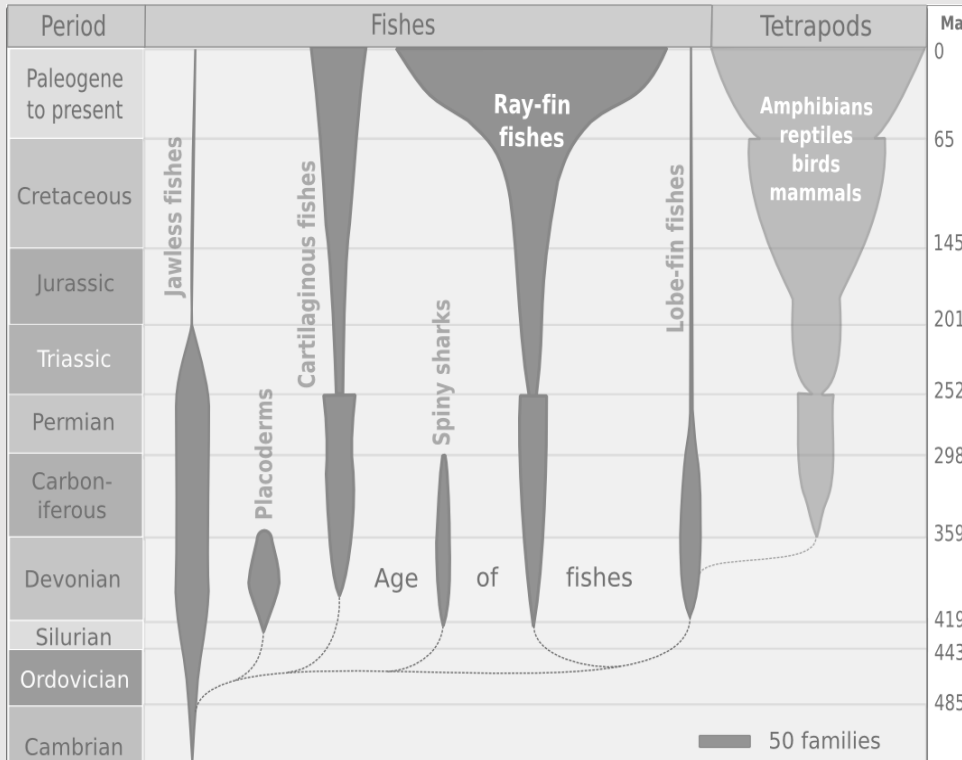


TERRESTRIALISATION / AMPHIBIAN EVOLUTION

- **An Amphibian:** is a creature with two lifestyles, one in water, the other on land.
- **Lobe-finned fish:** are fish that possessed both lungs and gills and had four fleshy fins supported by bones in a similar structure to a hand, e.g. lungfish.
- **A swim bladder:** is a sack-like structure, which can be filled with gas or fluid, to control buoyancy in fish.
- **A tetrapod:** is a creature with four limbs.
- **Terrestrial:** describes anything relating to land.

