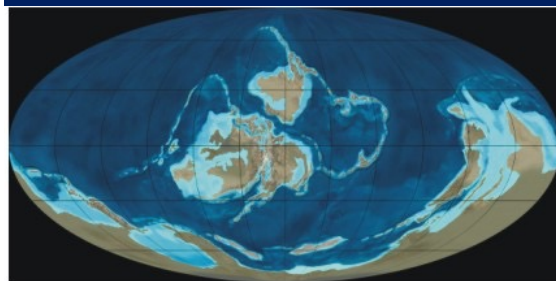
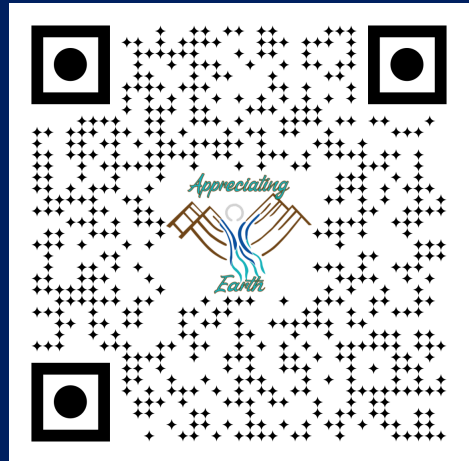


Skeletal Evolution & Earth History

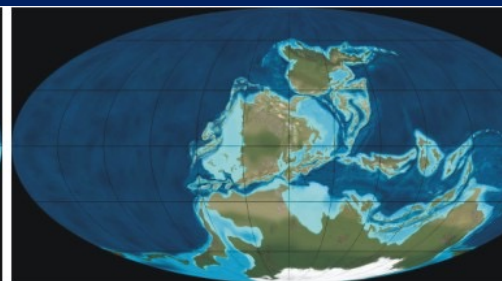
Lecture 2

with Nicole Myers

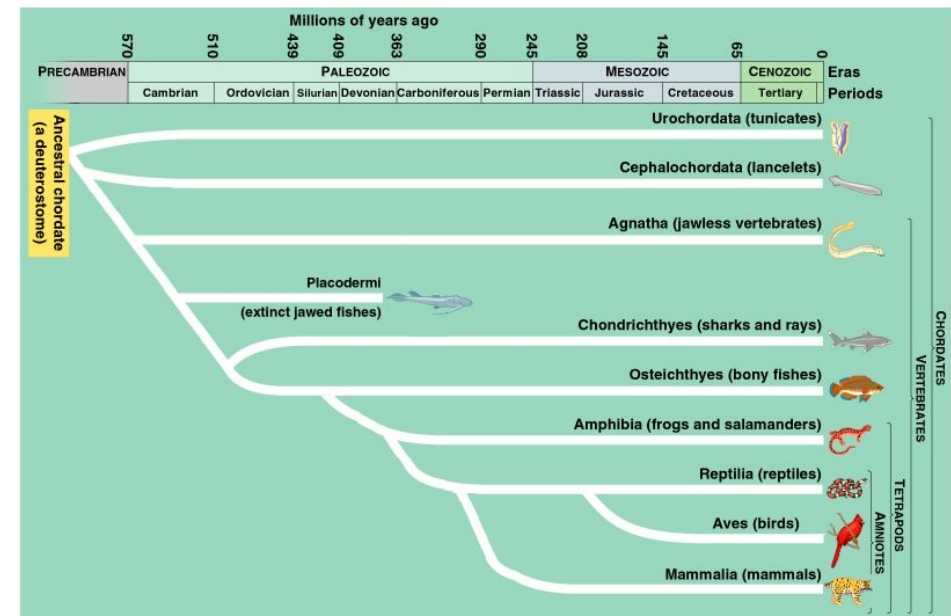
www.appreciatingearth.com/olli



430 mya



340 mya



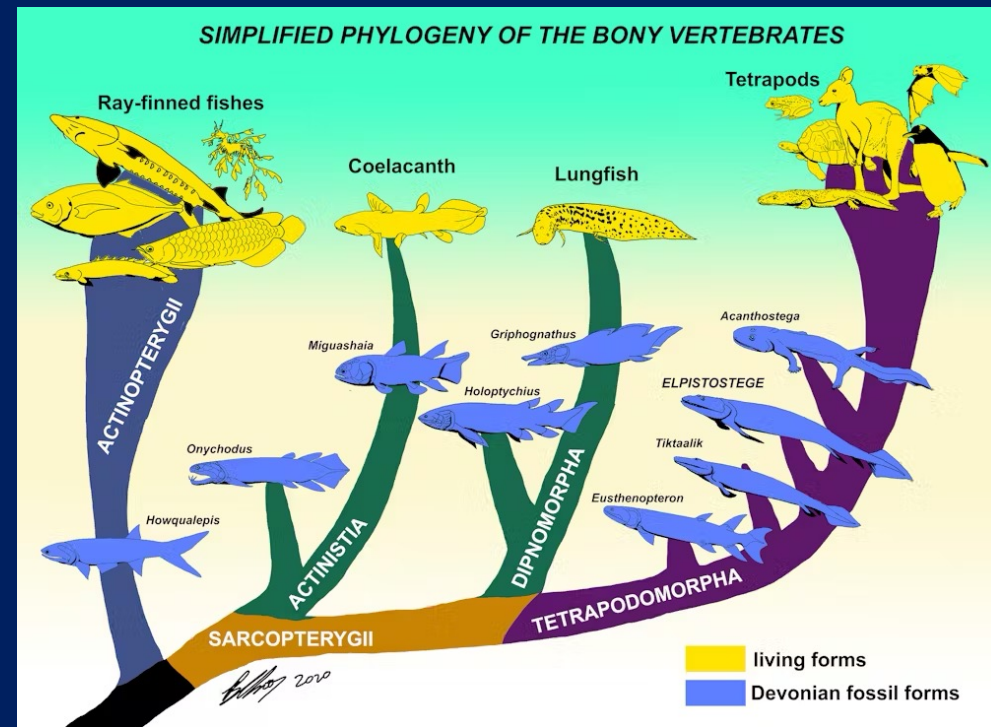
Adapting to the Environment

What are organisms adapting to?

- **Energy sources & acquisition** (diet, feeding habits, niches)
- **Climate** (temperature, humidity, precipitation, aridity, seasonality)
- **Water** (salinity, temperature, pressure)
- **Sunlight** (water depth, cloud cover)
- **Locomotion** (aquatic, terrestrial, aerial)

What is Adaptation?

The process which enables organisms to adjust to their environment in order to ensure survival.



Cambrian - Ordovician - Silurian - Devonian

- Warm climate
- Oxygenated & chemical-rich seas
- First chordates & vertebrates



- Warm climate ended with ice age
- Great Ordovician Biodiversity Event (GOBE)
- First land plants
- Increasing oxygen levels
- First jawed fishes

- Warm climate
- Orogenies: Appalachian, Caledonian
- First cartilaginous fish & osteichthys fish

Age of the Fishes:

- Cooling climate
- First forests
- Increased oxygenation
- First tetrapods
- First Amphibians

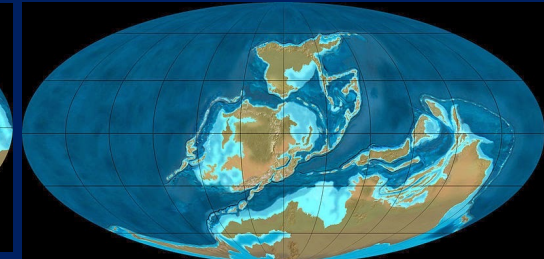
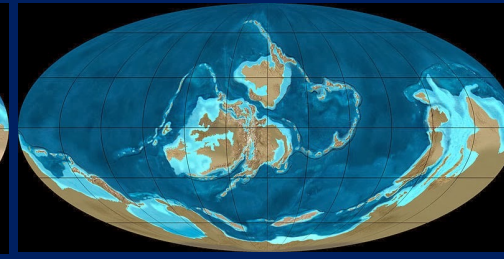
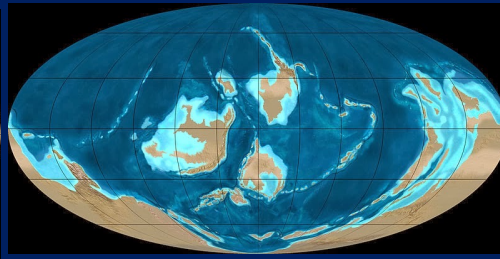
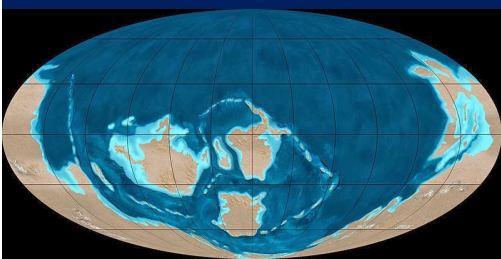
538.8Ma

