Evolution of the Earth and Life
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Journey to Land: Transitional Forms

Welcome to the course Evolution of the Earth and Life. Today we are going to learn about the transitional forms between the fish and tetrapod when we talk about the transition of fish and tetrapod and before we can comment on what kind of features we are looking for in an organism that represents the transitional form it is important to understand what are some of the challenges a group faces when it moves from water to land.

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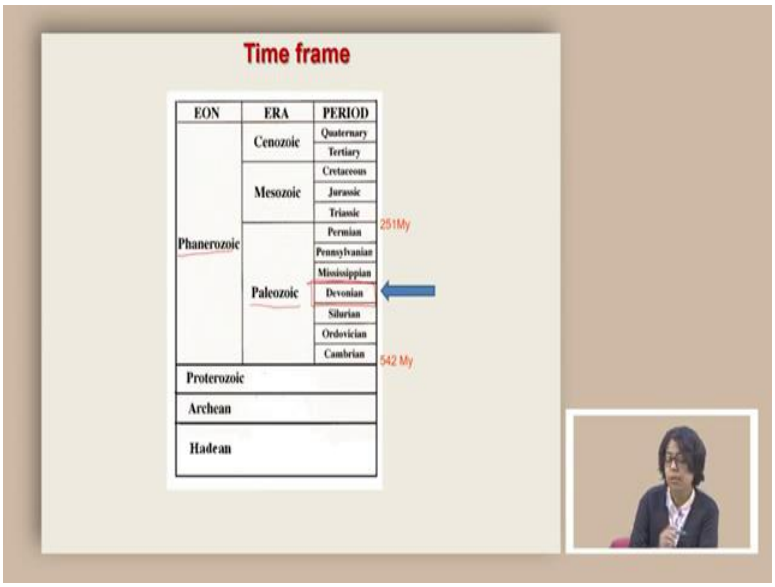

And the timeframe that we will be talking about again would fall into the EON Phanerozoic the ERA Paleozoic and we are focusing on the period of Devonian.

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The challenges of transition from water to land involves various things. The very important thing involves support and locomotion, let us try to understand it. So, when we think about water it is quite heavy on the other hand when we think about air it is quite light we are talking about density. Now, when we think about water the body density is almost equivalent to water density.

So, even when we swim today we know that apart from the head the rest of our body is neutrally buoyant. For majority of the organisms that we think we can think of they are neutrally buoyant. That means that their body is well supported by the water and the amount of water they are displacing has equal weight compared to their body mass as a result they are neutrally buoyant they are not going to sink they are not going to float up completely. And this is a perfect position to be in. Because that means in order to support the internal organs of a body you might not need real reinforcement in terms of major skeletons.

However, if a body is has to survive in air then the situation is quite different. In the air the body density is much much higher than the air density. As a result, we have to support our body through skeletons just to support ourselves and then locomotion is another challenge. So, gravity is the dominant force on land and therefore even if you are trying to preserve the internal organs it has to be encased in a solid skeleton. And that skeleton that robust skeleton needs to have some sort of a ground clearance so that nothing collapses at the ground.

So, that is one of the important differences of life in water versus life on land. So, for a fish, the movement is very easy because it is neutrally buoyant it can either go with the flow just

utilizing the various currents of the water or it can simply move just by small changes in the angle of it is body and therefore moving along those lines of the water current. We are primarily talking about horizontal motion and not vertical motion. For vertical motion, they have to change the buoyancy and that often is controlled or impacted by the bladder.

For land it is a completely different challenge on the land. There is no passive movement especially when we are talking about organisms with a high skeleton especially the coordinates. They are heavy they need to have a proper mechanism of locomotion. Second, to preserve their internal organ. They also need some robust skeleton so that things which are inside cannot collapse due to gravity.

So, movement of limbs become of crucial importance for the organisms which are living on the land. This is also related to how they can feed. For example, there are some fishes which can simply take water a lot of water and the nutrients which are mixed with water it can be particles that are coming from decaying flesh, it can be a lot of plankton, which are very fine and mixed with water. And they can basically take the water along with nutrients and finally release the water and take only the nutrients.

However, for land living organisms it is very difficult to do it. And therefore, they also have to have some way of monitoring the surrounding very carefully and go for active hunting. If they are eating either vegetable or flesh for either way they have to develop a mechanism by which they can eat. When fishes are moving in water again because they are spending really less energy in order to move and navigate. Often, if they have to take a view somewhere here that they rotate their entire body.

