The Evolution of the Earth and life
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Development of Bipedality

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

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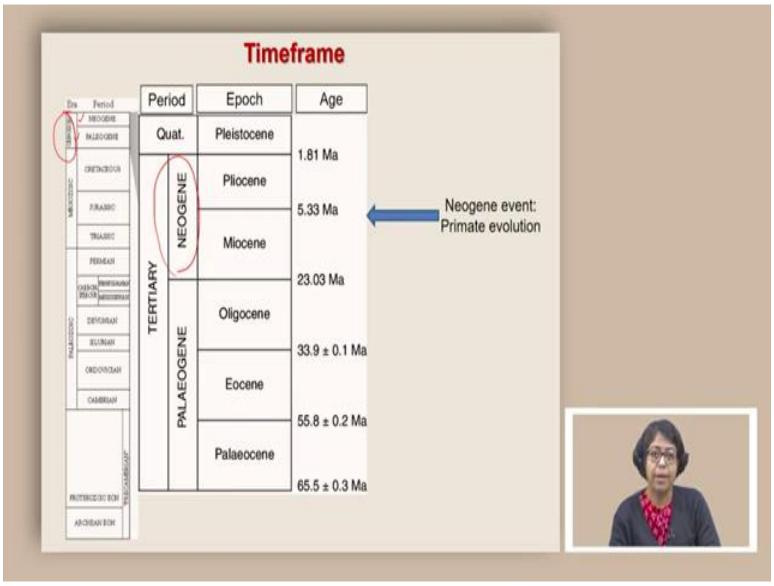

Let us see the timeframe. As I mentioned that we are in Cenozoic, and there are two periods within Cenozoic, namely the Palaeogene and Neogene. And today we are going to focus on Neogene developments. One very important aspect of the Neogene development is primate evolution. So, we are going to talk about primates, but more specifically a group of primates which can walk on two legs.

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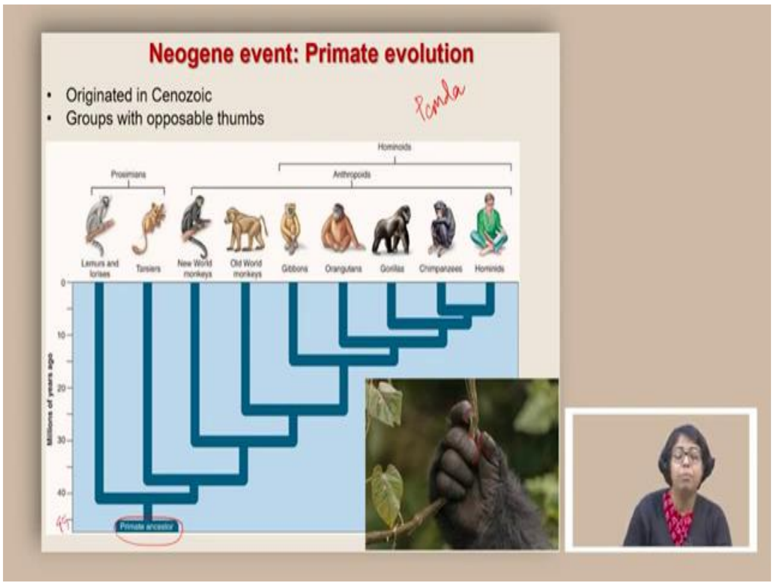

Primates originated in Cenozoic and we define primates as the group of mammals which have opposable thumb. And this opposable thumb gives us a fantastic benefit of grabbing things using tools. So, there are lots of benefits of opposable thumb, which the primates enjoy. So, if you look at this particular picture, you will see that this thumb and the rest of the digits, they can basically make a perfect grip, which is very important in picking up objects from the ground, grabbing tree branches, and also changing arrangement of very finer things.

Which is sort of difficult for groups which do not have this ability of using their fingers in this different direction. Now, except for the primates, there is another group outside the primates, which also has an apparent opposable thump, and that is panda. So, panda belongs to bear family, and it seems like that they also use their fingers similar to a primate, especially when they are holding a bamboo and chewing a bamboo.

