The Evolution of the Earth and life
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Megafaunal Extinction

Welcome to the course Evolution of the Earth and Life. Today we are going to talk about an extinction event that is still continuing today.

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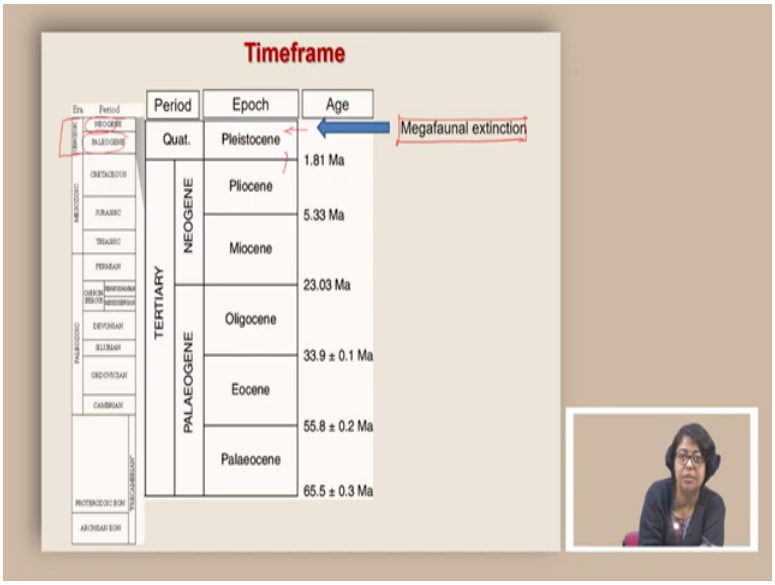

So let us orient ourselves in terms of the timeframe. As I mentioned, we are talking about Cenozoic and it has two periods, the Paleogene and the Neogene. Now within after Neogene, we have a period called Quaternary. It is one of the most recent periods. And the transition from Neogene to Quaternary is what is called Pliocene and Pleistocene.

And we started to see an extinction event towards the end of Pliocene and which continues till today. And we are going to learn about the first phase of it and which are the groups which went extinct. Generally, it is called a megafaunal extinction.

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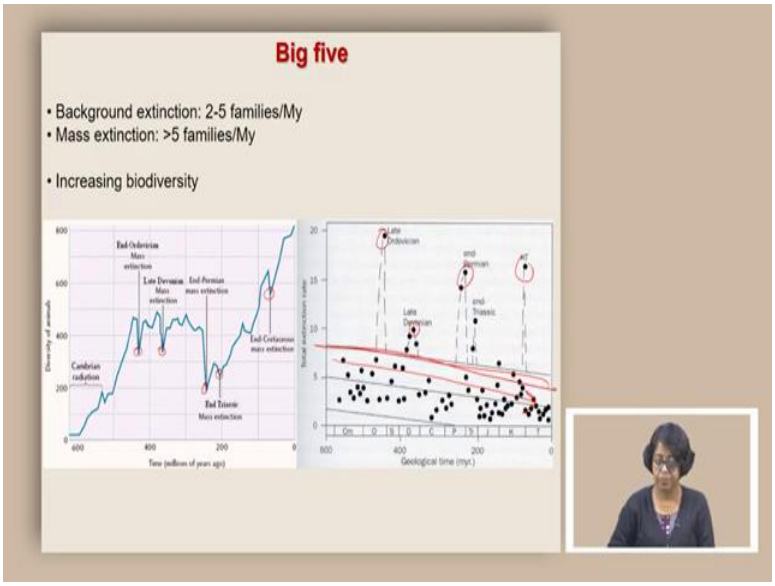

As we know that the earth has gone through multiple extinction events. And if we look at the diversity curve, we know there are five mass extinction events that took place in different times of the geologic time scale, but did it end at KPG extinction? And we are going to see today that there is a major extinction weave that started around Quaternary and then continues today.

Now when we think about the extinctions, there are two different types of extinction. Mass extinctions are those catastrophe events where more than five families co-extinct in a million year, and that is a quite high rate. More importantly, we also do not find any selectivity of extinction in mass extinctions. The groups which are very diverse just before the extinction boundary, they might get extinct in mass extinction.