For land living organisms that is quite difficult and that can become very costly they have to do things quite fast. As a result, they detached their head from the rest of the body to take a look in different directions. As a result, we started finding the neck region which is a more flexible region and they can have our flexibility of the head without moving the rest of the body. So, these are very important locomotion support related issues that a group needs to change if that group moves from a water to land.

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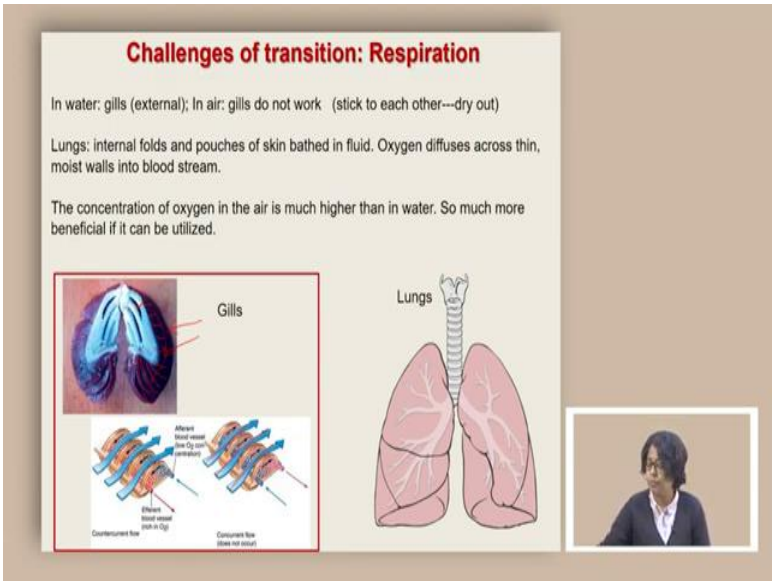

But then there is even more complicated things and the very basic things and those are respiration. Everybody has to breathe and respiration is a vital thing for any living organism. In water gills are the primary breathing apparatus. So, for fishes gills are external where the water can enter and these water have oxygen in it. And when they go through these gill slit is or these gills which are different they look like plop hanging from a structure. And when they are going through multiple such structures the water basically gets removed and they can absorb the oxygen from it.

But the important thing to recognize is this is not happening until it is external because it requires constant water movement so that things do not stick with each other different layers of gills they do not stick to each other the moment you take it out of the water it will dry out and it will dry out means they are going to stick to each other and there cannot be any passing of water and they cannot breathe air because if air passes through it this process is not going to work.

And therefore, gills can only work in the water where it is constantly washes it. When something is in air and it needs to breathe air the first thing that needs to be done it has to be something which is internal and therefore we really find lung which is a breathing apparatus for us it is an internal organ. The lung is an internal organ. It has these internal folds and pouches of skin and it is by the fluid oxygen diffuses through these thin moist walls of the bloodstream. The moment we take it out it dries out very quickly and it cannot be functional.

The concentration of the oxygen at this point is quite high in the atmosphere as a result if an organism can breathe oxygen from the air or it is very beneficial they can utilize in the same amount of air they can have much more oxygen compared to the same amount of water. However, the challenge is to utilize the air which can dry things and clearly the gills are not going to be a good option when an organism is breathing air. So, when we are thinking about transitional forms we should keep these points in mind and this will also tell us a particular organisms ability to live in the water or on the land.

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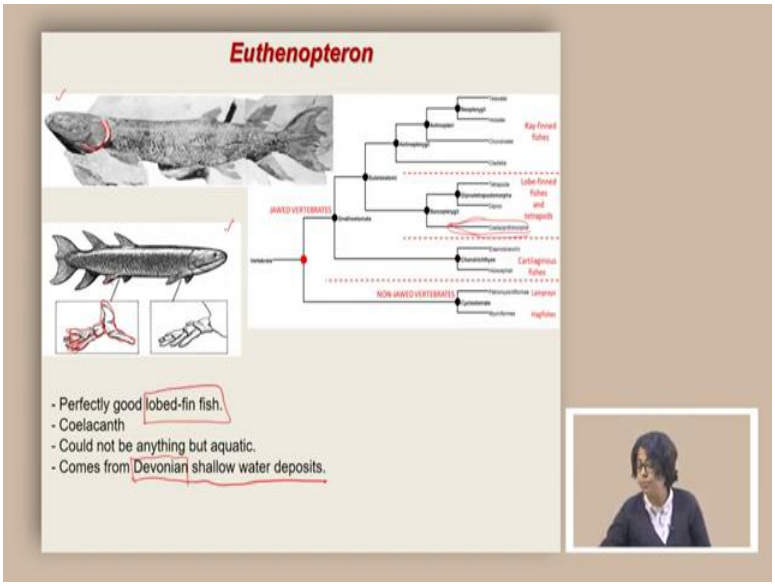

