Test one stats

- Mean 71.5
- Median 72
- Max 101
- Min 38

30	40	50	60	70	80	90	100
1	4	13	23	23	19	9	1

Sarcopterygii Step Out

Text, Ch. 6 pp. 119-125;

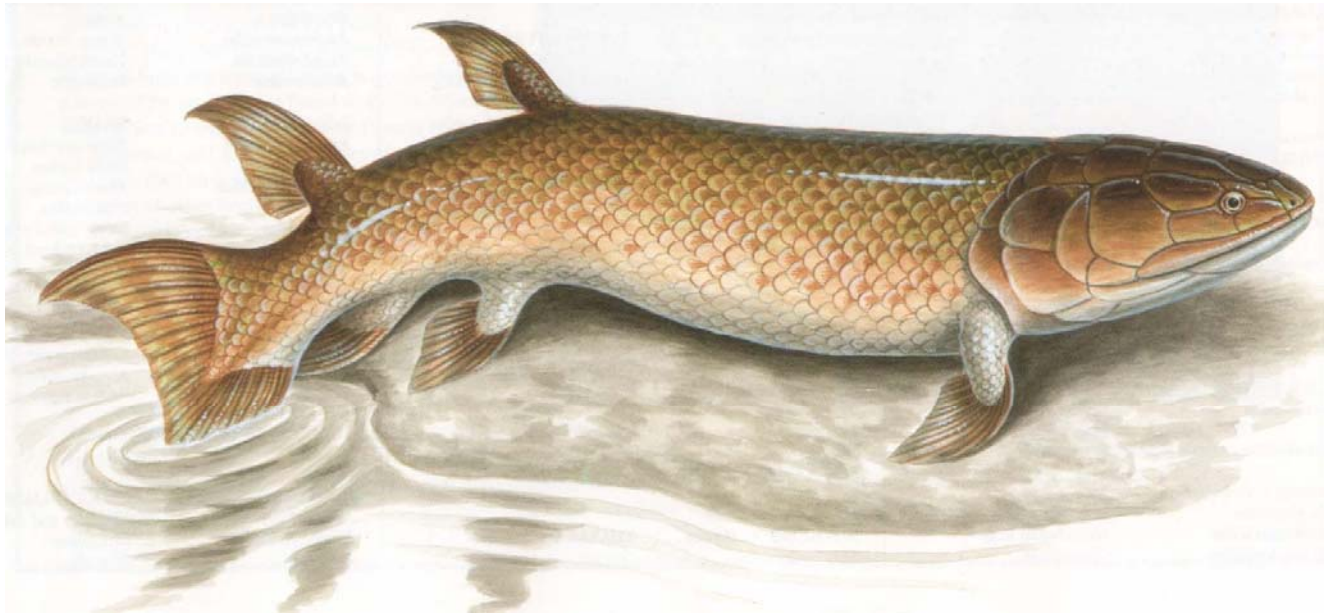
Text Ch. 9; pp. 196-210

Tetrapod Evolution

- The tetrapods arose from some Sarcopterygian ancestor.
- Understanding the origins and relationships among tetrapods is important because there is much current controversy about how terrestrial vertebrates arose, and what groups of terrestrial vertebrates gave rise to amphibians, reptiles, birds, and mammals.

- **The confusing tetrapod ancestors:** Try boiling it down as follows, and understand what this means to the point you could have written it yourself.
- *Was the ancestor to tetrapods a lungfish, a lobe-finned coelacanth, or what?*
  - lungfishes (Dipnoi) exist in South America, Africa, and Australia,
  - The famous Coelacanth is known from offshore Madagascar and was also found in Indonesia in 1998.
- It turns out that when the characters are analyzed, the **osteolepiforms**, are the best candidates as ancestors to Tetrapoda.

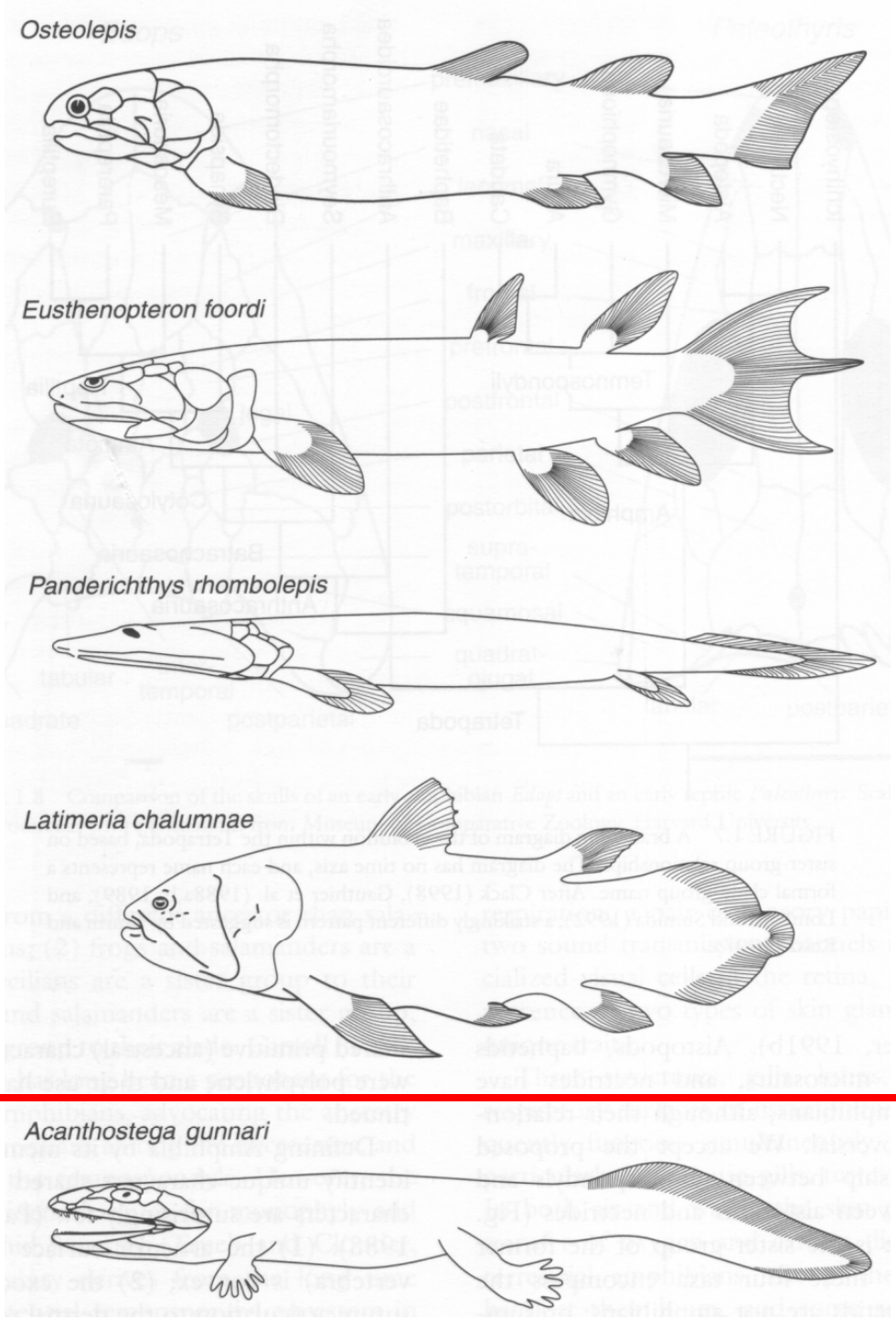
- ***Eusthenopteron (another Osteolepiform known from a fossil)*** is a cylindrical osteolepiform that was a good candidate to be the sister to tetrapods for a while.
- Cylindrical body
- **4 unpaired fins** (2 dorsal, caudal, and anal fin)
- **Vertebrae**: neural arches do not articulate, short ribs
- **Skull**: Area anterior to parietals on skull is mosaic of small bones



