Palaeontology

Lecture 8

Animal Kigdom: Chordates, Tetrapods, Amniotes

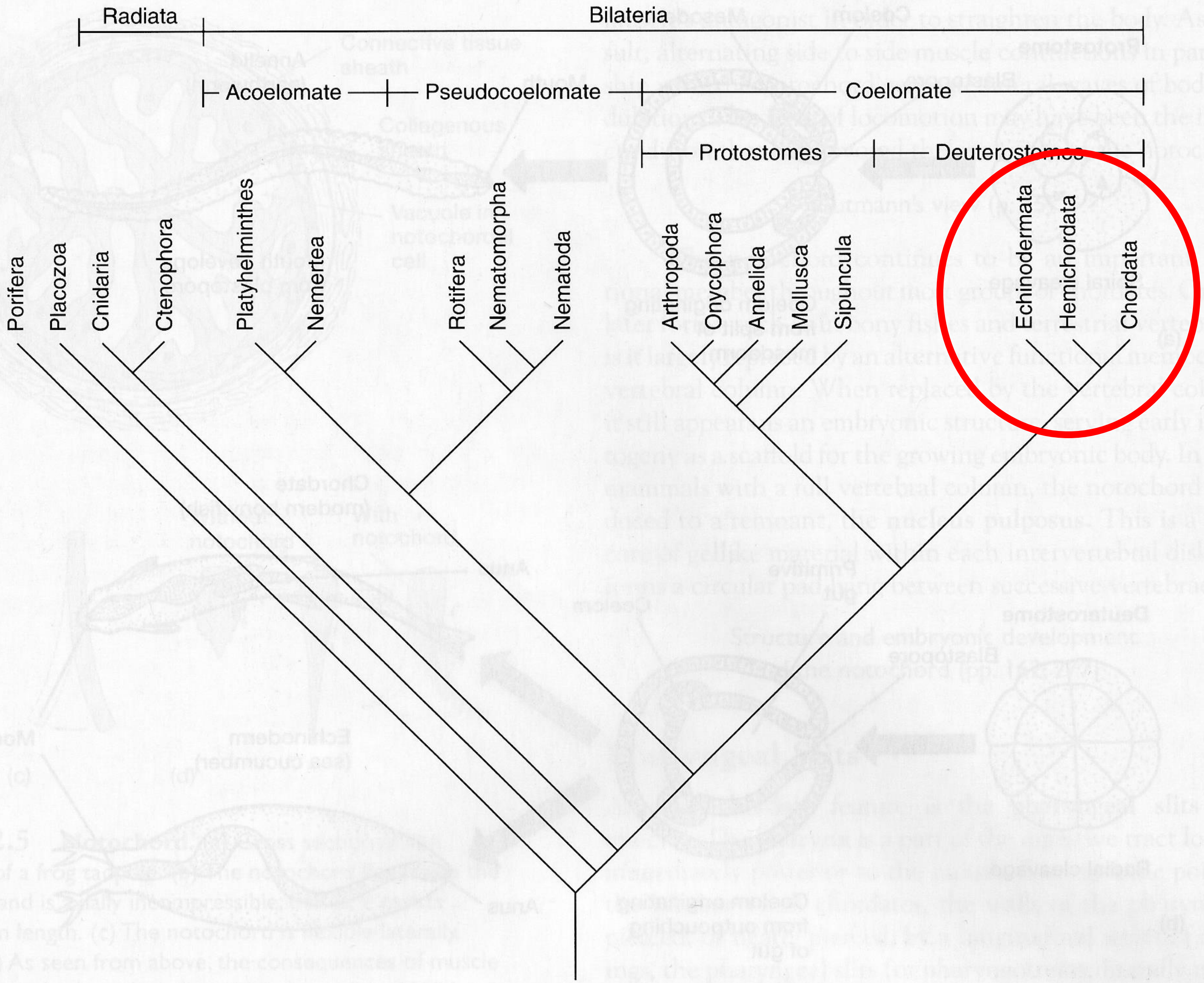


FIGURE 2.2 **Phylogenetic relationships within major animal groups.** Note that chordates are coelomate deuterostomes along with hemichordates and echinoderms. The protostomes are a separate lineage.

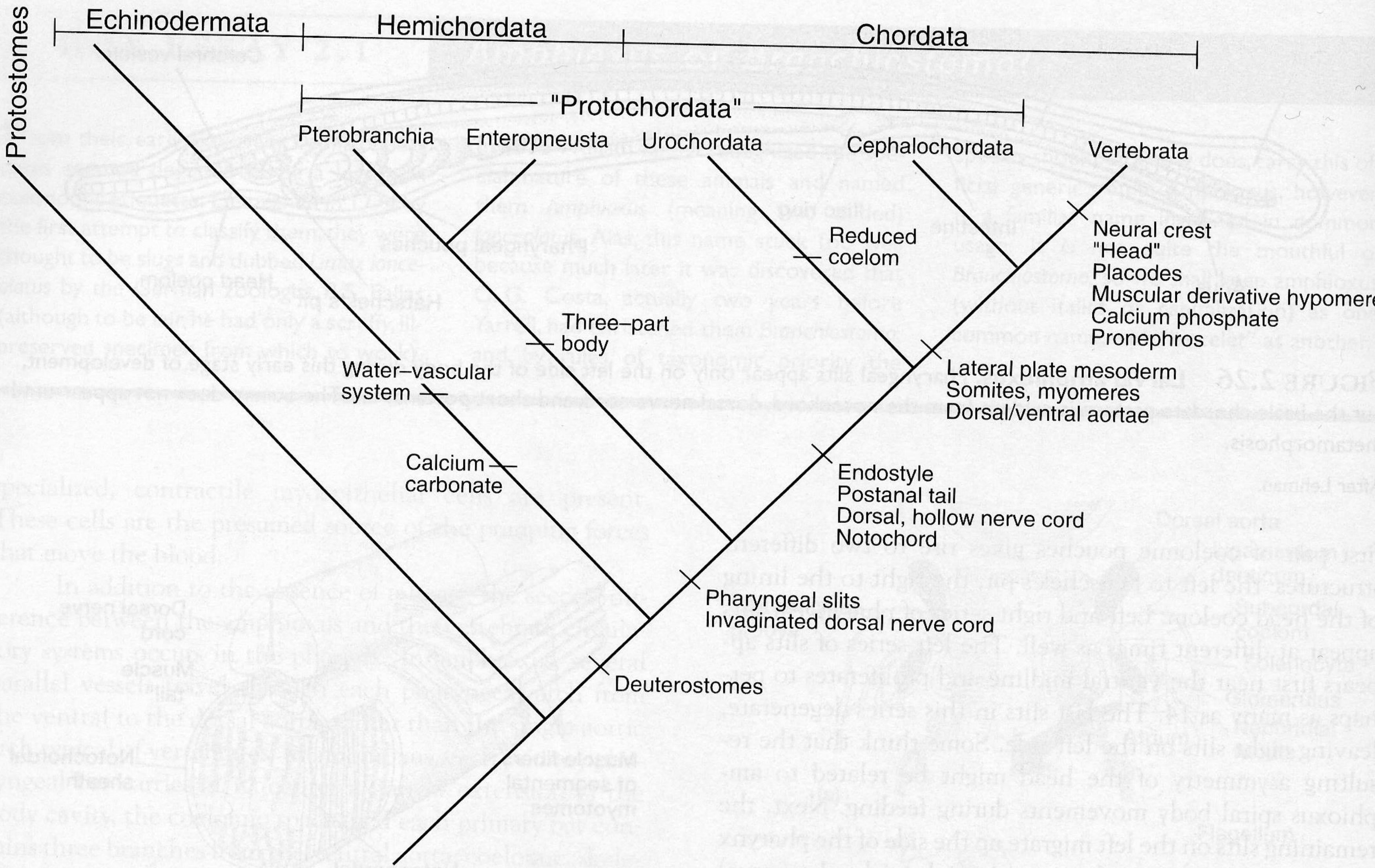
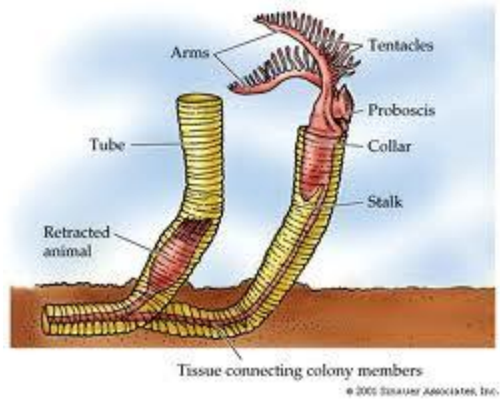


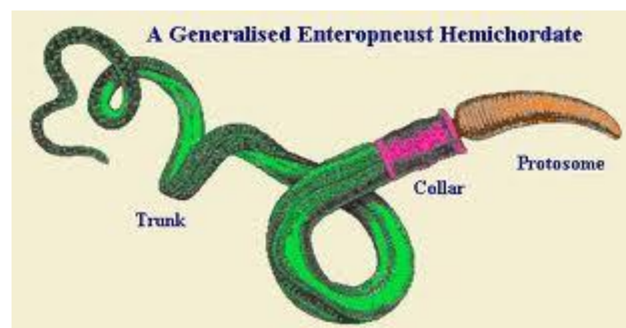
FIGURE 2.28 **Phylogenetic relationships within the "protochordates."** Protochordates are compared to echinoderms and, more distantly, to protostomes.

Phylum: Hemichordata (Greek chordi)

- Class Pterobranchia



- Class Enteropneusta

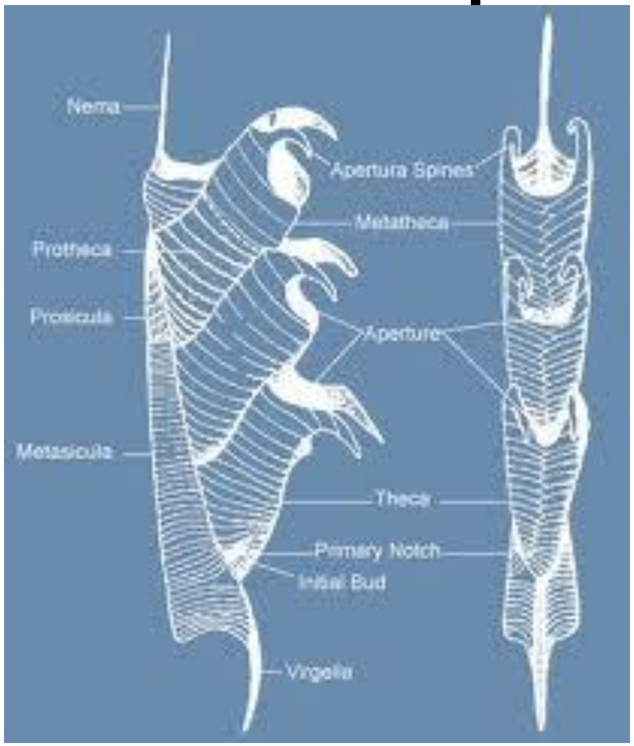


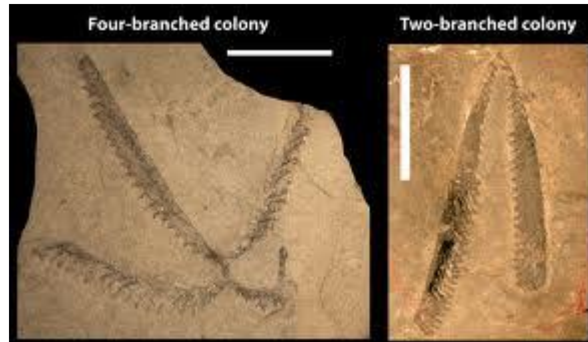
- Class Graptolithina

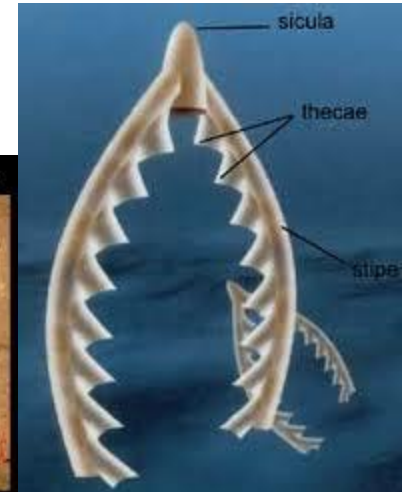
Class Graptolithina

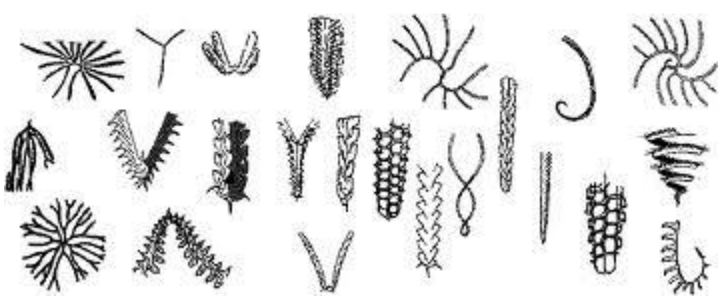
- Stratigraphic range Middle Cambrian – Middle Carboniferous
- Pelagic floating organisms
- Characteristic of L. Paleozoic
- Exoskeleton made of Chitin
- They form colonies consisting of 1, 2 or more branches
- Preservation in fine-grained sediments

