

Evolution of the Earth and Life
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Nature of Paleontological Data

So, today, we are going to learn a little bit about what the earth and climate sciences, especially focusing on the animal kingdom, and how do we know anything about them when they are not around. So if you think about Earth and climate science, we have a general interest about the things that are happening around us in the earth, and climate and we try to understand it using principles of Physics, Chemistry, Mathematics, Biology, and looking at observational patterns in the field and around us. So it is quite different in some cases, when it comes to experiments.

Think about a classical experiment that you would like to do in let us say biology. But your question is that how or whether a bacterial colony changes or grows, depending on light? That is it is a silly question, but still let us say that is your question. How do you go about, you will probably develop an experimental setup, and you keep some petri dishes, you try to grow the bacterial colony, and you expose them at a different intensity of light, because you are interested, whether changing the light intensity actually changes the growth of the bacteria? And so you are changing the initial condition of the experiment, and you are trying to understand what is the outcome, and how the outcome is changing?

Now, in earthen climate sciences our questions often involve things that happened over millions of time years and it is not possible do an experiment involving that time. For example, let us say many of us are curious to know how the Himalayas is formed. And let us say my question is, very specifically, if I want to know whether two tectonic plates collided and formed the Himalayas over a few million years. Now how do we approach it?

It is not really possible to change the initial condition and finally see what is the outcome, because there is no experimental facility at this point where we can really generate the Himalayas of the same scale. Instead, what we try to do, we try to break the question into smaller component, we first start with the field observation, we first start with the Himalayas, and try to understand how did it form, what are the patterns that we are observing? And then we try to make smaller questions of smaller scales that we can do in the experimental facility. But a big challenge is to bridge the gap between the experimental scale and finally what is the observational pattern.

So in some ways, it is slightly different and that is why it is so much fun to actually break a big question into smaller component design the experiment. But at the same time if you asked me to perform an experiment today here, it is going to be difficult. Because as I said, that the scales are very different both the time and the species scale, and it is not really easy to do it right here. So I will try to give you a general sense of a particular topic of earth and climate science, which I find fascinating and hopefully by the end of session, you will appreciate some of the aspects of how we do research or how we try to understand a question?

So my field of focus is paleontology, which basically means the study of ancient organisms. Paleo means old and the rest basically means study of organisms. And the first thing where we start from are the fossils. Although you might not be familiar with this term called paleontology or fossils, I am sure that you have seen enough things that are relevant to this discussion.

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So let us go to the first slide and let me show you a few pictures. Now, if you look at these pictures, I am sure that you have seen these pictures before and these pictures are taken from popular films. If you see in the left hand panel, you see this is a shot from the movie Ice Age, it is a cartoon film. If you look at the right hand panel, at the top, you see a clips from Jurassic Park, the latest version, and at the bottom, you see another movie clip from the recent movie called Meg. So these are all part of popular culture, many of you have seen these movies, many of you have probably looked at some of the clippings of these movies. Have you ever thought that what is what else is common among these three pictures? So let me give you a few seconds for you to figure out.

Yes, you are correct. None of these animals exist today. None of them you see around living and walking and moving, all of them are extinct. What means that they died long back ago, and we do not really have them around? Now my next question is, then how do we know anything about them? How do we know that whether this woolly mammoth actually walked on the earth? How did we know that these dinosaurs actually walked on the earth, killed animals, and they were so big? How did we know these big sharks, the Megalodons were living in the sea?

So this brings us to the question of fossils, because all of these information comes from the fossil record. So in next couple of minutes, we are going to talk something about the fossils and how do we know what we know, and how much of it is imagination that goes into the movies. So to start with fossils, by the just the term fossils, it basically means something that is dug up. In fact, historically, people did not really know what fossils were and they simply call anything that was dug up a fossil. But later on, people realized that we should have a proper definition and by that time people finally meet the definition as the remnant of any animal or their activity, any organism or their activity, as long as it is recorded in the rock, we are calling them fossils.