Tetrapod ancestor was some type of osteolepiform fish

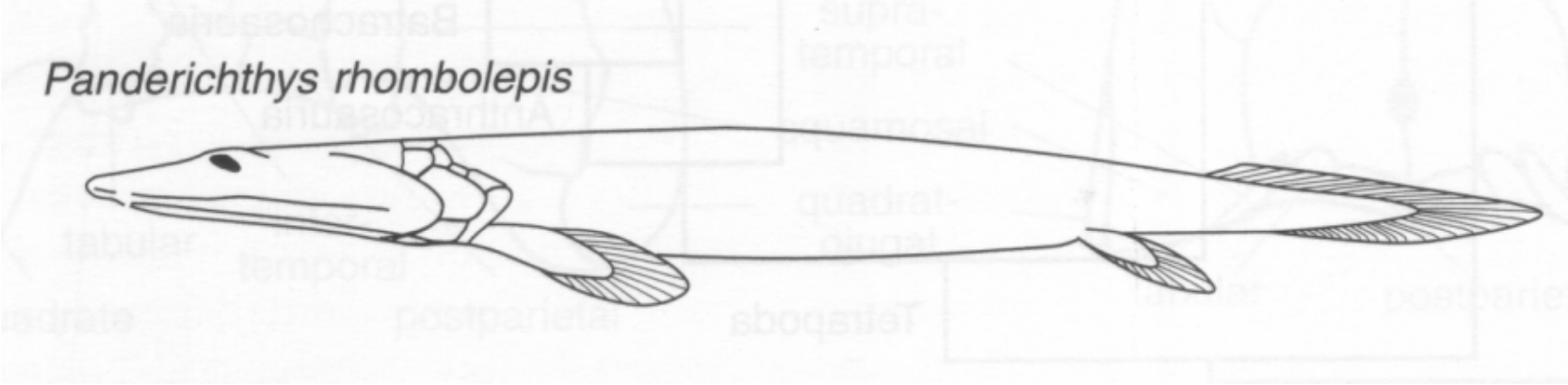
Panderichthyes is a great candidate for the sister group to Tetrapoda

And a more recent discovery, *Tiktaalik* (on subsequent slide).



Acanthostega is an early tetrapod

- **Panderichthyidae: some of these appear truly intermediate between osteolepiforms and tetrapods**
- Dorsolaterally flattened body with long snout, eyes on top of head
- Vertebrae: Large ribs project laterally and ventrally
- Single pair of large frontal bones (like tetrapods)