Their functionality of their fingers are very similar to a primate, however, it is part of the bare family. So how can they have things which are similar to a primate? The answer is that they have an interesting adaptation of their wrist bone. So, their wrist bone gets extended a bit and works like a thumb, and therefore they actually have claws. But the extension of the wrist bone works like a thumb and works like an opposable thumb, and that is how they can maneuver the bamboo and other finer objects.

But apart from the exception of panda, all the other groups belong to primates which have this opposable thump. And if you look at their ancestors, their ancestors originated sometime around 50 million years ago, and it is important to 45 or 50 million years ago. It is important to recognize that this is a group that is part of the mammal group, and mammal group originated in Triassic.

So, we are talking about a sub branch of a mammal group, which is primates, which originated in Cenozoic and sometime around 45 million years ago or before that.

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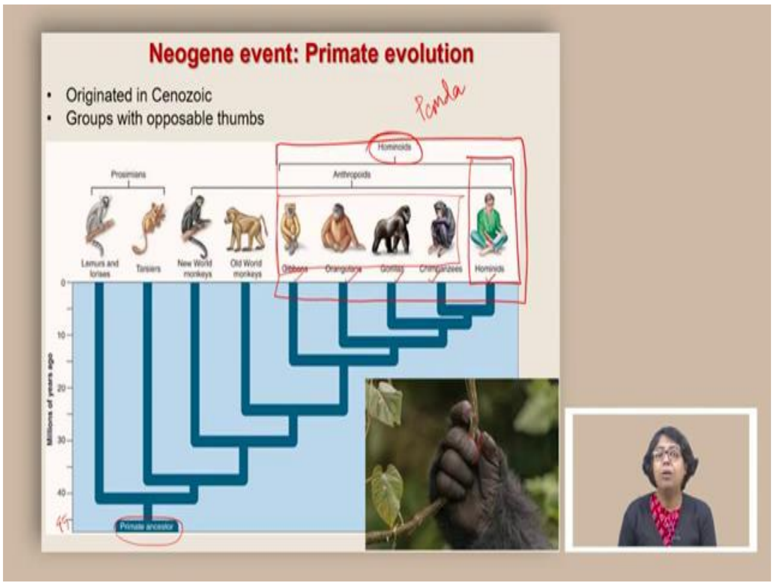

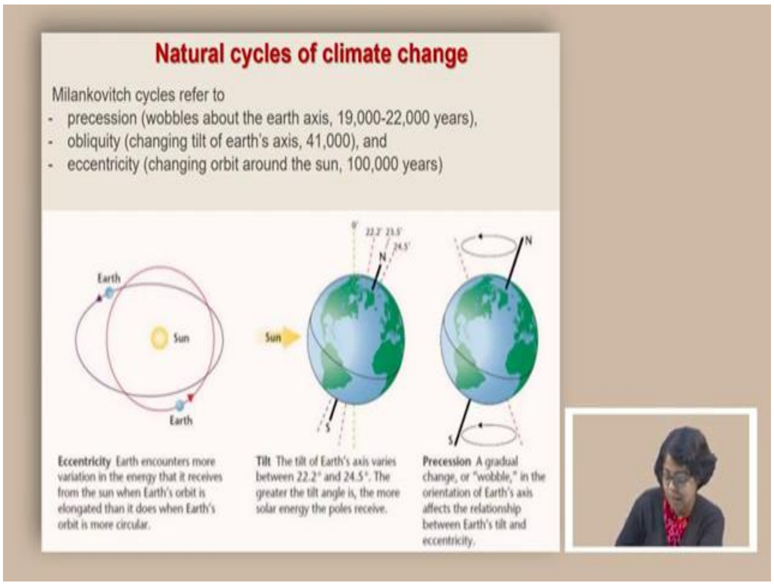

Now, once we see these developments of primates, it is not just the primates what we are interested, because during Cenozoic we understand that there was a diversity of primates, but it is one specific group of primates that we are going to be talking about, and that particular group is the hominid group. So now if we look at the primate classification, we will see that there are different primates.

But if you come to this part of the branching diagram, we find things which are quite similar to us. It has gibbons, it has orangutang, gorillas, chimpanzee, and then humans. And all of these have are under this group called hominoid. And these hominoid share certain characters. And then when you come to this particular branch called hominid, they have a specific character which is by bipedality, which means they can walk on their two legs upright for a consistently long time.

