Lecture 32:

Deuterosomes II: Chordates

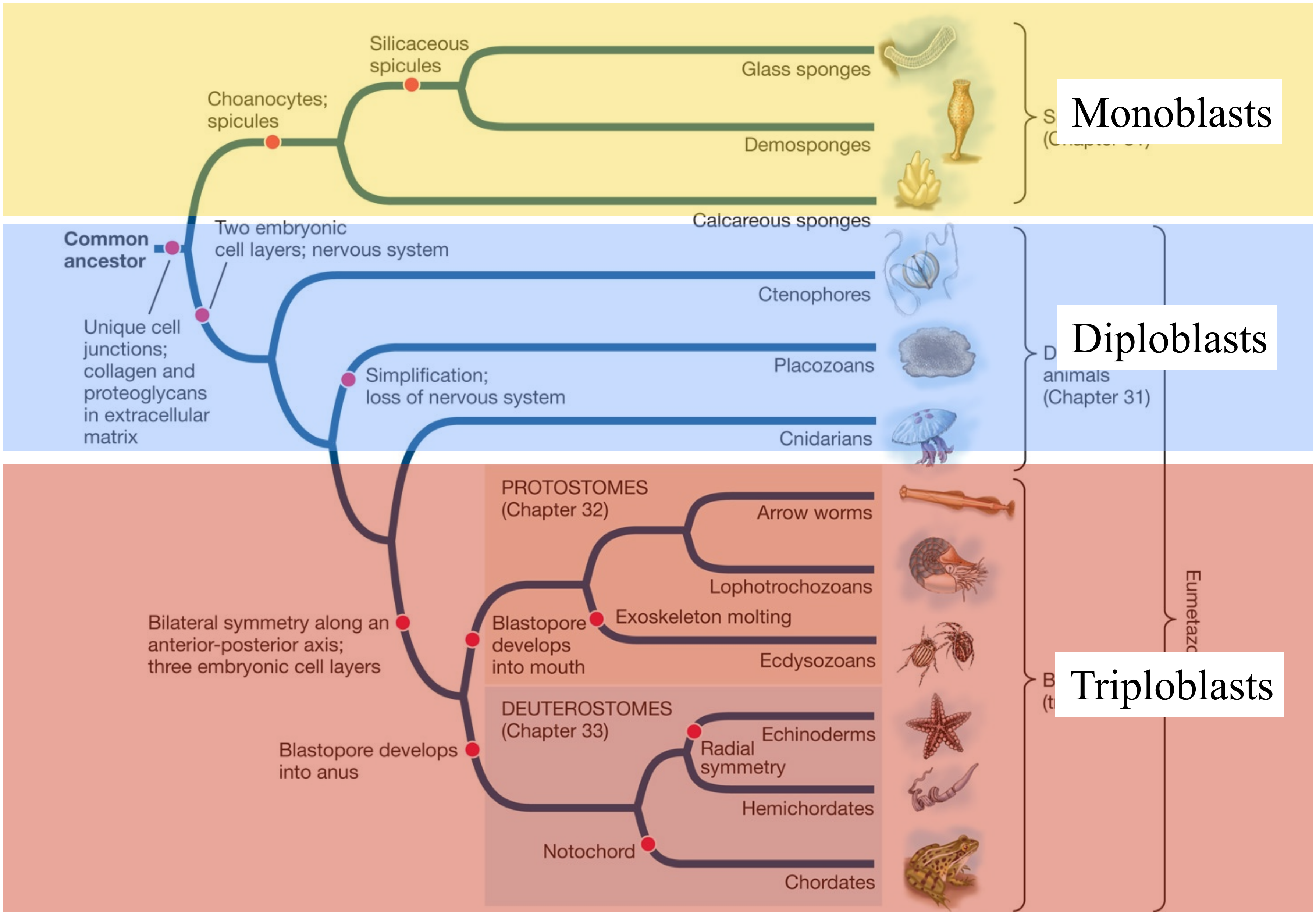
BIS 002C
Biodiversity & the Tree of Life
Spring 2016

Prof. Jonathan Eisen

Where we are going and where we have been…

- Previous lecture:
  - 31: Deuterosomes I: Echinoderms & Hemichordates
- Current Lecture:
  - 32: Deuterosomes II: Chordates
- Next Lecture:
  - 33: Deuterosomes III: Chordates II

Animal Diversity



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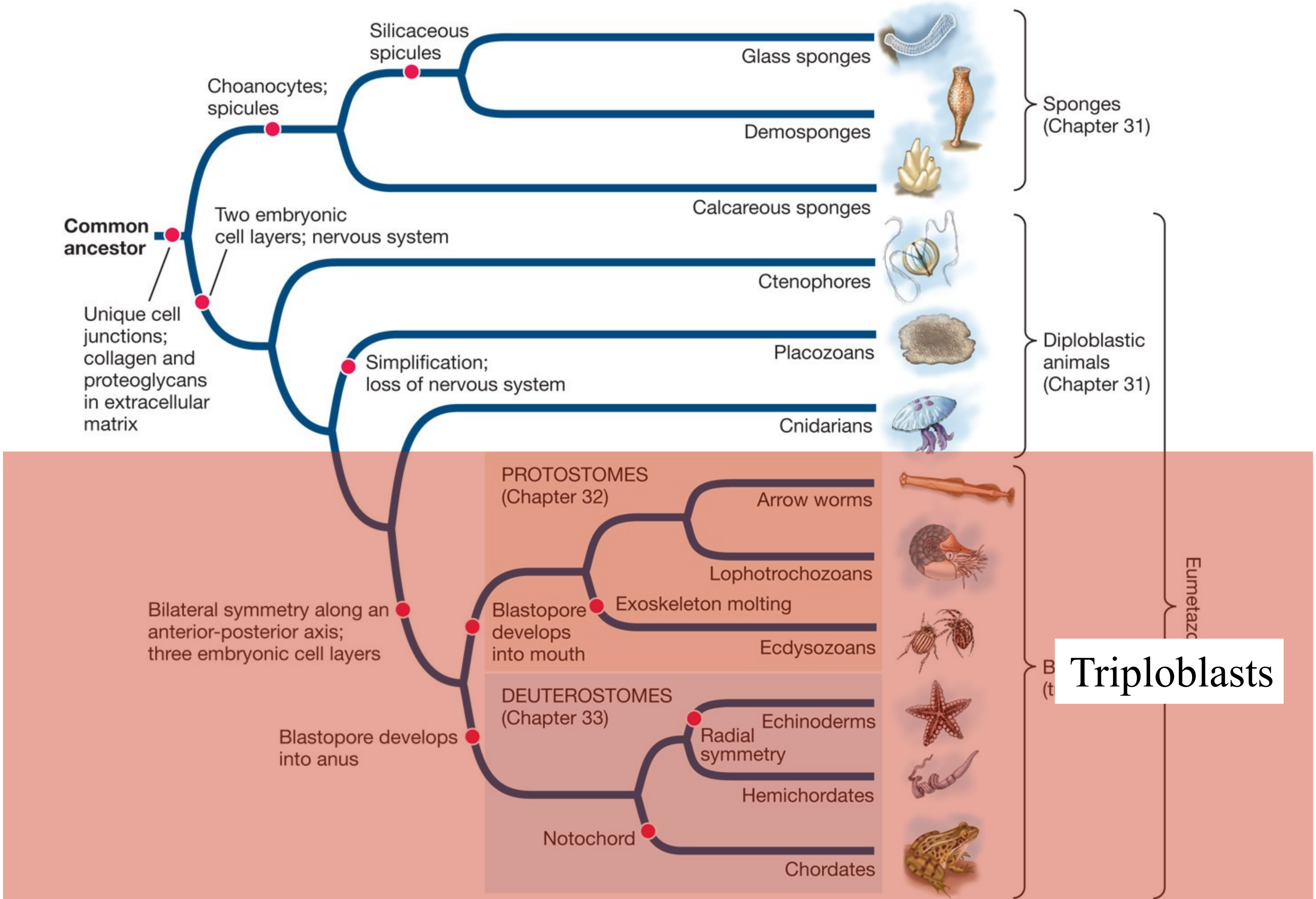
Triploblasts



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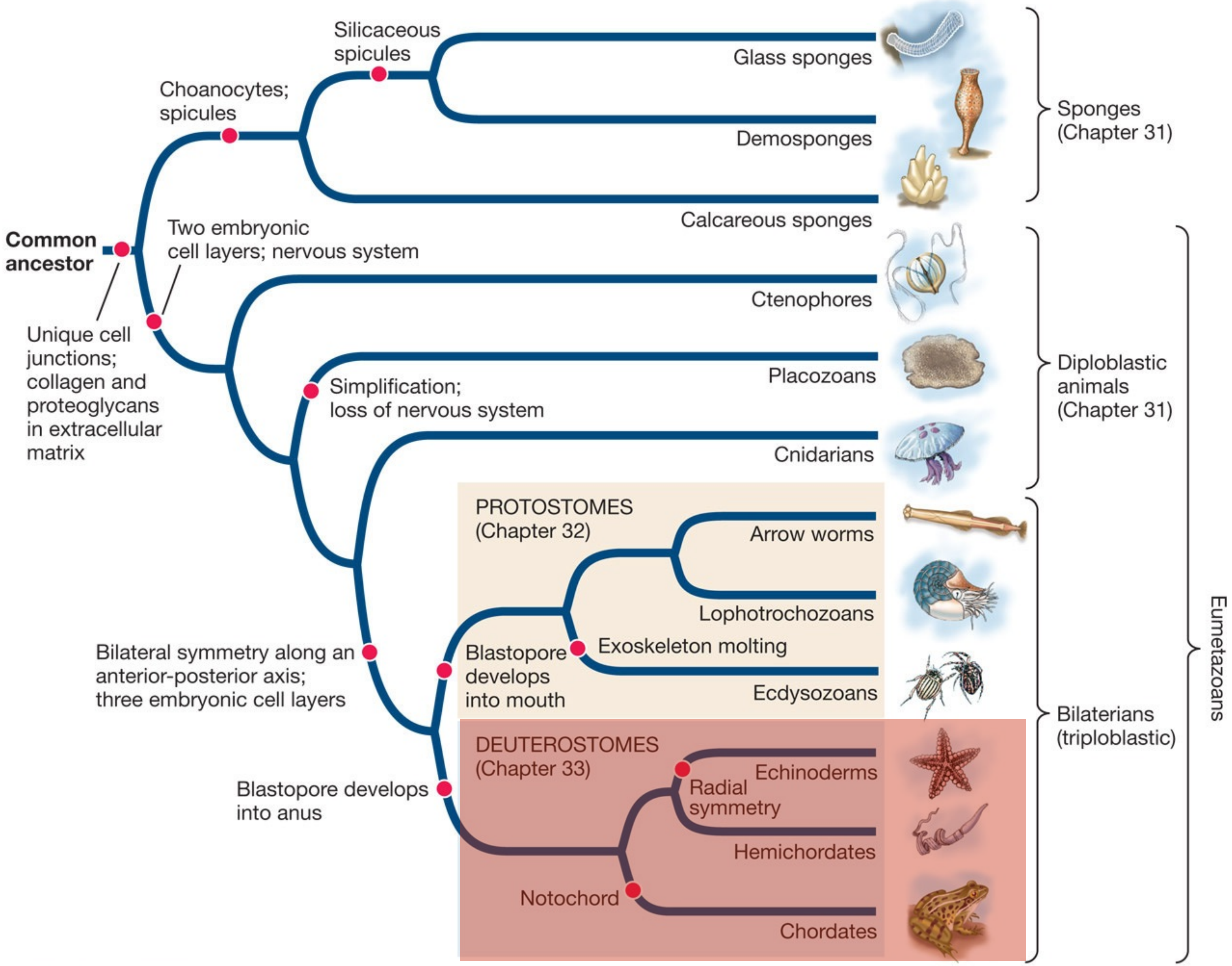
Protostomes



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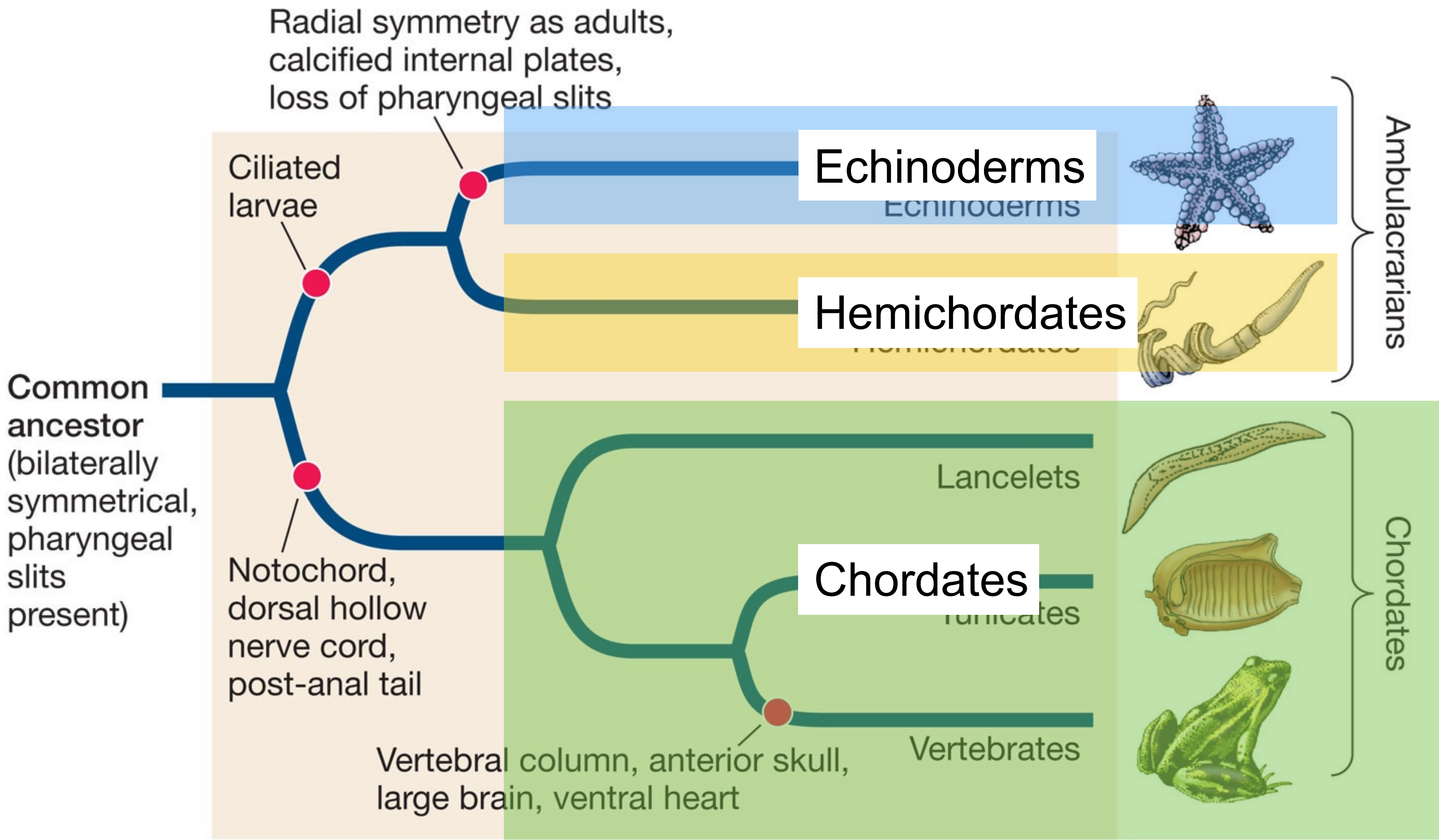
Chordates



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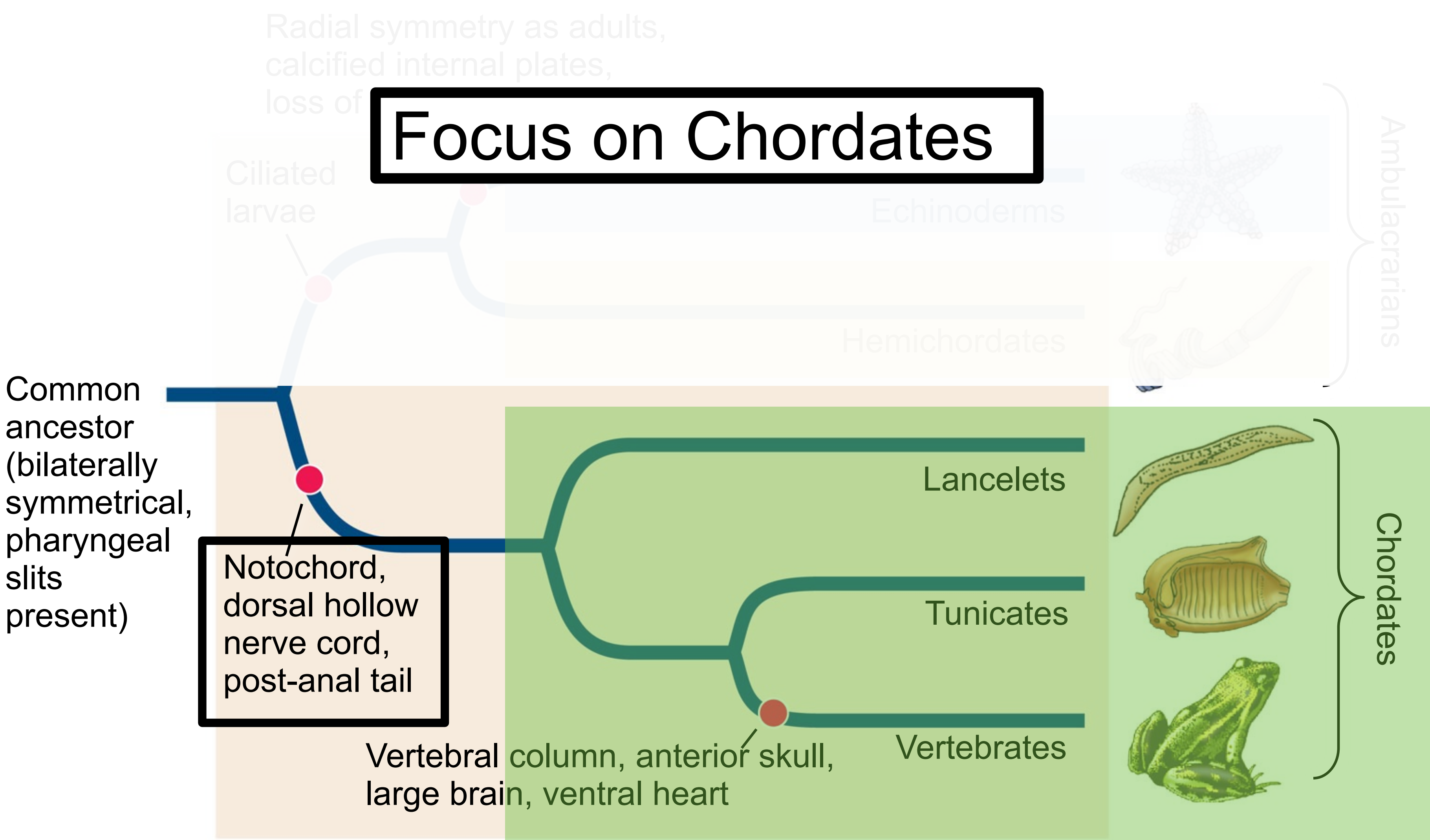
Chordates