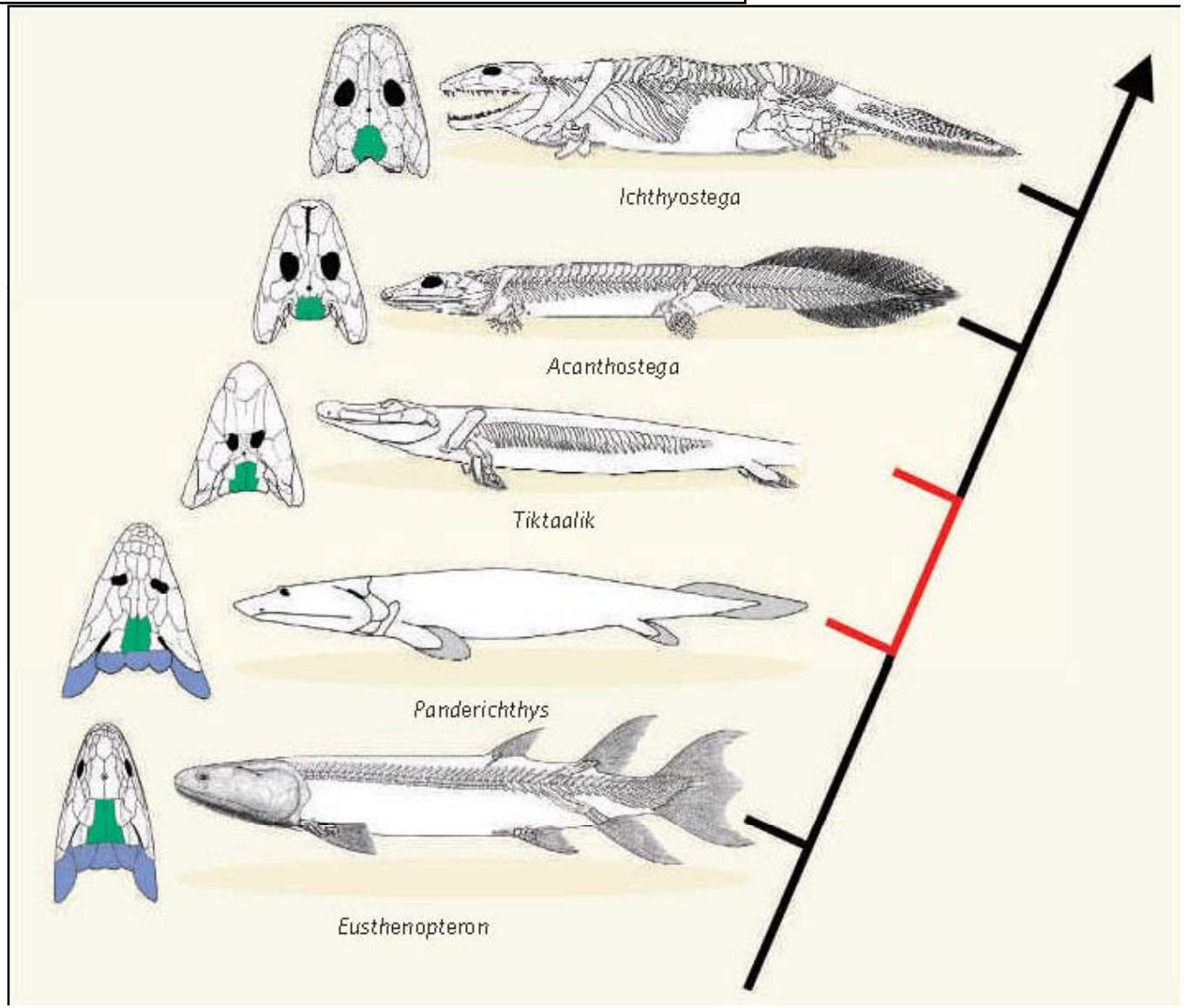
PALAEONTOLOGY

A firm step from water to land

Per Erik Ahlberg and Jennifer A. Clack

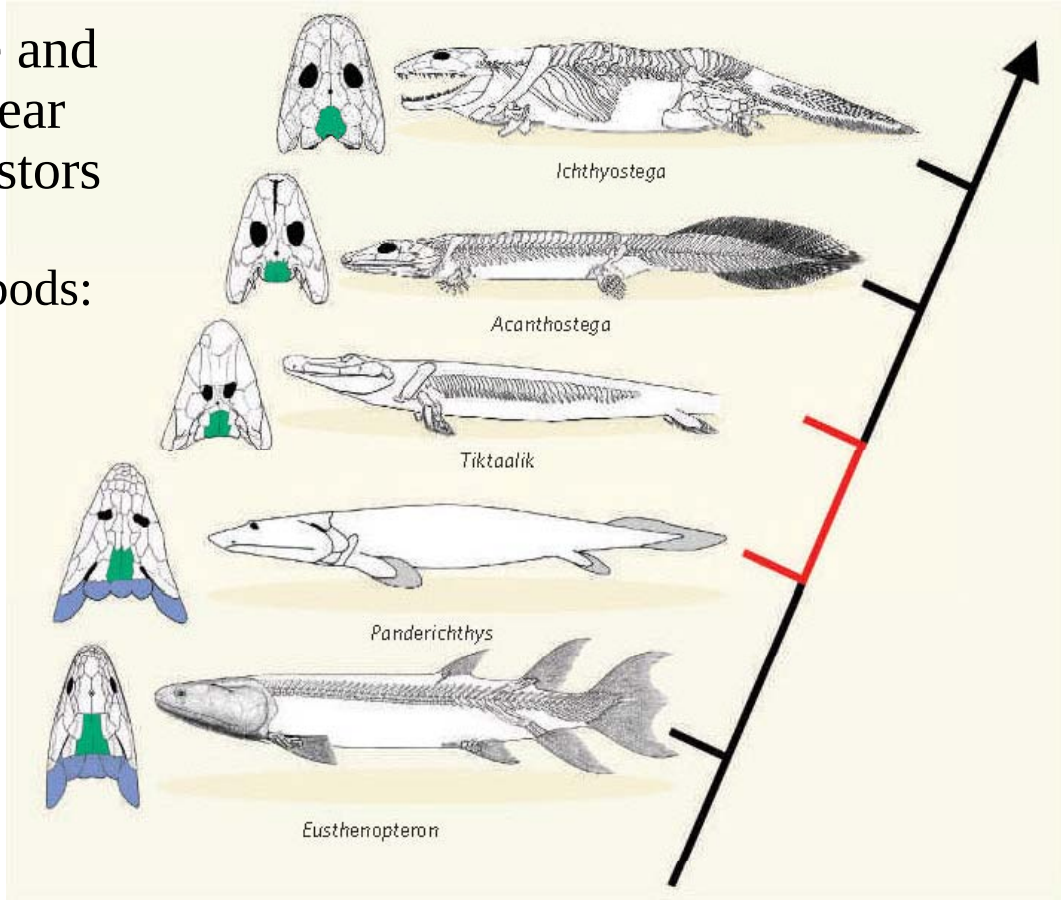
A project designed to discover fossils that illuminate the transition between fishes and land vertebrates has delivered the goods. At a stroke, our picture of that transition is greatly improved.

- ***Tiktaalik roseae*** Daeschler, Shubin, Jenkins Jr.
  - Nature 6 April 2006
  - Elllesmere Island, Nunavut Territory, Canada
- Clear link between fish and tetrapods
- Researchers succeeded in finding a link between *Panderichthyes* and tetrapods in late Devonian
  - Demonstrates predictive capacity of paleontology. i.e., "missing links" needed to clarify evolutionary history of a group should exist. In this case the team knew where to look and succeeded in finding the fossil.