In contrast, there can be events which are background extinctions. The background extinctions are extinctions, which are always going on some species or some families are always going extinct. And generally, the rate is two to five families per million year and that is a general low rate. And if you look at the extinction rates, we know that the background extinction is actually coming down as we are progressing towards a more recent age.

But the mass extinctions do not have such a decline in terms of their rate. Now if we look at the relatively recent events of extinction, exactly where do they fall? Do they fall under this background extinction criteria or do they actually represent a mass extinction? So that is what we are going to understand today.

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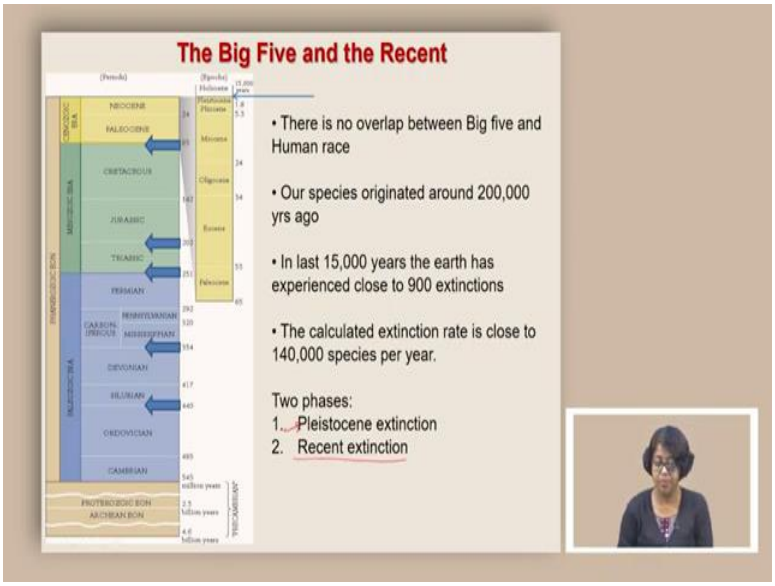

Now, when we try to compare this big five mass extinctions and the recent one, there is a slight difference. So, if we think about the big mass extinctions, the big five, there was no overlap between big five and human race. Our species originated around 200,000 years ago. And in last 15,000 years, the earth has experienced close to 900 events of extinction and therefore the calculated extinction rate is close to 140,000 species per year, which is a very high number.

However, we are observing it only for last 15,000 years, whereas any of these big five, the minimum duration over which it has been observed is close to a million year or in most of the cases more than 1 million years. And therefore, whether they can be comparable in terms of rate is a question that is hard to answer.

Today we are going to talk about the two phases of this recent extinction. One phase is an extinction, which primarily affected the Pleistocene megafauna and we are going to see that in this class. And the other one is a more recent extinction, which we will discuss later. Today's focus is going to be on the Pleistocene megafauna and their disappearance.

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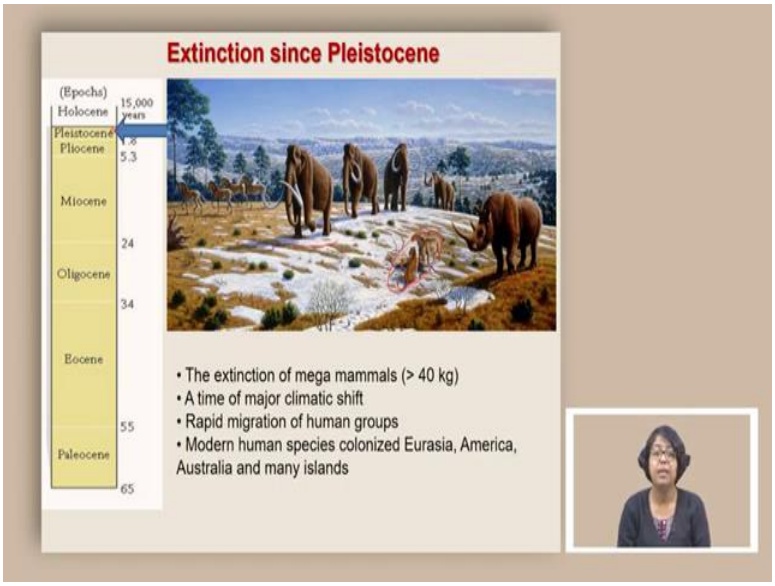

So around 15,000 years ago, which falls into the Pleistocene megafauna epoch, we started seeing disappearance of certain types of animals. So Pleistocene megafauna was a time of quite cold climate and expansion of the ice sheet, and it covered a substantial amount of the northern hemisphere. And there were a variety of animals which were adapted to it.

