Alles Introductory Biology: Illustrated Lecture Presentations

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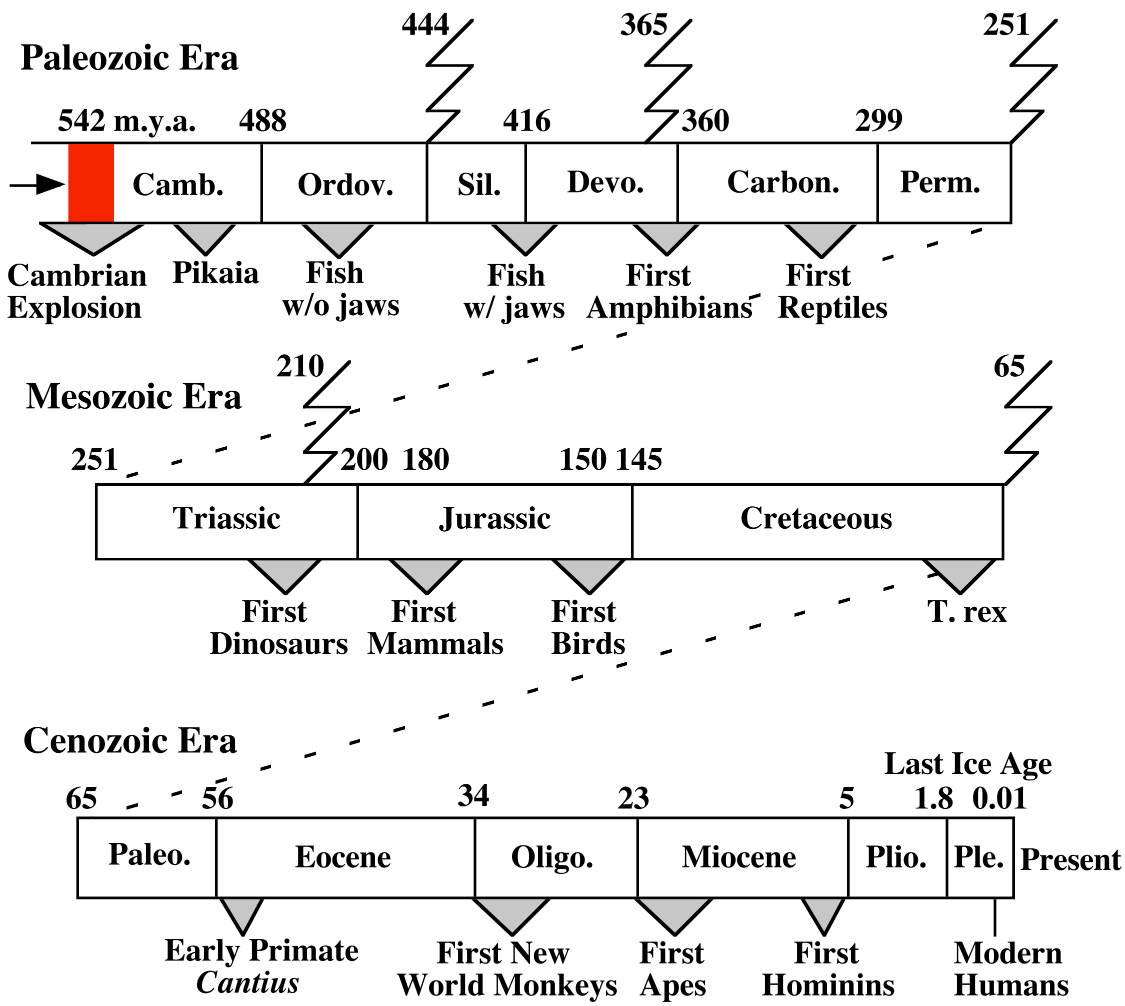
Part Three: The Integration of Biological Knowledge

Major Events in the Paleozoic Era

The Cambrian Explosion

The Phanerozoic Eon



The Cambrian Explosion: Before and After

What major adaptive features were in place before the Cambrian explosion, and what major evolutionary adaptations arose during the event?

There are three points to be made:

Point 1 — What didn't change was that before and after the event all life lived in the oceans.

Point 2 — The major features that were already present:

eukaryotic cells

sexual reproduction

multicellular organisms

The Advantages of being Multicellular

1. cell specialization

2. size as it increases mobility

3. getting food — size as an advantage for predators

4. not being food — size as a defense against predators

This sets up the predator / prey arms race.

Point 3 — The major evolutionary adaptations that arose were the body plans of all the major phyla of animals:

- **radial symmetry (cnidarians—the jellyfish)**
- **a tube-like body (nematode round worms)**
- **segmentation (annelid worms)**
- **calcareous shells (mollusks)**
- **the exoskeleton and bilateral symmetry (arthropods)**
- **the notochord (vertebrates)**

Web Reference for Cambrian Explosion
http://palaeo.gly.bris.ac.uk/Palaeofiles/Cambrian/index.html#interest

Body plans start with a simple, hollow ball of cells as in Volvox. You can then imagine pushing the ball, like a tennis ball, with your thumb until you form a cup with two layers of cells. When you do, you get the next step in the evolution of body plans—radial symmetry.

Jellyfish (Cnidarians) come in many shapes and sizes, but they all have **radial symmetry**. Note the cup-shape analogy in the jellyfish above.

Some of the oldest animal fossils known, dating to 600 million years ago, are of jellyfish-like creatures that have radial symmetry.

The jellyfish *Aequorea victoria* shows a simple but elegant radial symmetry.

Round Worms (Nematodes)

The next step in imagining the evolution of body plans is to take our cup with two layers of cells and poke a hole in the top of the cup. Then imagine elongating the cup into a long tube, hollow in the center and with a hole at each end. In a crude way you then produce the tube-like body plan of round worms.

A Segmented Worm (Annelids)

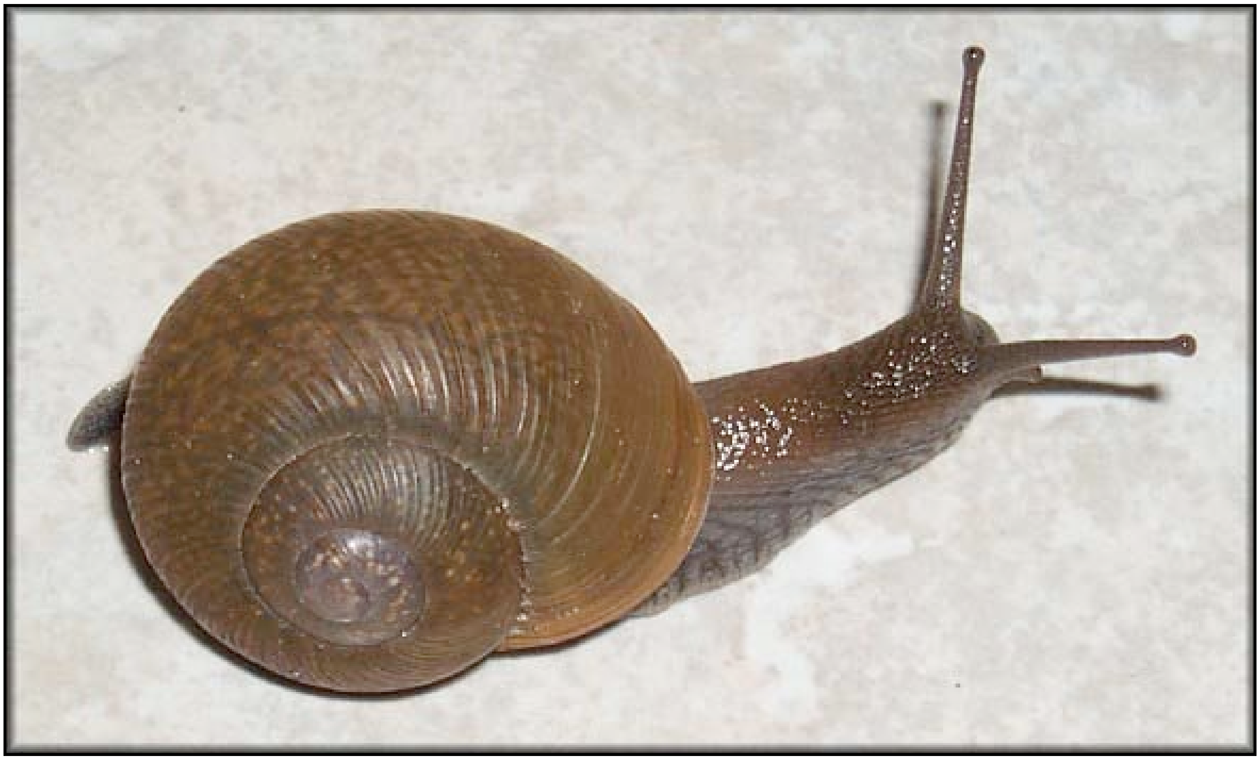
The next is to divide our tube into segments. Annelid worms are segmented. Their tube-like bodies have been divided along their length into compartments so that each compartment can specialize in function.