A BRIEF INTRODUCTION TO TERRESTRIALISATION

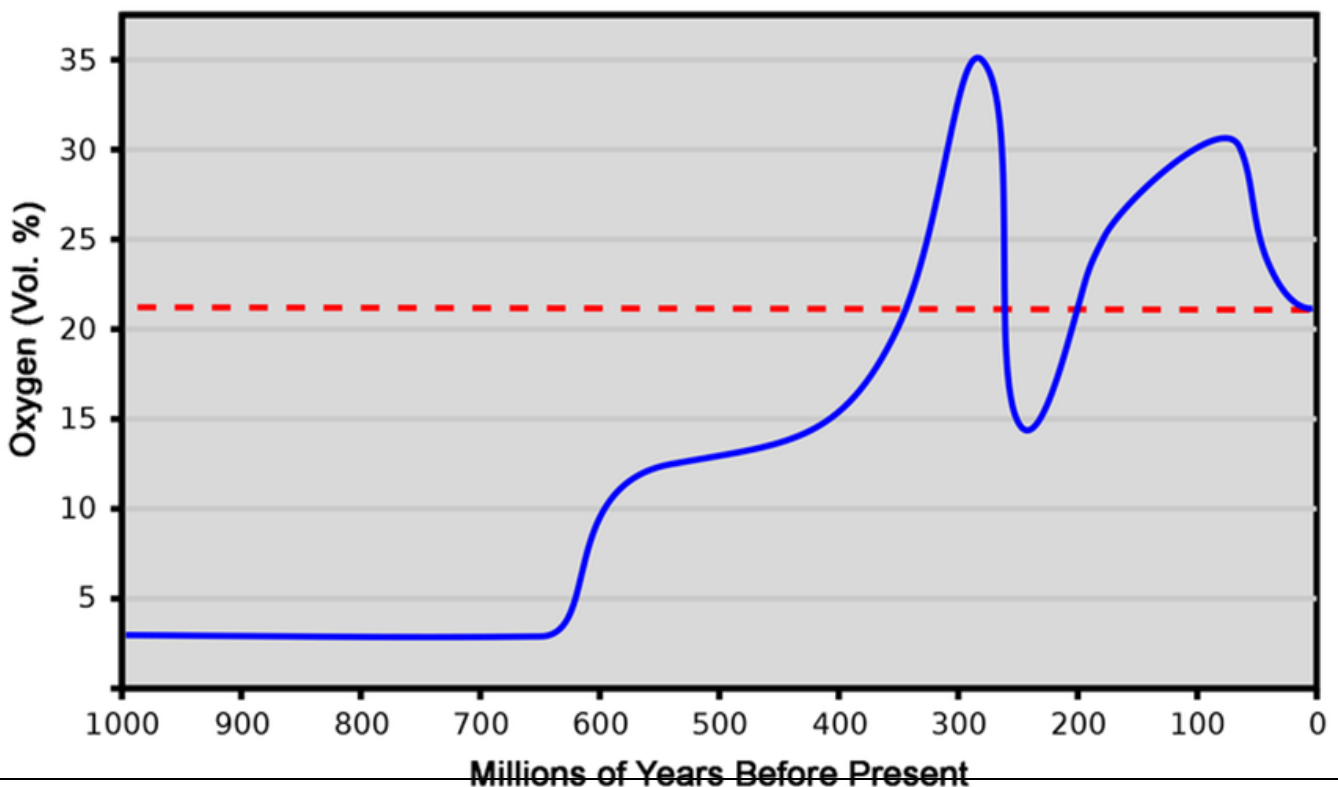


“The most significant event in the evolution of life during the Phanerozoic has been the colonization of land”


Life migrated from the sea onto land during the middle-late Palaeozoic. In doing so, they radically altered the living space available and the climate of the earth.

For example, **terrestrialisation** led to the evolution of land plants which generated much higher volumes of oxygen, this

Oxygen Content of Earth's Atmosphere During the Course of the Last Billion Years



irreparably changed the chemical make-up of the atmosphere, temperature, rainfall, weathering and erosion rates.

Ordovician and early Silurian	Plants migrate onto land , these provide widespread very low plant cover in moist areas close to coastlines.
Devonian Cooksonia – one of the most well-known fossil plants to have lived in the Devonian. Leaves had not yet evolved. 	Plants evolved structural chemicals (lignin and cellulose) which allowed them to fight desiccation and to grow tall, forming the first forests . Arthropods also migrated onto land (spiders, insects, other primitives etc.) By the late Devonian , the fossil record shows many lobe-finned fish , living seas, lakes and mudflats close to land. Tetrapods that were land and sea dwellers evolved, these are called amphibians .
Carboniferous	Fully terrestrial vertebrates called reptiles evolved. Forest ecosystems were at peak diversity.

PROBLEMS ASSOCIATED WITH EVOLUTIONARY CHANGE FROM SEA TO LAND

When an organism evolves to become terrestrial, it must have beneficial adaptations to an entirely new climate:

1. **Preventing desiccation (drying out / dehydration)**
2. **Problems of support (lack of suitable limbs for locomotion)**
3. **Gas exchange with the atmosphere**
4. **Reproductive systems**
5. **Thermoregulatory issues**

The organism may also encounter new predators, UV radiation, new food supplies/shortages the list goes on...

LOBE-FINNED FISH

1. Lobe-finned fish are **lungfish**.
2. They are fish which possess both **lungs** (terrestrial respiration) and **gills** (marine respiration).
3. They **developed lungs from modified swim bladders**.
4. They had **four fleshy fins** supported by **bones in a similar structure to the hand of tetrapods**. However, they **lack the strengthening girdle** which **links the extremities** to the **central skeleton**, i.e. they have not evolved the bones that makeup arm/leg limbs.
5. They are (*OCR exam board*) the **evolutionary ancestors of all terrestrial vertebrates**.

