“PROTOCHORDATES” & ORIGIN OF VERTEBRATES

Basic Chordate Characters: present at some stage in life cycle

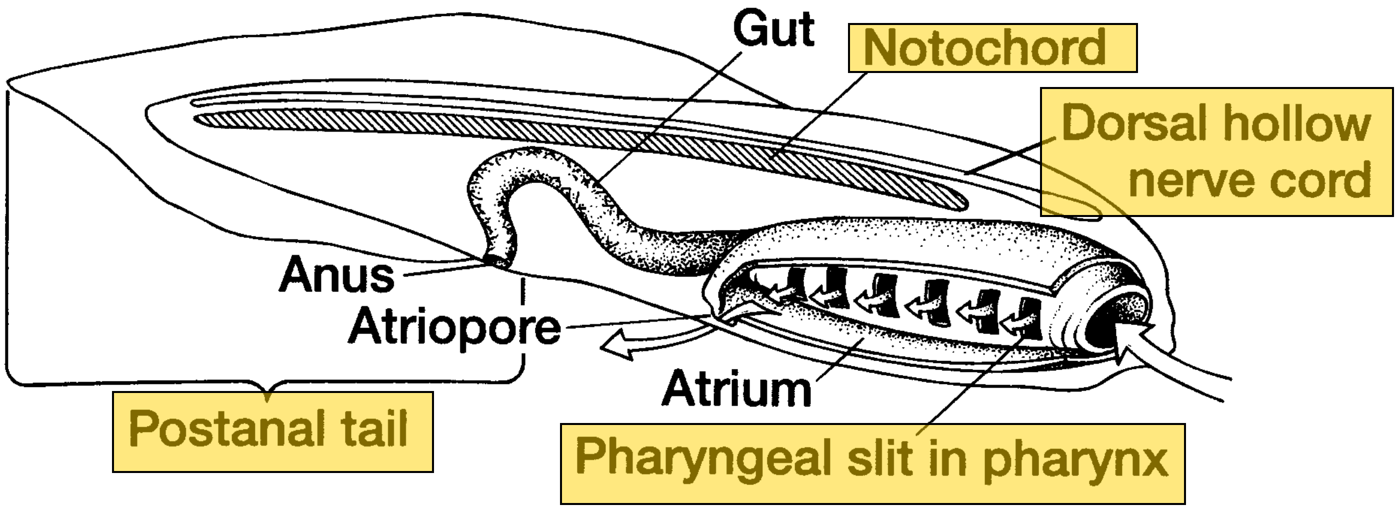


FIGURE 2.4 Generalized chordate characteristics. A single stream of water enters the chordate mouth, flows into the pharynx, and then exits through several pharyngeal slits. In many lower chordates, water exiting through the slits enters the atrium, a common enclosing chamber, before returning to the environment via the single atriopore.

TABLE 2.1 Fundamental Patterns in Coelomate Development

Protostomes	Deuterostomes
Blastopore (mouth)	Blastopore (anus)
Spiral cleavage	Radial cleavage
Schizocoelic coelom	Enterocoelic coelom
Ectodermal skeleton	Mesodermal skeleton

Vertebrates are Chordates
Chordates are Deuterostomes

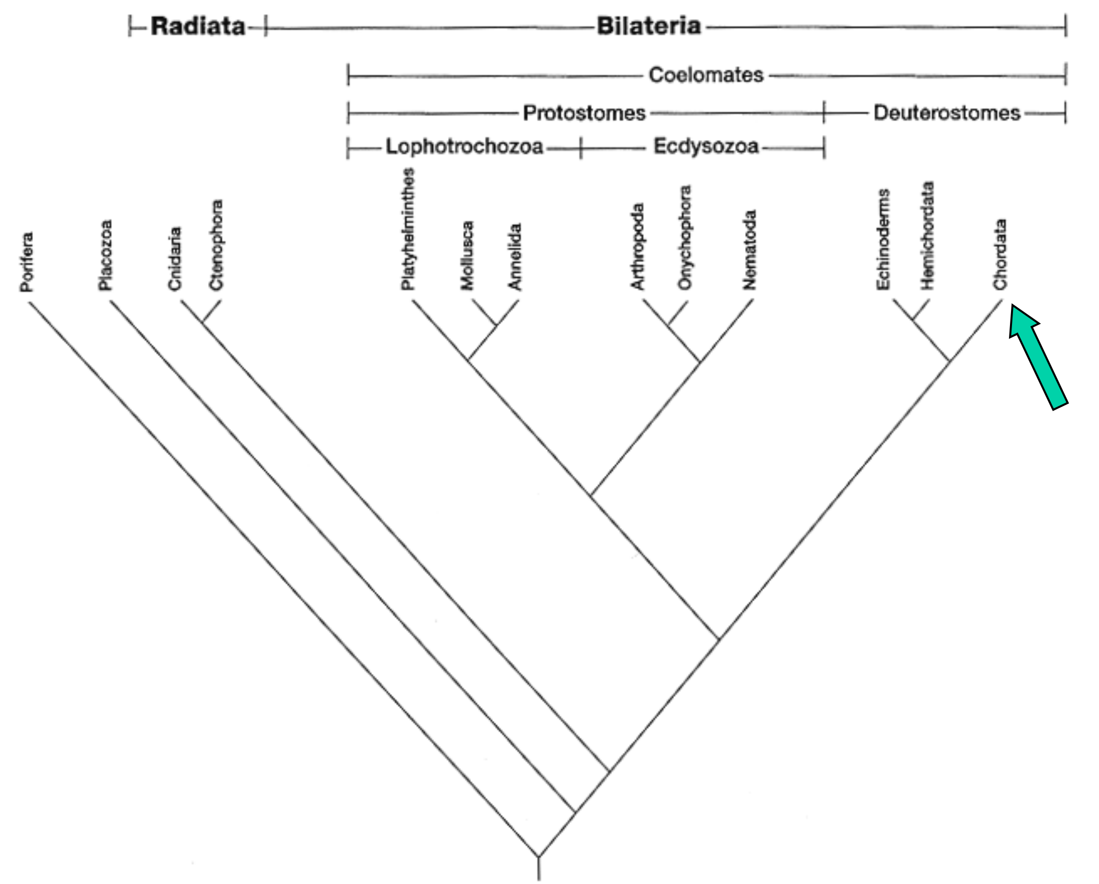
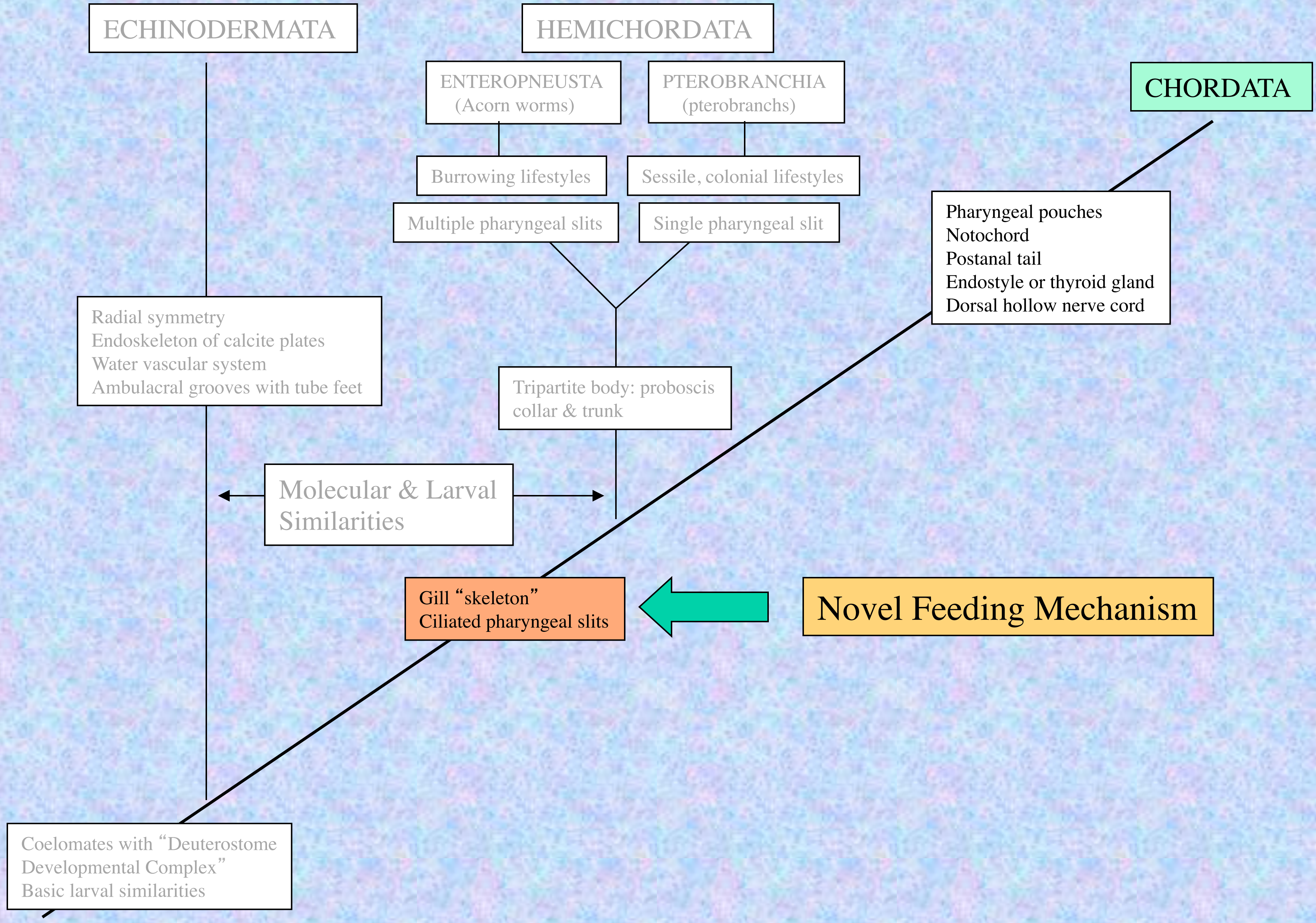


FIGURE 2.2 **Phylogenetic relationships within major animal groups.** Note that chordates are coelomate deuterostomes along with hemichordates and echinoderms. The protostomes are a separate lineage.

Relationships of the Deuterostome Phyla



HEMICHORDATES

Tripartite body

Perforated pharynx*

All suspension feeders

Pterobranchs (sessile & colonial)

Acorn worms (solitary burrowers)

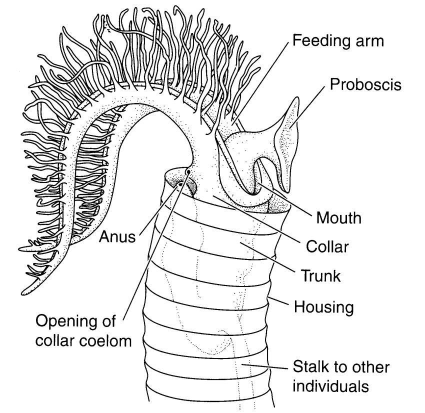
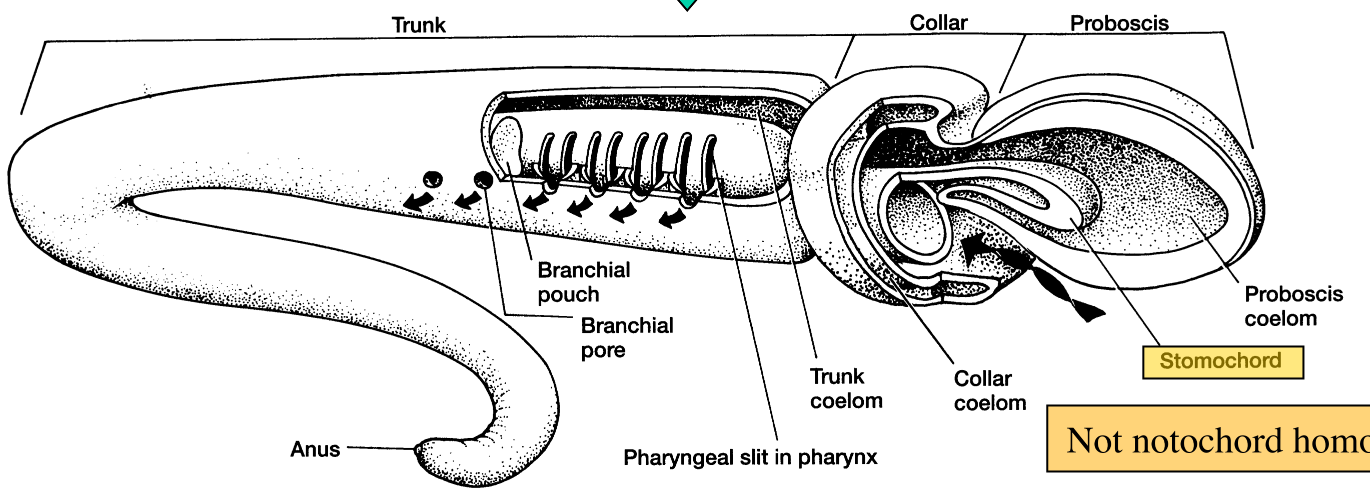


FIGURE 2-2
Anatomy of a representative pterobranch. The animal illustrated belongs to the genus *Rhabdopleura,* which forms colonies; only one individual of the colony is shown here. All hemichordates have a tripartite body consisting of a proboscis, collar, and trunk.

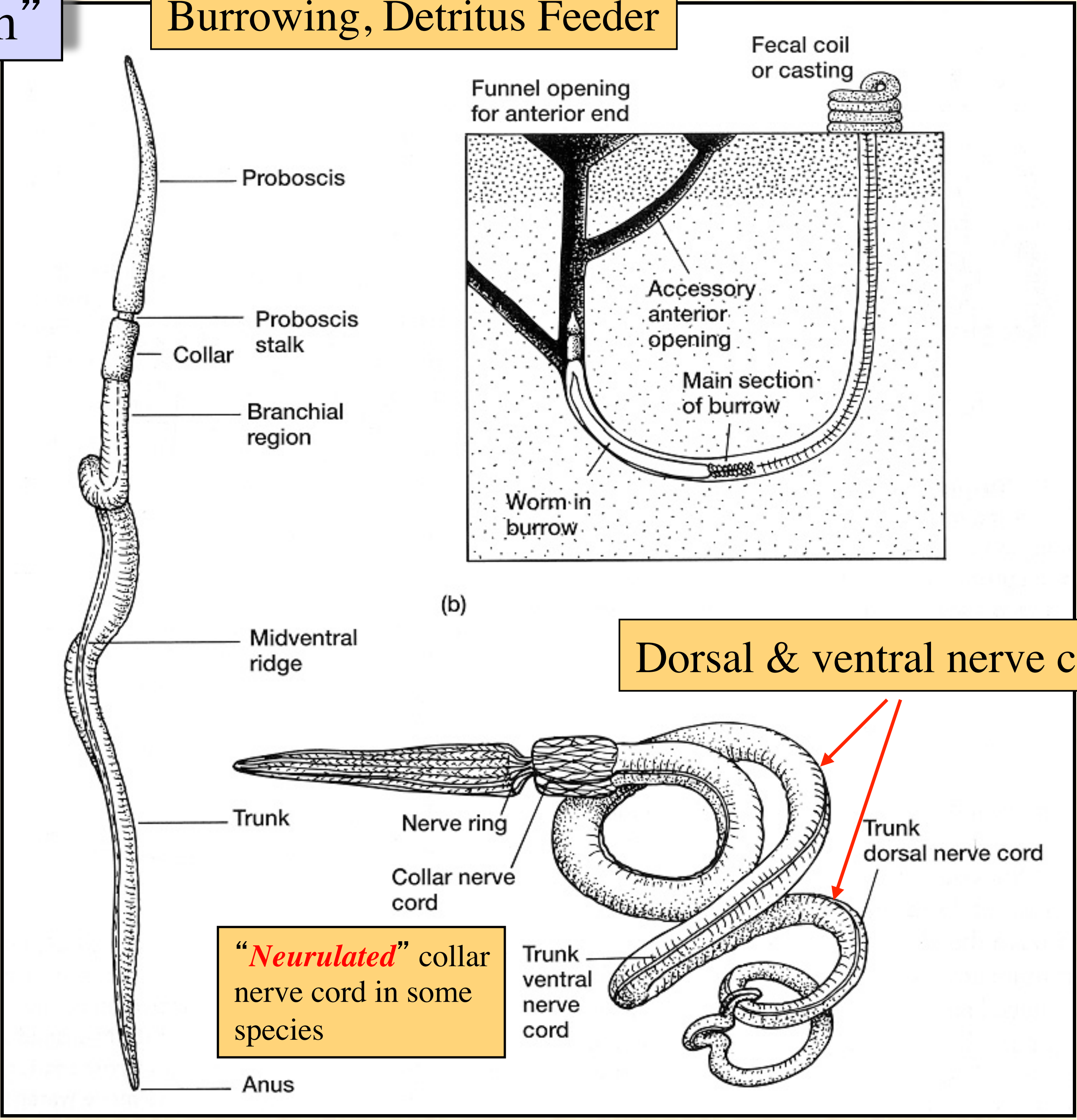


Not notochord homologue

FIGURE 2.7 Generalized acorn worm. Proboscis, collar, and trunk regions are shown in partial cutaway view, revealing the coelom in each and the associated internal anatomy of the worm. Within the proboscis is the stomochord, an extension of the digestive tract. The food-laden cord of mucus (spiral arrow) enters the mouth together with water. Food is directed through the pharynx into the gut. Excess water exits via the pharyngeal slits. Several slits open into the branchial pouch, a common compartment with a pharyngeal pore that opens to the outside environment.

"Acorn Worm"

Burrowing, Detritus Feeder



Dorsal & ventral nerve cords

"*Neurulated*" collar nerve cord in some species

Ciliary Suspension Feeding in Acorn Worms

Suspension *vs*. Filter Feeders

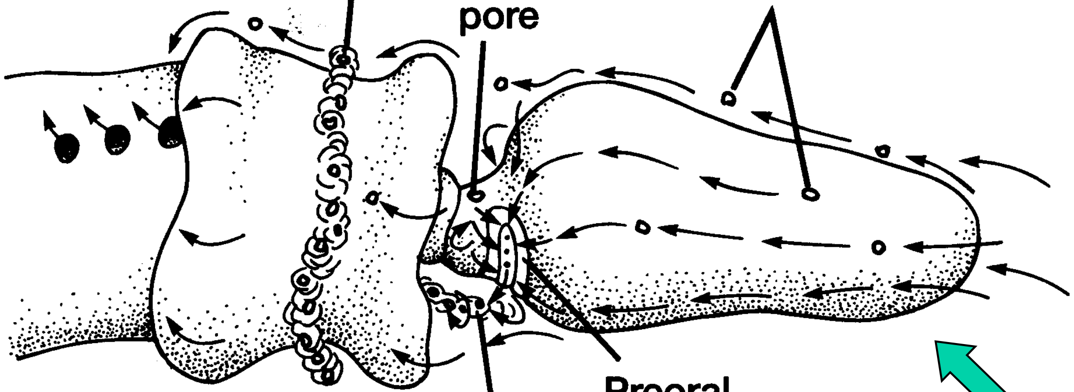
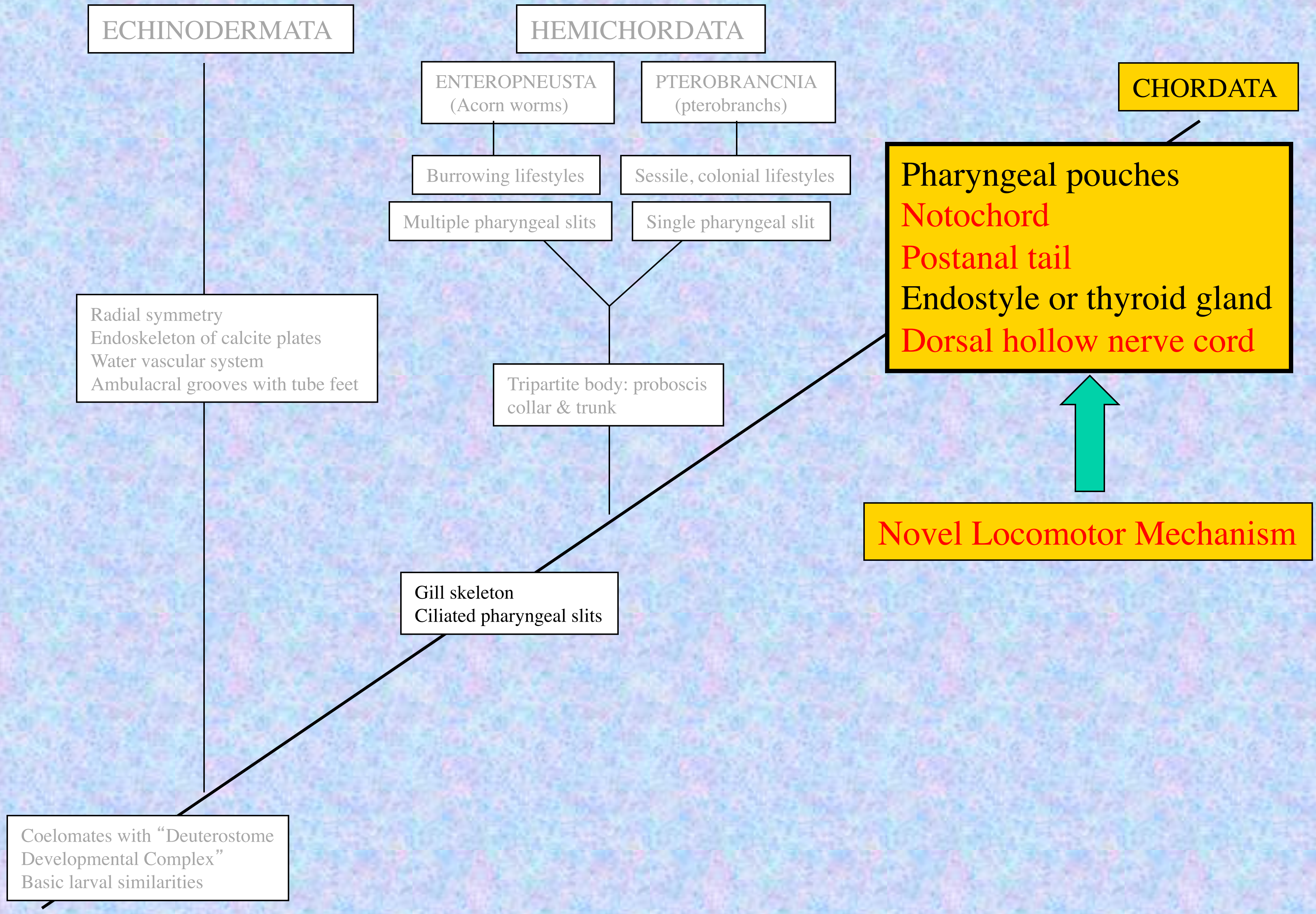


FIGURE 2.10 Suspension mucus feeding. Direction and movement of food and mucus are indicated by arrows. Food material, carried along in the water current generated by surface cilia, travels across the proboscis and into the mouth where it is captured in mucus and swallowed. Rejected food material collects in a band around the collar and is shed.