So, now we are going to learn about three types of fossils, three fossils that we find from Devonian. So, the first fossil that we are going to learn about is called and use euthenopteron, it looks something like this. And the artists reconstruction makes it something like this where the most important point to recognize is they have these bony skeletal structure which makes their fins and these bony structures have a central bone then followed by another part of the bone. And then the last set of bones create some bifurcation and some of the bones are quite distinct in terms of their size and shape compared to the surrounding bone. And this is how it looks like if you take a section of these fins.

Now, in terms of their place in this fish diagram, it would be somewhere around here. It is very similar to this coelacanth that we talked about which we still find today. So, this is a perfectly good lubed finfish it could not be anything but aquatic. The reason being that we even we are even finding these gills slits which are necessary for it is breathing and therefore it cannot be anything but aquatic.

But it also shows us these lobes, lobed fins, which may be quite handy in terms of the places where there is enough mud. And we find these kind of fish records from Devonian shallow water deposits where often there is quite a bit of sediments and not a very thick column of water. And again, just to orient ourselves, we are still talking about Devonian time and we are talking about a perfectly good lobed fin fish. It is still a fish.

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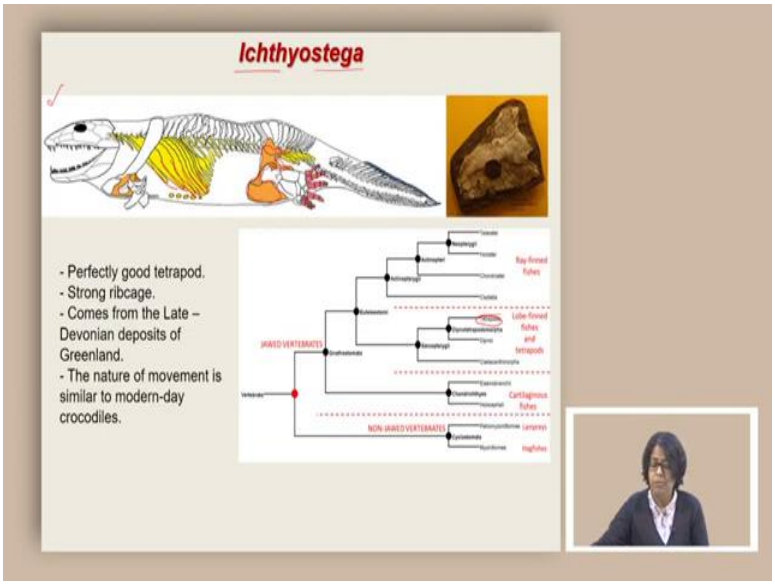

The second group that we are going to talk about is a perfectly good tetrapod. This is called an ichthyostega. Ichthyo means a fish and stega is the tetrapod or which can move around so it is like a fishy lizard. Now, this is quite different from euthenopteron. And the way we know that it is a perfectly good tetrapod is primarily because it comes from a deposit which is not always aquatic. The second important point is the ribcage. So, these ribcages are showing you that they really require support when they are dragging their body a very important character for any tetrapod which is living on the land.

And this ribcage are clear indications that they were living on the land. Another important part is how they are joints look like for the hind limb. This is again, something which is close to our pelvic girdle and it is quite similar to what we are finding in this ichthyostega. Where would it be plotted it would be plotted somewhere here and it the nature of the movement of this was probably similar to the modern-day crocodile.

And therefore, it is quite clear that there is no sort of transition, at least for this particular fossil which can tell us anything about the transition between euthenopteron and the tetrapod because this is already a developed tetrapod. So, we have to find something which is

primarily showing as the connection between the euthenopteron which was the loped finfish and ichthyostega which is a perfectly good tetrapod.