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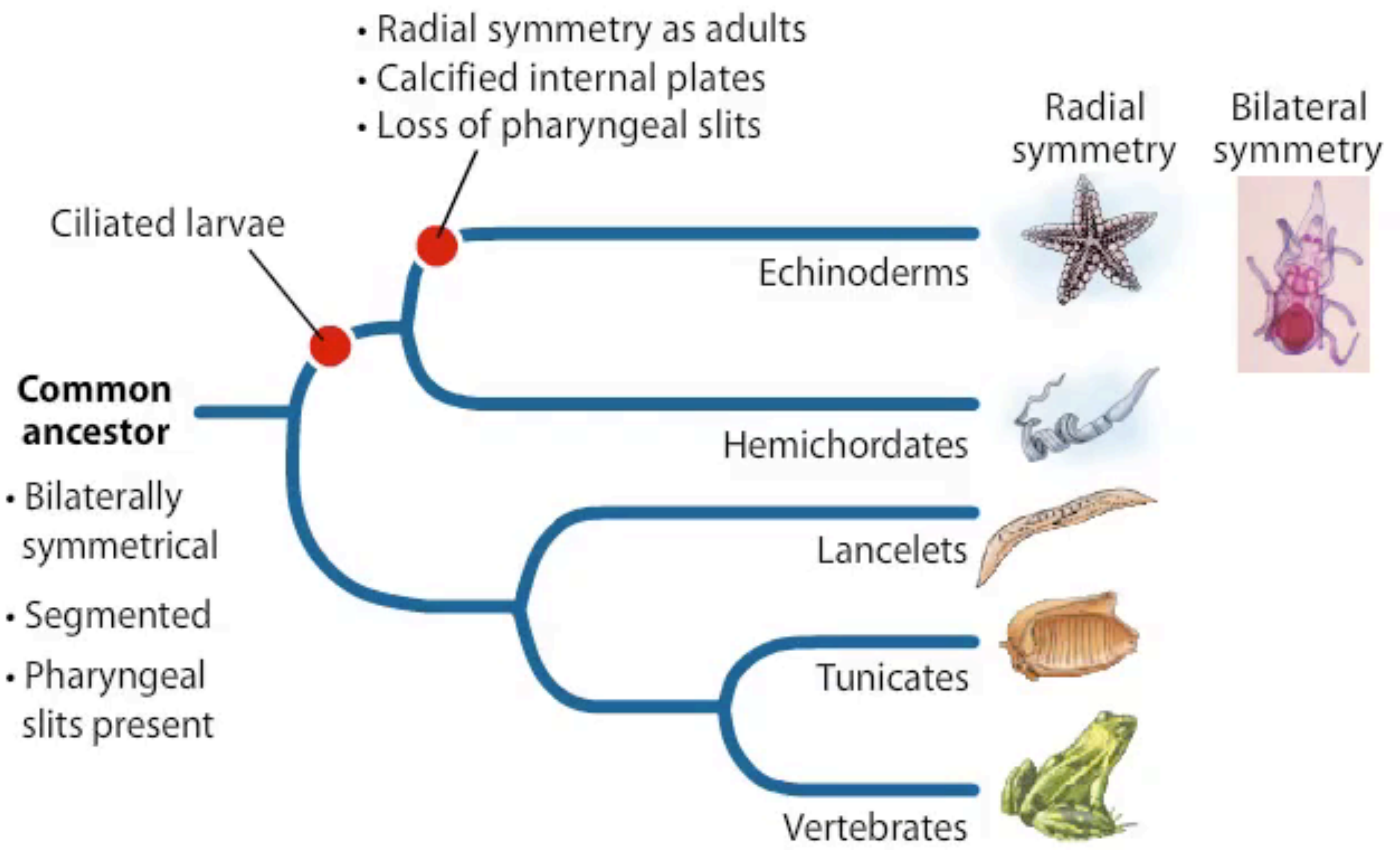
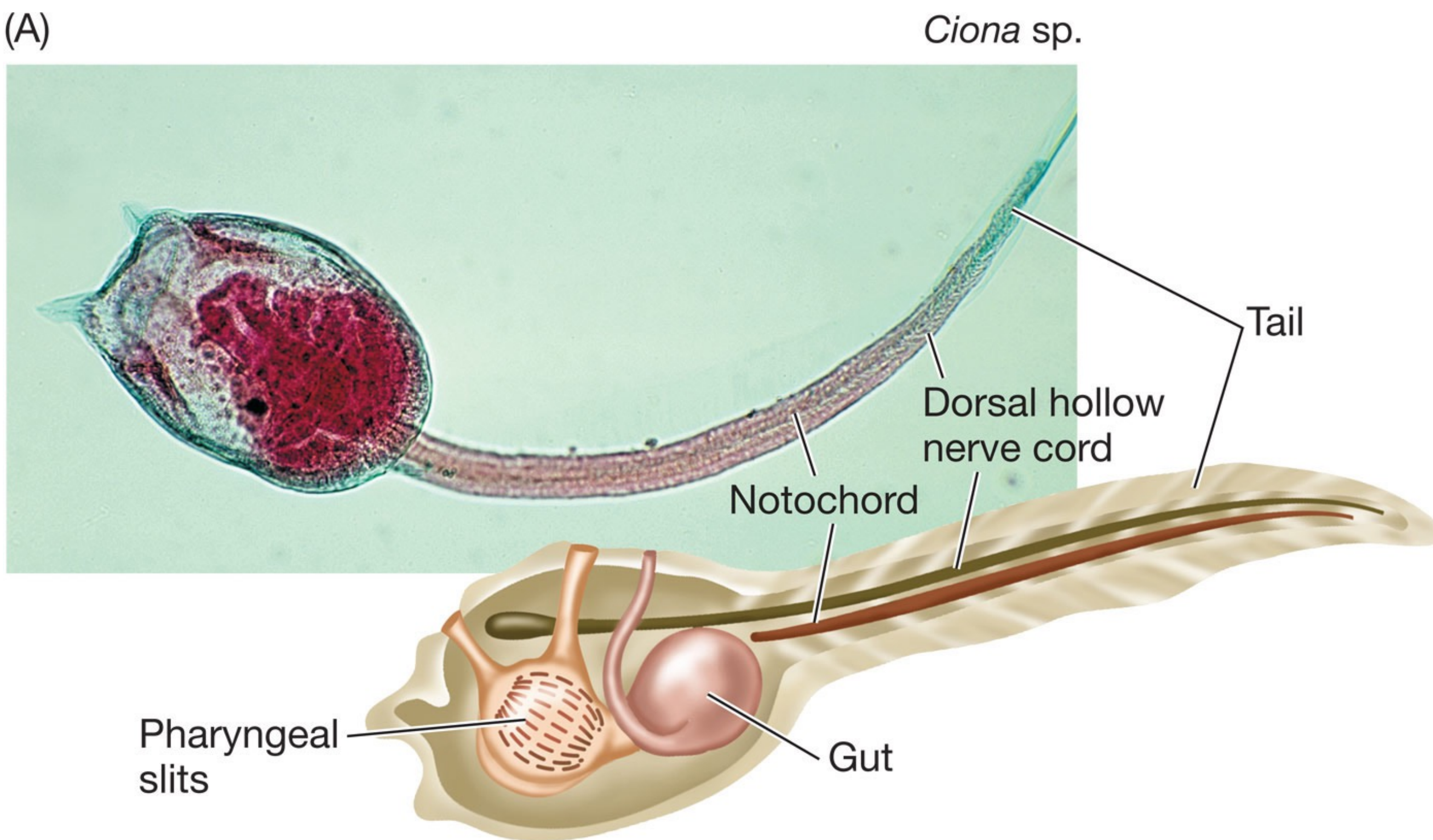
Deuterostomes



Chordate Derived Traits Most Apparent in Juveniles



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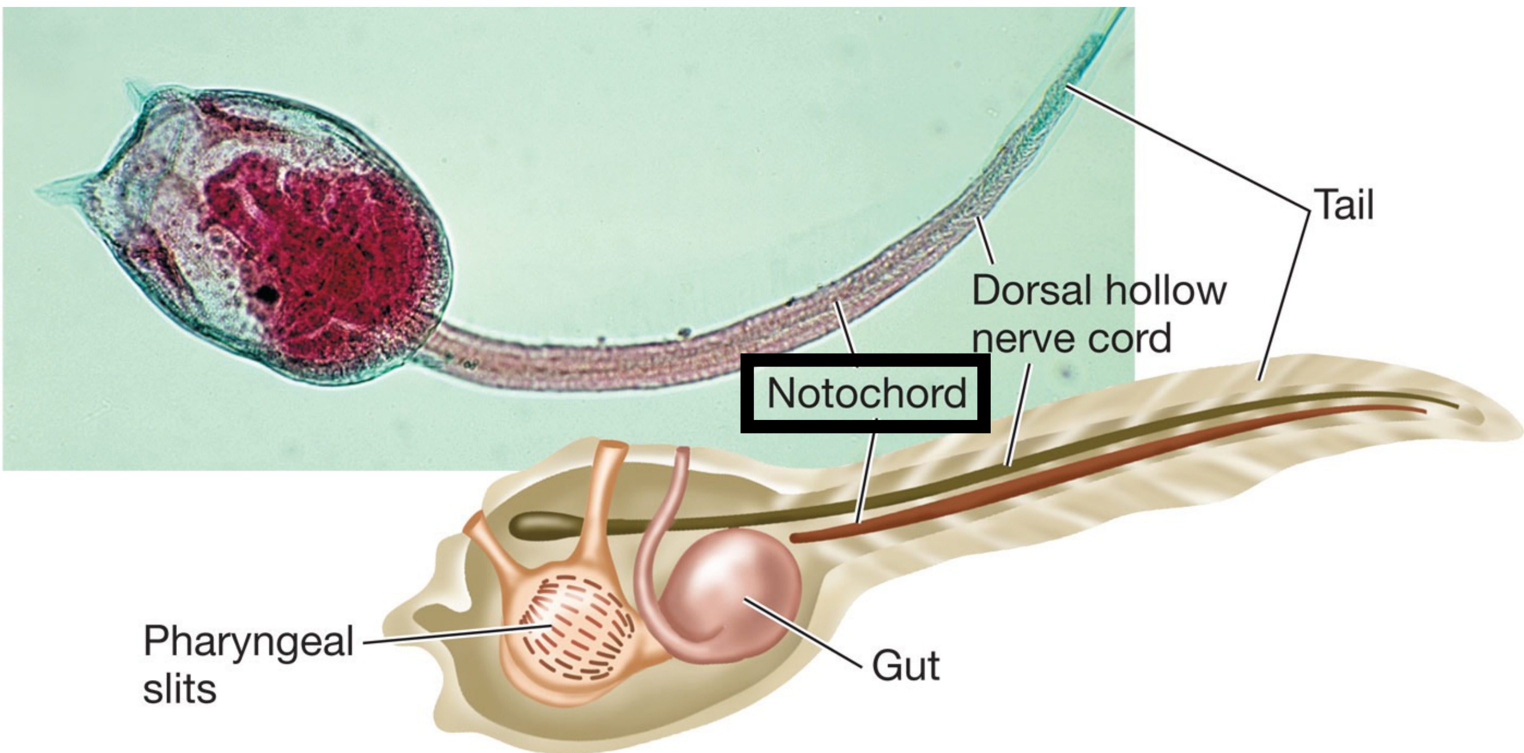
Notochord

- Notochord is a dorsal supporting rod.
- Core of large cells with fluid-filled vacuoles, making it rigid but flexible.
- In tunicates it is lost during metamorphosis to the adult stage.
- In vertebrates it is replaced by skeletal structures.



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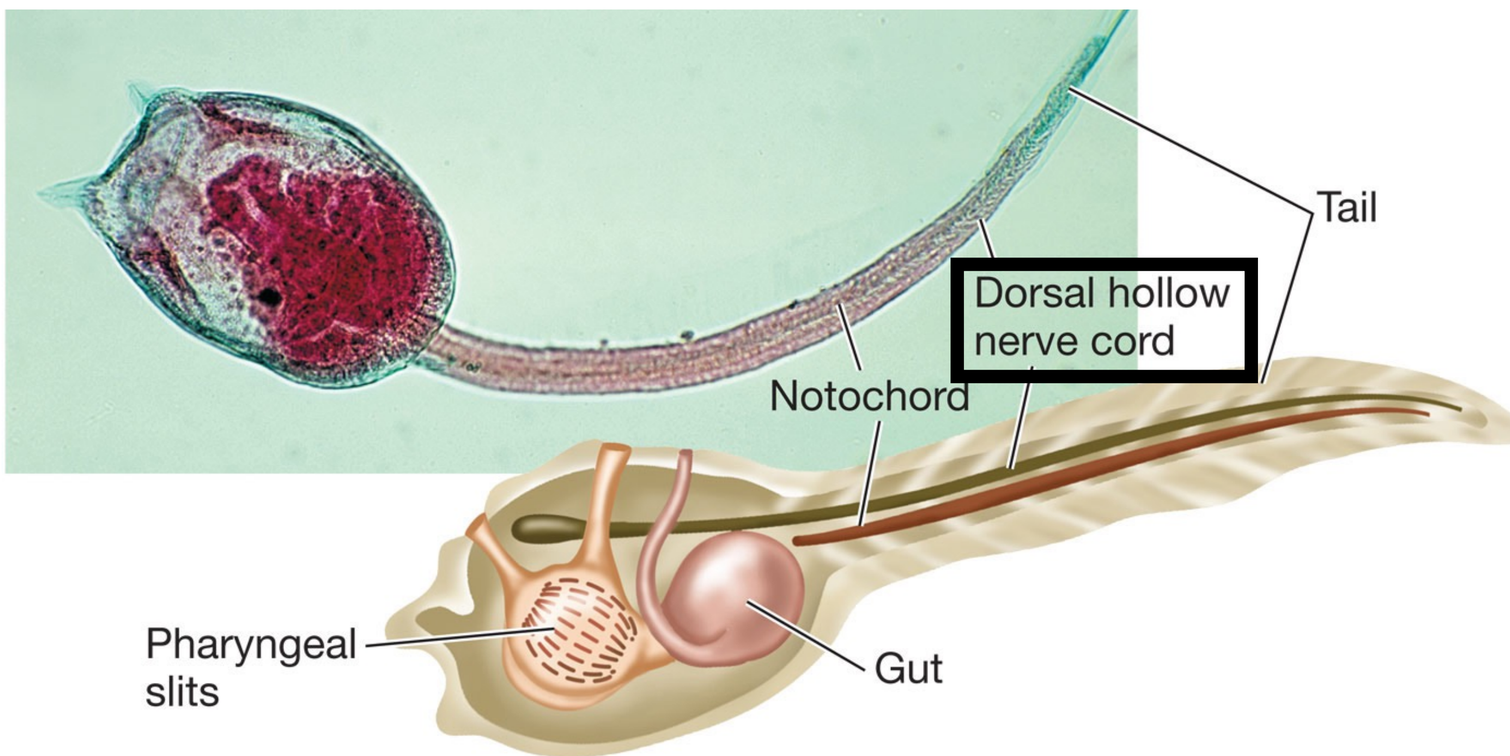
Dorsal hollow nerve cord

- Formed by an embryonic folding of the ectoderm
- Develops to form the central nervous system in vertebrates



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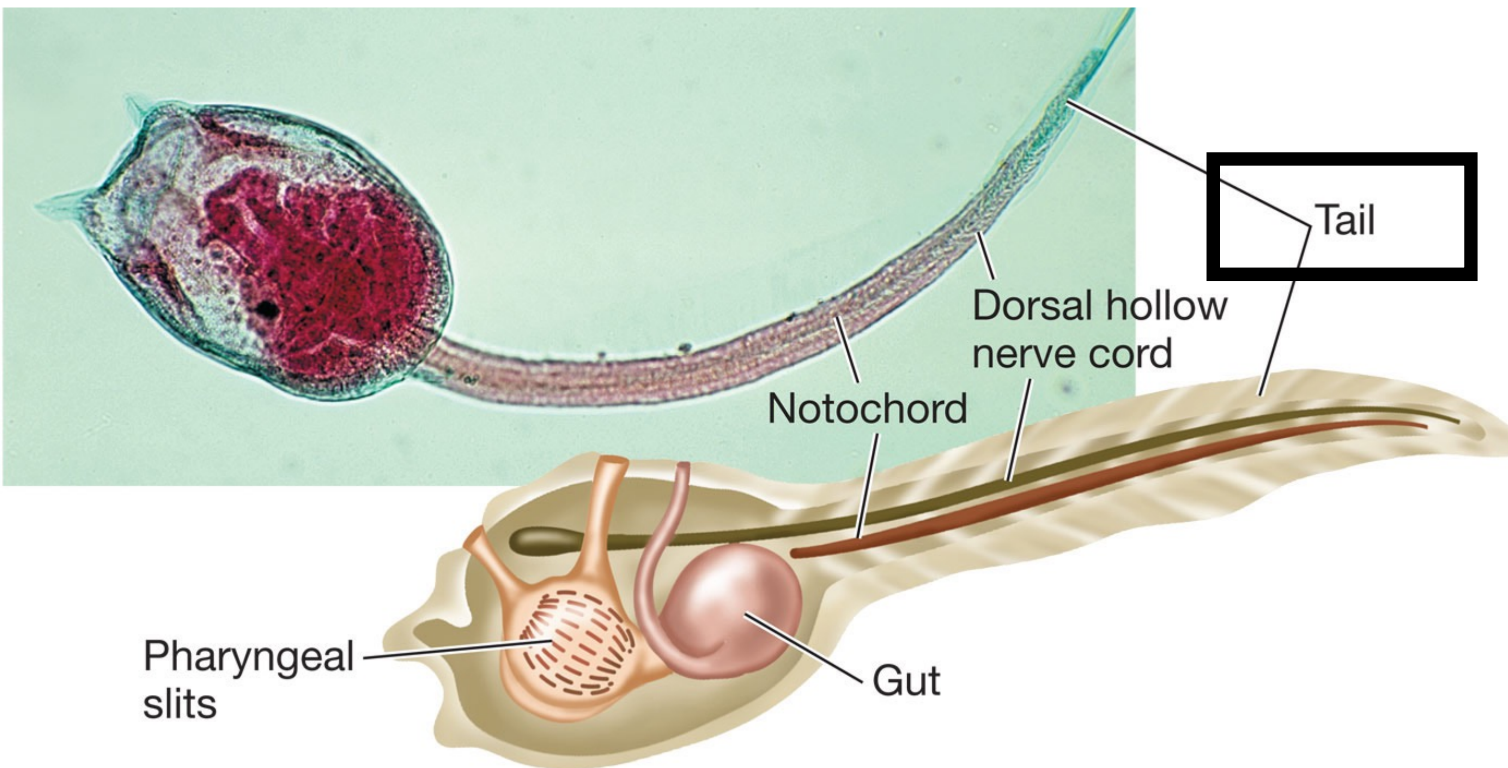
- Extension of the body past the anal opening
- In some species (e.g., humans) most visible in embryos
- The combination of postanal tail, notochord, and muscles provides propulsion



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Pharyngeal Slits

- The pharynx is a muscular organ that brings water in through the mouth (via cilia) which then passes through a series of openings to the outside (slits).
- Ancestral pharyngeal slits present at some developmental stage; often lost or modified in adults.
- Supported by pharyngeal arches.