After Burdon-Jones.

Ciliary-Mucus Feeding Mechanism

Relationships of the Deuterostome Phyla



Relationships of Chordate Subphyla : Origin of Vertebrates

UROCHORDATES

Greatly expanded pharynx
Reduction of nervous system
Sessile

CEPHALOCHORDATES

Anteriorly extended notochord
Oral cirri (tentacles)
Burrowing

VERTEBRATES

Distinct head & brain (cephalization)
Muscularization of pharynx
Special paired sensory organs (eyes, nose, ears)
Neural crest tissue & **neurogenetic placodes** in embryo

Somites; segmented trunk muscles
Notochord & postanal tail retained in adult

BASIC CHORDATE FEATURES

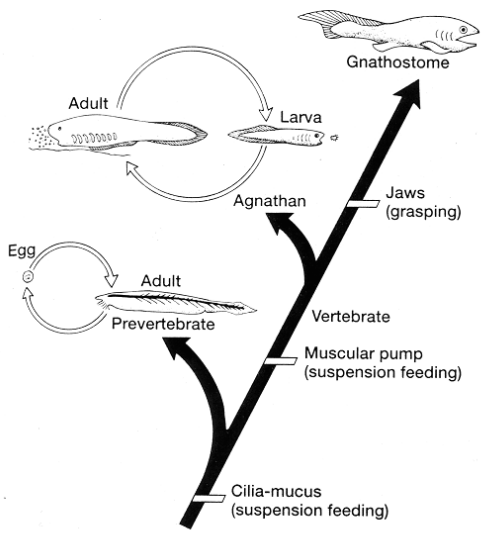
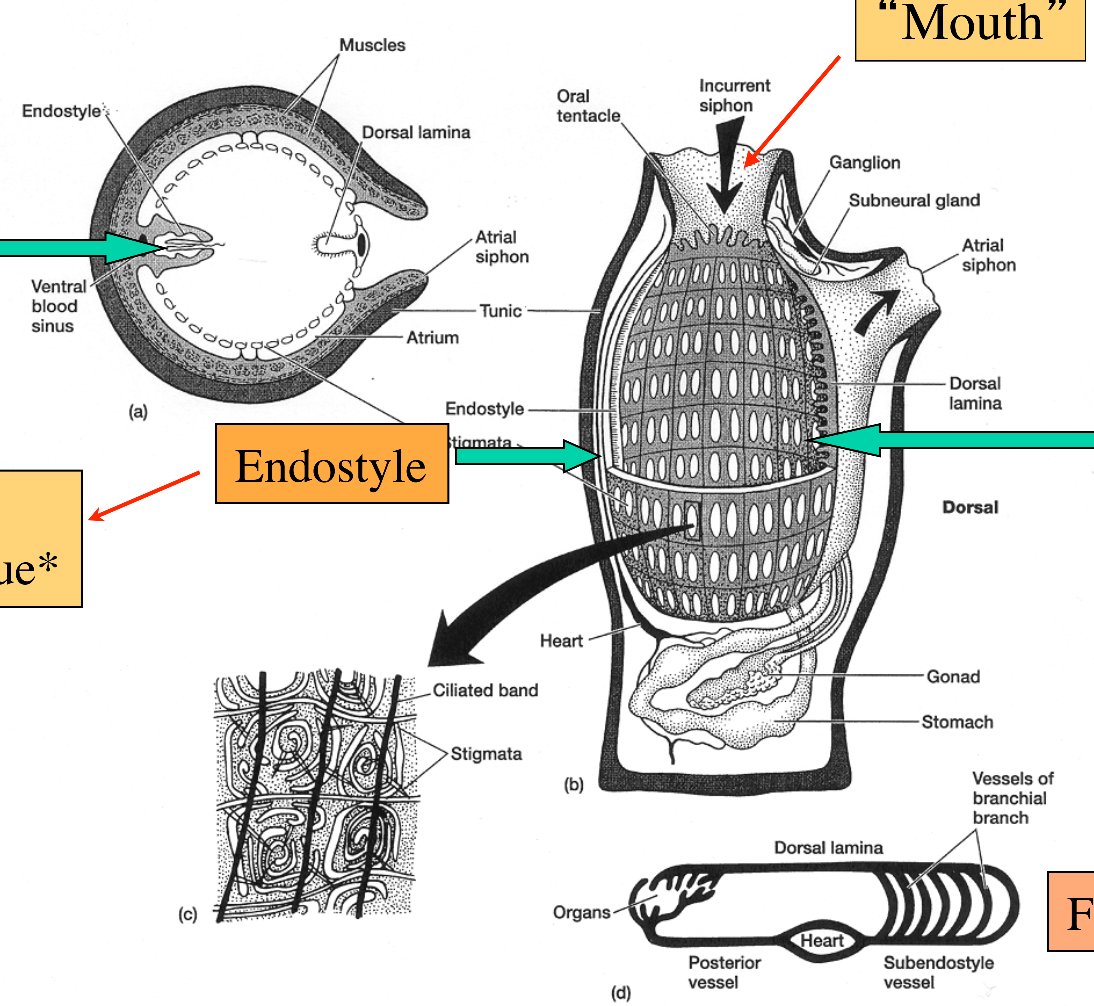


FIGURE 3.3 **Origin of vertebrates.** A more active, predaceous lifestyle characterized vertebrate evolution, leading vertebrates away from suspension feeding that typified their ancestors. Prevertebrates are envisioned as suspension feeders, perhaps something like amphioxus, but they came to depend on a muscularized pharynx to produce feeding currents of water. Following prevertebrates, an agnathan stage developed in which adults might have been benthic feeders, but larvae continued the trend toward a more active lifestyle. Selection and capture of specific prey may have next led to gnathostomes. Thus, the early trend in vertebrate evolution was from ciliary to muscular mechanisms of moving feeding currents, and then to jaws that directly snatched prey from water.

Adult Tunicate (Urochordate) Morphology



"Mouth"

Endostyle

Endostyle

Feeding Groove
Thyroid Homologue*

Perforated Pharynx

Flow Reversal

FIGURE 2.17 Adult solitary ascidian. (a) Schematic cross section of the body at the level of the atriopore (atrial siphon). Food captured in the lining mucus is collected dorsally in the dorsal lamina and is passed to the stomach. (b) Left side of the body and part of the branchial basket have been cut away. Oral tentacles exclude large particles entering with the stream of water via the incurrent siphon. The water passes through the pharyngeal slits (stigmata), into the surrounding atrium, and exits the atriopore (excurrent siphon). (c) The structure of several highly subdivided pharyngeal slits is depicted. (d) Diagram of urochordate circulation. Blood flows in one direction and then reverses itself rather than maintaining a single direction of flow.

Structure of Urochordate Larva

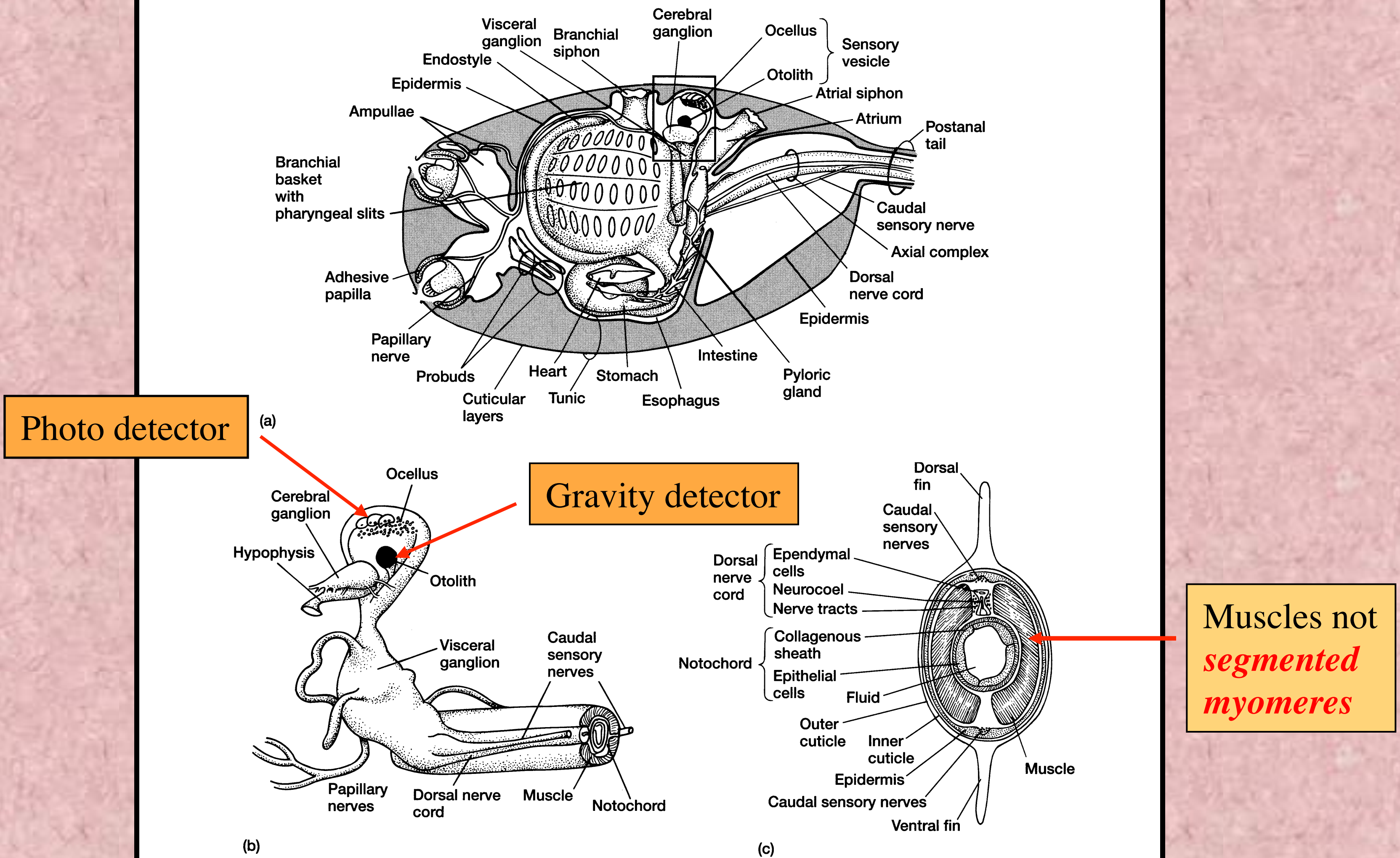


FIGURE 2.14 **Urochordata, Ascidiacea.** (a) Larva of the ascidian *Distaplia occidentalis.* (b) Enlarged view of the anterior larval nervous system of *Diplosoma.* (c) Cross section of the larval tail of *Diplosoma.* During development, the tail twists the dorsal fin to the left side of the body, but in this figure, the tail is rotated 90° and drawn upright. Notice that the ventral and dorsal fins are formed from the outer layer of the tunic and that the central notochord is bounded by sheets of muscle. The dorsal nerve cord is composed of ependymal cells around a neurocoel, with axons of sensory nerves coursing along its side.

From Cloney and Torrence; Torrence; Torrence and Cloney.

Urochordate Larval Metamorphosis

Residual Chordate Features

Perforated Pharynx

Endostyle

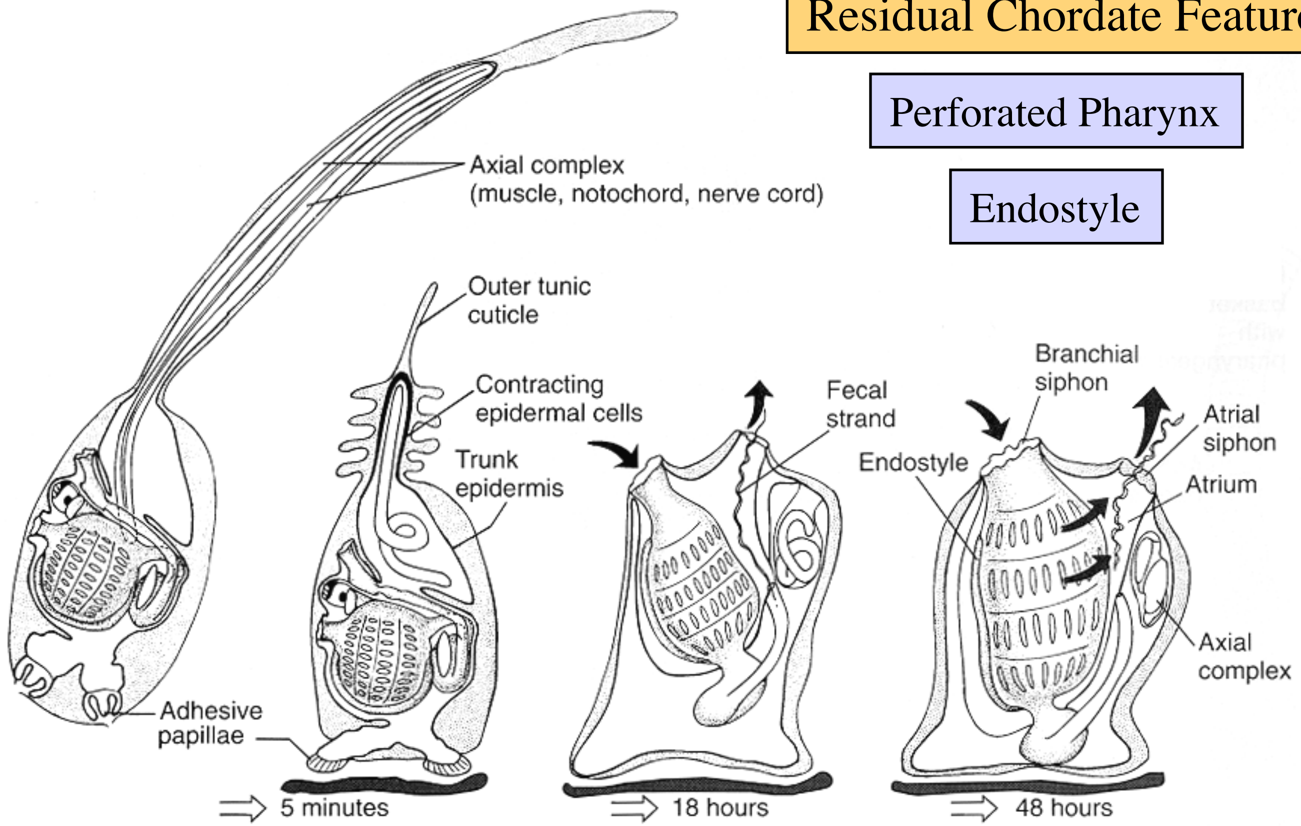
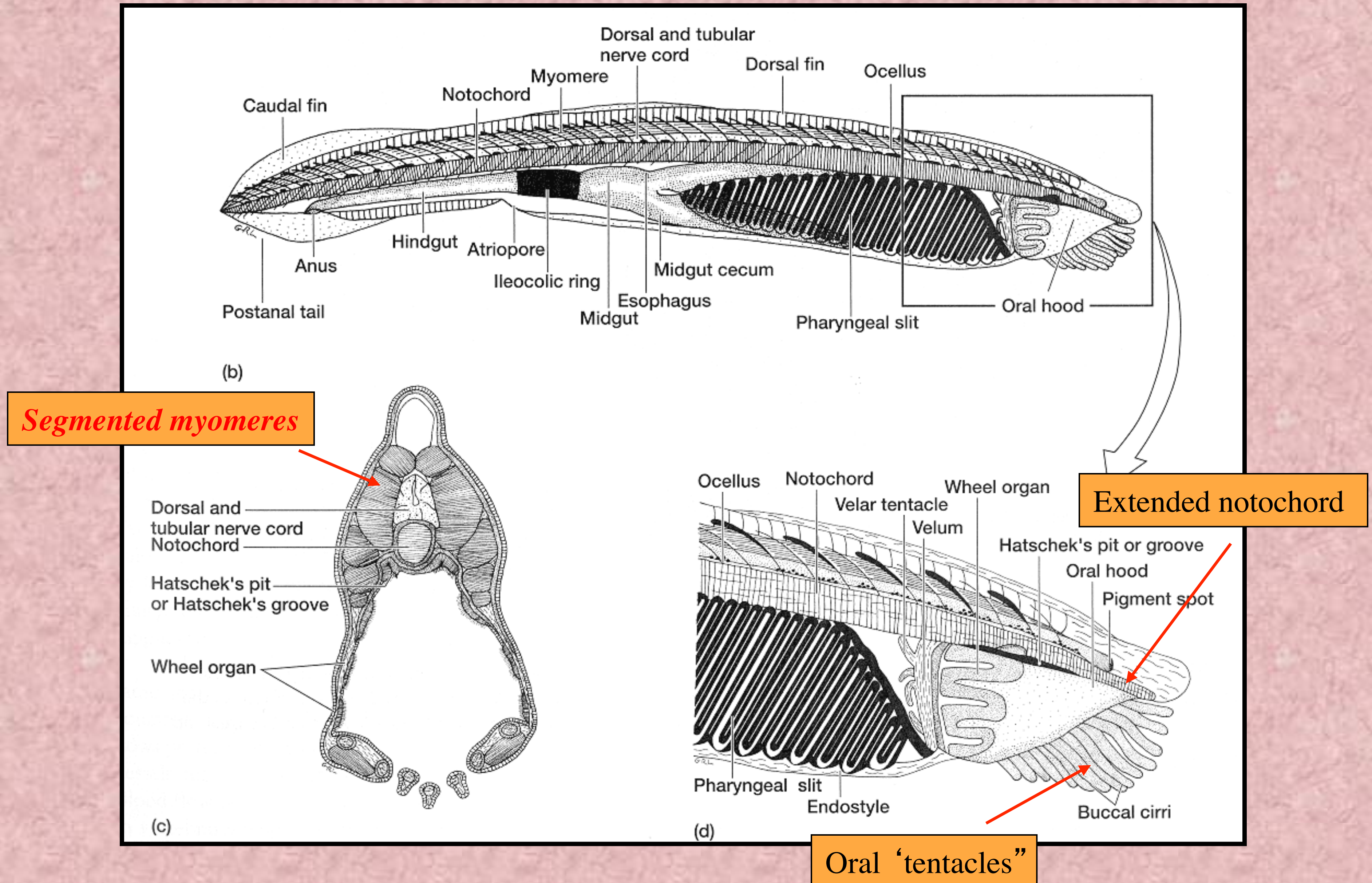


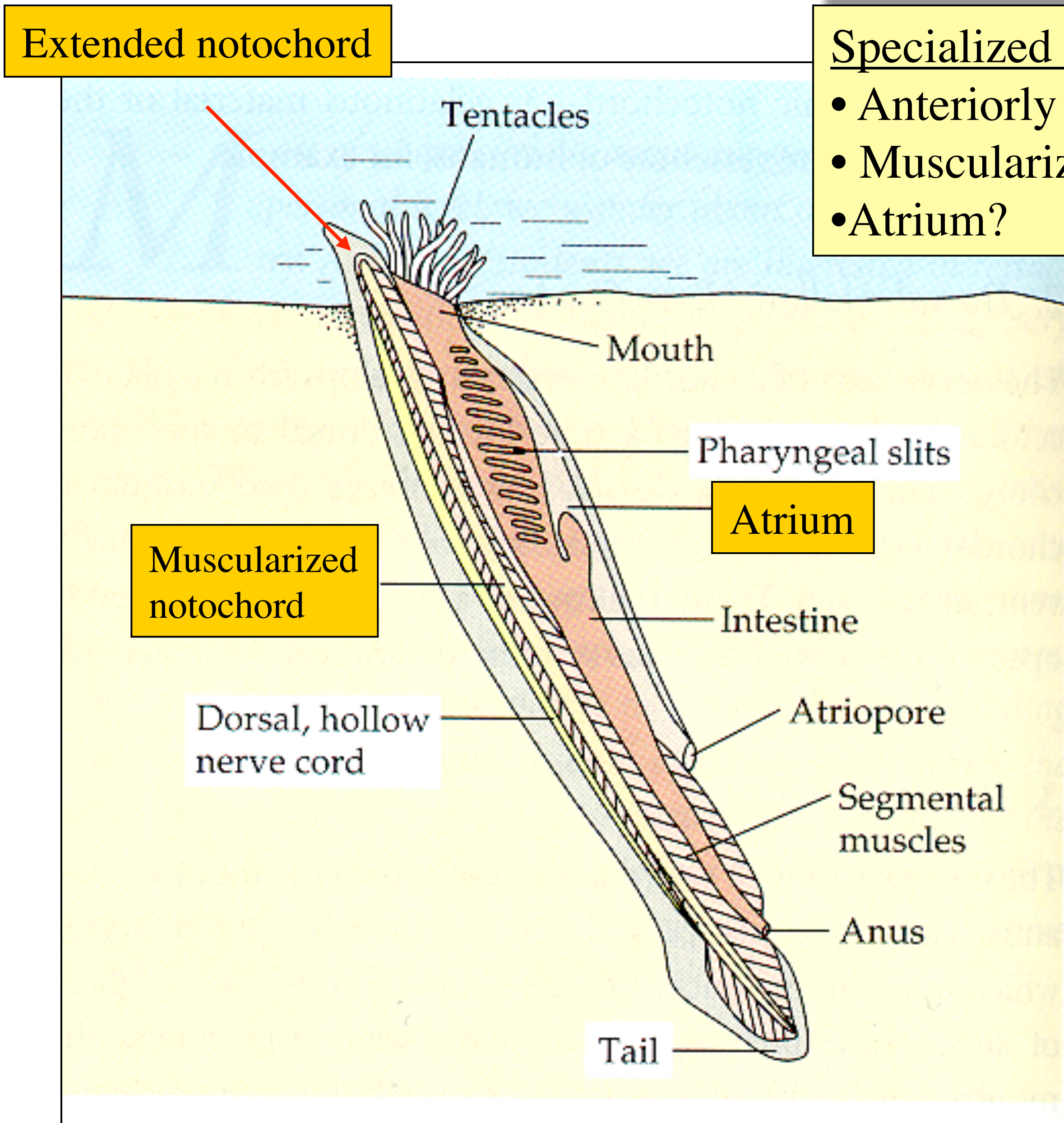
FIGURE 2.15 Metamorphosis of the ascidian larva *Distaplia*, from left to right. The planktonic nonfeeding larva settles and attaches to a substrate. Adhesive papillae hold the larva in place, contraction of tail epidermis pulls the axial complex into the body, and the larva sheds its outer cuticle following attachment. By 18 hours, the branchial basket rotates to reposition the siphons, and the appearance of a fecal strand testifies that active feeding has begun. By 48 hours, most of the axial complex is resorbed, rotation is complete, and attachment to the substrate is firm. At this point, the juvenile is clearly differentiated.