And what we observe are that certain types of animals, mostly the mega mammals, which weigh more than 40 kilos, they went extinct. This is also a time of major climatic shift. This is also a time when there was human migration across the whole world, modern than human species, colonized, Eurasia, America, Australia, and many other islands. And now the question is, what caused the extinction?

Was it the climate or was it the human expansion, or are these two things related? Now let us look at some of the victims which went extinct around this time. Just for a reference. I am saying that Pleistocene was a cold time and many of the animals which were living around this time were cold adapted. So, if we look at this artist reconstruction, we will find animals, which we really do not see today.

For example, you will see these large elephant-like organisms, but they have a very thick coat of far on their body. We will also see the rhino like organism, but again, it has a thick furry coat on top of it. We also have different types of horses all around the world. We have different kinds of tigers and lions, and some of them show slightly different characters than what we see today.

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So, if we have to summarize, this particular extinction accounted for 103 genera and it went extinct out of 186 genera. And we are primarily talking about the mega mammals. So out of 186 mammal genera, 103 genera when extinct, which is an enormously high rate, some of the very important component are some of the very important victims of this extinction include saber tooth tiger.

These were really large tigers which are abandoned in different parts of the world, including the Americas and the Europe. And it has this very large canine, and therefore it was named saber tooth tiger. Another example of animal which went extinct during this time, which was quite abundant in the northern hemisphere, was this wooly rhino.

And this wooly rhino had two horns and it has a very, very thick fur coat, which again shows its adaptive qualities in a cold climate. Now it was there in various parts of the world, which is clear from some of the cave paintings by early humans, where you will see these will rhinos. And this particular picture came from France, a cave from France, which also shows that they were abundant in Europe during this time.

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Some more extinction events which caused the extinction of different types of elephants. So this one is an wooly mammoth, which used to be abundant in cold areas including Europe and Northern America. There is also mastodon, which is another type of elephant. Again, cold adapted, slightly smaller than a wooly mammoth, but they were also abundant during this time for the entire North America.

The victims are not only associated with colder areas, we have a major extinction that we observe even in Asia, including India. So, this particular exhibit is found in India in the Indian Museum where it represents a type of elephant. It is called straight tusked elephant. And it is no longer surviving today it is completely extinct and it used to be very common throughout Asia in different parts of Asia.

And this went extinct around the same time. So, we have really large elephants which went extinct, different types of elephant, different species of elephant, which went extinct during this time. And today's diversity of elephants are really small and it is restricted only to three or four types.

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There are other victims too, giant kangaroos or large kangaroos, stag moose. It is a type of a deer, which used to be common in Europe, and they used to have a very large horn. And this is no longer available. This particular animal, the stag moose is no longer exist today. Apart from the mammals, we also find examples of extinction of other animals such as armadillos.

So, these large armadillos were very common in northern United States and no longer available today. They are completely extinct. Then there are these Asian ostrich, which used to be present in India and other parts of Asia, and they are completely extinct. There are tortoises which used to be there in various islands and other parts of the world, majority of them went extinct.

Apart from this Asian ostrich, there were other types of large birds. Some of them were called elephant birds. Many of those large birds also went extinct. And if you have to talk about the maximum amount of extinction in a specific area, it is the islands which show the maximum destruction or maximum extinction events are happening in a relatively short amount of time and short area, small area, which sounds quite interesting.

Because unlike mass extinctions, this particular extinction actually shows a selectivity. It is showing a selectivity, which shows that it is primarily the victims are primarily of large body size, which are mostly more than 40 kilos, and the extinction rate is maximum in smaller islands compared to large connected lands.