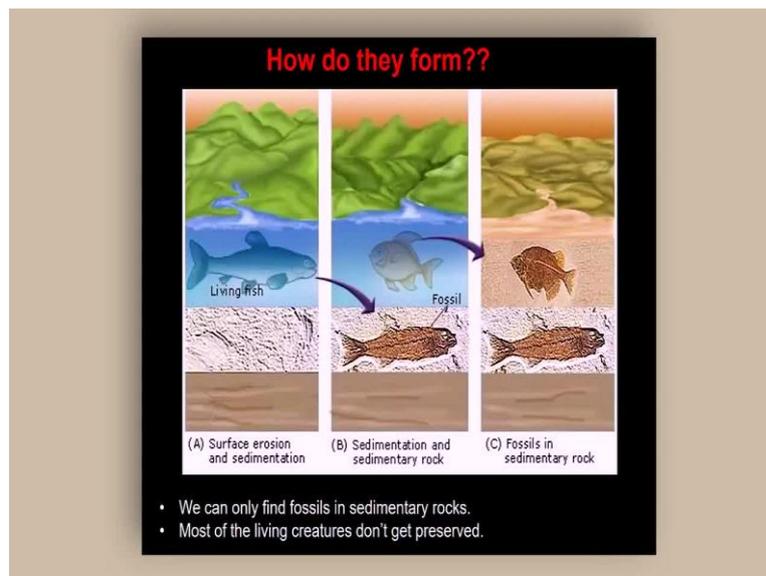
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Now the next question is, how do you get a fossil? So let us take a quick look at a picture. this is a classic fish fossil. Now, if you take a look at this fish fossil, what you will find that it has a skeleton, and it has some dark material inside and the rest of the light colored materials is actually the rock. Now, take back this idea a little bit more and think about it just for a second that we are talking about a living organisms, a living creature, swimming fish. How

do you get to make it trapped in a rock, rock is a solid thing. And that is one question which people wandered about for a very long time, they could see that there is a solid fish impression and they could also see that it is actually part of a solid rock. How do you ensure that a solid gets trapped inside another solid? It is a very simple question, but it bothered people for a very-very long time.

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So to start with a very old paleontologist, although they were not called paleontologist, they were primarily called naturalist at that point. He started to think about this problem and he came up with this idea that at some point of time, the rock that we are seeing today must have been in a situation where it was not solid, it must have turned solid at a later stage and that is the only way it can go and take the remnant of the fish and eventually solidify. So that was the first step of understanding how the fossils are made.

Now we know that fossils are primarily found in a specific type of rock, which is called a sedimentary rock. Now, if you look at this particular slide, you will see at the very left, there is this river which is flowing, and it is depositing its sediments. These are clay, sand, and a fish is swimming. In the next panel you are seeing that that particular fish died and it is covered by mud and it is buried. In the final panel at the very right, you are finding that the fish sort of looks like a fossil.

So in in very simple words, that if you have a live animal, you bury it, and then cover it with sediments, then with time if the sediment becomes really hard, and by the way, the sediments becomes harder if it gets pressed if it suffers through high temperature, pressure, then the

space between the sediments decreases, and it becomes really, really hard. It no longer becomes mushy like a mud rather, it connects to each of these particles and eventually becomes very, very hard, what we call a rock.

But the important part of it is, the animal after its dead should survive for some time before it goes into this rock building process, how does it happen? It is not so simple. Let us take a thought experiment. let us look around. I am sure wherever you are sitting or standing, you can see some creatures around. Maybe you can see a house lizard or maybe there is a fish in your aquarium. And let us take a moment to think what happens if unfortunately, one of these die.

So let us take the example of the fish. So when the fish in your aquarium dies, in the first couple of days, you will see that soft tissues rot. That means they are being attacked by the bacteria and eventually it will all fall off and you will probably see the skeleton, bare skeleton. And then if you keep it there, even though it will stink really bad, if you keep it there for some time, you will find that even the skeletons are disintegrating. And if you keep it there for a very-very long time, let us say a couple of years, probably we will see that there is absolutely nothing it is all mixed with the sediments if your aquarium actually has some sand at the bottom, and you do not really find anything.