Based on the research of R. A. Cloney.

Cephalochordate Adult Morphology



Cephalochordates: Structure, Function, Lifestyle



<u>Specialized Features Related to Burrowing</u>

- Anteriorly extended notochord
- Muscularized notochord
- Atrium?

Cephalochordates (live)

Urochordates (Live)

ORIGIN OF VERTEBRATES

Relationships of Chordate Subphyla : Origin of Vertebrates

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- Reduction of nervous system
- Sessile

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- Burrowing

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- Distinct head & brain (cephalization)
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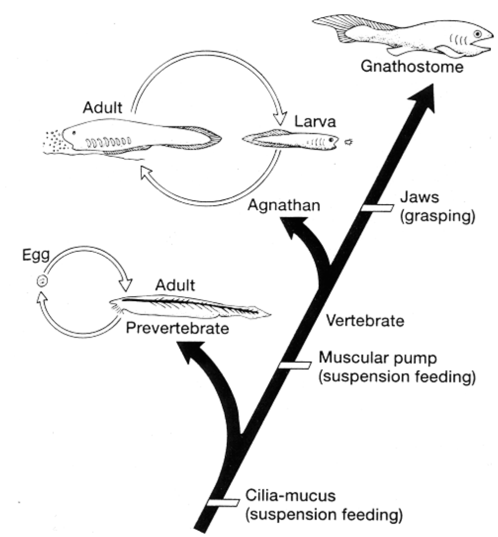
- Special paired sensory organs (eyes, nose, ears)
- **Neural crest tissue** & **neurogenetic placodes** in embryo

Somites; segmented trunk muscles
Notochord & postanal tail retained in adult

BASIC CHORDATE FEATURES



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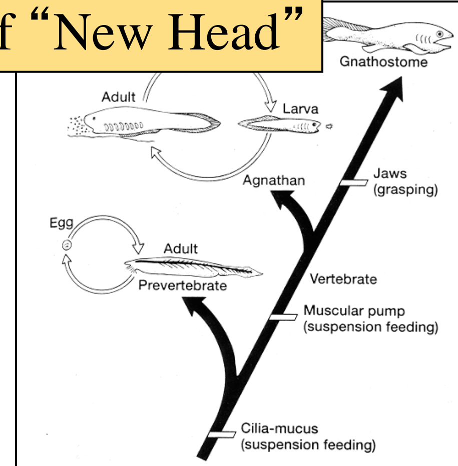
Development of "New Head"

- Somites; segmented trunk muscles
- Notochord & postanal tail retained in adult

BASIC CHORDATE FEATURES



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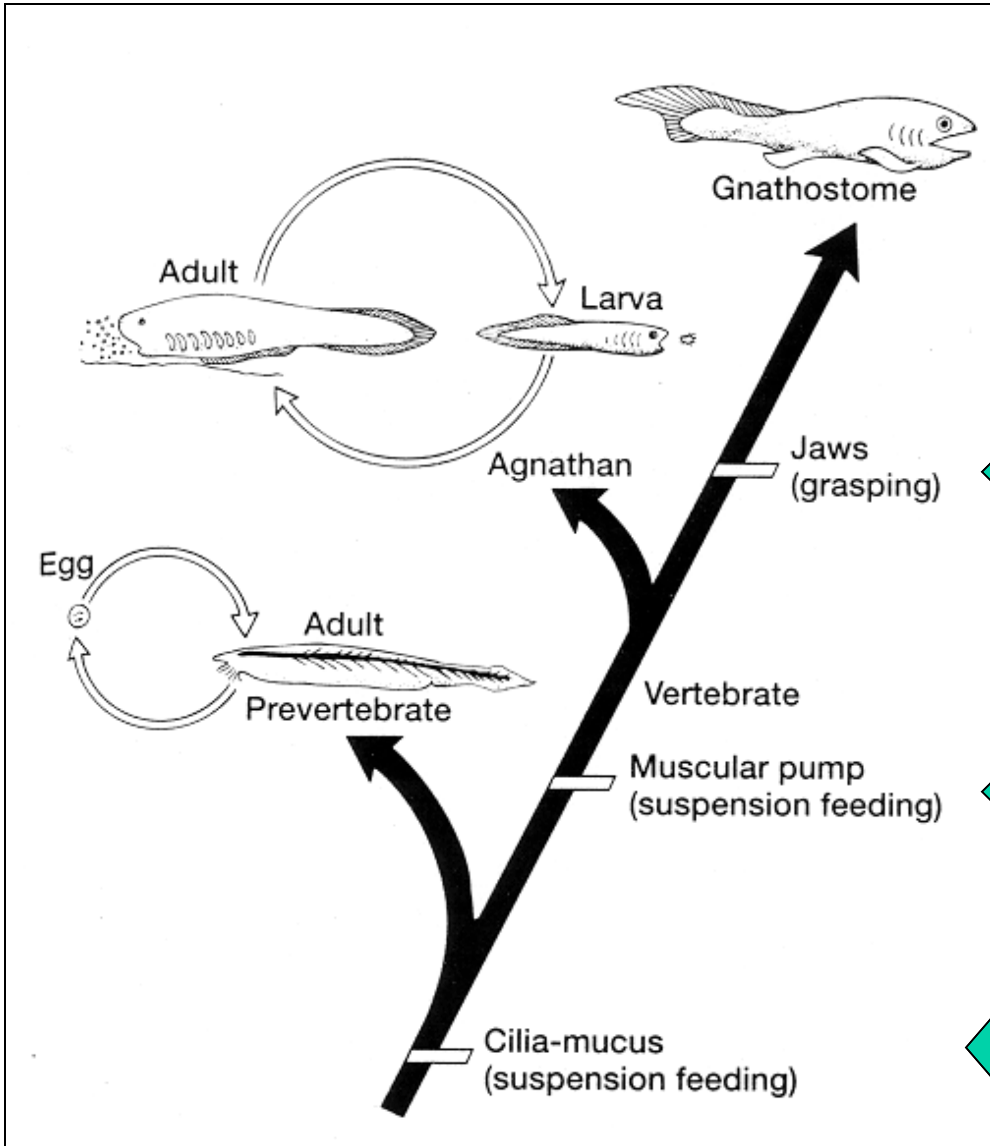
Feeding Strategies & Vertebrate Evolution



Large Prey Now Possible
Become Dominant Predators

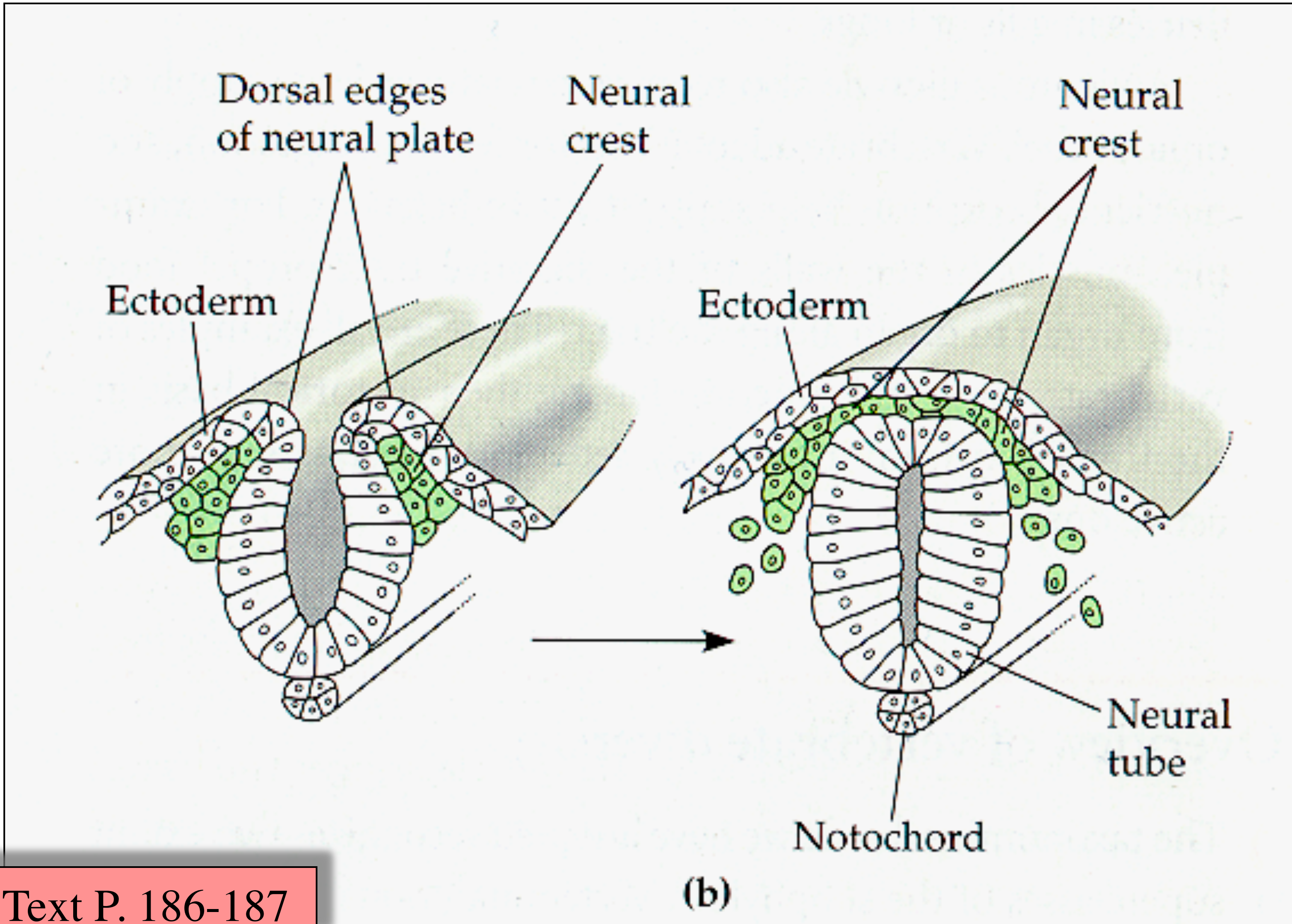
Neural Crest Structures

Muscularized Pharynx & Supportive Skeleton
Suction Feeding Begins

Ciliary Driven
Food Restricted to Zooplankton

Neural Crest Tissue & Ectodermal (Neurogenic) Placodes

Key Innovation in Vertebrate History



See Text P. 186-187

Developmental Innovation & the "New Head"

Ectodermal Placodes

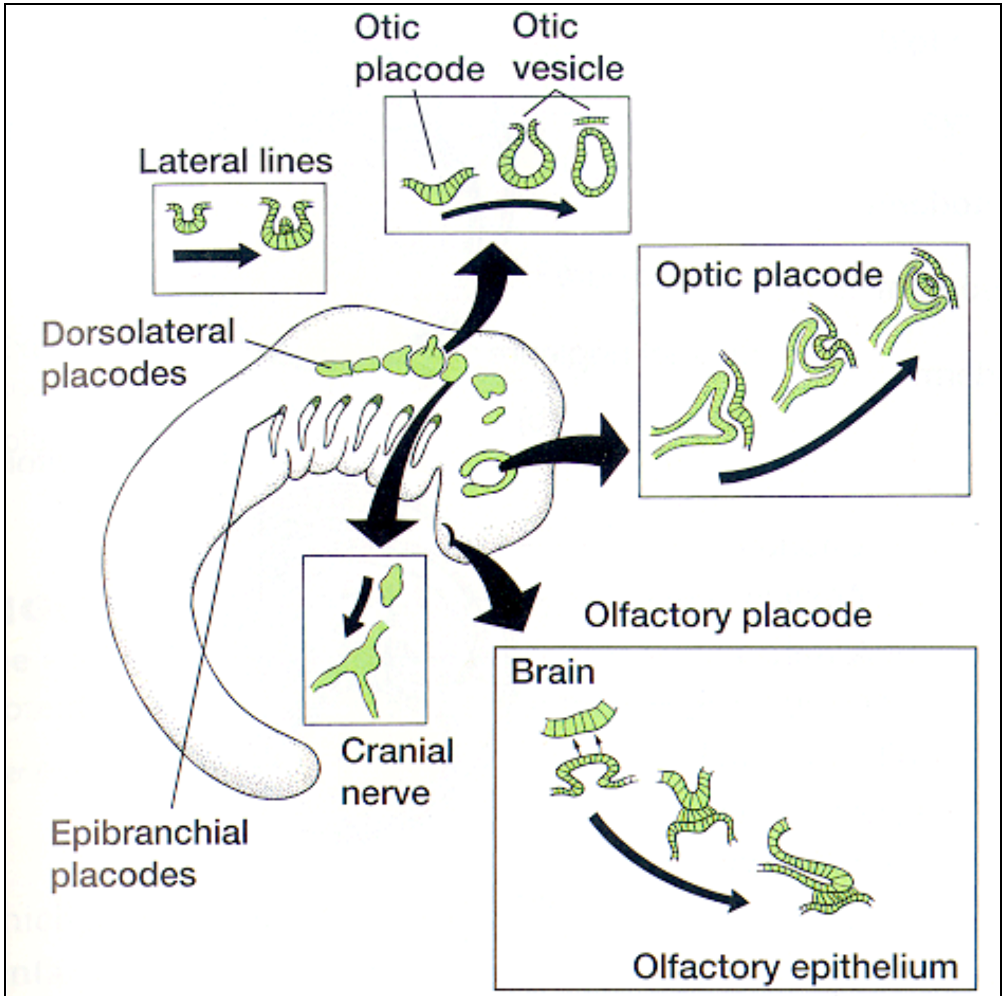
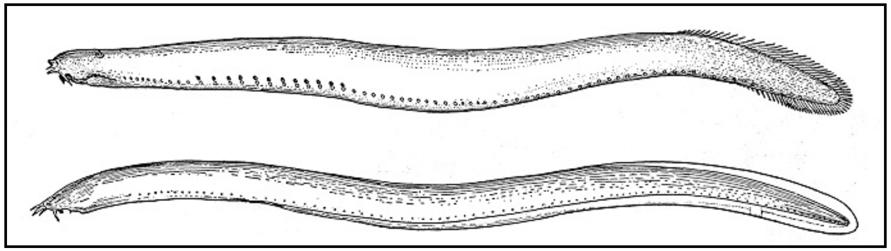


TABLE 5.3 Placodes and Their Derivatives

Placode	Derivative
Dorsolateral	
Lateral line	*Lateral line mechanoreceptors and electroreceptors*
Otic	*Vestibular apparatus*
Cranial nerve	*Sensory nerve ganglia*
Epibranchial	
Cranial nerve	*Sensory nerve ganglia, VII, IX, X*
Olfactory	Sensory epithelium
Optic	Lens of eye

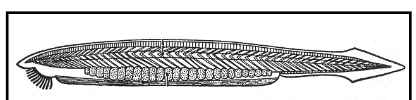
ORIGIN OF VERTEBRATES
(And Fossil Record)

Driving Forces (Selection) For Vertebrate Body Plan



Myxines (hagfish)

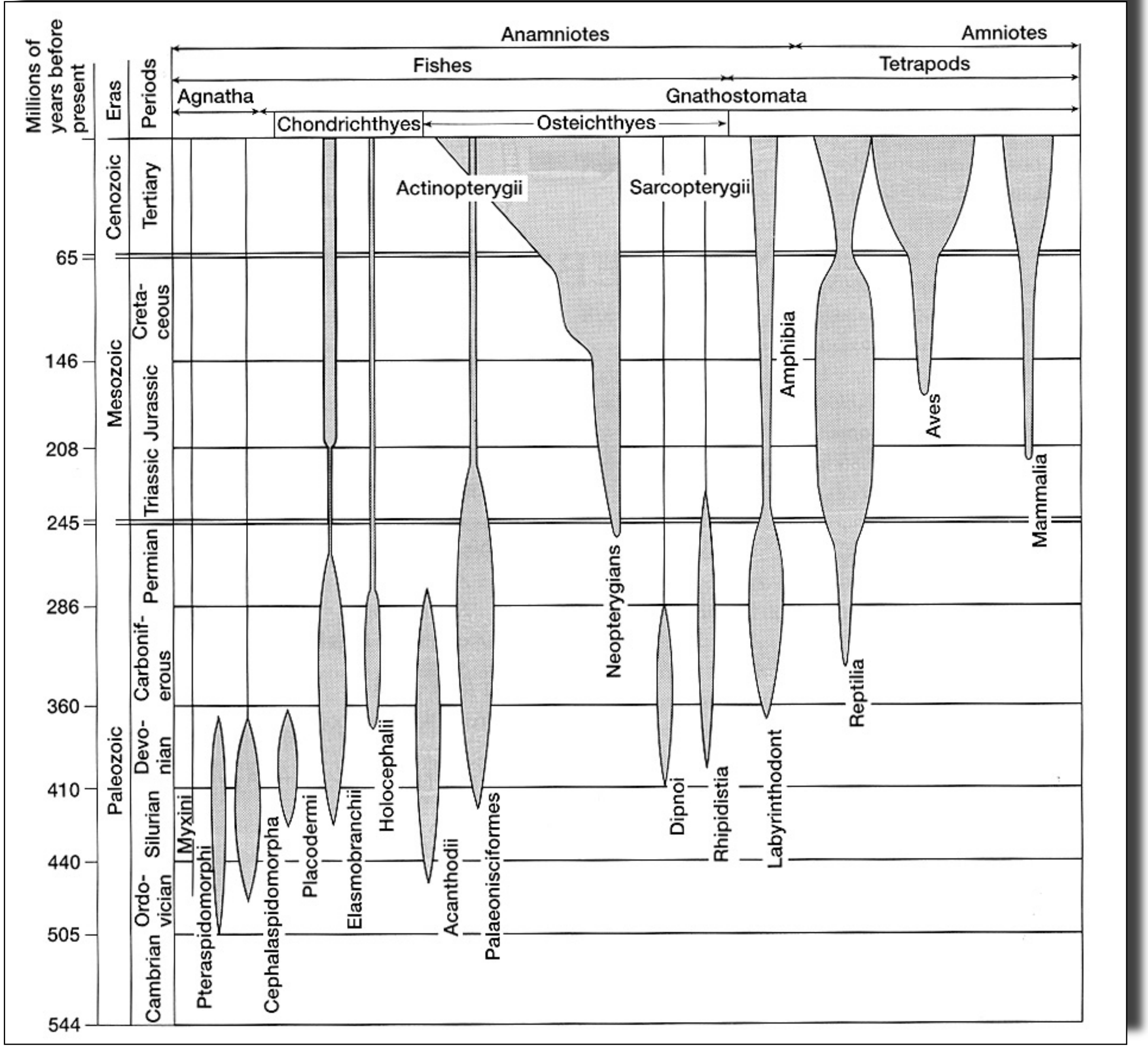
Increasing: Body Size & Aerobic Capacity (= sustained locomotion)