Why are we saying consistently long time? Because there are times when even the monkeys or the orangutangs, they can stand up and stay upright on two legs for some time, but not consistently. And therefore, we are saying that although they have some bipedality, but they do not have a consistent bipedality, the consistent bipedality or true bipedality.

We are finding in hominids, which is represented today by only our species, and the development of bipedality is something which is related to the climate change and climate variability of the Cenozoic. So, we know that there are natural climate variability, and often these climate variabilities are related to the position of the earth and how it is rotating.

And this is summarized in the Milankovitch which cycle. We know that there are three types. One is procession, one is obliquity, and there is eccentricity and they have different periodicity. So, if one is looking at the climate record, they are going to encounter different times and different periods of reputation of climate signal.

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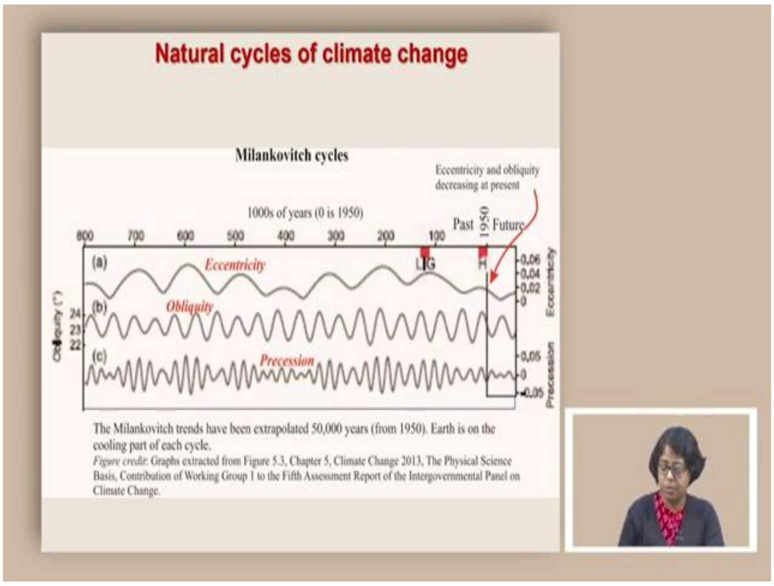

When we look at a signal like this, we will basically find changes and sometimes they are in sync, sometimes they are not in sync. But what it is going to show is, for example, precision has a much quicker change. And on the other hand, eccentricity shows you a much longer time scale change. And often these natural variabilities are resulting in drastic change in climate. It could be warming of the climate, it could be cooling down of the climate.

And what we find is we do see significant changes in the cooling in the phase in the last 10 million years or so where there is a periodic change in terms of cooling and subsequent warming, especially during the Neogene time it becomes even more pronounced. This changes within glacial and interglacial time.

Glacial time means the time when it is the average temperature is relatively lower and especially the ice sheet from the polar region extends to quite a bit. On the other hand, the interglacial times are the times when you see reduction in the ice cover and they are only concentrated in near the polar region.

So now we are going to look at the effect of these glacial and interglacial times on the change in the vegetation, and that is going to show us interesting patterns. But the question is how do we observe it when it is long passed? So, we are talking about a historical record of the climate and we have to use some paleoclimatic proxies to understand how that climate variability occurred in during the Neogene.

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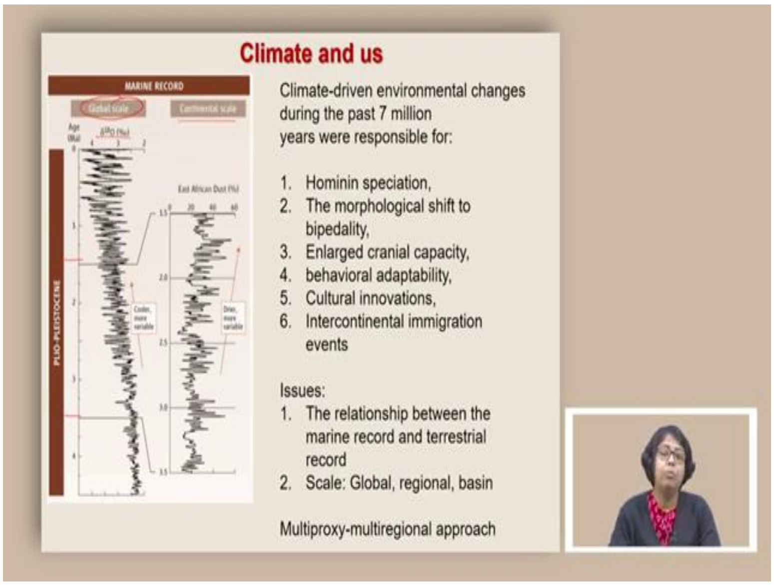