Now the question is, is it going to be different if you look at the house lizard? Well probably no, you are still going to see the same thing that initially it is getting eaten by ants, then it is getting disintegrated, it starts to rot and eventually we will find the skeletons. Even the skeletons do not survive for very-very long. Finally, we will probably not find anything that is recognizable as part of the house lizard.

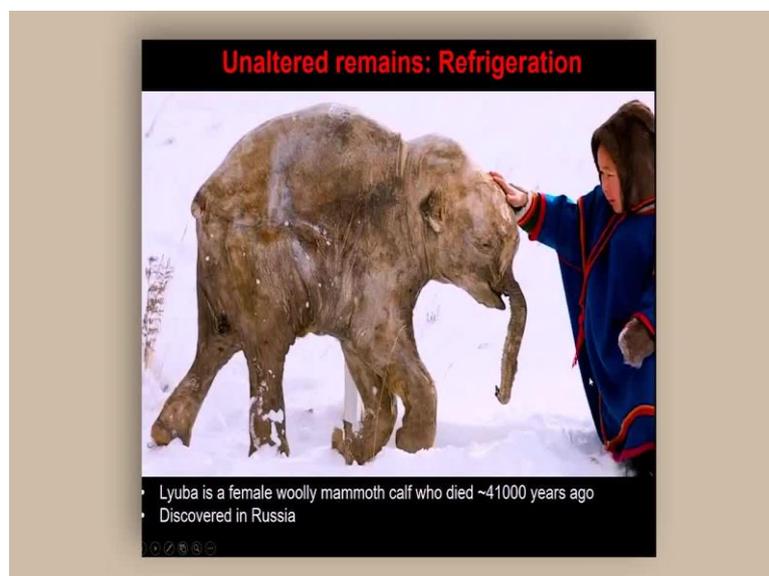
So if this is the common thing, then how come we do find fossils or remnants of old life, how do they escape this initial part where they are being attacked by bacteria or other kinds of scavengers? So somehow, they need to be get preserved in the very early phase before they are covered by sediments and they finally get into the rock building process. And we are going to think some of the ways where you can really think about how to preserve things.

So let us think start to think it is the kitchen. In kitchen we do use different techniques to preserve things. If you bring, let us say, a few carrots, and if you keep it aside, probably it is going to rot, but if you see the pickle were the carrots are still there, it might be surviving

there for a couple of years, and you are still enjoying it. So there are very simple things that we do to preserve organic materials, which are quite stunning.

So let us start with some of those. So the first thing that we are going to talk about is the refrigeration. Many of you have a fridge at your house and it is a place where we keep our food. Sometimes when we are hungry at night, we even try to go there and grab some things, but the main utility of the fridge is to keep it for some time, and how does it happen? The primary thing is its temperature, its cold. When you make something cold, many of the bacteria they cannot grow properly and as a result, the initial bacterial hunt does not happen. And that is one of the ways of preserving things. And that is one of the ways where nature preserve things.

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So let us take a look at a picture, which you might have seen before, some of you might not have seen and this is a fantastic example of a natural refrigeration. The picture that you see, is a woolly mammoth puff. It is a baby woolly mammoth and the name of this woolly mammoth is Lyuba, it was found from Russia. Now, unlike the first picture that I showed you, of ice age, where you have seen a cartoon of a woolly mammoth, this picture is not photo shopped. This picture has not been changed in any way. The person at the right hand side, she is a living kid and she is touching this Lyuba, which is obviously dead, but Lyuba lived 41,000 years ago. So this kid is actually touching a fossil, which is very-very old, how did it happen?

So as I said that Lyuba was found from Russia and I was quite ecstatic about using this picture because it brings me back memories when I was in my PhD and I was a student. This expedition was going on, and one of our former professor was involved in this expedition. So we used to hear a lot of interesting anecdotes of this expedition that how did they find Lyuba and what was so interesting about Lyuba?