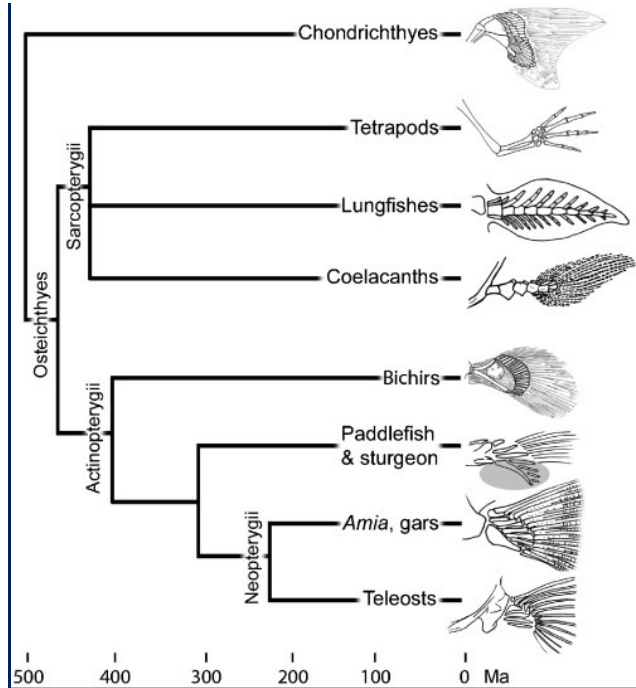
486.9Ma

443.1Ma

419Ma

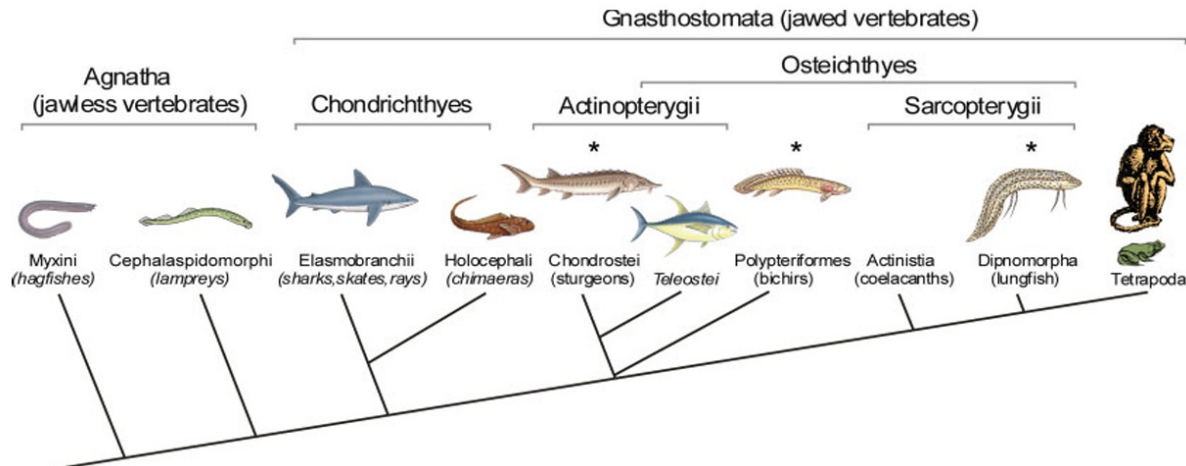
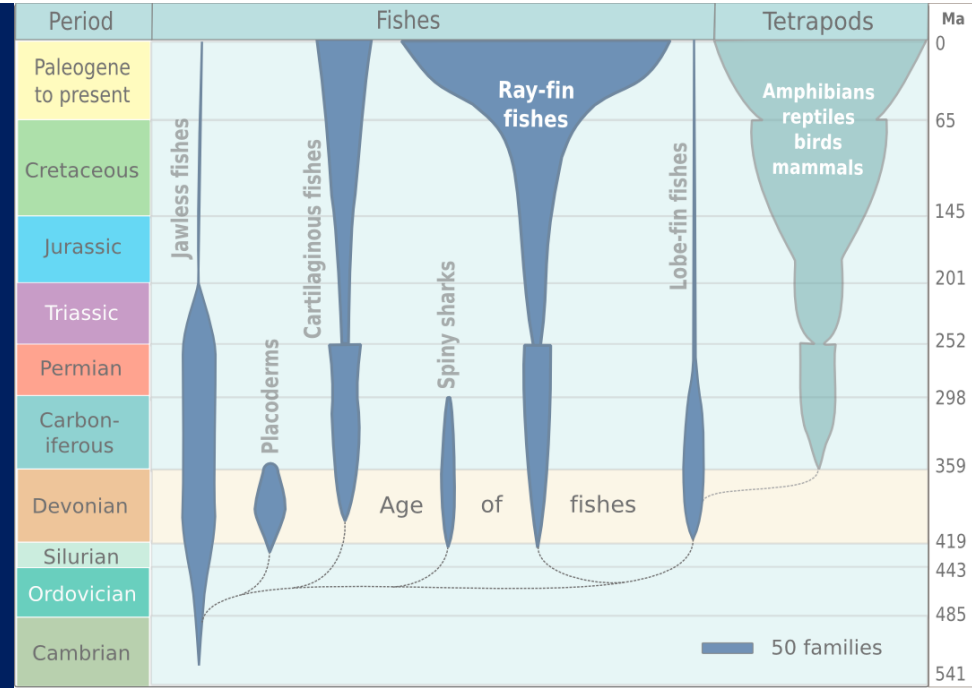
359.3Ma





Fish to Tetrapods

- Calcified bones
- Jaws
- Lungs
- Paired fins
- Limbs



Jawless fishes

Skull (cartilage)

Gill arches made of cartilage supported the gills.

Gill arches

Gill slits

Early jawed fishes
(placoderms, now extinct)

Some anterior gill arches became modified to form jaws, which at first had no teeth.

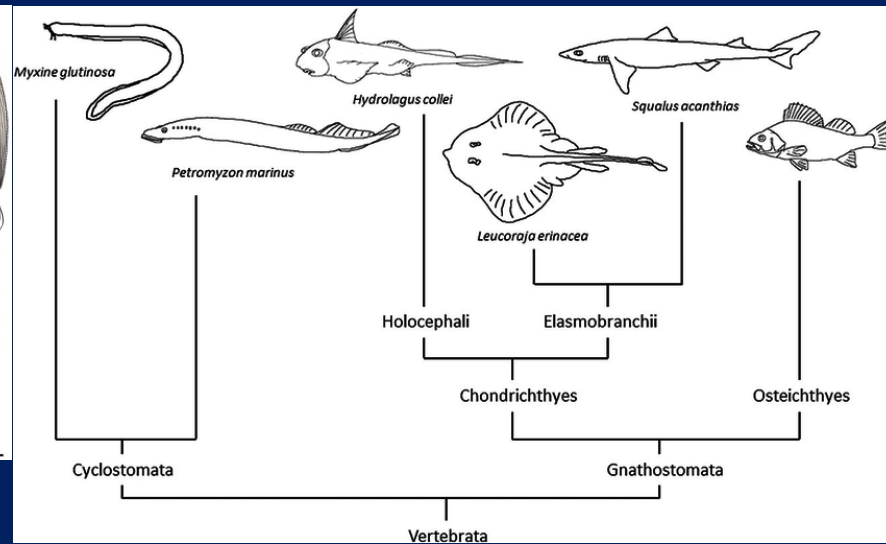
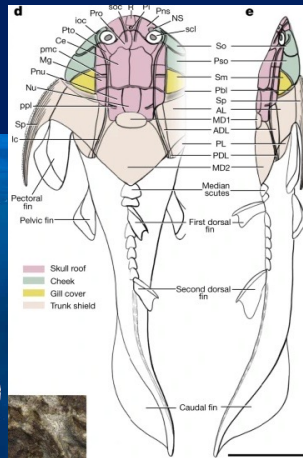
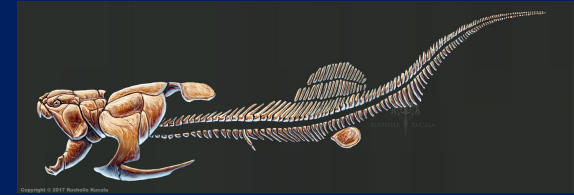
Modern jawed fishes
(cartilaginous and ray-finned fishes)

Additional gill arches help support heavier, more efficient jaws, which in turn, support teeth.

The diagram illustrates the evolutionary progression of the vertebrate skull and jaw structure. It is divided into three horizontal panels, each showing a cross-section of a fish's head and the underlying skeletal structure.
1. **Jawless fishes:** The top panel shows a fish with a simple, elongated skull made of cartilage. The gill arches are also made of cartilage and support the gills. Labels point to the 'Skull (cartilage)', 'Gill arches made of cartilage supported the gills.', 'Gill arches', and 'Gill slits'.
2. **Early jawed fishes (placoderms, now extinct):** The middle panel shows a more complex skull. The anterior gill arches have become modified into a jaw structure. A label points to this area, stating: 'Some anterior gill arches became modified to form jaws, which at first had no teeth.'
3. **Modern jawed fishes (cartilaginous and ray-finned fishes):** The bottom panel shows a further evolution. The jaw is now supported by additional gill arches. A label points to these arches, stating: 'Additional gill arches help support heavier, more efficient jaws, which in turn, support teeth.'
Arrows indicate the downward flow of evolution from jawless to early jawed, and then to modern jawed fishes. Small illustrations of representative fish are shown next to each stage.