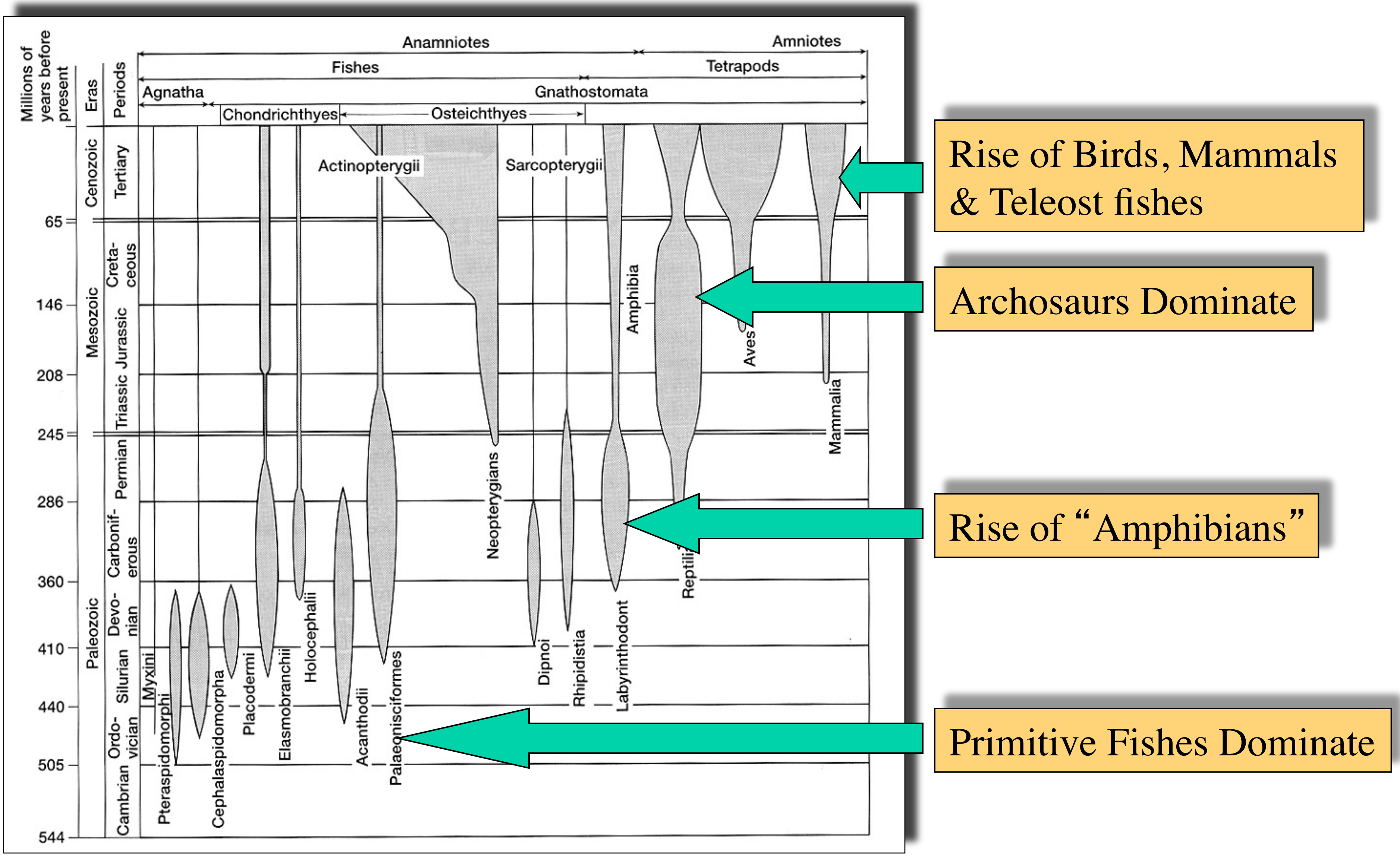
Cephalochordates

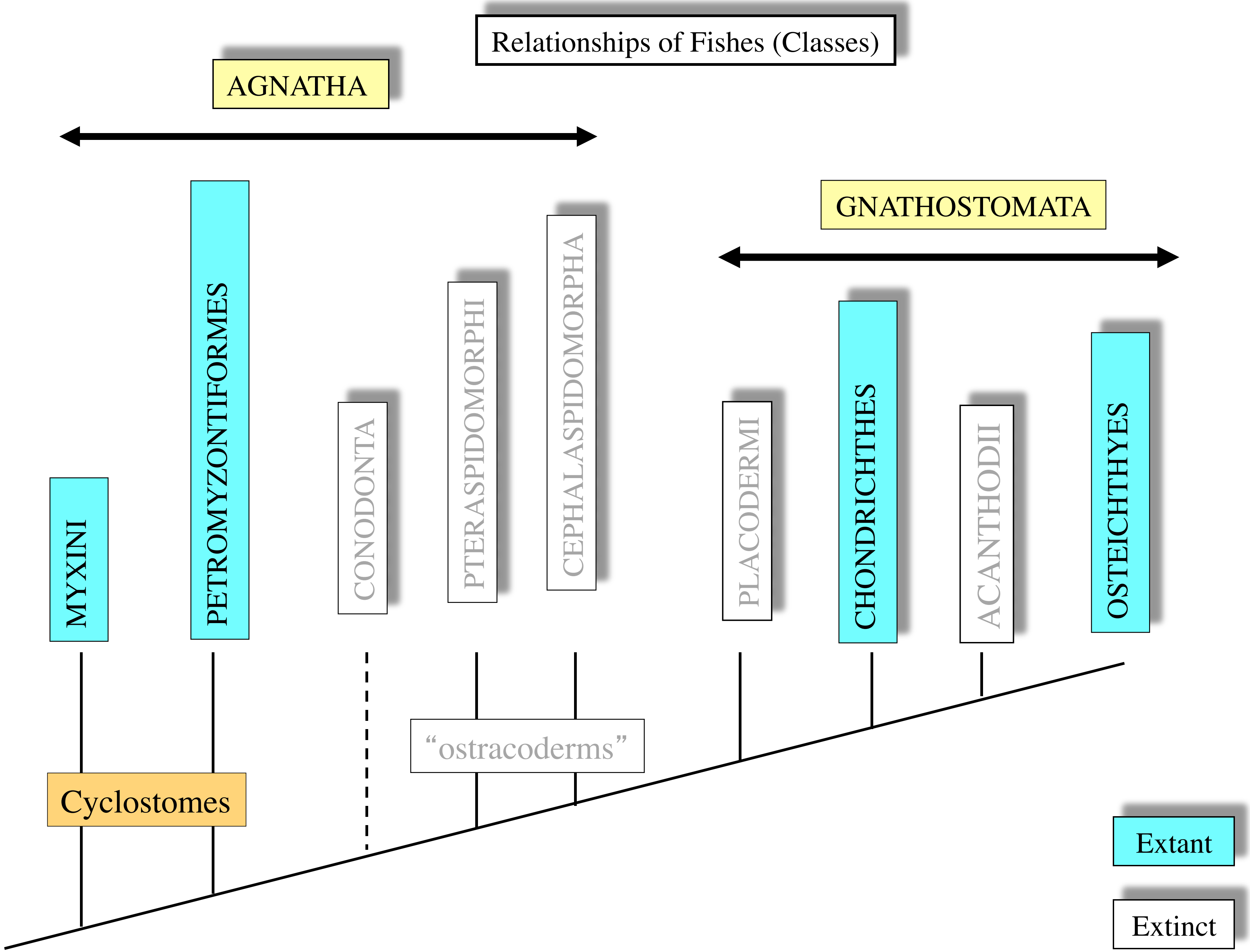
SURVEY OF VERTEBRATES: FISHES

Vertebrate Diversification & Time (Fossil Record)

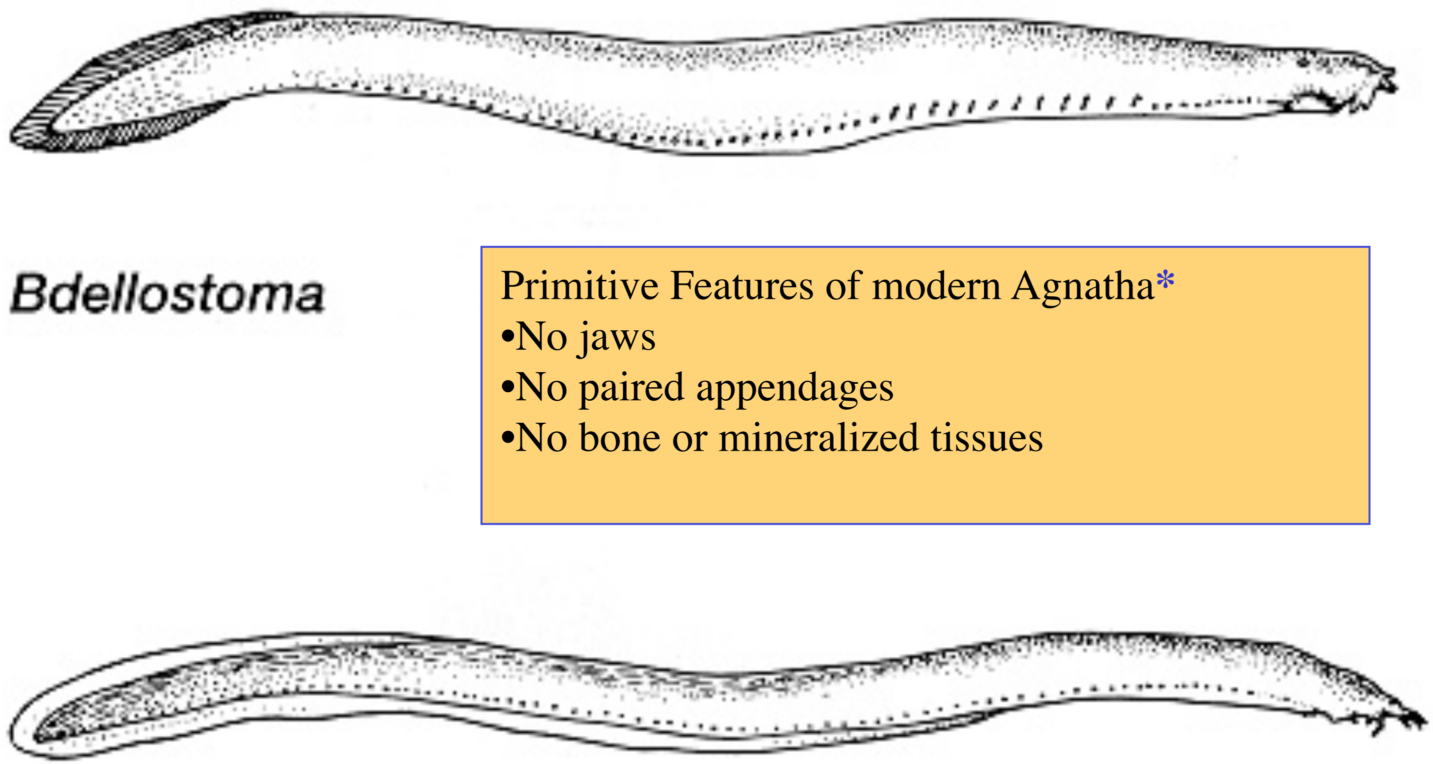


Vertebrate Diversification & Time (Fossil Record)




Relationships of Fishes (Classes)
AGNATHA
GNATHOSTOMATA
MYXINI
PETROMYZONTIFORMES
CONODONTA
PTERASPIDOMORPHI
CEPHALASPIDOMORPHA
PLACODERMI
CHONDRICHTHES
ACANTHODII
OSTEICHTHYES
Cyclostomes
"ostracoderms"
Extant
Extinct

Class MYXINI (Hagfishes)



(a) *Bdellostoma*

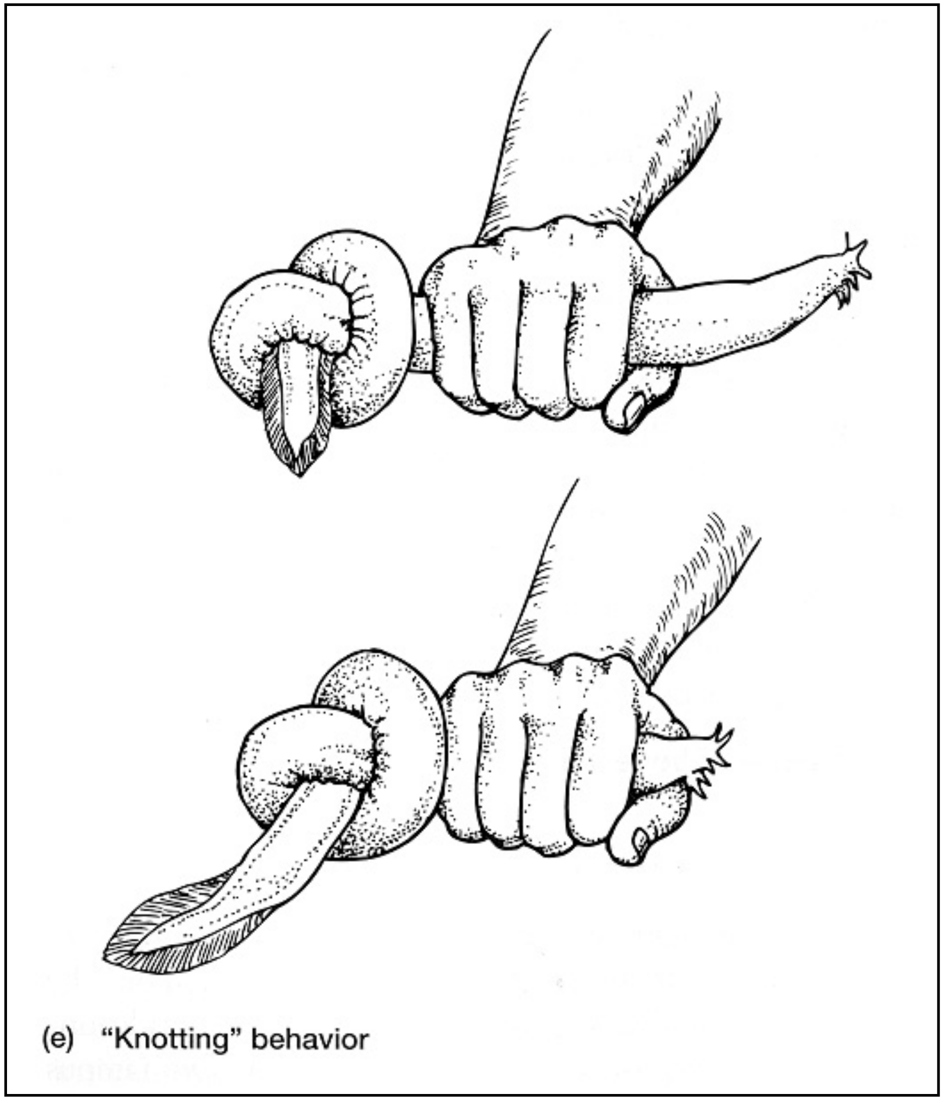
(b) *Myxine*

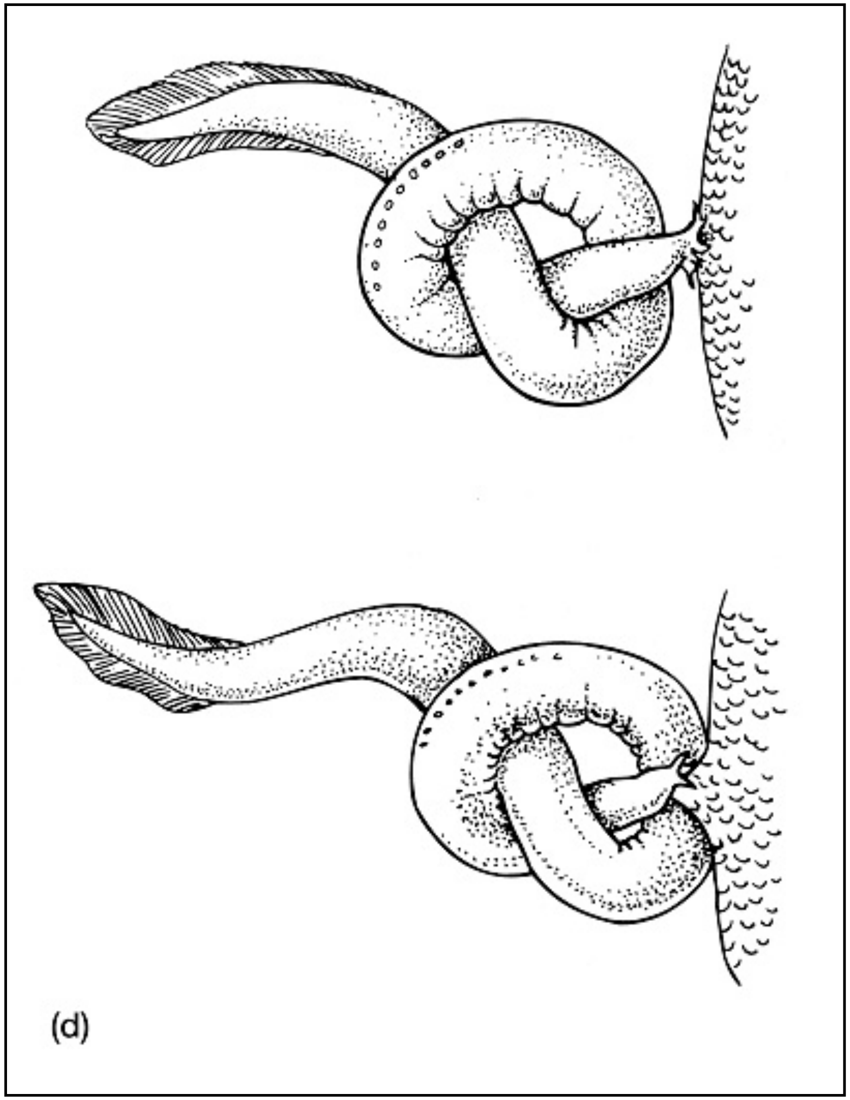
Primitive Features of modern Agnatha*
- No jaws
- No paired appendages
- No bone or mineralized tissues

(marine scavengers; carrion feeders)

* Plus other possible primitive traits in Mixini (see Handout)

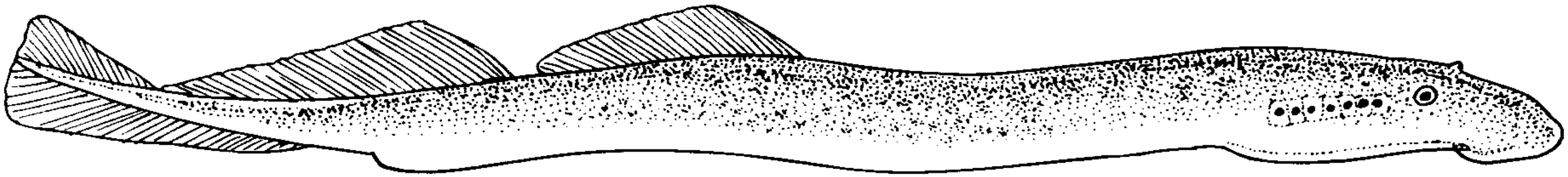
Hagfish Movements & Feeding Tactics





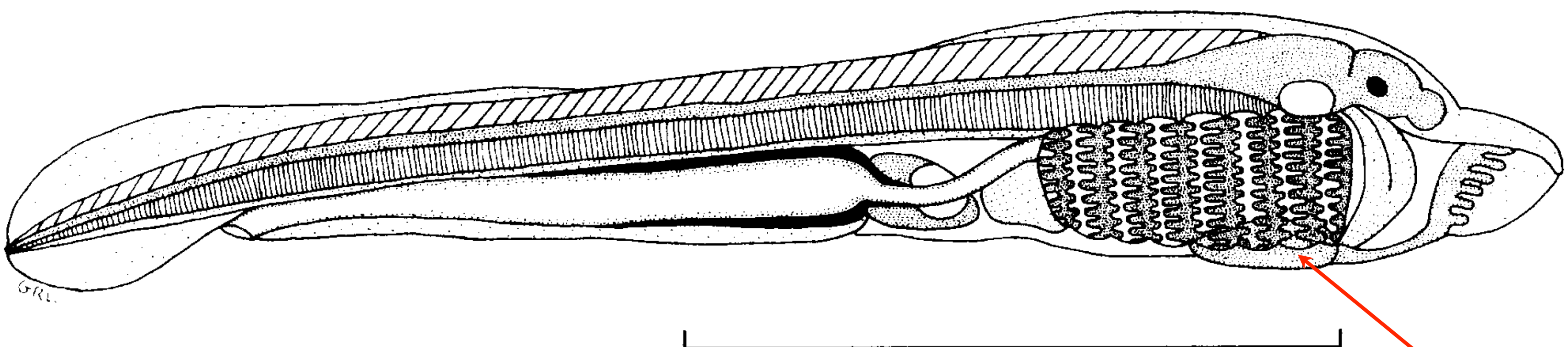
Knotting behavior

Class PETROMYZONTIFORMES



(c) *Petromyzon*

Lamprey (marine and fresh water predators / semi-parasites)