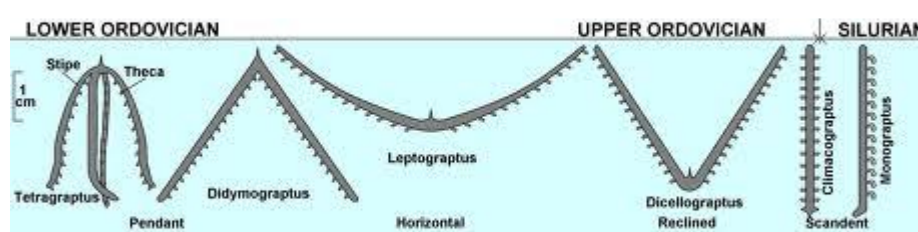
Class Graptolithina





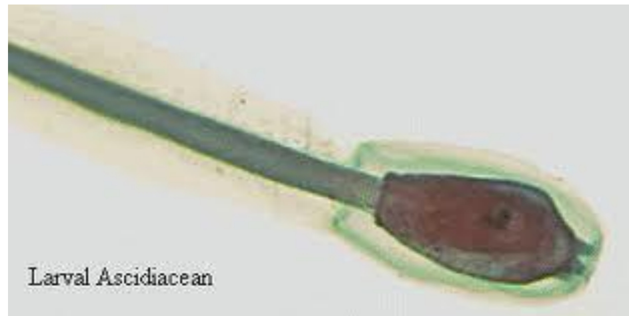


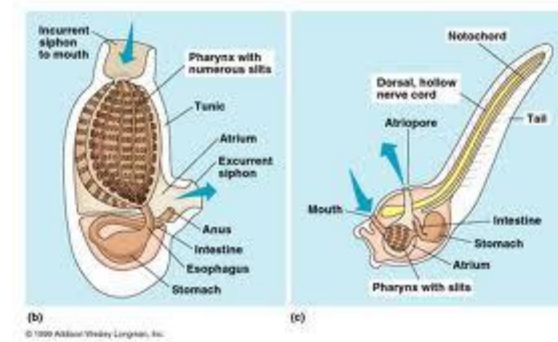




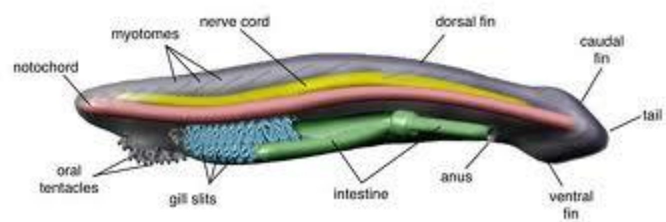
Phylum: Chordata (Greek chordi)

- Subphylum Urochordata





- Subphylum Cephalochordata



- Subphylum Vertebrates

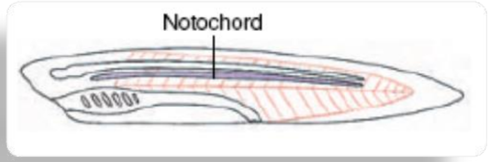
Phylum: Chordata

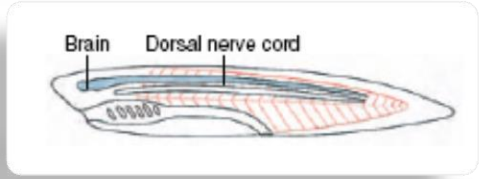
Some Biological Innovations

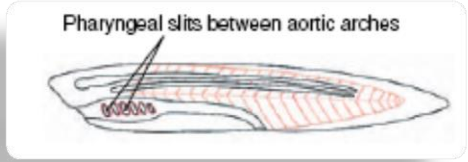
- Internal skeleton
- Perforated pharynx
- Feeding with preying
- Pairs of appendages

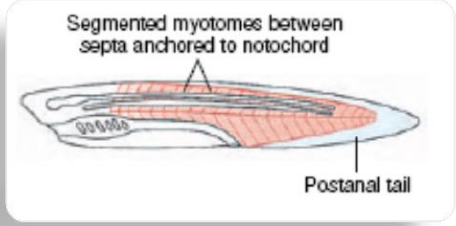
major chordate features

- All chordates show all major chordate features at some point in their life cycles
  - **Notochord**
  - **dorsal hollow nerve cord**
  - **pharyngeal slits**
  - **post-anal tail**

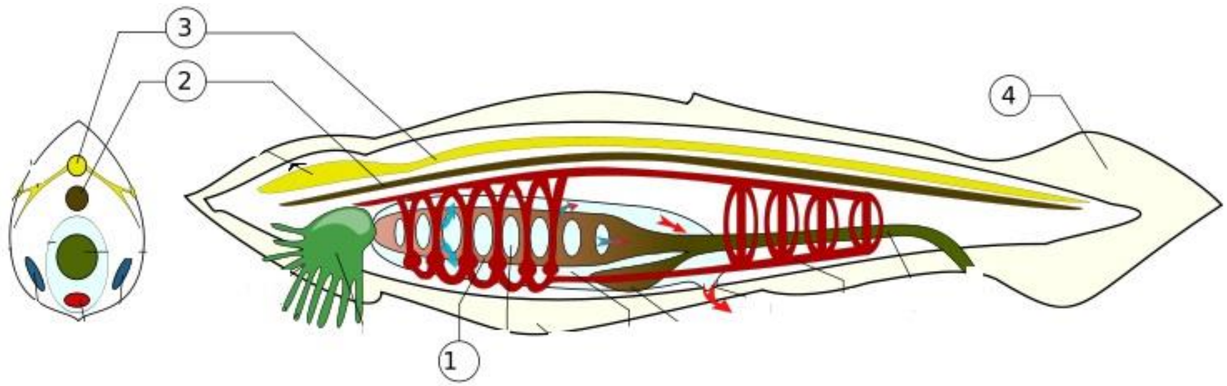








4 major chordate features



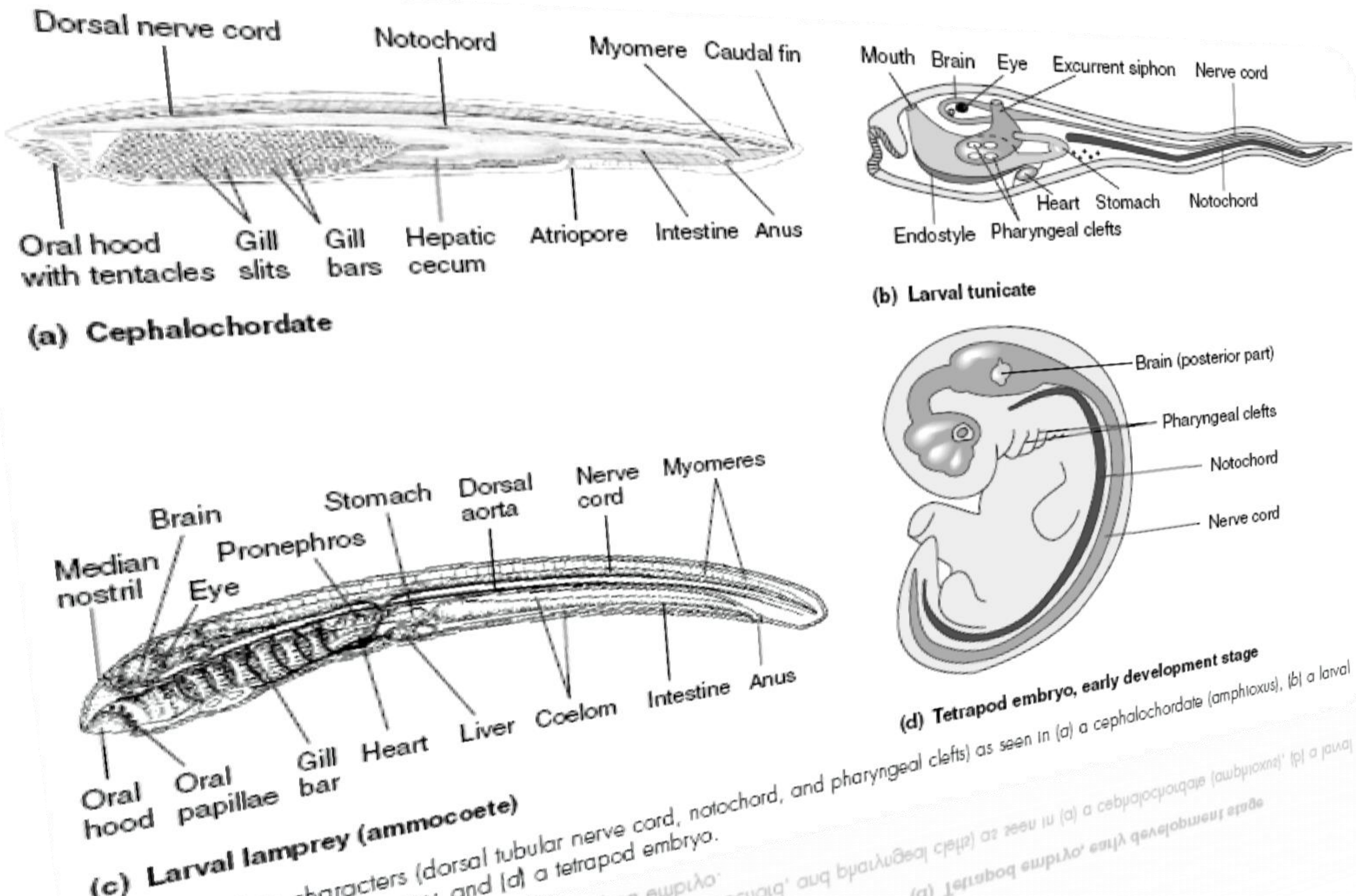
*Branchiostoma lanceolatum (*Cephalochordata*)*

1. pharyngeal slits

2. Notochord

3. dorsal hollow nerve cord

4. post-anal tail



Three chordate characters (dorsal tubular nerve cord, notochord, and pharyngeal clefts) as seen in (a) a cephalochordate (amphioxus), (b) a larval tunicate, (c) a larval lamprey, and (d) a tetrapod embryo.

What makes a vertebrate a vertebrate?

- The answer isn't as simple as you might think.
- a typical vertebrate feature, the **vertebral column**, or backbone, which surrounds and protects the main nerve cord
- Vertebral column consists of vertebrae
- Vertebrae consist of the **centrum** (a solid cylindrical body) which often encloses the notochord, a dorsal **neural arch** which encloses the spinal or nerve cord, and a ventral **hemal arch** enclosing blood vessels
- However the earliest vertebrates and living jawless fish today, hagfishes and lampreys, lack vertebral centra but they have neural arches (Craniata)

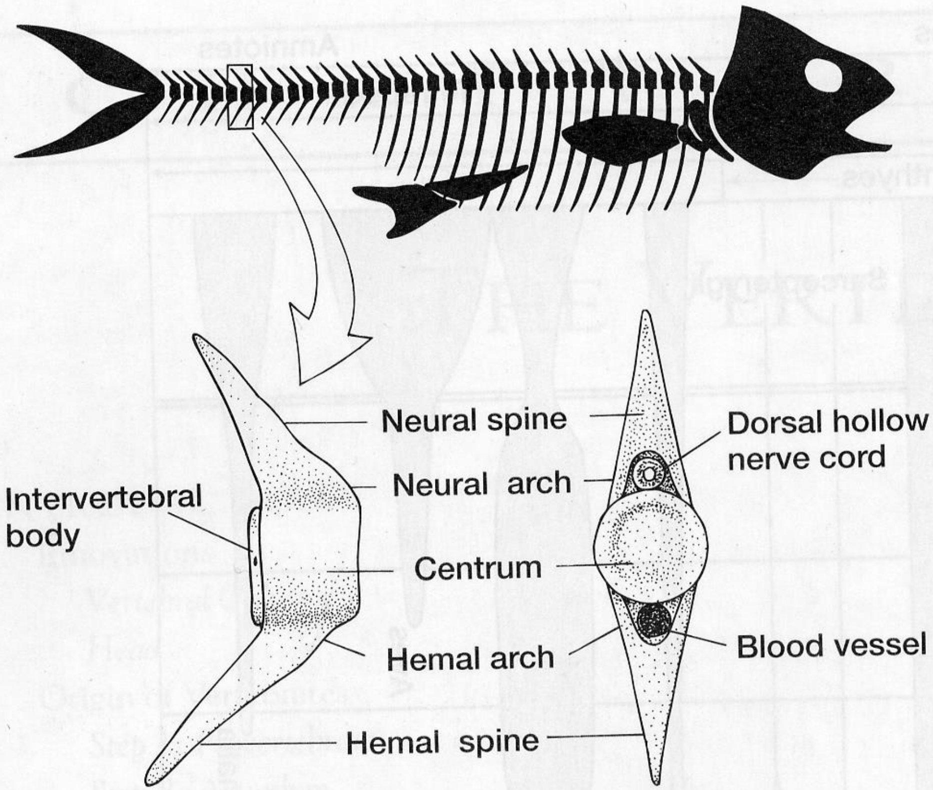


FIGURE 3.2 **Basic vertebrate.** Vertebrae replace the notochord as the predominant means of body support in advanced fishes and tetrapods. A typical vertebra usually consists of a single centrum, with a neural arch and a neural spine dorsally and a hemal arch and a hemal spine ventrally. The notochord becomes enclosed in the centrum. Intervertebral bodies are cartilaginous or fibrous pads that separate vertebrae. In adult mammals, these bodies are called intervertebral disks, which retain gellike cores that are remnants of the embryonic notochord.