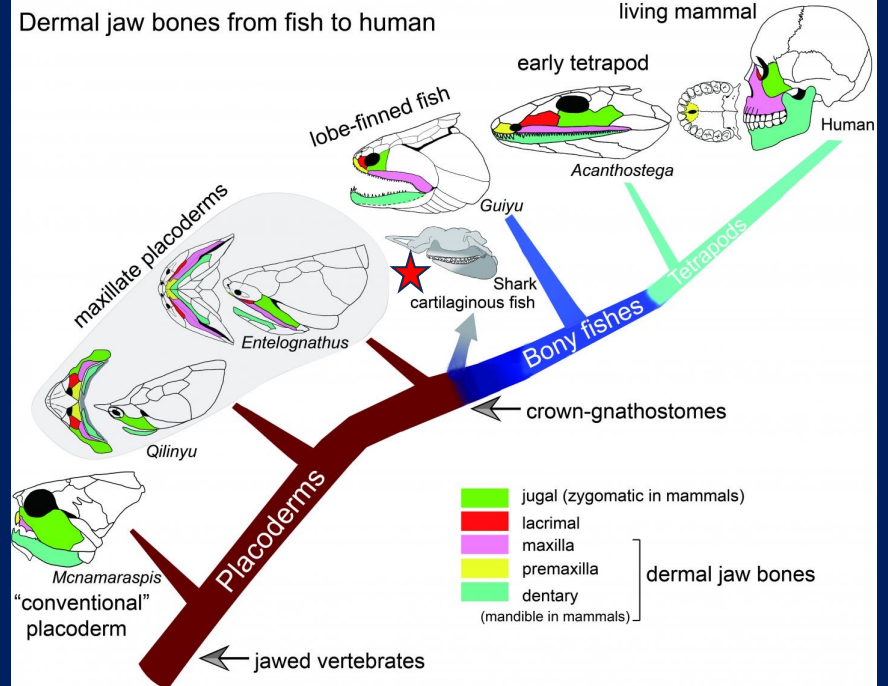
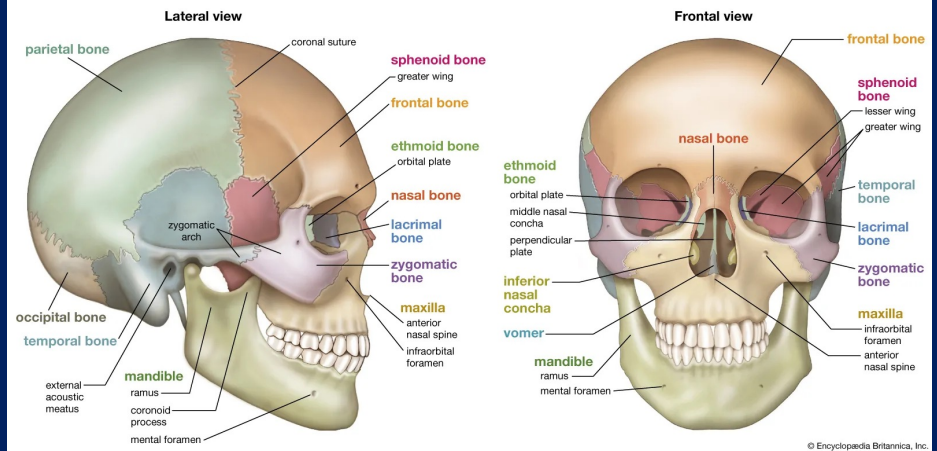
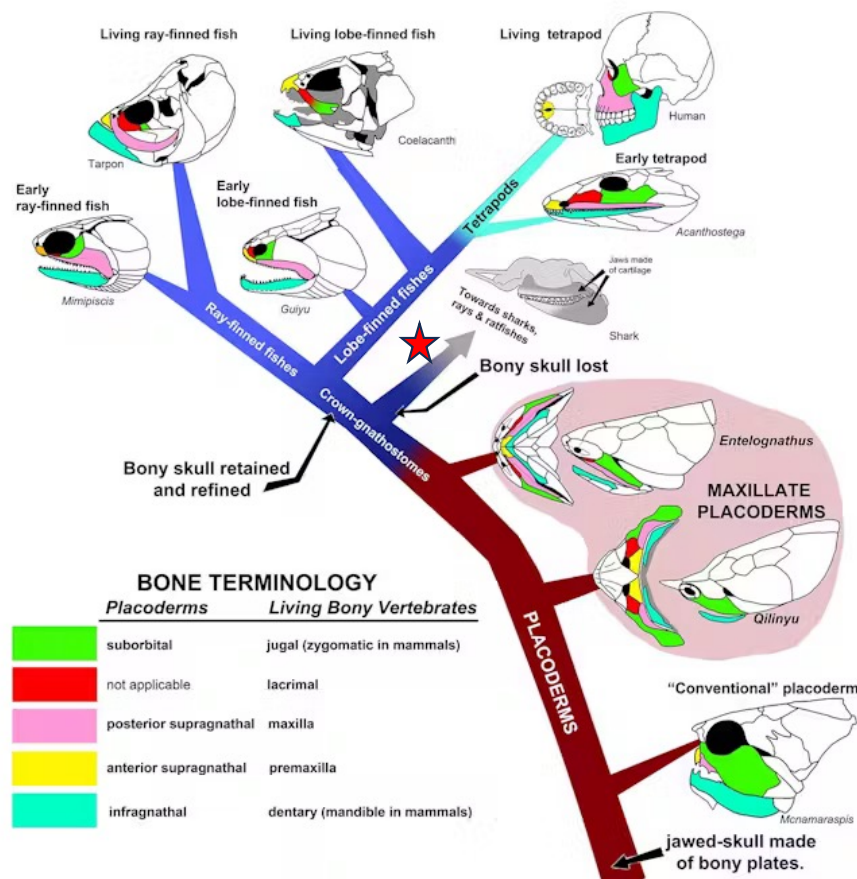
Jaws evolved from gill arches

- Gnathostomata = jaw + mouth = jawed vertebrates
- 1st jaws during GOBE → fish diversification
- ~436Ma *Xiushanosteus mirabilis* 1st known jawed fish
- ~382Ma armored placoderm *Dunkleosteus* had skeletons with some tetrapod-like bone & cartilage



Evolution of Jaws

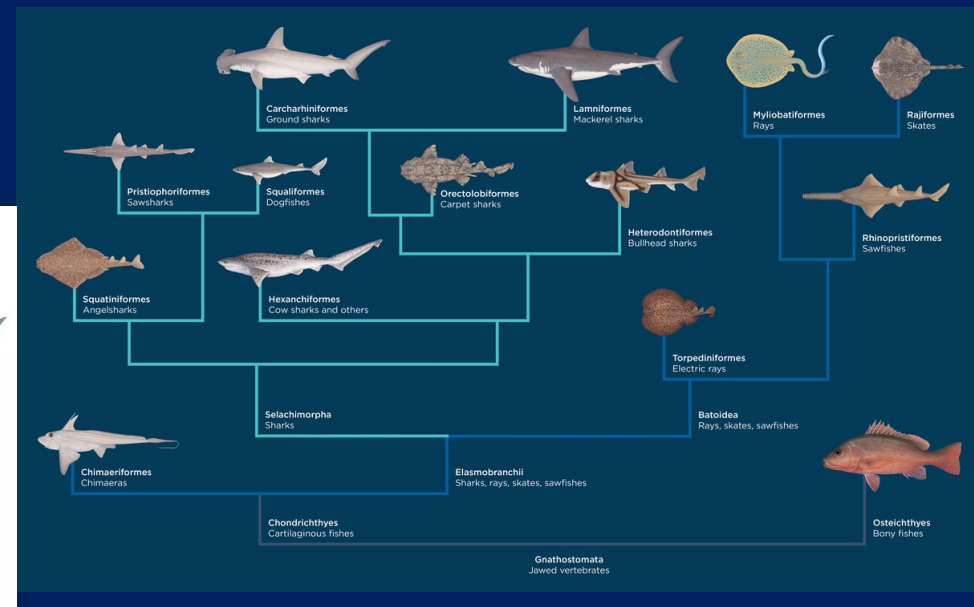
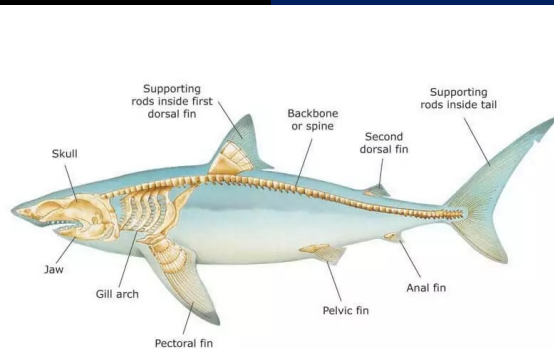
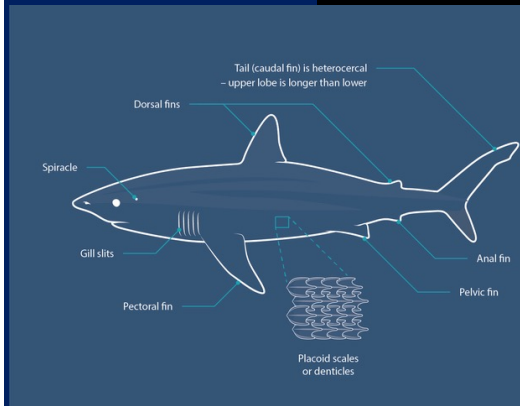
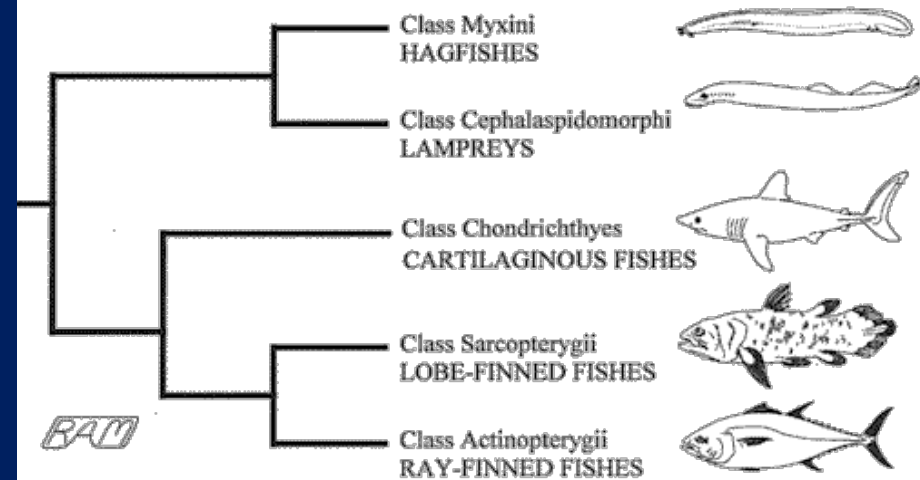
- Gnathostomata
- Skull & jaw evolution