(d) *Ammocoetes*

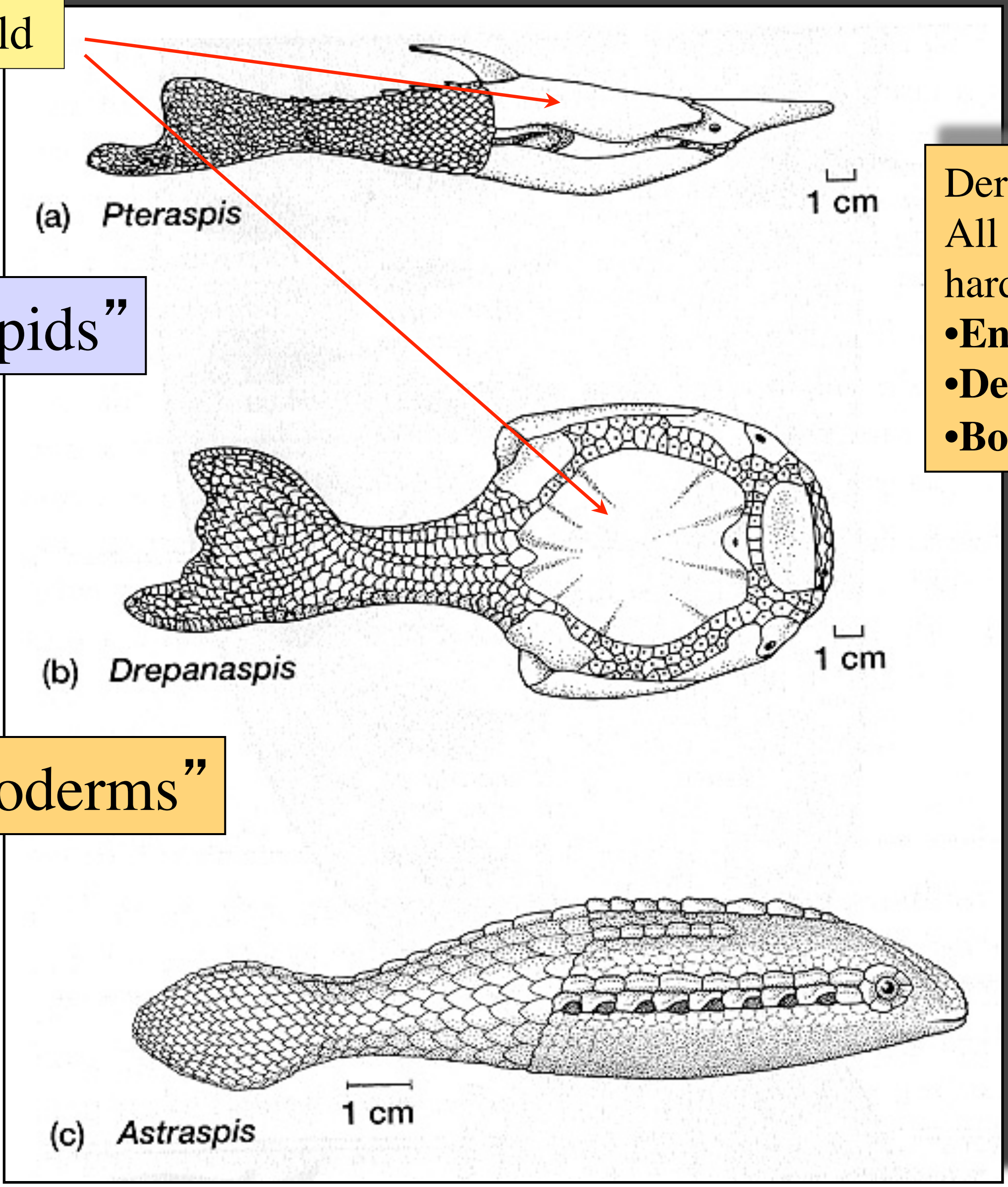
Larval stage: burrowing, suspension feeder

Class PTERASPIDOMORPHI

Thoracic shield

Extinct "pteraspids"

Oldest "ostracoderms"



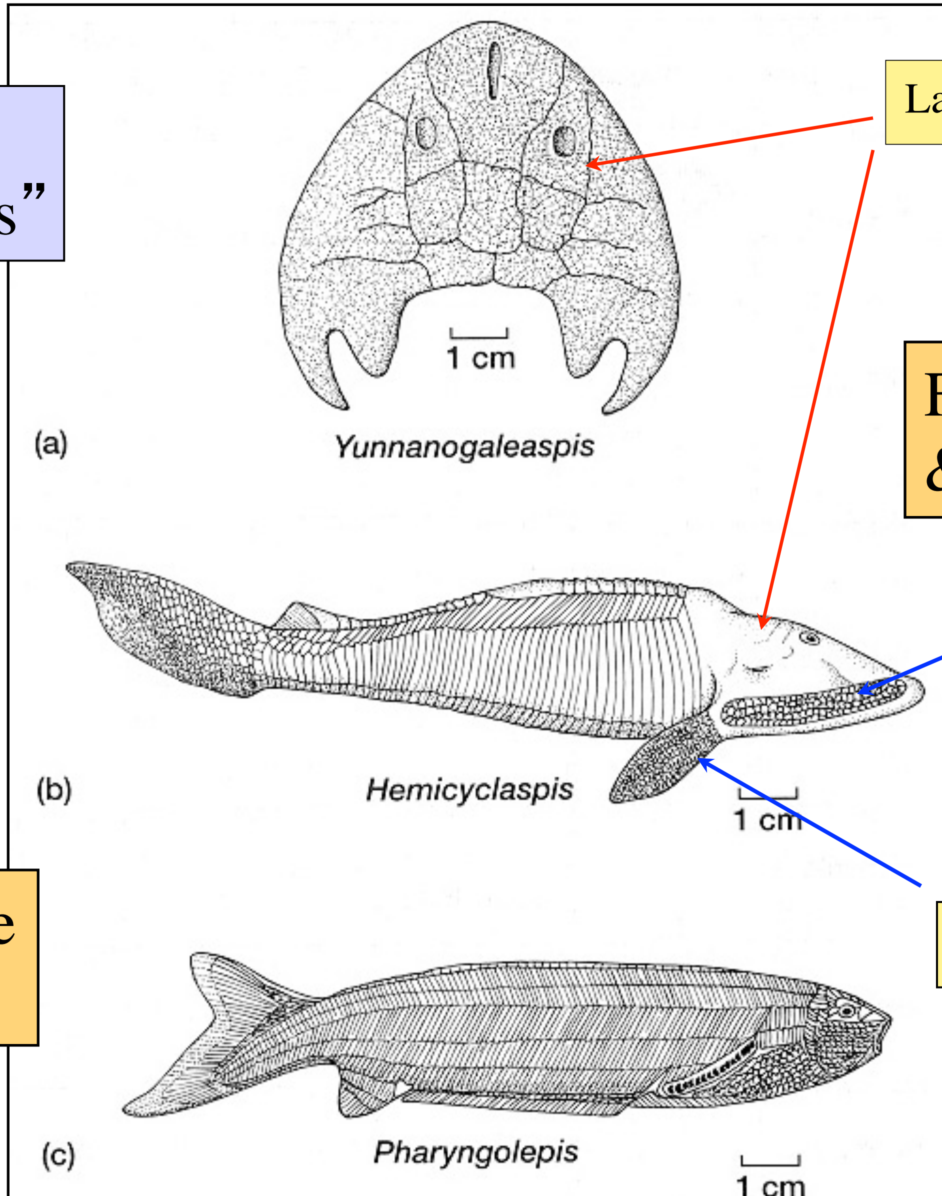
Dermal Armor
All 3 basic vertebrate hard tissues present
- **Enamel**
- **Dentine**
- **Bone (Aspidin)**

Class CEPHALASPIDOMORPHA

= "Other Ostracoderms" in current text

Extinct "Cephalaspids"

Shallow marine habitats



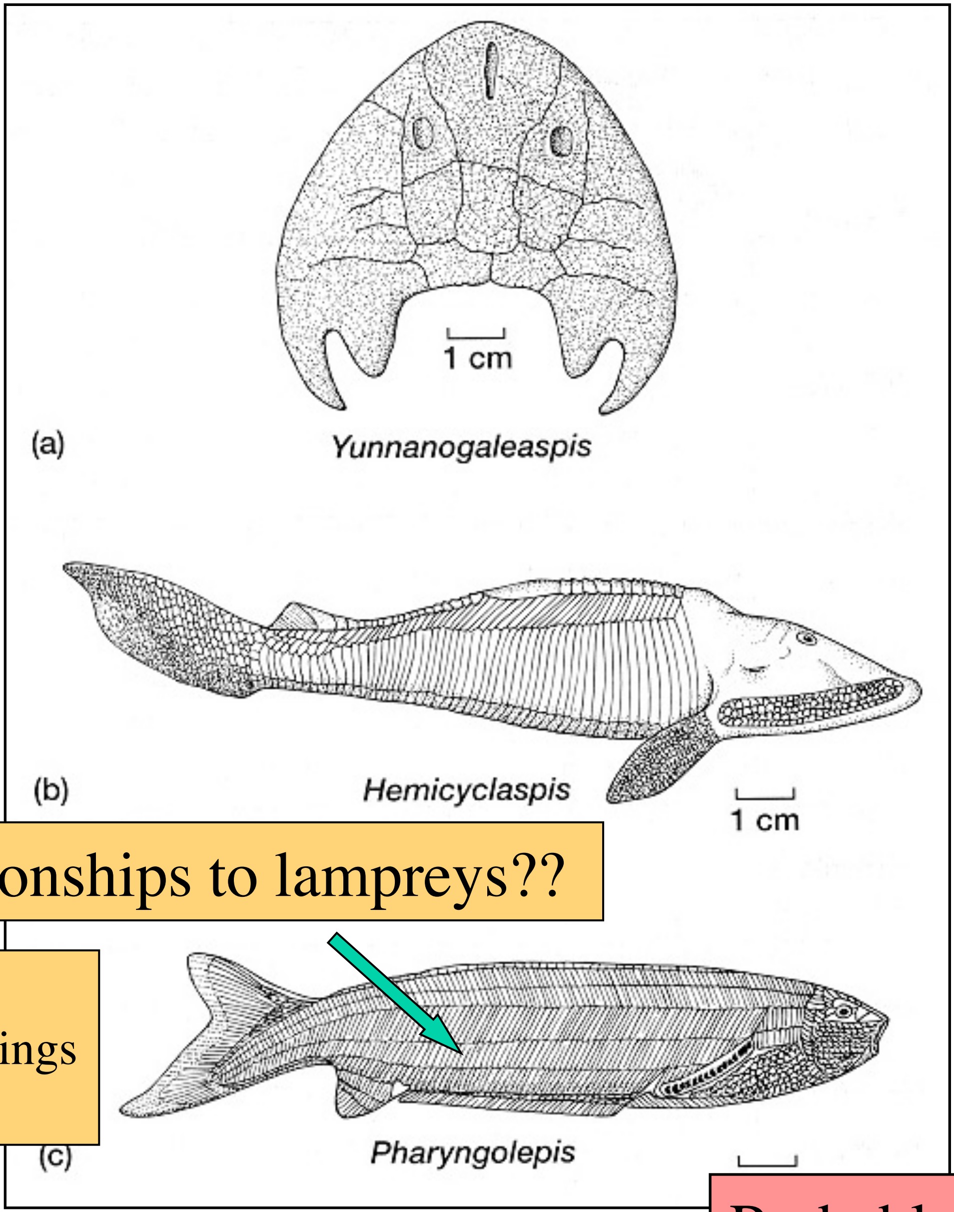
Large Head Shields

Fed on soft food & detritus

Electro-receptors?

Pectoral lobes

Class CEPHALASPIDOMORPHA



Anaspids: relationships to lampreys??

Reduced armor
Row lateral gill openings
Circular mouth

Probably Convergence!

Relationships of Jawed Vertebrates

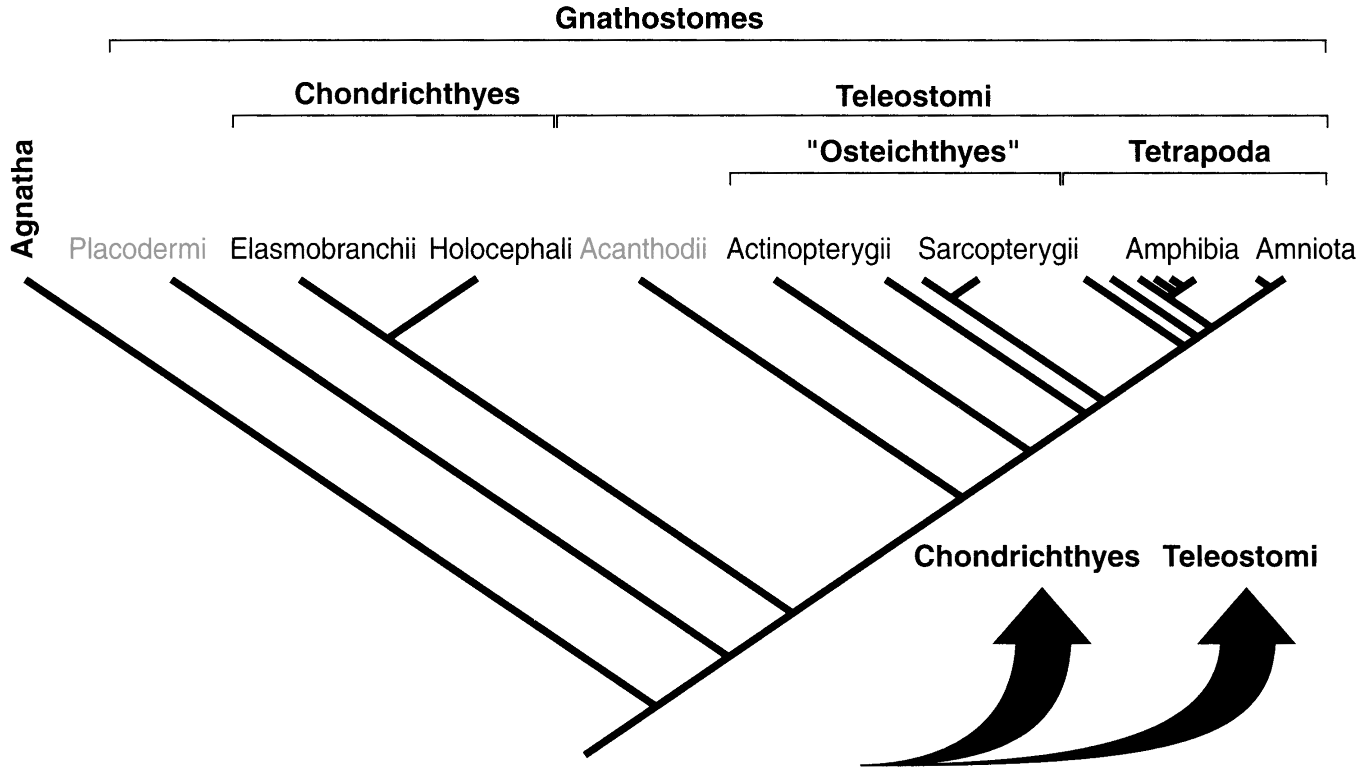
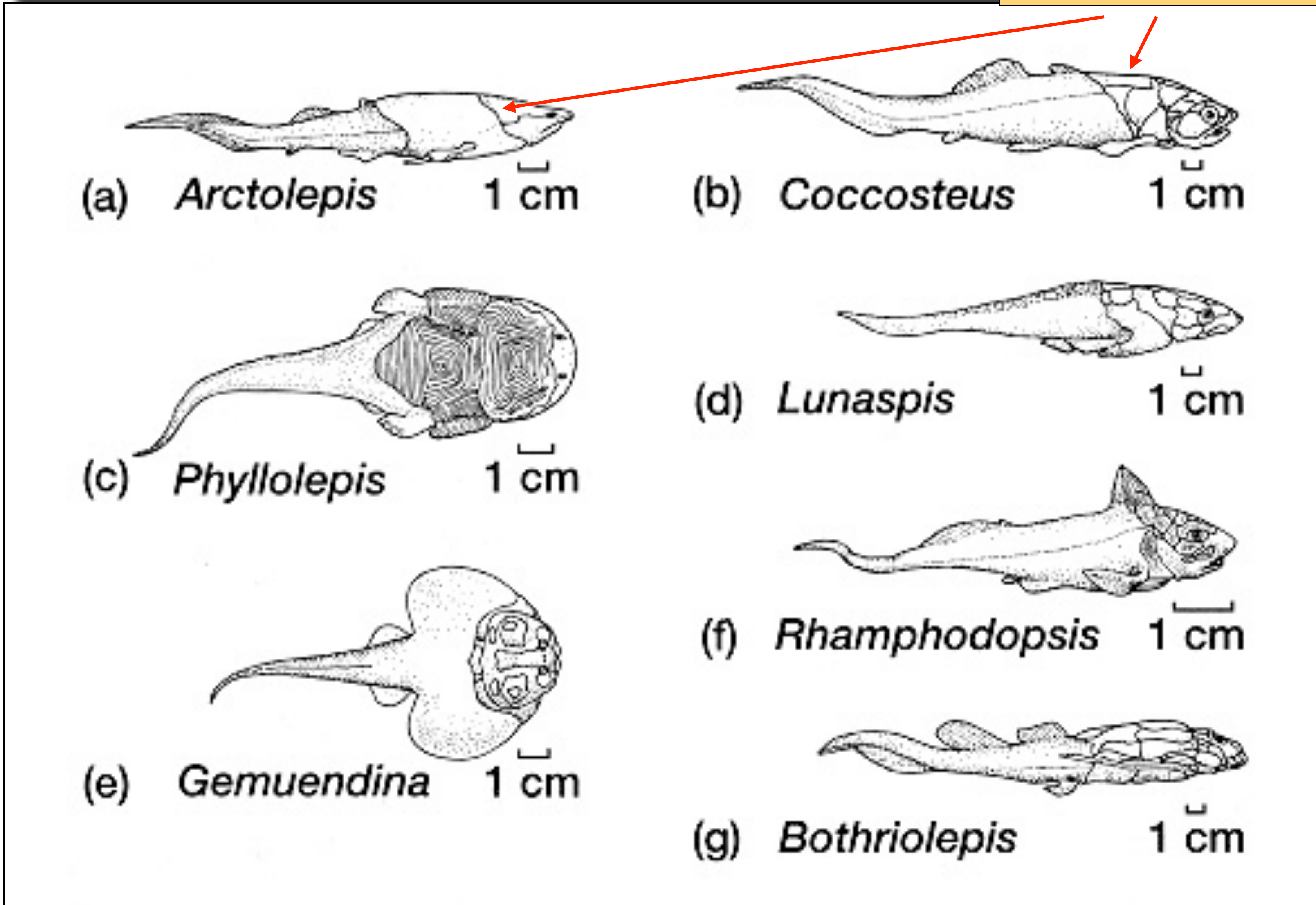


FIGURE 3.12 Gnathostomes, phylogenetic relationships. Note that gnathostomes, above the placoderms, evolved along two major lines—the Chondrichthyes and the Teleostomi.

CLASS PLACODERMI



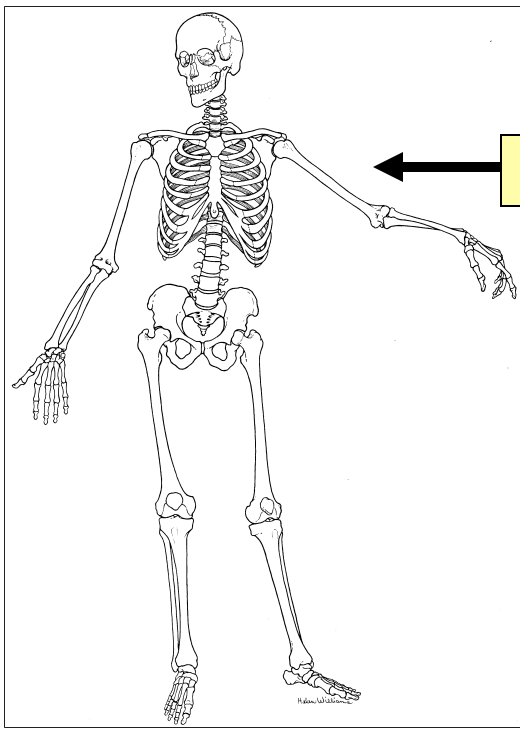
First to have true **jaws**; Jaws enable Vertebrates to become dominant predators

Ambush predators?

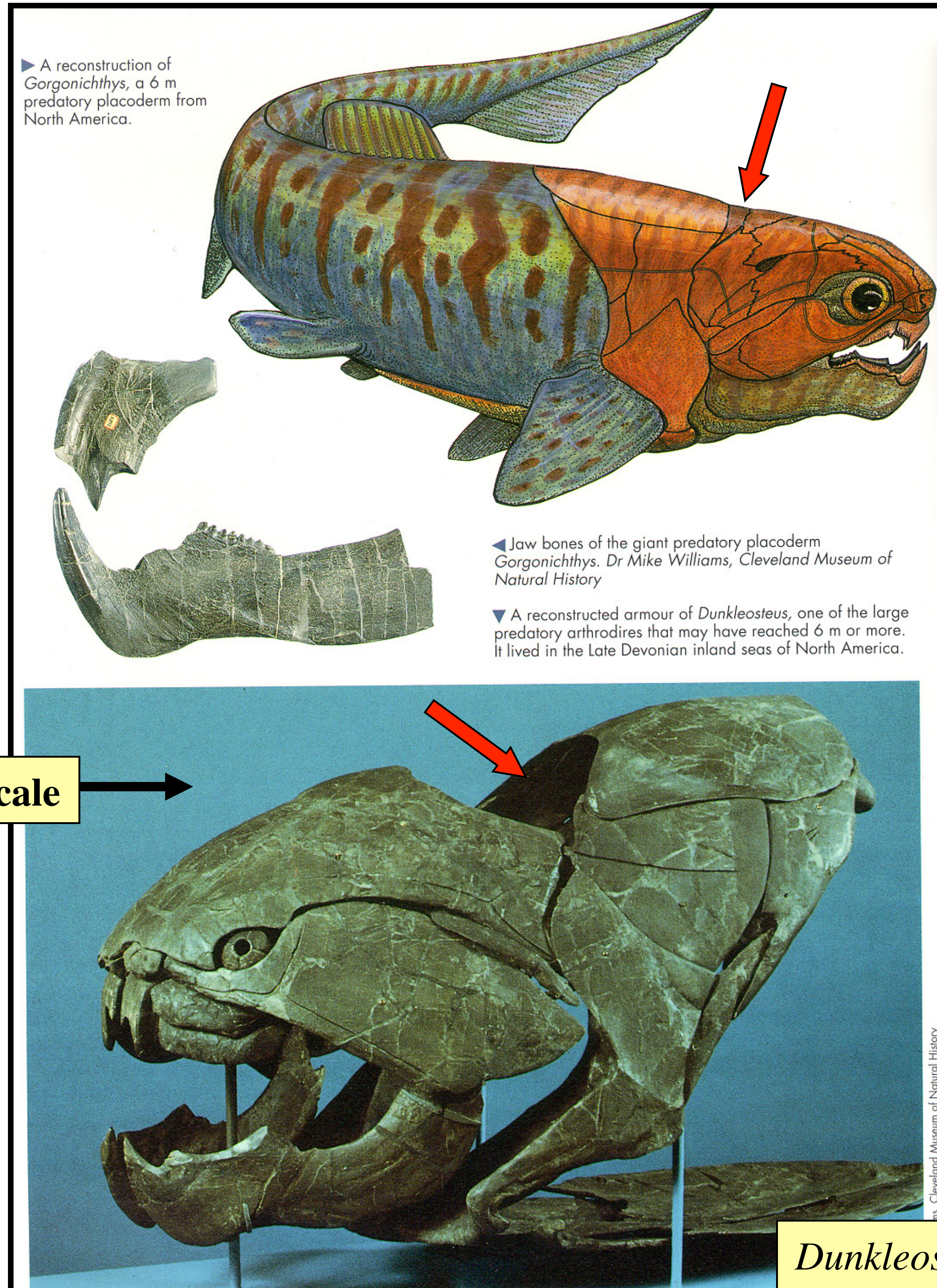
PLACODERMS
(Arthodires)

