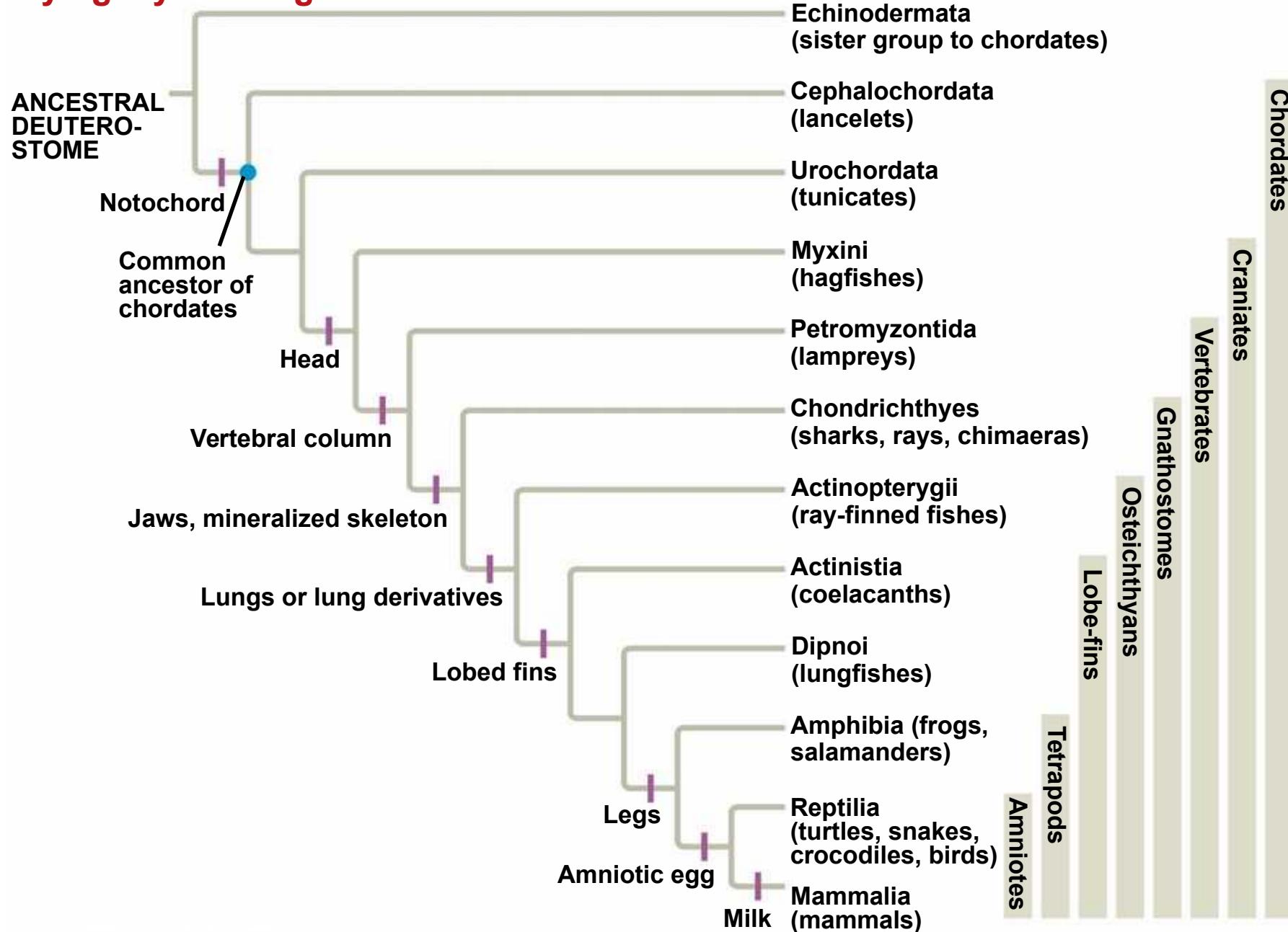


# Phylogeny of living chordates

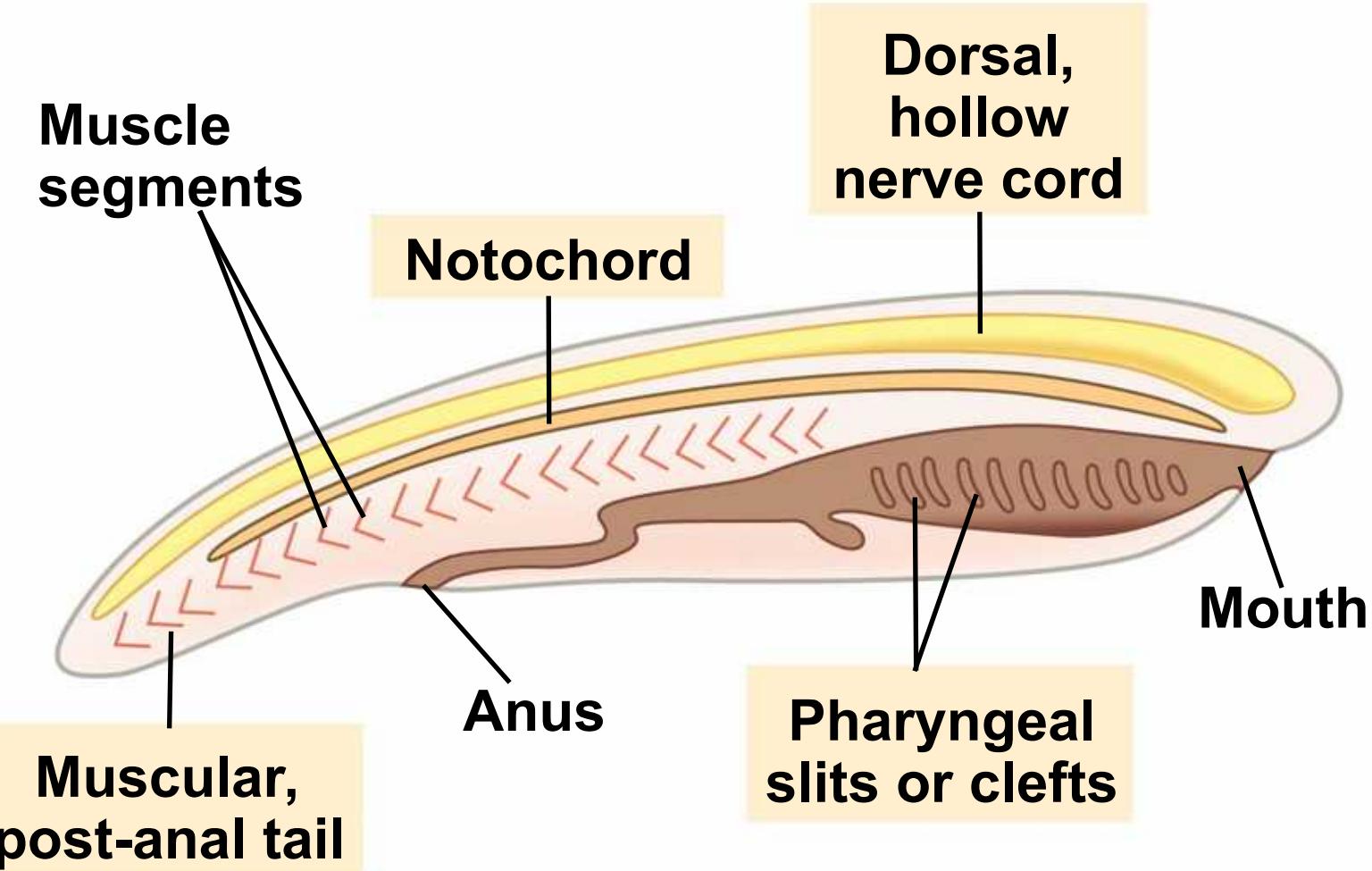


# Derived Characters of Chordates

---

- All chordates share a set of derived characters.
- Some species have some of these traits only during embryonic development.
- ***Four key characters of chordates:***
  - ***Notochord***
  - ***Dorsal, hollow nerve cord***
  - ***Pharyngeal slits or clefts***
  - ***Muscular, post-anal tail***

# Chordate characteristics



# *Notochord*

---

- The **notochord** is a longitudinal, flexible rod between the digestive tube and nerve cord.
- It provides skeletal support throughout most of the length of a chordate.
- In most vertebrates, a more complex, jointed skeleton develops, and the adult retains only remnants of the embryonic notochord.

## *Dorsal, Hollow Nerve Cord*

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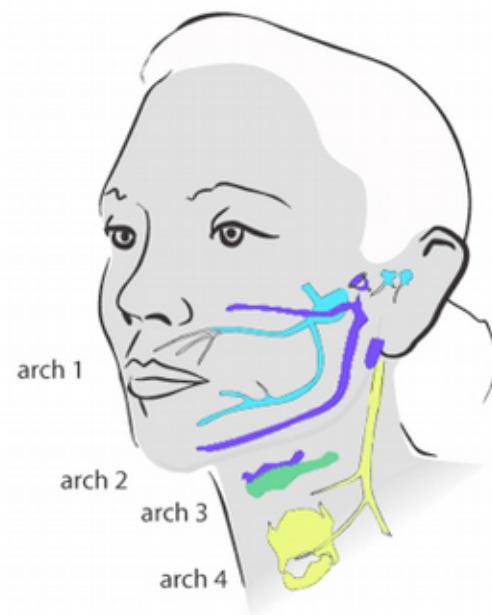
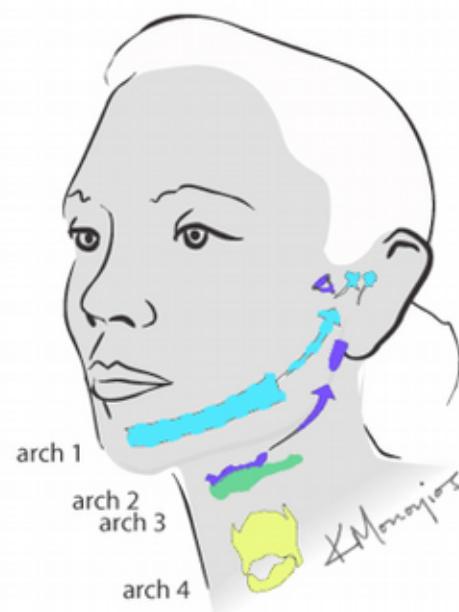
- The nerve cord of a chordate embryo develops from a plate of ectoderm that rolls into a tube dorsal to the notochord.
- The nerve cord develops into the central nervous system: the brain and the spinal cord.

# *Pharyngeal Slits or Clefts*

---

- In most chordates, grooves in the pharynx called **pharyngeal clefts** develop into slits that open to the outside of the body.
- Functions of **pharyngeal slits**:
  - Suspension-feeding structures in many invertebrate chordates
  - Gas exchange in vertebrates (except vertebrates with limbs, the tetrapods)
  - Develop into parts of the ear, head, and neck in tetrapods.