A Centipede (Arthropods)

Arthropods, such as centipedes, millipedes, spiders, insects, and crustaceans add the next step to evolving body plans by adding legs to the segments along their bodies. Note that this arrangement produces a new body symmetry—a **bilateral symmetry** where one side of the body is a mirror image of the other.

A Millipede (Arthropods)

Arthropods, have also added another feature to their body plan—a tough shell made largely of chitin and proteins, forming an **exoskeleton** that may or may not be further stiffened with calcium carbonate on the outside of their bodies. It provides protection and a firm anchor to attach muscles used to move their legs and antenna.

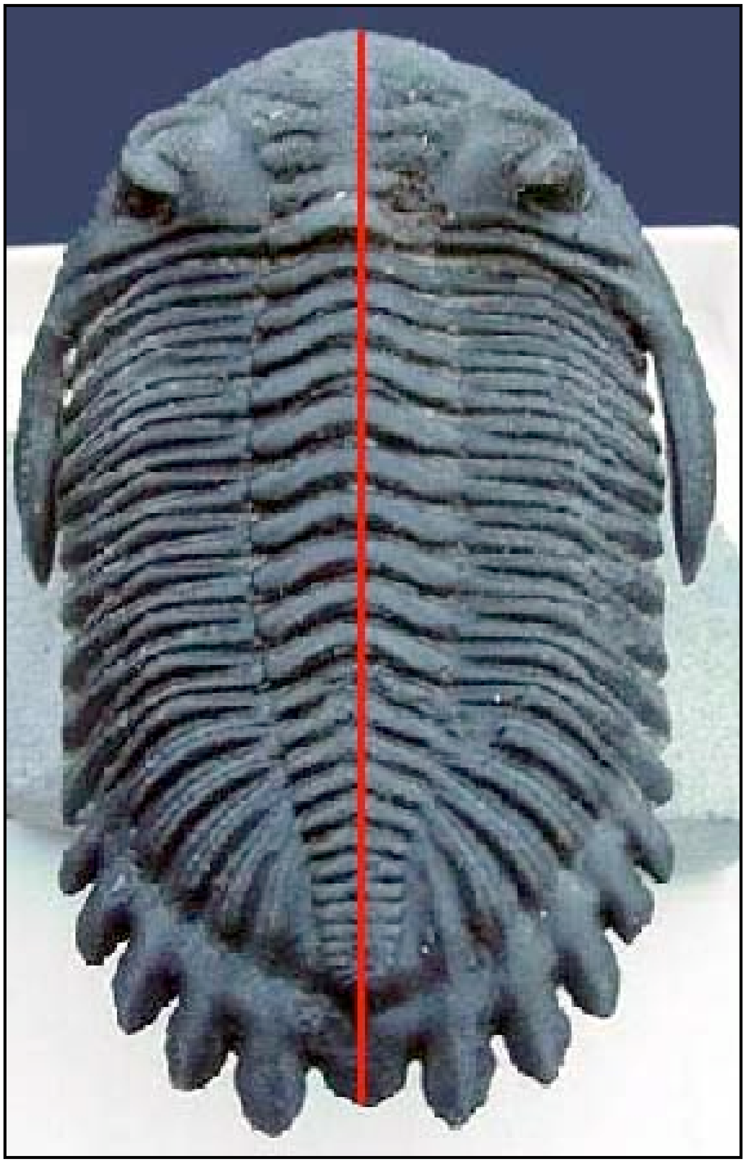


A Snail (Mollusks)

The evolution of a tough outer shell for protection is not unique to arthropods. Mollusks, such as the land snail above, have also added a strong shell, now made mostly of calcium carbonate, to protect their bodies. But note the lack of segmentation and legs. It's as if nematode round worms had just added a shell for protection.

The lobster, also an arthropod, has an **exoskeleton and bilateral symmetry**, and demonstrates one of the disadvantages of an exoskeleton. To grow bigger a lobster must periodically shed its exoskeleton in a process called molting. After shedding its old shell, it sucks in water to enlarger itself while a new exoskeleton forms on the surface of its skin. It can then expel the excess water after the shell has hardened and have room to grow until the next molt.

The process, however, has a built-in mechanical size limit, the limit that body fluids and oxygen can diffuse within the core of their body. This means that lobsters can't grow much larger than the largest lobster on record, which according to the 1998 Guinness Book of World Records, was 44 pounds, 6 ounces, and 3 feet 6 inches from the end of tail fan to tip of largest claw.



The red line demonstrates the bilateral symmetry in a Cambrian trilobite, an arthropod like the lobster but dating back to the early Cambrian Period almost 542 million years ago.

For more on Trilobites go to:
http://fire.biol.wwu.edu/trent/alles/Trilobites.pdf

Pikaia, known from fossils of the Burgess Shale dating to 503 m.y.a., is possibly the first animal with a **notochord**—a rod of cartilage running down inside of the length of the body to which muscles are attached. Note the chevron pattern of muscles down the length of the body.

The notochord represents the next major change in body plans that evolved and has the striking evolutionary advantage of allowing the body to grow very large. Pikaia, itself, was only about 2 inches (5 cm) in length.

(Painting by David Miller)

Web Reference
http://www.nmnh.si.edu/paleo/shale/pfoslidx.htm

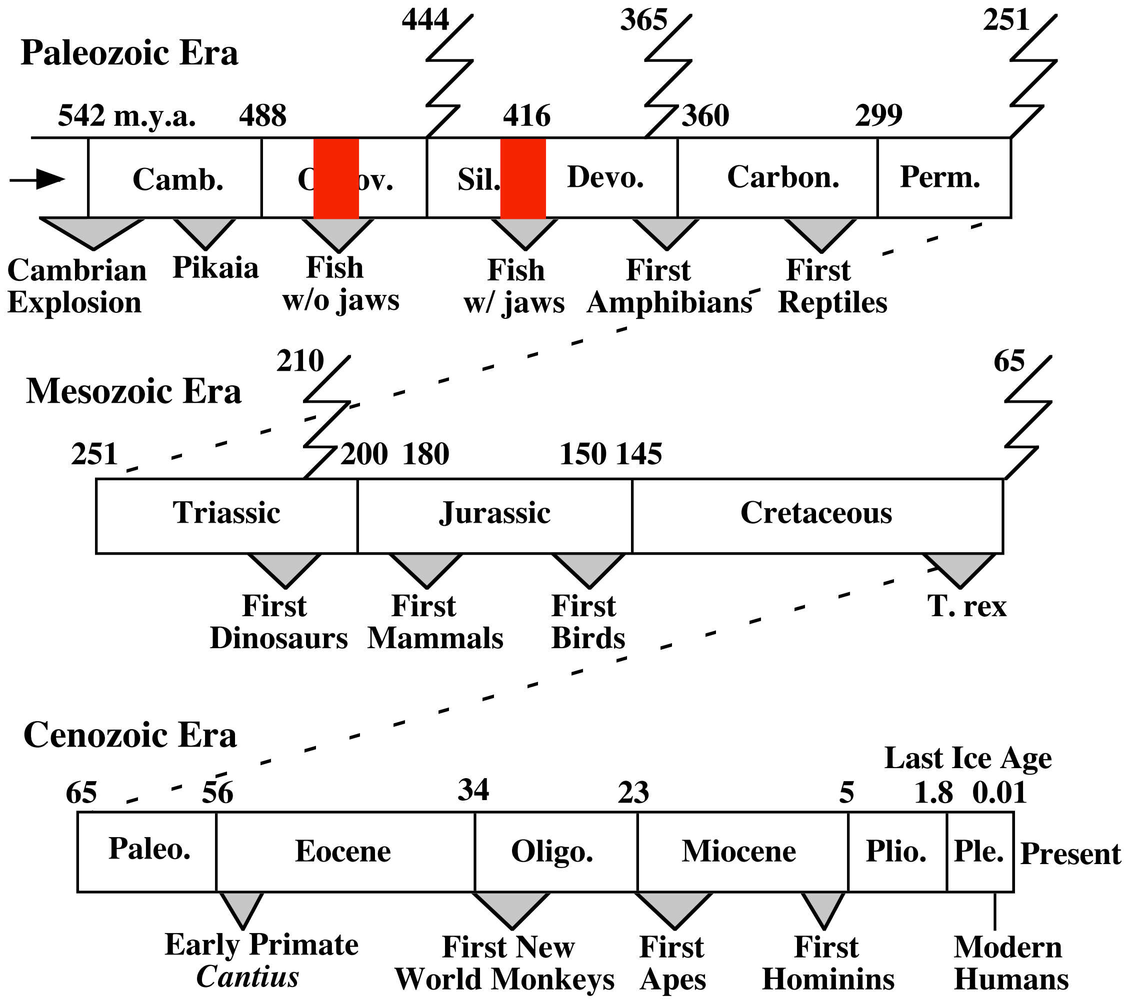
An average Blue Whale, on the other hand, is between 75 and 80 feet long, and weighs between 110 to 150 tons (300,000 pounds), making them the largest animal ever known to exist.