Lobe-finned fish are technically a **clade of `fish`** that evolved to eventually give rise to all **terrestrial vertebrates**. On the other hand, **this fact is often ignored** and **they are** treated as **lungfish**.

A **swim bladder**, an **organ with a sack-like structure holding air/fluid**, was used to **increase the buoyancy** of the animal in the water column. The technique to control height in the water column was very similar to other species: like the inflated glabella in trilobites, Belemnites would use a Phragmocone with gas-filled chambers instead and some planktonic graptoloids would have had an arrangement around a gas-filled membrane that acted as a buoyancy aid.

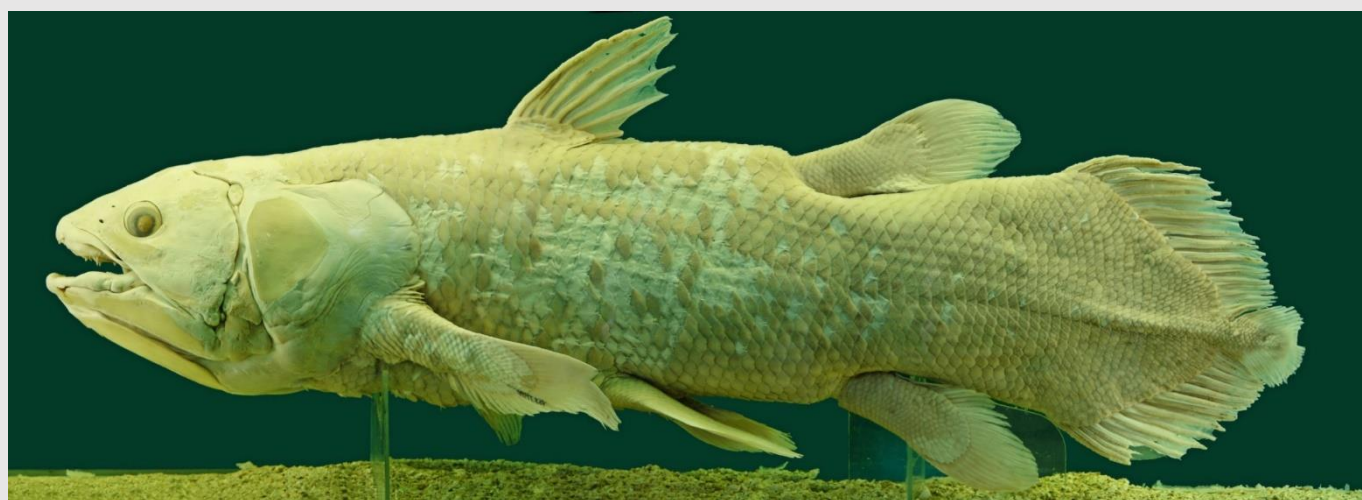
LOBE-FINNED FISH: THE COELACANTH

#A living fossil is the term used to describe an extant species that had seemingly not changed during a long (geological) lifetime.

The average species 'lifetime' is 2-3 million years. If a species exists for **significantly longer** than this and **is extant** today it is termed a **living fossil**.

The Coelacanth was thought to have become extinct **65Ma ago**. However, it **was rediscovered** in 1938, off the Comoros islands, living between 150m-300m depth. The modern Coelacanth has not changed its physical resemblance to its fossil ancestors some 80Ma.

The Coelacanth is from a group of fish that first evolved 400Ma. Fossil lungfish are found in sediments more than 400 million years old, and modern ones live in fresh-water streams and lakes in South America, Africa and Australia.



Coelacanths were roaming the oceans when their **close relatives** became the **first vertebrates** to venture **on land**. They shared the ocean with **primitive molluscs and trilobites**.

The limb-like ventral and pectoral fins make it possibly the first fish to crawl out of the sea. That could make them the closest living ancestor of all amphibians, reptiles, birds and mammals. However, the debate is unsettled as this could be the lungfish.

The Coelacanth group peaked ~200Ma (Triassic-Jurassic) and has been in decline ever since the Triassic.