Other common features in vertebrates

- The other major innovation that evolved in vertebrates is the **Cranium.** Paired eyes and ears, nose and other sensory organs of the head become prominent. A distinct brain is developed. The bony or cartilaginous cranium supports these sensory organs and encases the brain
- Another important vertebrate feature is the presence of the embryonic **neural crest cells** only found in vertebrates. In early development, as the nerve cord is forming, neural crest cells leave the nerve cord and move through the body. These cells form, or cause to form, many important nerves, neural ganglia, and many head and facial features.
- A well developed circulatory system with a heart

Early Chordates & early fishes

- The oldest chordate:

  Cathaymyrus diadexus (535 my)

Other primitive chordates (Yunnanozoa)

Yunnanozoon lividum

Haikouella lanceolata

- Oldest Craniata, fishes:

  Myllokunmingia fengjiaoa (535 my)

  Haikouichthys ercaicunensis

  Zhongjianichthys rostratus

oldest chordate

- *Cathaymyrus diadexus*
- 535 my

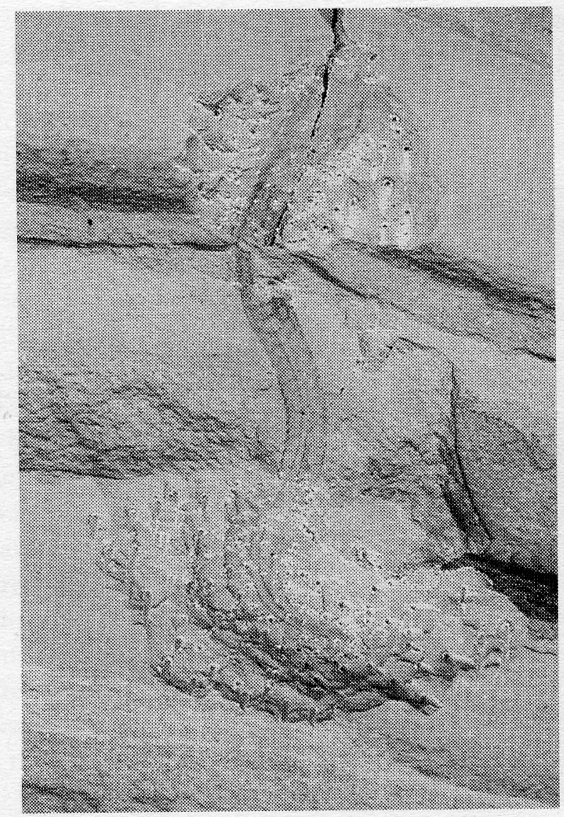
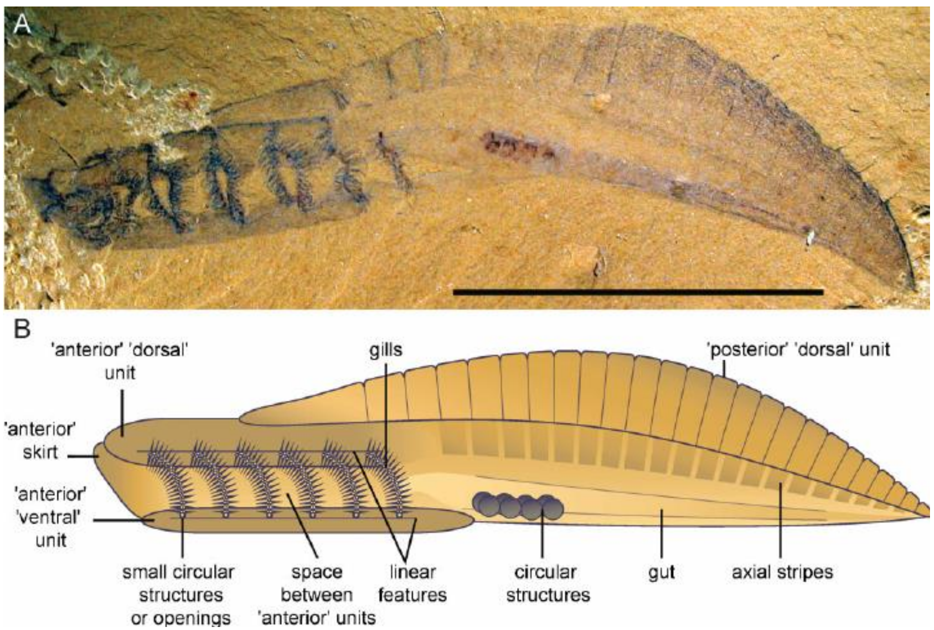


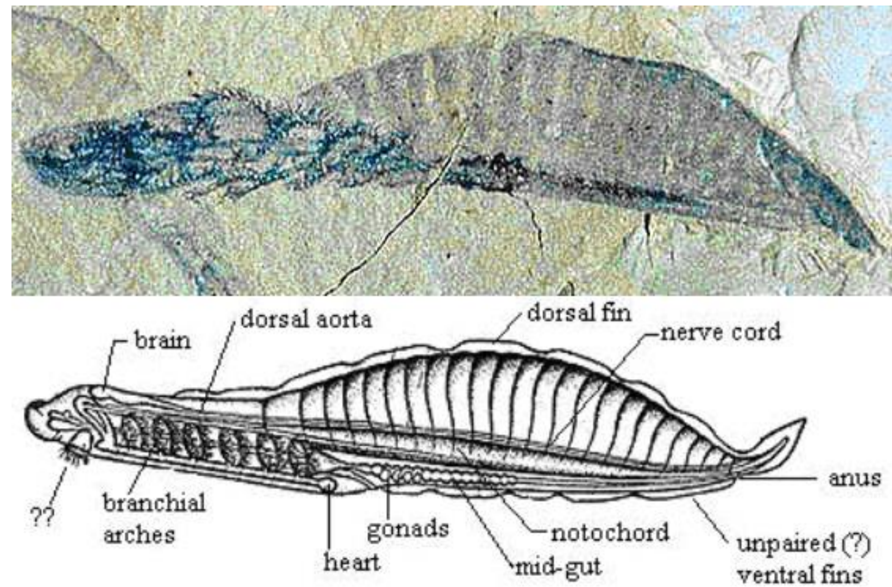
Fig. 62. The Chengjiang fossil *Cathaymyrus diadexus*, interpreted as the oldest chordate yet identified. The figure was electronically prepared to combine the images of part and counterpart of the specimen (courtesy of Dudley Simons). Specimen is about 2 cm long.

Other primitive chordates (Yunnanozoa)

Yunnanozoon lividum



Haikouella lanceolata

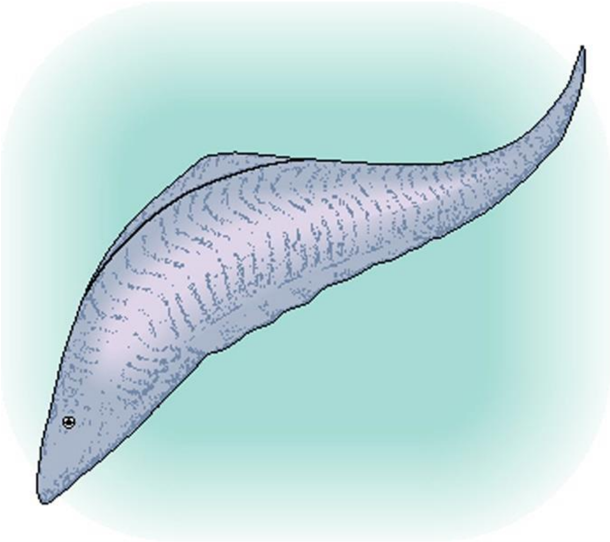


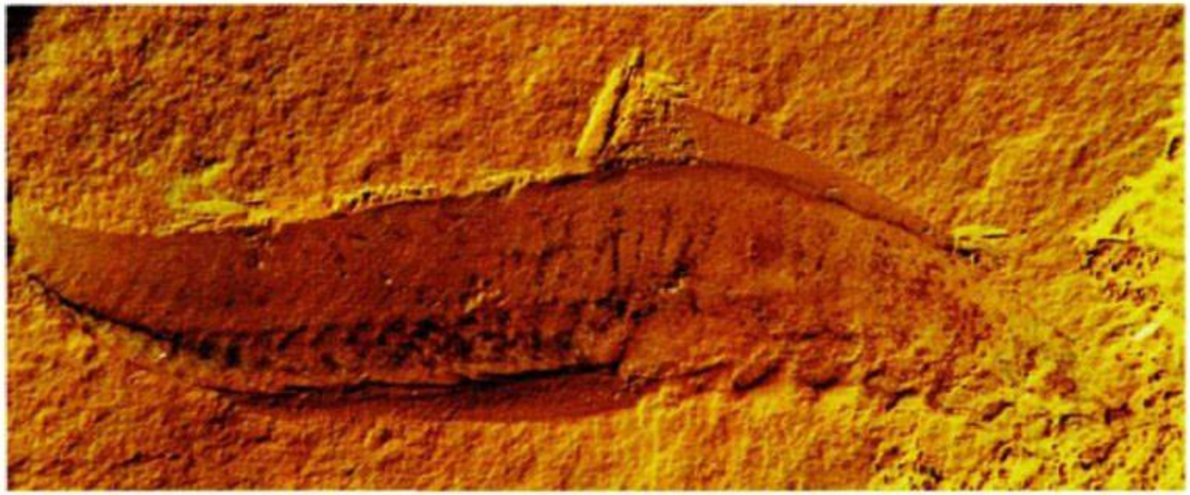
***Haikouella lanceolata*: modified from Chen et al. (1999)**