So to give you a quick peek into Lyuba, Lyuba was found from Russia, as I said, and she was preserved in ice. Initially, she was covered with a mud blanket, and then trapped in ice. How did it happen in nature? Lyuba along with many other mammoths, they were crossing a river and they were trapped because the river had mud at the bottom and she was trapped inside. Eventually, she was completely covered by mud and because of the changes in the temperature, the river was frozen, and Lyuba got trapped in this frozen part of the river, which never melt.

As a result, it is like a permanent refrigeration for 41,000 years. And it is not very specific to Lyuba, because there are Siberian mammoths and mastodons which have been found like this, even in other spots. So preservation by refrigeration by natural refrigeration is quite common when it comes to animals, which lived in sub-arctic regions. Just to give you some more interesting facts about Lyuba, if we can go back to this picture, Lyuba was a tiny baby mammoth. It was 35 days old, and the age of the mammoth how old she was, in terms of her own age, can be deciphered by the teeth.

You can go through the development of tooth, and you can come up with a pretty good estimate of how old the fossils are, in terms of your own age. How old are they, in terms of our timescale, like 41,000 years old, that comes from the fact that you can really date the surrounding regions by where you carbon method in this case, and come up with a good age estimate.

Now, when people dissected Lyuba, they found that in its gut, there was still milk, undigested milk, and some feces or poop. And it is quite common among elephants to digest poop, because that helps them to grow bacterial colony in their gut, which helps them to digest other kinds of food, especially when they are babies. So all of these information comes from studying Lyuba, this one fossil, where it is preserved, to the point where all these tiny details are preserved in there. And if you look closely at its ears, you will see that part of the year is not preserved, it is actually chewed off by dogs, before it was reported. So the dogs did not

really did not find it, I mean, problematic to chew on a 41,000 year old meat, but that is the extent of preserving.

Now coming back what else do we do in terms of preservation, apart from refrigeration? Another technique that we use is, when we keep things in a plastic bag, and then take out the air out of it, it is generally called shrink wrap. This is another way of preserving things and it can survive for quite long. A close approximation would be if you keep things in a very tightly sealed pack, let us say a bag of chips, often it can survive quite long, compared to if you just keep it outside. And these natural shrink wrap are places or processes, where animals can be trapped inside a very thin layer of glue, which does not allow any air to go inside.

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Let us take a look at this slide. This is called an amber preservation, I am sure that you have seen a picture like this in the first Jurassic Park movie, where a Mosquito was trapped inside three sap, and these three saps have very light thin constitutions so it covers the entire insect, eventually it dries up. So it does not allow any air to go inside. So that organism in this case, the insect lives there forever. Extracting DNA from it, that is the part of the imagination, we are still not there yet the DNA degrades very quickly, so it is not possible at this point. But the insect gets preserved really well in this amber. So this is the natural shrink wrap. In fact, most of the insect history that we know comes from these kinds of amber preservation.

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The final one I am going to talk about, which constitutes this entire class of fossils, where which we call it a body fossil or unaltered remain, where you can actually find the soft tissue also, is pickle. So in your kitchen, when you go for pickling, what do you do? You play with extreme conditions, either you increase the salt content very much so that again, bacterial colony cannot survive, or you play with the pH make it extremely acidic, or you put a lot of oil that makes it survive for very long. Again, you do not allow any kind of bacterial growth or even if the bacterial growth is there, it is not basically making the things wrong, it can contribute in some other ways.

Now, this is one example that we are going to see in a few minutes, which actually shows the natural pickling. So again, I will go to this idea of what do we do in pickling? We ensure that there is no bacterial growth, or we are exhausting everything that is there. This particular fossil it is called the Ida. It is 47 million year old. It is one fossil which represents a primate. Primates are very small mammal organisms. We are primates and primates are almost defined by character that we have opposable thumbs, our thumbs are going on the other side of our fingers, so that is sort of a definition of primates. And Ida is one of the early primates.