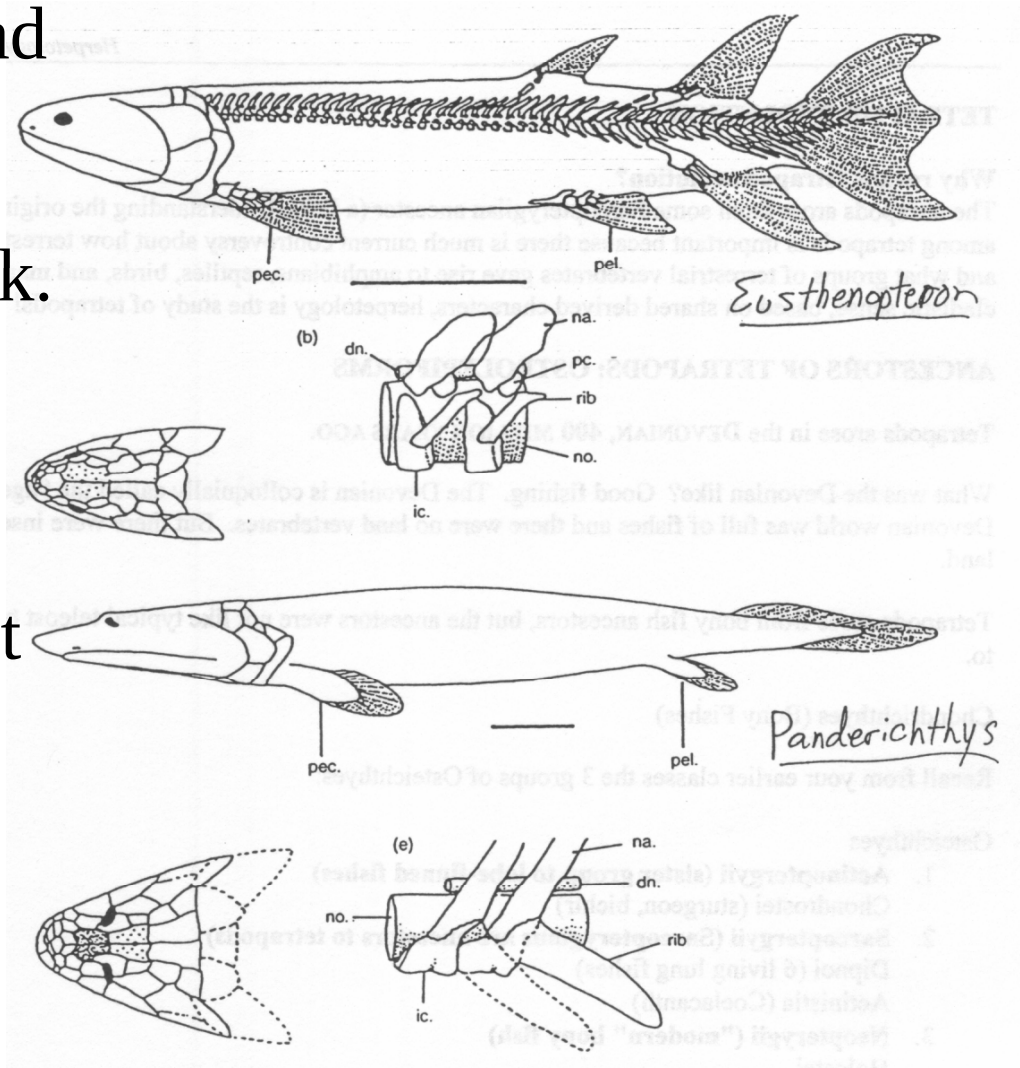


In Summary:

- Sarcopterygian bony fish classified as Osteolepiforms are sister group to all terrestrial vertebrates (Tetrapoda).
- The extinct Panderichthyidae and more derived Tiktaalik are clear links between bony fish ancestors and tetrapods
- Key upper Devonian early tetrapods:
  - *Acanthostega*
  - *Ichthyostega*



- Loss of several cranial bones allowed the head to become detached from the pectoral skeleton. Made a neck.
- Relevant to locomotion, feeding, breathing.
- Shorter notochord that does not extend into the braincase.
- Vertebrae with neural arch, zygapophyses, pleurocentrum.



Life in Devonian, 360 mya

- http://www.youtube.com/watch?v=egywKnwsw_Y
- http://www.youtube.com/watch?v=9S4TA9RfDb8
- Realize tetrapods arose from fish-like ancestors that functioned well in their aquatic environments. [It is not really clear whether tetrapods arose in fresh water or brackish lagoons.]
- Early tetrapod limbs may have been used for supporting these fish on the bottom as they stalked prey. They could have lived in dense mats of aquatic vegetation.
- Tetrapod ancestors all probably had lungs. Actinoptergyians, Dipnoi, actinistians, tetrapods all had lungs.
  - Lungs is a basal character on the tree, and it is pretty safe to assume the lineages of tetrapod ancestors all had lungs.
  - Lungs is an old trait, lungs are even the predecessors of swim bladders in advanced fishes.

Why go terrestrial?

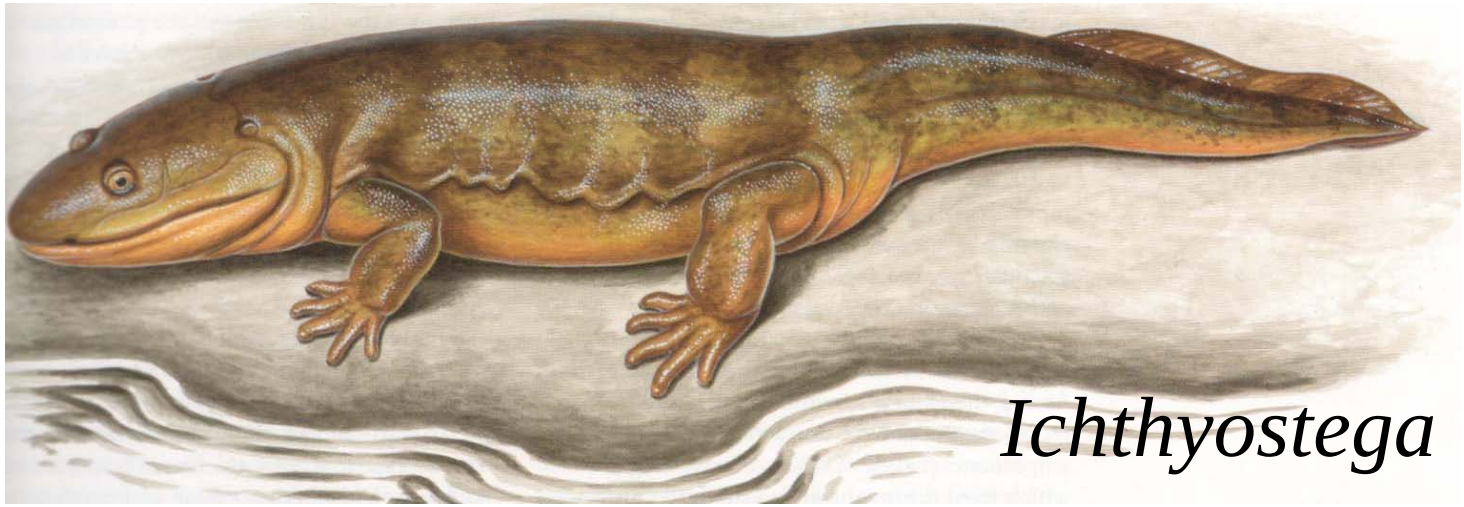
- The transition from fish to tetrapod occurred in water.
  - Tetrapod ancestors were aquatic, not particularly well suited to life on land.