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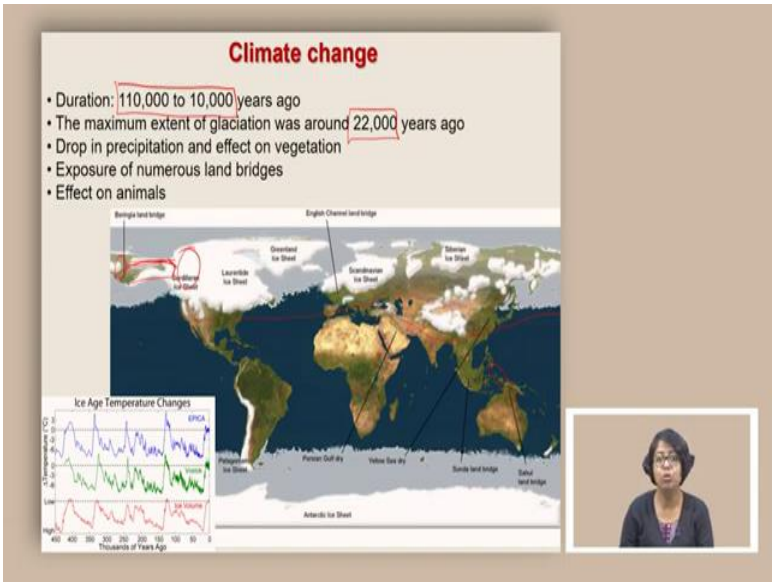

Now, what caused this extinction? This is one of the debates where the scientists have been contributing for a very long time without the final resolution. Now, one idea was that it is during the climate change and hence climate change contributed to the extinction. The duration of this event was between a 110,000 to 10,000 years. And the maximum extent of the glaciation was around 22,000 years ago.

When you have a major glaciation, and this is a map of the glaciers, there are two things which are very important. One thing is that because of the glaciation, first of all, there would be an ice cover. And you can see the ice cover extended covering almost the majority of the world where we do not really see the ice today, especially the continental ice sheets. Today. As a result, there are places which get connected.

So, two things happen. One is because of the cold climate, because the ice is accumulating in the form of glaciers, that water is not going back to the ocean, and therefore the ocean level drops down. When ocean level drops down, it exposes land bridges. The moment the ocean level goes up, these land bridges are getting inundated. But during glaciation, first of all, some of the land bridges gets exposed.

Most importantly, on top of those exposed land bridges. If you have ice cover, then it is fairly easy to go from one land to the other land through these exposed land bridges, which are often covered by ice and therefore making it a stable platform. And this in some way aided the movement of organisms. But another very important aspect of climate change and how it affects the organisms is through the change in vegetation.

So, during glaciation precipitation drops and as precipitation drops the overall vegetation cover effects. In normal times when there is no glaciation, wherever you have the wooded forest, they will suffer because of the lack of precipitation during glaciation. As a result, it is often going to convert to more open grasslands. And then the organisms, which were more adapted to live in wooded forests or thick canopy of forests, they suffer because these grasslands become more extensive.

Not only the grasslands which kind of type of bush or shrub can survive in cold climate versus a warm climate also depends on the adaptability of the plants. And if an organism is always adapted to eat a certain type of bush or shrub, change of glaciation or change in climate can affect their food source. So, change in climate can really severely impact what kind of organism is going to be there and whether their food is guaranteed or not.

But the issue is that to link this climate change with the extinction event is slightly difficult, primarily because the duration is sort of fixed. And once the duration is fixed, then you would expect all the extinctions to fall around the same time. So, the maximum extent of glaciation was 22,000 years ago, and then we expect to see the major extinction event around this time all over the world. But that is not the case. Now, the other option or the other alternative that people proposed is something to do with the human existence.

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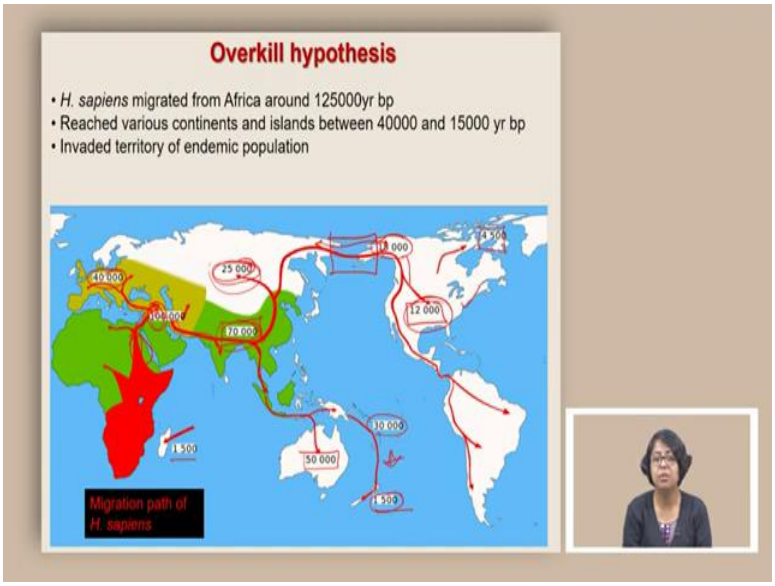