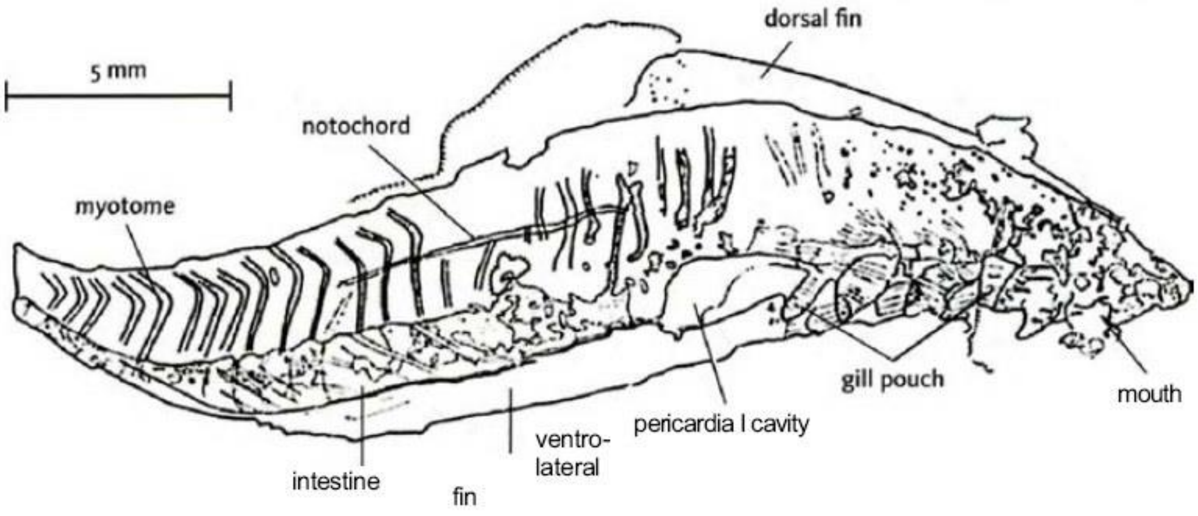
Myllokunmingia fengjiaoa

Oldest Craniate (vertebrate), fish

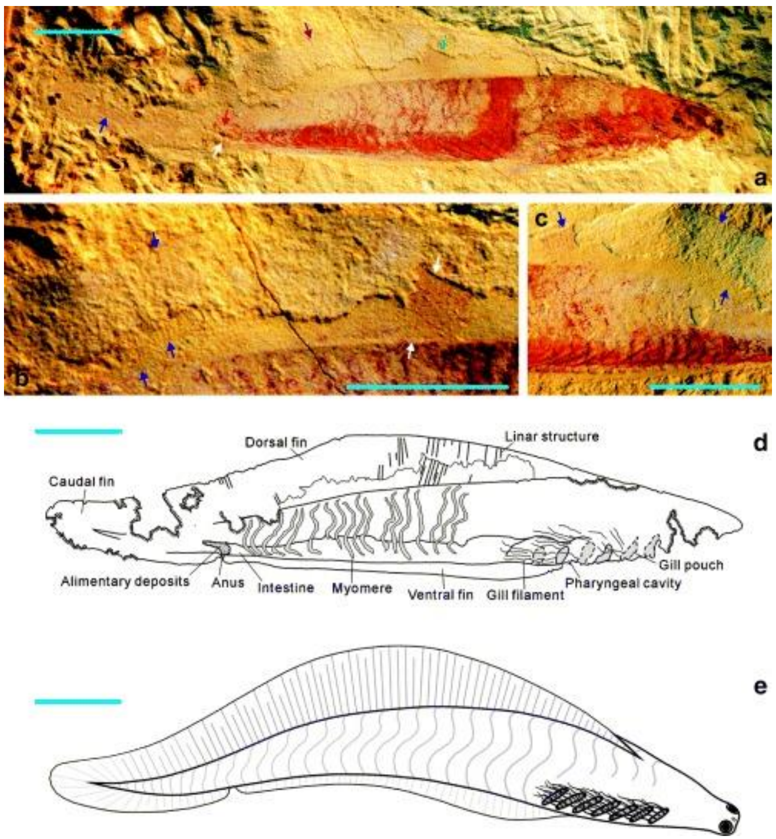
535 my



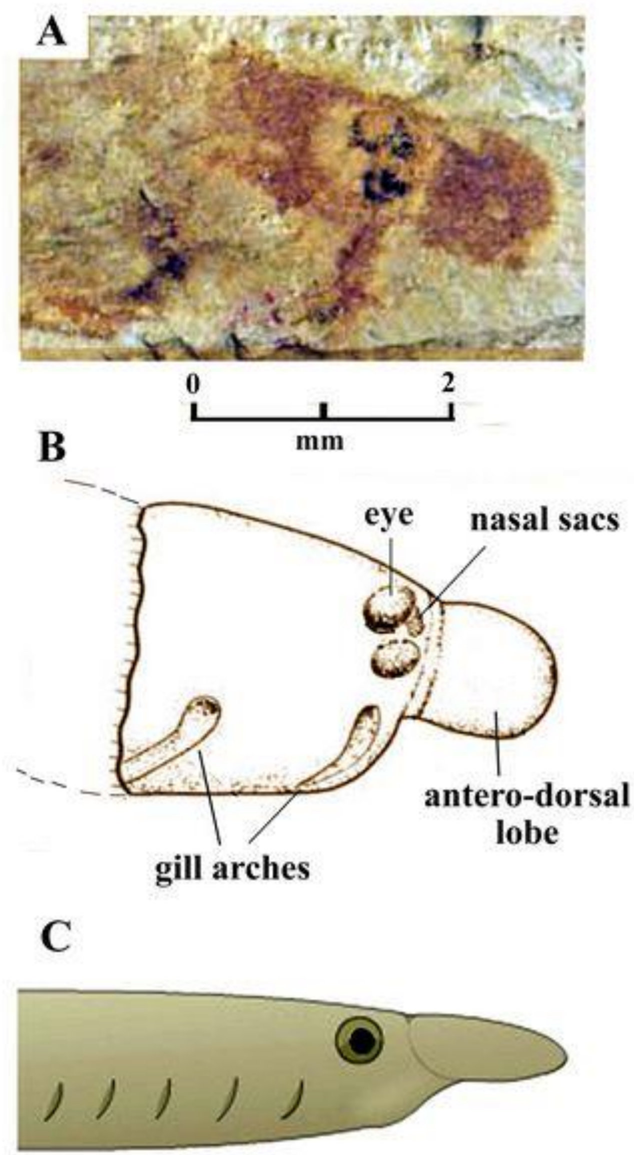




Haikouichthys ercaicunensis



Zhongjianichthys rostratus

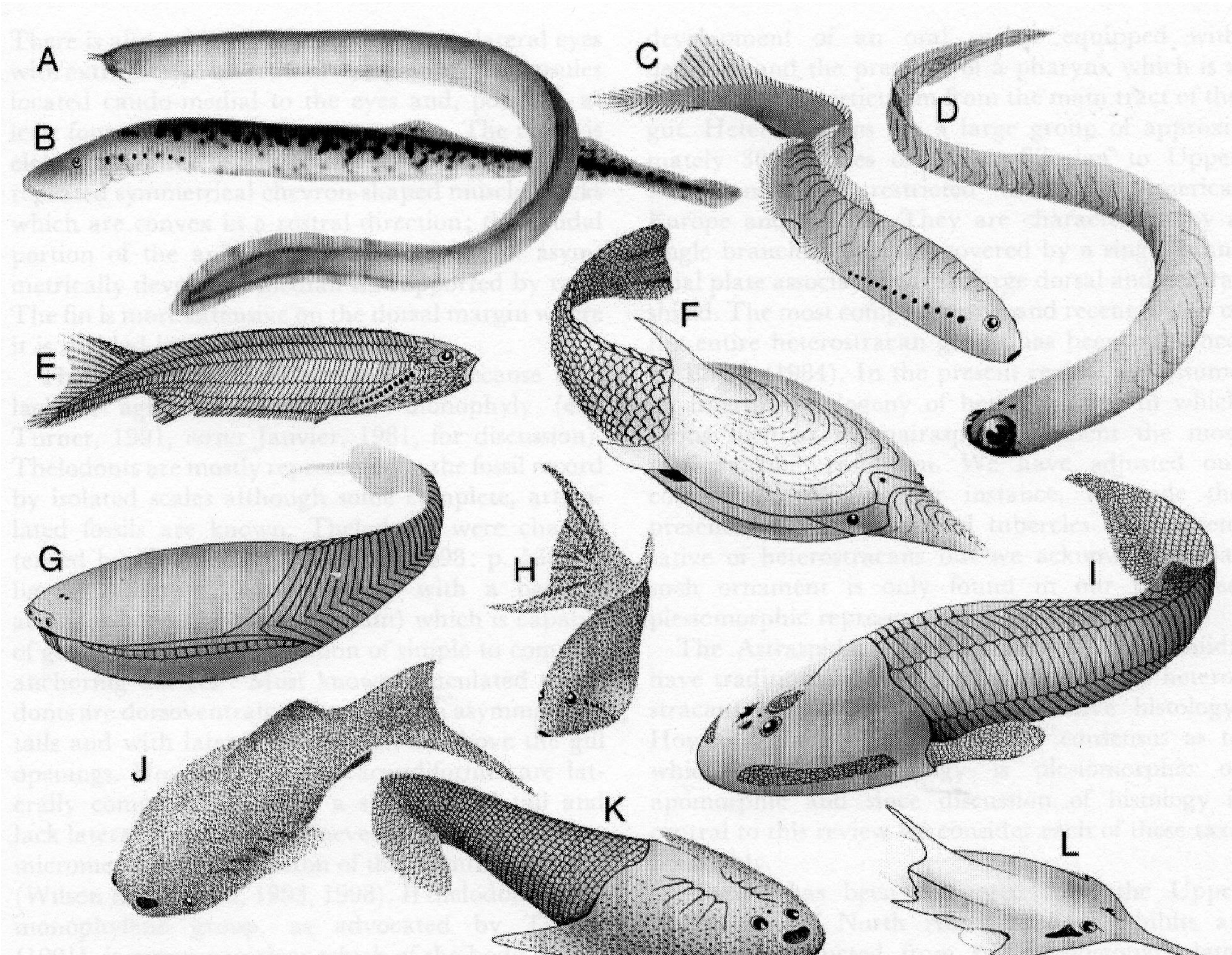


First fishes with hard tissues

- Dental elements and dermal bone plates made of apatite from the Late Cambrian.
- Apatite the biomineral that characterises vertebrates
- The oldest presumed fossil vertebrate *Anatolepis heintzi* from the Late Cambrian (520-505 my) of Wyoming (small black phosphatic fragments of dermal bone plates, an heterostracan jawless fish)
- Dental elements belong to conodonts

Agnatha (jawless fishes)

- The first fishes
- Maximum development and diversity between Silurian and Devonian.
- The main fossil groups
  - Conodonta
  - Arandaspida
  - Astraspida
  - Anaspida
  - Heterostraci
  - Thelodontia
  - Galeaspida
  - Osteostraci
- Living
  - Myxinoidea
  - Petromyzontida



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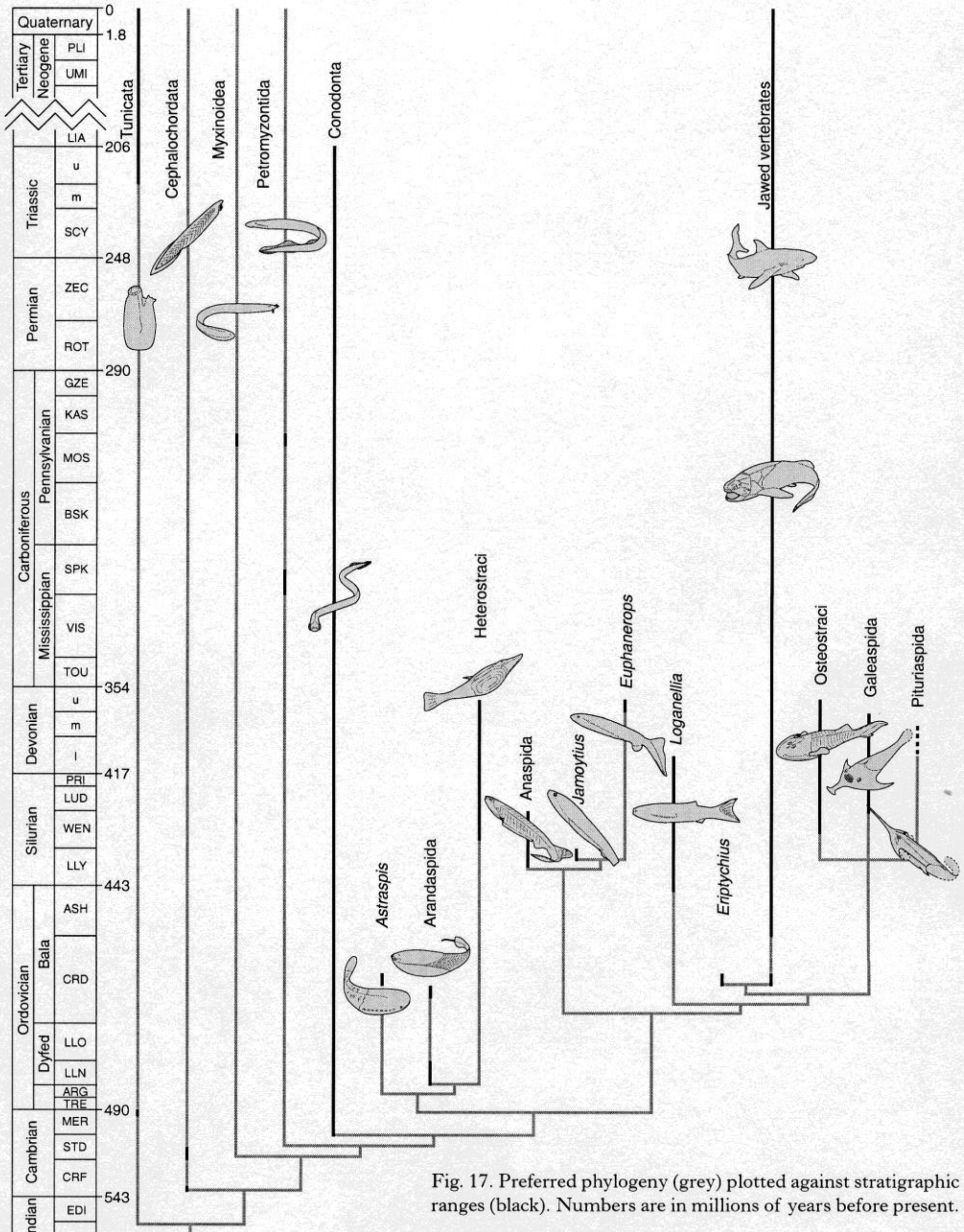


Fig. 17. Preferred phylogeny (grey) plotted against stratigraphic ranges (black). Numbers are in millions of years before present.