Old hypothesis:

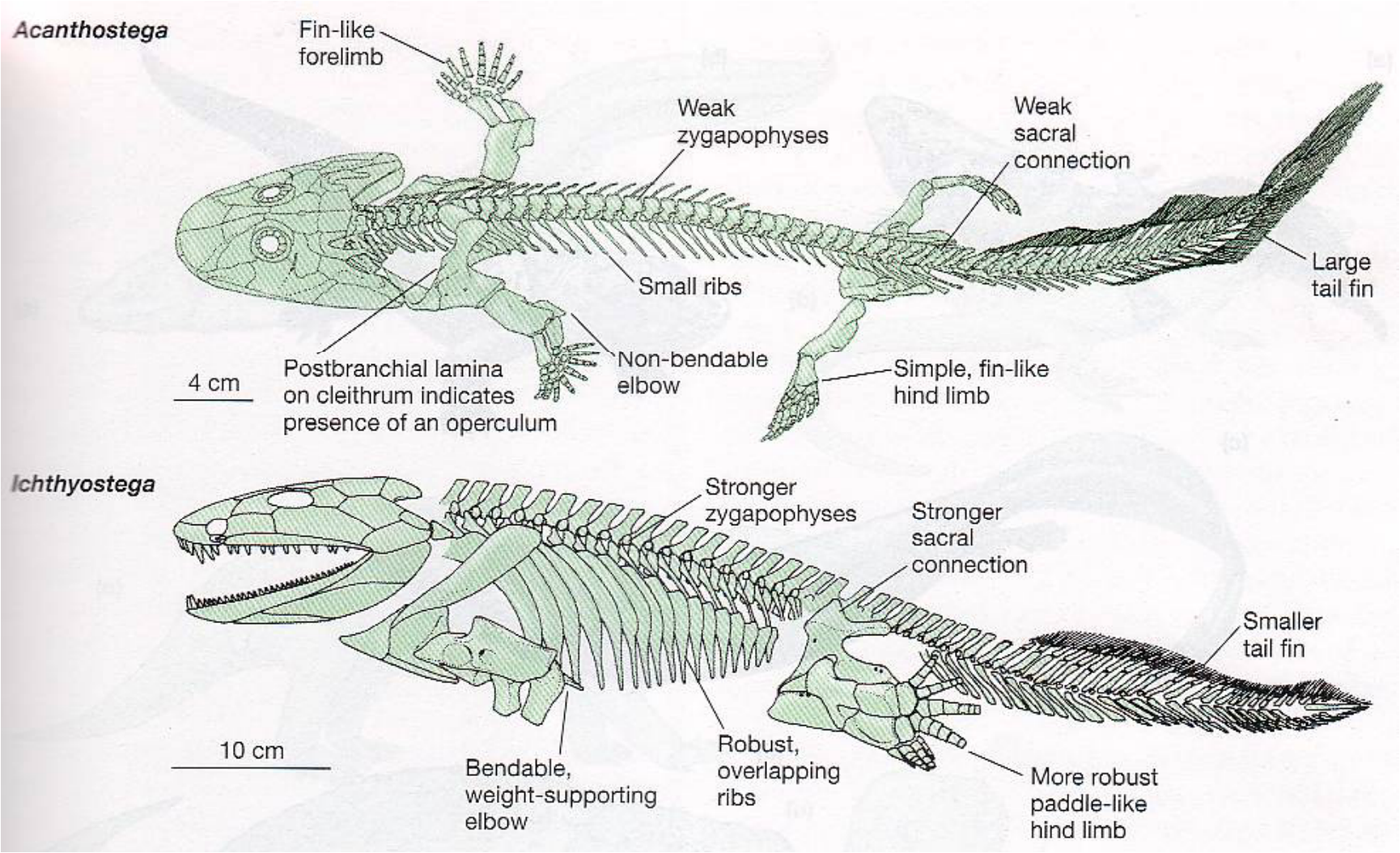
- *An old theory* speculated that the Devonian was drying up, and early tetrapods moved from one drying pond to the next, like a walking catfish does.
- Problems:
  - If an organism is successful being a fish that flops along to the next pond, it's still being a successful fish.
  - The Devonian was probably not a drying up world, there was still plenty of water.

Devonian tetrapods

- Still very aquatic, such as *Acanthostega* from Greenland.
- Still had internal gills. Showed polydactyly: *Acanthostega* had 8 toes on front.
- These tetrapods were carnivores, 50-120 cm long.
- Another form, *Tulerpeton*, was more lightly built with longer limbs.
- Hard to say how they lived: Were they seal-like with front limbs to prop them up on land and hind limbs as rudders?



- Compare and contrast *Acanthostega* and *Ichthyostega* (fig 9-7, Pough text)
  - *Acanthostega was more aquatic.*
  - Note differences in how the limb girdles and vertebral column made *Ichthyostega* better built for supporting the body on land