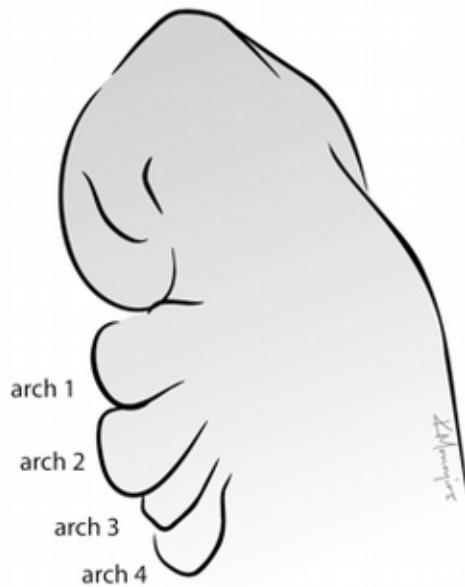
from Neil Shubin's  
***Your Inner Fish***  
***A Journey into the 3.5-Billion-Year History of the Human Body***



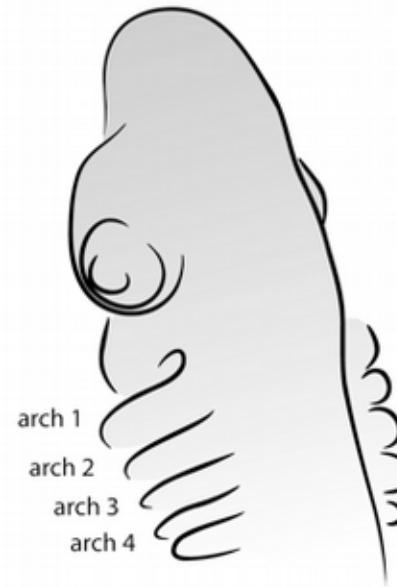
If we follow the gill arches from an embryo to an adult, we can trace the origins of jaws, ears, larynx, and throat. Bones, muscles, nerves, and arteries all develop inside these gill arches.

from Neil Shubin's  
***Your Inner Fish***  
***A Journey into the 3.5-Billion-Year History of the Human Body***

human embryo

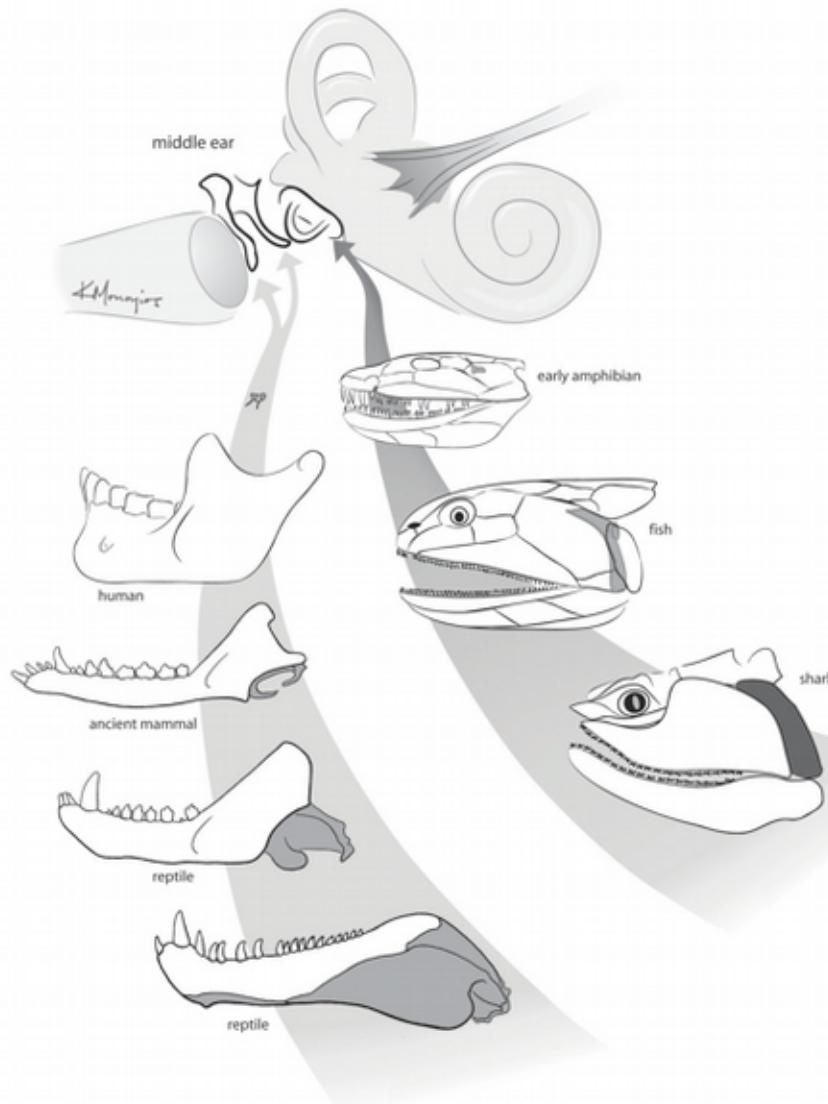


shark embryo



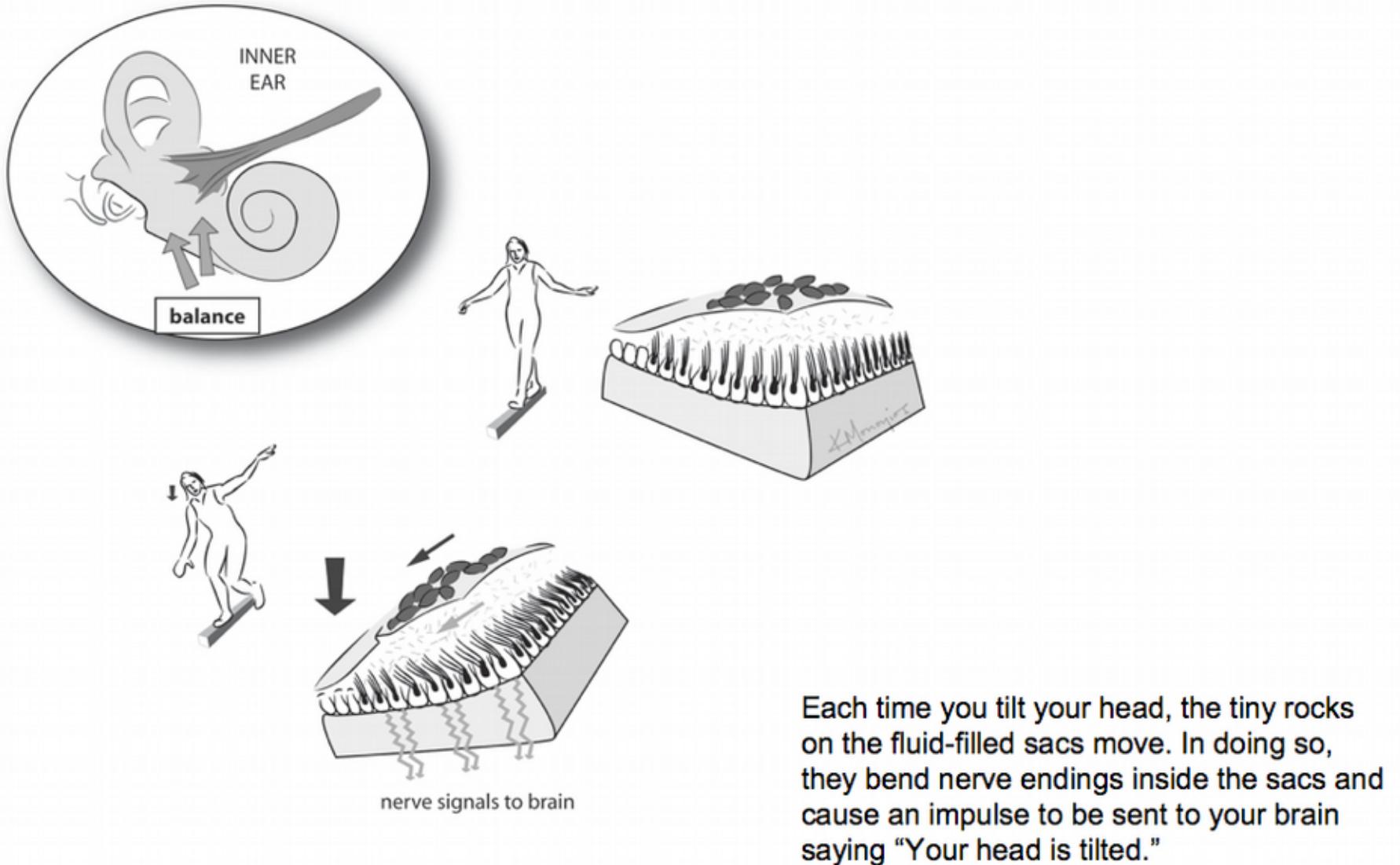
The gill region of a developing human and a developing shark look the same early on.

from Neil Shubin's  
***Your Inner Fish***  
***A Journey into the 3.5-Billion-Year History of the Human Body***

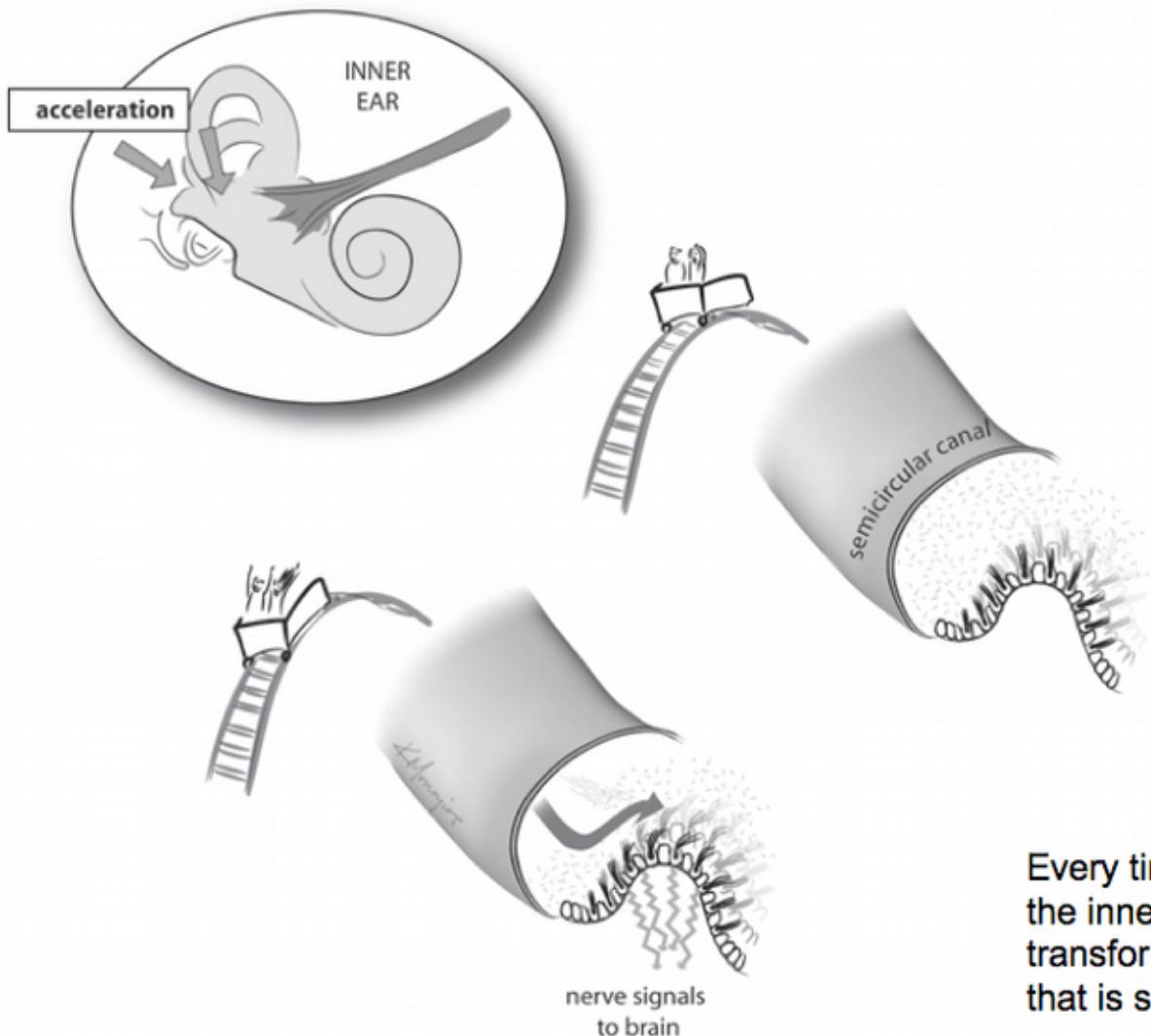


We can trace bones from gill arches to our ears, first during the transition from fish to amphibian (right), and later during the shift from reptile to mammal (left).

from Neil Shubin's  
***Your Inner Fish***  
***A Journey into the 3.5-Billion-Year History of the Human Body***