Conodonta

- Known since 1856
  Recently identified as fishes
  Tooth-like mineralised structures that consist of apatite
  Abundant and common in marine sediments from Late Cambrian to Late Triassic.
  Important and useful for biostratigraphic determinations

Dental elements of conodonts

The conodont enigma

- Different interpretations, conodonts attributed to members of three different kingdoms and almost every major animal group

  a. jaws of worms

  b. jaws of arrow worms
  c. jaws of molluscs d. chaetognaths

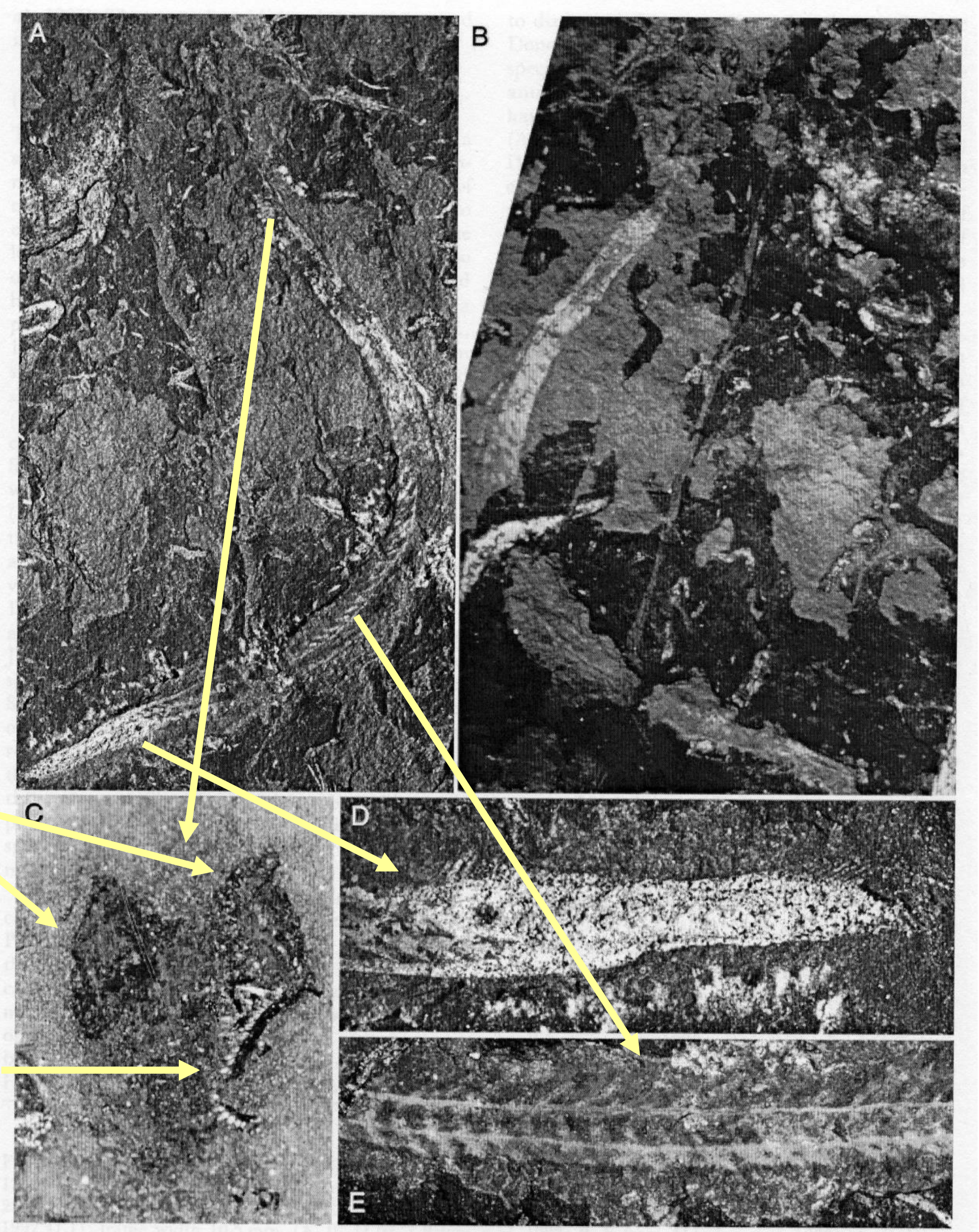
  e. basal chordates f. cephalochordates

  g. even as plants

The conodonta enigma

- The first whole animal (Clydagnathus) from Edinburgh Cobalt Carbonate (Briggs et al., 1983)
- It was considered a separate phylum with similarities to chordates.
- Eel like with head with eyes, notochord, myomeres
- Nine extra specimens and elements for head with large eyes and other characteristics of vertebrates led Aldridge et al. (1993) to identify the conodonta as vertebrates.
- Size 3-10cm, and up to 30cm
- Histological analyses of dental elements showed dental tissues as other vertebrates, with apatite crystals, enamel, dentin and calcified cartilage.

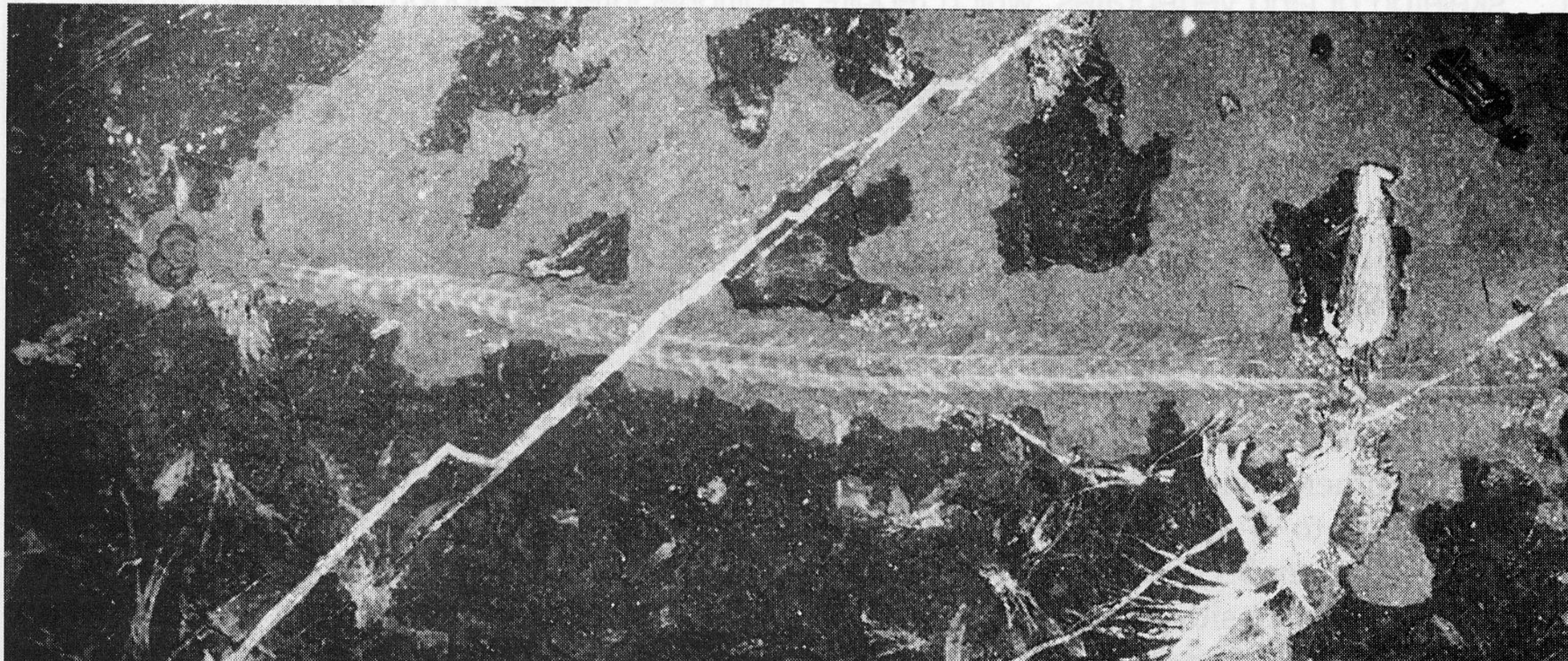
Shoom shale, South Africa1993



Clydagnathus, Edinburgh 1983

Eyes

Dental elements



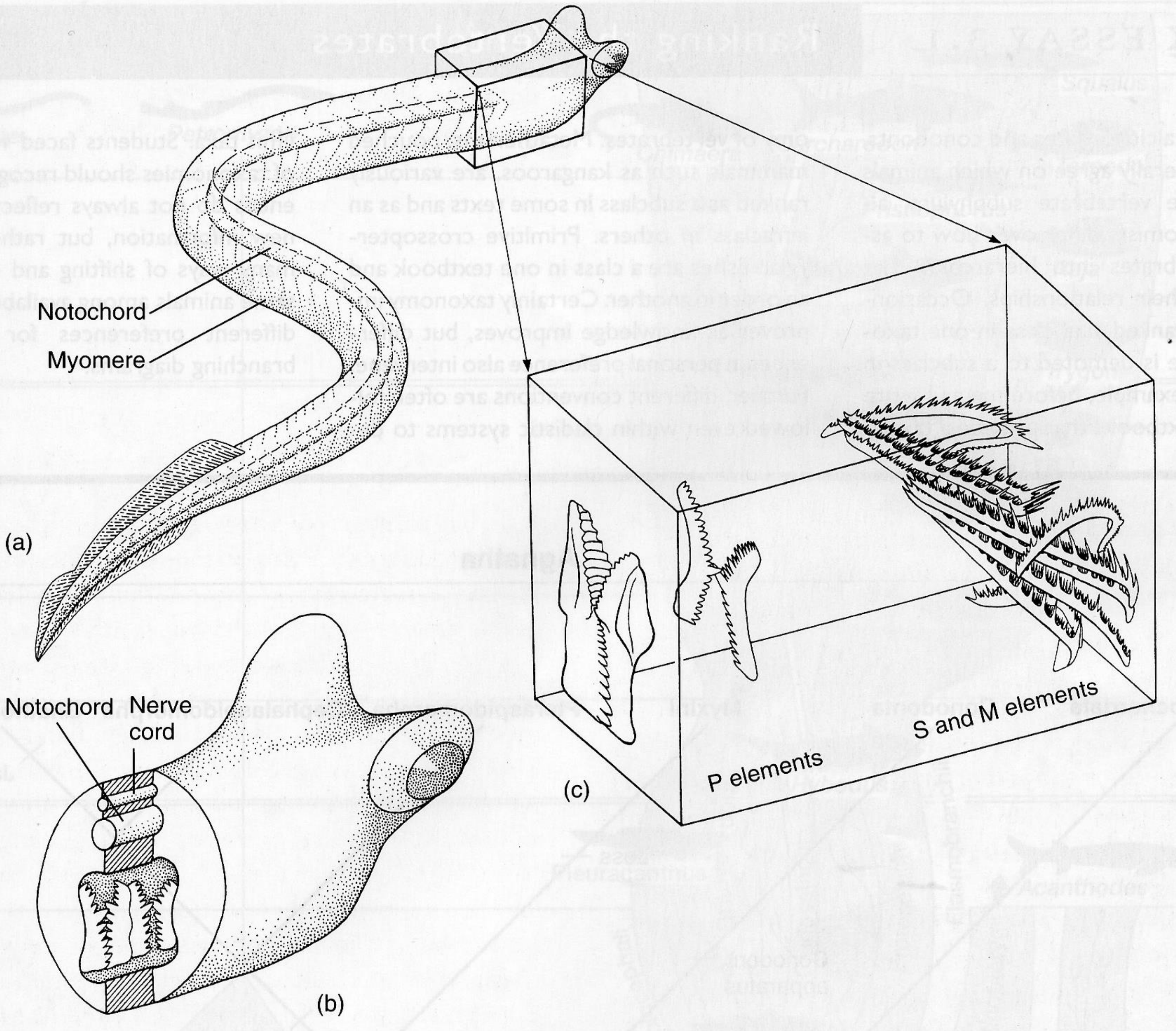
(b)

Evidence

- Trunk with V-shaped myotomes
- Notochord
- Well developed eyes
- Caudal fin rays – post anal tail
- Above notochord dorsal nerve cord
- Histological analysis of conodont elements showed: mineralised dental tissues known from vertebrates, cellular bone, apatitic crystals, calcified cartilage, enamel and dentin