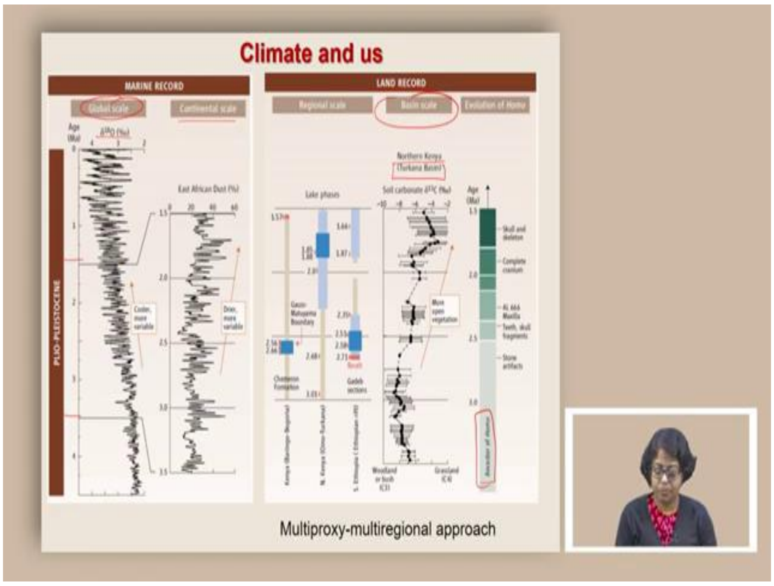

So, climate driven environmental changes during the past million years are supposed to be responsible for a lot of changes, and we will talk about it. Some major changes are home hominin speciation, the morphological shift to bipedality, enlarged cranial capacity, behavioral adaptability, cultural innovation, intercontinental immigration events. So, it is very important that we understand how the climate actually change during this period.

However, the problem is that the relationship between marine record and terrestrial record. So, what the marine record is telling you is not always supported by the terrestrial record. Secondly, at which scale you are looking at often impacts the results. So, for example, this is a marine record, which is of a global scale where if we look at this time period, it basically shows oxygen isotopic value and it basically shows a cooler, more valuable change in climate.

But at the same time, if we look at the continental scale, then we try to find the dryer more valuable. Now the question is which one is true and how do we do it? So, then people propose that let us look at multiproxy multi-regional approach where we are going to look at the paleoclimate proxies of different types from different areas covering different distances, and then probably we can resolve this issue.

And when people started doing it, they started finding interesting results, especially at the land record near the basin scale. So, majority of these changes in the last 7 million years or so within the primate group, especially in the hominoid group, are very well preserved in Africa. So therefore, there was an interest to understand the change in African landscape as well as the climate that is recorded in African record.

And when people did it for northern Kenya, this is called Turkana Basin, they have looked at the lakes, they have looked at the soil carbonate, which again contains this isotope of carbon, sometimes isotope of oxygen. And you can look at the variability. And when they looked at the variability, they found that this is a time when it is generally showing more open vegetation.

And this is also a time where we started finding from the ancestors of homo species to more advanced evolution of homo sapiens and other species. So how are the climate change related to vegetation?