And this was proposed by Paul Martin where he proposed that it was basically an overkill hypothesis. We know that according to the out of Africa hypothesis that homo sapiens migrated from Africa around 125,000 years ago. And originally, they were primarily restricted to this region, but then they started to move all over the world at different times. And it is important to look at the times.

So, if we look at the Africa, that is where the, the oldest remains of homo sapiens appear. But then if we track the times, we will find that around 40,000 years ago, they reached Europe 100,000 years ago, they reached the Arabian Peninsula and some parts. Now, the reason why this is earlier, and this is later, is because this is closer in terms of the migration path and one has to go from here to the European part.

And that is why it took some time. And only 40,000 years ago, we started finding the remains of homo sapiens from Europe. Whereas if we look at the Arabian Peninsula and these parts of the world, we have records which goes back, which dates back 100,000 years ago. From here, coming to places like India again took some time. And therefore, the record is between India and this part differs in time.

The Indian record, or the Asian record in general, shows a timing of 70,000 years, whereas around this one we have 100,000 years ago, the areas in the north, in China and parts of Russia, they show records which show a much younger time, which is 25,000 years. So, it took more time to basically cross the barrier of the mountains and reach these regions. Things are very, very young when we look at the islands.

So, we find this record around 70,000 years ago, but when we look at Australia, it shows a very young record. It is 50,000 years. So basically, it took this population to move from here to reach Australia almost close to 20,000 years before they could reach this relatively isolated island. And the way they reached is through connecting land bridges. And these land bridges are often showing evidence of these movements now even farther south.

If you look at New Zealand and other places, we find even younger times because it actually requires navigation and building of boats before one can actually go to far islands like this. So, this shows 1,500 years ago, Madagascar also shows 1,500 years ago, farthest islands they also show 30,000 years ago. So generally, islands are difficult to navigate to and difficult to reach, and therefore their records are much younger.

The case of this particular continent is also very different because this continent, in some extent was completely isolated. The American continent was completely isolated from African continent and Eurasian continent. And the thing changed during the change of the climate because then this part of it got connected through the land bridge as well as through thick ice cover where the people could actually walk from the Asian continent to North American continent through bearing straits.

And this happened 15,000 years ago, which is relatively young considering that we have human records in this region, which date back to 70,000 years ago. And in this region 25,000 years ago, it took even some more time for them to reach the central part of North America. We started getting records only 12,000 years ago, and this is a general way how the human migration worked.

We also find records of very northern part northeastern part of Northern United States where the record goes to only 4,500 years. And the migration to South America also happened after this time. Now the question is now that we know that different parts of the world was populated at a different point of time, if it was the case of extinction because of the human interference, do we see a pattern by this time?

And this is one of the question that many people started pursuing because the idea was that many of the endemic population of species of animals were invaded by these expanding human groups. And what was the effect of these extremely skilled predator, which can hunt in groups?