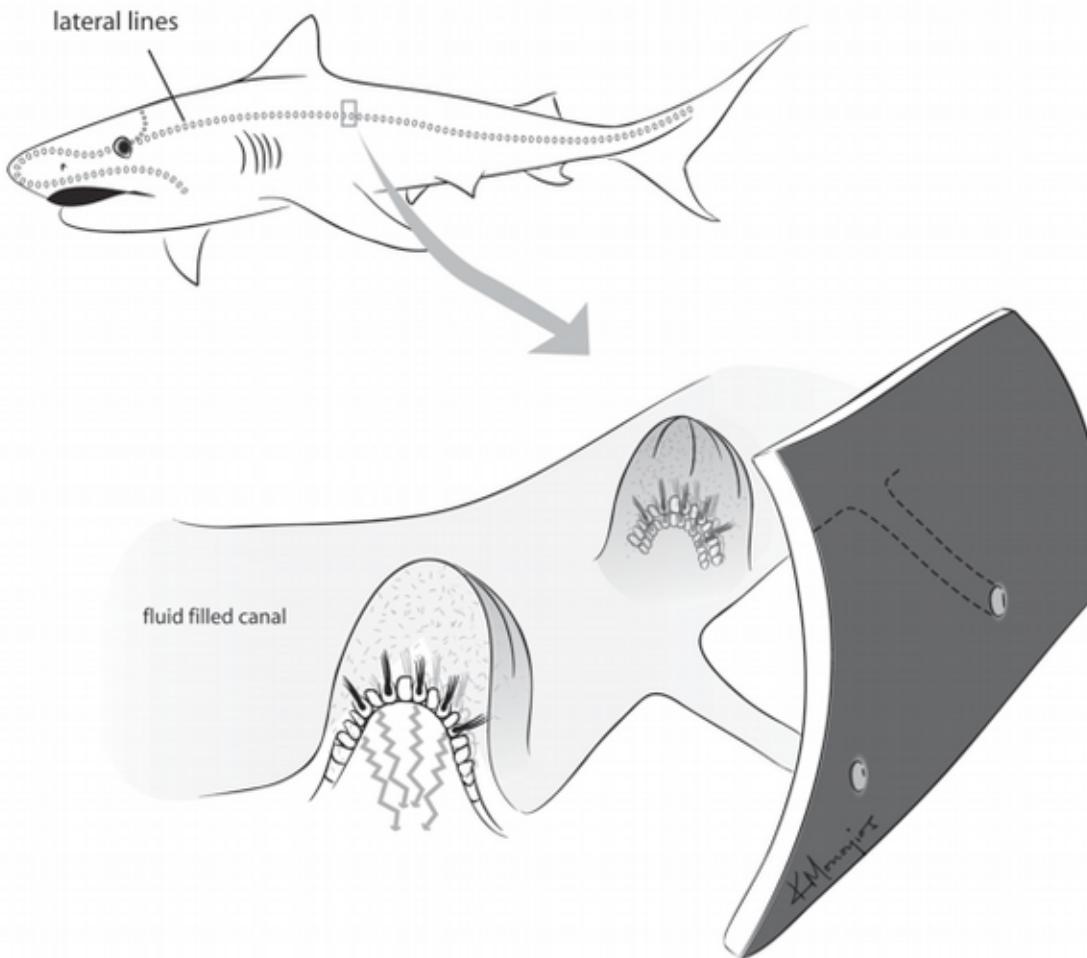


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Every time we accelerate, fluid in the inner ear swishes. The swish is transformed into a nerve impulse that is sent to the brain.

from Neil Shubin's  
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***A Journey into the 3.5-Billion-Year History of the Human Body***



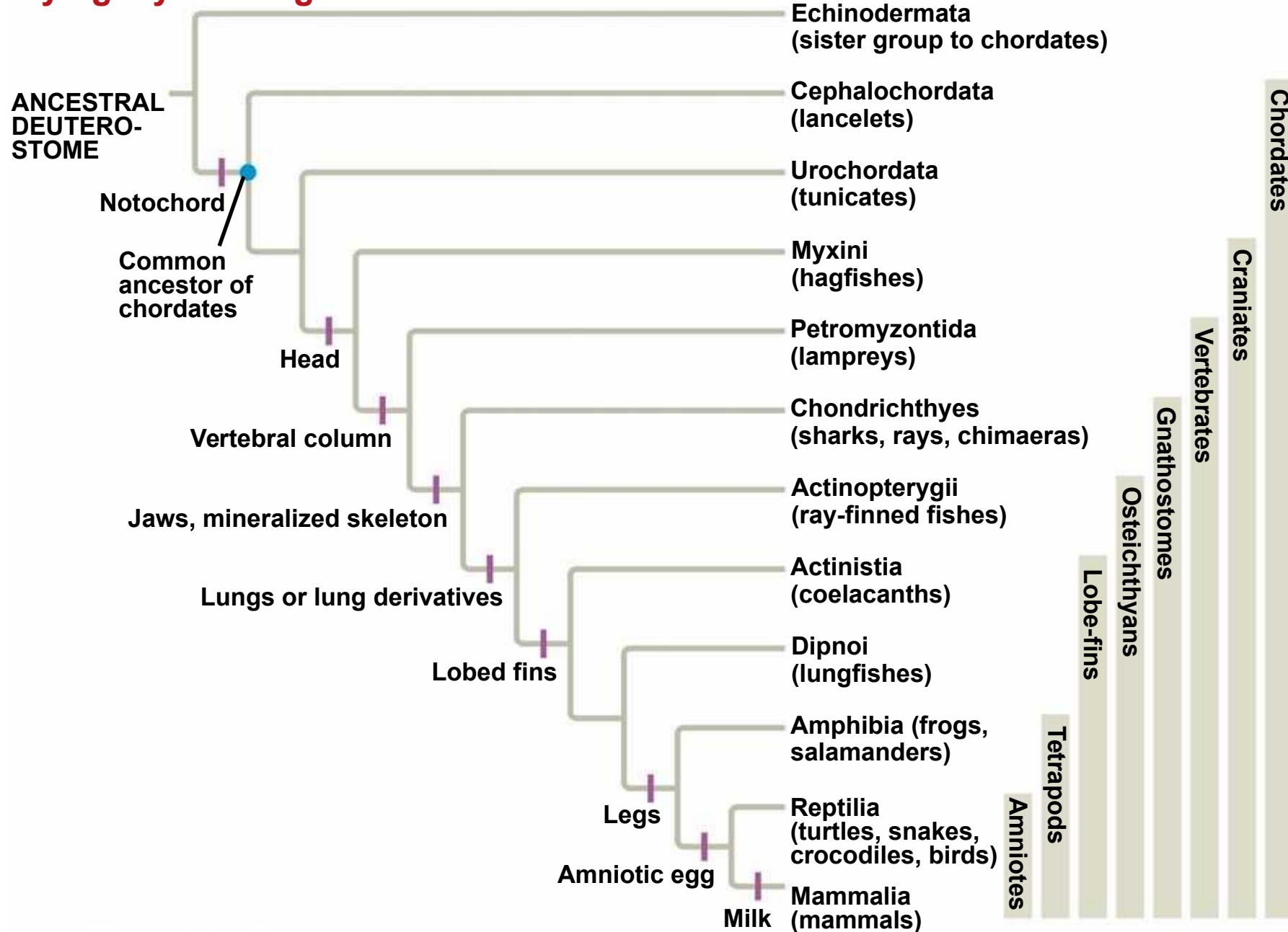
A primitive version of part of our inner ear is embedded in the skin of fish. Small sacs - the neuromasts - are distributed around the body. When they bend, they give the fish information about how the flow of water is changing.

## *Muscular, Post-Anal Tail*

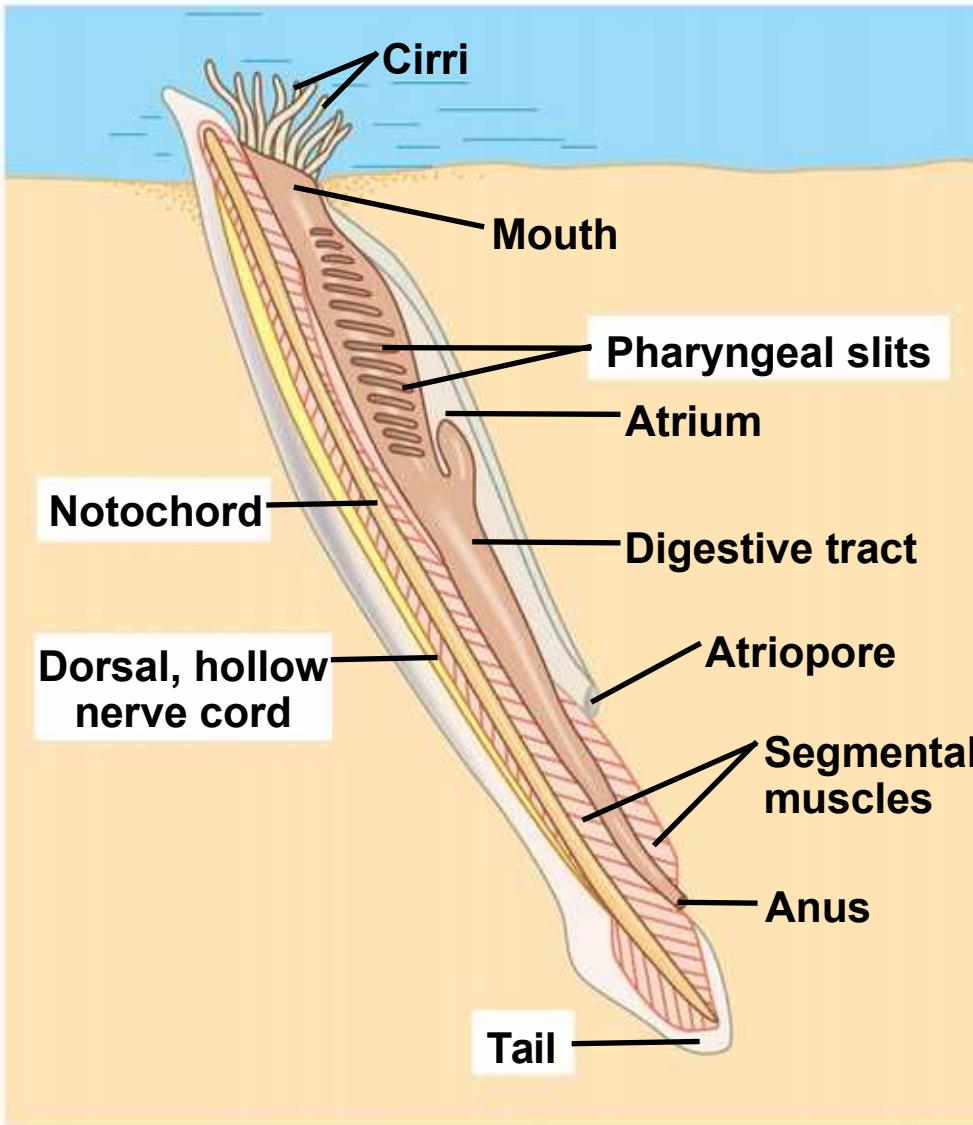
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- Chordates have a tail posterior to the anus.
- In many species, the tail is greatly reduced during embryonic development.
- The tail contains skeletal elements and muscles.
- It provides propelling force in many aquatic species.

# Phylogeny of living chordates

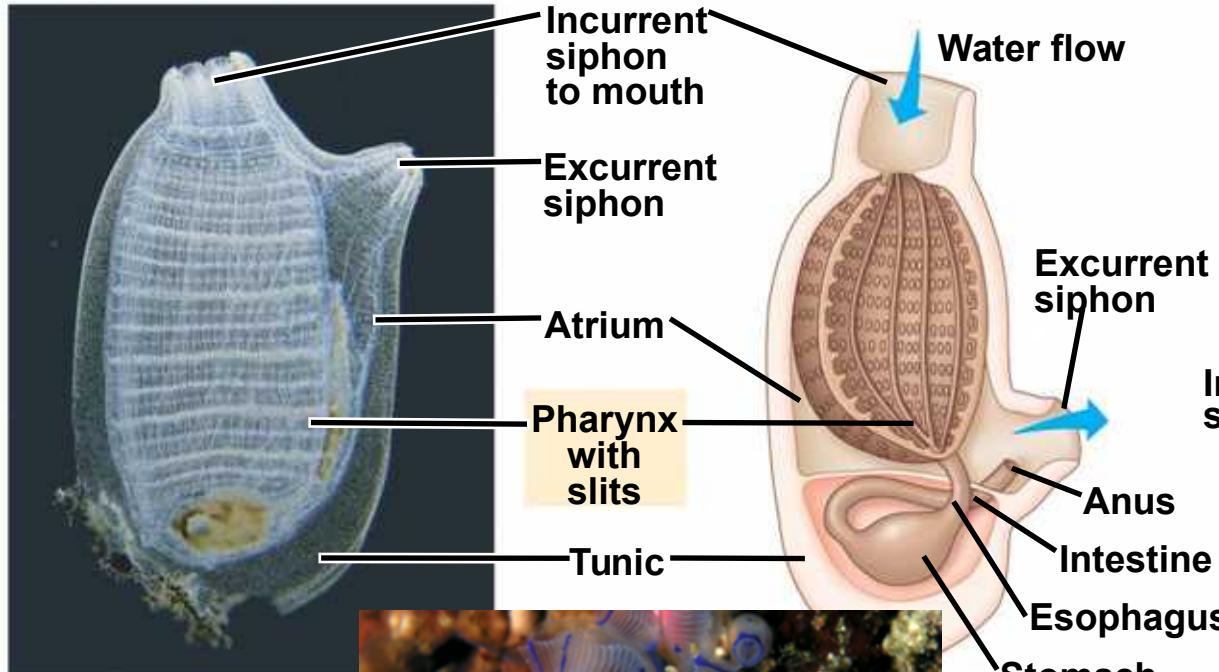


Lancelets are named for their bladelike shape. They are marine suspension feeders. Adults retain characteristics of chordate body plan.