Why go terrestrial? New thinking

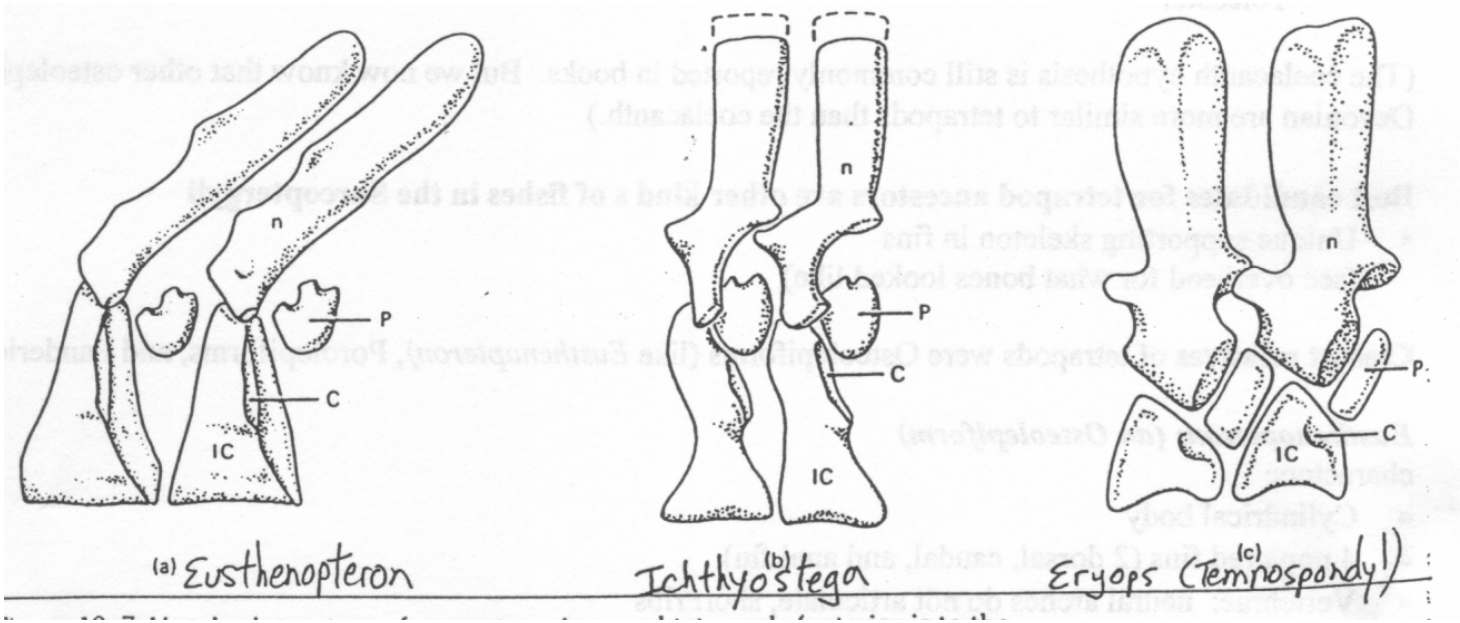
- The Devonian was swarming with fish competitors and predators. The land was empty of vertebrates.
- *Acanthostega* and *Ichthyostega* could easily have lived in shallow water, especially as **juveniles** to escape predators in deep water, and to feed on invertebrates along the shore.
- Their limbs could hold their heads out of the water, and they could breathe air. Imagine a little juvenile *Ichthyostega* foraging among aquatic plants along the shore, maybe running after bugs.

Why go terrestrial? New thinking

- Terrestriality may also have favored the dispersal of juveniles.
- This transition could have occurred in freshwater or brackish lagoons.
  - Most, but not all fossils are from freshwater deposits, and tetrapod kidneys are built to deal with maintaining water balance in lieu of fresh water problems.

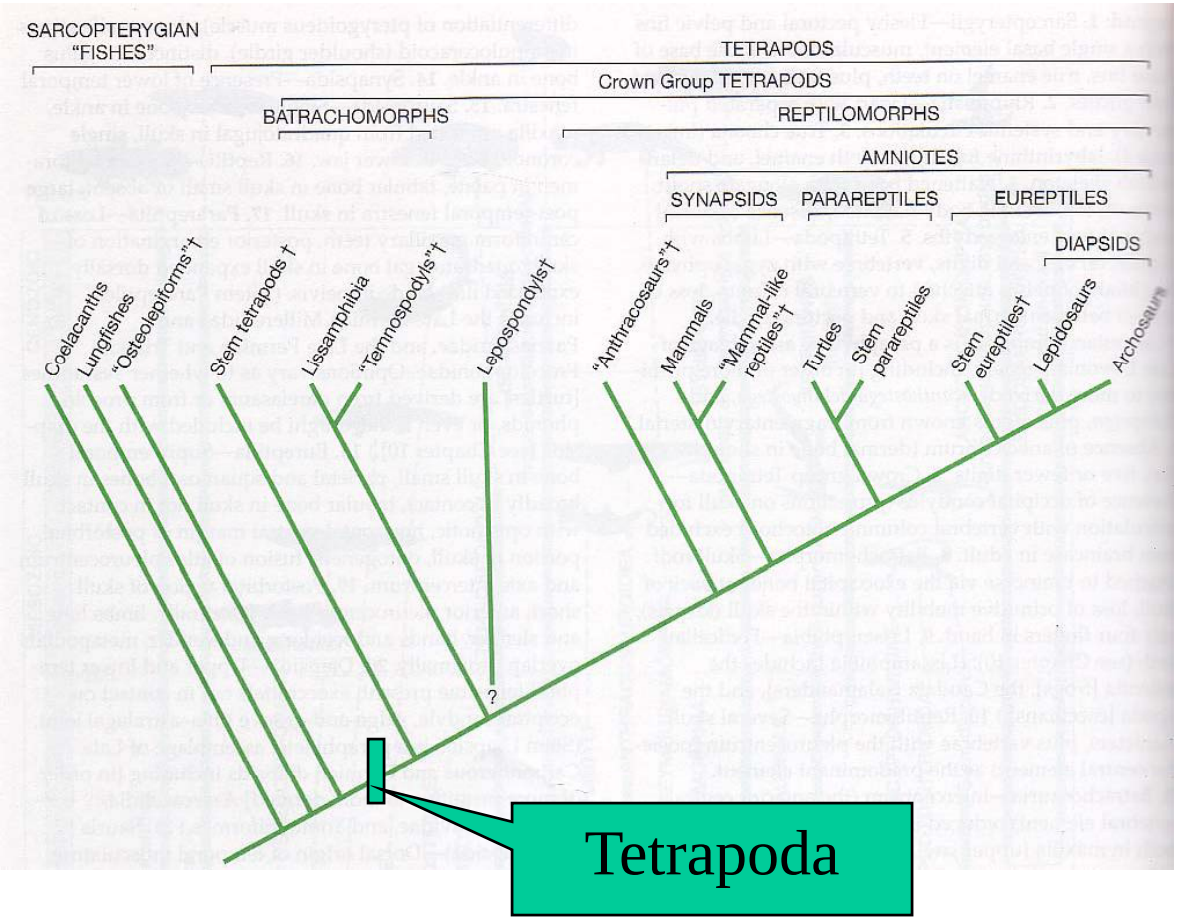
- **Relating Ecology to Characteristics of terrestrial vertebrates: Life on land**
- Massive skulls, roofed with dermal bone; Snout elongated
- Relevant to feeding, breathing on land (filling lungs with the buccal pump)
- Fishes use suction feeding, whereas most tetrapods use tongue or jaws to seize food.
- Loss of the opercular bone that covered gill chamber. Not needed without internal gills.
- Sacral rib connecting the axial skeleton to the pelvic girdle. Allows weight to be transmitted to hind limb. There was no connection in osteolepiforms.

- *Eusthenopteron* (an Osteolepiform fish) had loose vertebrae.
- *Ichthyostega* had characteristics associated with terrestrial life
  - interlocking vertebrae that made it's backbone act like a suspension bridge between the pelvic and pectoral girdles.
- Later forms such as *Eryops* had even more tightly articulated vertebrae.