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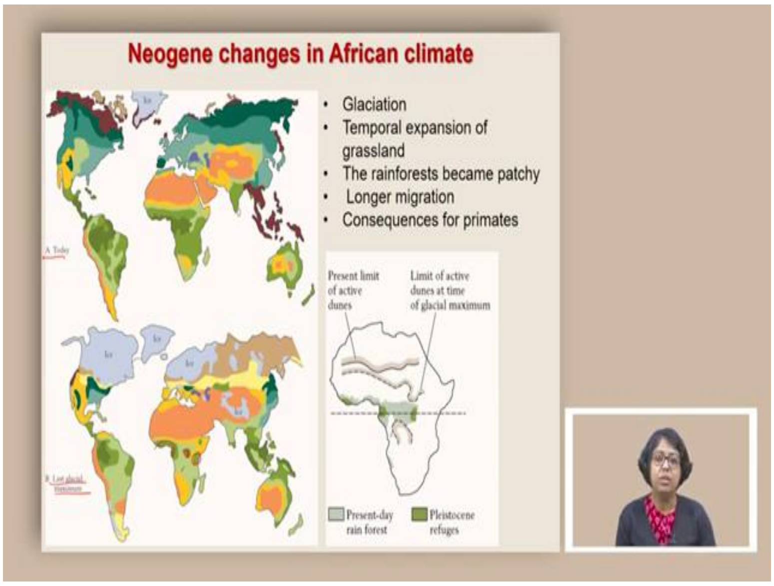

So, when you have major glacial period or cooler period, generally it impacts the precipitation, amount of rainfall becomes more variable, sometimes unpredictable, and sometimes less generally warmer temperature and warmer climate supports more precipitation, more rain.

Now when you have more rain during interglacial period, during those times, during those warm times, the Africa will be covered by a large forest cover. And these forest covers that we are talking about, they basically have large trees and which are completely a dense forest, provides a completely dense forest canopy. And this is ideal for many of the primates because many of these primates to start with were completely dependent on tree.

They are not big animals, they are not even very fierce animals like the cat family or the bears. So, one of the major advantages that they have and one of the ways they can protect themselves is by basically being a tree dweller. And when we look at the evolution of the primates, we actually see that they have all kinds of adaptation for living in the tree, either fully or at least partially so they can climb up the tree very well.

They are ankles are designed like that so that they can go up and down without any difficulty. They have opposable thumbs so they can grab the branches of the tree and will not fall very easily. They also have a tail in many of the early primate group. And these tails also provide balance. Sometimes they basically can hang themselves using the tail in the branch. So, they are primarily a group which are adapted to tree living.

And forest cover helps them because that is the resource that they are used to. They have a lot of trees where they can get protection and they can also get all resources starting from fruits, all kinds of ripe fruits. And leaves. These also make the primary component of their diet. Now this is during warm times, but during cold times, the scenario changes. So, this is a picture of today which is relatively warmer than the last glacial maxima.

Now if we compare, we are going to see an interesting thing that if we look at the African landscape today, it is looks more green. And if we look at the reconstruction of last glacial maxima when it was much colder, we will see these green patches are reducing, but most importantly they are becoming more patchy. Now the question is what is in between? What are these light green shades?

These light green shades are basically savanna. So, every time the climate goes to a relatively colder phase, we will see expansion of savanna. Savanna basically means a grassland. So instead of dense big tree cover and big canopy cover, we are going to see patchy forests. And in between them there will be really miles extending the grasslands. And those are the savanna.

And once the ecosystem changes because of the environmental change, this has an impact on the tree dwelling species because then they are forced to either adapt to savanna, which becomes very difficult because they basically do not have any resource that they can utilize. In savanna, they are primarily tree dependent. They are food comes from the tree and therefore it becomes difficult for them to live in savanna. The other possibility is to move to the next forest cover.

If one forest cover is completely depleted in resources. Smaller forest covers means it can support only a small group. But if the group grows in size, some of them have to migrate to the next forest cover where they can get the resources and migrating to the next forest cover means that they have to go through savanna where they are not really adapted to. And these longer migrations have a very important consequence on the evolution of primates.

So, so far we have been talking about primates, which are primarily tree living, things like monkeys, orangutang, bonobos. But how do they behave when they have to walk for a consistent amount of time or when they are in a longer migration through a patch where there are no trees?