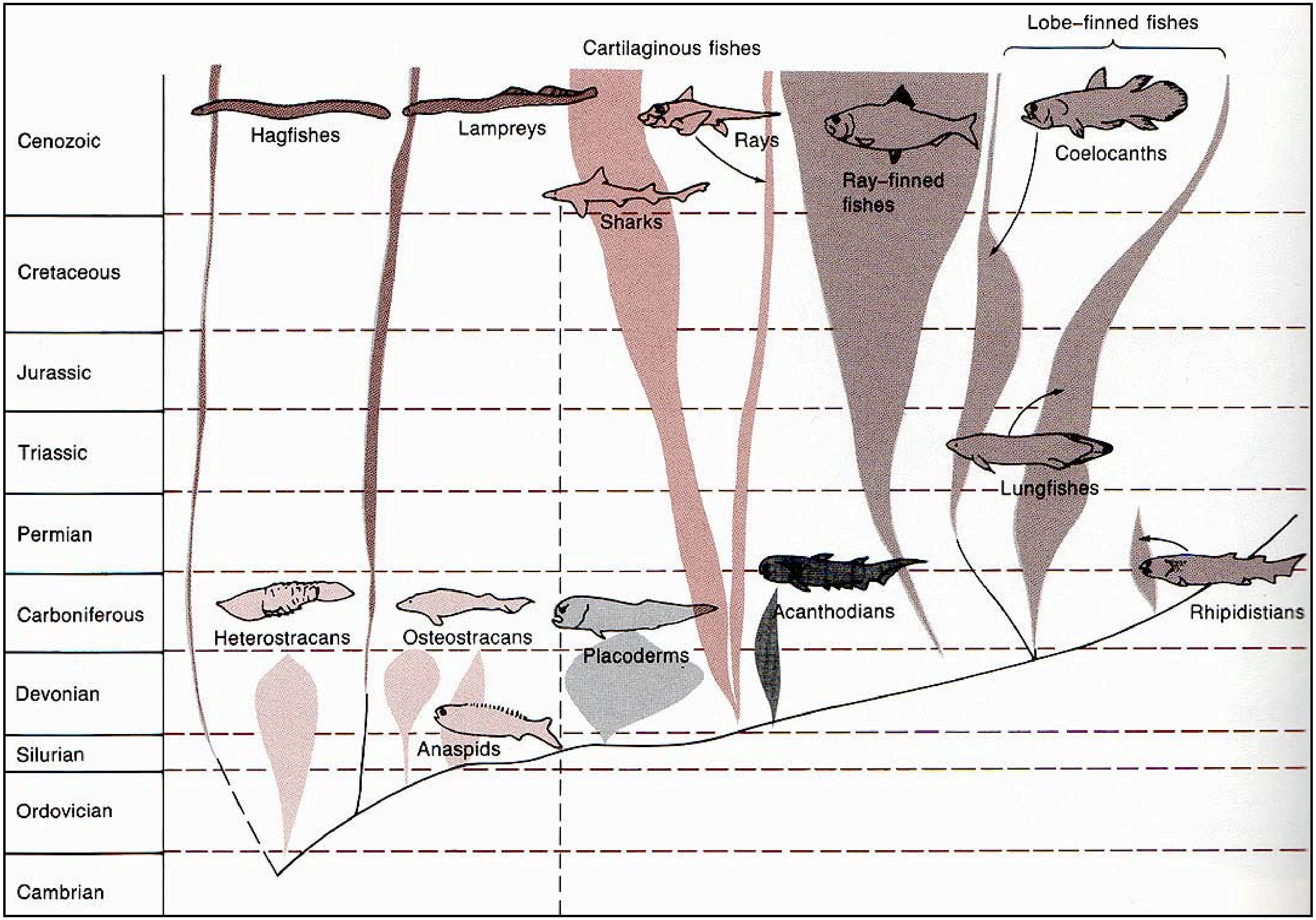
Blue whales are the evolutionary extension of the notochord, which evolved into the ridged internal skeleton characteristic of all **vertebrates**. Without this basic internal structure, life on Earth could not have attained the size of animals we see today.

(Photograph by Mike Johnson)