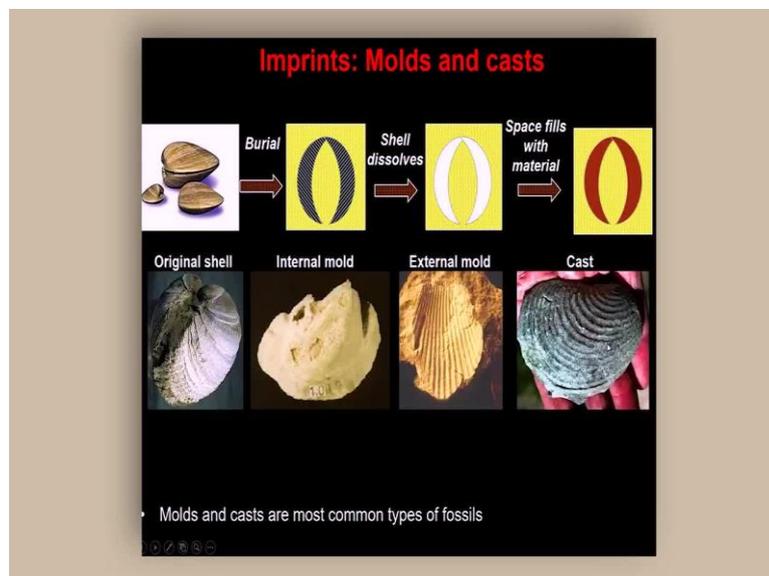
If you look closely, you will even see some of the hair, which is munched around the edges. And Ida was found in a place in Germany in a lake sediment, and this lake had a volcanic event, which basically contributed to the formation of the lake. But because of the high temperature in the initial phase was oxygen level was quite low. And whatever oxygen was there was consumed by the initial part where the leaves fell into it and got rotted, it all took

up the oxygen. So the bottom part of the lake got quite anoxic, that means there, not much oxygen available there. So there were no many living things that were there.

So after this tiny primate died, it fell down and it went into this lake and got deposited at the very bottom of the lake, there are no oxygen, so it did not start to rot. Eventually, it was covered by tiny sediments, some of them even had qualities, which make them very tightly bonded. So there is no way the oxygen can go inside or even any air can go inside and got trapped. So it is almost like a crust, but you are making sure that even the soft parts are there and it is not changing.

Eventually, the lake dried up, all the sediments got buried and finally it became a rock. And you have the preservation of this tiny little organism, with everything present, starting from its fingers to the tip of the tailbone, everything is preserved, including the hair on its body. So as I said that it is difficult to find development of fossils today, but because earth actually has a long history, although it is rare, we do find a number of fossils in various cases. And as I say that the development of fossils are rare incident, but even the natural centers or natural events can lead to the formation of force fossils.

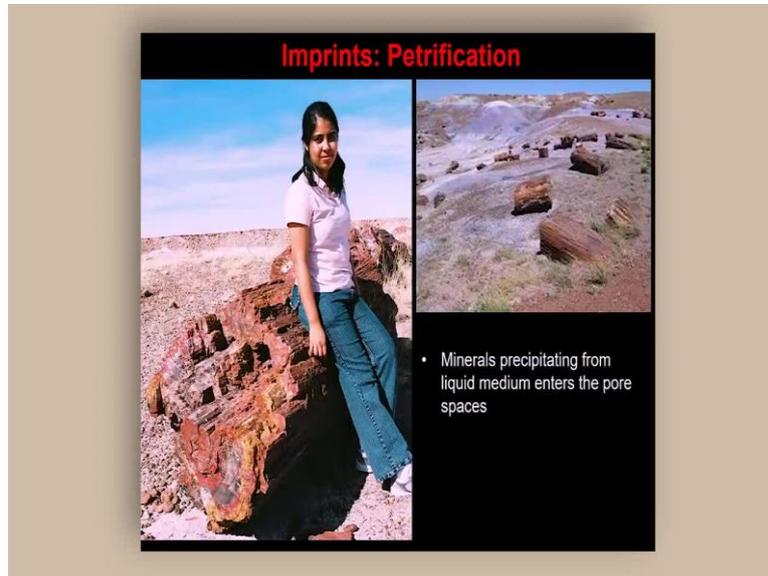
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Now, I will show some of the fossils, which are relatively more common, where we do not find the soft body, but we do find different kinds of preservation. So if we go to the next slide, will show that this is a cast and mold. So this is when the imprint of hard skeleton gets on the surface of the soft sediments, and they leave an impression of the hard body, these are