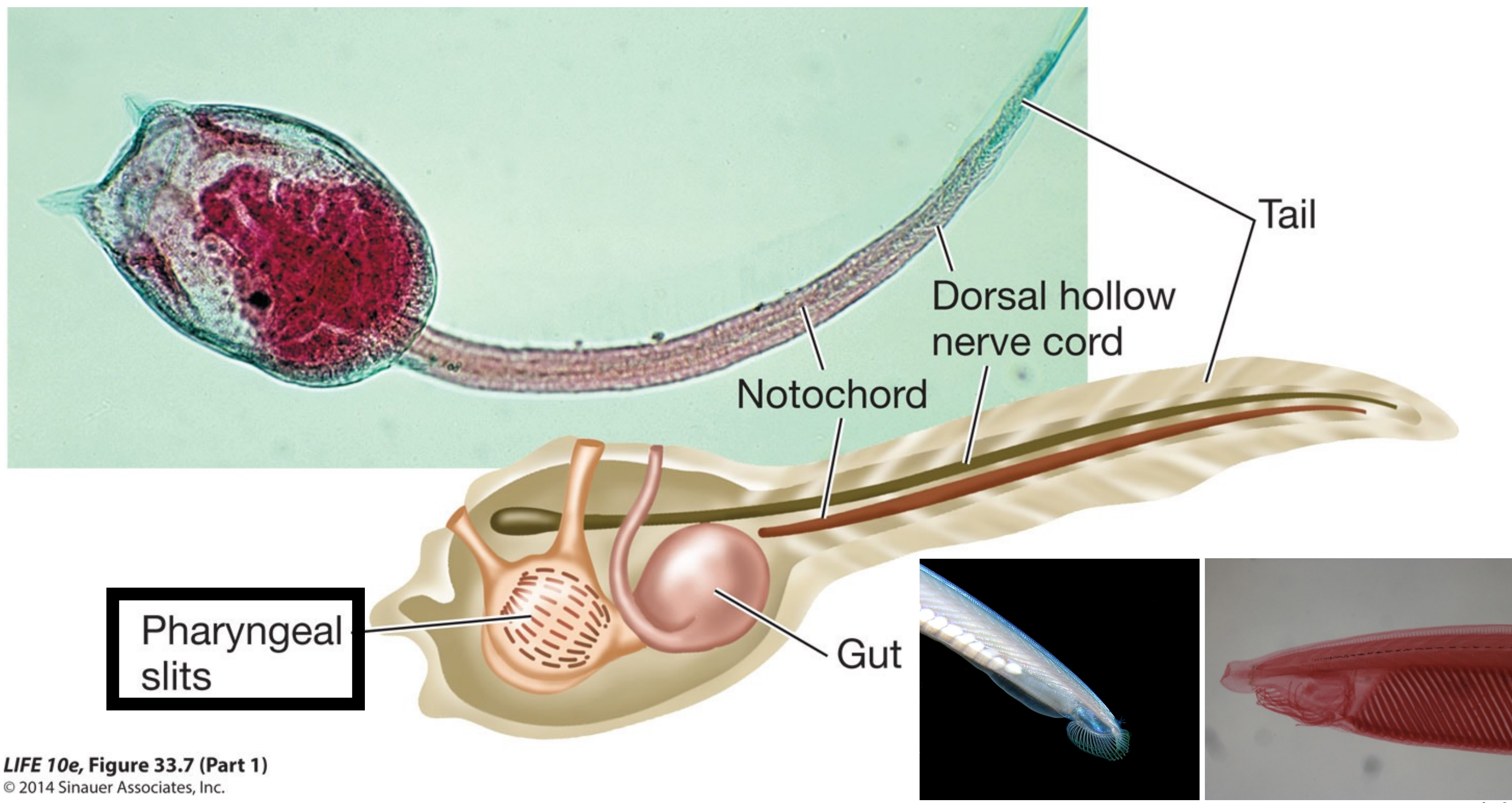

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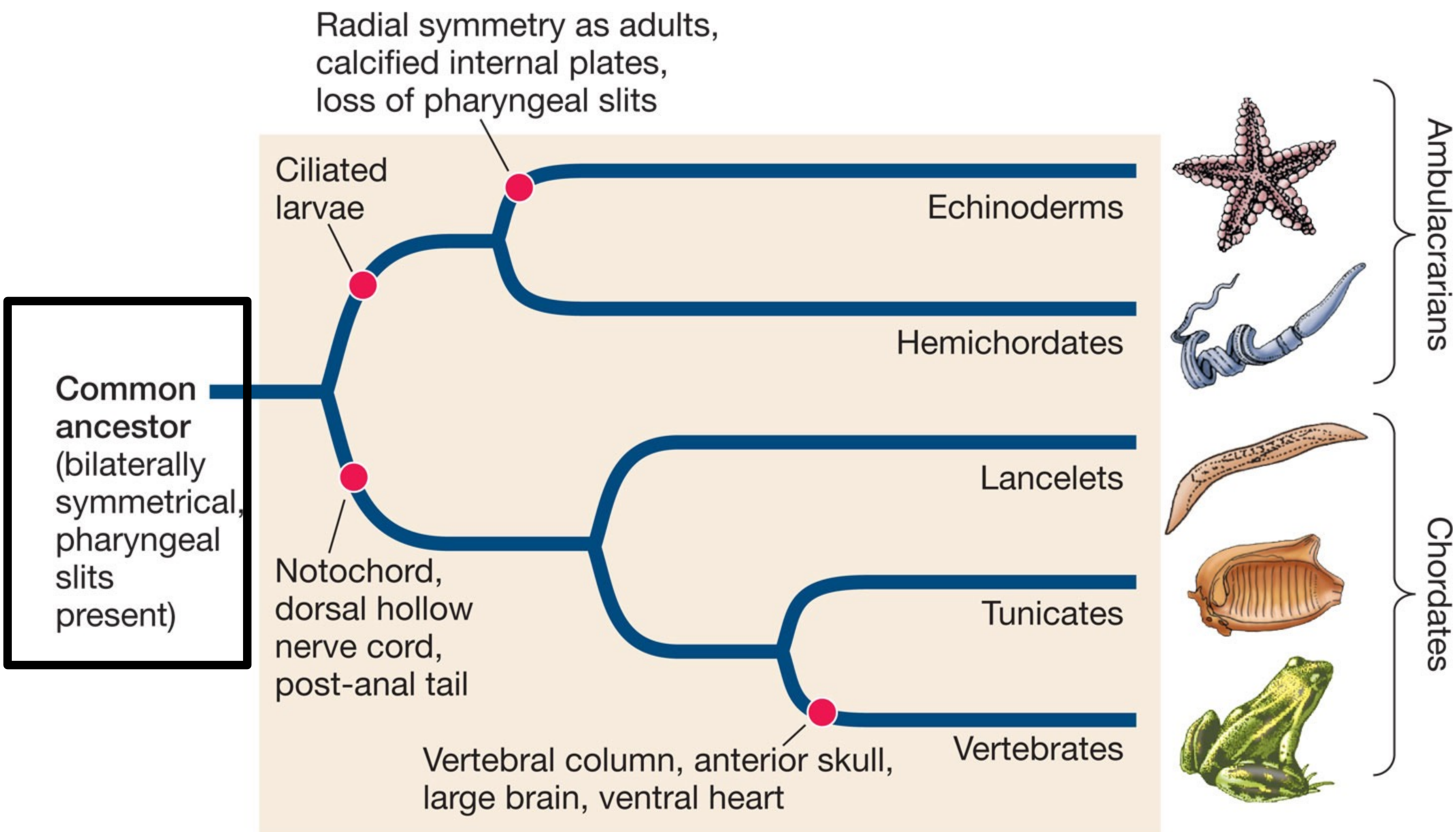
Figure 33.1 Phylogeny of the Deuterostomes



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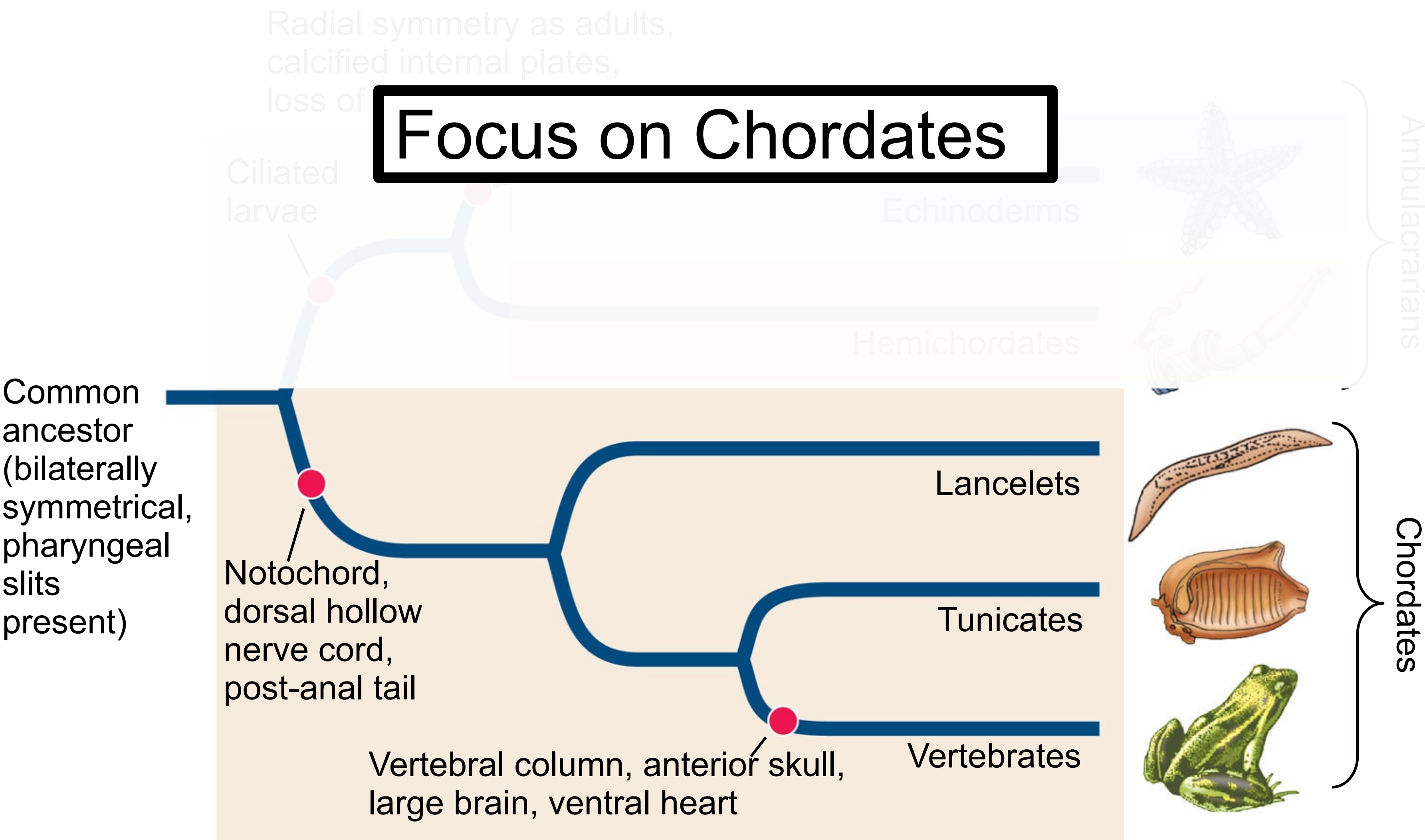
Chordates



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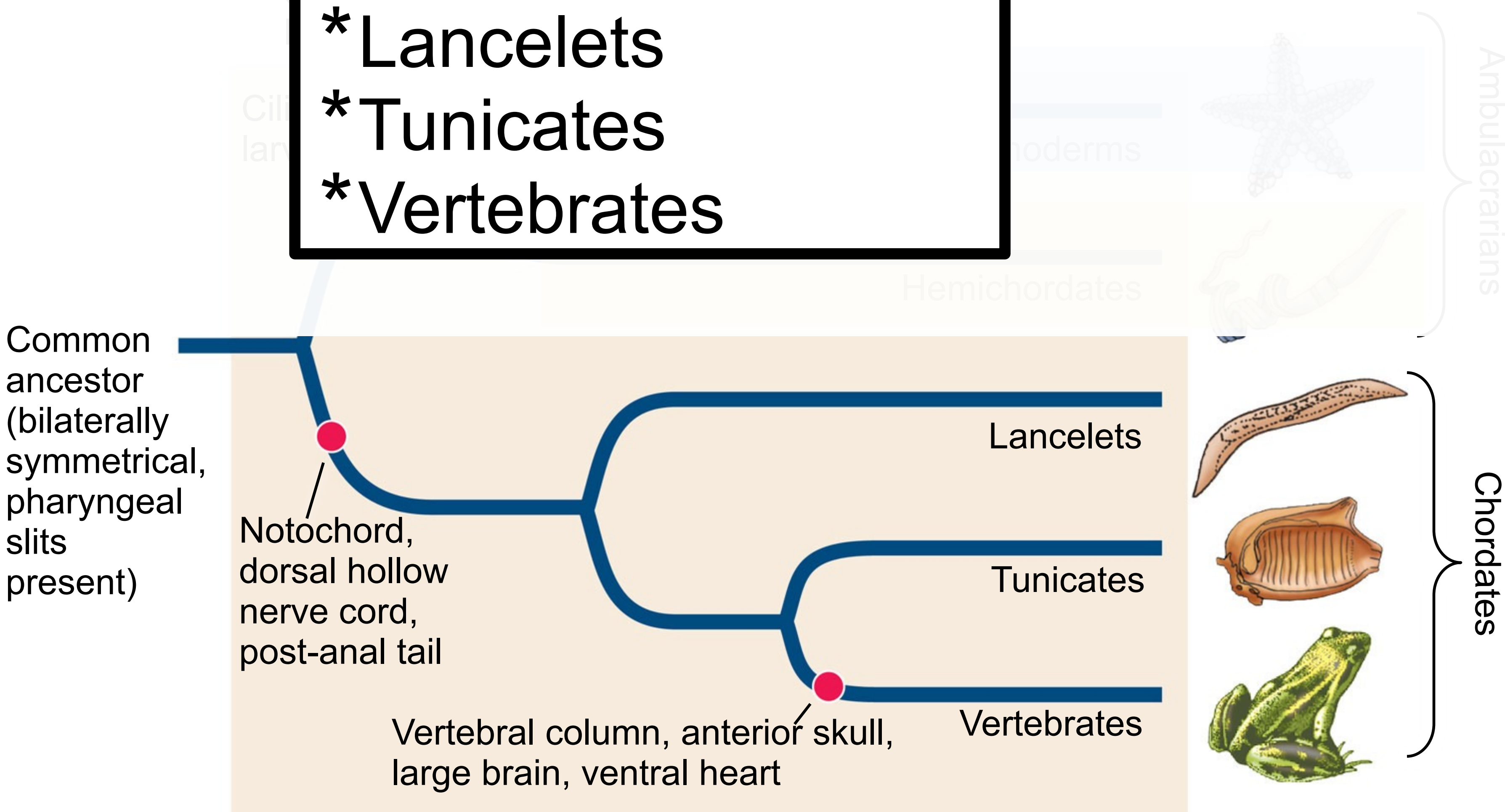
Chordates

Three Major Groups
*Lancelets
*Tunicates
*Vertebrates



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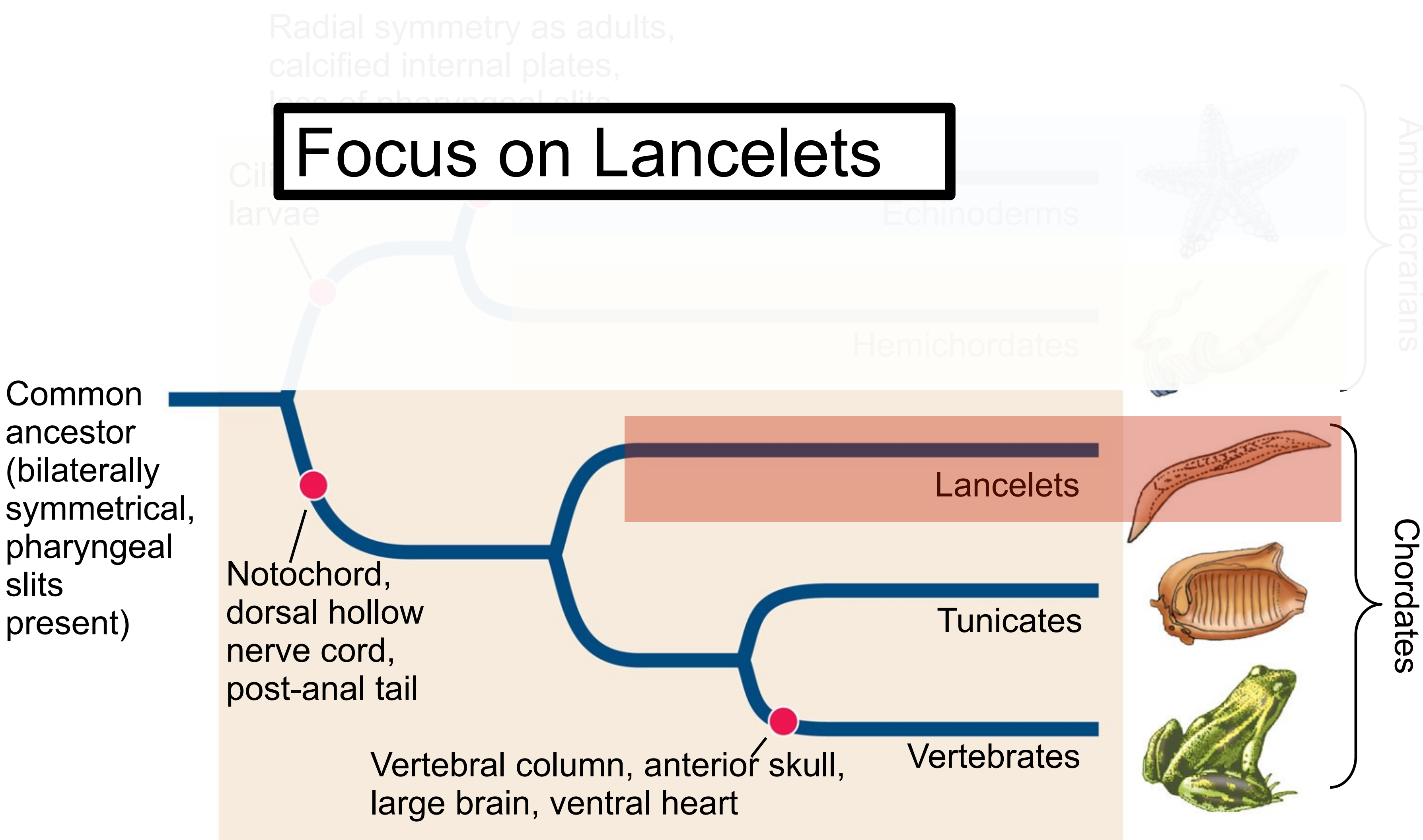
Lancelets (aka Cephalochordates)