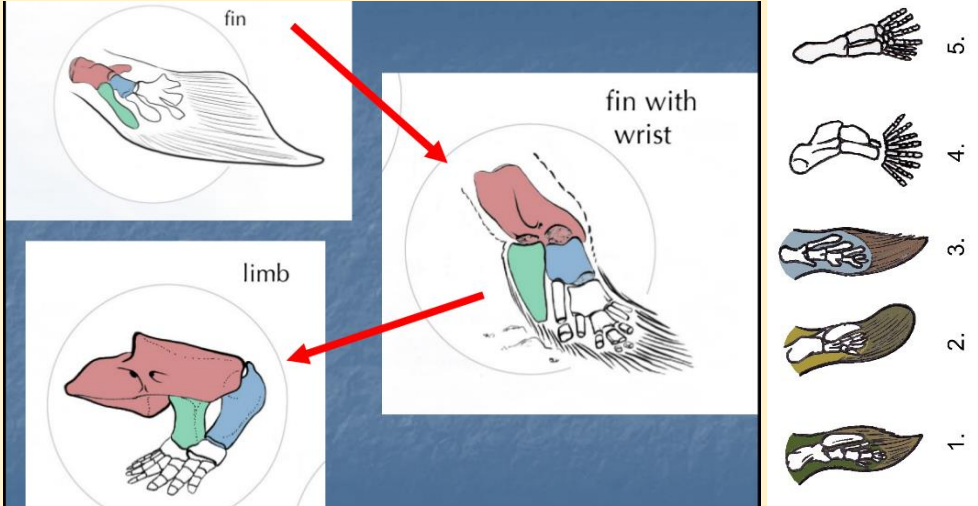
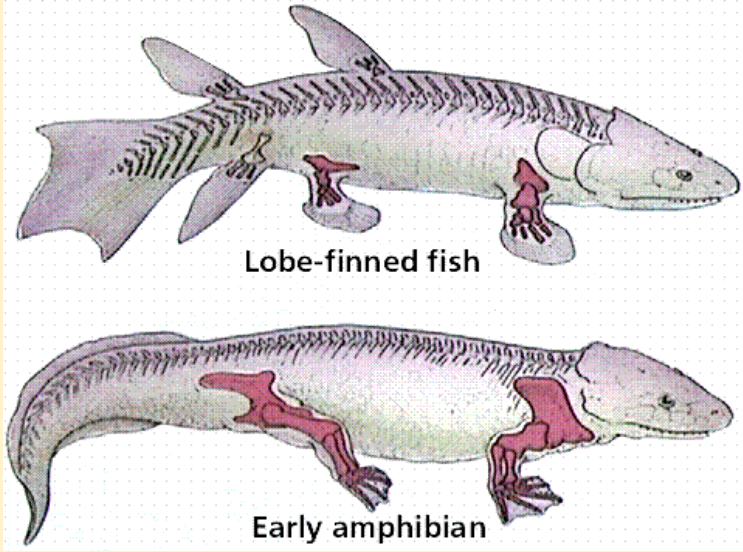
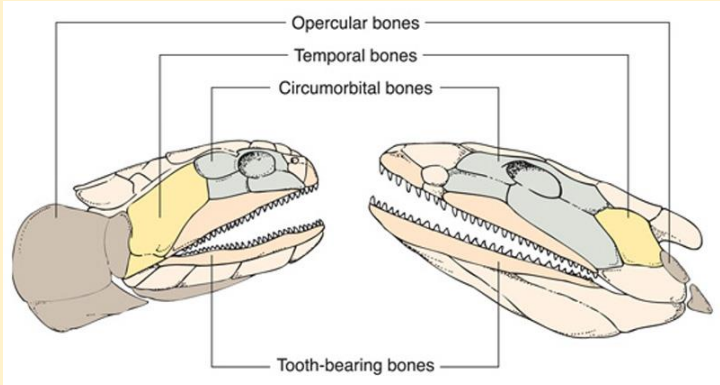
WHAT ARE AMPHIBIANS?

1. The first group of **tetrapods to colonise land**.
2. They evolved from lobe-finned fish in the **late Devonian/Carboniferous**
3. They are the evolutionary ancestors to **reptiles, birds and mammals**.
4. They have many defining characteristics: they **breathe through their skin** which must stay moist for respiration to occur, the **larvae are aquatic** and the **adults are terrestrial** and they **undergo metamorphosis**.