Now, the question is where should we look for it. And as we mentioned before that the best place to look for it would be a place where we are finding the rocks which represent aquatic rocks and which we should also focus on Devonian because this is the time when we are finding both the fish as well as tetrapod.

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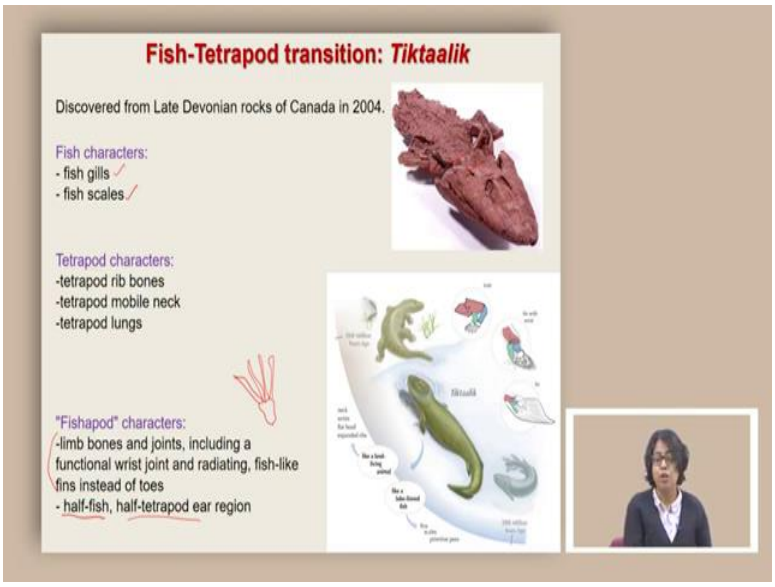

And such a transition appeared to the scientific community around 2004 through a discovery of late Devonian rocks of Canada. And the name of this fossil is tiktaalik. Now, tiktaalik has interesting characters. So, let us first focus on the characters that we will call as fish character. So, we find fish gills and also fish scales. And these are very typical characters of fish and this tells us that definitely they have some connection with the fishes. Then we also have characters in the same fossil which are typical tetrapod like characters.

The first one is the rib bones. We just learned that the robust rib bones are our signature of tetra pods which live on land, because when they are in the water and working just like a fish they do not need this kind of a robust rib cage. But in tiktaalik we do find such remnant of rib cages. We also find something called a mobile neck. Again, a feature that is not really required for typical fishers because they can rotate their body very easily. But for tiktaalik, we started finding an evidence of a mobile neck which helped them to move their head region without moving the entire body.

We also found evidences of lungs. And that is something which is clear that it is not really there for those fishes which never ventured out of their marine habitat or aquatic habitat. But the most amazing part of tiktaalik are some of the characters and those characters cannot be put in either the fish basket or the tetrapod basket. And those are the characters which we are calling fish a pod characters they are truly transitional. The first such character is their nature of limb bones, and the joints.

So, the limb bone and the joints show a functional wrist joint, again something which we never find in a fish. But it also has radiating fish like fins instead of just toes. So, this is a place where we started finding a wrist like bones and this wrist bone is very important for moving the did jets that we want to move those things without moving the entire hand or entire limb. But at the same time unlike our digits we actually have radiating bones which represent more of a fin.

So, this is a character which cannot be put either in tetrapod character or in fish character. The other important aspect of tiktaalik is their ear region. So, the ear bones are modified themselves depending on whether they are inside the water or in the air because the density of these mediums are different and therefore the hearing requires different bone structure.

And if you look at the bone structure of tiktaalik it shows a half fish half tetrapod ear region. And that is what is very important to recognize about this transitional form. So, after it is discovery it has been showcased in various peer reviewed literature with detailed description of each of these features. So, that we know very well about each of these features and how it relates a fish and a tetrapod.

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So, this is Neil Shubin, one of the discoverer of tiktaalik they explained the feature of tiktaalik joint in their limb joint and their digits in different places. So, you can actually find the wrist bone as well as these diverging digit like wounds but they are arranged in a more radiating fashion.