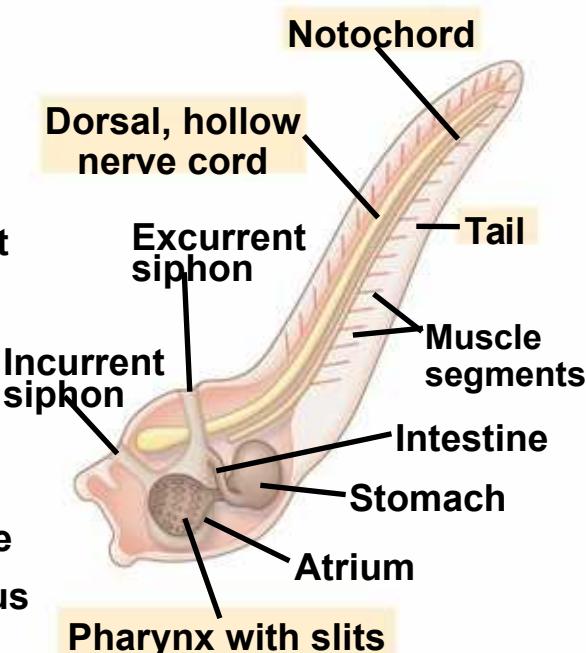
**Tunicates (Urochordata)** are more closely related to other chordates than they are to lancelets. They are marine suspension feeders commonly called sea squirts.

As an adult, a tunicate draws in water through an **incurrent siphon**, filtering food particles. Juveniles, not adults, have a notochord.



An adult tunicate

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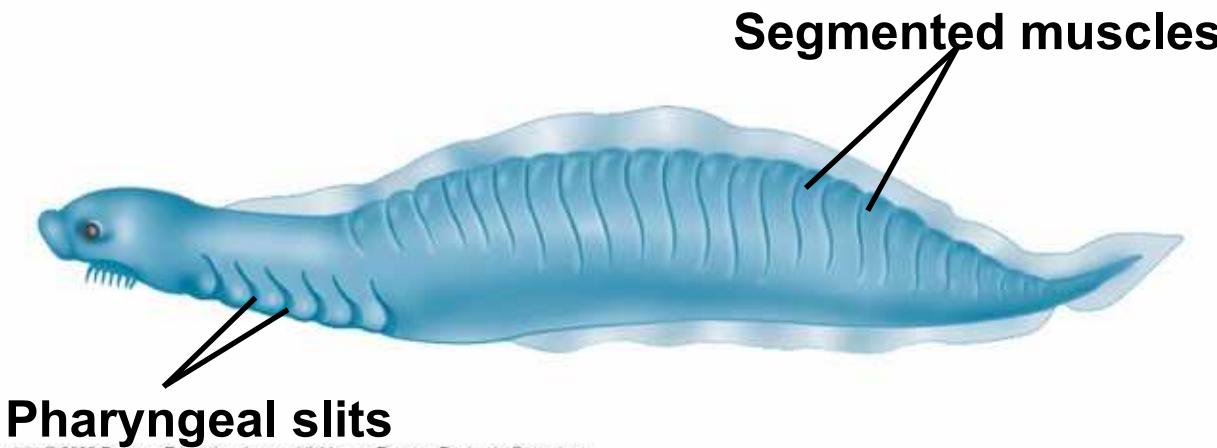


A tunicate larva

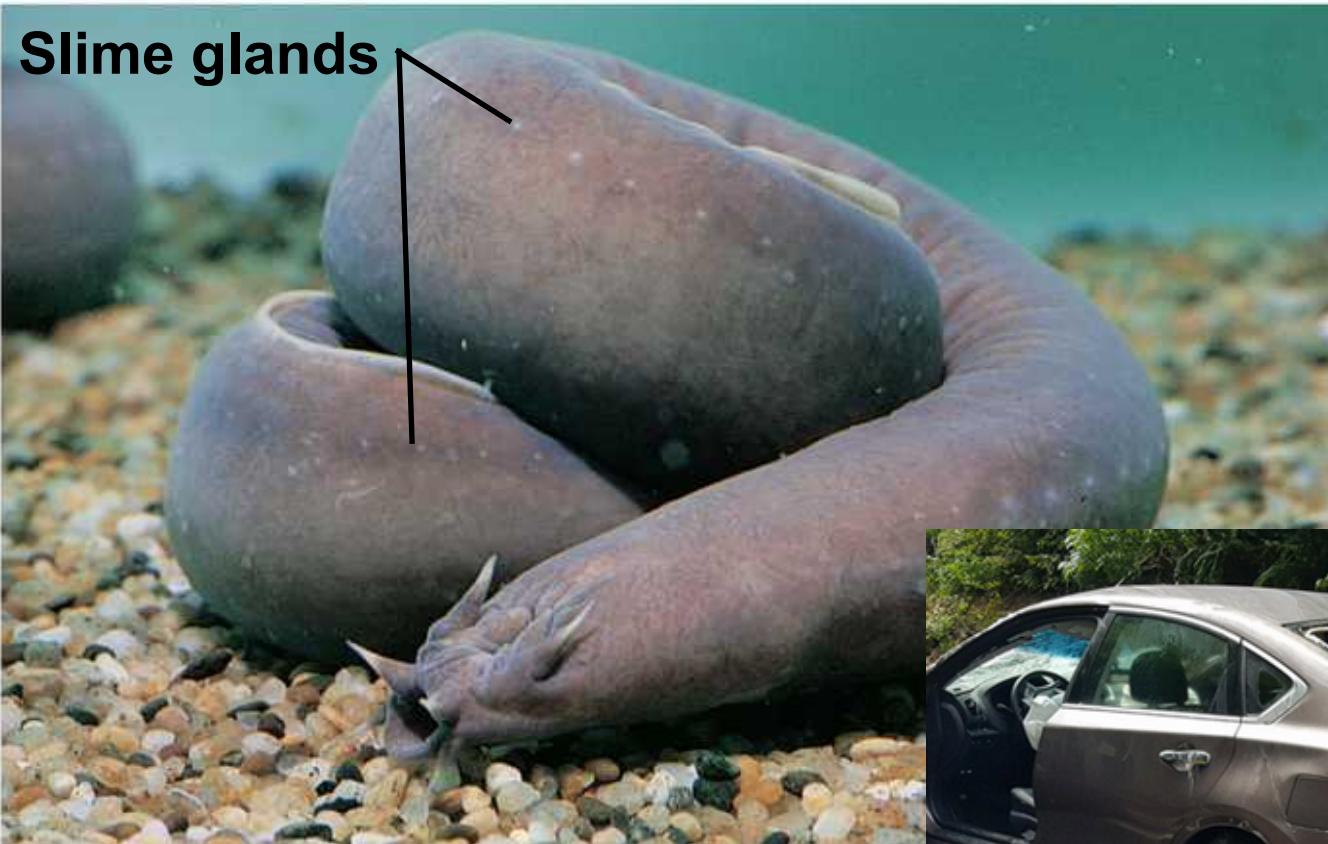
# Fossil of an early Chordate



5 mm



**Hagfishes have a cartilaginous skull and axial rod of cartilage derived from the notochord, but lack jaws and vertebrae**



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# Derived Characters of Vertebrates

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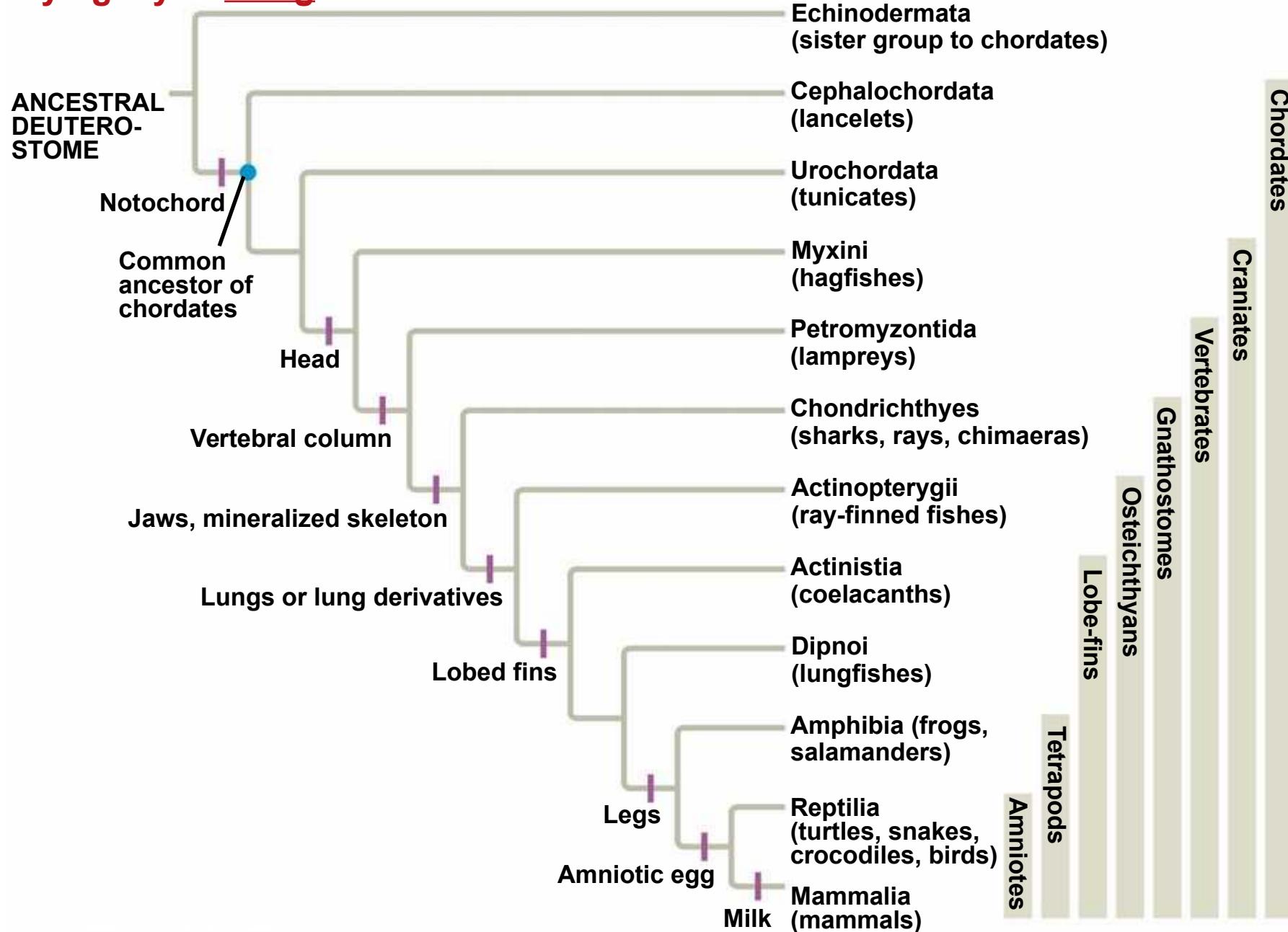
- During the Cambrian period, a lineage of craniates evolved into vertebrates. Vertebrates became more efficient at capturing food and avoiding being eaten.
- Vertebrates have the following derived characters:
  - Vertebrae enclosing a spinal cord
  - An elaborate skull
  - Fin rays, in the aquatic forms.