Major Predators of Devonian Seas

Hinged between head & Thoracic armor plates

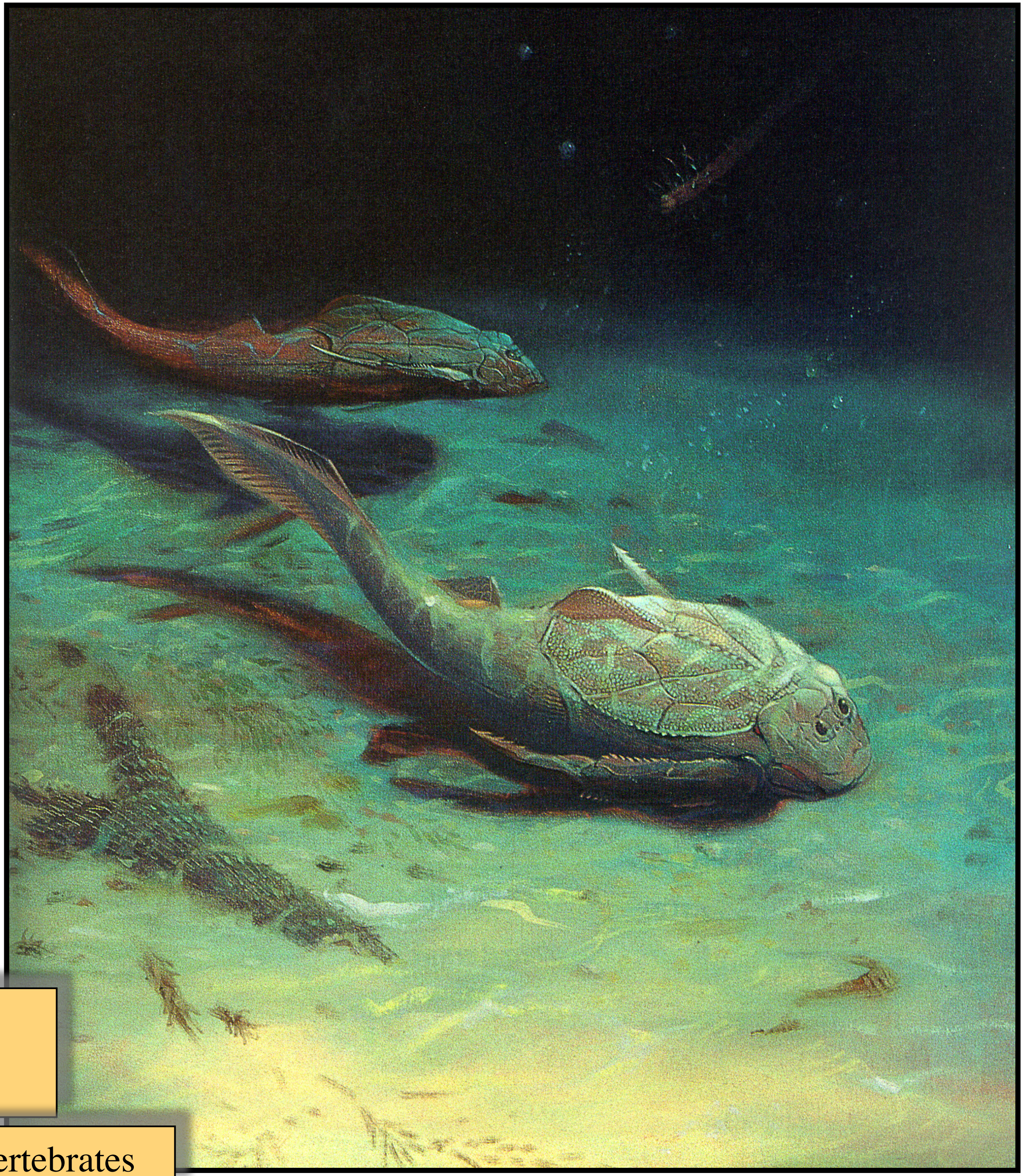


Scale



Dunkleosteous

PLACODERMI (Antiarchs)

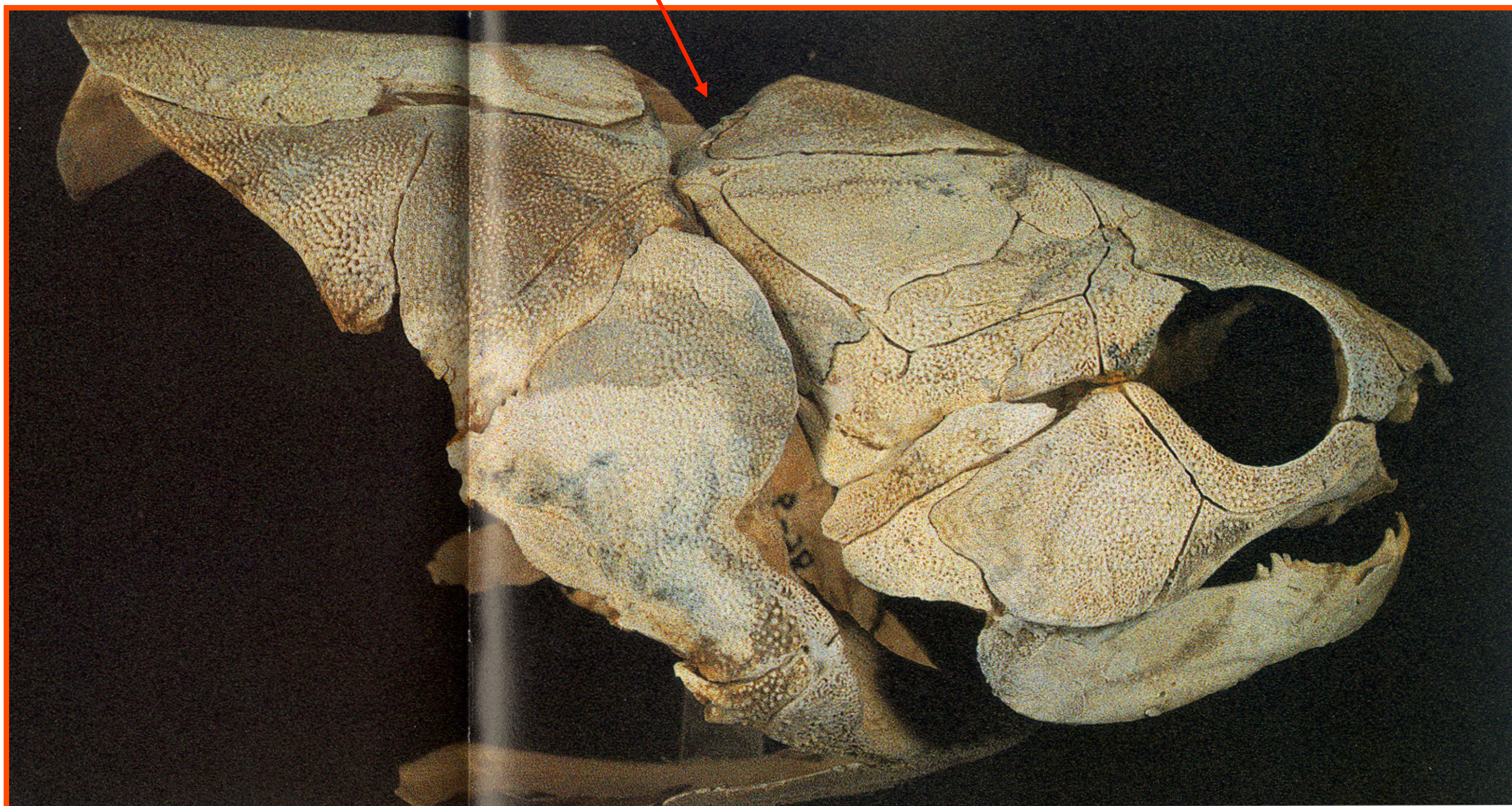


First to successfully invade continental waters

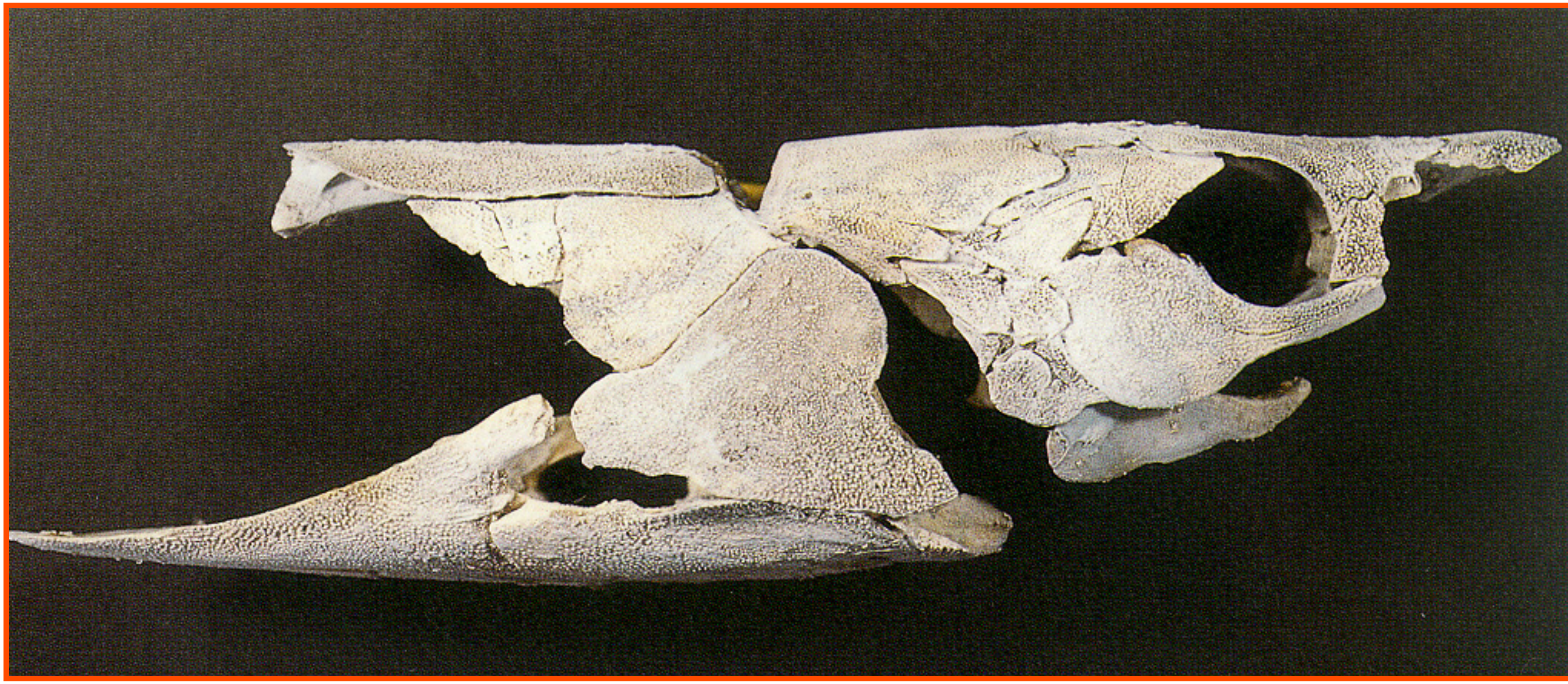
Might be first air breathing vertebrates

Arthrodire : Late Devonian of Australia

Hinge

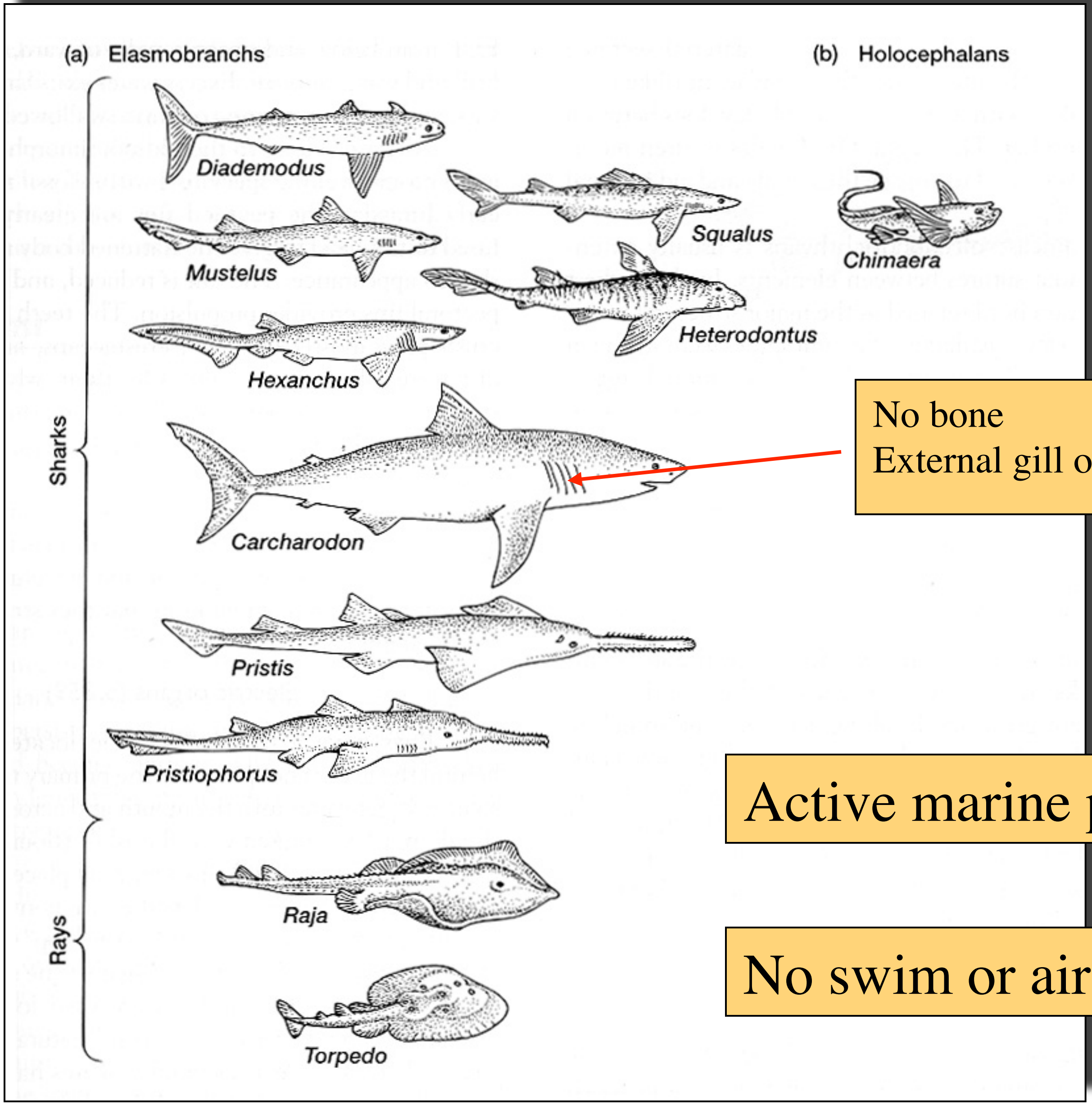


Arthrodire : Late Devonian of Australia



Note: no ossified internal skeleton

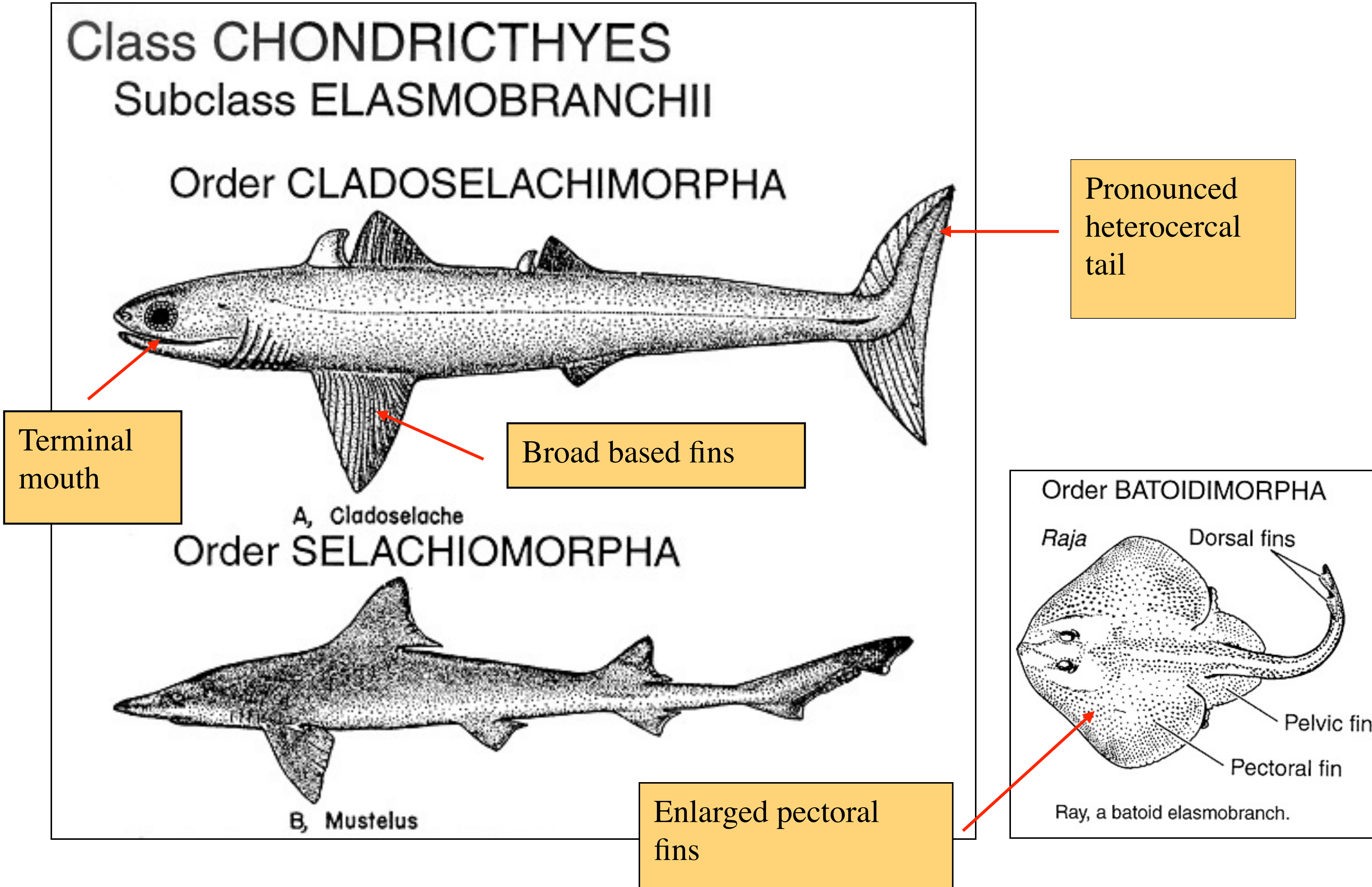
Class CHONDRICTHYES: **(modern)** Subclasses: Elasmobranchii & Holocephali