The Adaptive Radiation of Fish

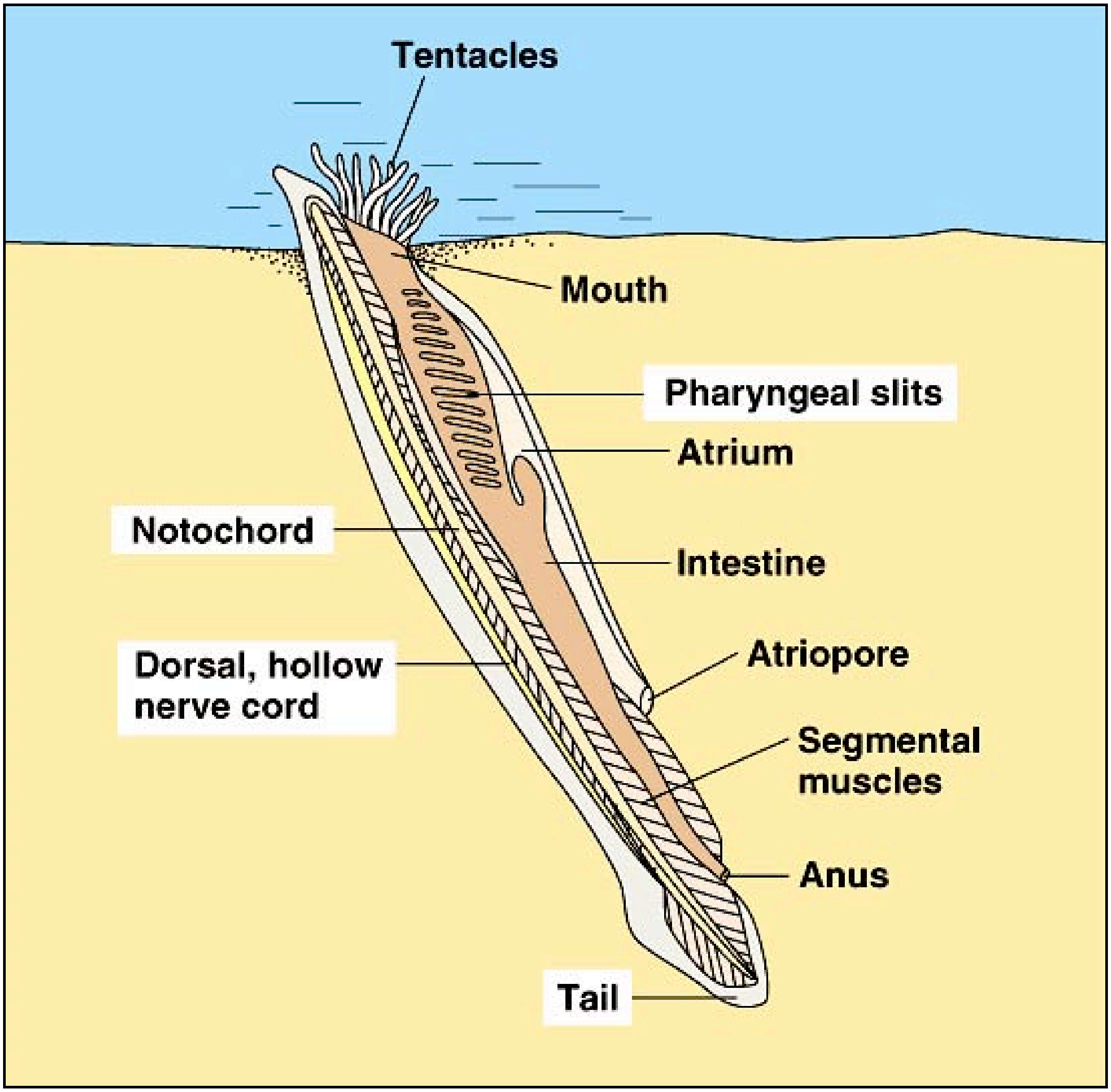
The Phanerozoic Eon



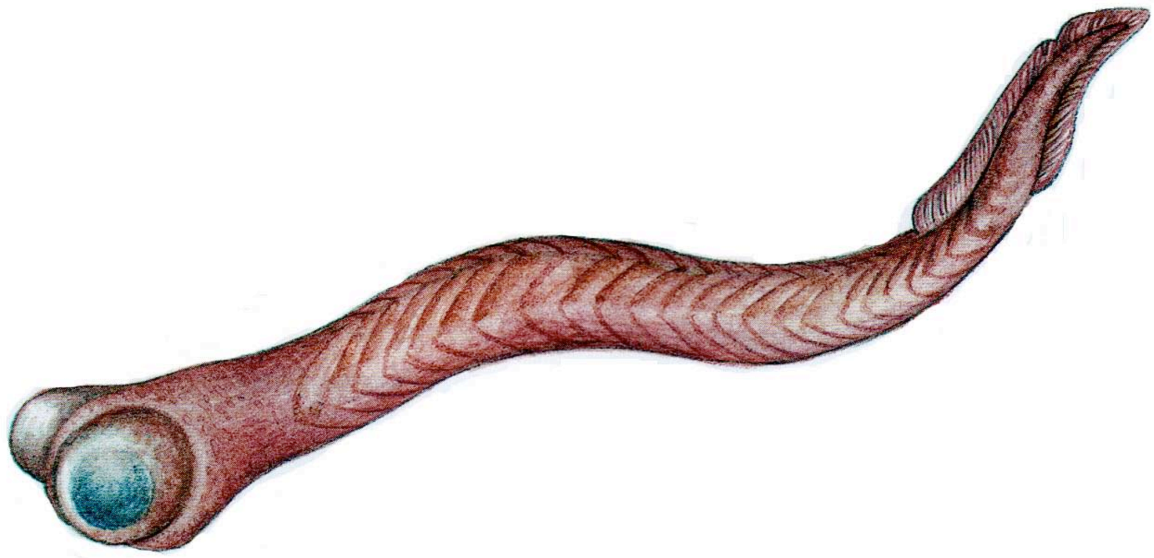


The Adaptive Radiation of Fish in the Paleozoic

Amphioxus (the Lancelet) is a **living primitive chordate** similar to Pikaia.



Anatomy of *Amphioxus* showing the **notochord and chevron segmented muscles**.



Conodonts, a group of very primitive jawless fish dating from 500 to 250 m.y.a., may have been minnow-sized, with two large eyes, and chevron-shaped markings along the body suggesting muscle blocks found only in chordates. In order to support their large eyes, conodonts may have been the **first vertebrates with a cranium**.

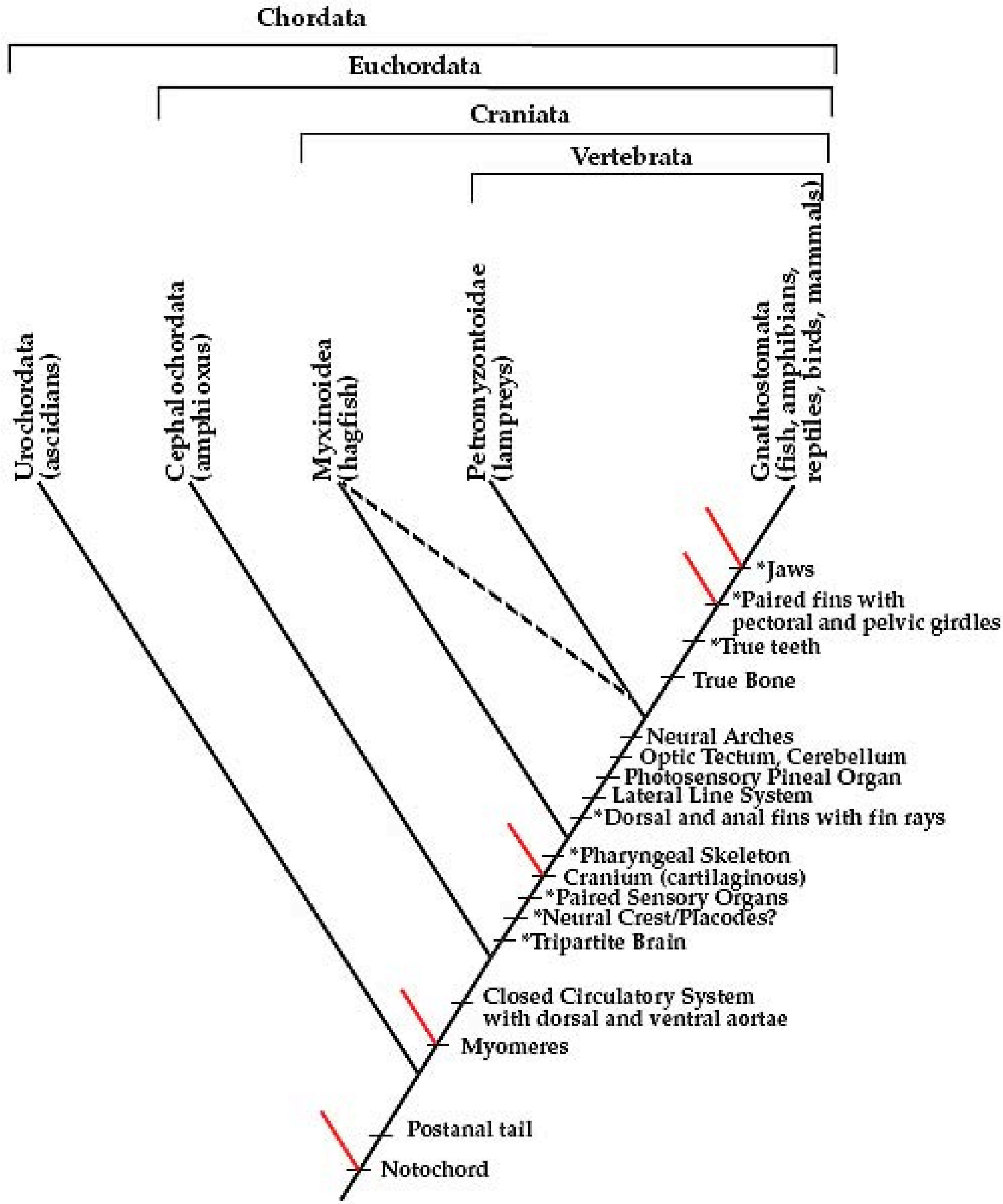
(Painting by David Miller)

Web Reference
http://www.geocities.com/CapeCanaveral/Hall/1383/2TopCone.htm

Lamprey, a group of living primitive **jawless fish**, have changed little over the 480 million years of their evolutionary history.

Lamprey attach themselves to their prey by means of a sucker disk.