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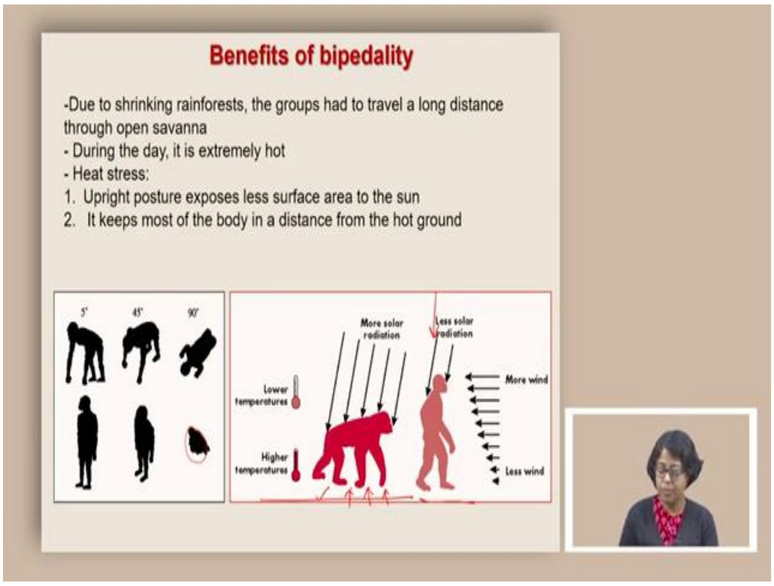

And that is where we started to see the benefit of bipedality. Again, bipedality means it is about the organismal character where they can walk on their two legs for a considerable long amount of time. Again, as I mentioned that there are organisms such as gorillas which can walk on knuckles and at times they can stand up.

But that does not really qualify for uh, bi movement or bipedality, because bipedality implies that they can do it for a considerable amount of time. Now, let us imagine an animal which is an obligated bipedal organism. That means it can walk on its two feet for a considerable amount of time. What are the benefits that it is going to get over the other organisms which cannot do it? Among the primates?

Now due to shrieking rainforest, the groups had to travel a long distance through open savanna. And in open savanna, because it is a grassland without bigger trees during the day, it is extremely hot and that impacts the organisms which are migrating because they will get heat stress. Now heat stress is relatively common for organisms which have larger surface area because I mean that posture basically attracts more sunlight.

So, if we are comparing a knuckle walker, then there it is absorbing their whole body is absorbing more solar radiation. More importantly, the ground has higher temperature and because it is closer to the ground, it is also experiencing very high temperature from below. On the other hand, if somebody is a bipedal walker, so they are not really walking on their knuckles. In that case, they are showing getting less solar radiation because of their what they are exposing to.

And also, majority of their body is quite far away from the ground because of both of these reasons. And the fact that if you look at the shadow of how an animal is oriented and how much shadow it is being created, it is quite clear that when you are standing upright, it basically creates very small amount of shadow. That means it is basically how much sunlight you are blocking. And both of these facts are going to give an advantage against the heat stress to organisms which can walk on their feet and not on their knuckles.

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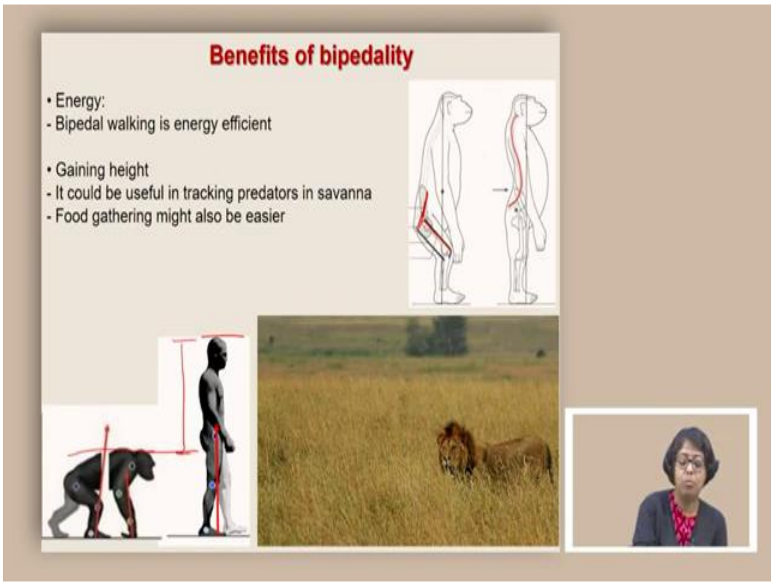

The second very important aspect is the energy. So, people did these experiments where they try to make the organisms walk, the primates walk, which are not really bipedal. So, as I mentioned that there are some gorillas occasionally stand up and they can walk on their two feet for some time even chimpanzees can do that. So, what people did, they basically made them walk for some time and measured how their heart is performing and how their stress level is.