Class Chondrichthyes

Sharks, skates, rays, ratfishes

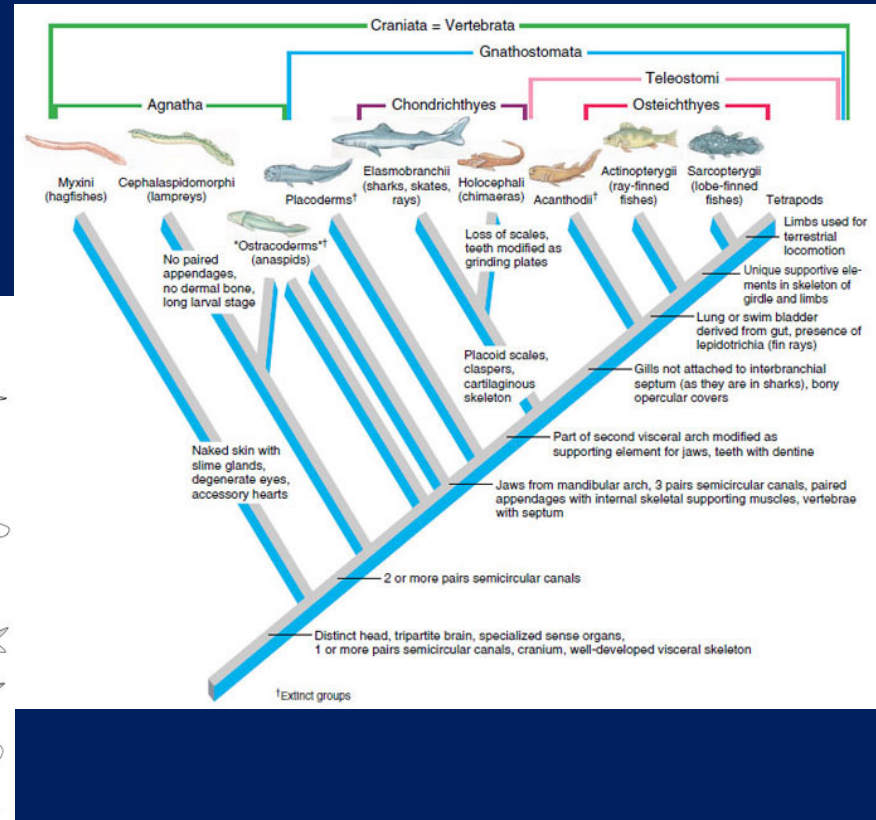
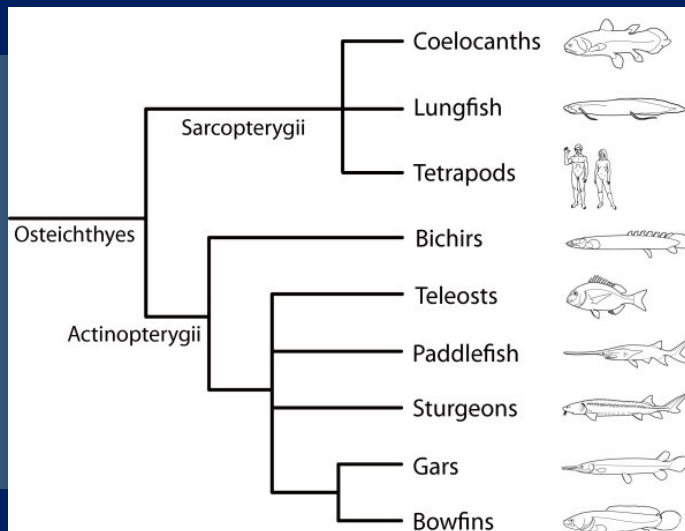
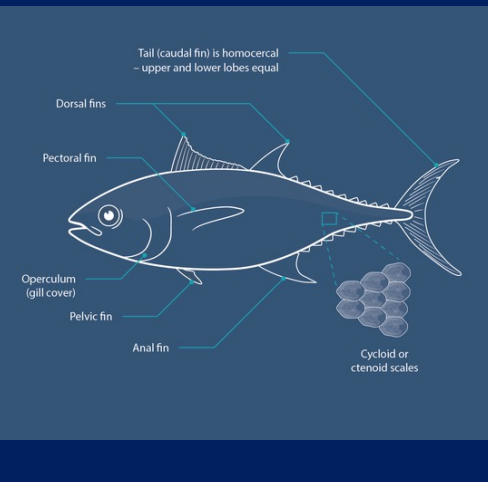
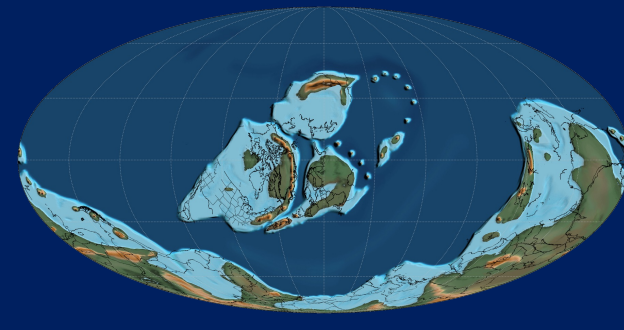
- 1st ~439Ma Silurian Period → Carboniferous golden age of sharks
- Skeleton = hard mineralized cartilage
- Cartilage = chondrocyte cells within collagen



Bony Fish

Osteichthys (bony fish)

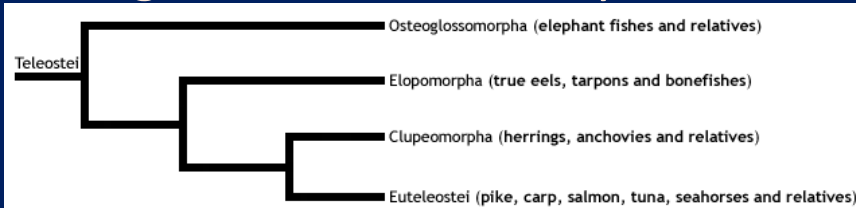
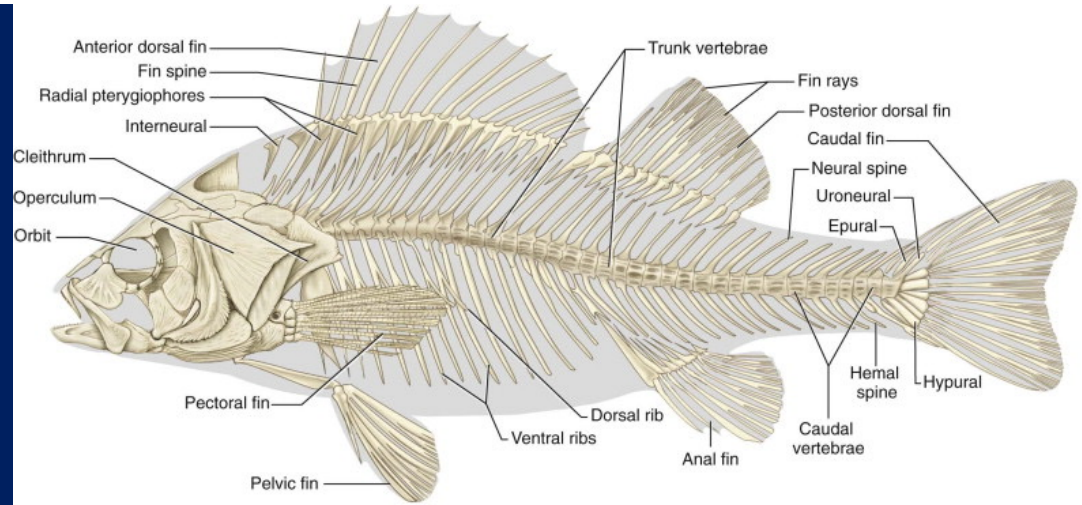
- 425Ma Late Silurian Guiyu oneiros
- Ossified bony endoskeleton (calcium phosphate & collagen)
- Have vertebrae, skulls, jaws + ribs
- Placoderms (Placodermi) → Actinopterygii & Sarcopterygii)