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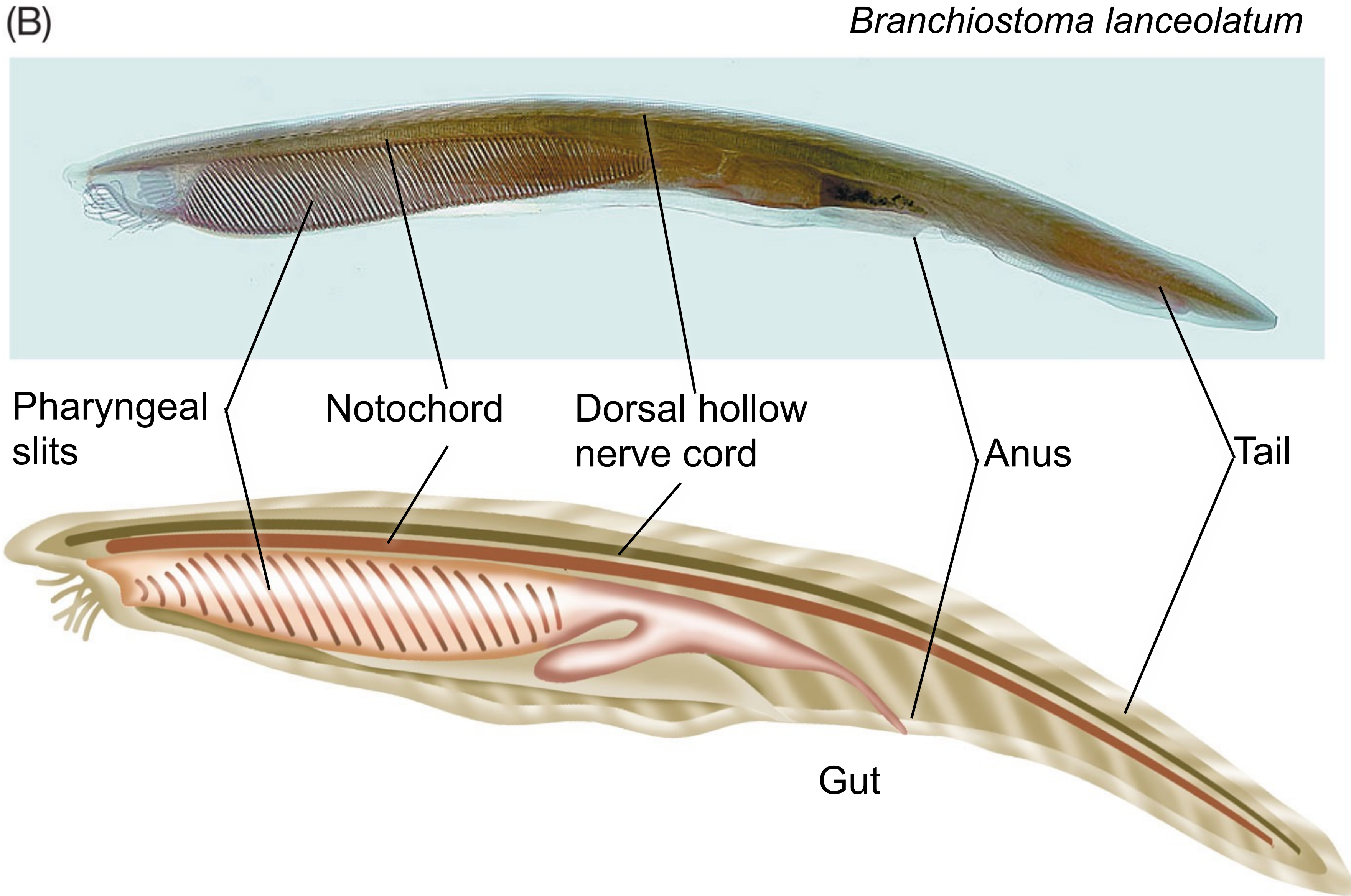
Lancelet development

Lancelet Has Key Chordate Features



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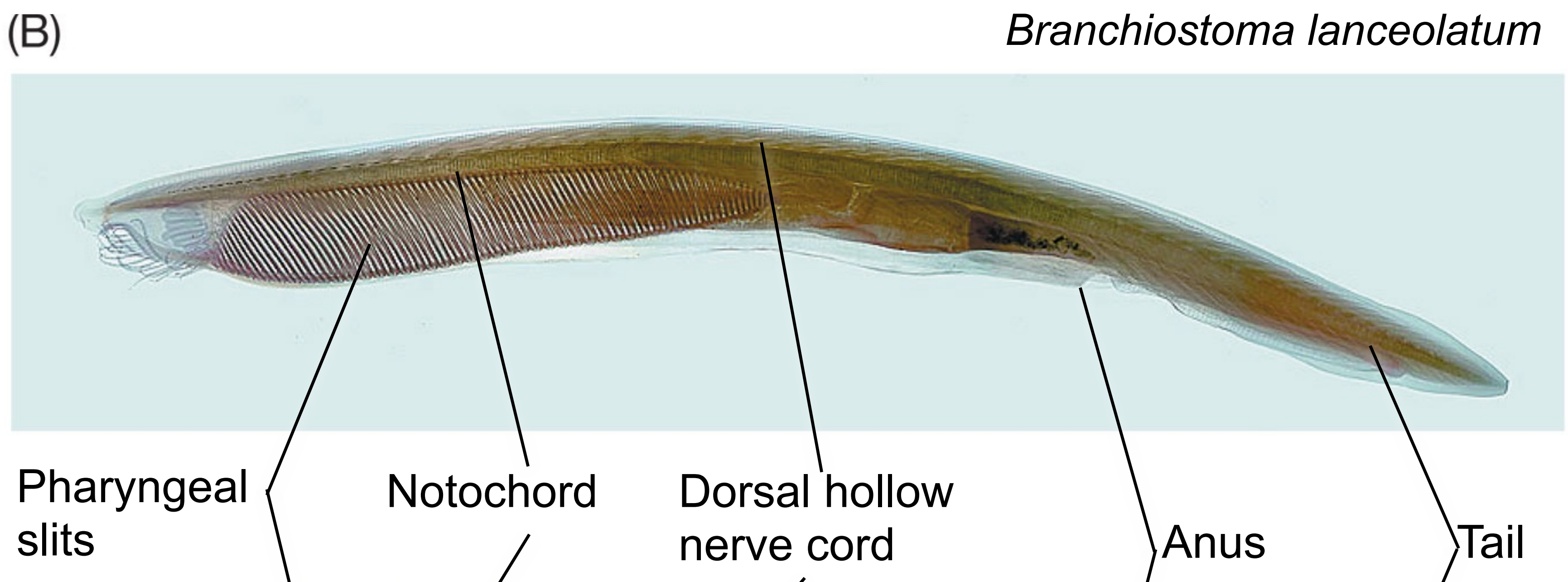
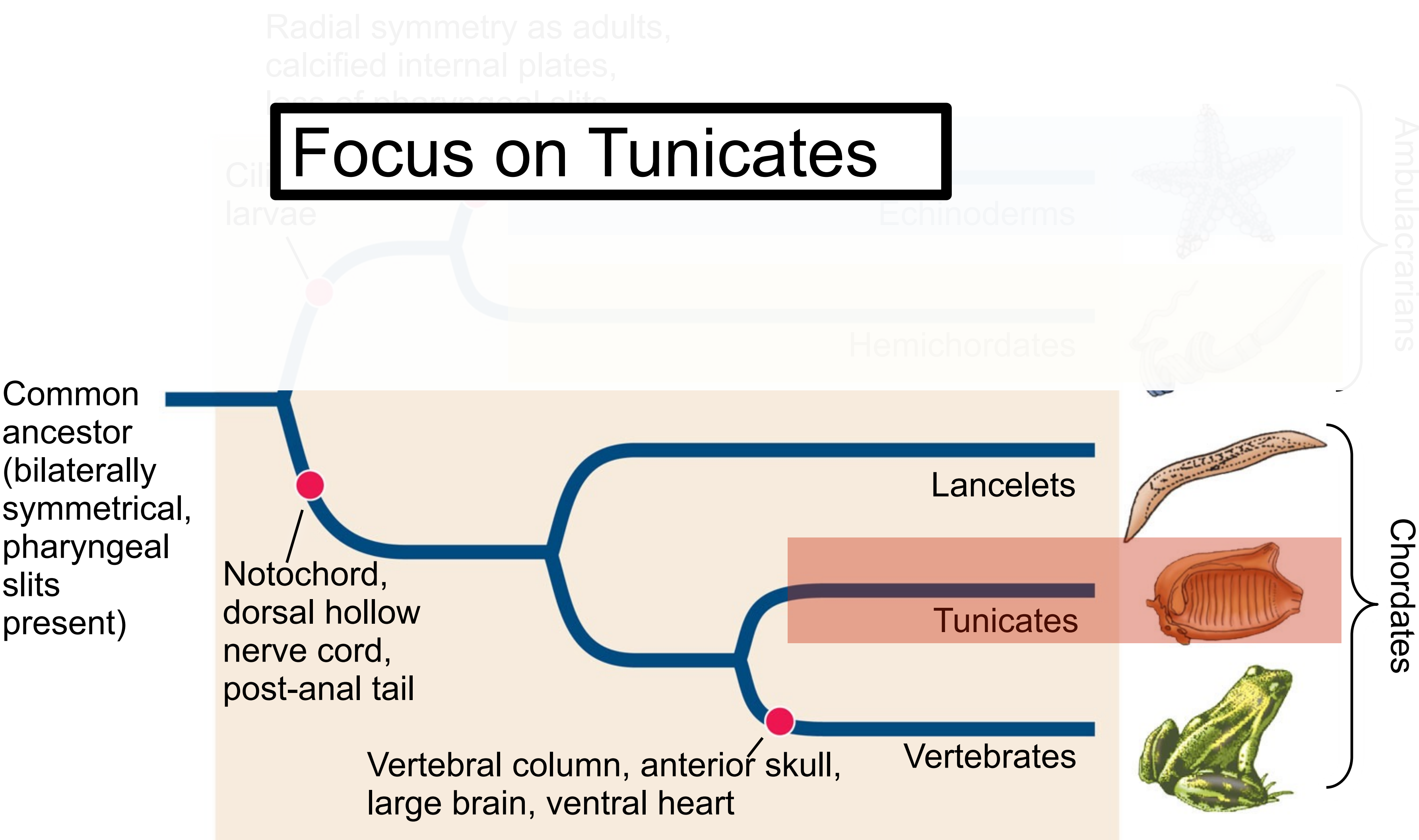
Lancelet Features

- Lancelets (aka amphioxus) are very small, less than 5 cm.
- Notochord is retained throughout life.
- Burrow in sand with head protruding; also swim.
- Pharynx is enlarged to form a pharyngeal basket for filtering prey from the water.
- Fertilization takes place in the water.
- Segmented body muscles



Tunicates



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Adult Tunicates

- Tunicates (sea squirts or ascidians, thaliaceans, and larvaceans):
- Sea squirts form colonies by budding from a single founder. Colonies may be meters across.
- Adult body is baglike and enclosed in a "tunic" of proteins and complex polysaccharides secreted by the epidermis.

(A) *Clavelina dellavallei* 1 cm

(B) *Pegea* sp. 1 cm

Adult Tunicates

- Solitary tunicates seem to lack all of the synapomorphies of chordates?
- No dorsal hollow nerve cord, no notochord, no postanal tail

(A) *Clavelina dellavallei* 1 cm

(B) *Pegea* sp. 1 cm

Adult Tunicates

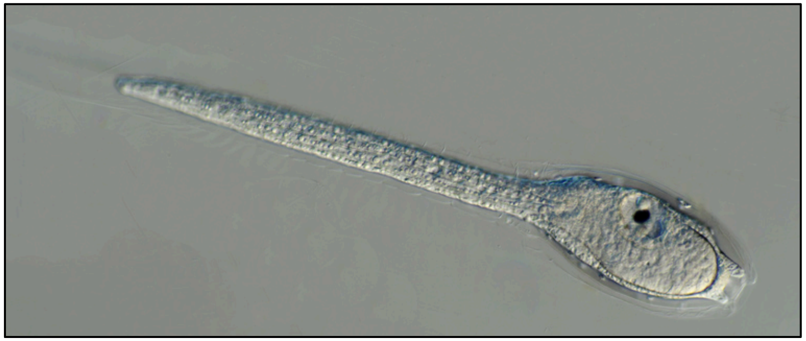
- Solitary tunicates seem to lack all of the synapomorphies of chordates?
- No dorsal hollow nerve cord, no notochord, no postanal tail

HOW ARE THESE CHORDATES?

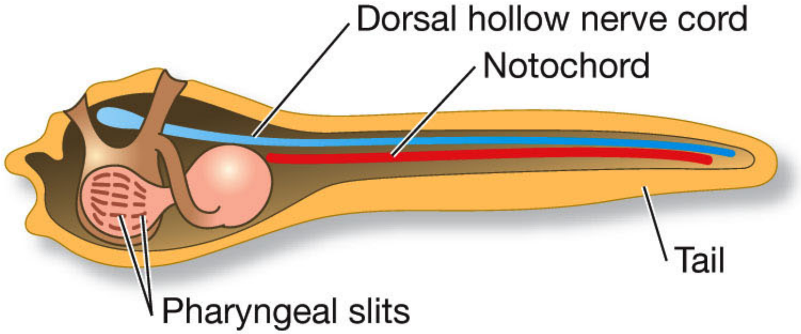
(A) *Clavelina dellavallei* 1 cm (B) *Pegea* sp. 1 cm

Juvenile Tunicates

- Sea squirt larvae have pharyngeal slits, a hollow nerve cord, and notochord in the tail region.
- The swimming, tadpolelike larvae suggest a relationship between tunicates and vertebrates.
- Larvacean tunicates do not undergo the metamorphosis and retain all of the chordate features.



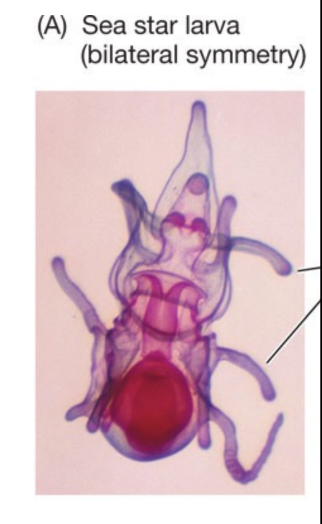
Ascidian tunicate larva



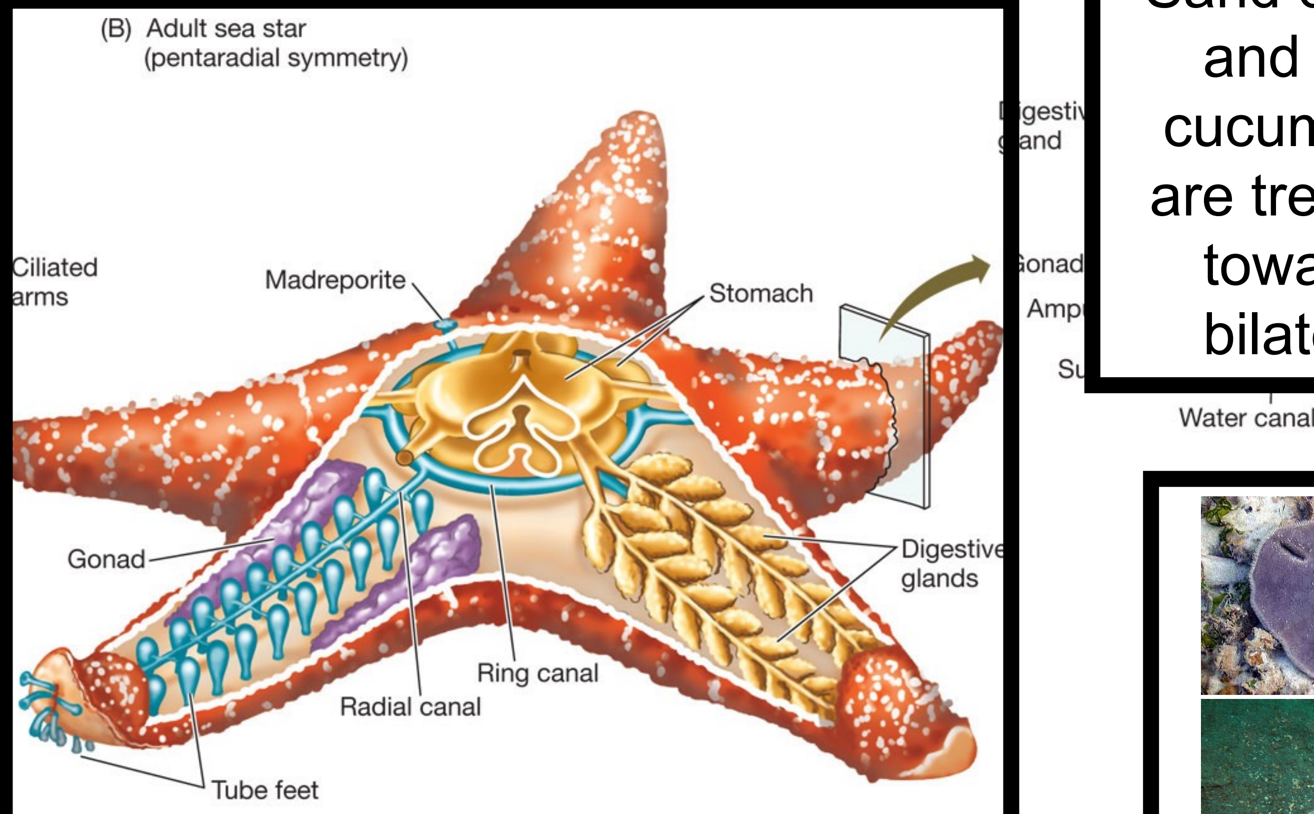
Larvacean tunicates

Symmetry

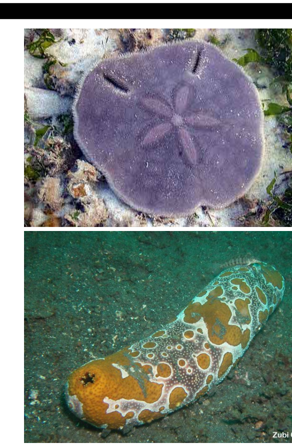
Larvae are bilateral



Adults are pentaradial with exceptions



Sand dollars and sea cucumbers are trending towards bilateral



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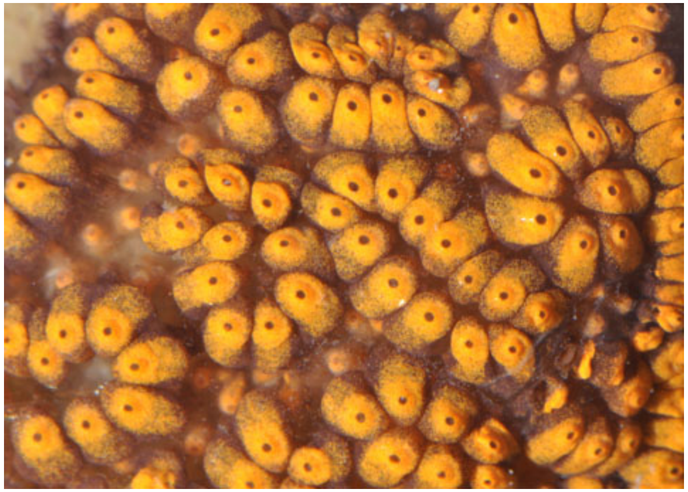
Tunicate Diversity

- ~2,000 described species, all marine filter-feeders
- Body surrounded by a **tunic**; a thick cellulose covering
- Mostly sessile, one lineage **free-swimming**
- Feeding through **incurrent** and **excurrent** siphons