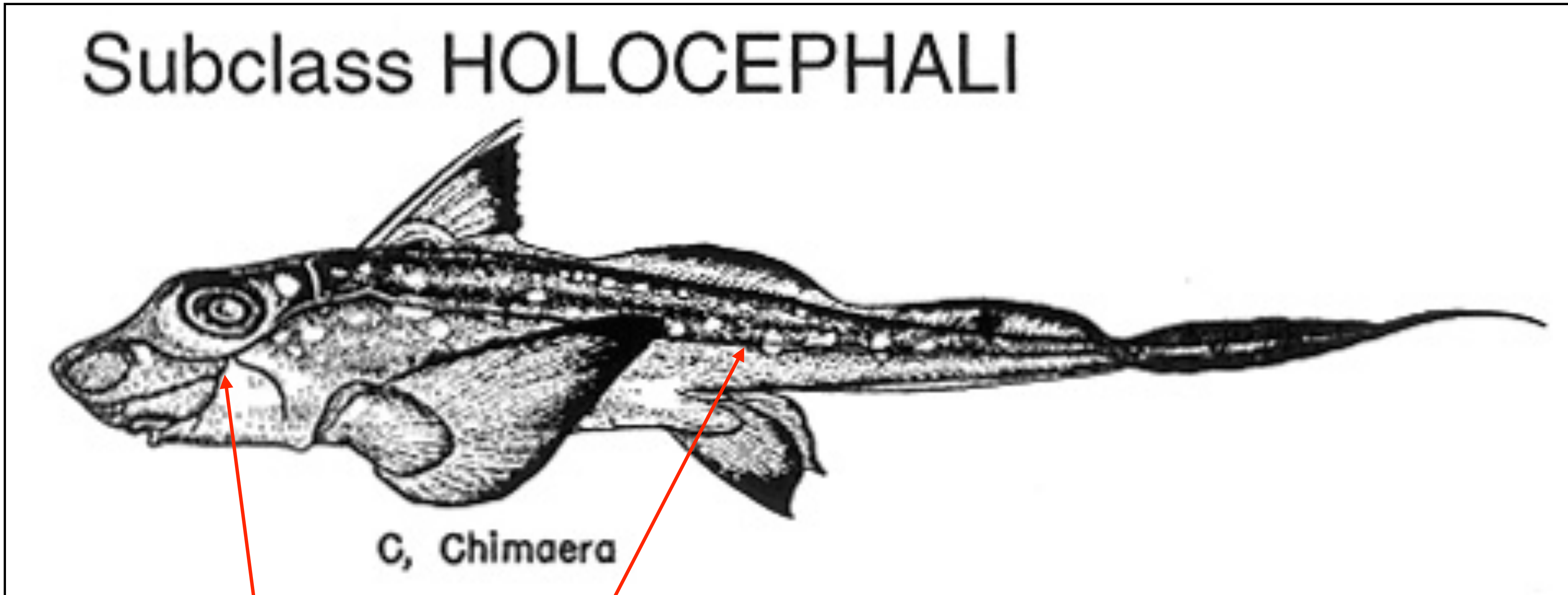
No bone
External gill openings

Active marine predators

No swim or air bladders

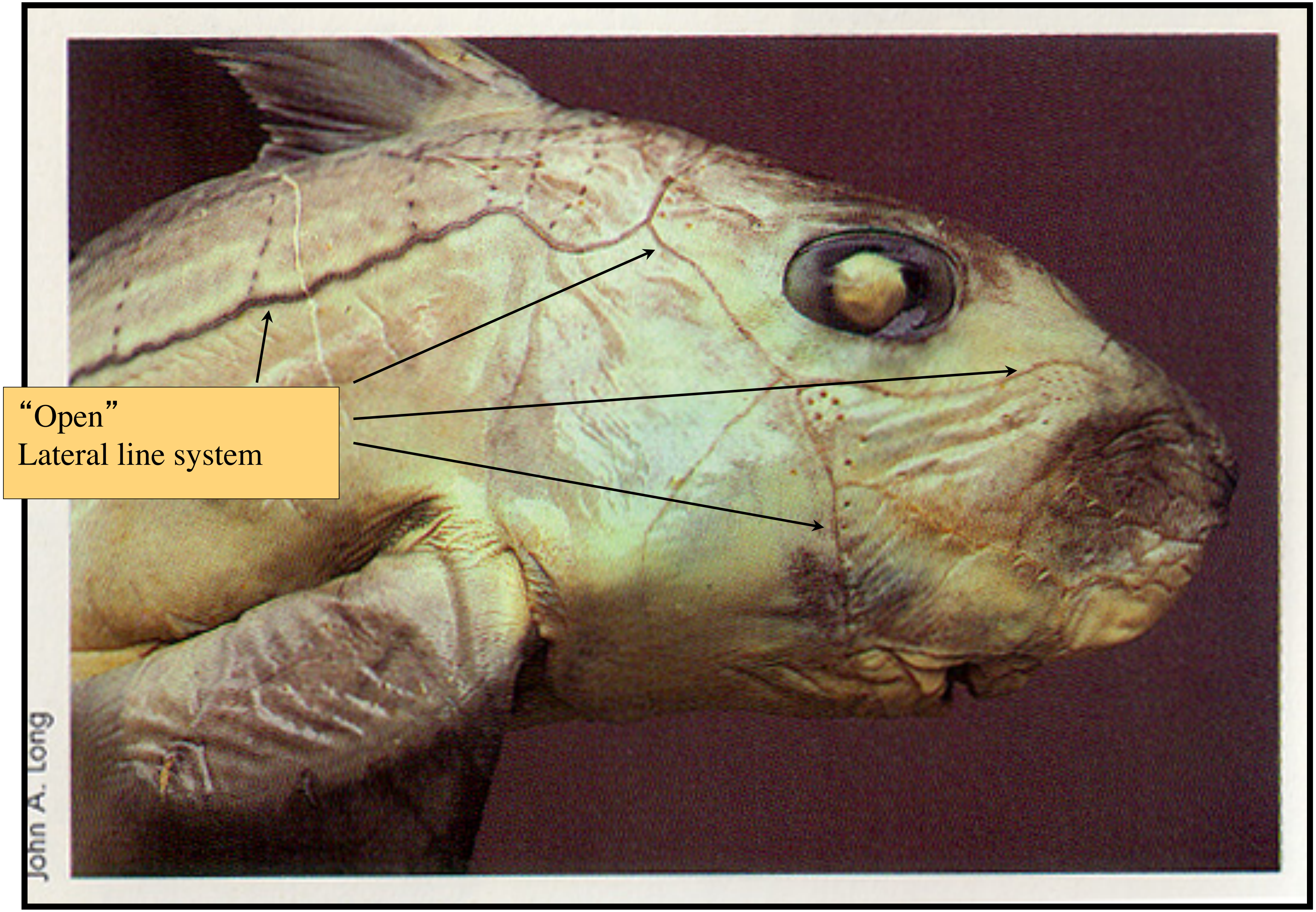

Class CHONDRICTHYES
Subclass ELASMOBRANCHII
Order CLADOSELACHIMORPHA
Pronounced heterocercal tail
Terminal mouth
Broad based fins
A, Cladoselache
Order SELACHIOMORPHA
B, Mustelus
Order BATOIDIMORPHA
Raja
Dorsal fins
Pelvic fin
Pectoral fin
Ray, a batoid elasmobranch.
Enlarged pectoral fins

Specialized, deep water shellfish feeders

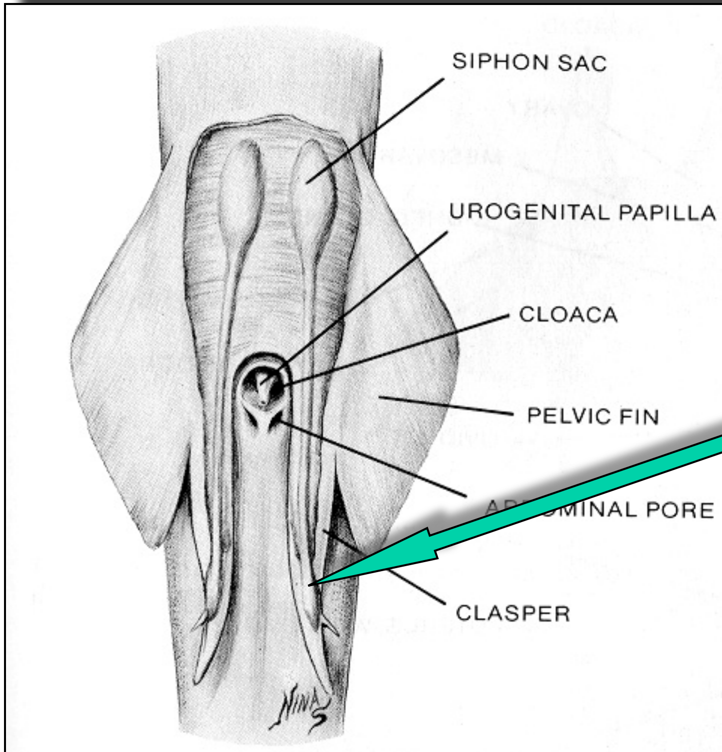


Scale-less,
Open lateral line canals

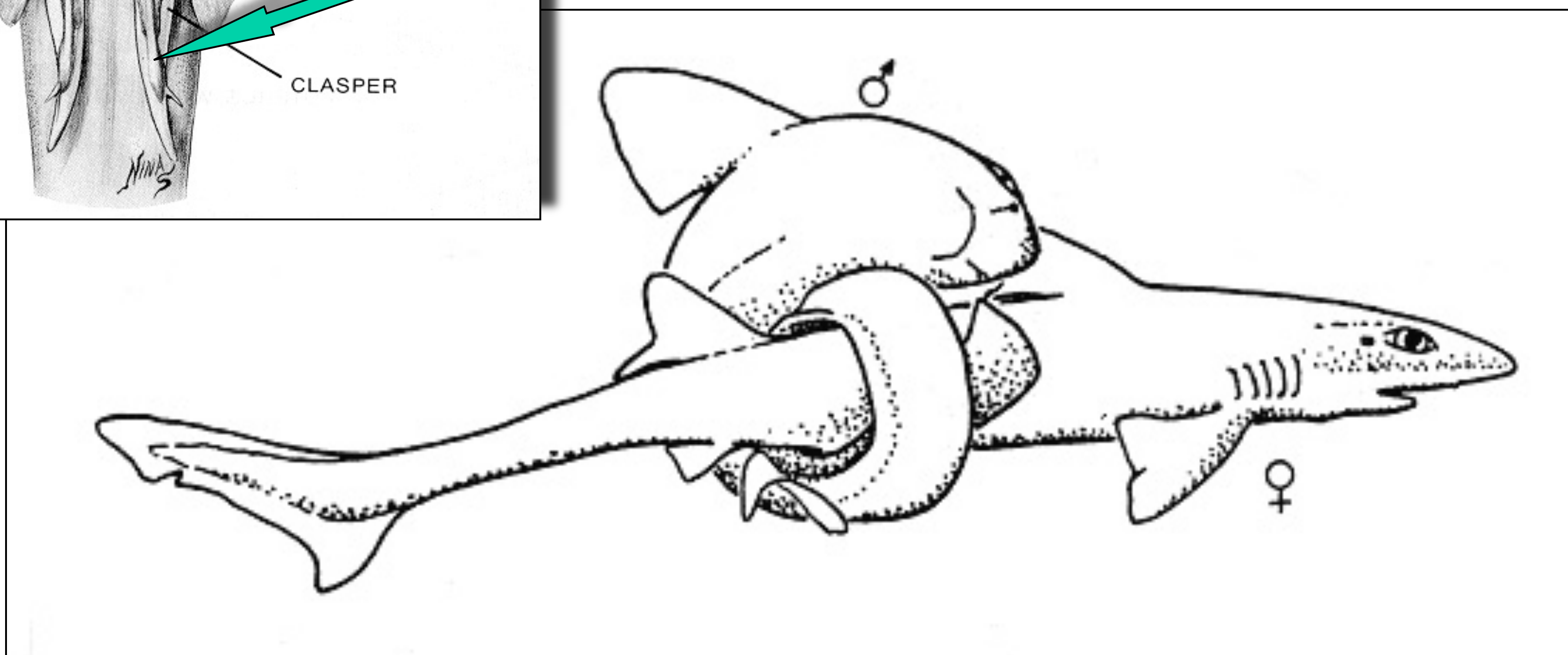
Holocephalian (“Ratfish”)



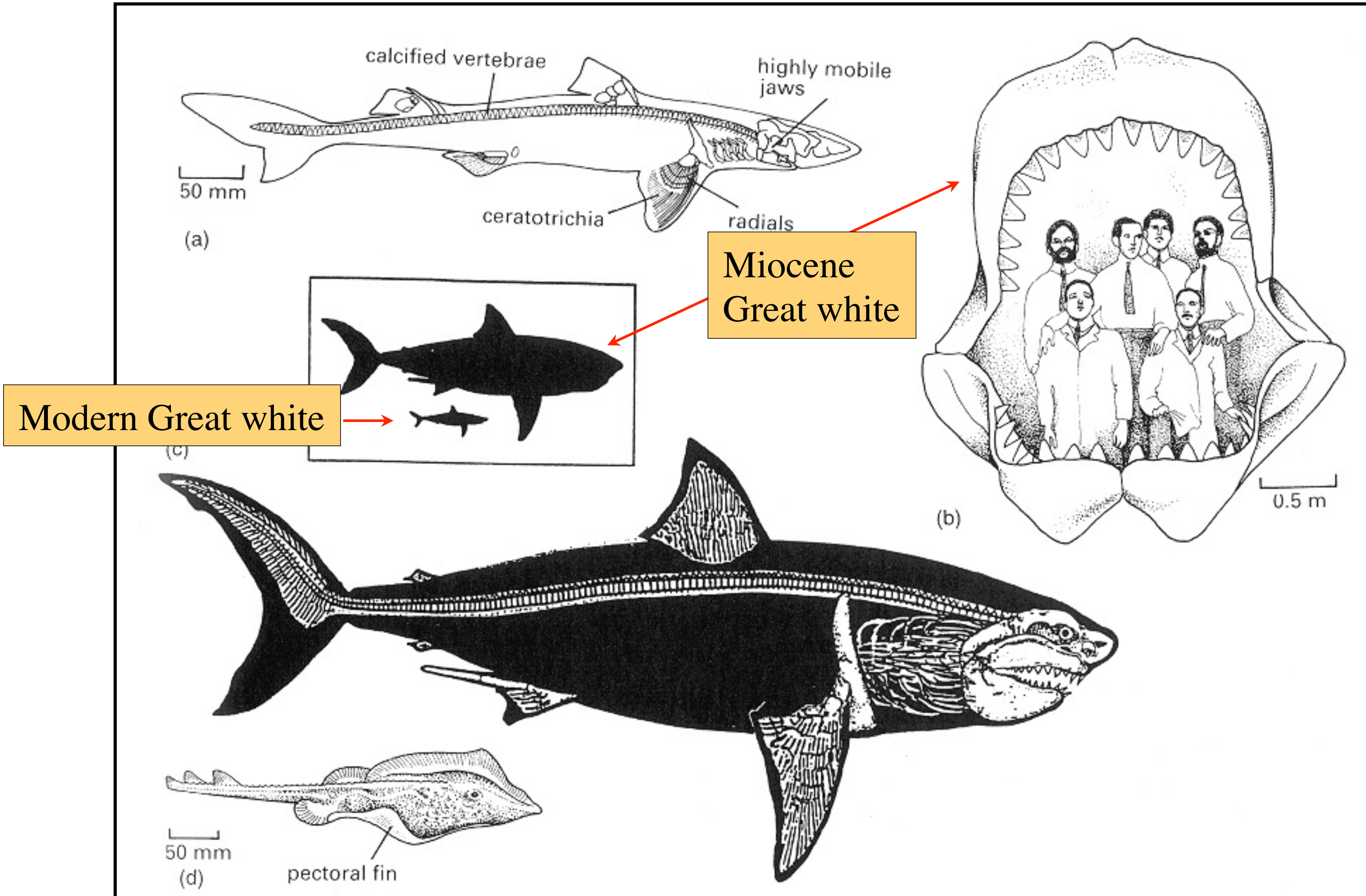
Internal Fertilization in Most Chondricthyians



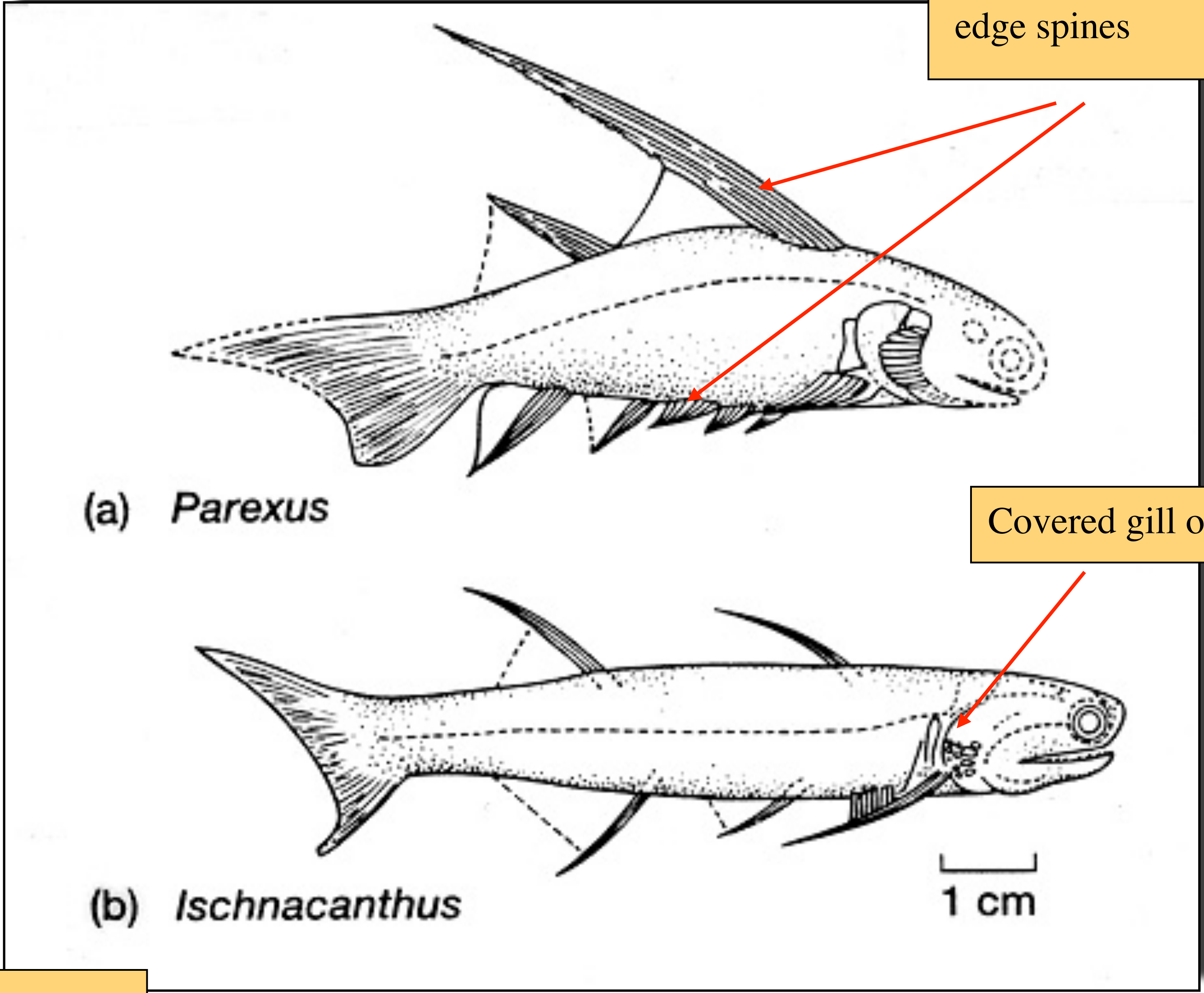
“Claspers”on pelvic fins of males



Elasmobranchs: large predators (marine mammal specialists)