Definition of a Tetrapod:

- Any vertebrate with four limbs; has included many lineages of terrestrial vertebrates.
- Specifically, the vertebrate category **Tetrapoda** is a monophyletic group including some extinct lineages of amphibians, living amphibians, the sister group to amniotes, and the amniotes (reptiles, birds, and mammals).

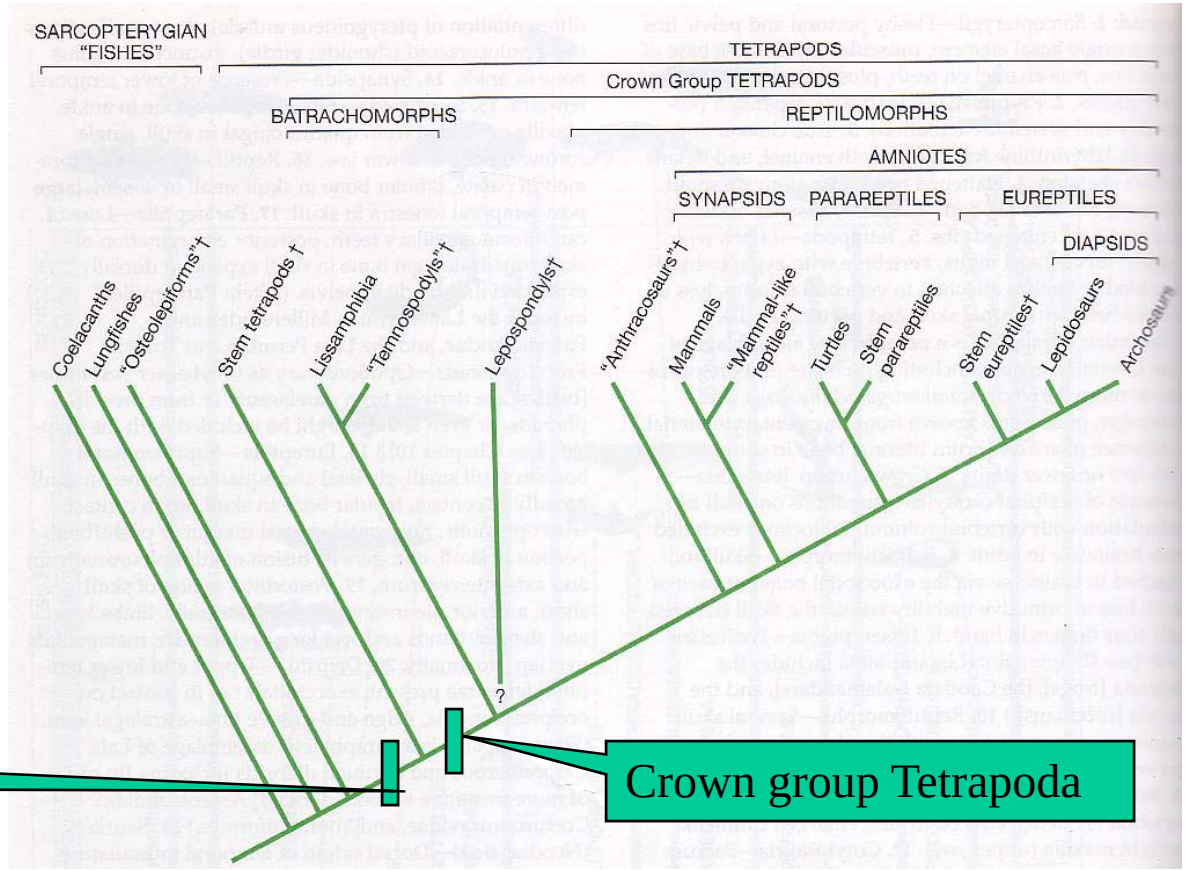


Tetrapod traits

- Tetrapoda clade:
  - Limbs with carpals, tarsals, digits
  - Vertebrae with zygapophyses
  - Pelvis attached to vertebral column
  - Loss of contact between dermal skull and vertebral column

- Crown group Tetrapoda

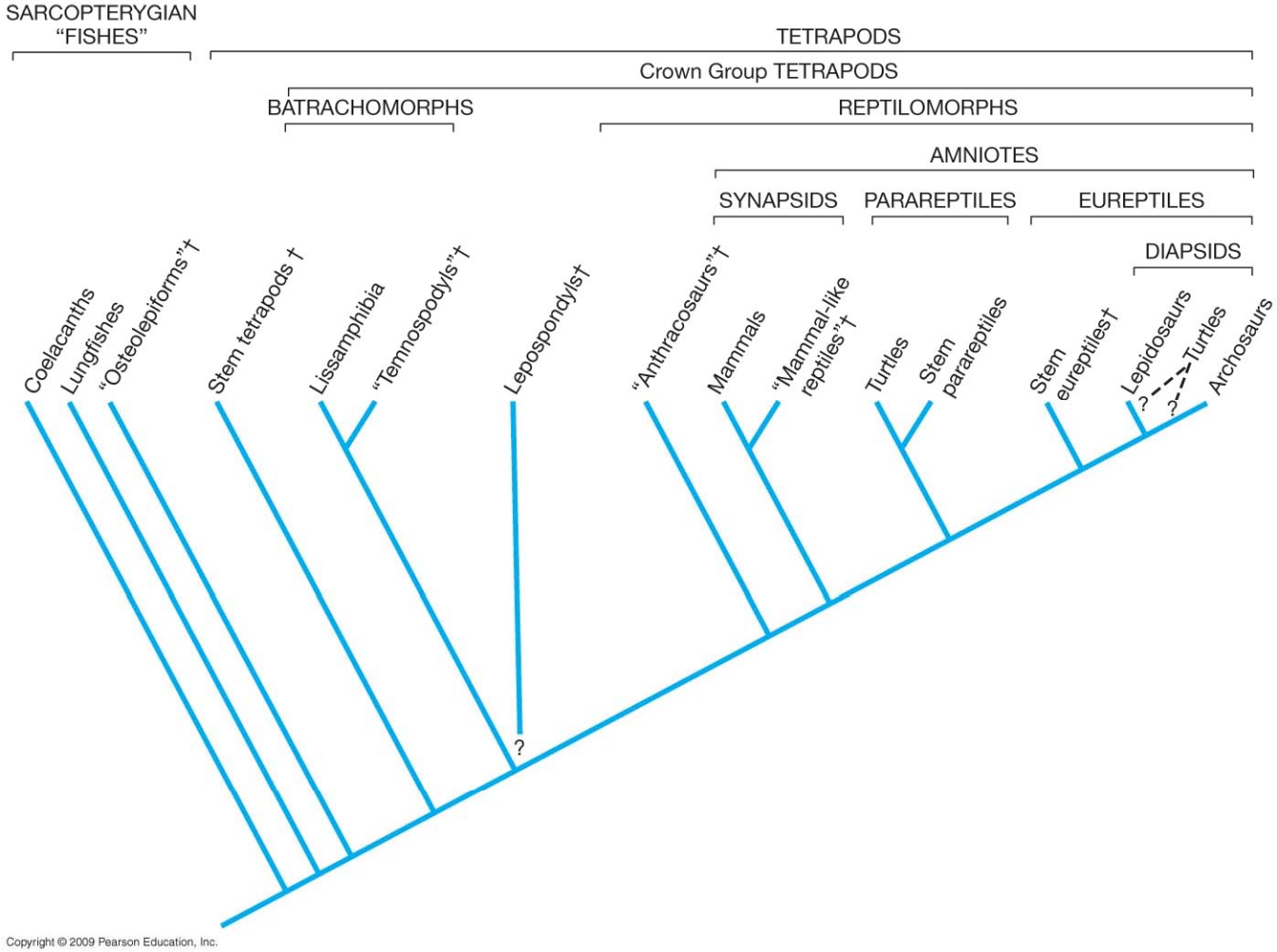
  Notochord excluded from braincase in adult