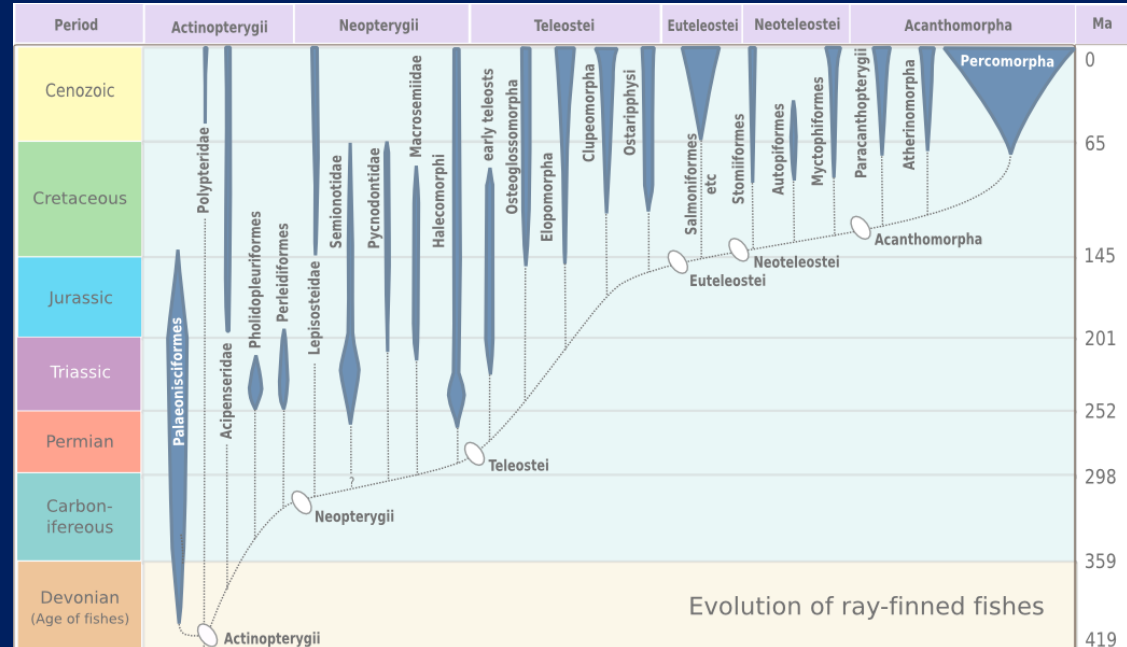
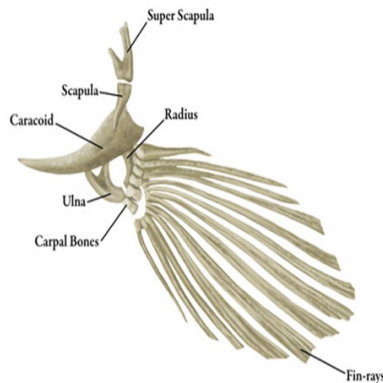
Ray-Finned Fish

Actinopterygii = having rays

- 50% of all vertebrate species
- Calcified Skeleton (lacks cartilage)
- Mostly Teleosts (= “complete bone”)
- Elongated flexible fin rays



Rayed fin

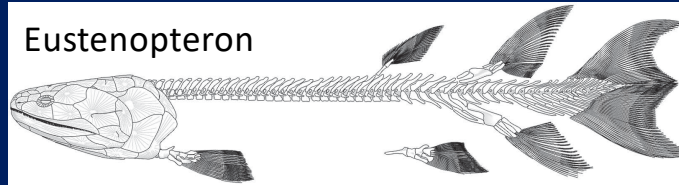


Lobe-Finned Fish

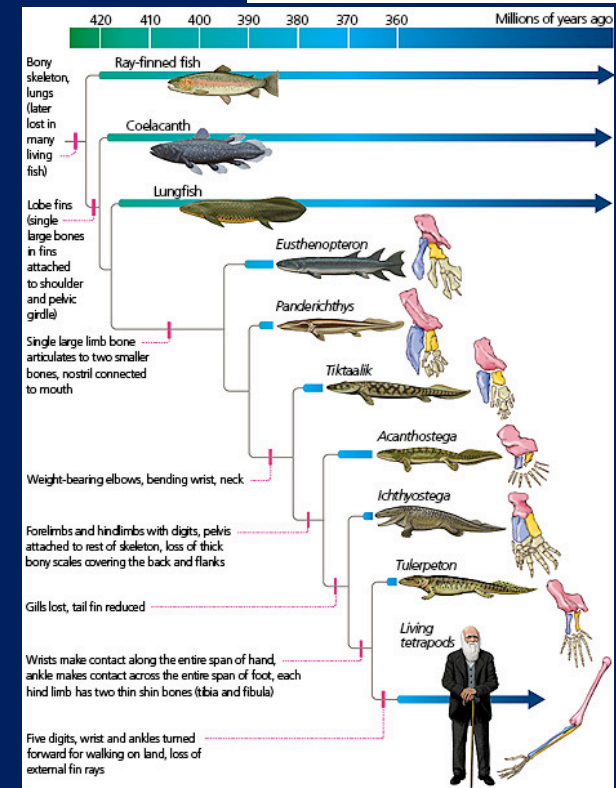
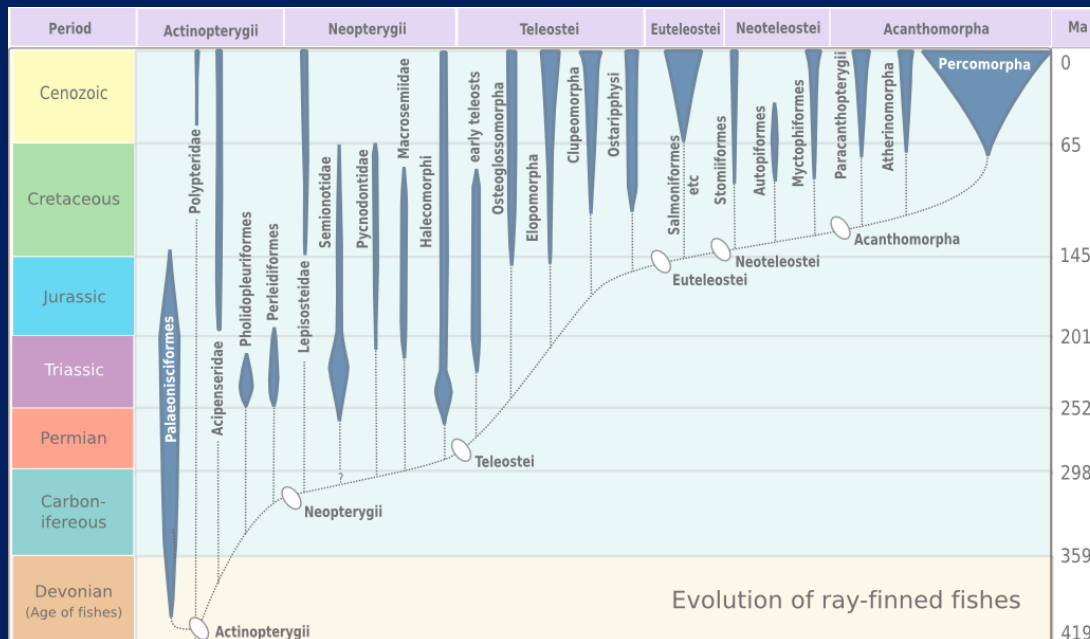
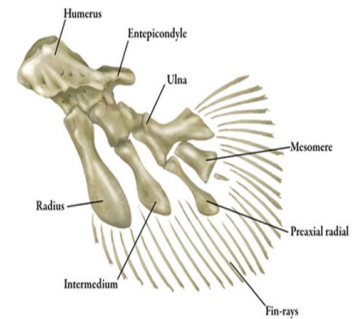
Sarcopterygii = flesh fin

- Lobes = limb buds = articulated appendicular skeletons
- Pectoral & pelvic fins with rod shaped bones + muscles
- Habitat range = ocean, rivers, swamps, land
- Living = coelacanth, lungfish, tetrapods

Eustenopteron



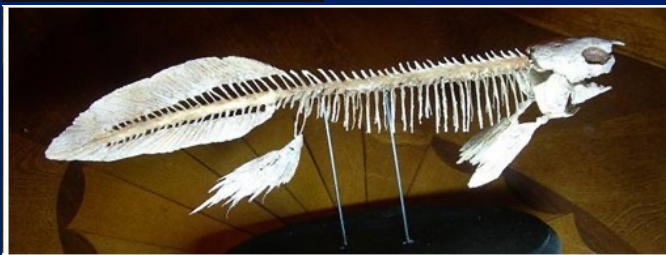
Lobed fin



Lungfish & Coelacanth

Sarcopterygii (lobe-finned fish)

Lungfish



Australian lungfish
(*Neoceratodus forsteri*)



African lungfish
(*Protopterus annectens*)



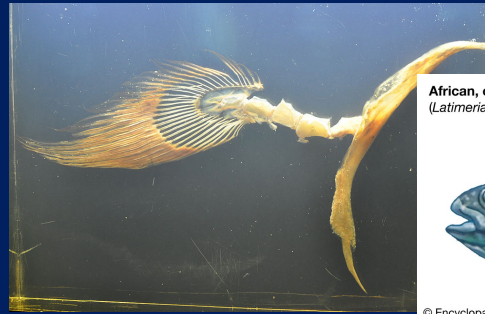
South American lungfish
(*Lepidosiren paradoxa*)



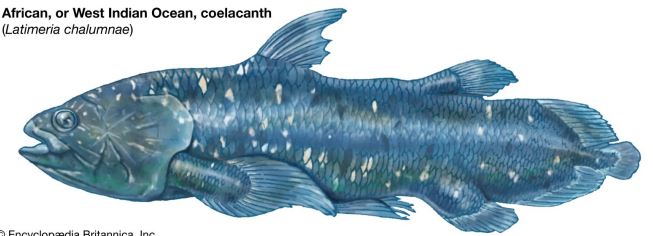
Devonian lungfish
(*Dipterus*)