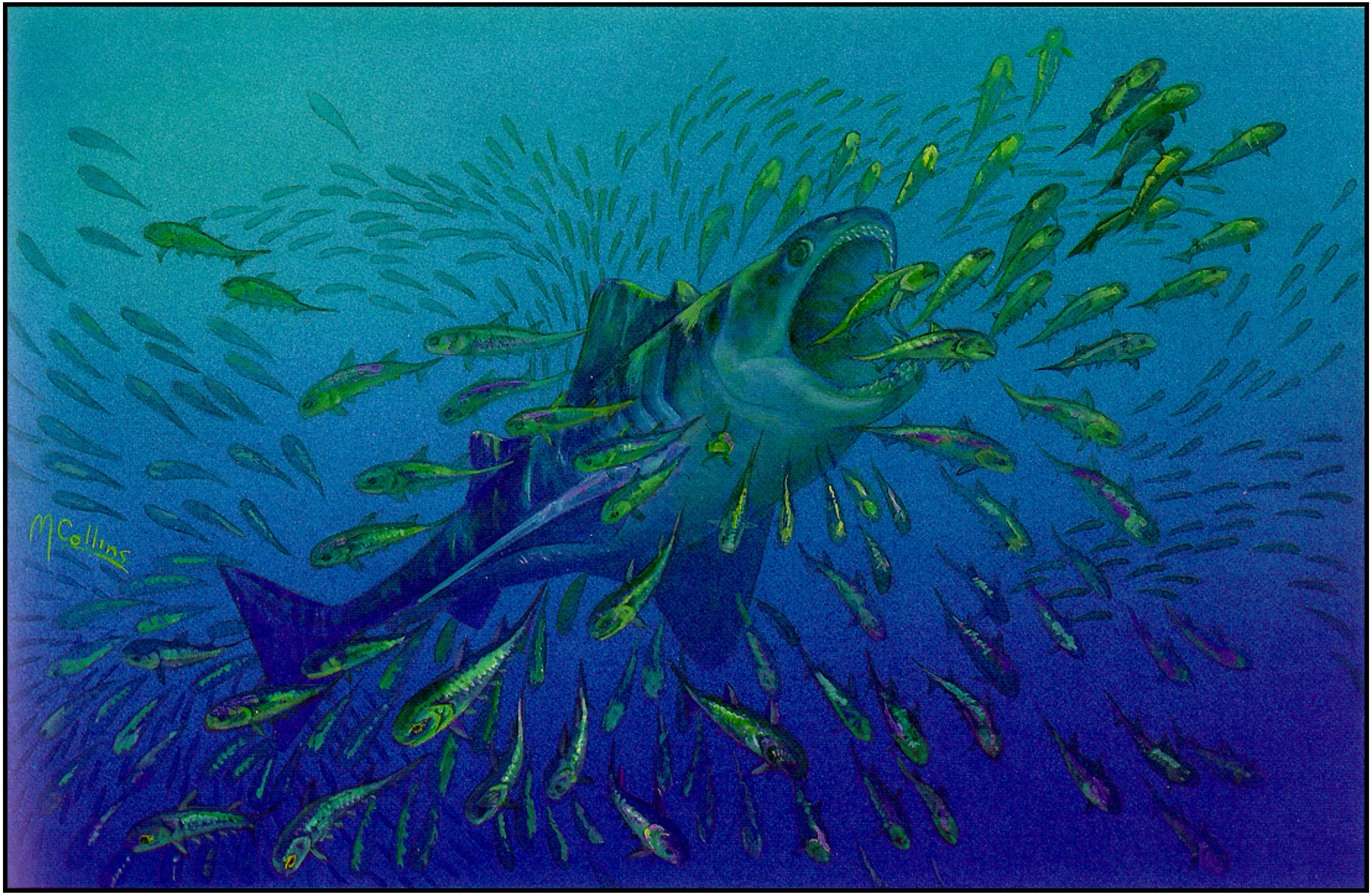
Class ACANTHODII



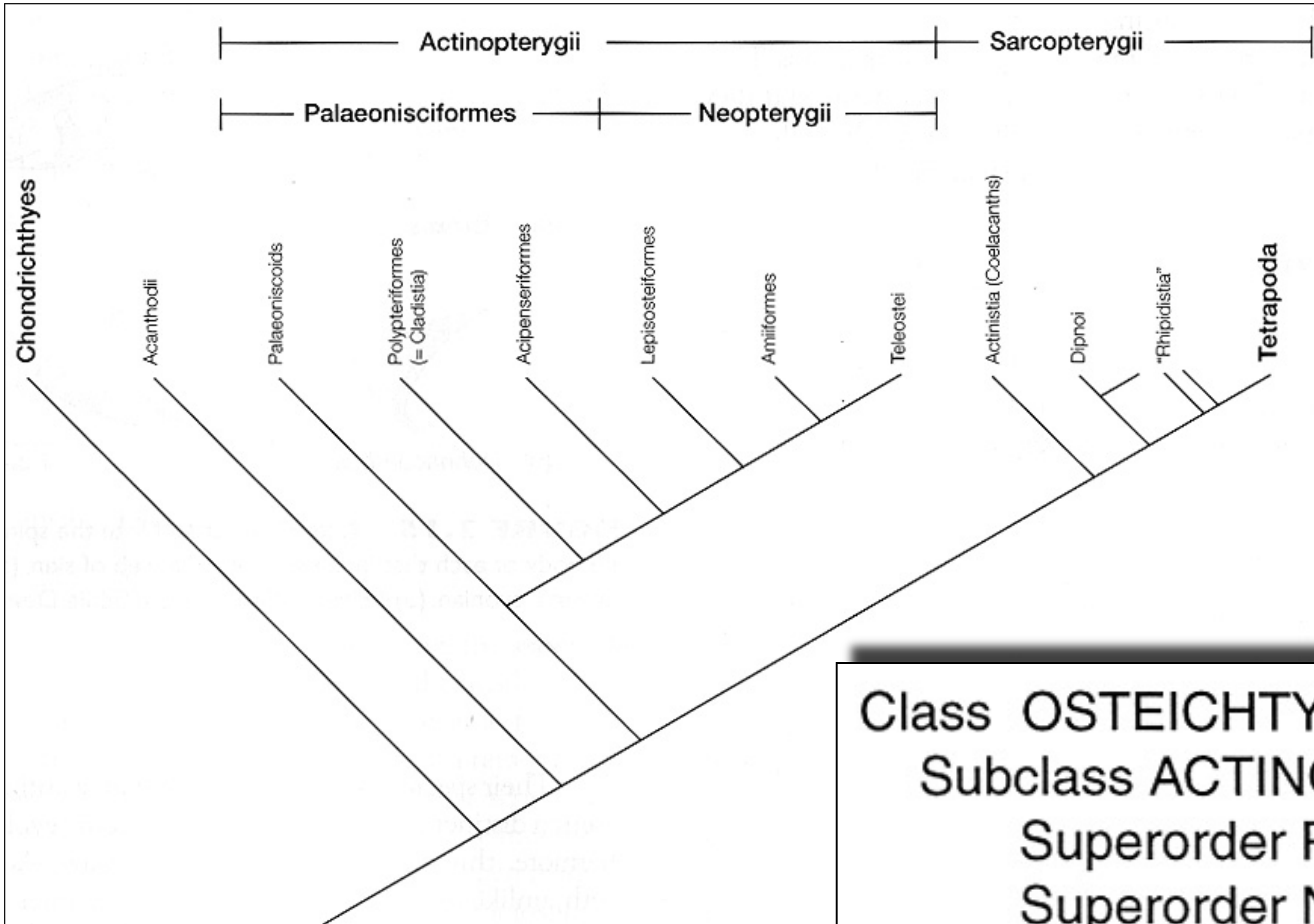
Small, marine

Late Devonian Seas

Cladoselache & Acanthodians



Class OSTEICHTYHES : BONY FISHES



Class OSTEICHTYES
- Subclass ACTINOPTERYGII
  - Superorder Palaeonisciformes
  - Superorder Neopterygii
- Subclass SARCOPTERYGII
  - Superorder Crossopterygii
  - Superorder Dipnoi

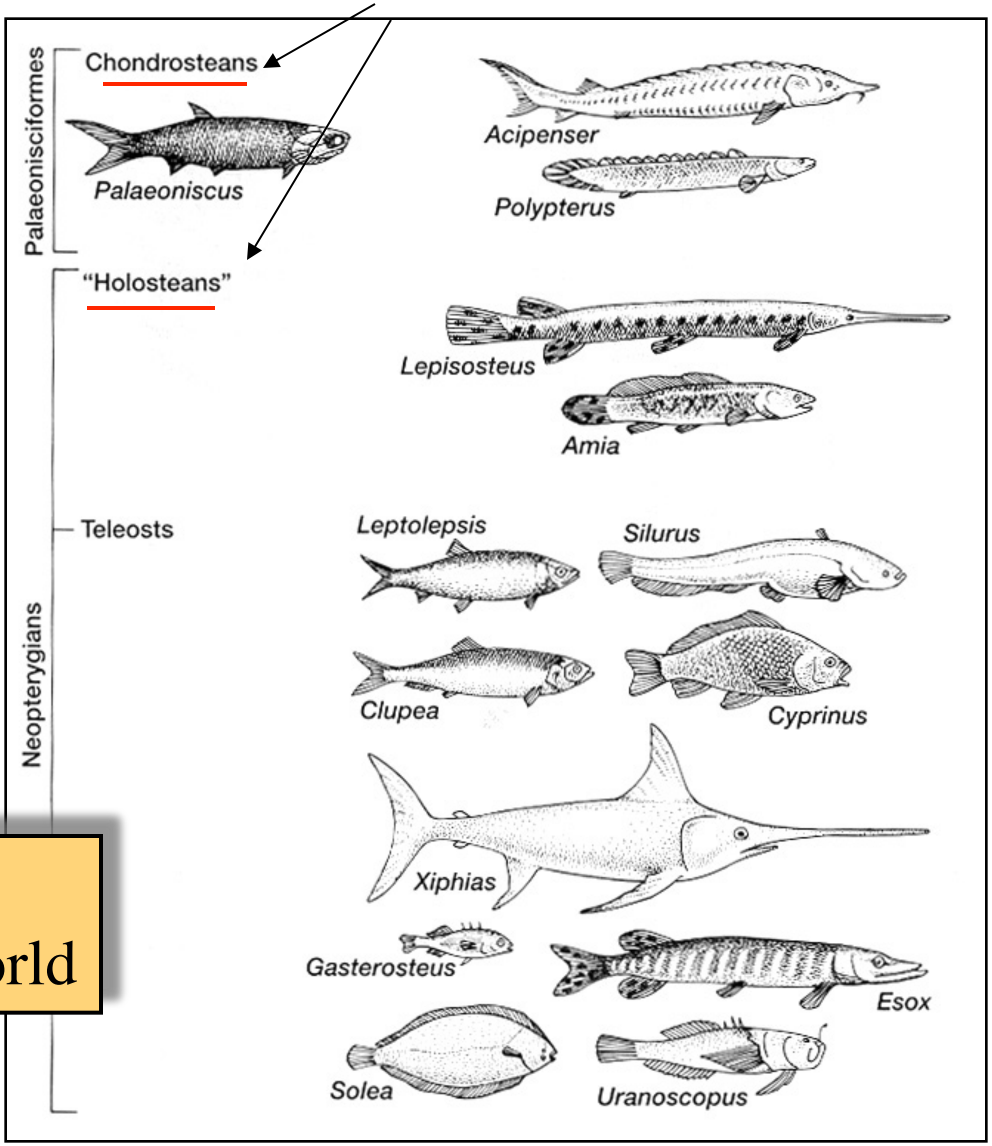
Class OSTEICHTHYES

Subclass ACTINOPTERYGII

Superorder PALAEONISCIFORMES

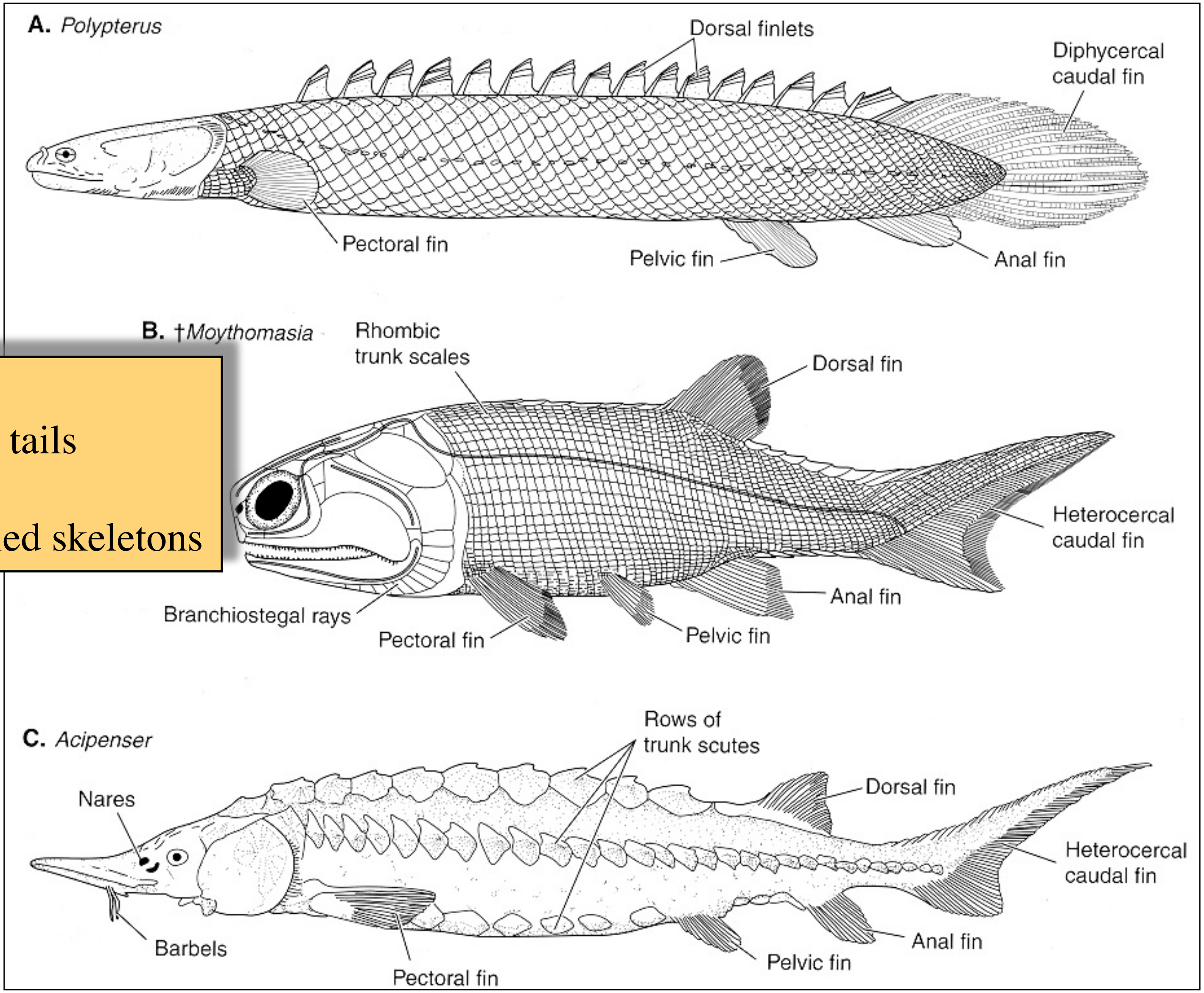
Superorder NEOPTERYGII

Grades (not clades)



Teleosts: most numerous of all vertebrates in modern world

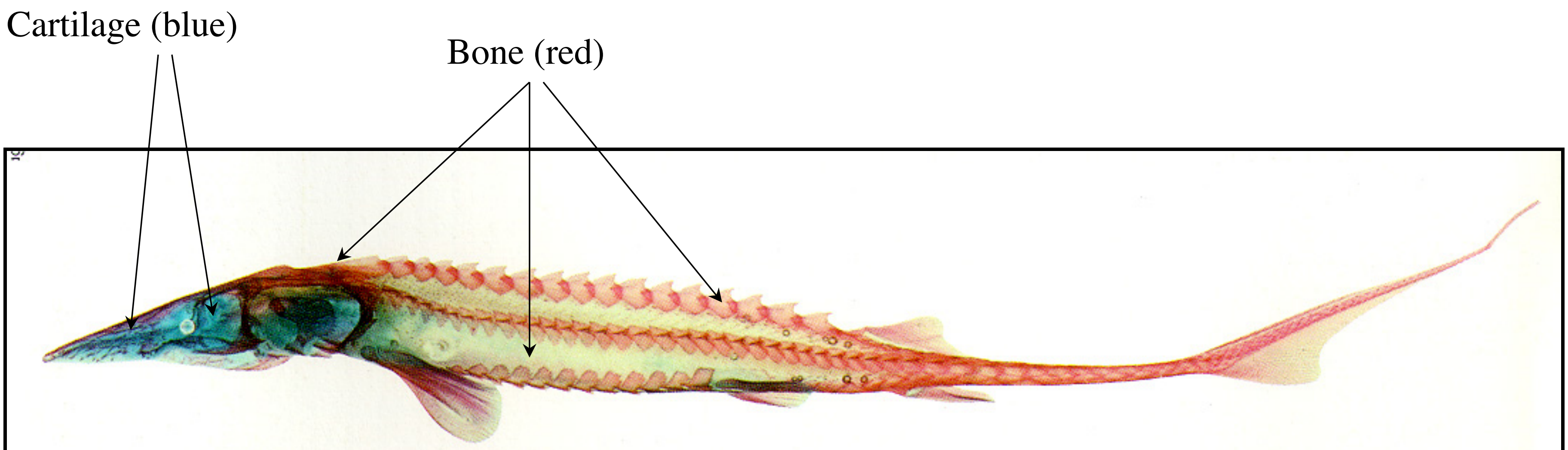
PALAEONISCIFORMES (“Chondrosteans”)



Typically: heavy scales
heterocercal tails
long gapes
poorly ossified skeletons

Sturgeon = chrondrostean (primitive actinopterygian)

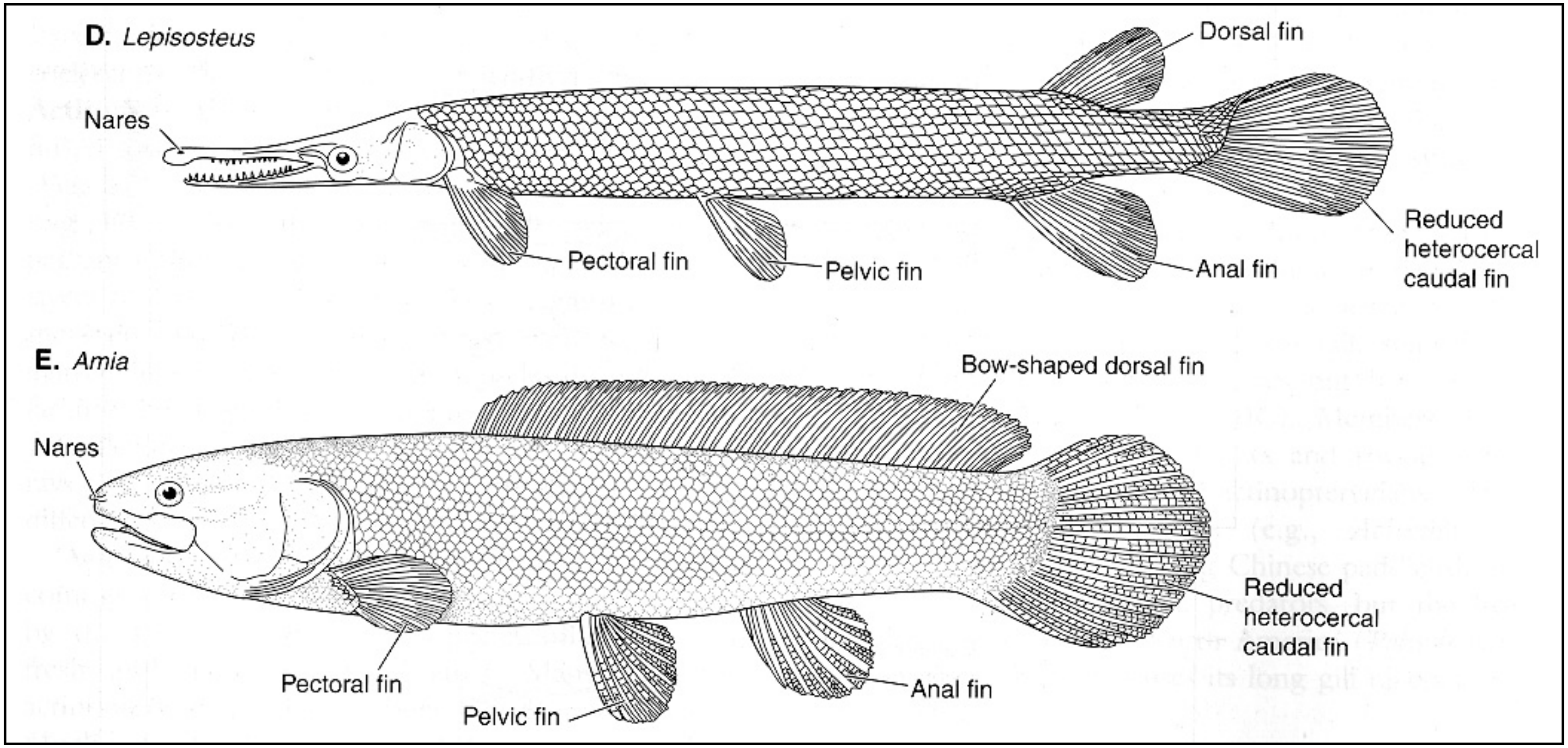
Chondrosteans : poorly ossified internal skeleton



▲ A stained specimen of the sturgeon *Scaphirhynchus* showing internal cartilage and bones.

Primitive NEOPTERYGII ("Holosteans")

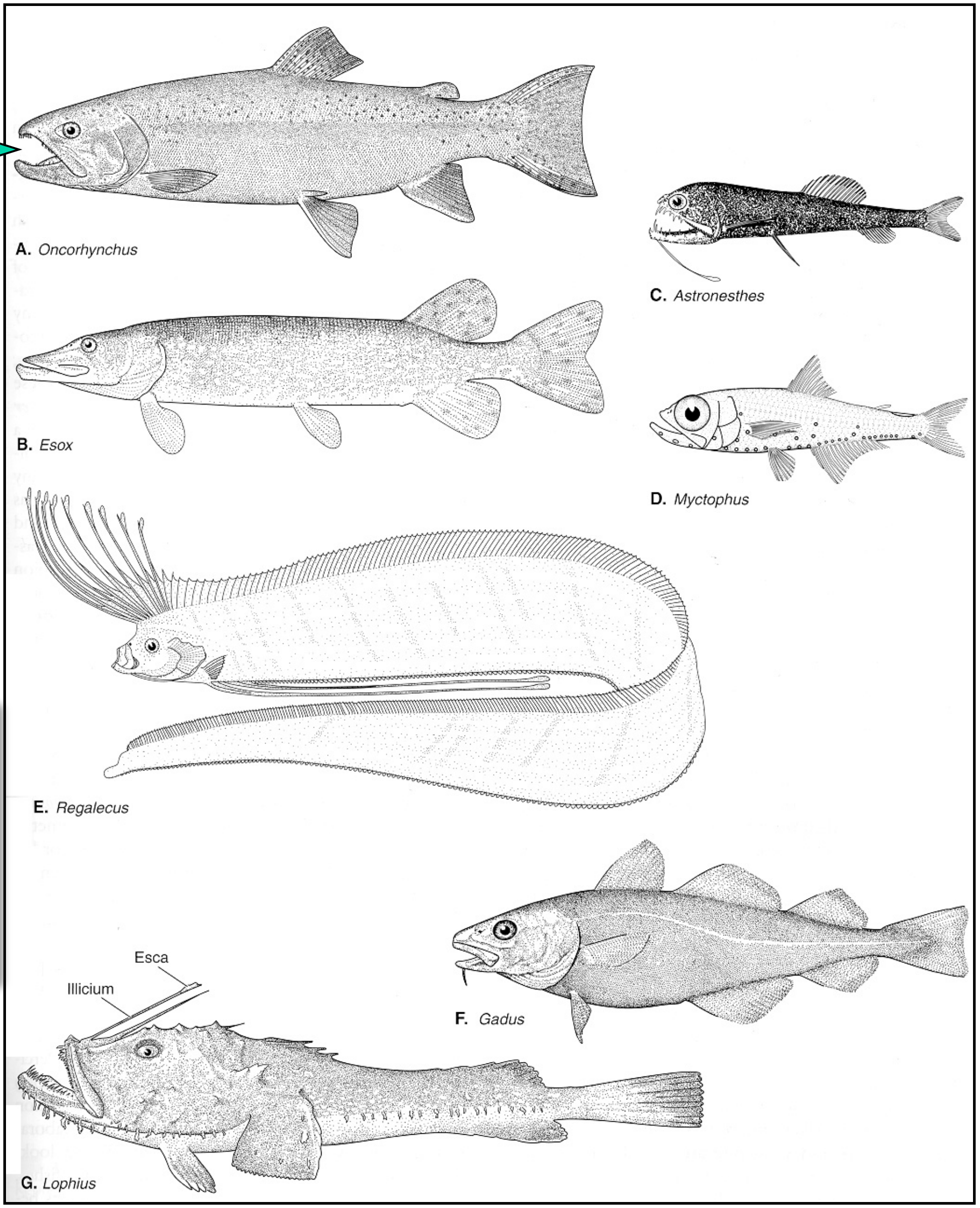
Relicts in Mississippi - Missouri Drainage



Reduced heterocercal tails
Well-ossified internal skeleton
Heavy scales

Advanced Neopterygians: Teleosts

Salmon & trout:
primitive teleosts



Typically: homocercal tails
reduced scales
protrusible jaws
strongly ossified skeletons

Advanced Neopterygians: Teleosts

Guppy

Enormous size range

Trenendous structural, behavioral & ecological diversity

Marlin