And what they found is the primates, which are not bipedal by nature, when they walk on their two legs, it basically causes a lot of stress on their body. So, their body is not really designed to walk on two feet because if you look at a gorilla for example, or a chimpanzee will see that there is a change.

There is a contrast in terms of how the pelvic region works and in us what we will see that the vertebral column has this s-shaped pattern, which is ideal for walking. It might not be very ideal for sitting and that is why often we get problems with the back. But this is ideal for walking because if you think in terms of a liver, it basically supports fully, whereas this one does not really support it and therefore often their walk is kind of wobbly. It is not on the same path and therefore it is not energy efficient.

On the other hand, complete bipedal walking is energy efficient. The second advantage, which is a great advantage in savanna, is to gain height. So, when a monkey or a chimpanzee or a gorilla walks because they are knuckle walking, the average height reduces. And when in the savanna where because of the grass cover, it is difficult to spot any other animal unless you gain height.

It is a big disadvantage, especially if there are large cats. Large predator knowing their existence in much earlier than when you are facing them can prove to be a big advantage for bipedal organism, which are gaining a considerable amount of height in contrast to the knuckle walkers.

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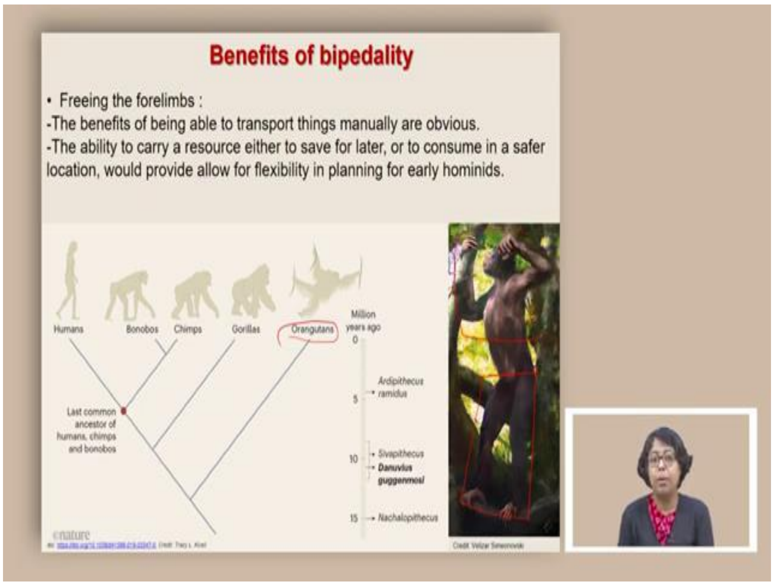

The third one is another important aspect. It is basically the moment you become a bipedal organism, completely bipedal organism. It also frees the fore limb. And freeing the fore limb is advantages because then they can transport things manually. For example, they can actually carry their babies much better. They can also carry some of food in two hands. They start to become better users of tools.

And the ability to carry resource either to save for later or to consume in a safer location provides more flexibility in the early home needs. Now when do we think that this bipedalism appeared and where did it appear from? So, there are two ways of thinking about it. Some people argue that there were, there are knuckle walkers and this bipedalism appeared from the knuckle walking and these knuckle walkers were sometimes in the trees also.

So, these are the groups which lived in trees for some time, but primarily walked on the ground on their knuckles and they gave rise to groups which started to walk bipedally from knuckle walking. And the other argument is that there can be groups which were primarily three living primates and they started walking bipedally. The present understanding is difficult.

The present data does not completely resolve this issue. However, there are recent findings which argues very strongly for groups which had skeletons which had the lower part of the limb adapted for bipedal walking on the other hand, the top part of the body and top part of the limbs. So, the fore limbs are adapted for tree living.

So, at times it is known even today that orangutans while in living in the trees can basically extend their body and completely stand bipedally, sometimes move bipedally while in the tree. And scientists think that there could be an ancestor based on certain fossil records where we find the upper torso or upper body and the fore limbs adapted for tree living and tree grabbing, whereas the lower limb is adapted for walking.

So, there could be some of these early hominids which were adapted this way. Finally giving rise to the groups which can walk completely bipedally. Now do we have a fossil evidence of bipedal walking?