Amphibians are the earliest tetrapods which evolved in the **Devonian Period** from **fish with lungs and bony-limbed fins**, features that were **helpful in adapting to dry land**. They diversified and became dominant during the

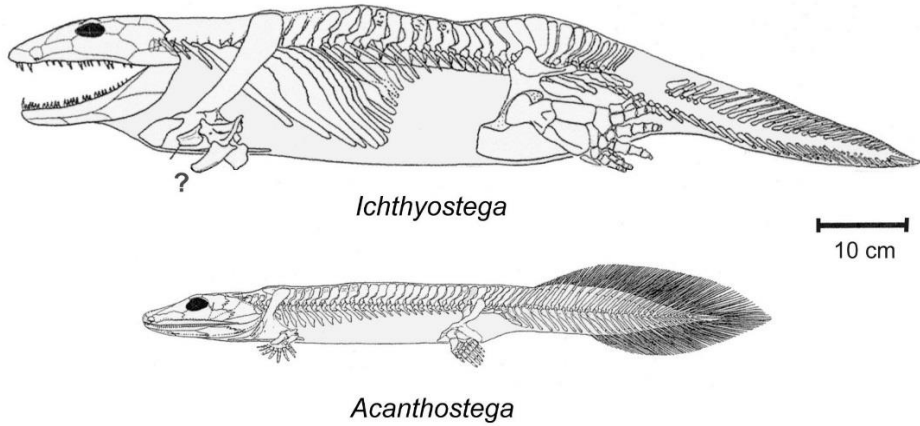
Carboniferous and Permian periods, but were later **displaced by reptiles and other vertebrates**. Over time, amphibians **shrank in size and decreased in diversity**. *The most extant amphibians are frogs.*

SIMILARITIES BETWEEN LOBE-FINNED FISH AND AMPHIBIANS

<p>Skeletal features</p>	<p>The skeletal structures in the four fins of the lobe-finned fish and the four limbs of early amphibians are very similar.</p> 
<p>Positioning of limbs/fins</p>	<p>The limbs/fins were positioned in the same positions on their bodies.</p> 
<p>Claws</p>	<p>Both lacked claws and nails</p>
<p>Skull morphology</p>	<p>Jawbones and teeth of both groups are very similar</p>
<p>Teeth</p>	<p>Both amphibians and lobe-finned fish had complex teeth</p> 

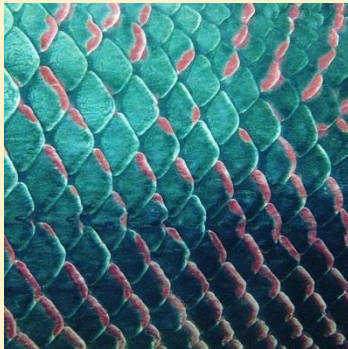
Tail fin

Early amphibians still had a tail fin suggesting it spent a great amount of time in water, the body shape and movement presumably resemble that of a lobe finned fish.



