs, and a long tail. So, they were small, but they had this advantage of primarily residing on the trees, and that is why the tails are important. And they appeared in early Eocene, the primates modernized during Oligocene. And these are the groups where we are the most, I mean, these were the groups where we have our ancestors from. So overall, we started to see all these major groups appearing during the early phase of Cenozoic.

(Refer Slide Time: 23:22)



So, in today's class, we learned about the predators that dominated the earth after the K-Pg extinction, which were the birds, large flightless birds. We also learned about the occupying of different ecological niches by the mammals throughout Cenozoic. We also learned how do we distinguish a mammal based on their skeletal structure and ear bone in Mesozoic. Here are some of the resources that I used to make the slides.

(Refer Slide Time: 24:04)



And here is a question for you to think about. Thank you.