**Lampreys represent the oldest living lineage of vertebrates.  
They are jawless vertebrates inhabiting various marine and freshwater  
habitats.**

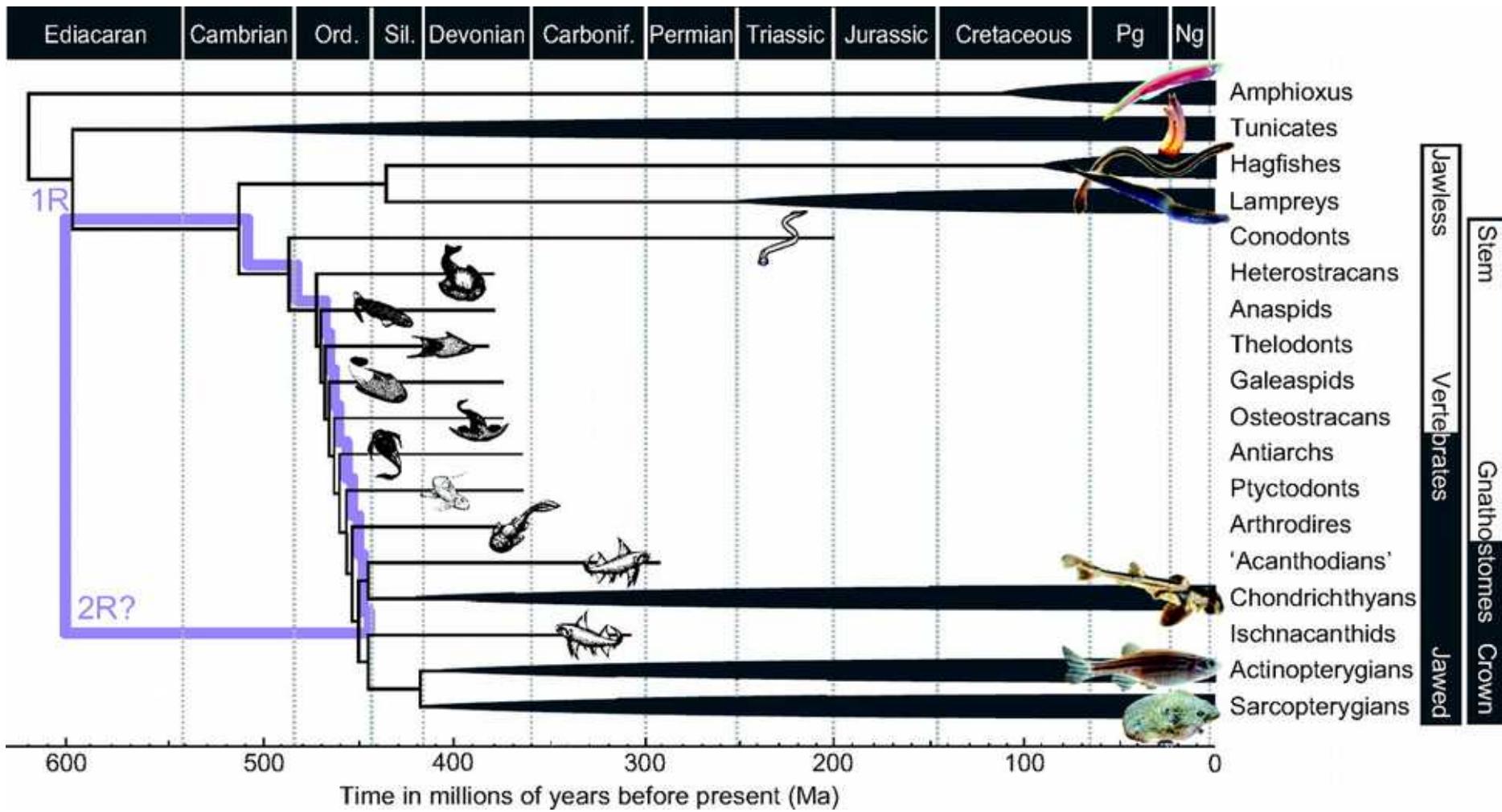


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# Phylogeny of living chordates



# Real trees are made up mostly of extinct species

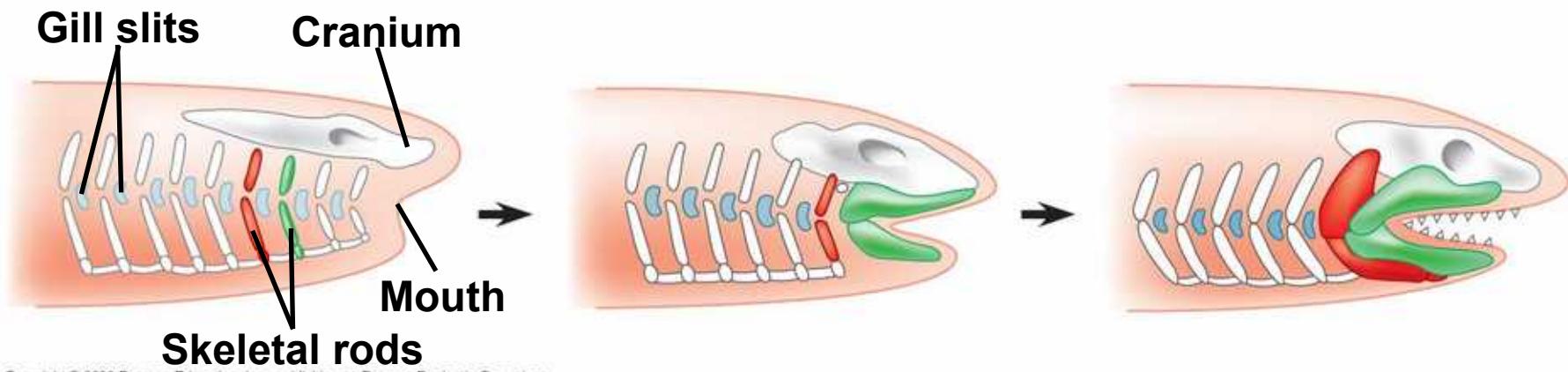


# Origins of Bone and Teeth

---

- Mineralization appears to have originated with vertebrate mouthparts.
- The vertebrate endoskeleton became fully mineralized much later.
- Today, *jawed vertebrates*, or **gnathostomes**, outnumber jawless vertebrates.
- Gnathostomes jaws might have evolved from skeletal supports of the pharyngeal slits.

# Hypothesis for the evolution of vertebrate jaws



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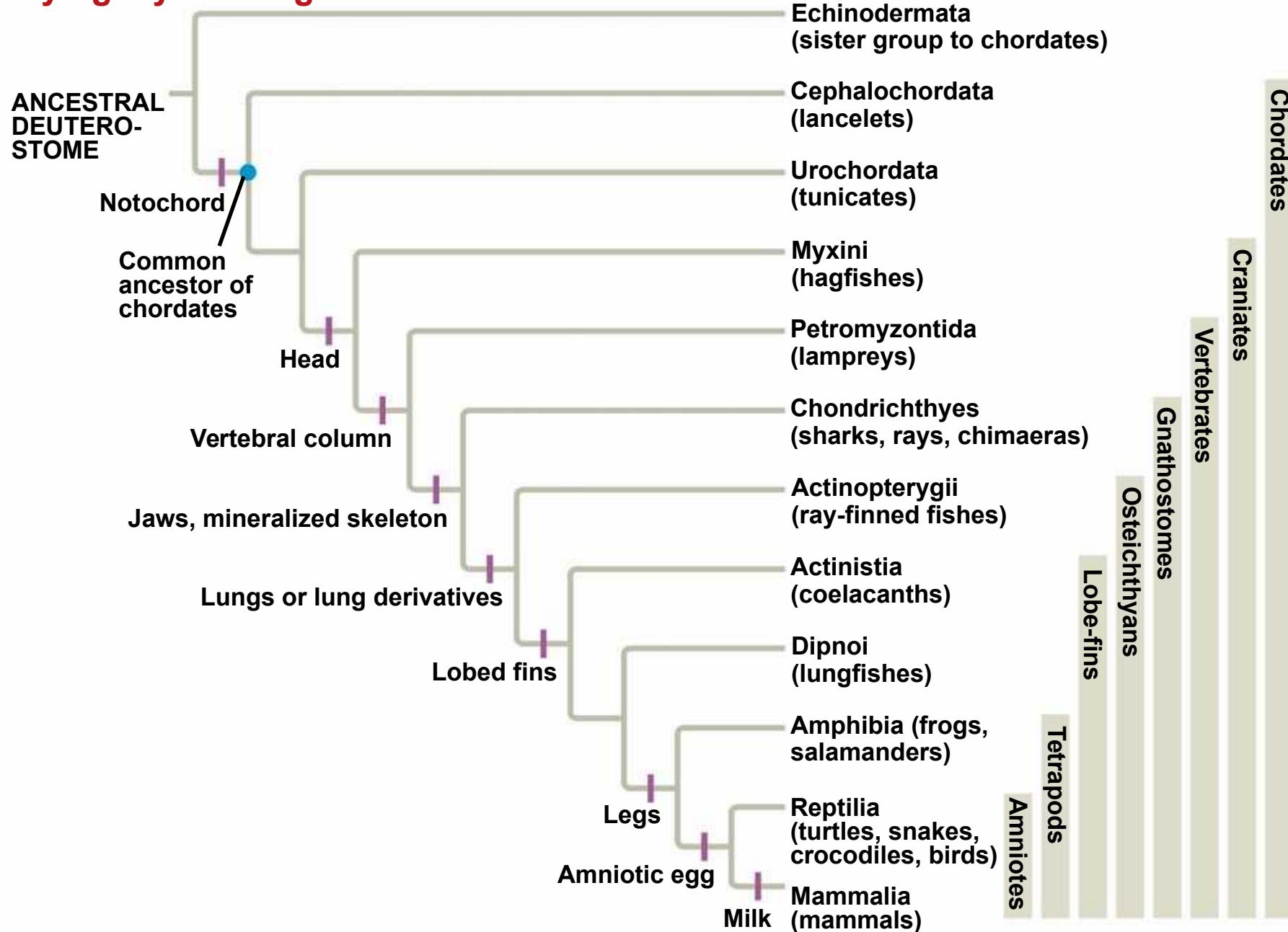
- 
- Other characters common to gnathostomes:
    - An additional duplication of **Hox genes**
    - An enlarged forebrain associated with enhanced smell and vision
    - In aquatic gnathostomes, the **lateral line system**, which is sensitive to vibrations.

# **Chondrichthyans (Sharks, Rays, and Their Relatives)**

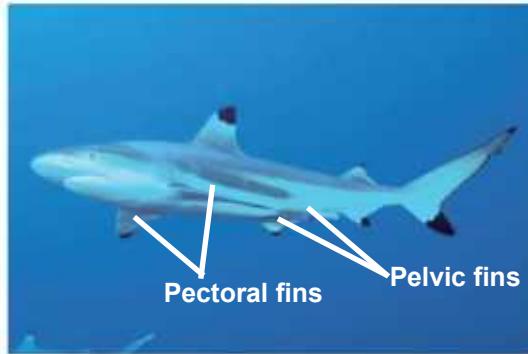
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- **Chondrichthyans** (Chondrichthyes) have a skeleton composed primarily of cartilage.
- The cartilaginous skeleton evolved secondarily from an ancestral mineralized skeleton.
- The largest and most diverse group of chondrichthyans includes the sharks, rays, and skates.