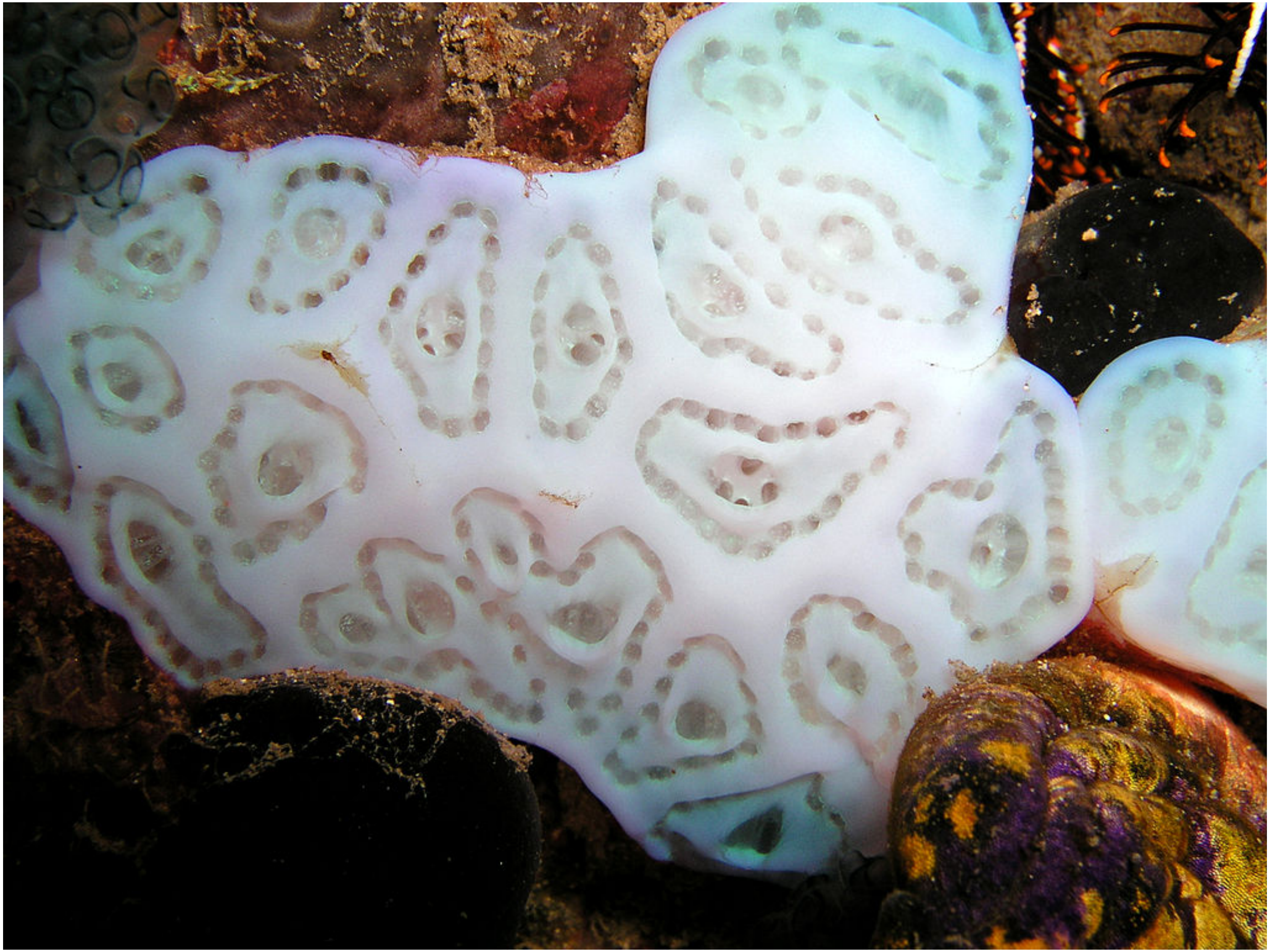
Solitary



Colonial

Free-swimming

Tunicate colony *Lissoclinum patellum*



1982

Antineoplastic Cyclic Peptides from the Marine Tunicate *Lissoclinum patella*

Chris M. Ireland,*† Augustine R. Durso, Jr.,† Robert A. Newman,*‡ and Miles P. Hacker‡

Section of Medicinal Chemistry and Pharmacognosy, School of Pharmacy, University of Connecticut, Storrs, Connecticut 06268, and Vermont Regional Cancer Center and Department of Pharmacology, College of Medicine, University of Vermont, Burlington, Vermont 05405

Received November 11, 1981

The tunicate *Lissoclinum patella* produces a family of lipophilic cyclic peptides all of which contain an unusual fused oxazoline–thiazole unit. The structures of three of these peptides, patellamides A–C have been determined by chemical and spectral methods. The patellamides are cytotoxic, exhibiting IC_{50} values of 2–4 μg/mL against L1210 murine leukemia cells. Additionally, patellamide A was active against the human ALL cell line CEM with an ID_{50} of 0.028 μg/mL. Ulithiacyclamide, a peptide previously reported from *L. patella* was also tested for cytotoxicity and exhibited 50% inhibition at doses of 0.35 and 0.01 μg/mL for the L1210 and CEM tests, respectively.

As part of a program to isolate antineoplastic natural products from marine invertebrates, we have undertaken a systematic study of didemnid tunicates from Palau of the Western Caroline Islands. The didemnids seemed

http://pubs.acs.org/doi/abs/10.1021/jo00349a002

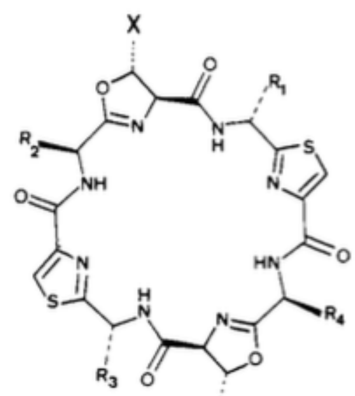
J. Med. Chem. 1989, 32, 1349–1354

New Cyclic Peptides with Cytotoxic Activity from the Ascidian *Lissoclinum patella*

Bernard M. Degnan,[†] Clifford J. Hawkins,[*,‡] Martin F. Lavin,[†] Elizabeth J. McCaffrey,[†] David L. Parry,[‡] Anna L. van den Brenk,[‡] and Diane J. Watters[‡]

Departments of Biochemistry and Chemistry, University of Queensland, St. Lucia, Queensland, Australia 4067.
Received December 21, 1988

The isolation and structures of a new patellamide (patellamide D) and two new lissoclinamides (lissoclinamides 4 and 5) from the aplousobranch ascidian *Lissoclinum patella* are described. Structures were determined largely by using two-dimensional NMR techniques and mass spectrometry. These peptides and other members of the patellamide and lissoclinamide families that have been reported previously are found within the obligate algal symbiont of the genus *Prochloron*. The cytotoxicities of the compounds toward fibroblast and tumor cell lines are reported. One of these compounds, lissoclinamide 4, is markedly more toxic than other members of the family. Structure–activity relationships are discussed.



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http://pubs.acs.org/doi/pdf/10.1021/jm00126a034

Lissoclinum & relatives have cyanobacteria symbionts

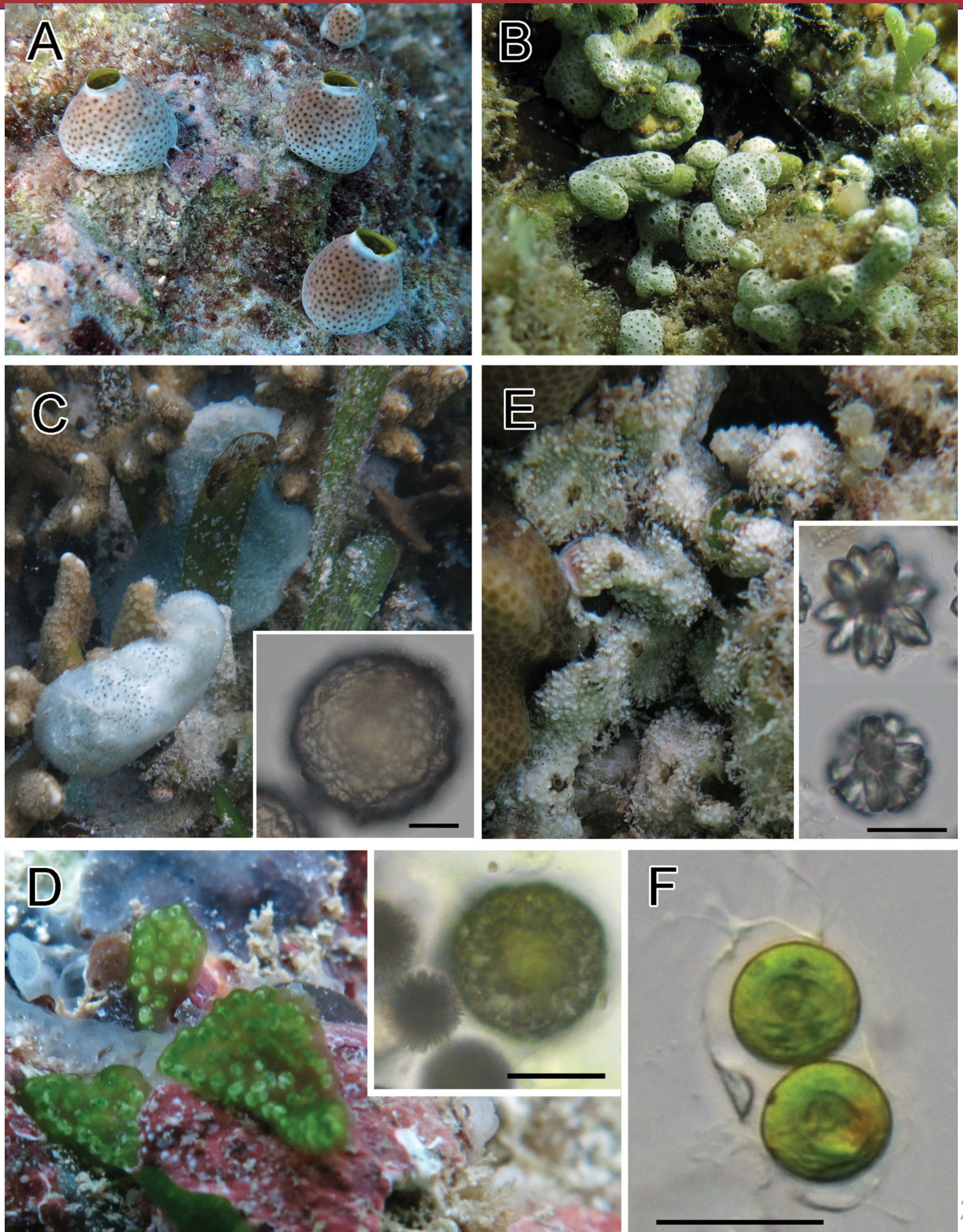


Figure 2.Photosymbiotic ascidians with tunic spicules. Colonies in situ and tunic spicules (inset) of Didemnum molle (A), Trididemnum miniatum (B), Lissoclinum patella (C), Lissoclinum punctatum (D), and Lissoclinum timorense (E). Tunic cells contain Prochloron cells in the tunic of Lissoclinum punctatum (F). Scale bars = 20 μm.

2016

Lesson …

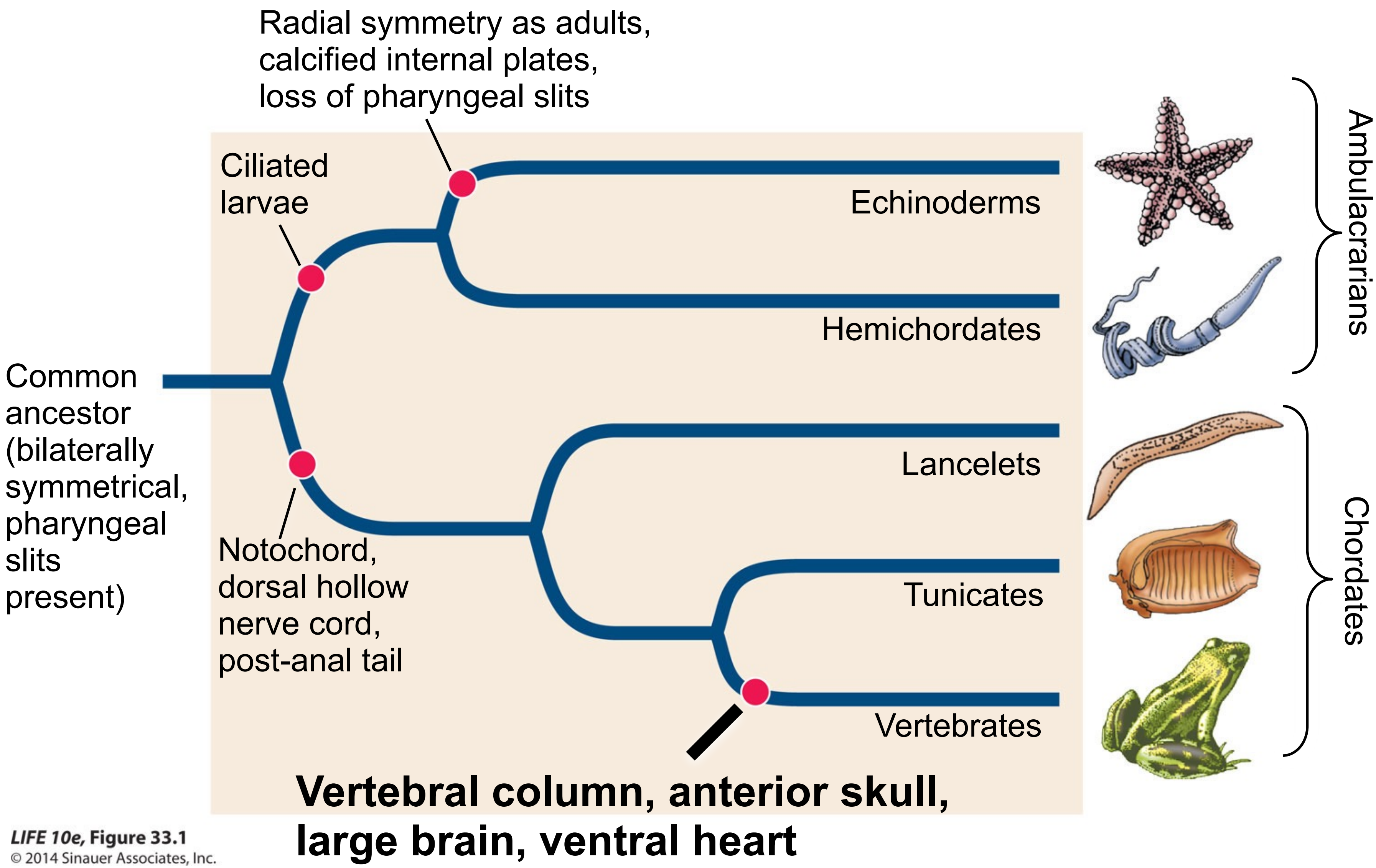
- If you find a novel biochemical activity in some animal …

Lesson …

- If you find a novel biochemical activity in some animal …
- Most likely it is NOT actually from the animal

Other Examples?

Vertebrate Origins



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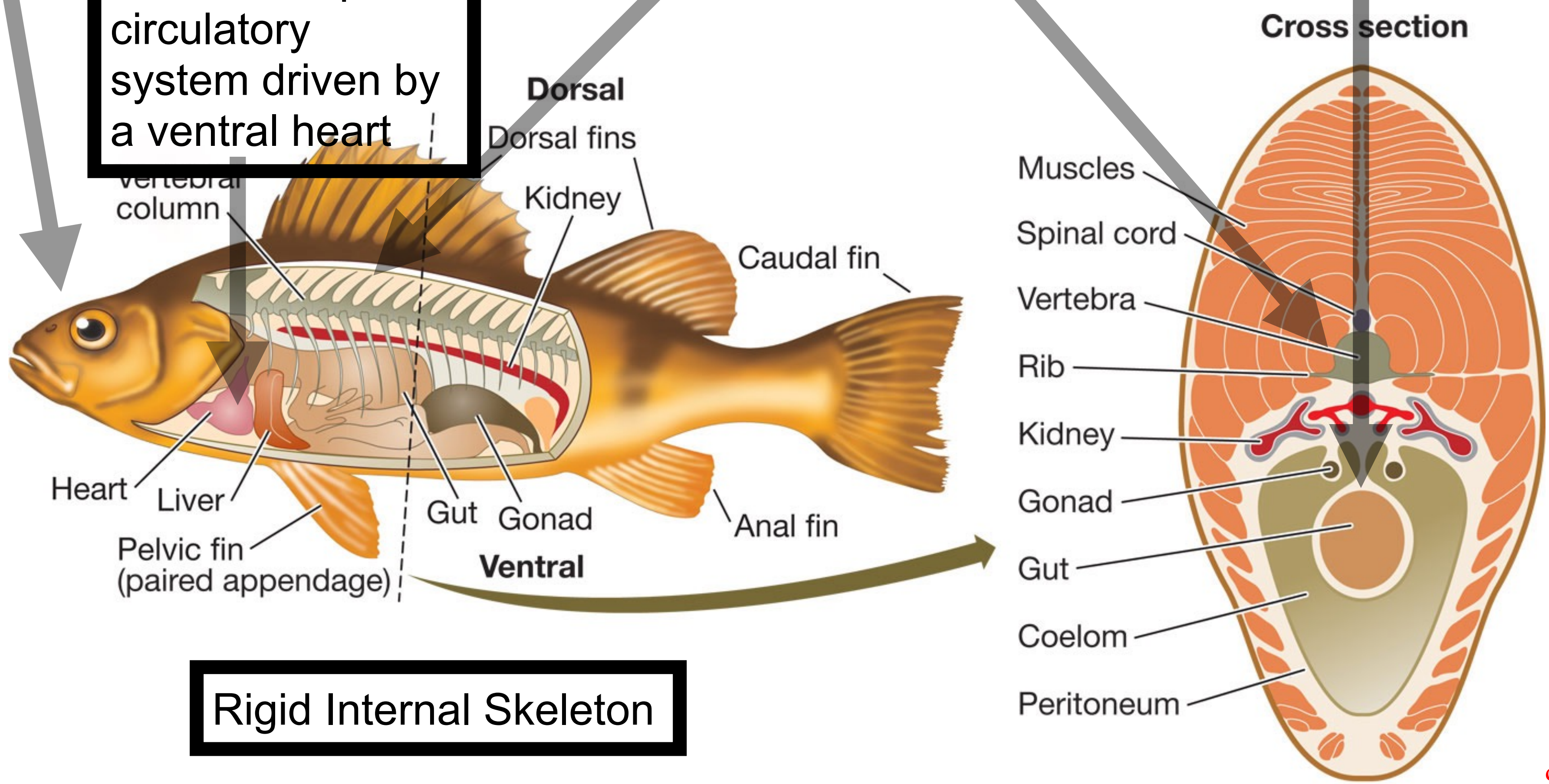
The Vertebrate Body Plan (not in all …)

Anterior skull enclosing a large brain

A jointed, dorsal vertebral column replaces the notochord during early development.