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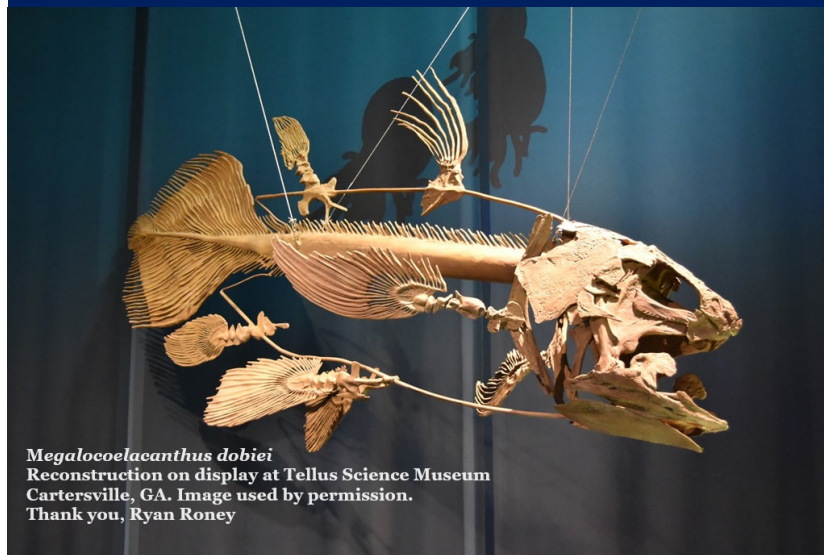
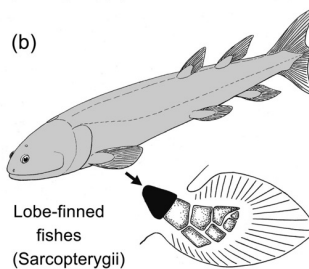
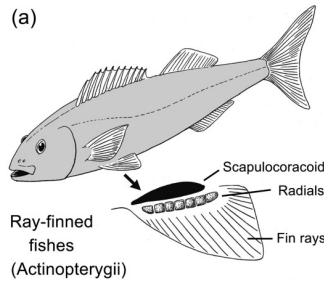
Coelacanth



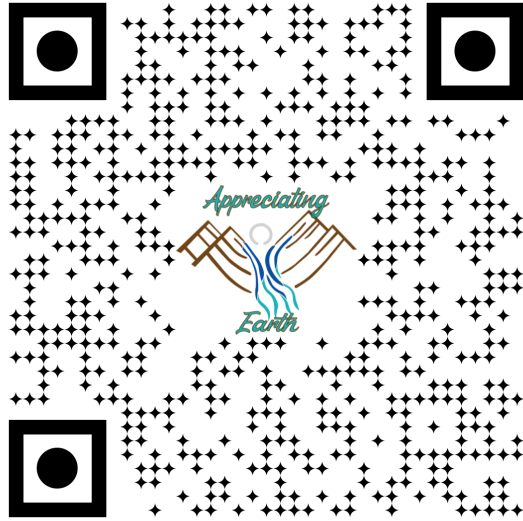
African, or West Indian Ocean, coelacanth
(*Latimeria chalumnae*)



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10min. Break!



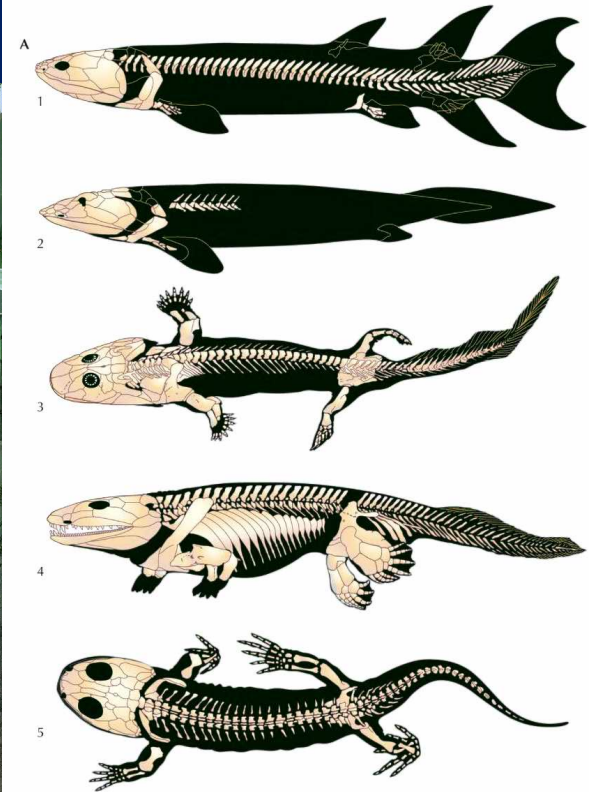
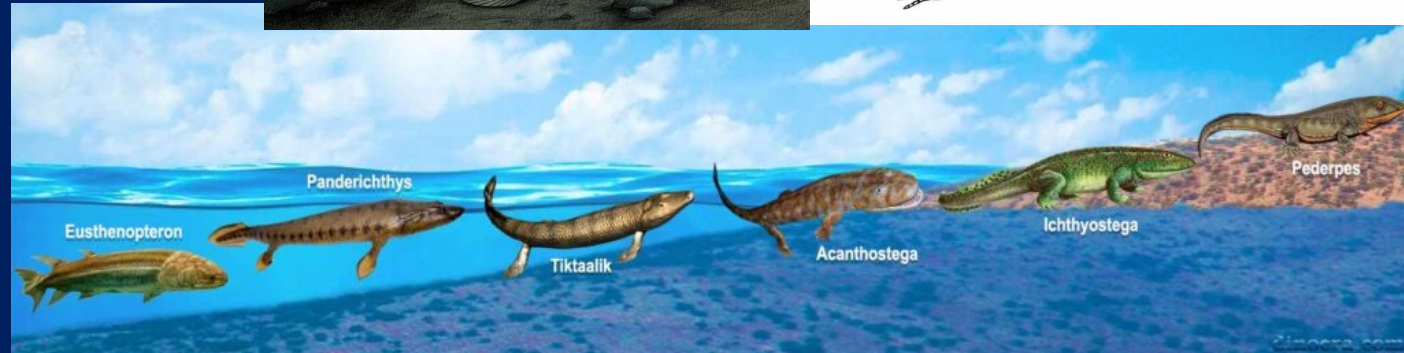
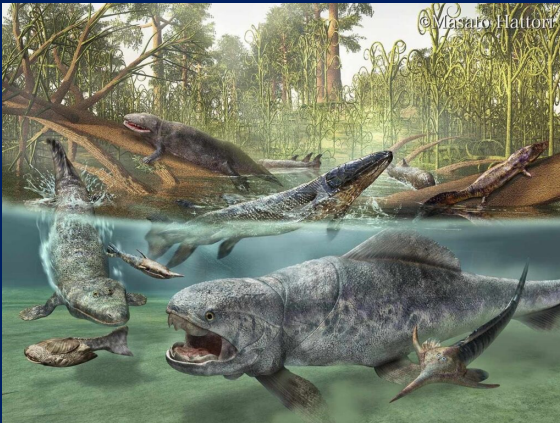
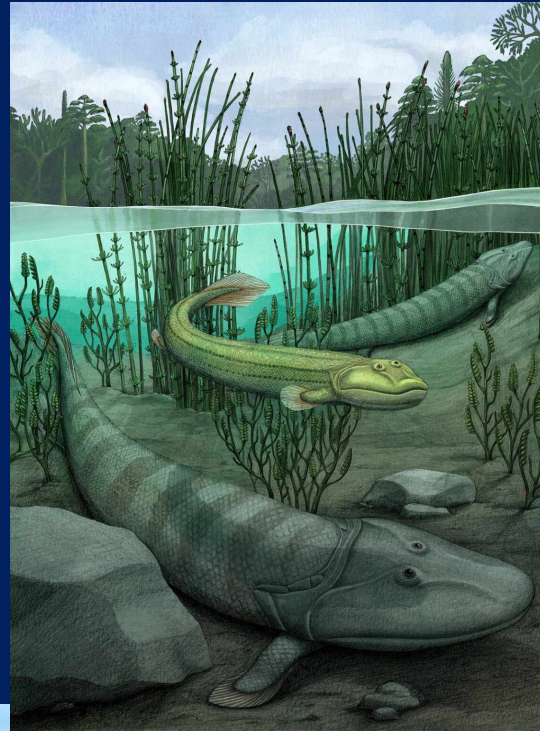
*Sign up for the
Appreciating Earth
newsletter!*

[https://www.youtube.com/
watch?v=J7rN3_tSb7g&ab_
channel=MothLightMedia](https://www.youtube.com/watch?v=J7rN3_tSb7g&ab_channel=MothLightMedia)