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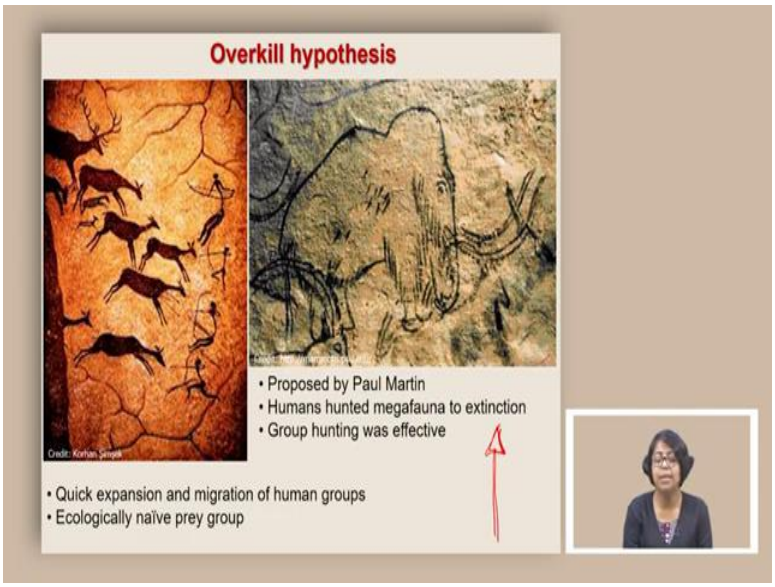

As I mentioned, that the overkill hypothesis was proposed by Paul Martin and what he proposed that humans hunted megafauna to extinction. It is quite clear that they were hunting in a group, and that is something quite unusual. And the animals which grew in isolation or the animals which grew without the human interference for a very long time, they were completely unaware of the evidence of such group hunting comes from the old cave paintings from Spain, some cave paintings from France, everywhere.

It is showing that a large group of animals are being hunted or a single large animal like Mammoth is being hunted by number of human beings with tools. This is also something that many of these endemic animals were completely unfamiliar with. The humans started to use tools initially, the stone tools and some of these stone tools at the beginning were blunt, but later they became much better in sharpening the tools.

And some of these tools helped them to attack the animal at a safer distance. So, they started using spears where there are stone heads on top of these peers. And because these piers were long, they could throw it and injure a large animal without being very close to it. And therefore, this group hunting was a very new thing for many of these animals which are not familiar with this phenomena.

The second point was that human beings were expanding at a very, very large speed. Their population growth was very high and such weak expansion and migration of human groups farther deteriorated the situation. The prey on the other hand, such as mammoths, such as deer, such as rhinos, they were unfamiliar with this group. And this group as a whole do not look very ferocious.

It is not a very large animal when we think from a perspective of prey when they are looking at a human being. Human beings are not really large animals. If we compare to mammoth or wooly rhino, they do not also have visible marks of predatory character like claws or tooth. So therefore, they appear unassuming. And some of these prey may have been unfamiliar with these particular predatory character, and therefore they could not cope with this particular form of attack and predation.

The other very important point is this is also the time when the human race were extensively using fire. And using fire means they were burning the vegetation. Burning vegetation basically leaves the ground baron often it does not yield any crop in the next development of plants for a very prolonged time. Now, these kind of animals such as large deers, will rhinos, elephants, all of them are herbivores.

And if you completely destroy the forest and destroy their grazing ground, then they will suffer from the lack of available food. So that also contributed to the overall decline of these large groups. These large groups typically have less number of offsprings in one grow, and their gestation periods are longer. And therefore, if you restrict the food and if you are killing

certain some individuals, the impact of it on a group becomes terrible, especially for large organisms.

One of the idea that why large organisms went extinct was the fact that large animals were being hunted specifically by human beings because they can provide a large amount of food to this group. On the other hand, if they were going for a medium sized organism or a small organism, the group hunting may still be successful, but the benefit out of it is very low, and therefore it makes more sense to go after the large animals.

That is one point. And the second point is that even if the human hunters were going after the large as well as small prey, it is only the large prey, which is going to be extremely poorly affected because of their smaller number of group size, smaller number of offsprings and their dependence on the group activity.

So, all of these probably contributed to the killing and final extinction of this large group. So, all of them have the same thing, common between them, not only the mammals, it is also the birds, it is also the tortoises. It is also all kinds of organisms, reptiles, everything is showing a very large size that when extinct in the same group, the large size when extinct, but there are other animals of the same group which are of the small size, they did not go extinct.