A Lamprey Sucker Disk



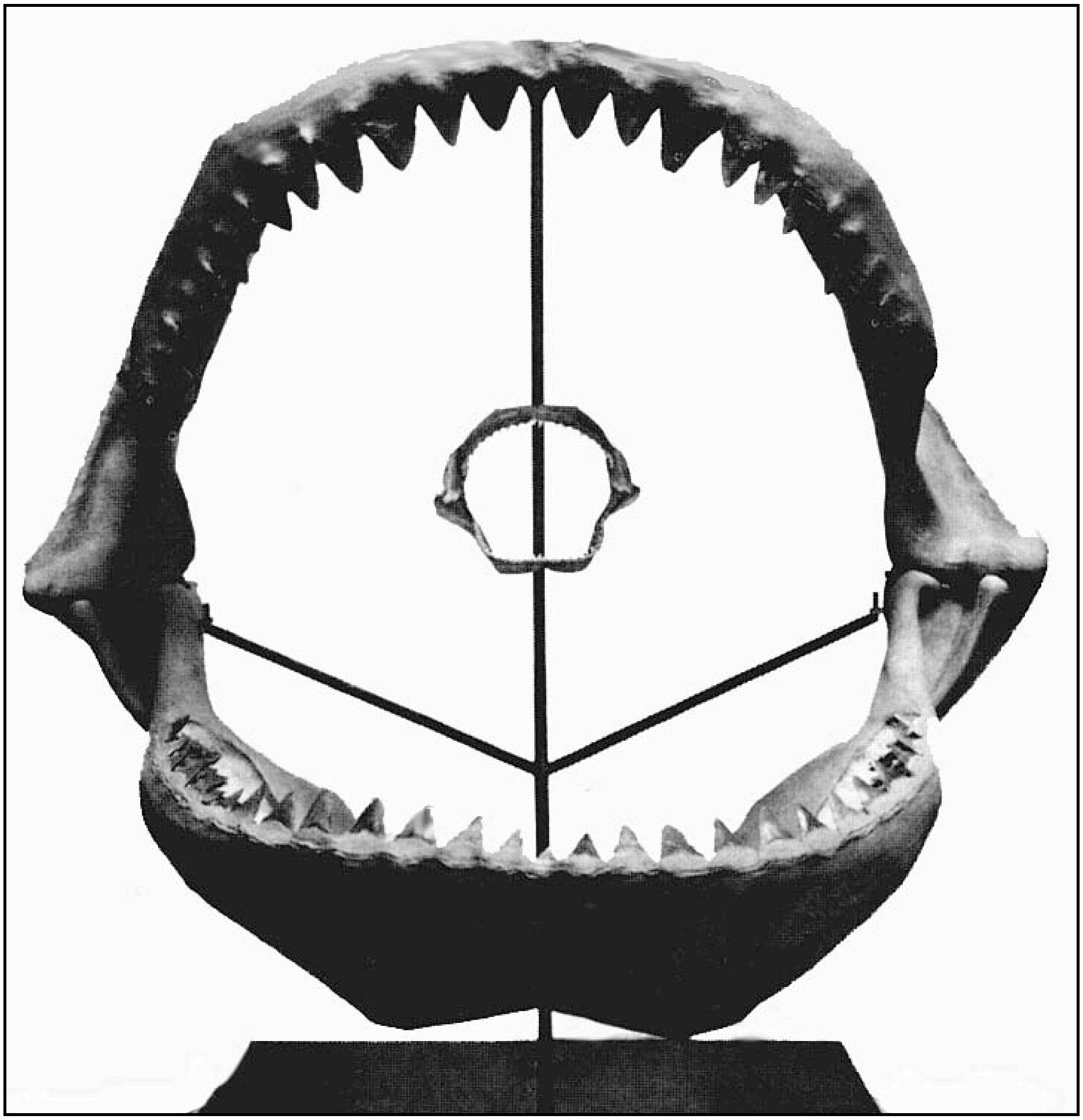
Adaptive Steps in the Evolution of Fish

The Great White Shark is an example of a fish with jaws.

Web References

http://www.flmnh.ufl.edu/fish/Sharks/White/White_Shark.htm

http://www.brunsonimages.com/gallery/Great_White_Sharks/great_white_sharks.htm

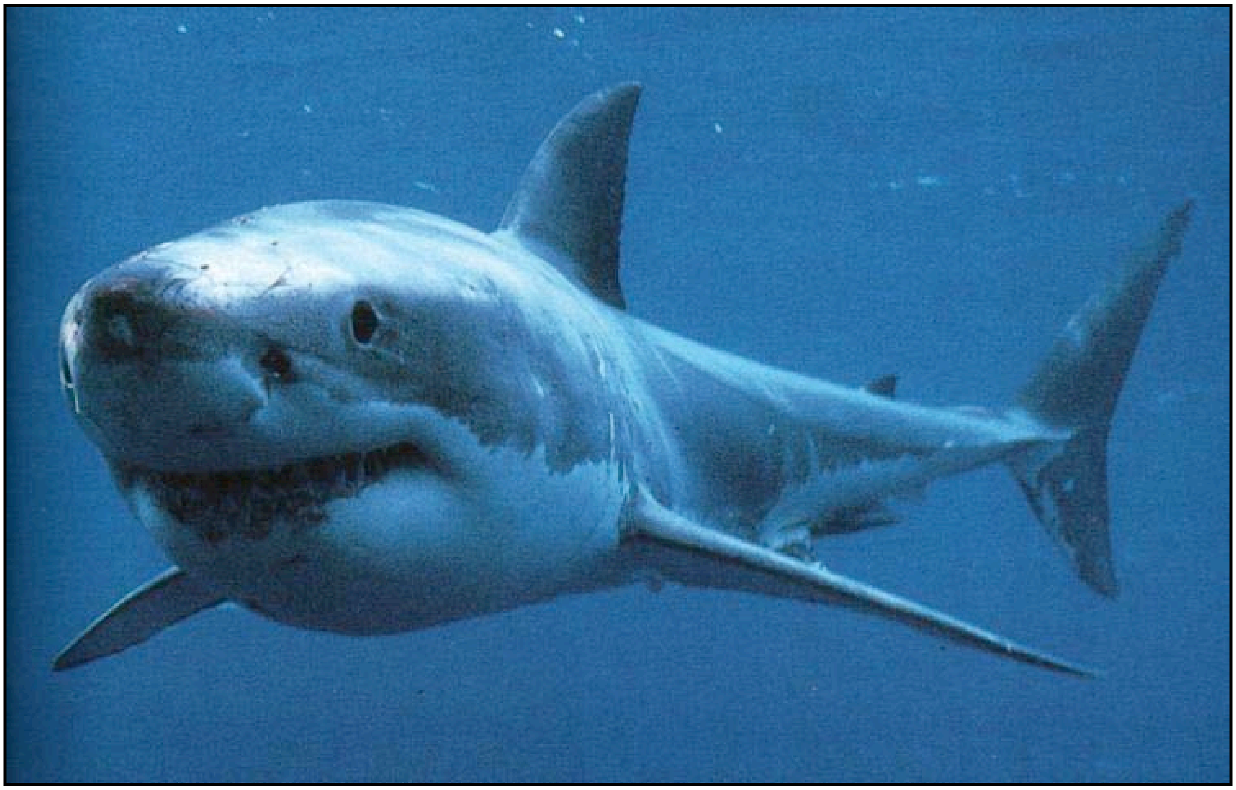


The Great White shark is not the largest jawed fish known. The set of smaller jaws center above are from a Great White. The larger jaws are from the extinct shark *Carcharodon megalodon* and measure 6-1/2 feet (2 m) across. *Carcharodon megalodon* lived in all of the world's warm water seas roughly between 25 to 2 m.y.a..

(Photograph courtesy of Chicago Field Museum of Natural History)