Water → Land Adaptations

385-359Ma land-water transition

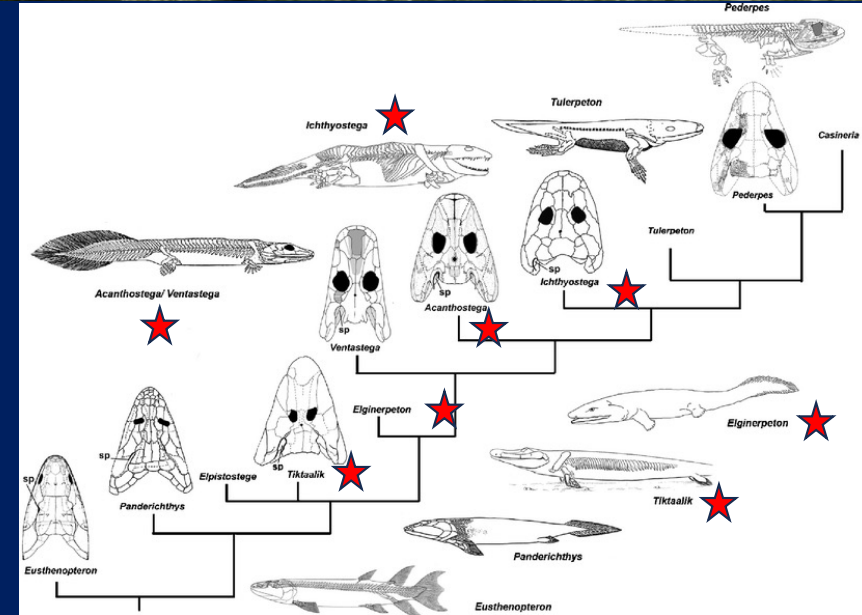
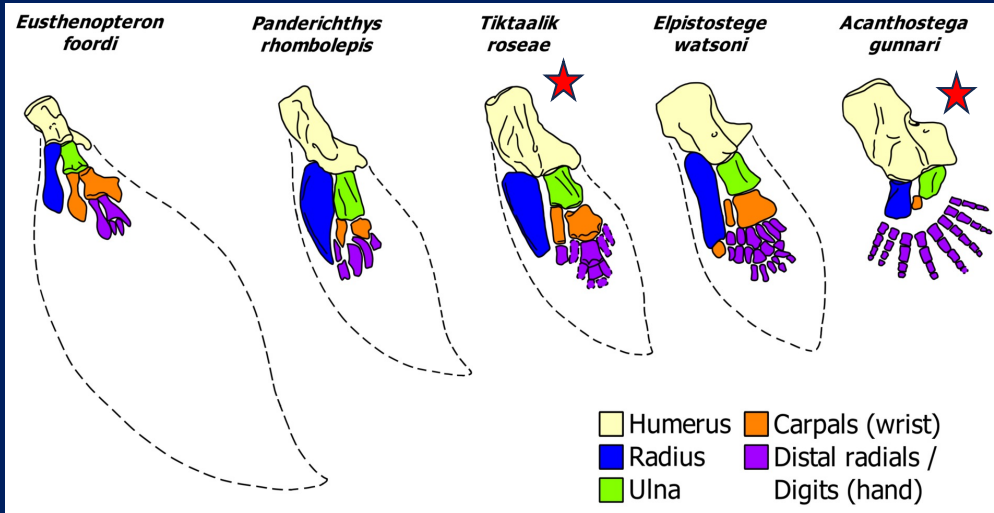
- Breathe air (lungs & nasal passages)
- Resist gravity (weight bearing)
- Prevent desiccation (water proof & thicker skin/scale protection)
- Improved vision
- Hearing adaptation for air



Tetrapodomorpha: Fins to Limbs

- ~397Ma tetrapod tracks
- ~375Ma Tiktaalik
- ~368Ma Elginerpeton (oldest amphibian?)
- ~365Ma Acanthostega
- ~363Ma Ichthyostega

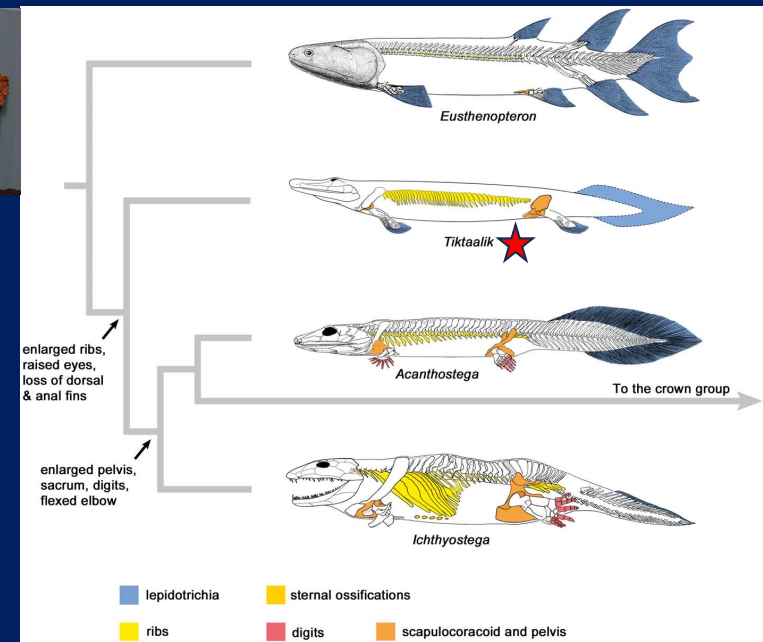
https://www.youtube.com/watch?v=q6PS5ucGDZk&ab_channel=WildDestinations



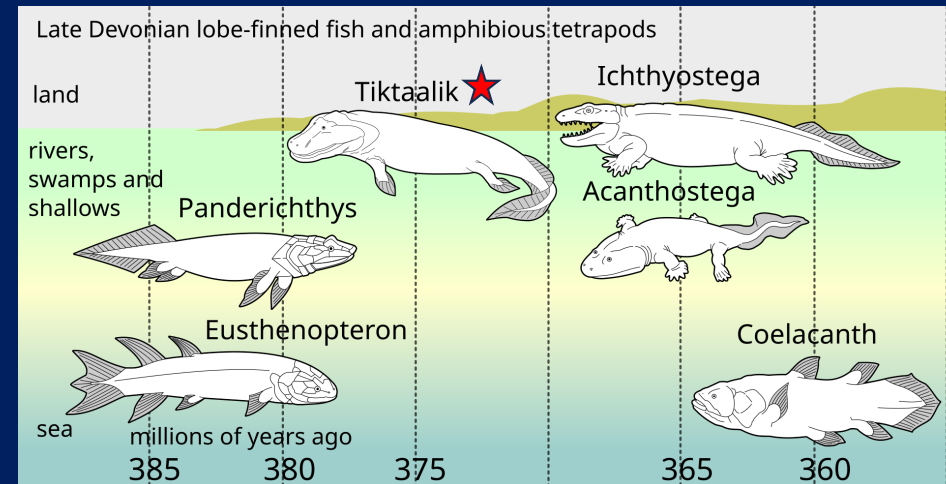
Tiktaalik

~375Ma transitional fossil = fishpod

- 4.1-9ft long with ~30 vertebrae
- Gills & primitive lungs + first ribs + otic notches
- Oldest known neck: restricted lateral head motion
- Weight bearing pectoral shoulder girdle separate from neck + bones in forelimb



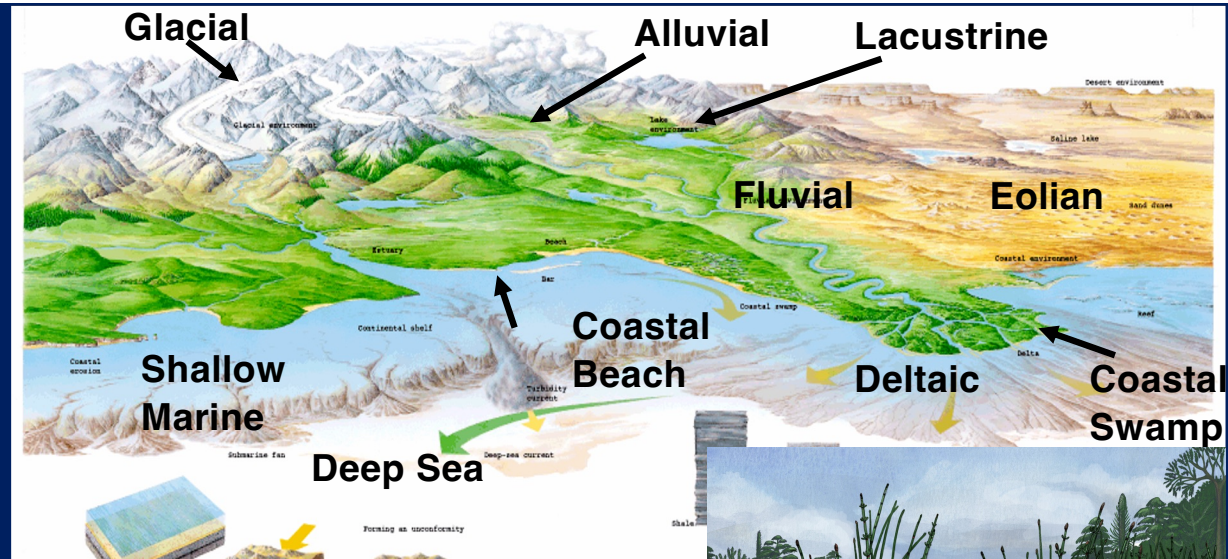
https://www.youtube.com/watch?v=y9BEwUvtCL4&t=26s&ab_channel=PennStateEberlyCollegeofScience



Tiktaalik Habitat

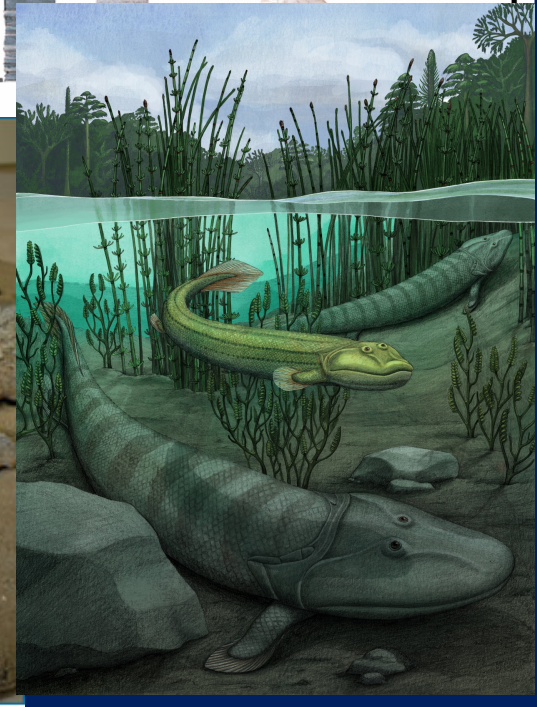
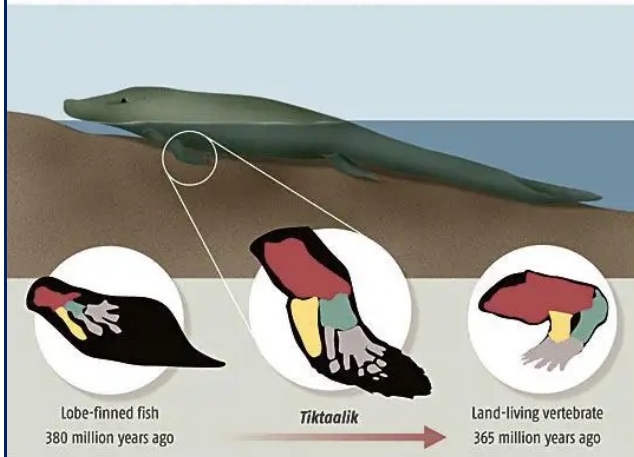
Mostly Aquatic: shallows & mudflats of freshwater floodplains, ponds & swamps