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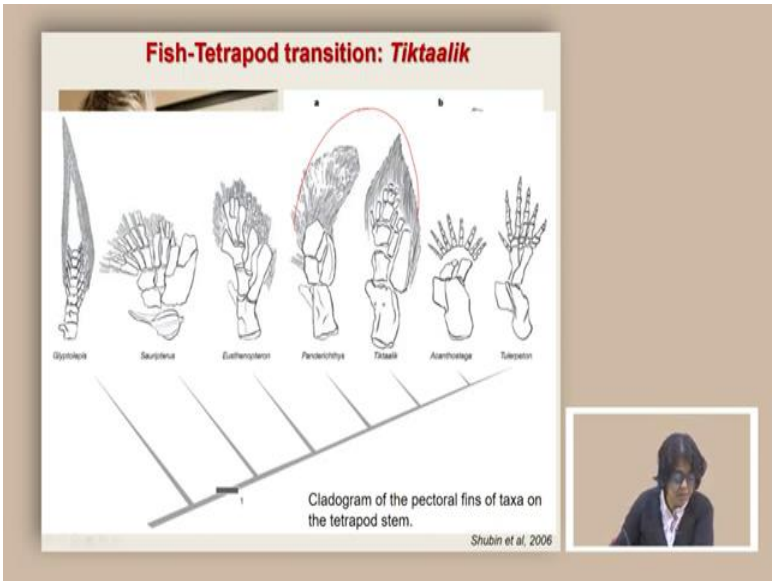

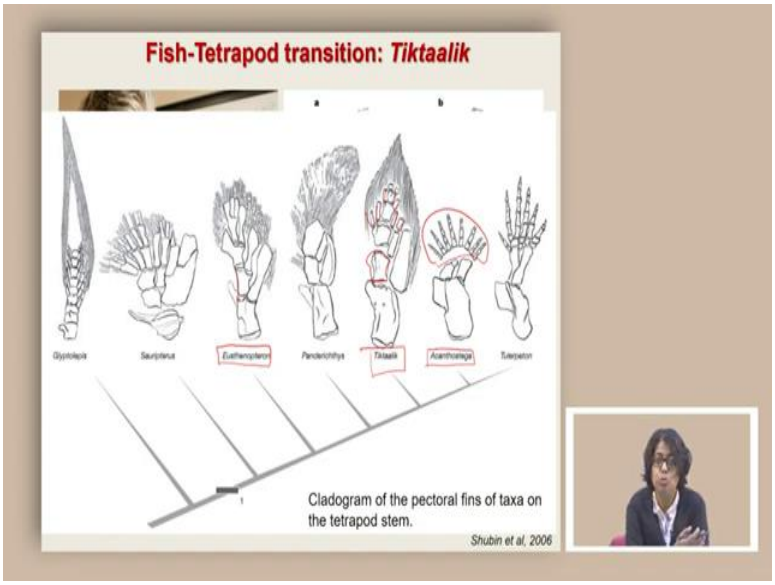

Now, if we look at all kinds of groups that we can expect in this place we will understand that there are different kinds of groups and it creates a spectrum there is not really a single transitional form. Rather, there are multiple forms which look somewhat similar to the next but creates a number of transition between euthenopteron and the ichthyostega. And these are some of the representative specimens. And everywhere we are looking at their limb region.

So, these are different names and the names that we are familiar with are these euthenopteron. So, where we can see that these bones clearly show a pattern which is more lobe like and then we have a acanthostega and then eventually ichthyostega where we have more like digit like patterns. And then there is tiktaalik where we see distinct difference from euthenopteron but also different from a acanthostega or ichthyostega or that we find later.

Because here, it is not a lobed rib fashion because we distinctly find bones like this which were not there. It is already marched in here. But then we also find digit like patterns. But these digits like patterns are not as clear and distinct that we find in the tetra pods. So, this is a truly remarkable transitional form in this whole spectrum of transitions that represent the journey from the water to land.