# Phylogeny of living chordates



# Chondrichthyans



(a) Blacktip reef shark (*Carcharhinus melanopterus*)



(b) Southern stingray (*Dasyatis americana*)



(c) Spotted ratfish (*Hydrolagus colliei*)

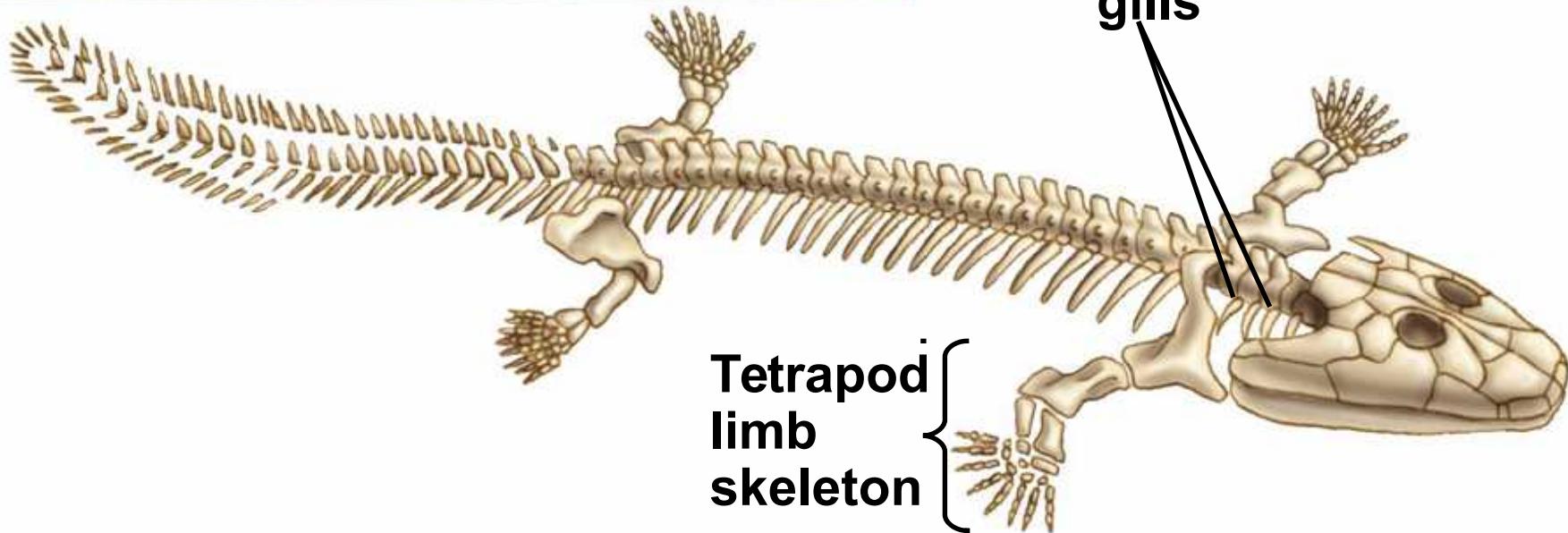
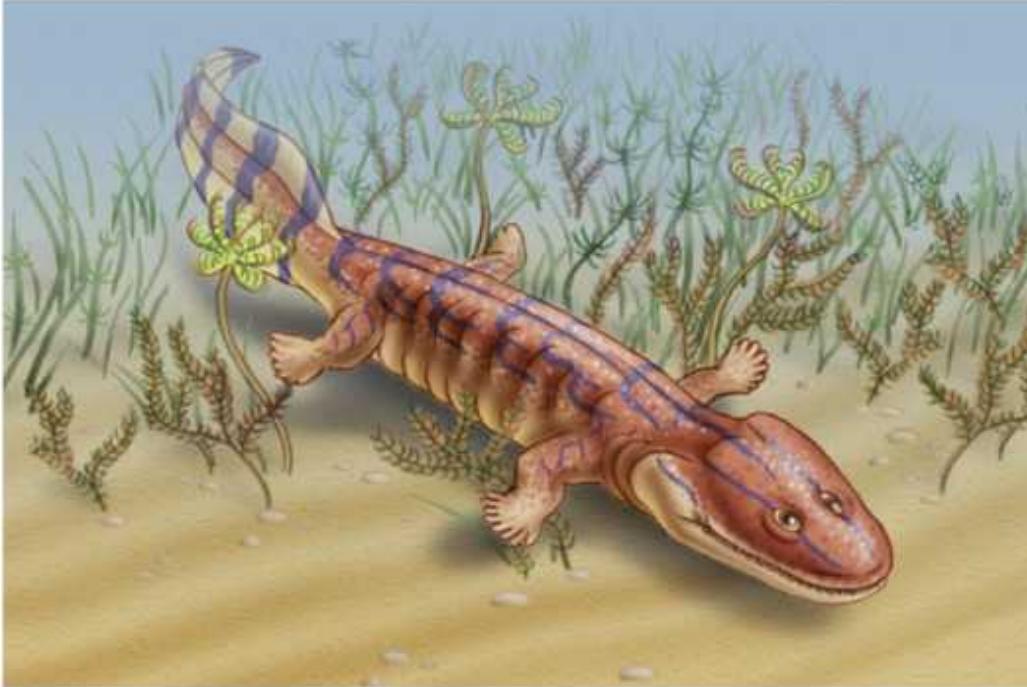
- 
- The vast majority of vertebrates belong to a clade of gnathostomes called Osteichthyes.
  - **Osteichthyes** includes the bony fish and tetrapods.
  - They have a *bony endoskeleton*.
  - Aquatic osteichthyans are the vertebrates we informally call fishes.

# Derived Characters of Tetrapods

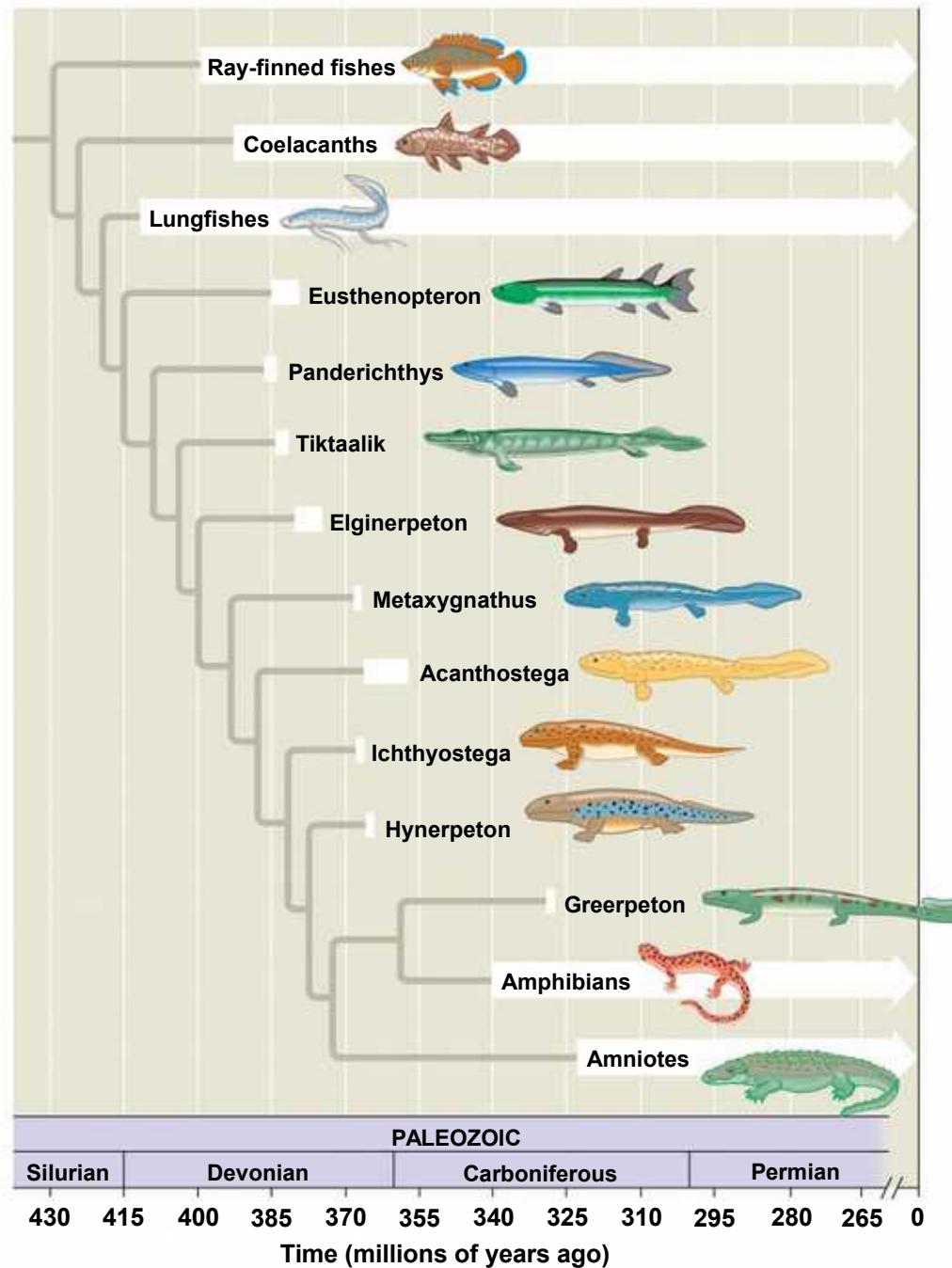
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- **Tetrapods** have some specific adaptations:
  - Four limbs, and feet with digits
  - Ears for detecting airborne sounds.
- In one lineage of lobe-fins, the fins became progressively more limb-like while the rest of the body retained adaptations for aquatic life.
- For example, *Acanthostega* lived in Greenland 365 million years ago.

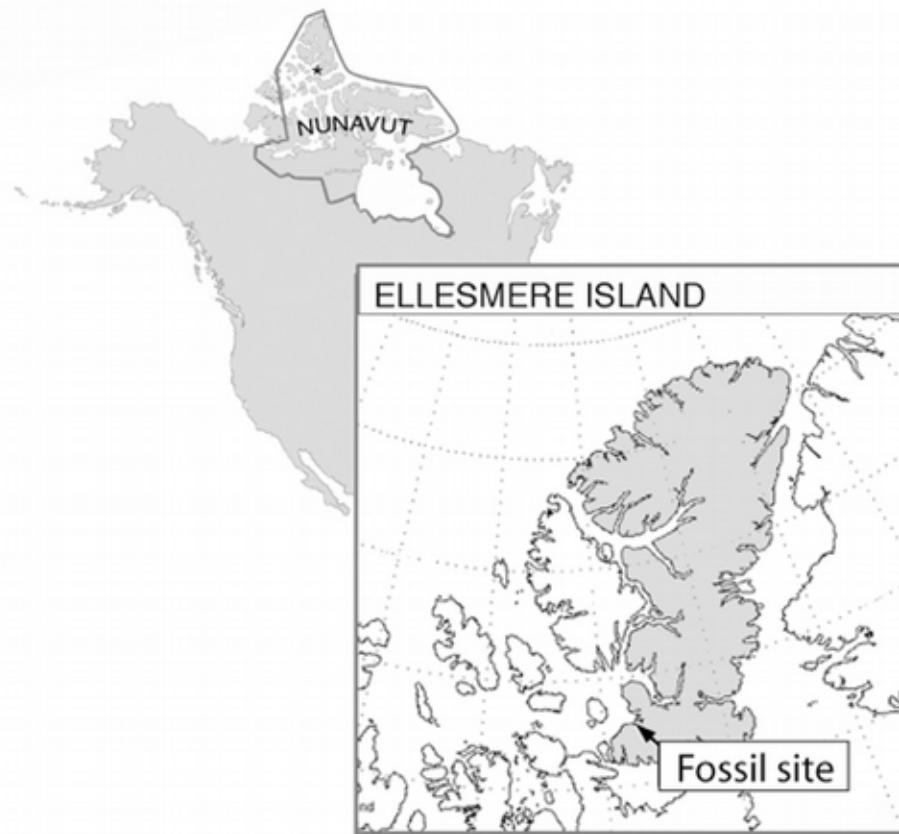
# A Devonian era relative of tetrapods



# Origin of Tetrapods



from Neil Shubin's  
***Your Inner Fish***  
***A Journey into the 3.5-Billion-Year History of the Human Body***



This is where we work: southern Ellesmere Island, in Nunavut Territory, Canada, 1,000 miles from the North Pole.

from Neil Shubin's  
***Your Inner Fish***  
***A Journey into the 3.5-Billion-Year History of the Human Body***



The process of finding fossils begins with a mass in a rock that is gradually removed over time. Here I show a fossil as it travels from the field to the lab and is carefully prepared as a specimen: the skeleton of the new animal.