- Large ferns, giant horsetails
- Equatorial: subtropical to tropical similar to modern Amazon basin



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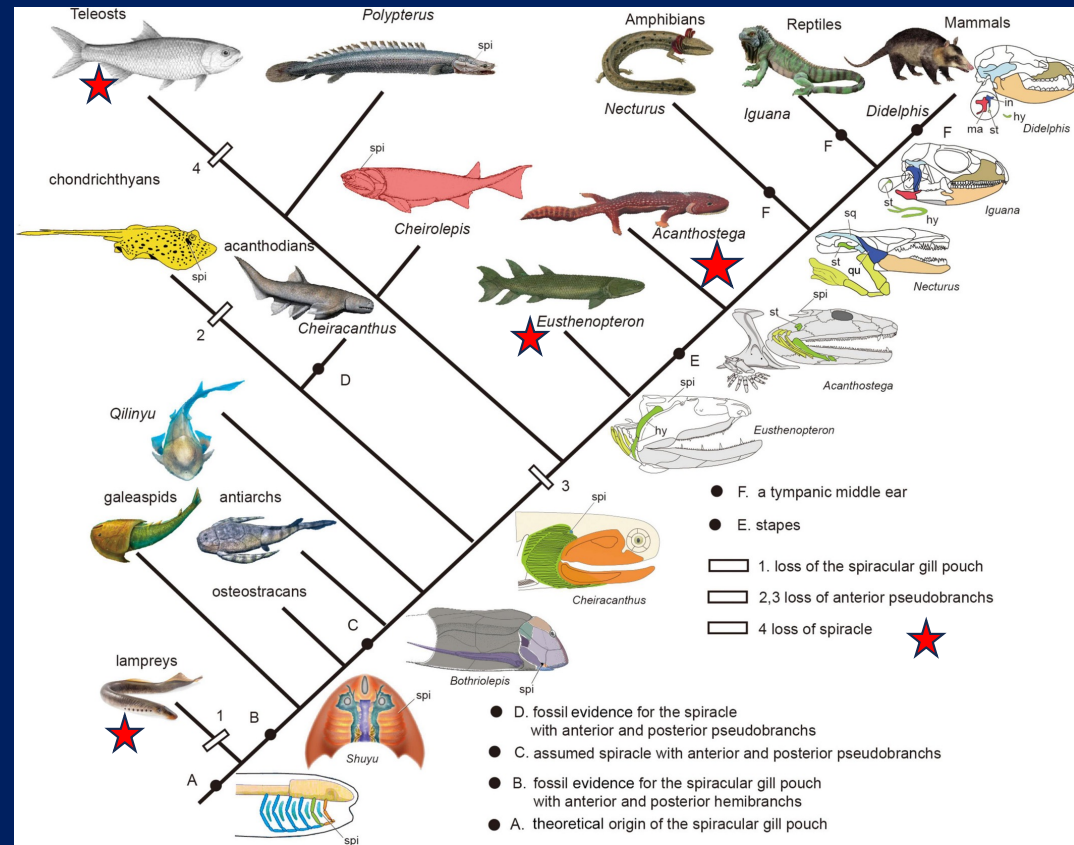
Tiktaalik is the first complete transitional specimen between fish and land-dwelling tetrapods. Its fins show the beginnings of elbow and wrist-like features



Spiracles

External respiration openings in some fish, sharks, whales, early tetrapods

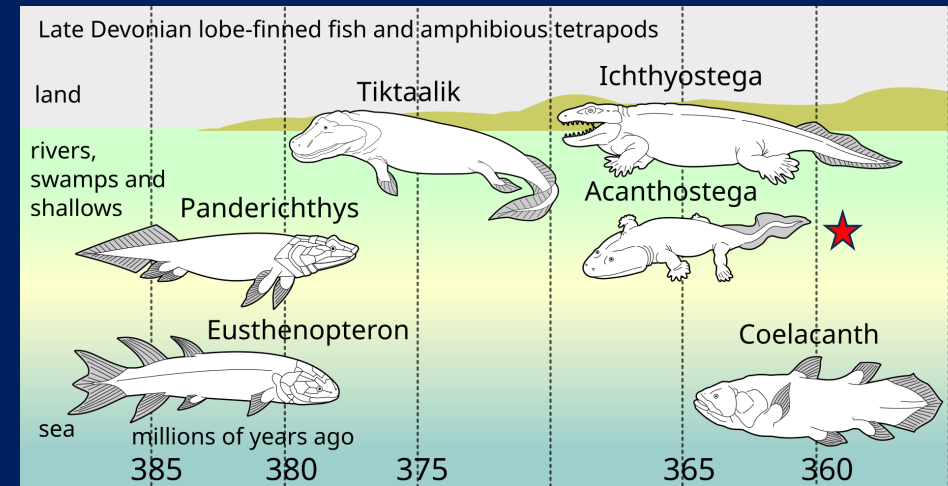
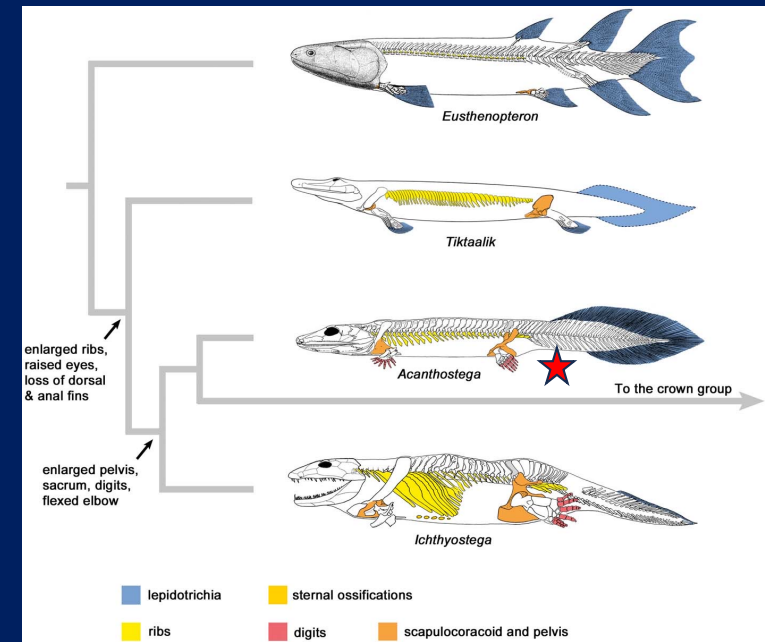
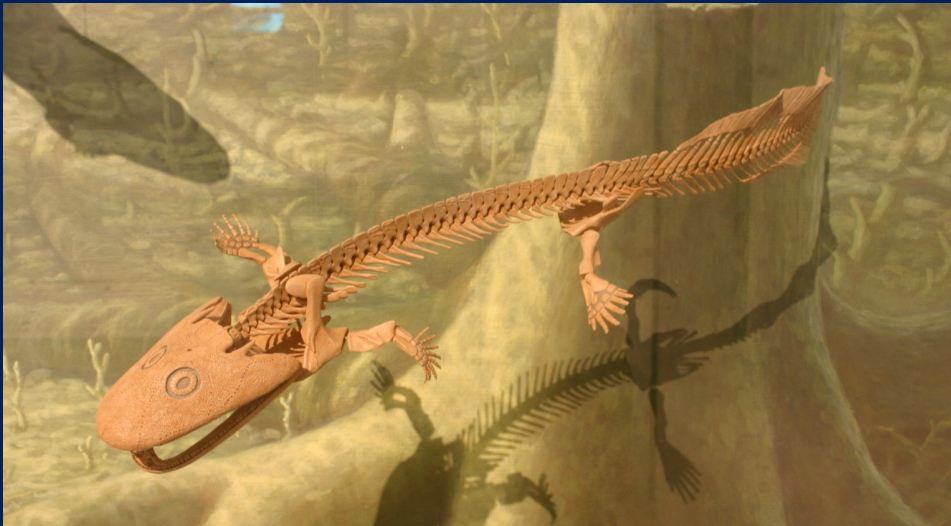
- Spiracles evolved into the otic notch used for respiration
- Some tetrapodomorpha had otic notches that may have held spiracles
- Later evolved into ear bone (stapes) of modern tetrapods



Acanthostega

~365Ma stem tetrapod

- ~2ft long, 5-10lbs
- 8 digits on each hand/forelimb but no rotation = more of a paddle
- Gills & primitive lungs + first ribs
- Weight-bearing pelvis



Ichthyostega

~365-360Ma stem tetrapod, oldest amphibian?

- 4.9ft long
- Pelvic girdle & 7 digits on each foot/hindlimb
- Gills & primitive lungs + first ribs + otic notch
- Could drag itself forward

Ichthyostega:
whole body reconstruction



https://www.youtube.com/watch?v=lf16z5zDm3A&ab_channel=FrancisVillatoro