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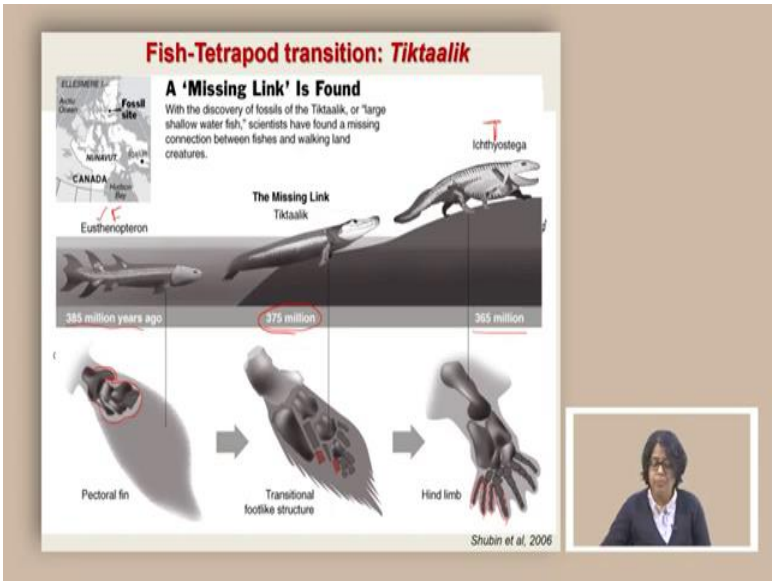

So, if we have to summarize we will find this interesting picture. All are happening around the Devonian. So, the tiktaalik was found from Canada and the meaning of the work tiktaalik basically means a large shallow water fish. And in terms of the timings we find that around 385 million years ago we started finding euthenopteron which is a lobed finfish. Then around 365 million years ago we started finding the tetra pods.

And then around 375 million years ago we started finding this transition. So, if we have to use the artist's reconstruction we are talking about a journey of a perfectly good fish moving on and then eventually creating a group which is a perfectly good tetrapod. And this transition is marked around 375 million years ago which falls into the Devonian.

And if we look at the character transition we find that even initially it was all a lobed fin which has bony structure. But then in tiktaalik we started finding a foot like structure where these bones are separated. And then in ichthyostega we find the development of digit is which are completely separated and it looks very close to what kind of tetra pods that we are familiar with it. Now, the question is, what were the advantages of moving on to land.

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So, probably one of the factors that helped the selection of the groups with limbs was their ability to move in the marshes. So, we know that during Devonian because of the growth of different kinds of plants many of the shallow water places had a lot of vegetation. That means these are the places which had a lot of thick vegetation creating a situation where it helps if the fishers have strong limbs to navigate through it.

The second point is when an area is has a thick vegetation in the water. This also consumes some of the because some of these vegetation also dies and decays and takes up some of the oxygen. Oxygen getting some oxygen outside the water always is beneficial for the groups which can take it. And while doing so that means they have to stick their neck up above the water and they are having a mobile neck helps because then you can catch prey just by observing them it also helps them to avoid by looking at or avoid some of their approaching predictors.

So, the massive growth of shallow water plants produced plant debris and the input. These kind of limbs help them to move around in those clogged marshes. And that is a big advantage. If a group develops some sort of limp and neck to go through it. Lungs help them to breathe air when the oxygen supply is relatively little it could be because of the decaying vegetation it could be because of a lot of sediments pod in shallow marshes. And if extended even short land ventures could enable them to escape some of the marine predictors which is a great advantage to survive.

And once they are on the land and even if they are sticking their neck out towards the land the land has already been occupied by organisms which belong to arthropod various kinds of insects are already there in the land. So, they could even tap into those food sources which are not available to those fishes which are only restricted in water. So, these kind of changes can give them and selective advantage. And researchers think that this could be some of the reasons or some of the reasons for the natural selection of this group which developed lung as well as the limbs.

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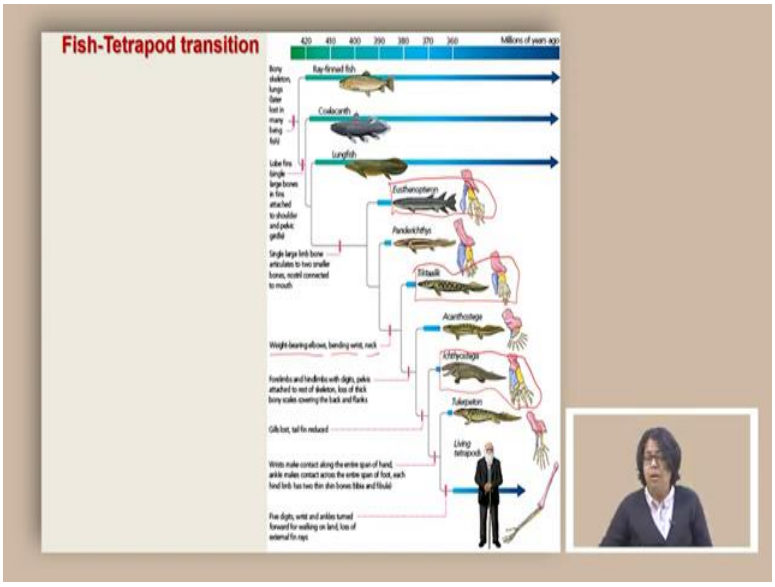