Tetrapoda

Crown group Tetrapoda

- Tetrapods arose in the **Devonian, 400 million years ago**.
- Soon after, Crown Group Tetrapods split into 2 lineages:
  - **1. Amphibians, or Batrachomorphs**:
    - Lissamphibia is the monophyletic group containing Frogs, Salamanders, and Caecilians
    - Temnospondyls are early tetrapod amphibians somehow related to Lissamphibia



The Lissamphibia:

Origins of Lissamphibia

- **Lissamphibia** (frogs caecilians and salamanders) is a monophyletic group,
  - (There is uncertainty about what are the closest relatives.)
- A bunch of weird tetrapods lived between the time of *Acanthostega* and *Ichthyostega* and the radiation of the Lissamphibia:
- **Anthracosaurs**, microsaurs, nectrideans, **temnospondyls** were all appearing then, and their relationships are not clear.

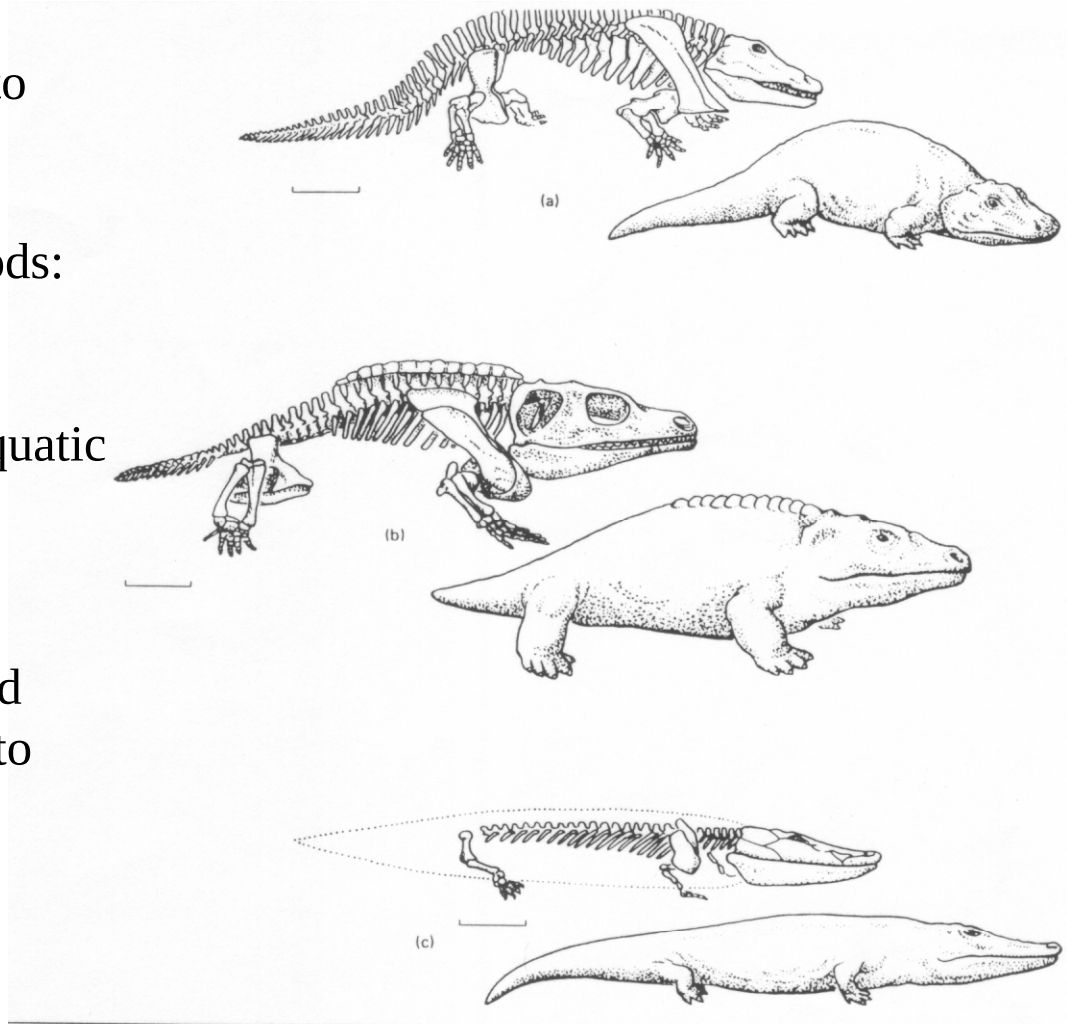
Temnospondyls

•Sister group to Microsauria

•Geologic period: Persisted well into Jurassic

•Most speciose nonamniotic tetrapods: Examples *Eryops*, *Cyclops*, *Cyclotosaurus*. Most were large-headed, stocky, short legged semiaquatic predators.

•Mode of life: Diverse ecologies, different forms of predators, showed lots of specializations. Size: small to large.



Temnospondyls

Some bizarre forms, like *Gerrothorax*, had big flat heads, eyes on top. It probably laid in wait for prey. Note it had external gills. Trematosaurids had snouts like Crocodilians, probably specialized as fish eaters.