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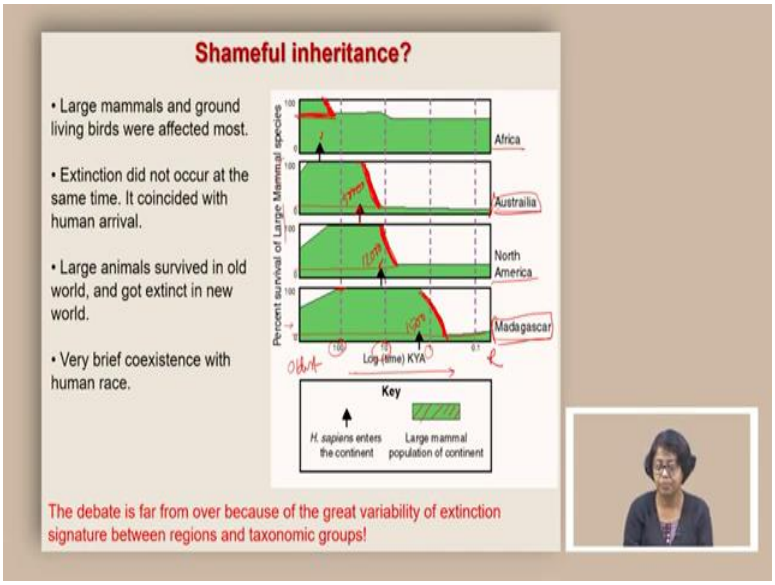

So finally, it is a time to look at the timing of these extinctions. If we look at the timing of the extinctions, we find a very interesting pattern. So, this is the extinction plotted here, where the time goes in here, and this is the most recent time, and this is the oldest time. And how many percent of the large mammals survived at a given point of time is represented by this green part.

So basically, if you look at this part, the entire thing is there. So, 100 percent of it is there. If we look at this particular part, the 100 percent, some start somewhere here. So that means 100,000 years ago, we find the largest number of large mammals around this time, around this place and these different parts of the world.

So, the first one is Africa, the second one is Australia, the third one is North America, and the fourth one is Madagascar. So, at 100,000 years ago in Madagascar, they have a very high diversity of large mammal species. And this is the 100 percent. And this 100 percent continues till 10,000 years ago till 1,000 years ago. But then it starts to decline.

And today it is only close to 10 percent of the original diversity of large mammal species that was there in Madagascar. Now, if we look at all these drops, this is when the drop happened in Madagascar. This is when the drop happened in North America. This is when the drop happened in Australia. This is the relatively small drop that happened in Africa. It is interesting that these drops are not of the same time.

In fact, the time differs significantly because this scale is a logarithmic scale. So, what we are saying is the African drop happened before 100,000 years ago. And when we look at Australia and North America, those drops happened sometime around 10,000 years ago. And when we look at Madagascar, it happened only maybe 500 years ago. So, the timings of when these extinction events were occurring are quite different.

The other thing that is important to notice here is always these drops marked in red are happening after you see this black arrow. Now, what are these black arrows? These black arrows are independent evidence of human settlement in these places. As I mentioned, that human settlements in all over the globe did not happen at the same time, homo sapiens started to migrate from Africa at different point of time and settled in different parts of the world.

So, in Africa, this happened the most quickly where the homo sapiens basically appeared. Now, if you look at this one, Africa shows a very early settlement of human beings. And when you have this settlement, after that, you started seeing this drop. When we look at Australia, the human settlement happened much later, and the red drop happened after that.

When we look at North America, the human settlement happened much later than that. Remember, this was close to 50,000 and this is close to 12,000. And the red line is always after this black line. In Madagascar, it is close to 1,500 years ago. And after that, this drop happens.

So, one of the argument was that we have these extinctions right after the human settlement started, and therefore humans are contributing in terms of their extinction. If it was because of the climate only, then it would have expected these declines to happen at the same time. More importantly, you would have expected these declines to have a seasonal and spatial signature.

So, for example, there is Australia, which is not really a very cold area. There is Madagascar, which is more or less a tropical area. And there the change in the climate might not be affecting it in terms of bringing the temperature down. There can be indirect effects, but only because of the temperature, it could not have been possible to wipe out the groups.

The other point of extreme cold wiping out the groups is not really valid because all of these organisms are cold adapted, and once an organism is cold adapted, it is going to survive better if the climate actually becomes colder. But they are not, they actually went extinct, which also says it is not really a direct effect of climate. There could be effect of indirect effect of climate by changing the vegetation, by changing the precipitation, but not a direct effect.