So, in summary, we learned some of the transitional forms that we talked about starting with euthenopteron and then moving on to tiktaalik we chose a clearly transitional form. Before we move on to things ichthyostega which is a perfectly developed to tetrapod and the major events or major characters that we find in tiktaalik includes weight bearing elbow bending wrist, neck, these are all characters, which are showing a change from what we find in euthenopteron.

But we do not really find things like complete loss of gills or tail fin the reduction of tail fin that we are finding in ichthyostega. So, this is a clear transitional form which is found from Canada, and it represents the Devonian events and we also learned why some of these changes were selected for through natural processes primarily because they gave them an advantage over the other fishes by going into the air just even for a short while and take air and also to navigate through marshes which have high vegetation.

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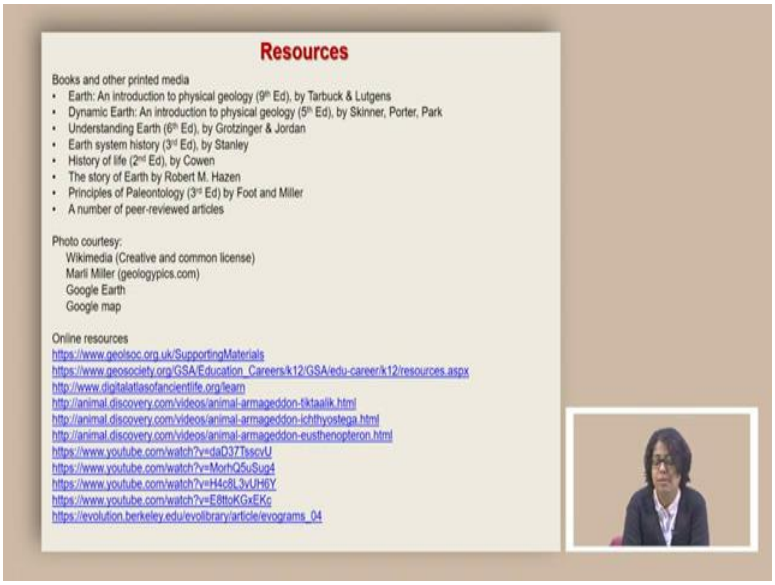

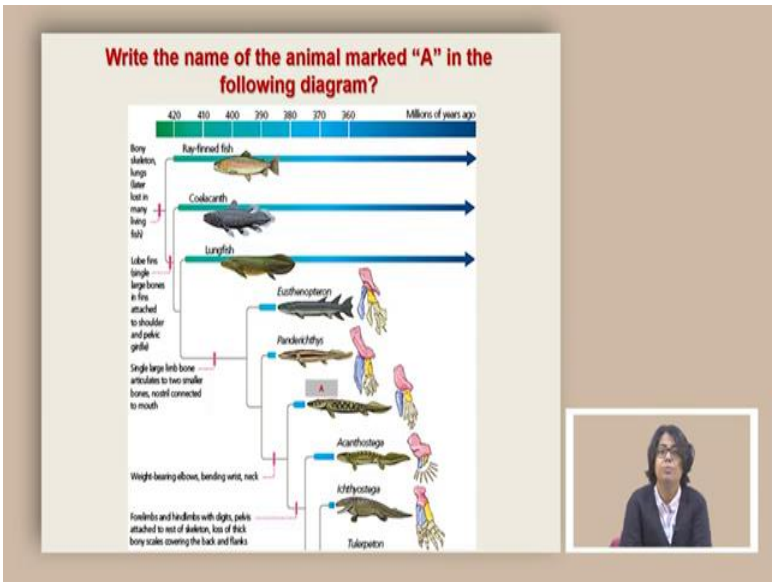

Here are some of the resources that I used to create the slides. Here is a question for you to think about. Thank you