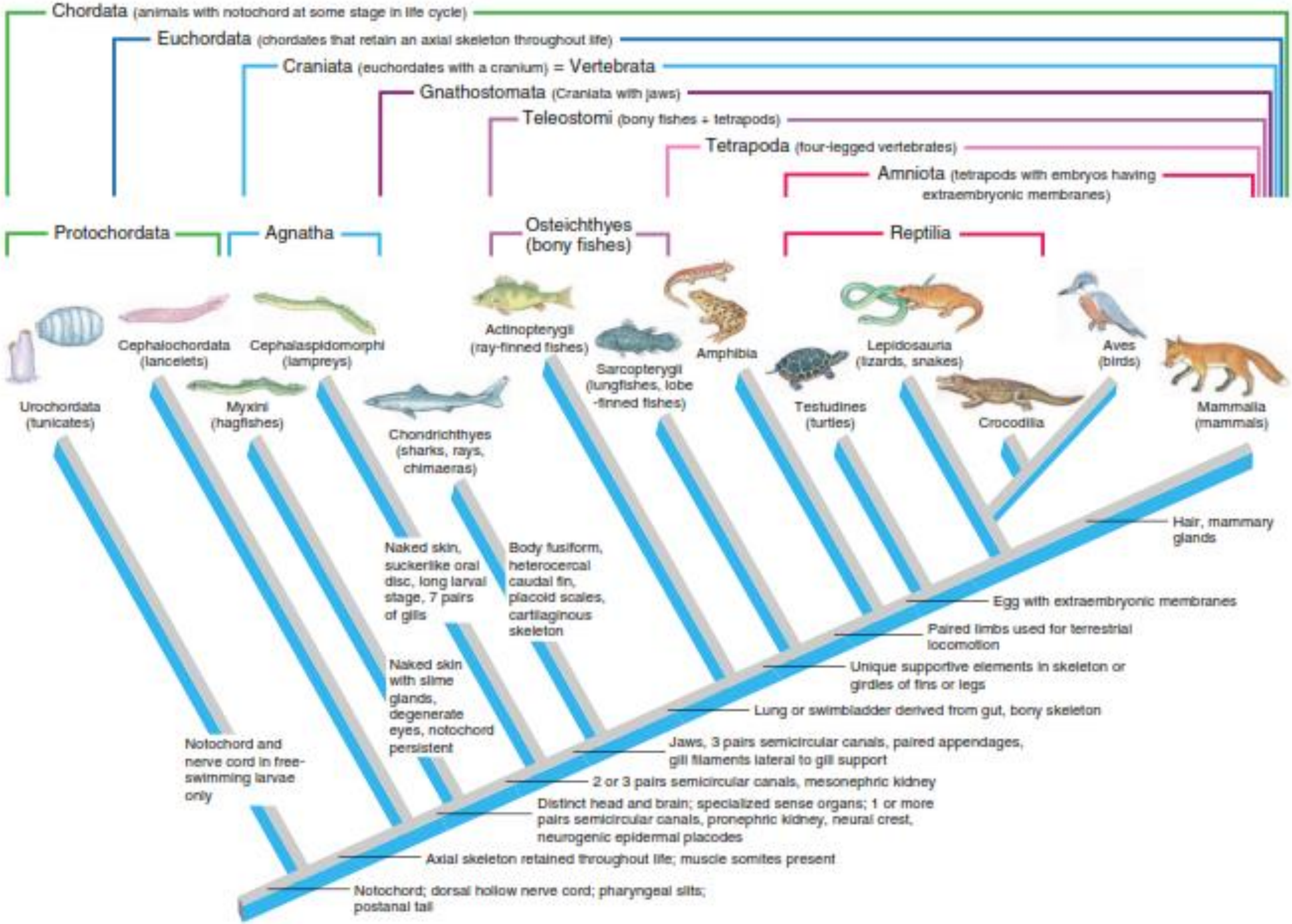
The conodont elements

- The tooth-like elements are located beneath the head region
- The elements consist a complex feeding apparatus
- Bilaterally symmetrical pairs of elements
- Each type of element has a specialised function
- S, M and P elements
- Used to slice, crash food (evidence from tooth microwear), thus they selected their food and not suspension feeders as other primitive chordates


Notochord
Myomere
(a)
Notochord
Nerve
cord
(b)
(c)
P elements
S and M elements

Gnathostoma

- Class Acanthodians
- Class Placoderma
- Class Chondricthyes
- Class Actinopterygii
- Class Sarcopterygii
- Class Amphibia
- Class Reptilia
- Class Aves
- Class Mammalia



Chordata (animals with notochord at some stage in life cycle)
Euchordata (chordates that retain an axial skeleton throughout life)
Craniata (euchordates with a cranium) = Vertebrata
Gnathostomata (Craniata with jaws)
Teleostomi (bony fishes + tetrapods)
Tetrapoda (four-legged vertebrates)
Amniota (tetrapods with embryos having extraembryonic membranes)
Protochordata
Agnatha
Osteichthyes (bony fishes)
Reptilia
Urochordata (tunicates)
Cephalochordata (lancelets)
Myxini (hagfishes)
Cephalaspidomorphi (lampreys)
Chondrichthyes (sharks, rays, chimaeras)
Actinopterygii (ray-finned fishes)
Sarcopterygii (lungfishes, lobe-finned fishes)
Amphibia
Testudines (turtles)
Lepidosauria (lizards, snakes)
Crocodilia
Aves (birds)
Mammalia (mammals)
Hair, mammary glands
Egg with extraembryonic membranes
Paired limbs used for terrestrial locomotion
Unique supportive elements in skeleton or girdles of fins or legs
Lung or swimbladder derived from gut, bony skeleton
Jaws, 3 pairs semicircular canals, paired appendages, gill filaments lateral to gill support
2 or 3 pairs semicircular canals, mesonephric kidney
Distinct head and brain; specialized sense organs; 1 or more pairs semicircular canals, pronephric kidney, neural crest, neurogenic epidermal placodes
Axial skeleton retained throughout life; muscle somites present
Notochord; dorsal hollow nerve cord; pharyngeal slits; postanal tail
Naked skin, suckerlike oral disc, long larval stage, 7 pairs of gills
Body fusiform, heterocercal caudal fin, placoid scales, cartilaginous skeleton
Naked skin with slime glands, degenerate eyes, notochord persistent
Notochord and nerve cord in free-swimming larvae only

The advantages

- Jaws a significant innovation in vertebrate evolution
- New adaptive pathways, new diets and food handling techniques
- Allowed a true predatory mode of life, bite or crush prey
- Jaws appear first in acanthodian fishes in non marine rocks (riverine and lacustrine deposits) and then in placoderm fishes

Origin of jaws

- Jaws arose from one of the anterior pair of pharyngeal arches (branchial arches, gill arches)
- In aquatic vertebrates each arch consists of a series of up to 5 articulated elements
  - pharyngobranchial
  - epibranchial
  - ceratobranchial
  - hypobranchial
  - basibranchial
- One of these arches comes to border the mouth, supports soft tissue and bears teeth and which are called jaws

Origin of jaws

- The first functional arch of the jaw = mandibular arch (the largest and most anterior)
- It is composed of the palatoquadrate dorsally and the Meckel's cartilage ventrally
- The second is the hyoid arch with the hyomandibular as the prominent dorsal element and the ceratohyal as the ventral
- A varying number of brachial arches follows the hyoid arch, numbered with Roman numerals

- Two theories for the origin of jaws
- Serial theory: the first or second arch of a primitive agnathan gave rise to mandibular arch, the next arch to the hyoid arch and the rest to the brachial arches
- Composite theory: more complex based on fossil fishes skulls and embryology of fossil fish forms. An agnathan with ten arches of which the first four are named terminal, premandibular, mandibular and hyoid, and the other six brachial arches
- Mandibular arch of jawed vertebrates is formed from premandibular arch and parts of the mandibular arch of the agnathan
- Palatoquadrate formed from fusion of the epibrachial of the premandibular with the epibrachial and pharingobrachial of the mandibular. Meckel's cartilage arises from the expanded ceratobranchial element
- The hyoid arises from the epibranchial, ceratobranchial and hypobranchial of the third arch

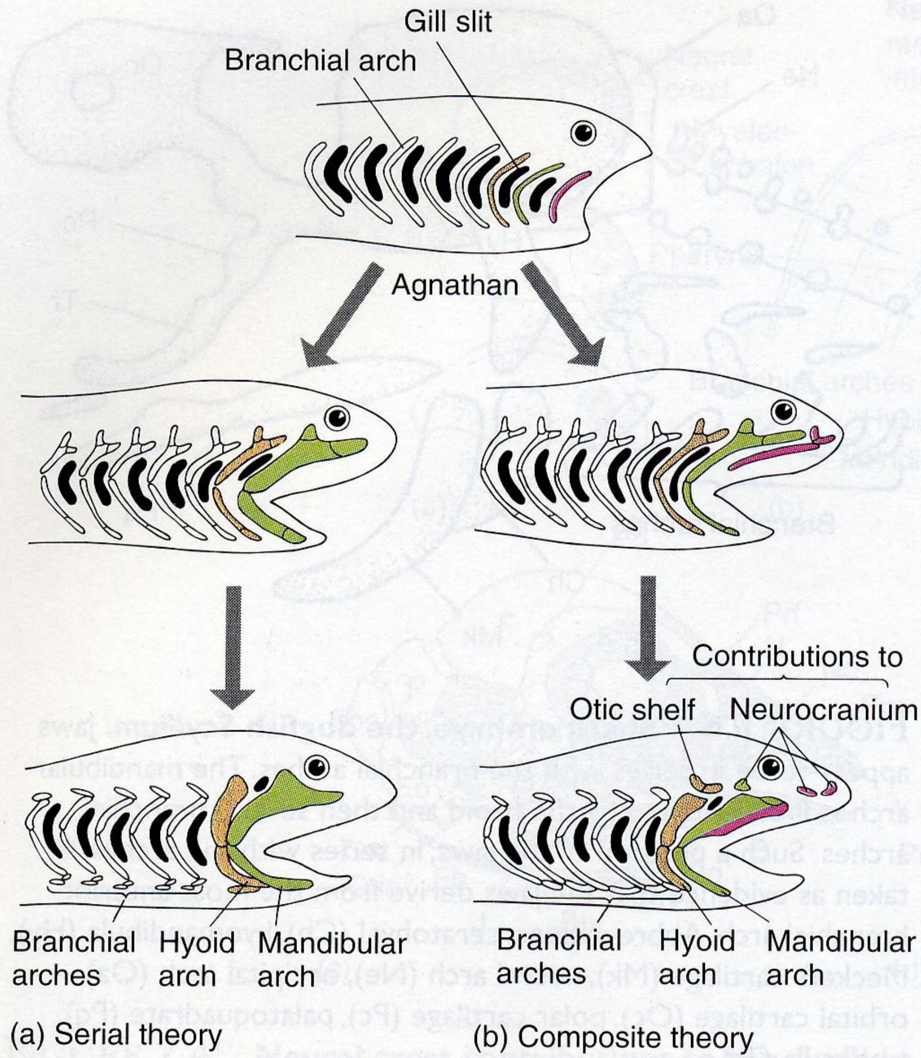


FIGURE 7.7 **Serial and composite theories of jaw development.** (a) The serial theory holds that jaws arise completely from one of the anterior branchial arches. Elements may be lost within it, but other elements from other arches do not contribute. (b) In the composite theory, the mandibular arch is formed from elements of several adjacent arches that also contribute to the neurocranium.