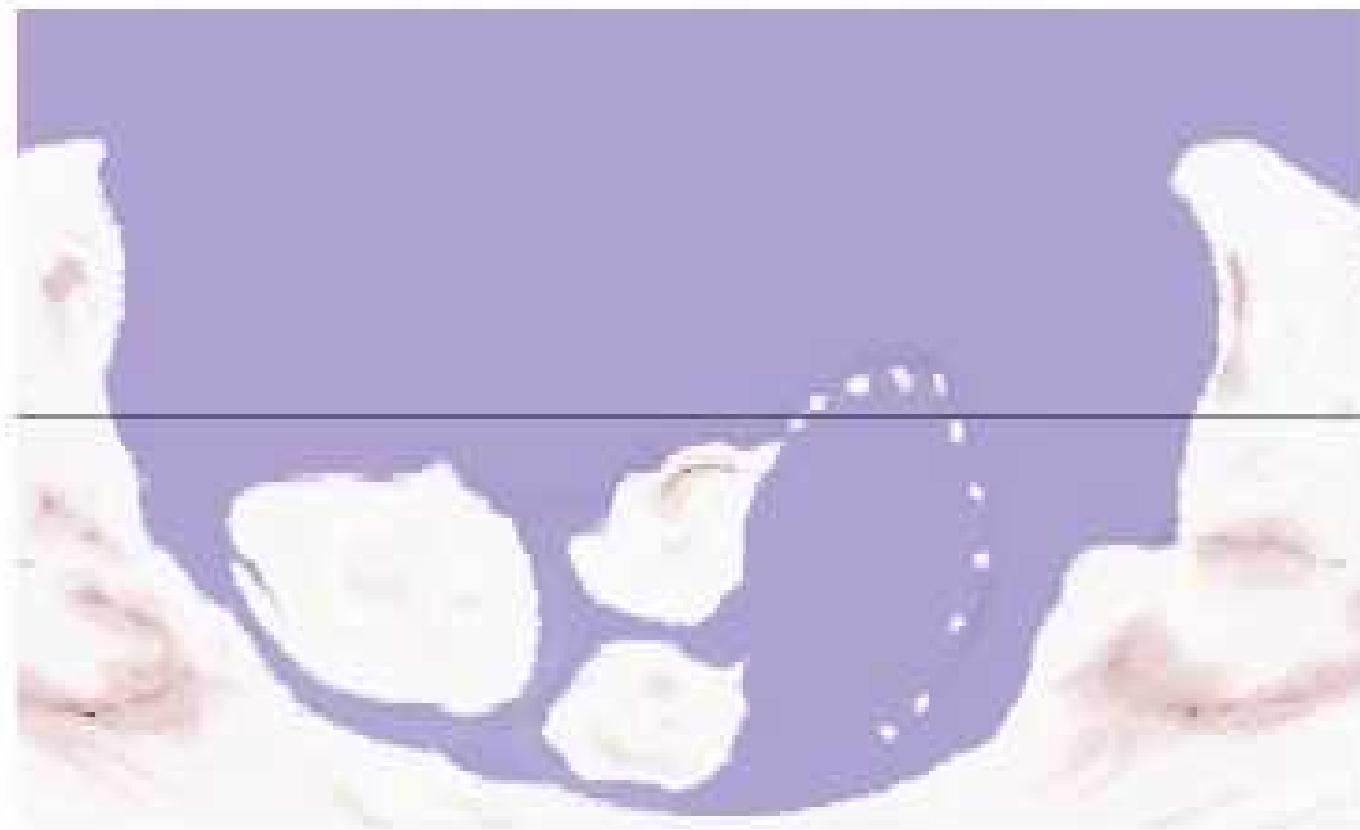
Photograph in upper left by N. Shubin; other photographs courtesy of Ted Daeschler, Academy of Natural Sciences of Philadelphia.

# What is it doing in Canada?

## How could they know to intentionally look there???



# Paleo DEM at 540 Ma (Cambrian)



Data: [earthbyte.org/paleodem-resource-scolese-and-wright-2018](http://earthbyte.org/paleodem-resource-scolese-and-wright-2018)  
Animation by Dewey Dunnington

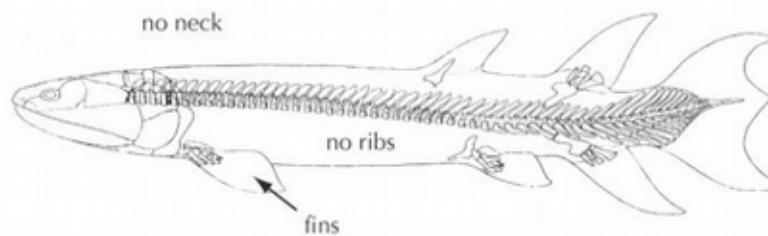
380 MA, that land was warm and had shallow seas

from Neil Shubin's  
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**FISH**



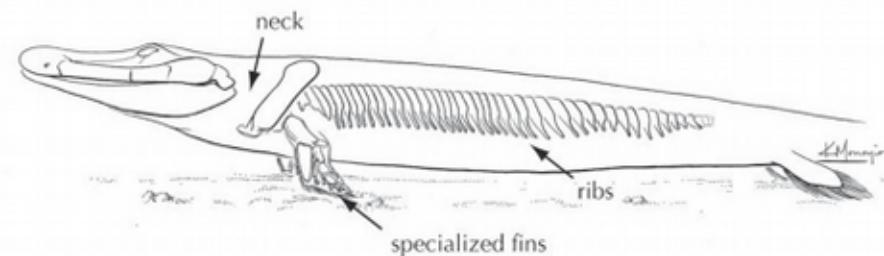
round head  
eyes on side



**TIKTAALIK**



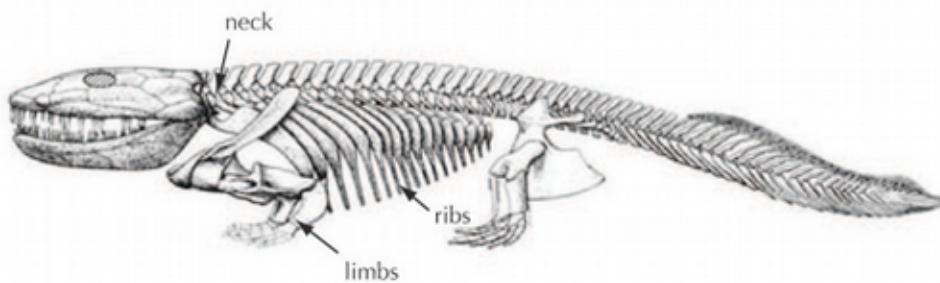
flat head  
eyes on top



**TETRAPOD**

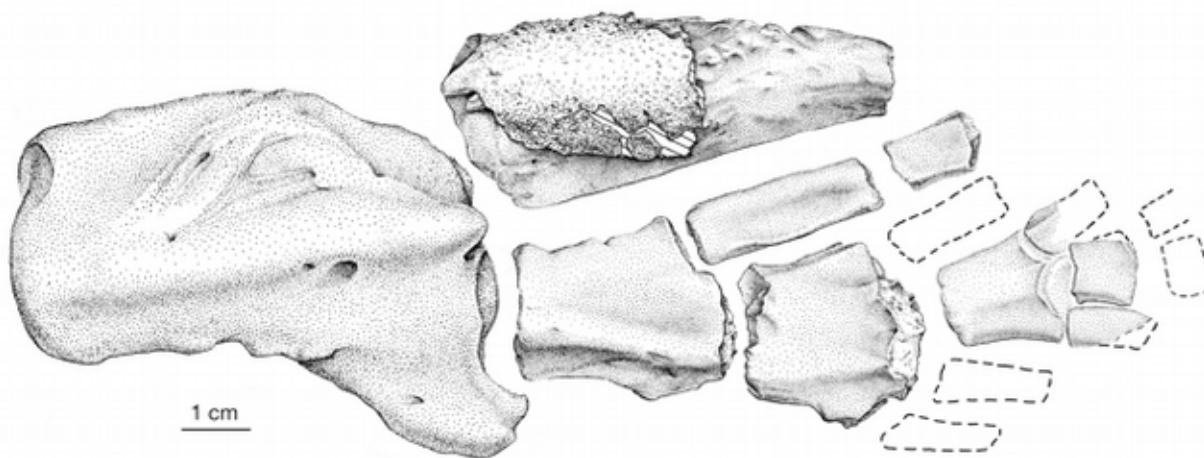


flat head  
eyes on top



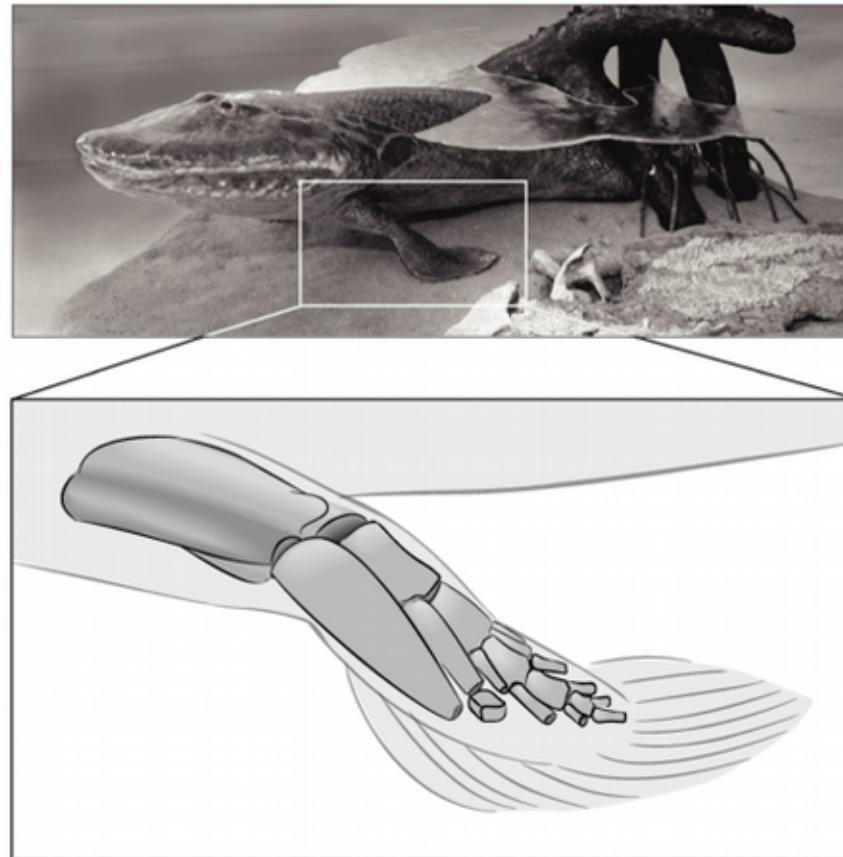
This figure says it all. *Tiktaalik* is intermediate between fish and primitive land-living animal.

from Neil Shubin's  
***Your Inner Fish***  
***A Journey into the 3.5-Billion-Year History of the Human Body***



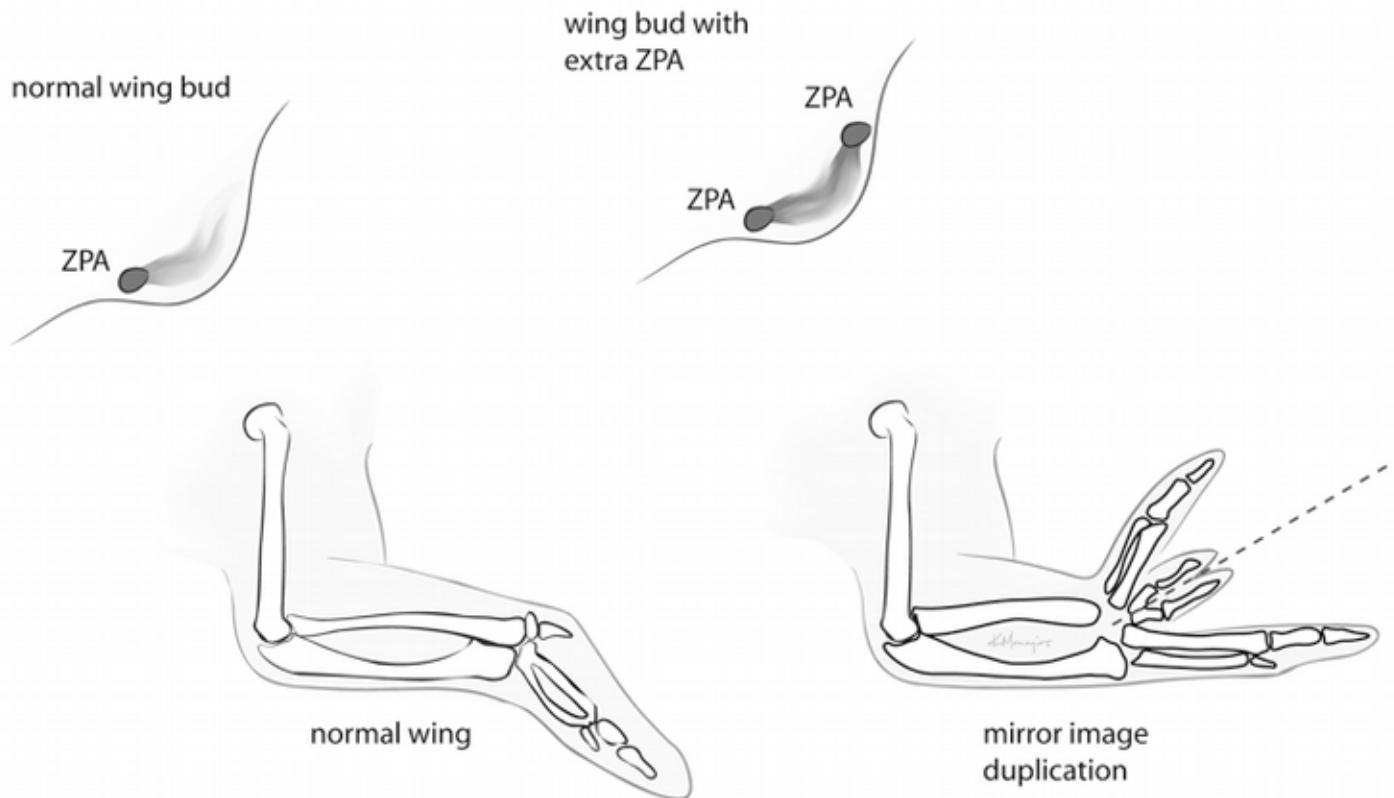
The bones of the front fin of *Tiktaalik* - a fish with a wrist.