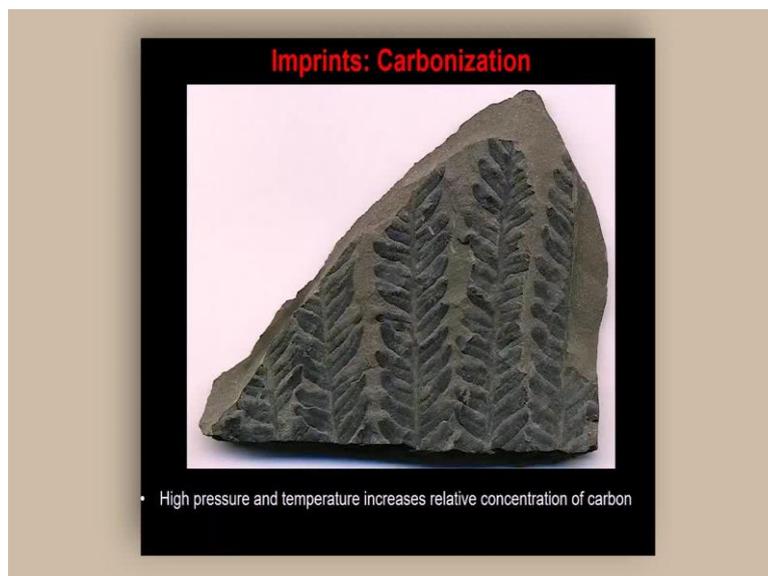
very common, and in fact, often we prefer these over the very delicate preservation of fossils, simply because we can find a lot of them in terms of its number.

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Now the next one is a different kind of an impression. This is where the minerals go inside the pore spaces of a tissue. In this case, I am sitting on a tree trunk, which is now have become a rock. So all the fine tissues have been replaced by silica, it is common sand, but it has been precipitated out of a silica solution. It happens near the volcanoes, but again, it is natural preservation and the picture that you see at the right shows that all kinds of tree trunks which are around all of them have been petrified.

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Going to the next slide is an example of carbonization. So if we quickly take a look at the table now and coming back from the slides, if we look at the table, I have some example of the carbonized fossil. So if you follow the arrowed area, you can actually see impression of some plant material right over there and here. So it is something like the formation of coal but not quite, it is happens relatively in lower temperature, where the carbon gets concentrated, retaining the shape of various animals that are trapped.

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But the other kind of fossil that is often found is the trace fossil, when you do not really find the animal or the impression of the animal, what you find is something about their activity, that there is a footprint, which shows the impression, but it actually shows that how the animal moved. There are other trace fossils also, the person is standing next to a large bottle, something like the barrow that I am holding in my hand. This is a barrow that we made by putting the wax in a crab hole.

But the same kind of thing you can also find in fossils, where the sediments filled the holes, which animals made, and then eventually gets liquefied. So these also tell us that exactly how the animals lived. The picture that you see a snail with a tiny hole, it is not the fossil of the snail that we are interested in. But what we see is something where the tiny hole is created by another snail to eat this snail. So it shows you something about their activity how they hunt.

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Now, I will quickly, very quickly show you a few fossils that I have on this table, and probably you can recognize that many of them have these impression. In this case, this is a past, so you do have the fossil and along with its original structure. And if you follow this one, this is also another fossil with very fine preservation. These all are fossils of things like this seashells that you find today, but we are talking about the age, which is in the tune of 25 million years. So this particular rock we found from Gujarat and it tells you a 25 million year old sea floor exactly how did it look like with all the sea shells and other kinds of animals.