Internal Organs suspended in a coelom

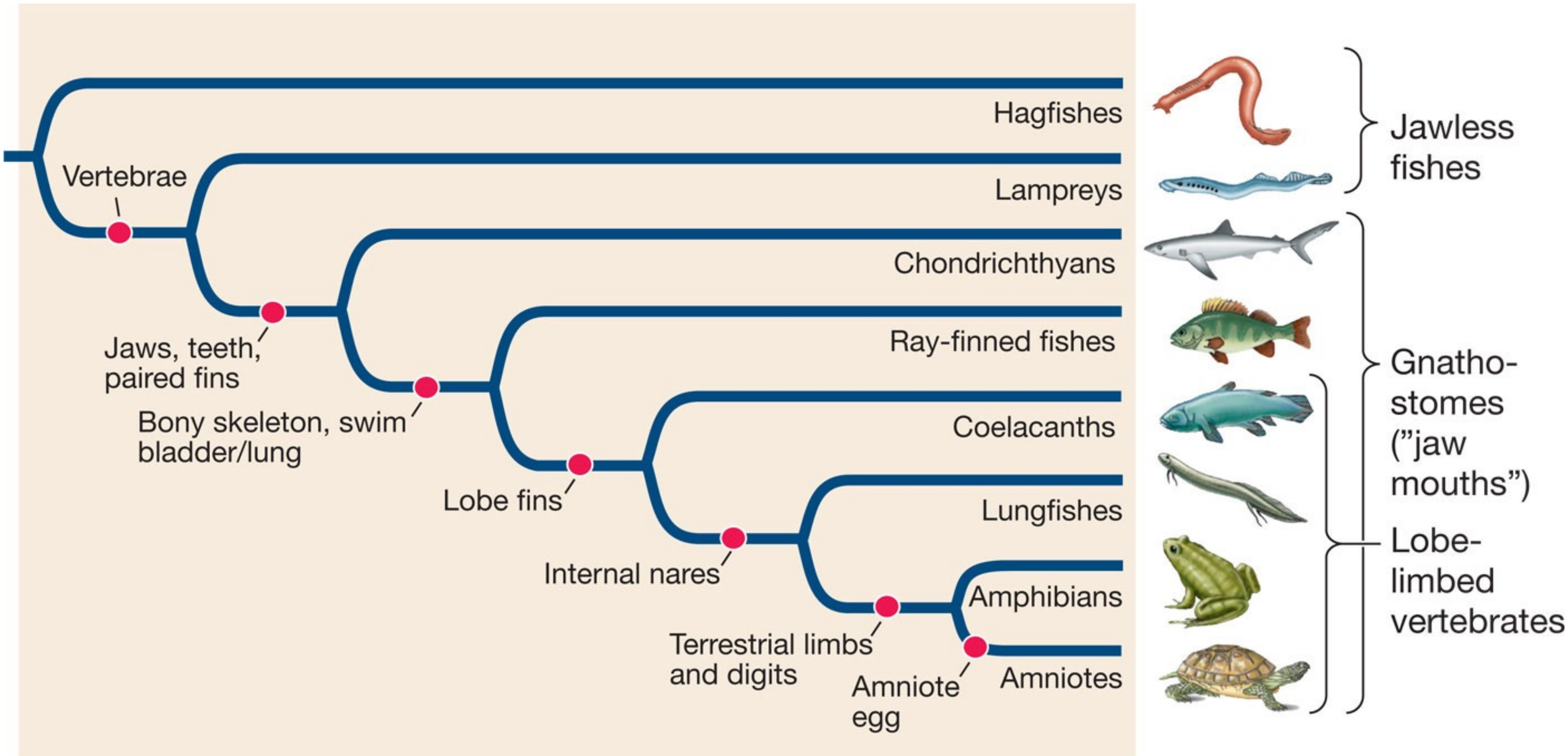
Well-developed circulatory system driven by a ventral heart



Rigid Internal Skeleton

- The structural features can support large, active animals.
- Internal skeleton supports an extensive muscular system that gets oxygen from the circulatory system and is controlled by the nervous system.
- These features allowed vertebrates to diversify widely.

Phylogeny of the Living Vertebrates



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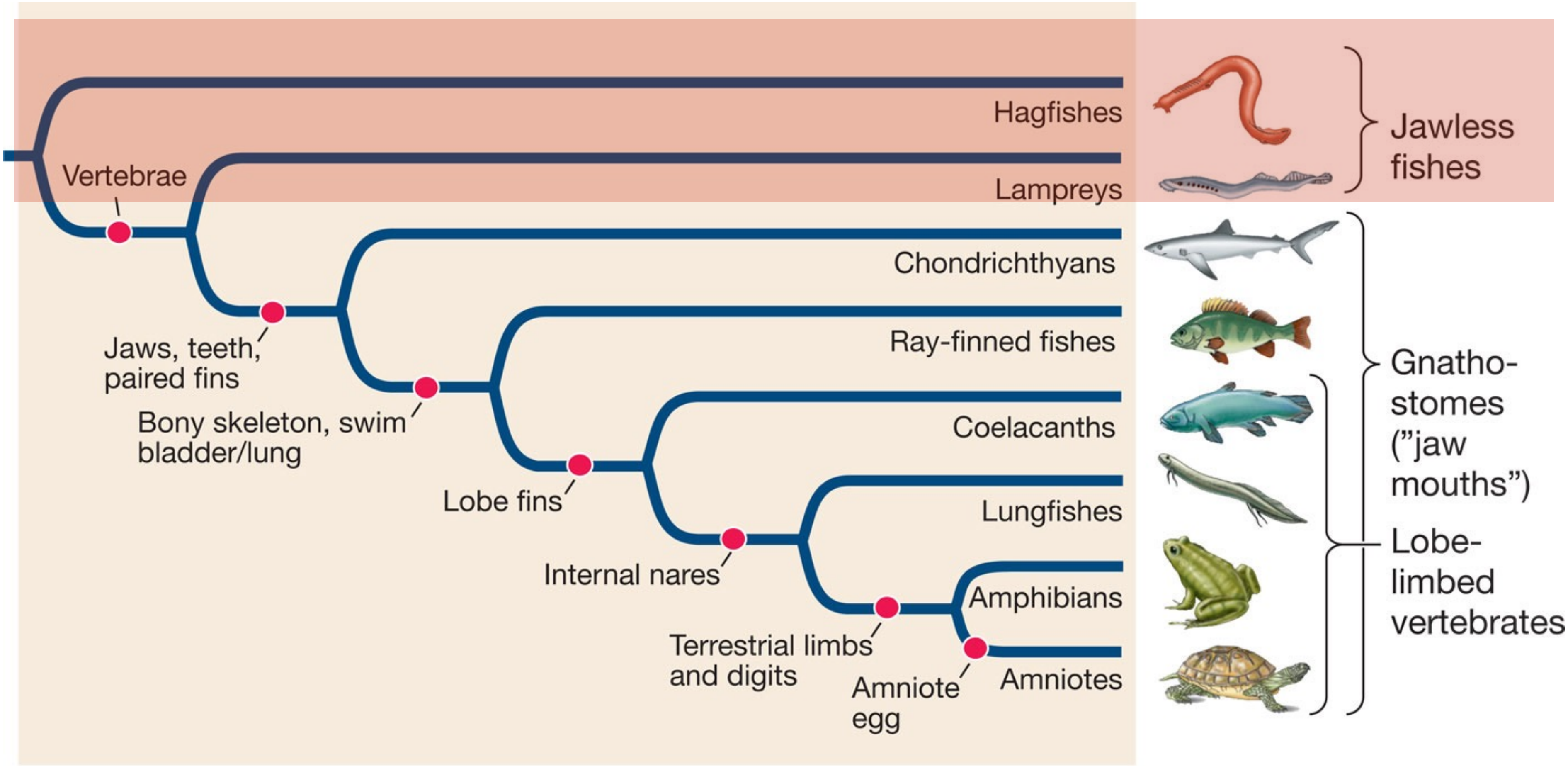
Vertebrates and Land

- All other deuterostomes are marine.
- Vertebrates probably evolved in the oceans or estuarine environments during the Cambrian period.
- They have radiated into marine, freshwater, terrestrial, and aerial environments.

Jawless Fishes (hagfish and lampreys)



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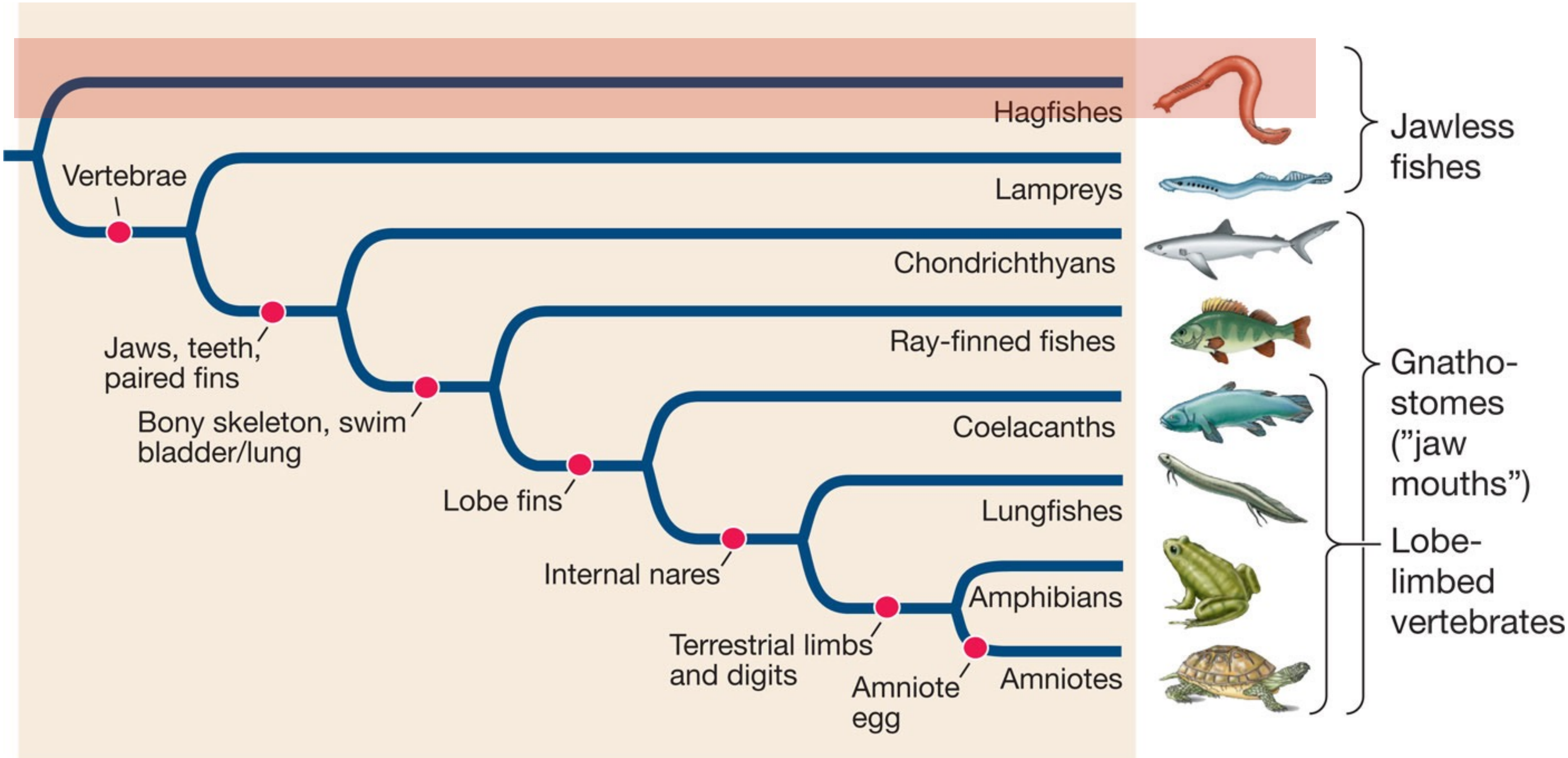
Sister group for all other vertebrates



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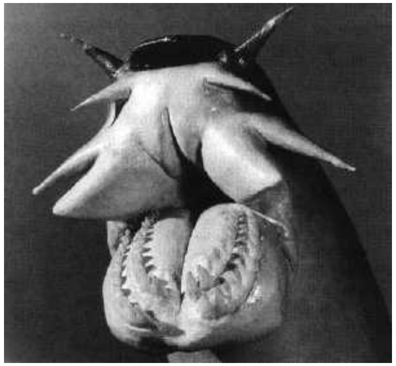
Hagfish not quite full vertebrates

- Weak circulatory system w/ 3 small hearts, a partial cranium, no stomach, no jaws
- NO BONE (skeleton is cartilage); no vertebrae.
- Blind and produce large amounts of slime as a defense
- They have a specialized structure to capture prey and tear up dead organisms.
- Development is direct; adults can change sex from year to year.

(A)

Eptatretus stoutii



- https://youtu.be/bqk0mnMgwUQ

You've Been Slimed

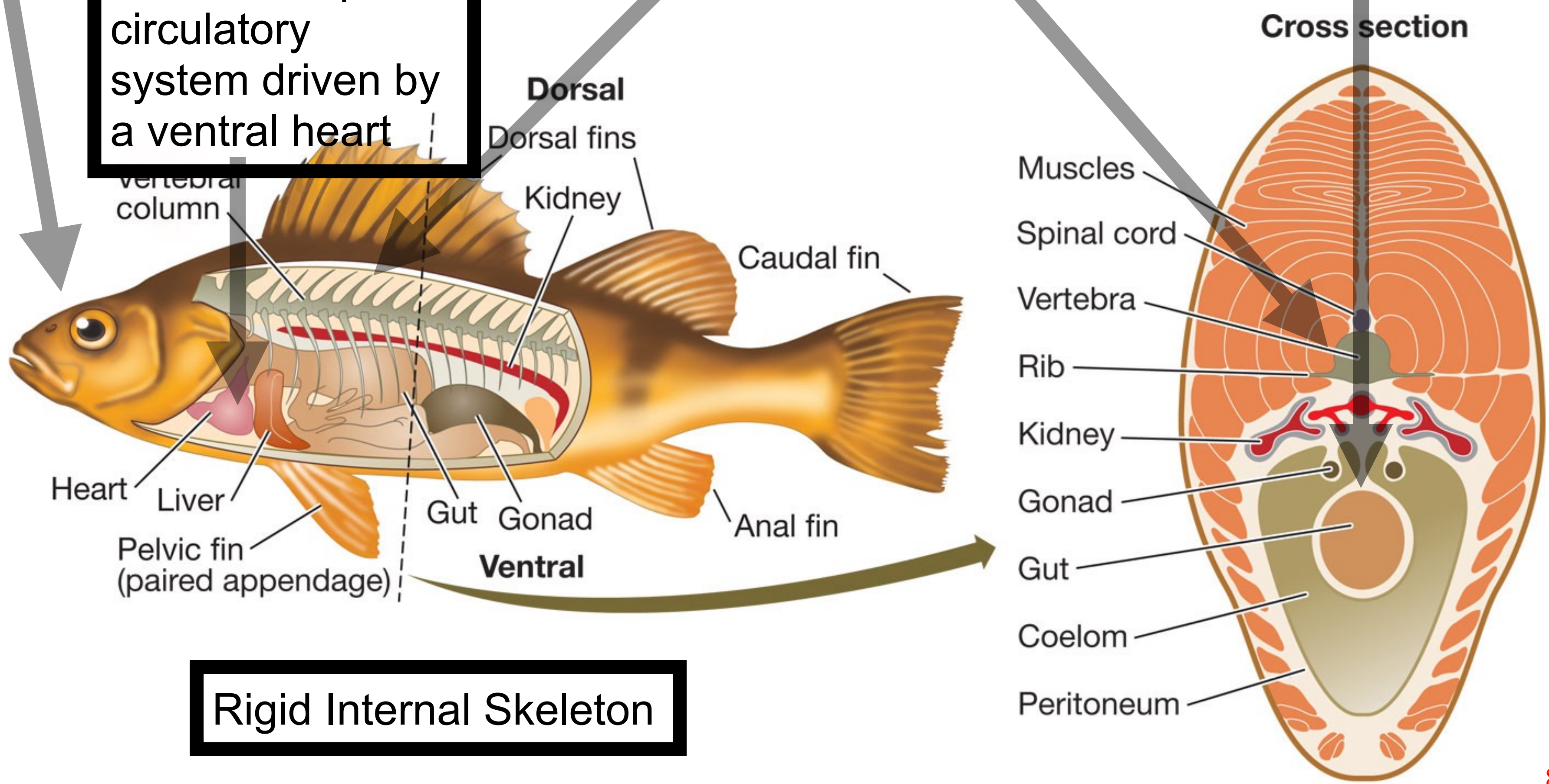
The Vertebrate Body Plan

Anterior skull enclosing a large brain

A jointed, dorsal vertebral column replaces the notochord during early development.

Internal Organs suspended in a coelom

Well-developed circulatory system driven by a ventral heart



Rigid Internal Skeleton

The Vertebrate Body Plan

Anterior skull enclosing a ~~large~~ brain

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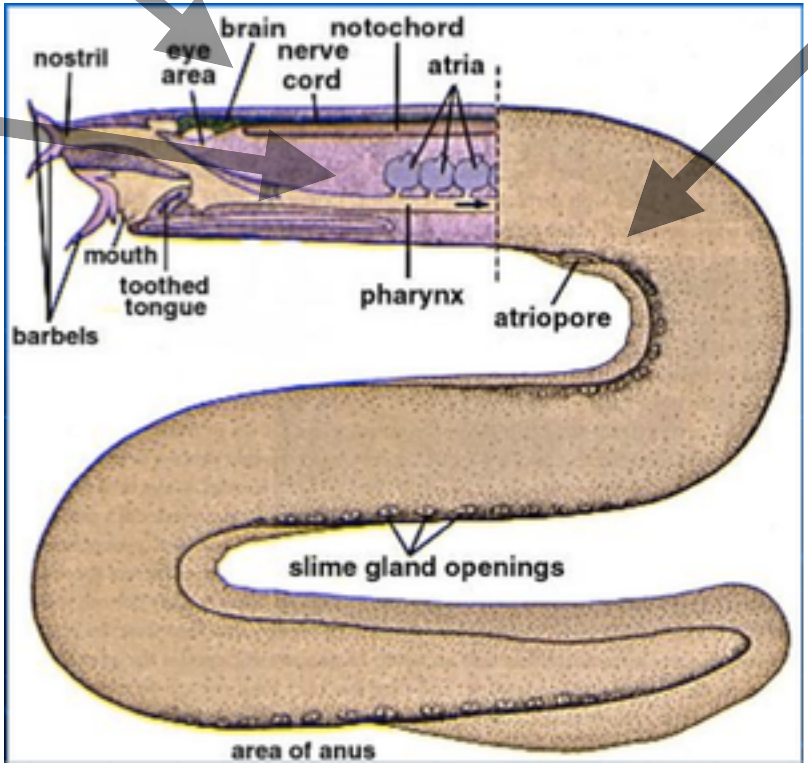
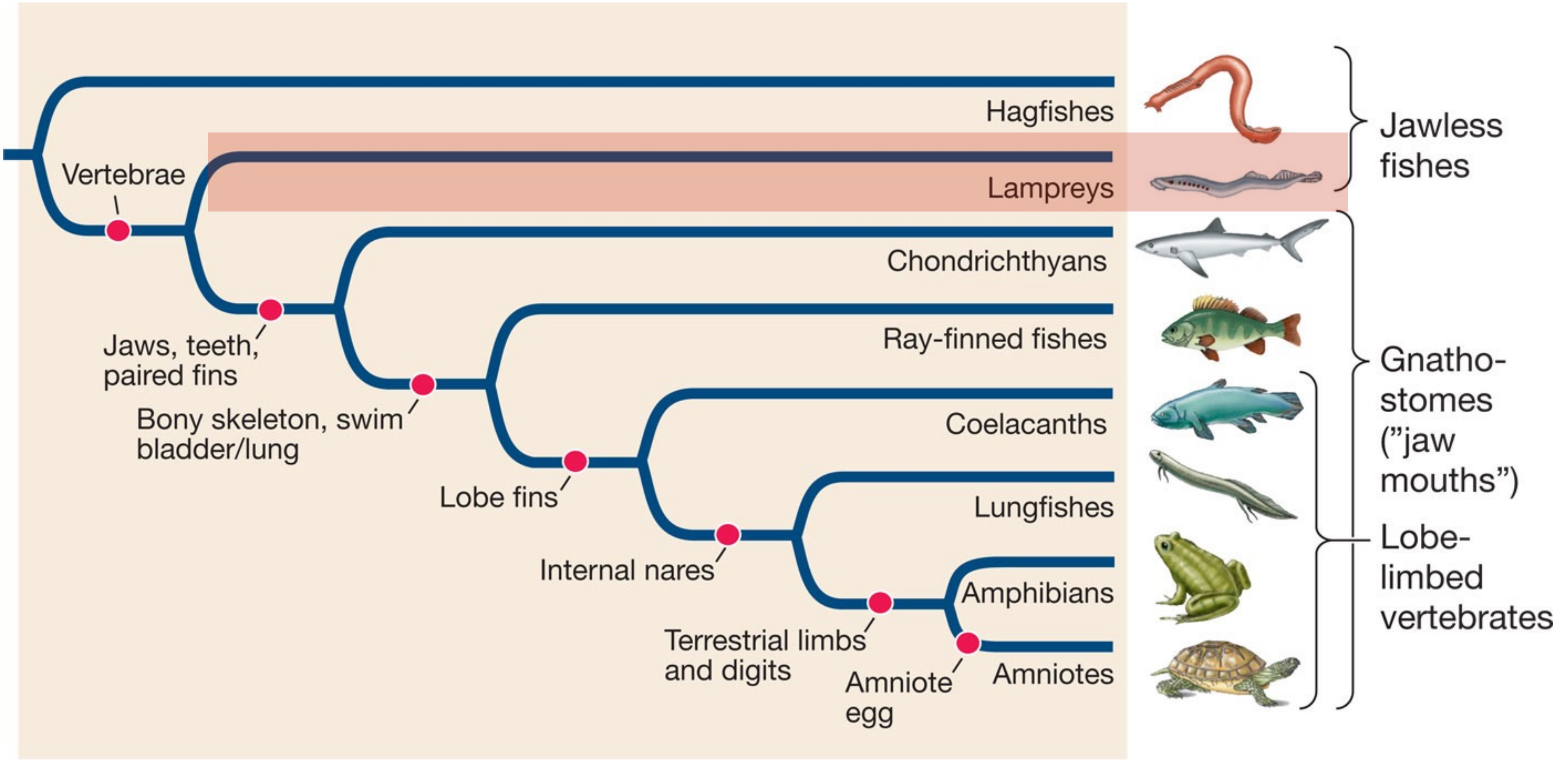