from Neil Shubin's  
***Your Inner Fish***  
***A Journey into the 3.5-Billion-Year History of the Human Body***



A full-scale model of *Tiktaalik*'s body (top) and a drawing of its fin (bottom). This is a fin in which the shoulder, elbow, and proto-wrist were capable of performing a type of push-up.

from Neil Shubin's  
***Your Inner Fish***  
***A Journey into the 3.5-Billion-Year History of the Human Body***



Moving a little patch of tissue called the ZPA causes the fingers to be duplicated.

# Amphibians

---

- **Amphibians** (class Amphibia) are represented by about 6,150 species of organisms in three orders.
- *Amphibian* means “both ways of life,” referring to the metamorphosis of an aquatic larva into a terrestrial adult.
- Most amphibians have moist skin that complements the lungs in gas exchange.
- Fertilization is external in most species, and the eggs require a moist environment.

# Amphibians

(a) Order Urodela



(b) Order Anura



(c) Order Apoda



# The “dual life” of a frog



(a) Tadpole



(b) During  
metamorphosis



(c) Mating adults

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## **Concept 34.6: Amniotes are tetrapods that have a terrestrially adapted egg**

---

- **Amniotes** are a group of tetrapods whose living members are the reptiles, including birds, and mammals.
- Amniotes are named for the major derived character of the clade, the ***amniotic egg***, which contains membranes that protect the embryo.
- The ***extraembryonic membranes*** are the ***amnion, chorion, yolk sac, and allantois***.
- Amniotes have other terrestrial adaptations, such as relatively impermeable skin and the ability to use the rib cage to ventilate the lungs.

# Hatching reptiles



- 
- Dinosaurs diversified into a vast range of shapes and sizes.
  - They included bipedal carnivores called **theropods**.
  - Paleontologists have discovered signs of parental care among dinosaurs.
  - Dinosaurs, with the exception of birds, went extinct by the end of the Cretaceous.

# Extant reptiles

(other  
than birds).



(a) Tuatara (*Sphenodon punctatus*)



(b) Australian thorny devil  
lizard (*Moloch  
horridus*)



(c) Wagler's pit viper  
(*Tropidolaemus wagleri*)



(d) Eastern box turtle  
(*Terrapene carolina carolina*)



(e) American alligator  
(*Alligator mississippiensis*)

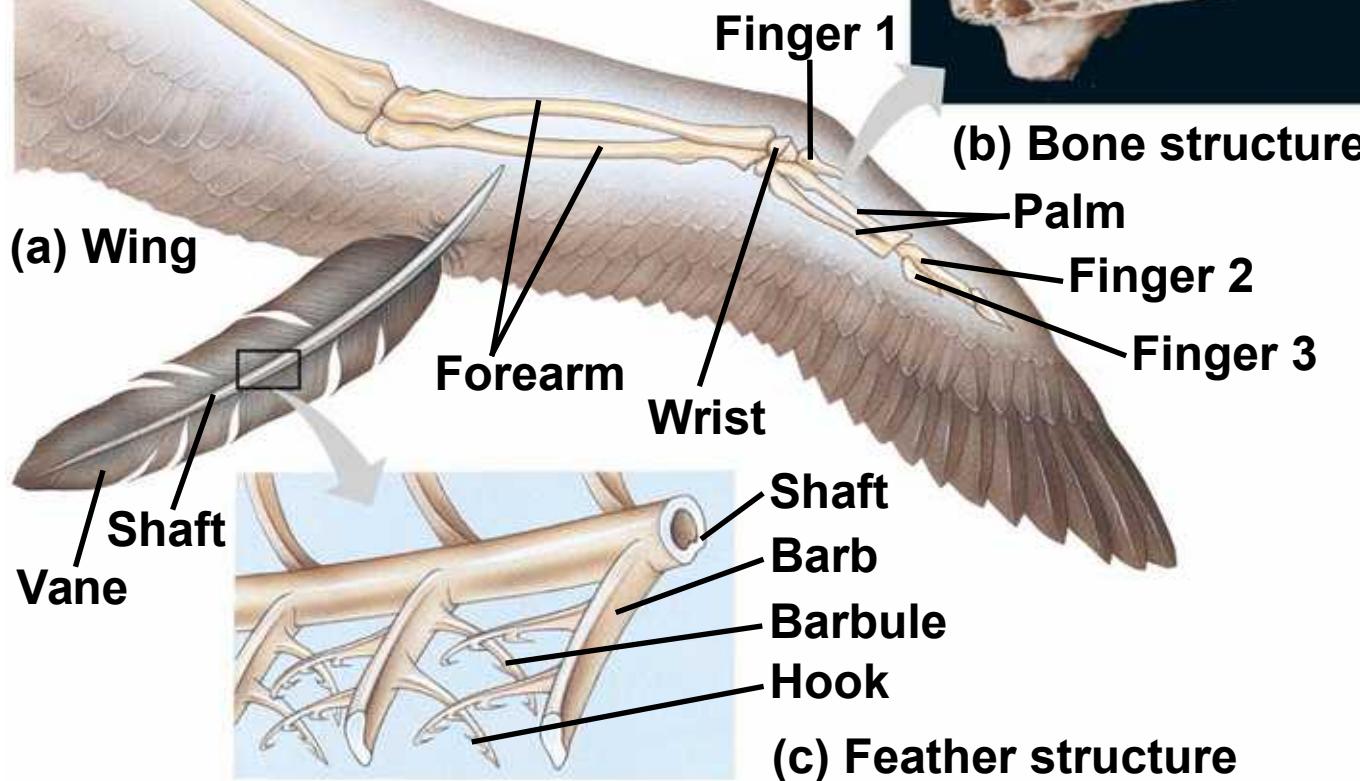
# *Birds - reptilian anatomy modified for Flight*

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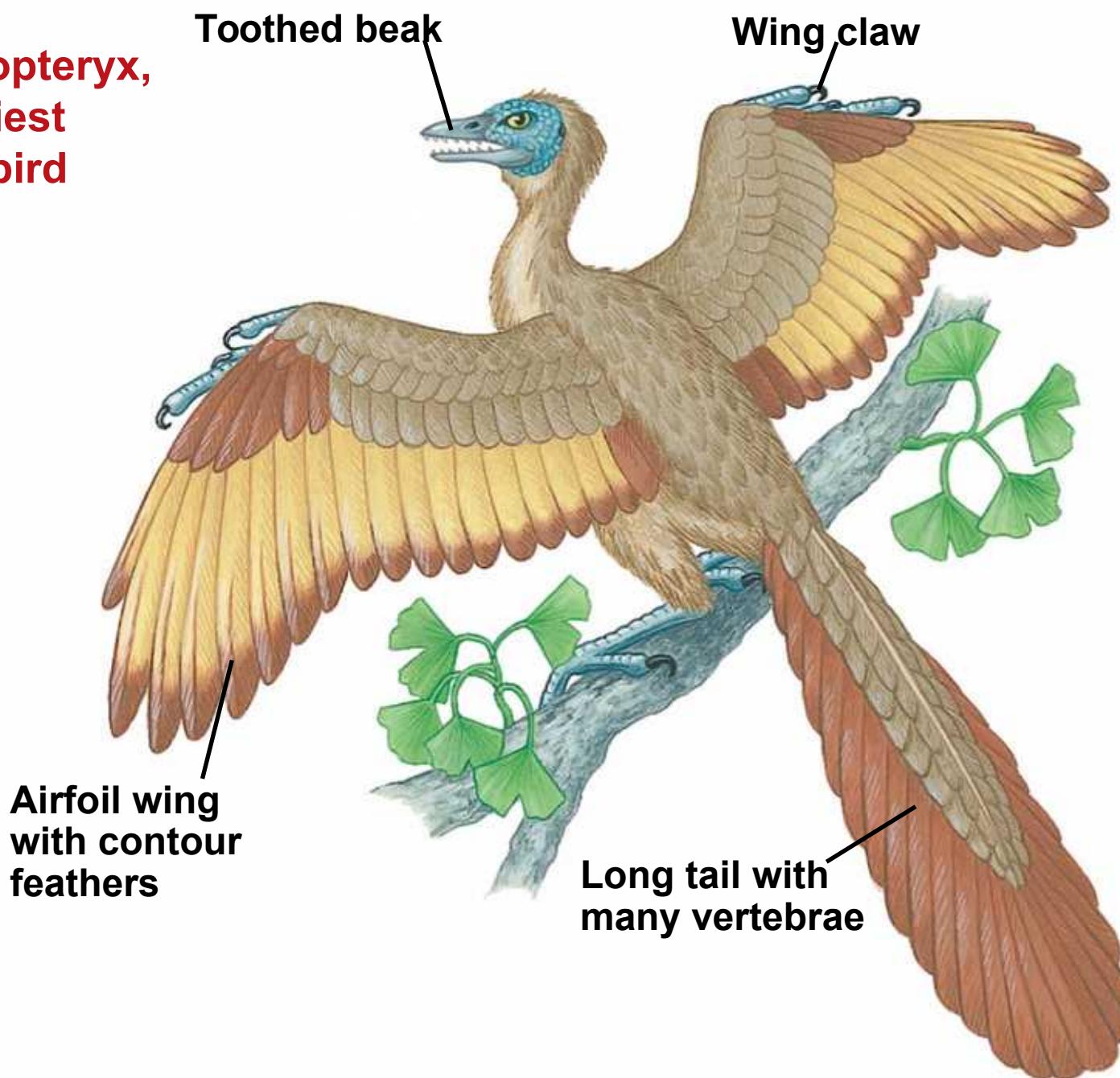
## Derived Characters of Birds:

- Many characters of birds are adaptations that facilitate flight
- The major adaptation is wings with keratin feathers
- Other adaptations include lack of a urinary bladder, females with only one ovary, small gonads, and loss of teeth.

# Form fits function: the avian wing and feather



## **Archaeopteryx, the earliest known bird**



150 MYA



# Feathered dinosaurs



# Diversity among living birds



(a) Emu - flightless



(b) Mallards - web feet



(c) Laysan albatrosses



(d) Barn swallows



# Chicken-osaurus

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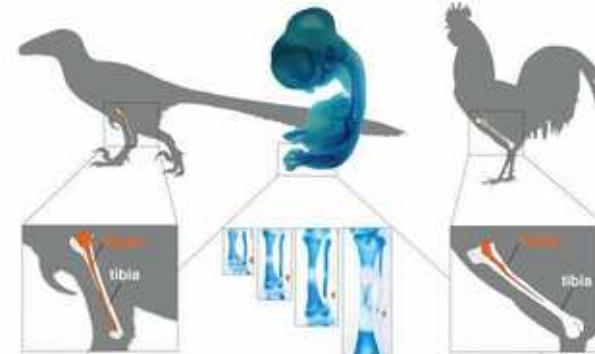
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*Deinonychus*

Chicken embryo

Chicken adult



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## Chicken grows face of dinosaur

A chicken embryo with a dinosaur-like snout instead of a beak has been developed by scientists

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