Early amphibians

They had **small bony scales** in their skin a trait of **all fishes**



Skull trend

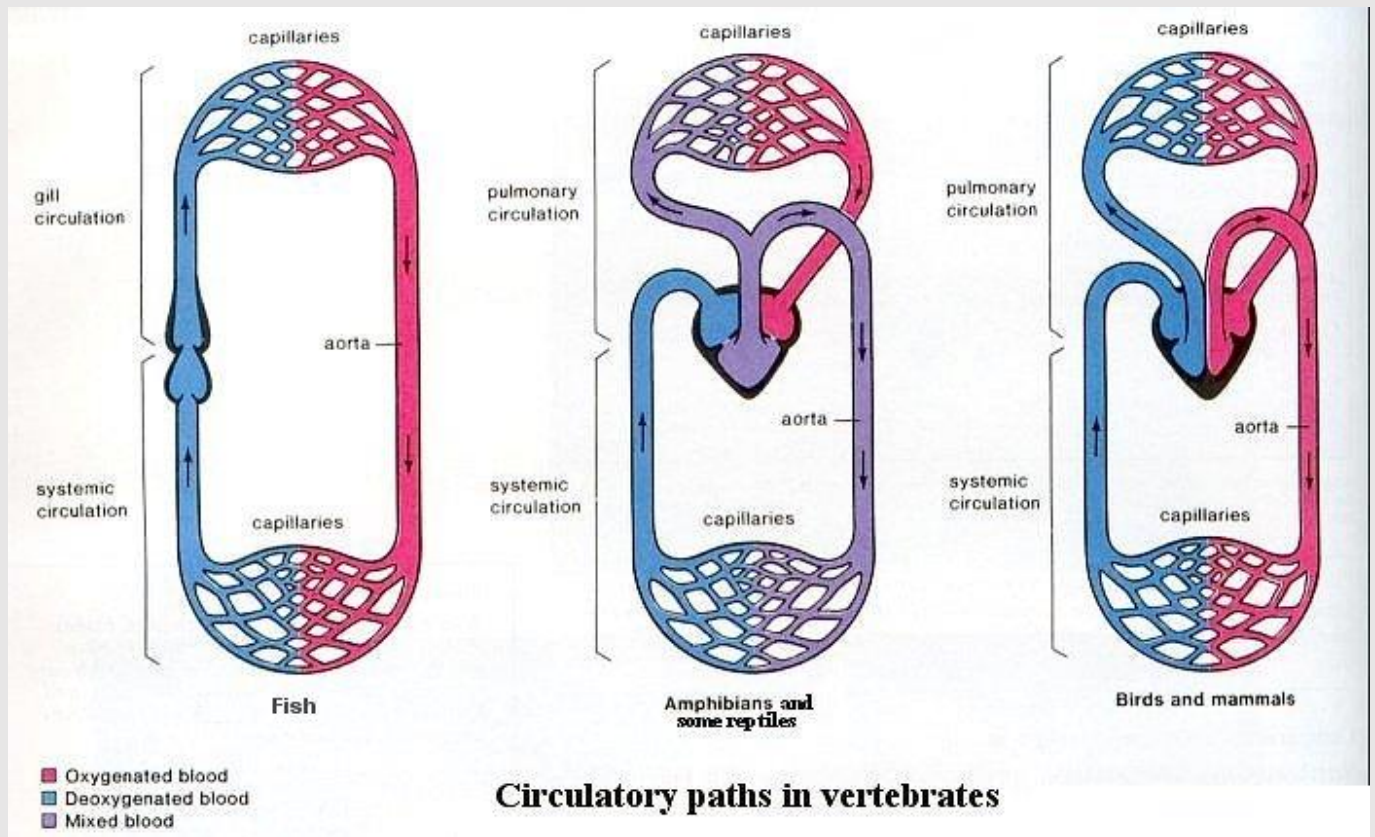
Amphibians **skull became slenderer** with **temporal and opercular bones becoming smaller** in size and the **jaws becoming more fused** together.



ADAPTATION TO LIFE ON LAND

Newly evolved amphibians had similar characteristics to that of a lobe-finned fish as well as some entirely unique features that allowed them to live on land:

- | | |
|---|---|
| 1 | The development of a girdle, connecting the limb bones to the skeleton for better movement on land . |
| 2 | A more robust central skeleton strengthening the vertebral column and rib bones , for support on land. |
| 3 | Eyelids formed to help keep eyes moist so they did not desiccate in a non-aquatic environment. |
| 4 | The development of a double-loop circulatory system with a three-chambered heart to pump blood before and after it had been to the lungs . This increases the efficiency of the delivery of oxygen to the more active cells and the removal of waste carbon dioxide, lactic acid. Overall gas exchange efficiency greatly improves. |
| 5 | The development a tongue (and cheeks) for the processing of food orally and for a sensory role . The tongue is important for some predators . |
| 6 | Ears adapt to process sound in the thinner medium of air (' acoustic impedance matching '). |



Amphibians are not fully adapted for life on land. They still need to remain near to large bodies of water for several reasons:

1. Amphibians needed to **stay moist** since they use their **skin for gas exchange** (respiration).
2. Amphibians **laid eggs in water** since they had **no desiccation protection**. The larvae were therefore aquatic.
3. Their young were **aquatic larvae** which grew into terrestrial adults following **metamorphosis** during adolescence.

CASE STUDY

In 2002, Geologists carried out an expedition high in the Canadian Arctic, analyzing the Devonian rocks in search of the first fish that dragged itself out of the water nearly 400 Ma.

They discovered several specimens of an almost perfect intermediate between lobe-finned fish and amphibians. The features were a combination of tetrapod and fish-like.

- It had **scales** on its back just like fish.
- It had **fins like fish** but it had a **similar bone structure** to the hands and legs of tetrapods with a developed wrist/hand.
- It had **eyes situated on the top** of the head as seen in tetrapods.
- There were **large interlocking ribs suggesting it had lungs**.
- It had a **mobile neck**, showing the head could move independently from the body so the animal could peer outside the shallow waters, find prey and avoid predators.

It was named the **Tiktaalik** – the Inuit word for large freshwater fish. First amphibians lived at the time that the first major terrestrial ecosystems were establishing themselves. **Full-grown forests** with **roots a meter deep** were developing, where formerly just mosses and other tiny shallow-rooted plants grew.