Web Reference
http://www.flmnh.ufl.edu/fish/Sharks/InNews/megatoothshark.htm

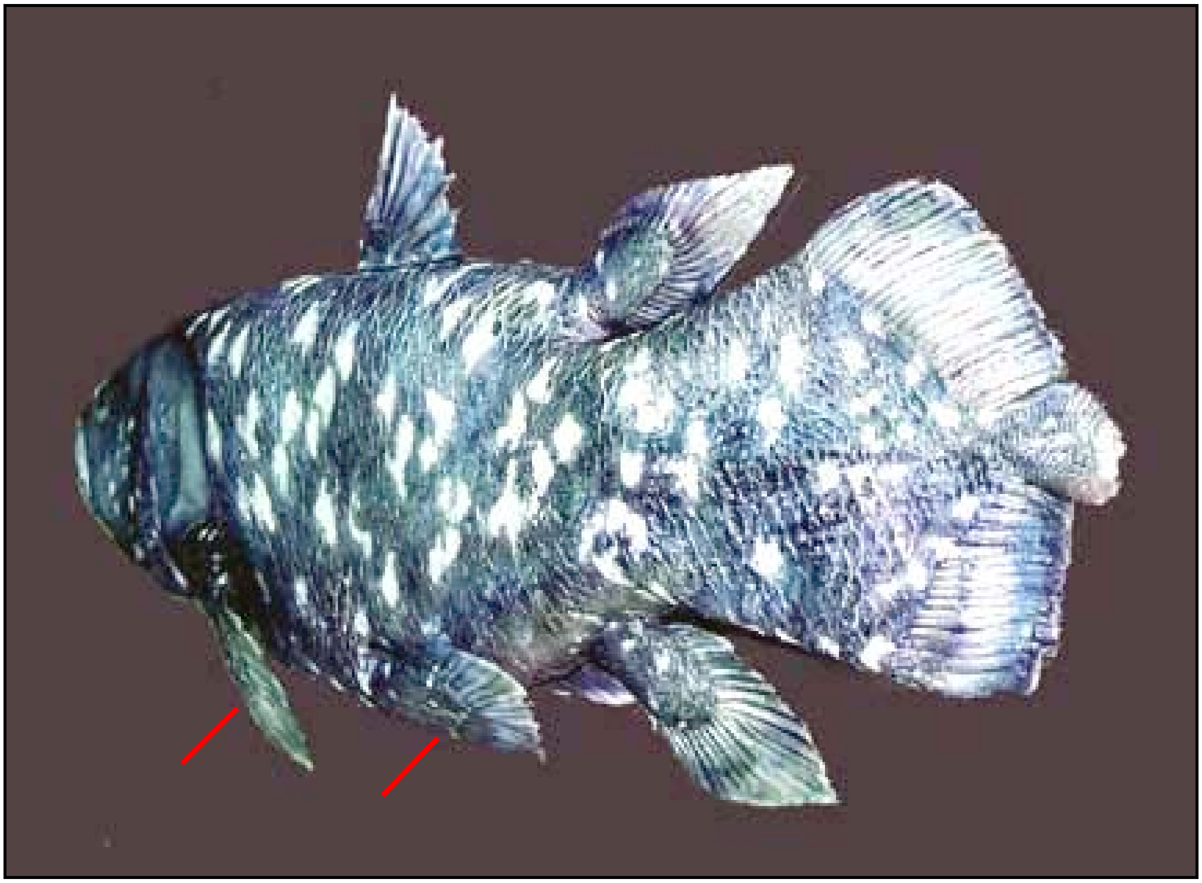
Fossil *megalodon* teeth can reach 6.5 inches (17 cm) in length.



Dorsal and pectoral fins first appear in the fossil record during the same period as jaws in the evolution of fish.

The coelacanth is a lobe finned fish.

Web Reference
http://www.ucmp.berkeley.edu/vertebrates/coelacanth/coelacanths.html



Note the two pairs of ventral fins.

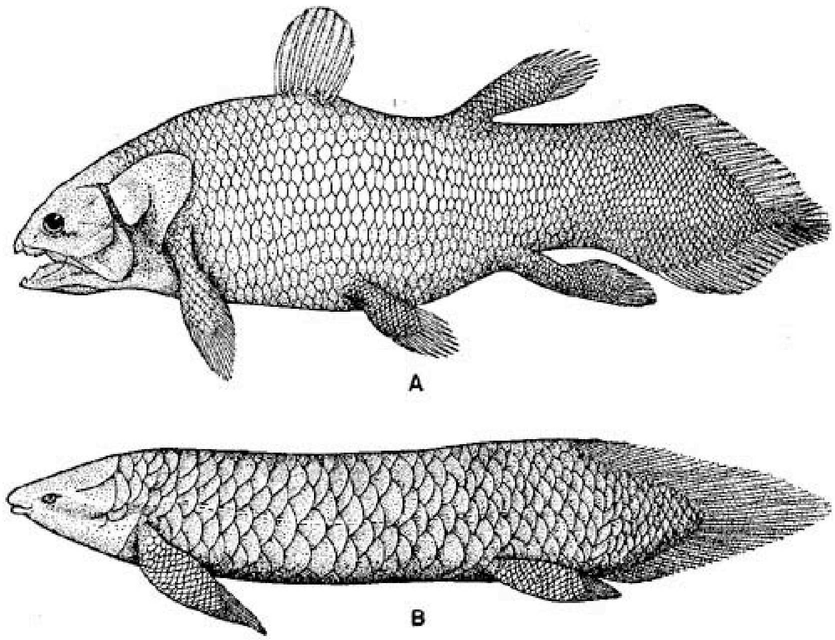
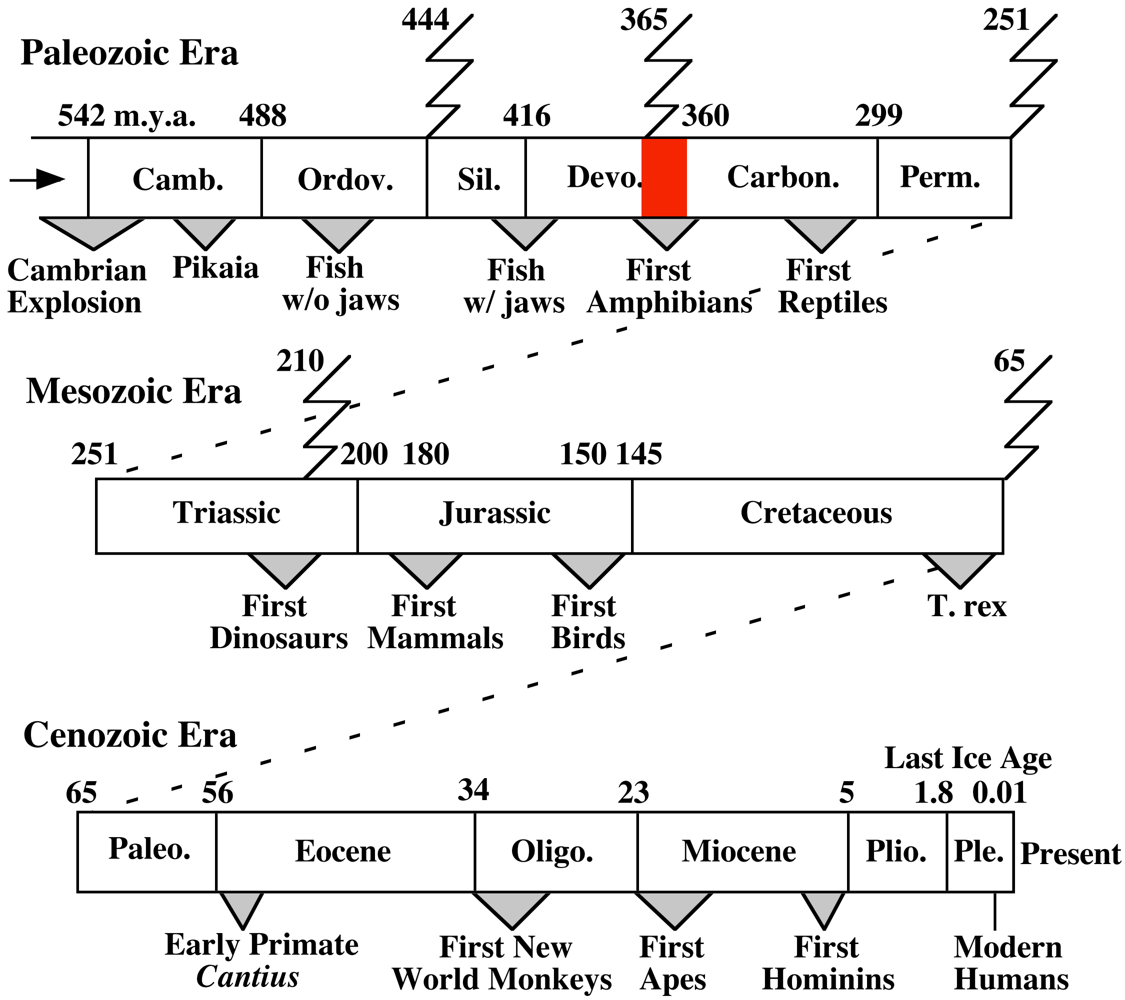