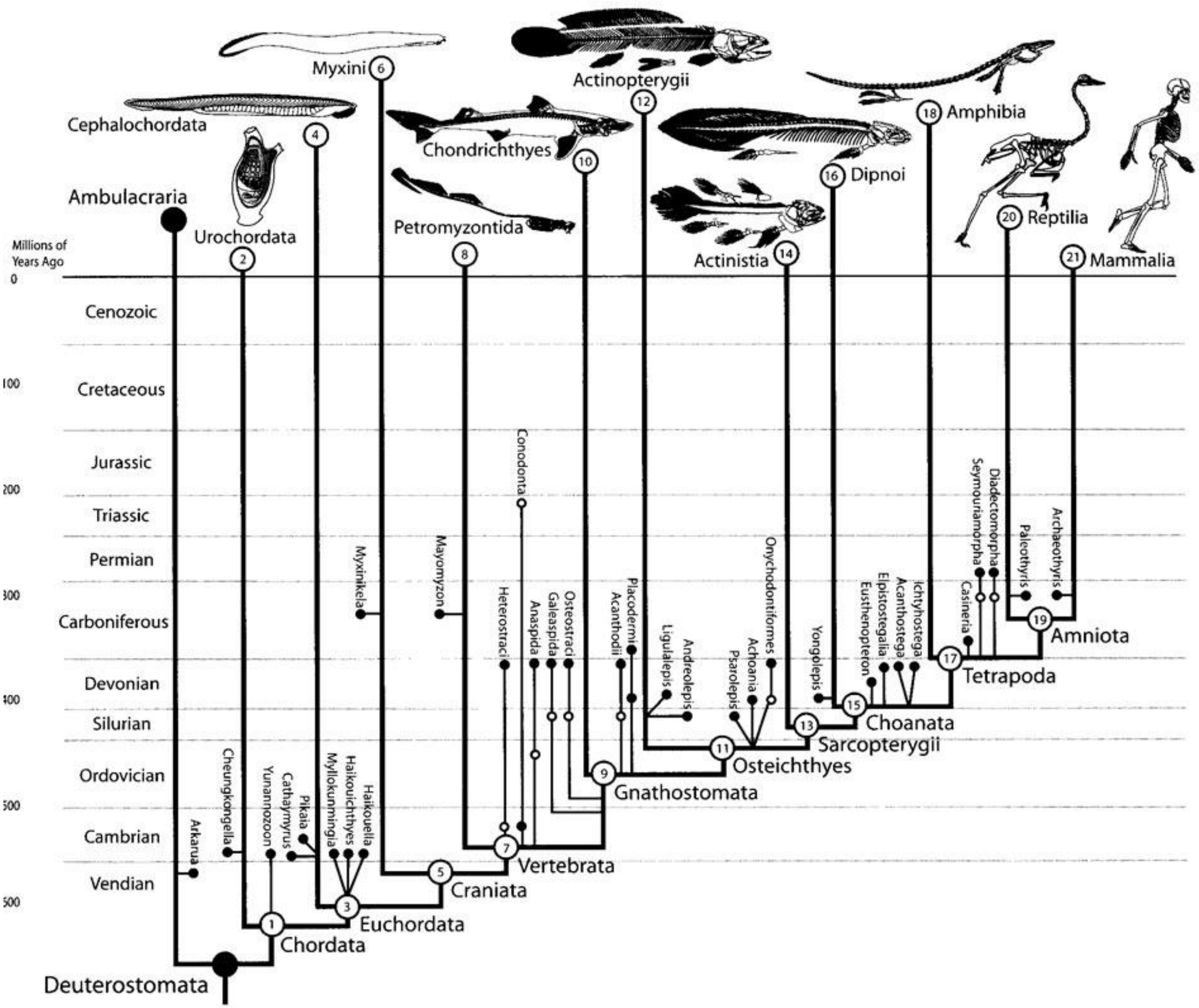
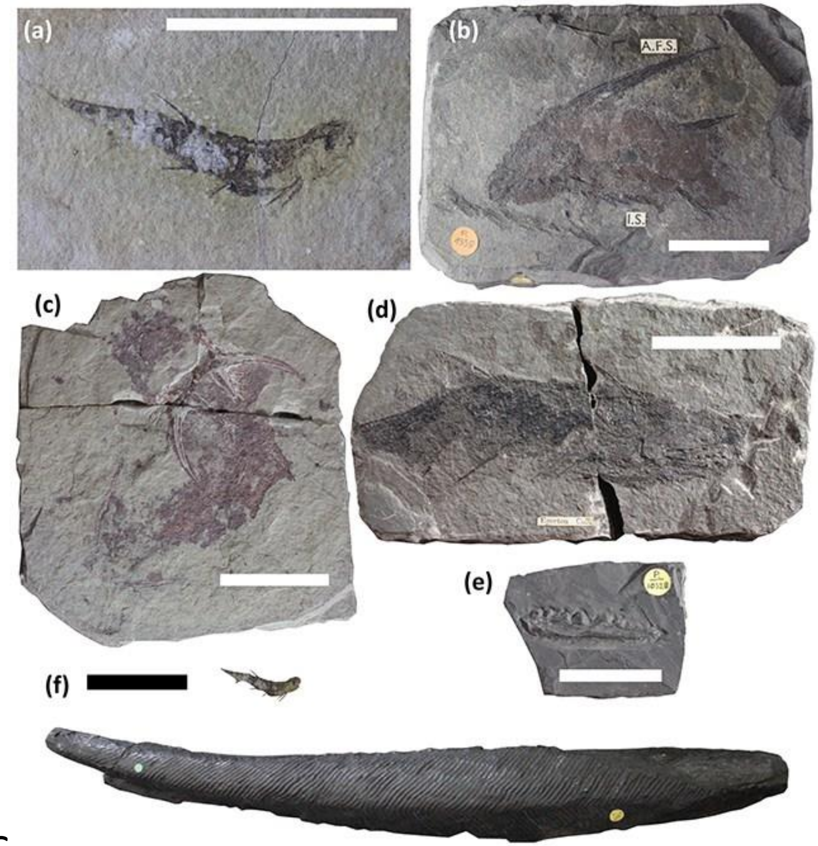


Figure 23.1. Chordate phylogeny, showing the relationships of extant lineages and the oldest fossils, superimposed on a geological time column. Nodal numbers are keyed to text headings.

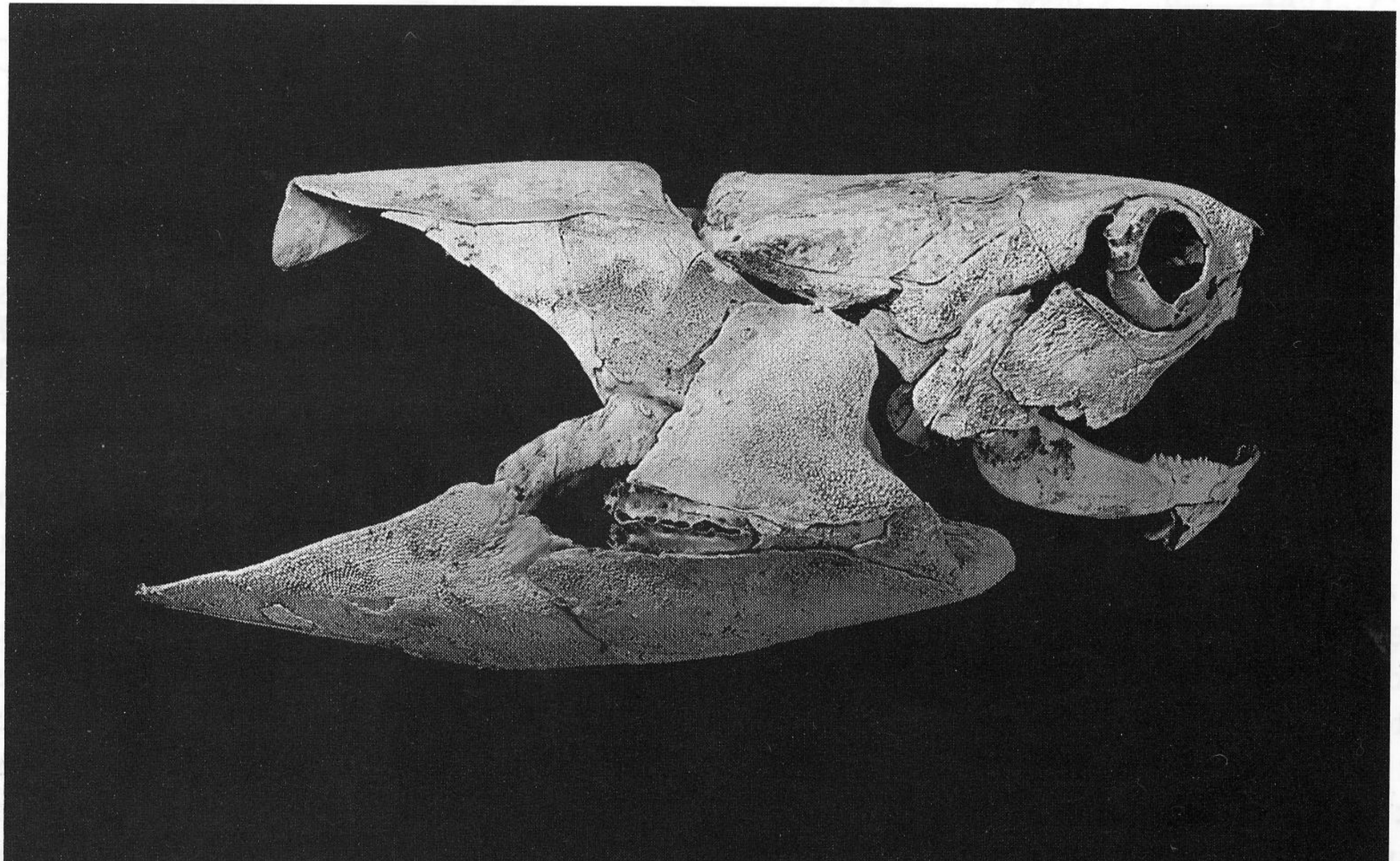
Class Acanthodii



- Small fishes
- Most have teeth
- The oldest jawed fishes dating from the early Silurian; survived until the Carboniferous and one into the early Permian
- Slender bodies with one or two dorsal fins an anal fin and heterocircal tail
- Pectoral pelvic fins modified to long spines
- In the early forms six pairs of spines along the belly
- Head is large and covered with light bony plates
- Ossified shoulder girdle (scapulocoracoid)
- Large eyes surrounded by a number of sclerotic plates
- Lightly scaled sensori canals in the lower jaw
- Body covered by small scales made from bone and dentine

Class Placodermi

- Heavily armoured fishes known from the early Silurian and dominated seas during the Devonian
- Their heads and shoulders were covered with bony, mobile plates
- Special neck jointed allowed the anterior portion of the head shield to be lifted
- Many species large reaching several meters in length
- Bottom living feeders
- Strong jaws, sleek bodies, small tail strengthen axial column
- Placoderms are separated in nine orders of which the following are reasonably well known: Arthrodira, Acanthothoraci, Petalychthyida, Rhenanida, Ptyctodontida, Phyllolepida and Antiarchi



The short-snouted arthrodire Compagopiscis *from the Late Devonian Gogo locality of Western Australia, showing near-perfect three-dimensional preservation. Head shield, 130 tmm long. (Photograph by Kristine Brimmell, courtesy of J.A. Long.)*

Class Chondrichthyes

- Cartilagenous fishes are generally reckoned to be the most primitive fishes
- Skeletons are made from calcified cartilage
- They have placoid scales; tail symmetrical but the notochord bench into the dorsal low only
- Two dorsal fins, pectoral and pelvic fins
- Pelvic claspers, serial replacement of teeth
- First appeared in the Late Silourian
- Marine dwelling except one fresh water genus that lived during the Late Carboniferous (*Cladoselache)*