Rigid Internal Skeleton

Lampreys



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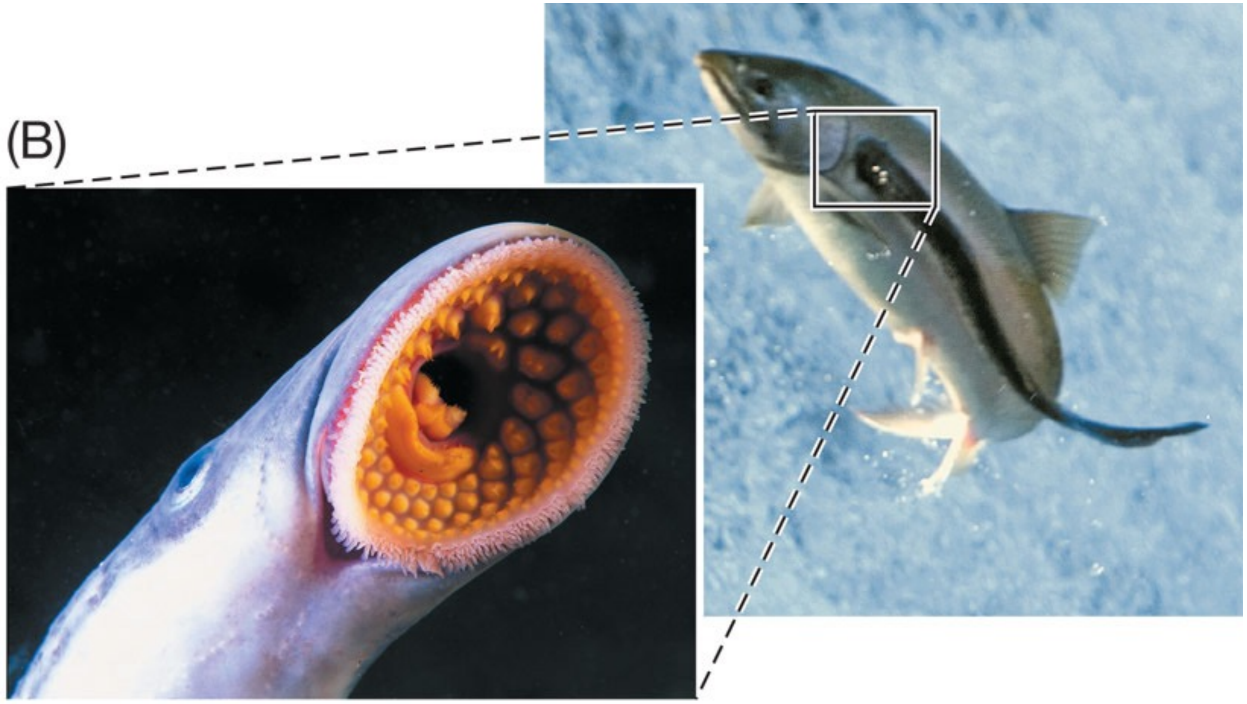
Lampreys

- Complete cranium and cartilaginous vertebrae.
- Complete metamorphosis from filter-feeding larvae (ammocoetes), which are similar to lancelets.
- No bone, no jaws, but cartilaginous **vertebrae** are present
- Sucker- like mouth with **rasping teeth**
- Many species are **ectoparasites** of fish



Petromyzon marinus

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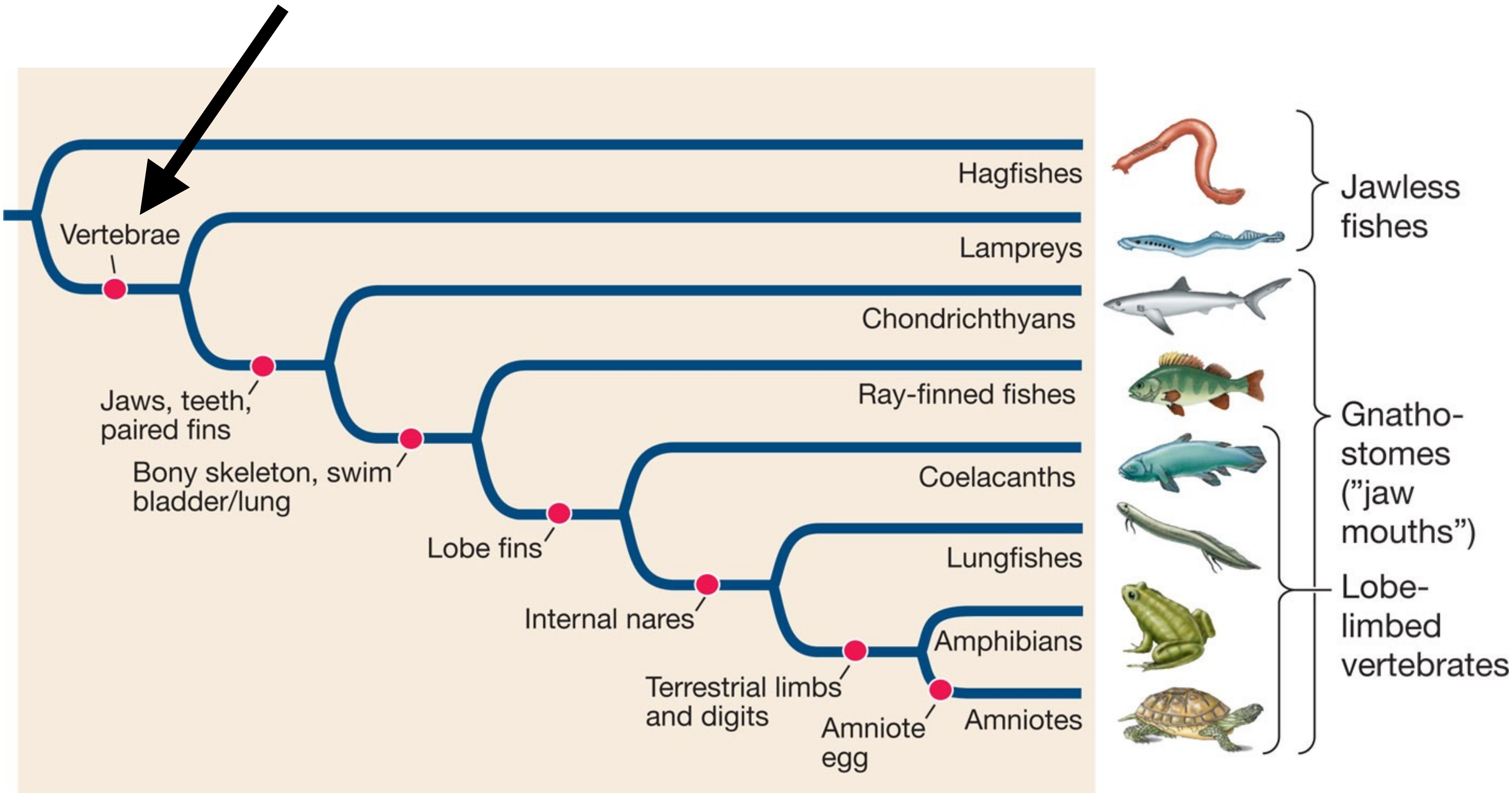
Vertebrae Evolution

Lampreys have cartilaginous vertebrae so infer that vertebrae evolved here.



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Gnathostomes - Jaw Mouths

- Jaws evolved from gill arches late in the Ordovician.

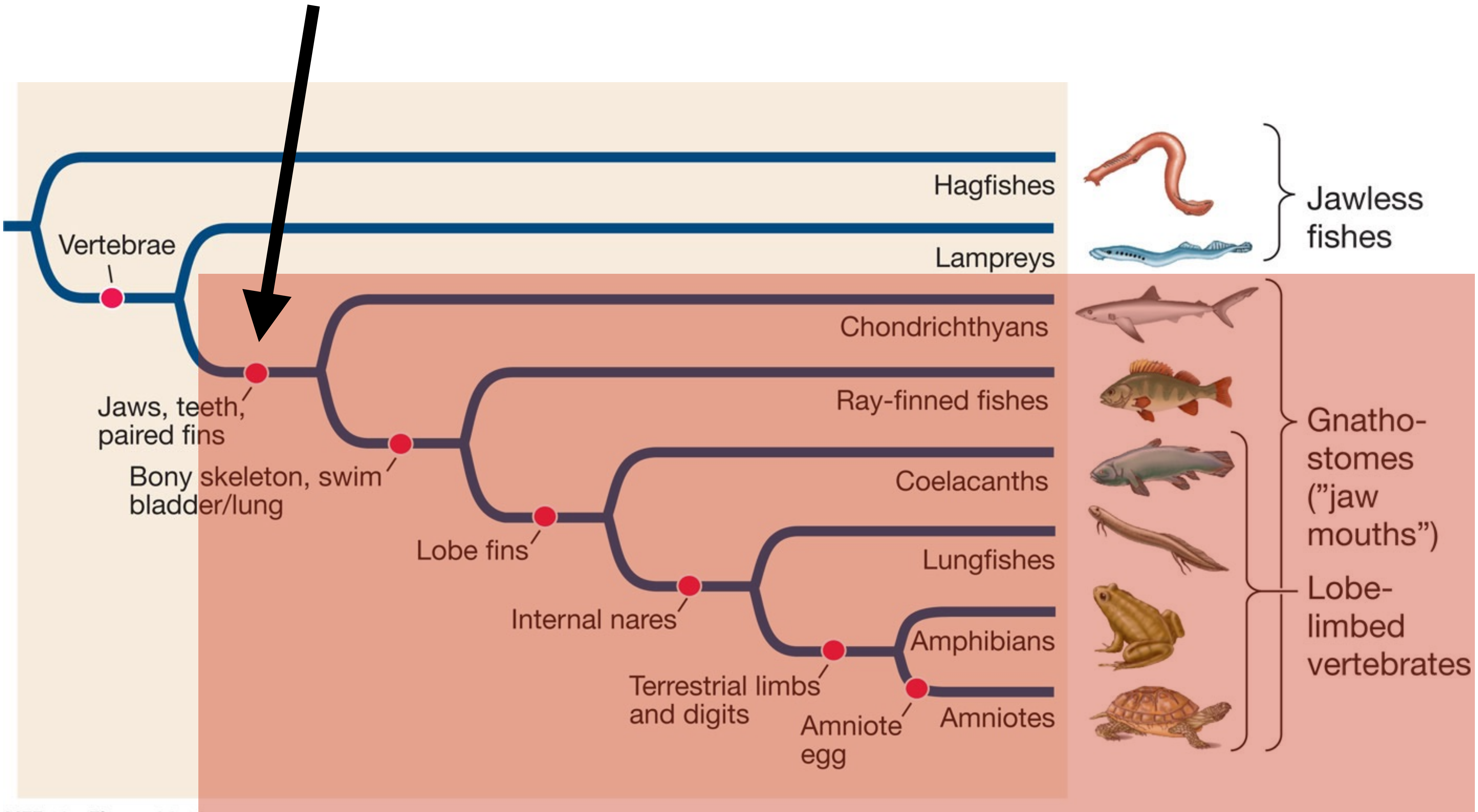

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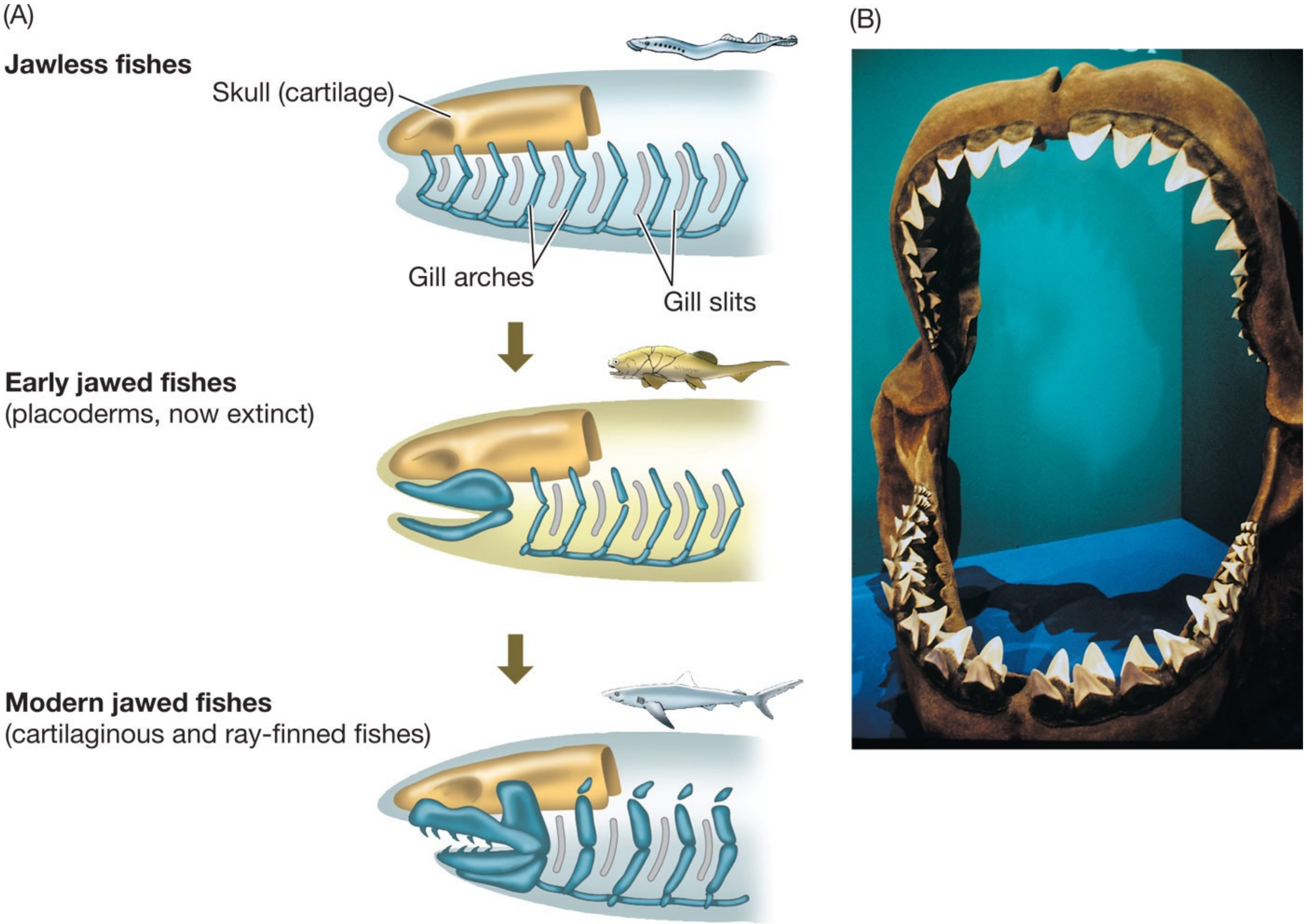
Figure 33.12 Jaws and Teeth Increased Feeding Efficiency



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33.3 What New Features Evolved in the Chordates?

- Jaws improved feeding efficiency and prey capture.
- Jawed fishes diversified rapidly and became dominant.
- Teeth made feeding even more efficient. Chewing aids chemical digestion and improves extraction of nutrients from food.

33.3 What New Features Evolved in the Chordates?

- Most jawed fishes have paired fins for stabilization and swimming.
- Median dorsal and anal fins stabilize the fish.
- Caudal fins help the fish move forward and make rapid turns.

Chondrichthyans (sharks, rays, skates, chimaeras):

- Skeletons of cartilage
- Flexible, leathery skin
- Sharks swim using lateral undulations of the body.
- Skates and rays swim by flapping enlarged pectoral fins.