But this particular pattern where after human entrance and human settlement appears in a continent, we start seeing a major extinction supports the idea of over kill hypothesis. The extinction did not occur in the same time, it coincided with human arrival. And large mammals and ground living birds were affected the most.

These were also the most lucrative prey to hunt large mammals and ground living birds are also very vulnerable because they have less number of offsprings ground living. Birds often

lay their eggs on the ground, which are easily destructible and therefore they were affected more.

Large animals survived in old world and got extinct in new world. So, when we think about Africa, that is generally called an old world. It is the place where the human origination happened. And the new world are the places like Australia, North America, Madagascar, where the human settlement happened much later after migration.

So, if we look at how many of the groups which were there before went extinct for Africa, this amount is really low. It is not more than 20 percent. Whereas when we look at Australia, it is close to 80 percent. When we look at North America, it is close to 80 percent. When we look at Madagascar, it is probably close to 90 percent.

So, this major decline in diversity in new world also tells us that somehow the animals in the new world were more unfamiliar and more vulnerable to the attacks of humans. Whereas in Africa, probably because they grew up and they coexisted in the same ecosystem with human beings for a longer time, the large animals in Africa were already co-evolving and therefore not affected by the human behavior so much.

And this also brings us to the point that now, which hypothesis is absolutely correct? Now, this is far from over. This debate is far from over because of the great variability of extinction signature between regions and the taxonomy group. So, we have a variety of groups which went extinct in a particular area, but not extinct in other places.

There is also quite a bit of controversy in terms of the extinction signature because it is based on the fossil record and not all the areas have the same kind of preservation potential, but it is clear that something started to change around it probably climate affected the precipitation and thereby vegetation. But human settlement definitely impacted them either by direct hunting or by habitat destruction, by clearing out the forests and clearing out the grassland which were primary areas to survive for these large animals.

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So, in today's class, we learned about an extinction event, which started the towards the end of Pleistocene and continued throughout Quaternary. We learned that mostly the large mammals where the victims of this extinction, these mammals were plenty during the time of Pleistocene, which was a cold time, it was a time of large glaciation. These animals were cold adapted, so effect of just temperature drop did not make them go extinct.

The climate change probably changed the precipitation and therefore impacting the forest cover and type of vegetation eventually impacting the ecological structure of these animals. There is also another hypothesis of over kill, which argues that it is the direct hunting of large human groups, which made them go extinct.

We think that considering that majority of these extinctions are not coinciding in time and they always appear after the human settlement record, it strongly favors a hypothesis which argues that it is the climate change, which probably impacted the overall vegetation pattern, but it is the human settlement and human hunting and human use of the vegetation and forest, which finally deteriorated the food supply of these large organisms that along with direct hunting, finally led them to extinction.

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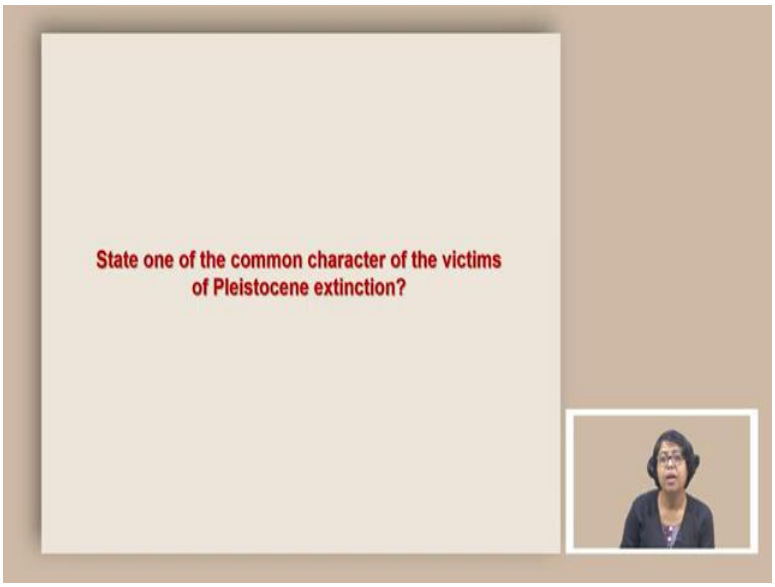

Here are some of the materials that I used for making the slides. And here is a question for you to think about. Thank you.