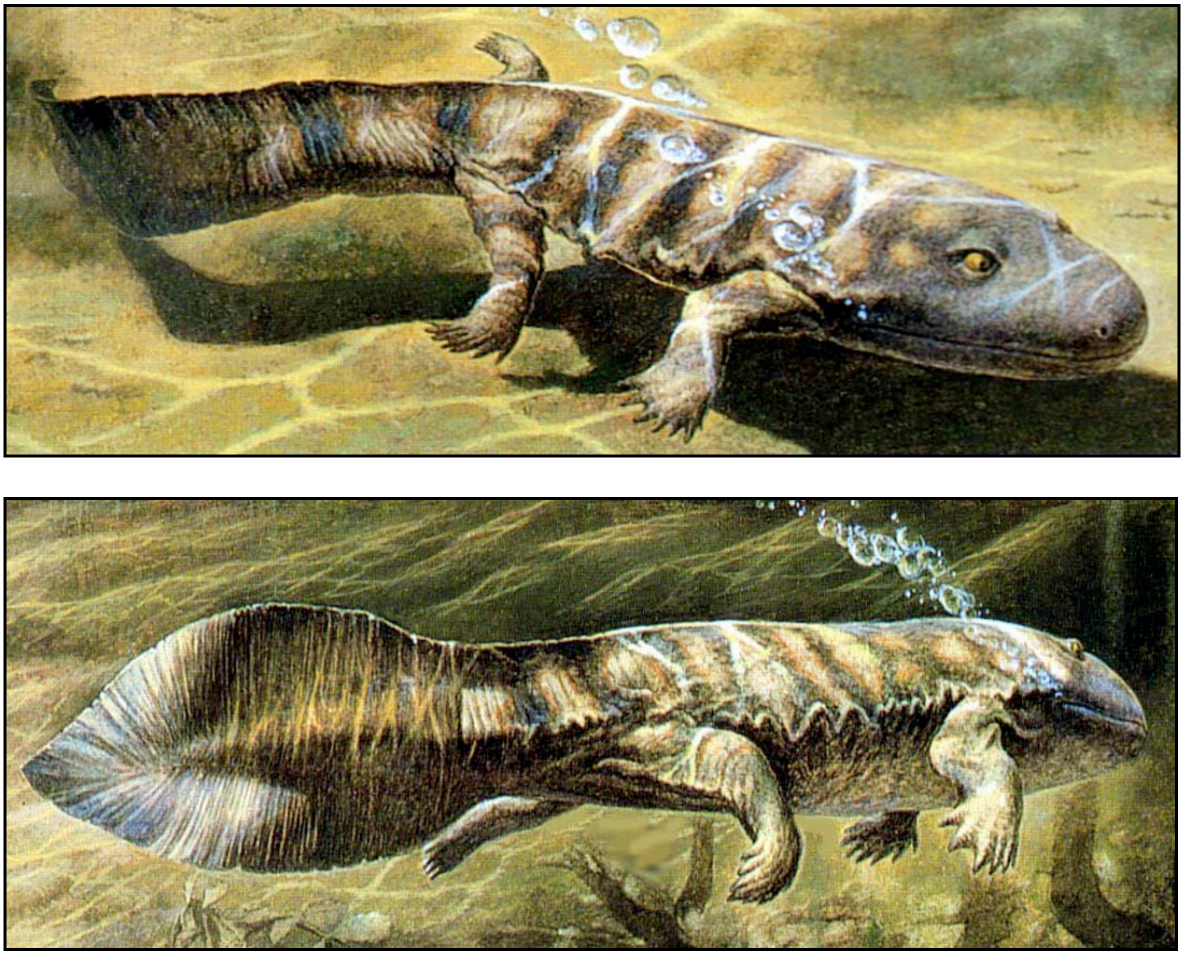
FIG. 3.5 Some choanichthyans. A, Latimeria, one of the three living genera of crossopterygians; B, Epiceratodus, a living dipnoan of Australia. (From Romer.)

A coelacanth and lungfish showing paired ventral fins in each group.

The Evolution of Amphibians

The Phanerozoic Eon

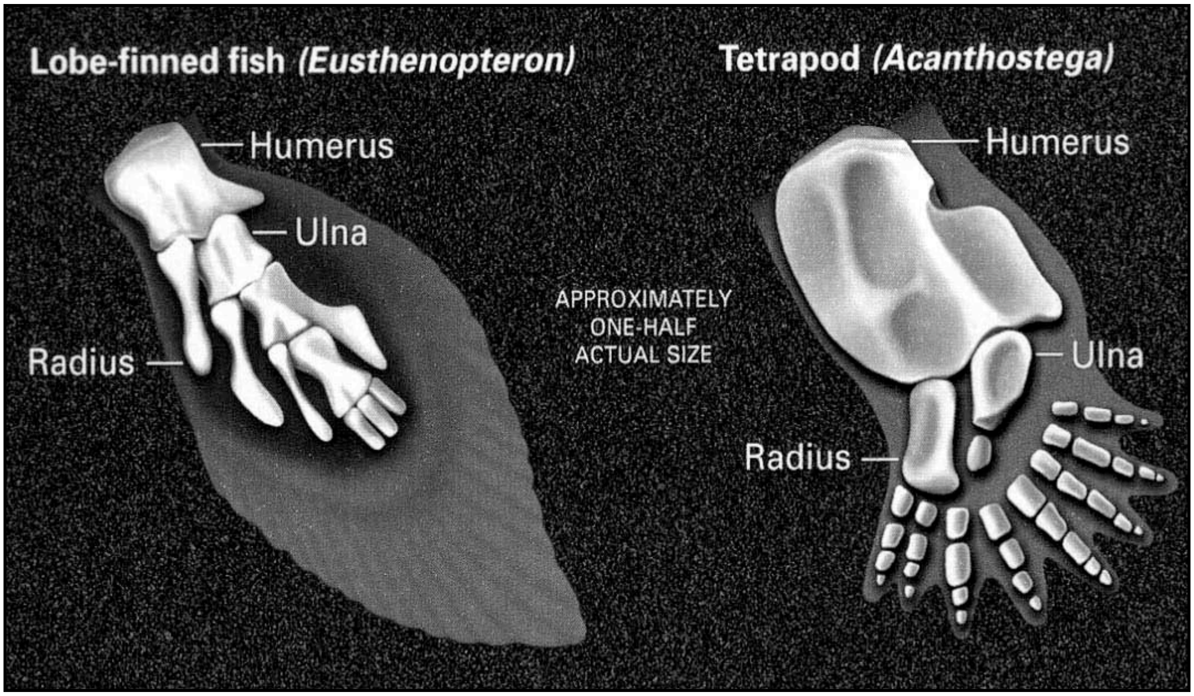




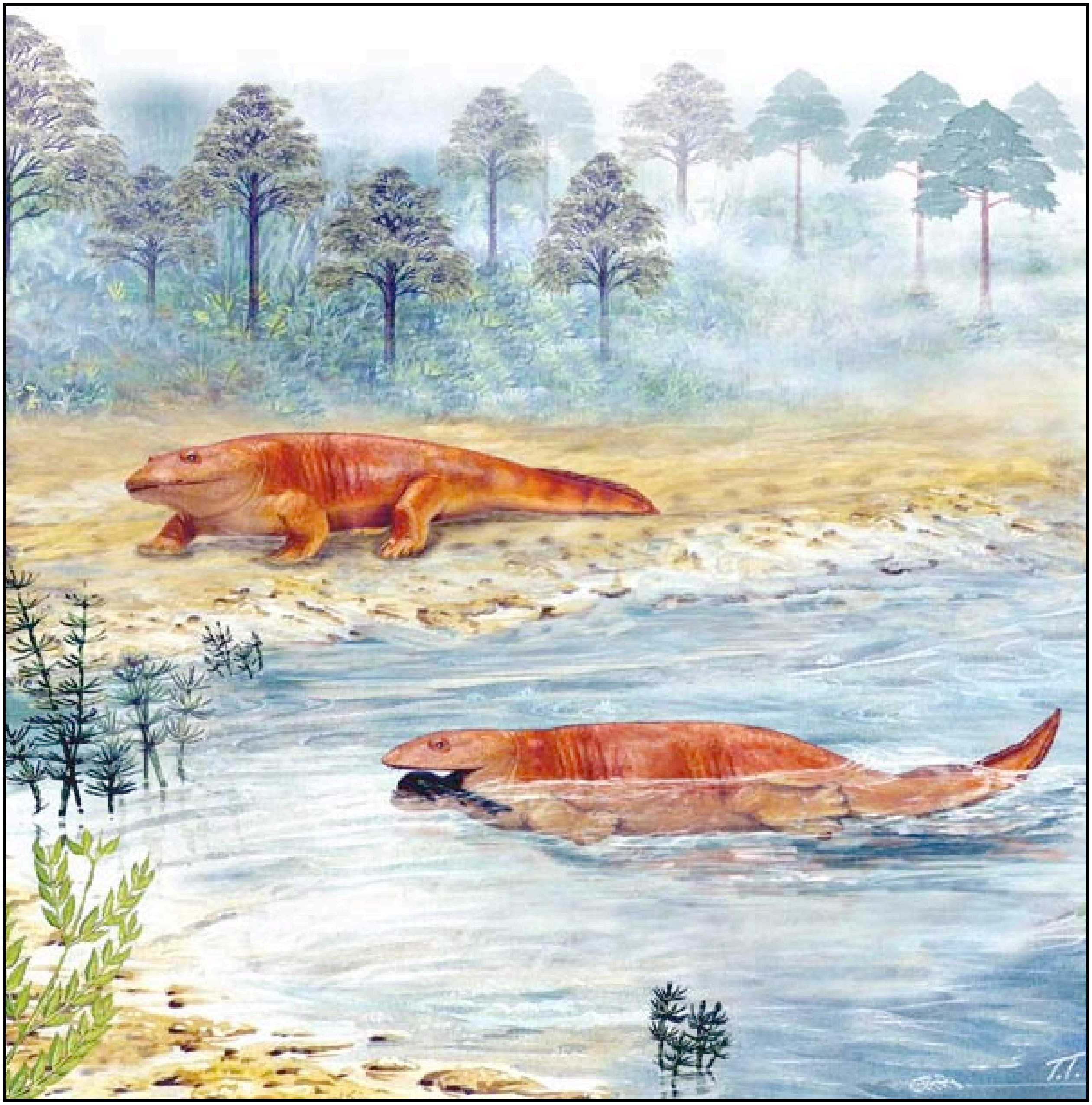
Acanthostega, an amphibian, was one of the first **tetrapods—vertebrates with four limbs**.