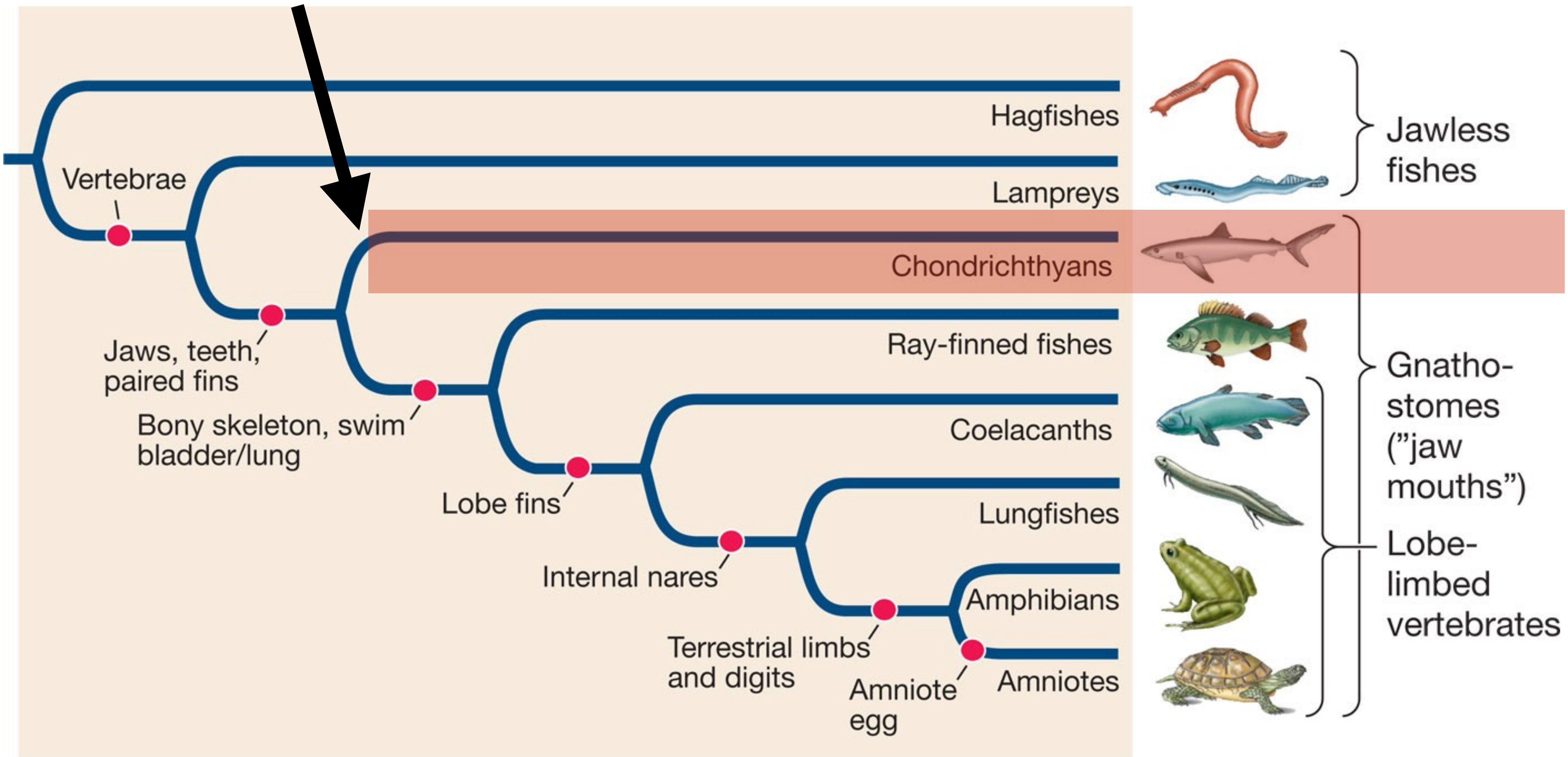

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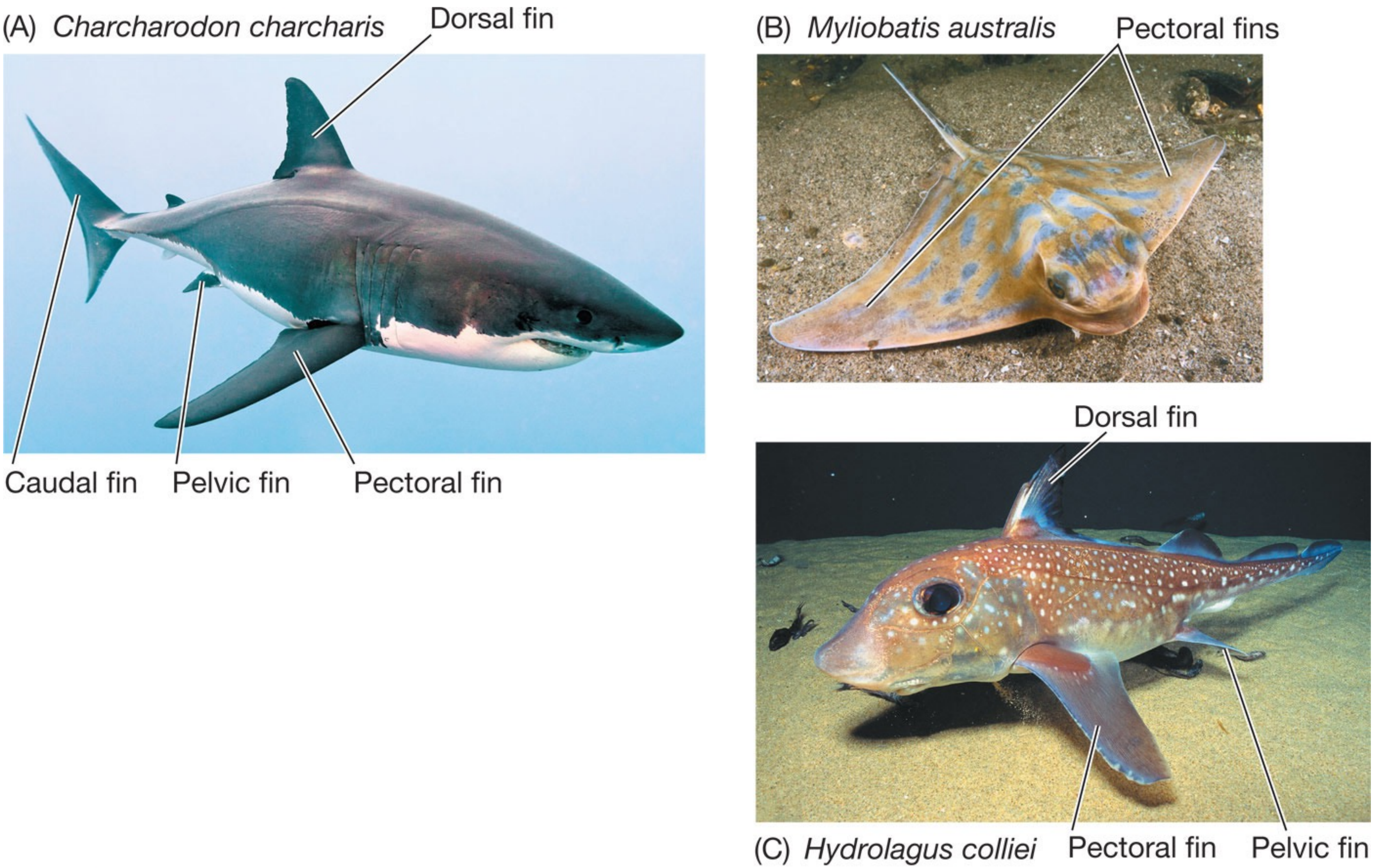
Figure 33.13 Chondrichthyans



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33.3 What New Features Evolved in the Chordates?

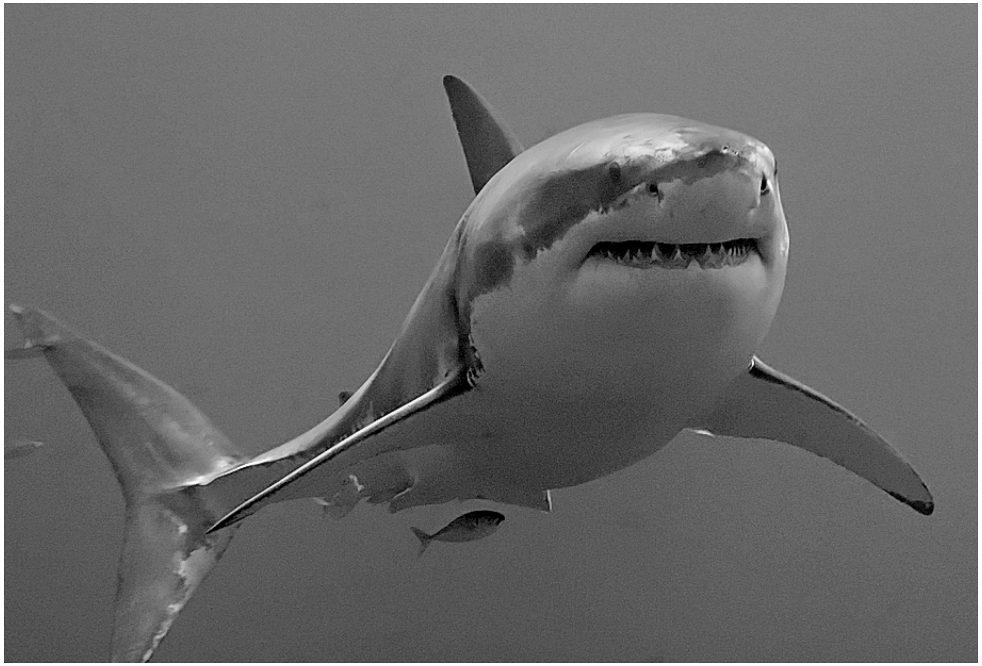
- Most sharks are predators; some strain plankton from the water.
- Skates and rays live on the ocean floor and feed on animals in the sediments.
- Chimeras live in deep sea, cold waters. Some have modified dorsal fins that contain toxins.

Megalodon

- One of the largest vertebrate predators, 50-60ft!
- Largest known tooth ~8 inches
- Extinct about 1.5 million years ago
- Likely fed on whales and other large prey

Great White Shark

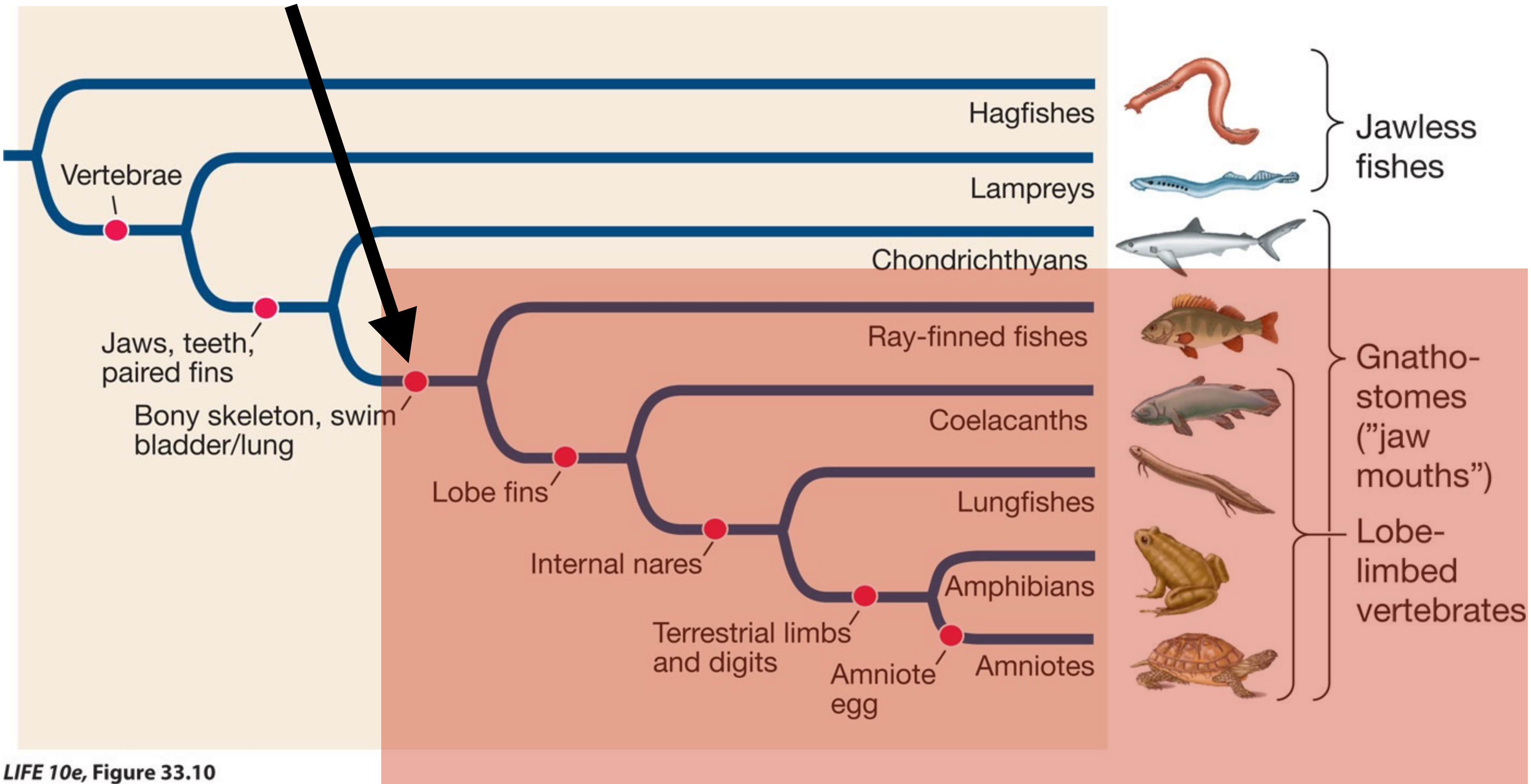
- Up to 20ft and 5,000 lbs; **apex predator**
- Feeds on marine mammals, fish, and seabirds
- Likely a close relative of *Megalodon*
- Global distribution; **migratory** behavior (12,000 miles/ 9 months)



Farallon Islands

Bones

- One lineage of gnathostomes gave rise to the bony vertebrates with internal skeletons of calcified, rigid bone.
- Some early bony fishes had gas-filled sacs that supplemented the gills in gas exchange.



LIFE 10e, **Figure 33.10**

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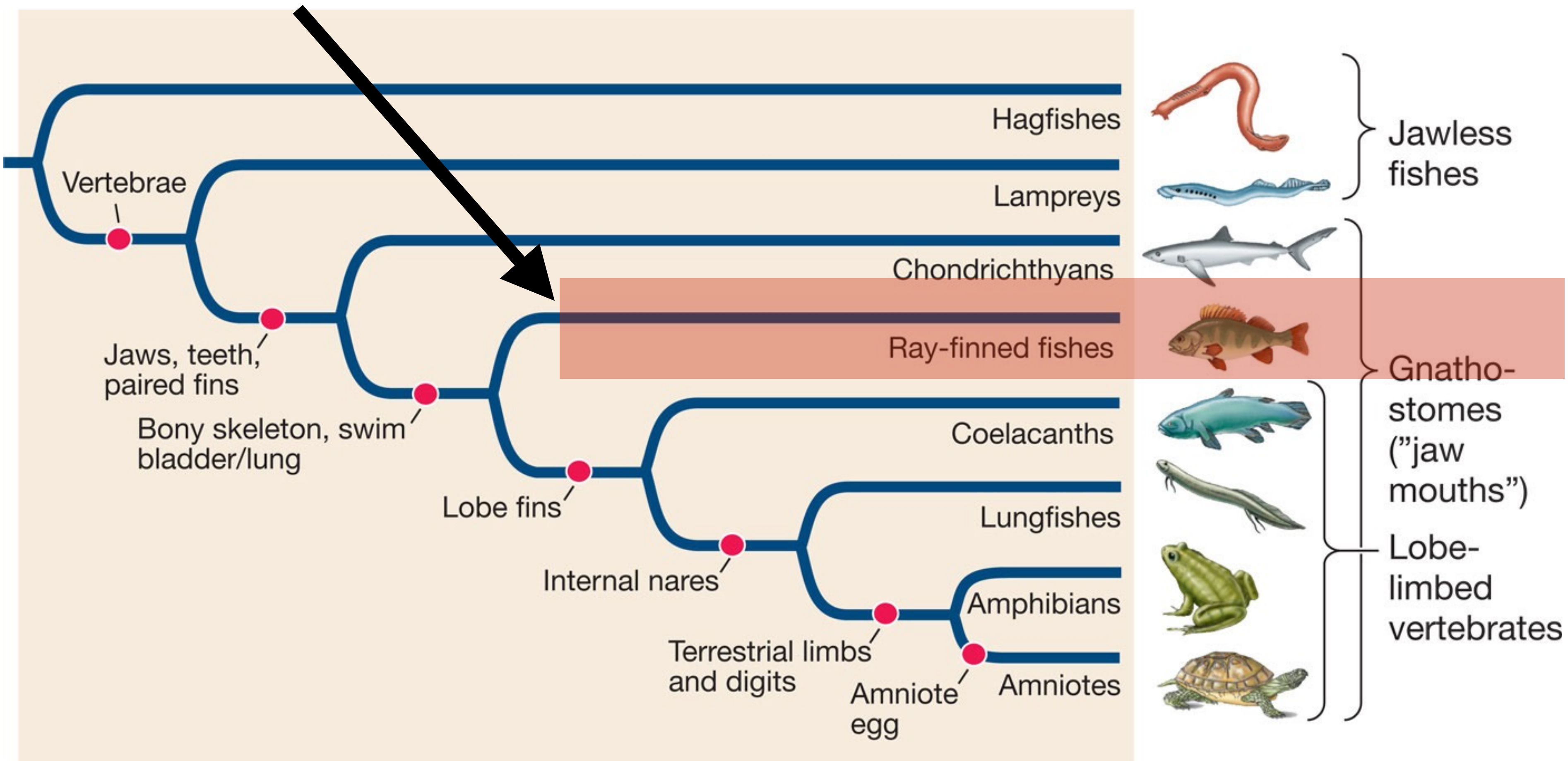
Ray Finned Fishes

- In ray-finned fishes, the sacs developed into swim bladders, organs of buoyancy.
- Allows fish to maintain position at specific depths.



LIFE 10e, **Figure 33.10**

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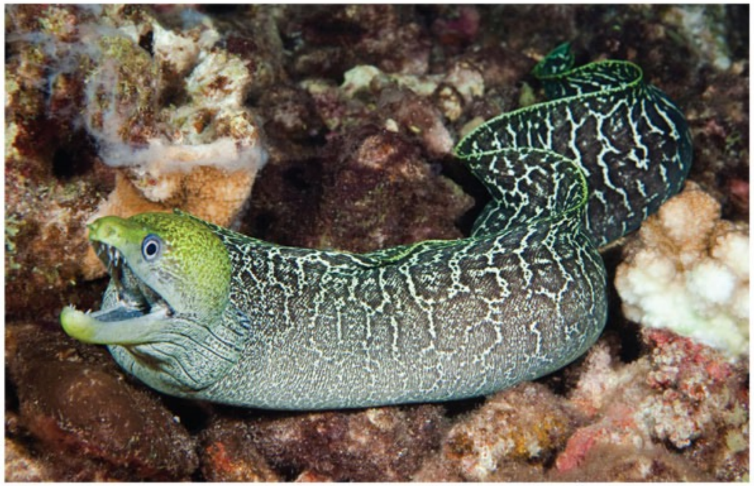
33.3 What New Features Evolved in the Chordates?

- Ray-finned fishes: (32,000 species)
- Most are covered by scales.
- Gills open to a chamber covered by the operculum. Movement of the operculum enhances water flow over the gills.
- Radiated extensively during the Tertiary period into a diversity of life styles.

Figure 33.14 Diversity among the Ray-Finned Fishes

(A) *Gymnothorax meleagris*



(B) *Cirrhilabrus jordani*

(C) *Cromileptes altivelis*

(D) *Gigantactis vanhoeffeni* luring prey

***LIFE 10e*, Figure 33.14**

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Ray Finned Fishes

- Ray-finned fishes exploit nearly all types of food in aquatic habitats:
  - Filtering plankton
  - Rasping algae from rocks
  - Eating corals
  - Digging animals from sediments
  - Predation
  - Eating terrestrial fruits and organisms that fall in the water

Ray Finned Fishes

- Many species form aggregations called schools.
- Complex behaviors maintain schools, build nests, choose mates, and care for young.

Ray Finned Fishes

- Most marine fish move into shallow water to lay eggs—coastal waters and estuaries are extremely important for many marine species.
- Some are anadromous (e.g., salmon).