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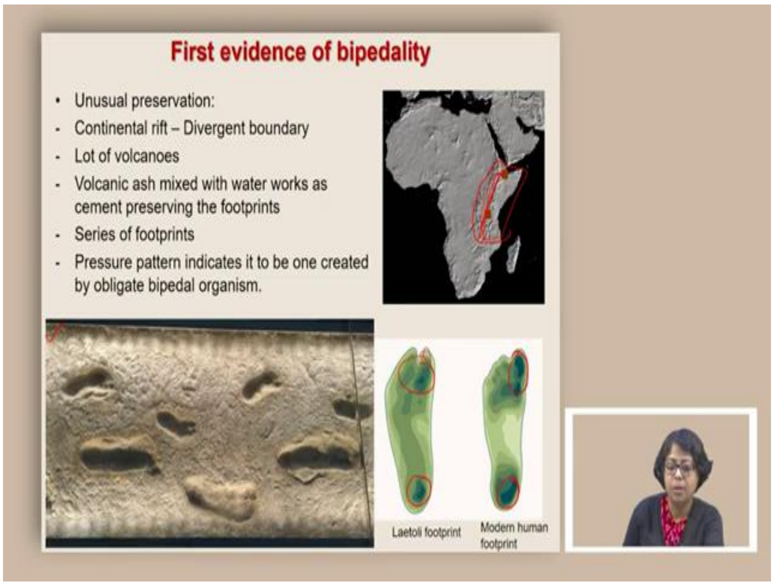

And the answer is yes. So, if you look at Africa, there are these regions which are known for their early homemade fossil record. It has a very unusual preservation. This is a continental rift region. This is called East African Rift. And there are a lot of volcans volcanic ash mixed with water work as cement preserving footprints. And there is a place called Laetoli where a series of footprints have been discovered.

And these footprints are shown a pattern which is inconsistent with knuckle walking. So, when we look at the modern human walking, we find that modern human footprints show a pressure concentration here as well as here knuckle walkers, even if they are using their legs, they never show this pattern. And when we see the Laetoli footprints, we basically find the same pressure concentration in these two areas.

However, the long big toe shows that it cannot be human group, but it is probably the earliest ancestor where we are seeing the bipedality. And this is a cast of the Laetoli footprint. And you see there are different sizes of footprints probably showing a group of early ancestors moving on the ash, which later hardened and preserved this record.

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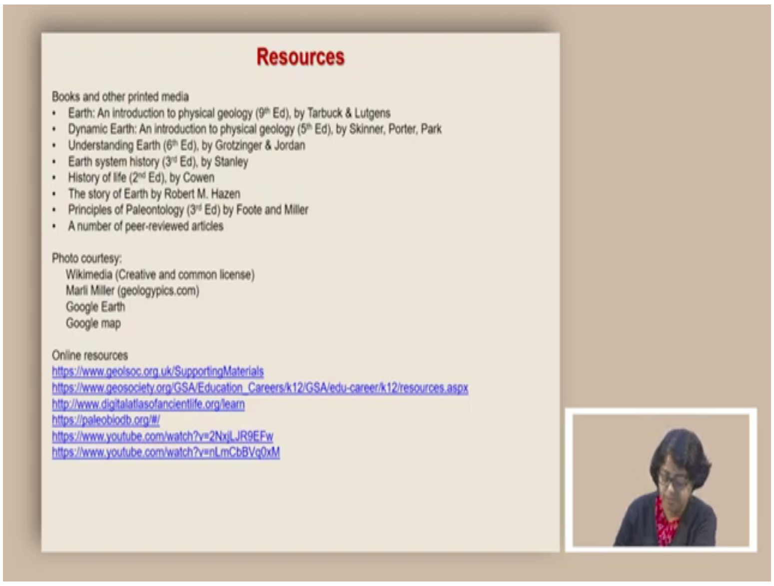

So, in summary today we learned who are the primates and how hominoids and hominids are part of the primates. What differentiates hominids from the primates is their ability to walk bipedally. We also talked about what might have been some of the advantages of walking bipedally for crossing savanna to go from one forest patch to the other forest patch.

And these expanding savanna during the times of glacial period was a real benefit for groups which can migrate more efficiently. We also learned that the ancestors of the first bipedal walking ancestor we do not have a fossil record of that particular ancestor but we do have fossil record at Laetoli, which shows a definite proof of bipedal walking. Here are some of the resources that I use to make these slides.

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