Web Reference

http://tolweb.org/tree?group=Acanthostega&contgroup=Terrestrial_Vertebrates#top

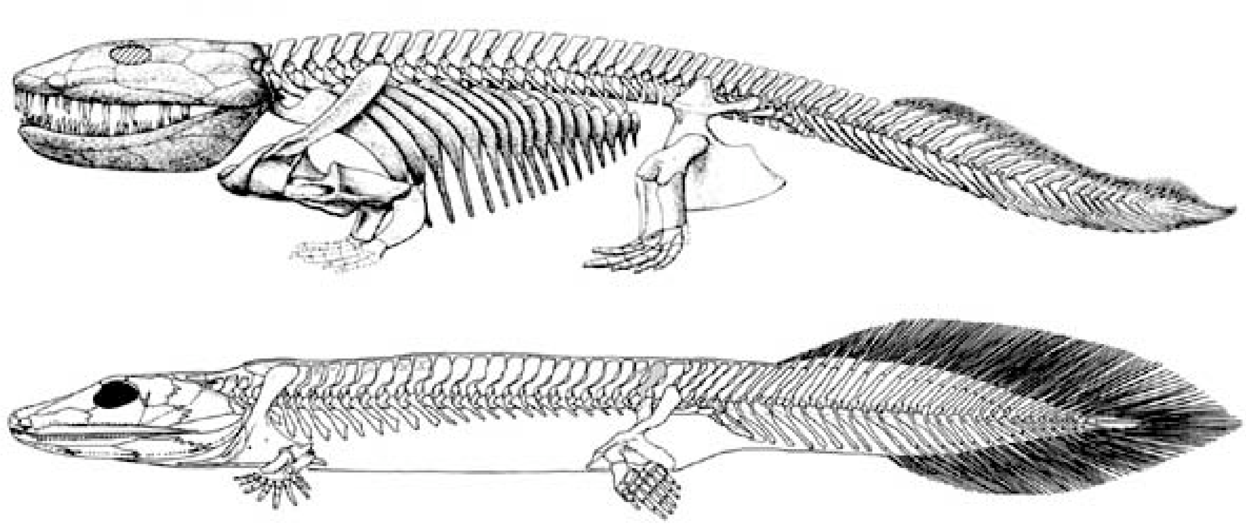


This figure shows a comparison of the limbs of a lobe-finned fish and *Acanthostega*.



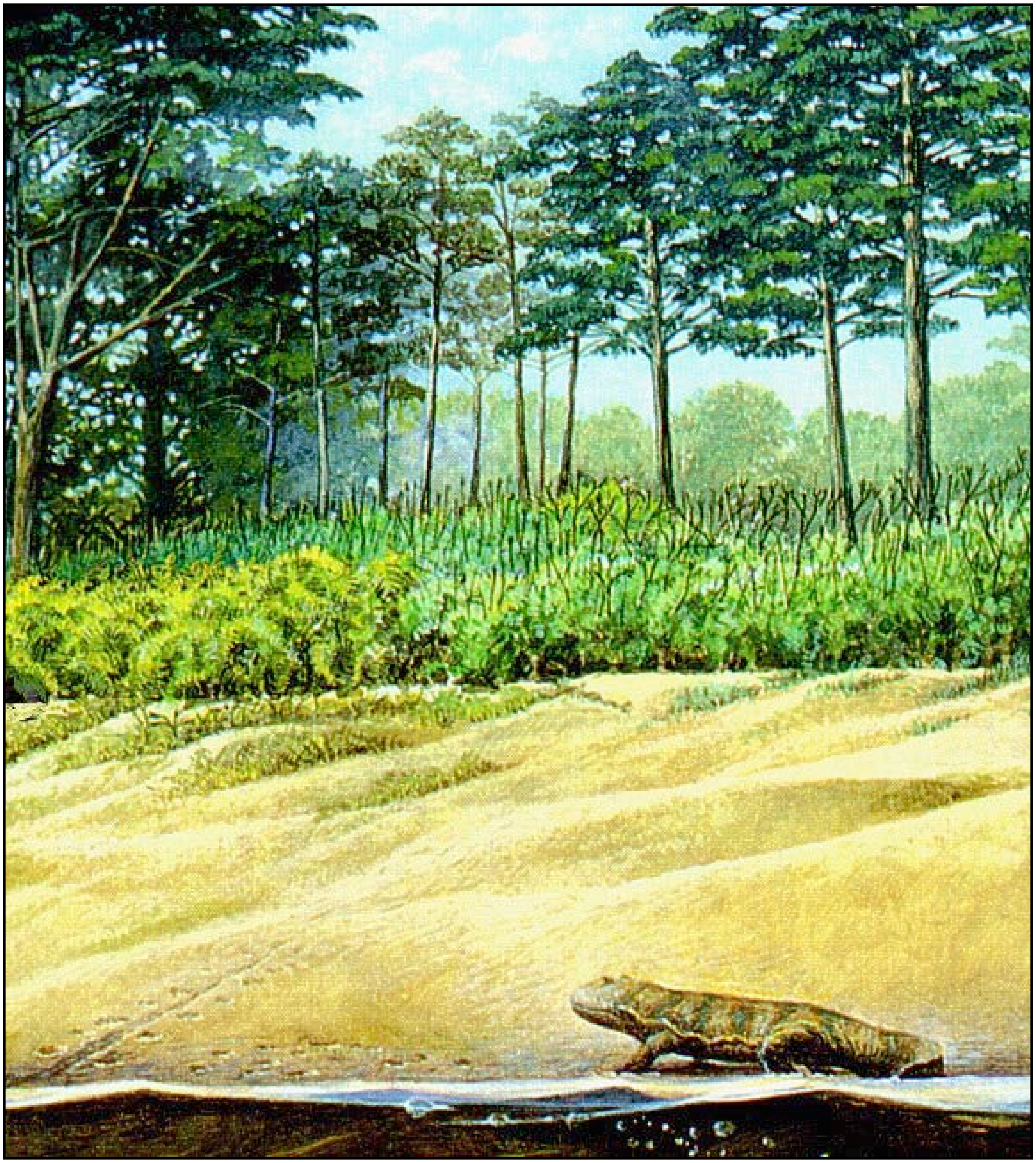
The amphibian tetrapod ***Ichthyostega***, shown in this reconstruction, is the earliest vertebrate to show obvious adaptations for terrestrial locomotion.

(Painting by Tony Terenzi from Carroll, 2005)



Above is a reconstruction of *Ichthyostega* (top) and *Acanthostega* showing the changes in the limbs and spine of *Ichthyostega* for movement on land, as compared to *Acanthostega*, who is thought to have been mostly aquatic. Both lived approximately 365 m.y.a. in the Late Devonian.

(Drawing from Ahlberg, et al., 2005)



Amphibian tetrapods were the first land vertebrates.

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