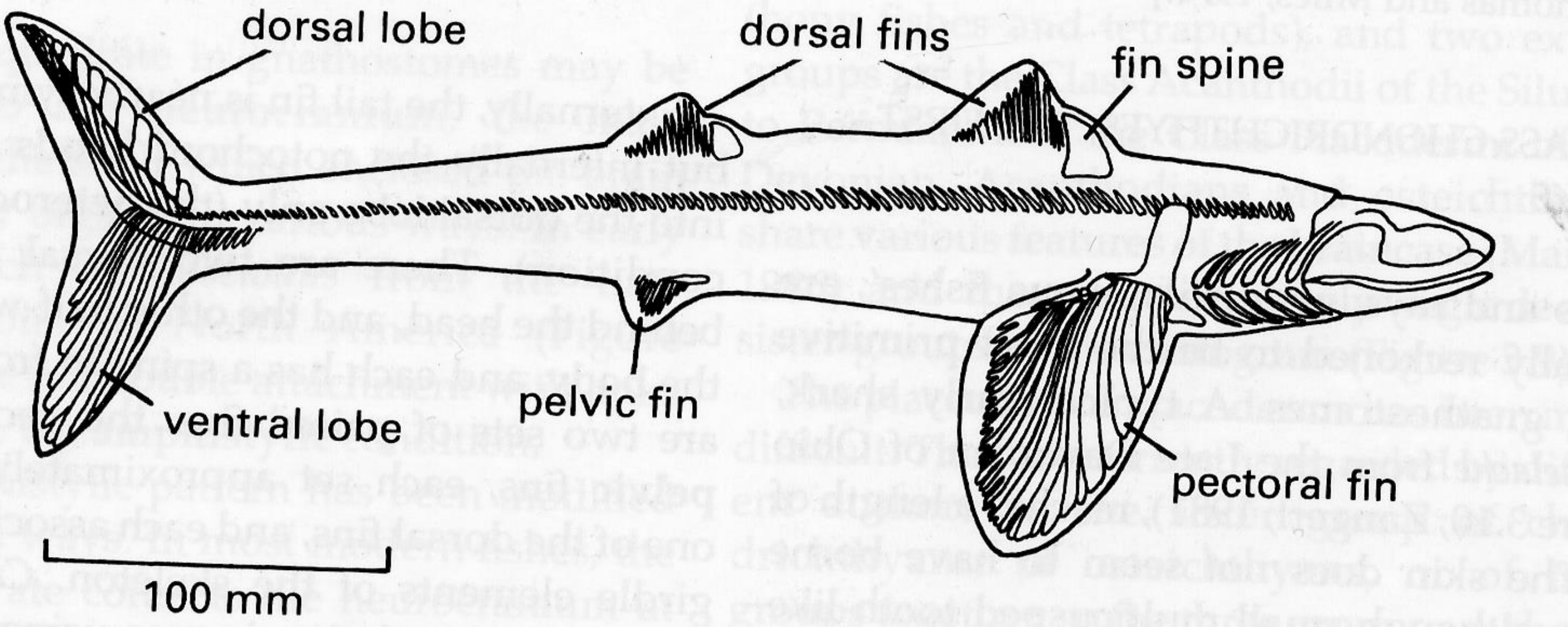
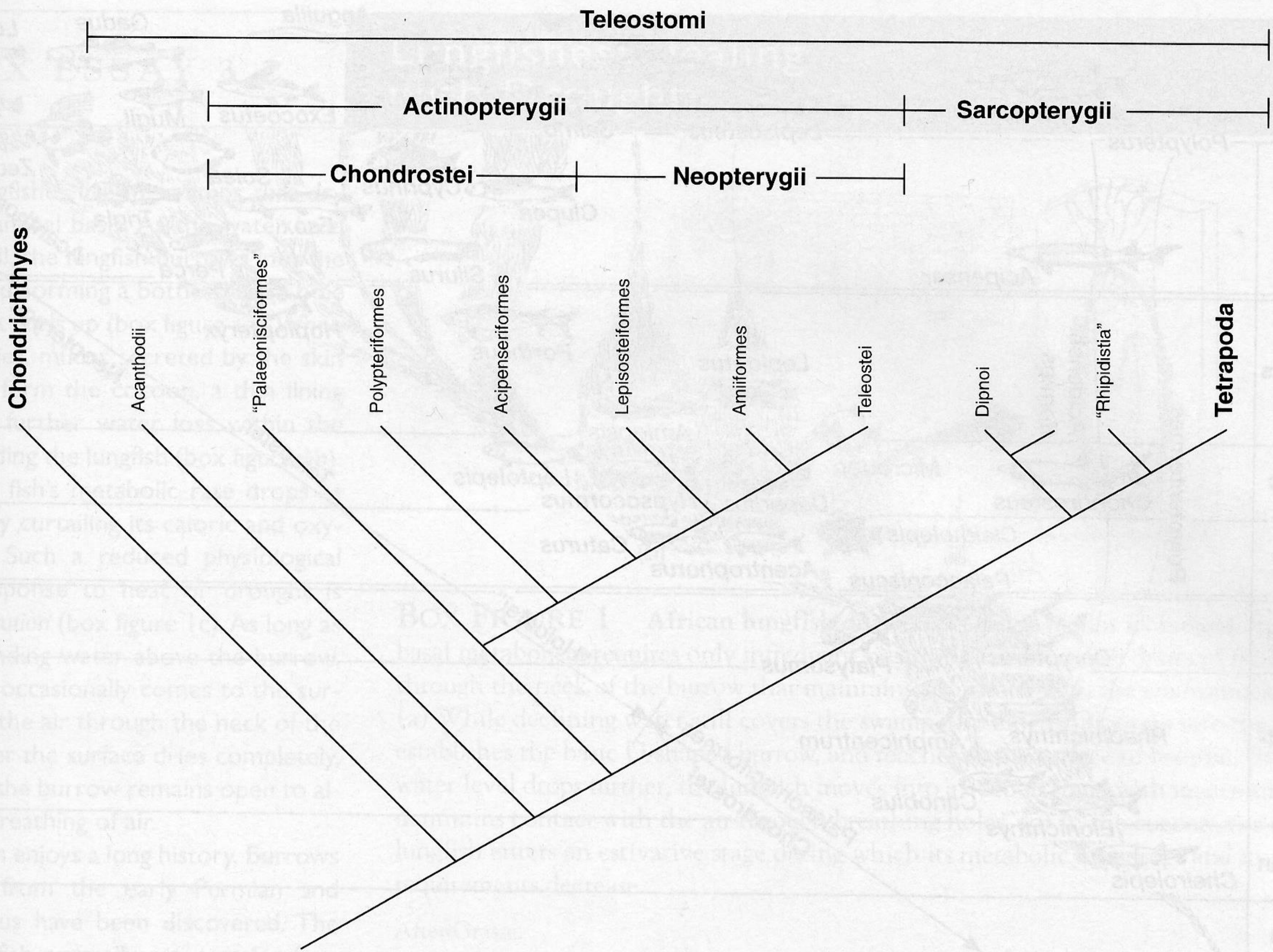


Fig. 3.10 *Cladoselache*, one of the first sharks. (After Zangerl, 1981.)

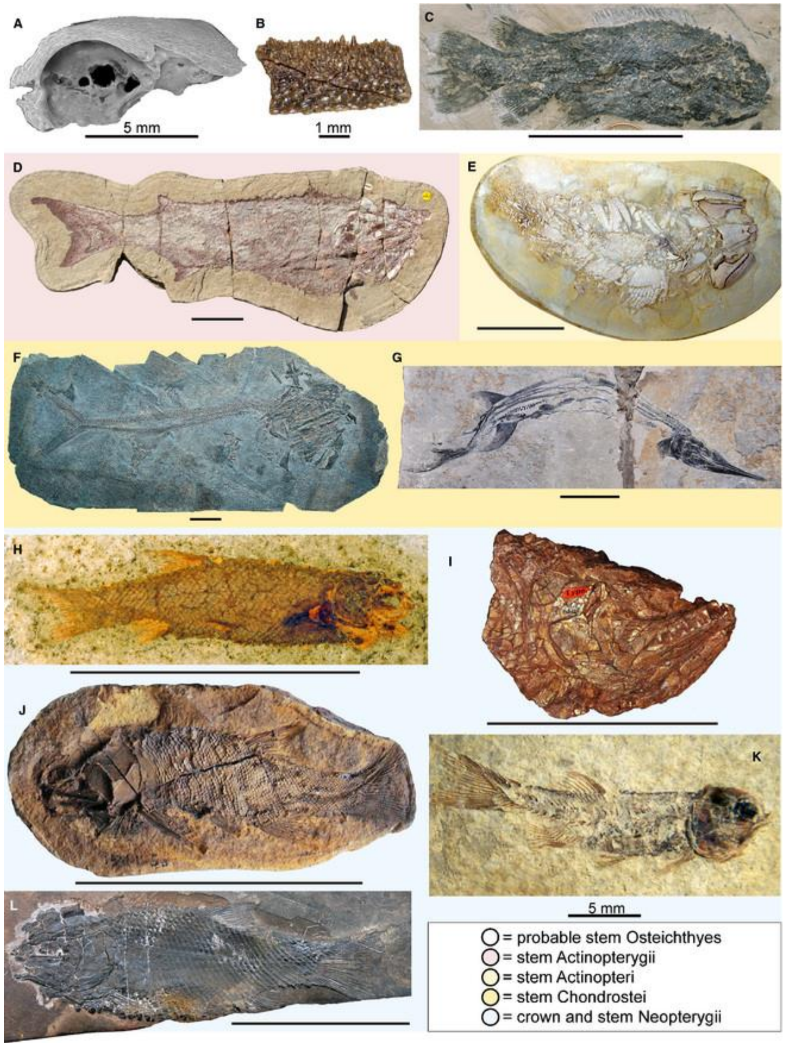
Class Osteichtyes

- Subclass Actinopterygians
- Subclass Sarcopterygians
- Bony skeleton
- First appeared in the Late Silurian and were fresh water dwellers
- Then moved to marine environments
- Most abundant, most diverse and most successful of all vertebrates


Teleostomi
Actinopterygii
Sarcopterygii
Chondrostei
Neopterygii
Chondrichthyes
Acanthodii
"Palaeonisciformes"
Polypteriformes
Acipenseriformes
Lepisosteiformes
Amiiformes
Teleostei
Dipnoi
"Rhipidistia"
Tetrapoda

Subclass Actinopterygii

- The oldest, late Silurian in age
- Also called ray-finned fishes
- Fin rays are covered with jointed dermal bones (lepidotrichia)
- Body covered by scales. Scales composed of bone dentine and enamel like substance (ganoin)
- First appeared in fresh water environments
- They are separated into chondrostei and neopterygii
- Chondrostei reached their greatest diversity during the late Palaeozoic and were replaced in the early Mesozoic by neopterygians
- Neopterygii: great range of morphology, increased jaw mobility during feeding, scales became round and thinner, more active swimmers, symmetrical tail



Friedman, 2015

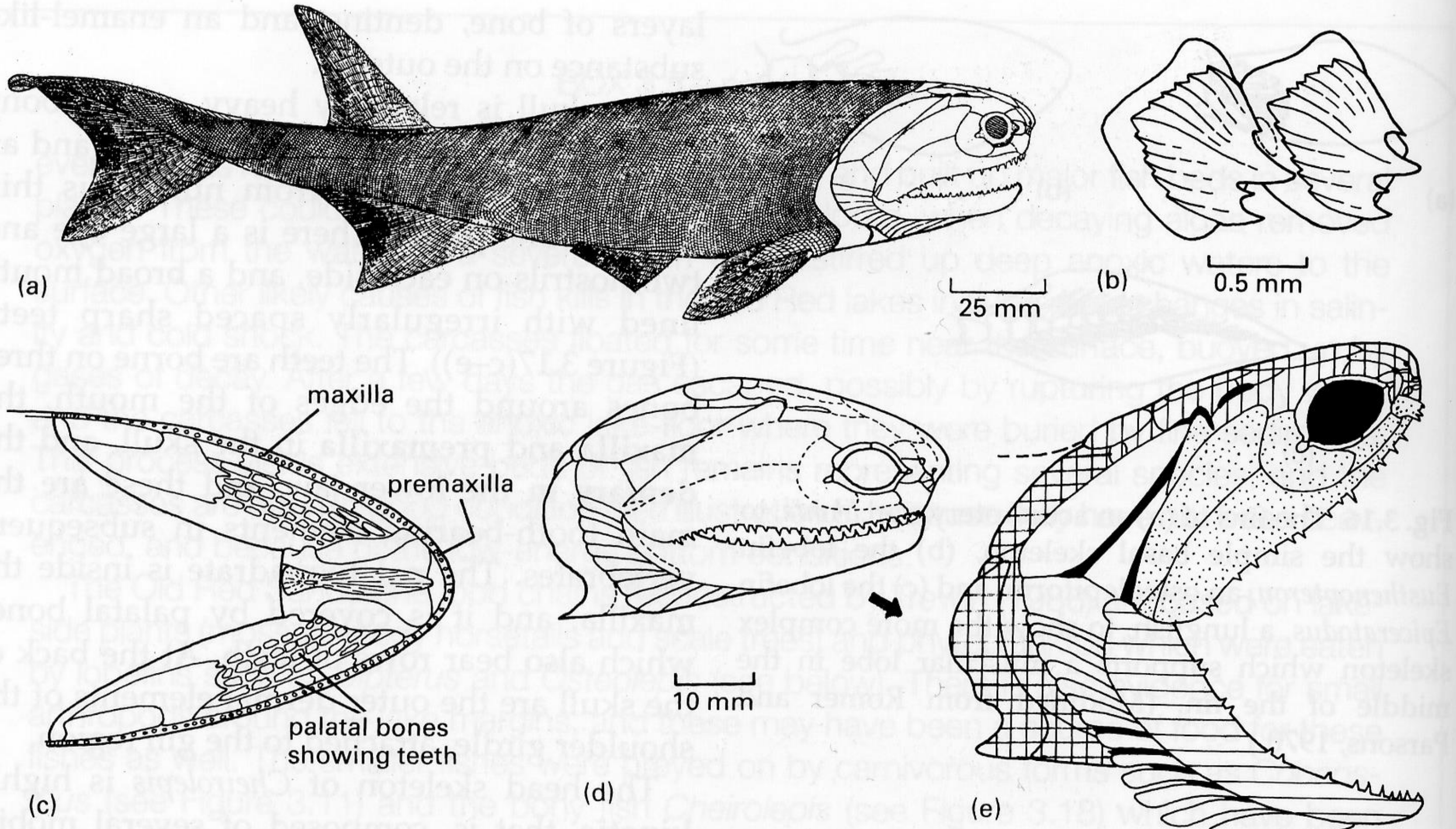
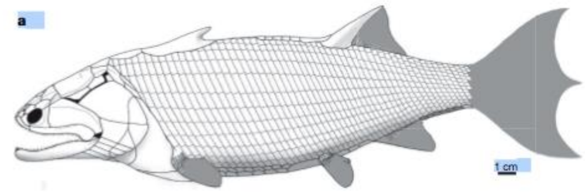
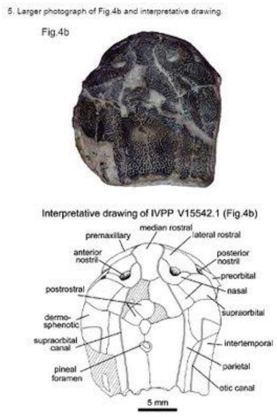


Fig. 3.17 The Middle Devonian bony fish *Cheirolepis*: (a) reconstruction of the body in lateral view; (b) two trunk scales; (c) ventral view of the palate showing the teeth; (d, e) opening and closing of the jaws, showing the five major mobile units, as described in the text. (After Pearson and Westoll, 1979.)

Zhu et al., 2009

Guiyu oneiros





- The oldest find of an articulated sarcopterygian

It gives us information about the origin and the initial diversification of the Osteichtyes

It shows that the minimum age for the separation of Actinopterygii-Sarcopterygii not later than Late Silurian (419 my)

Appeared 50 million years before we thought

Subclass Sarcopterygii

- Share mascular lobed paired fins with bony skeletons as well as several skull features not seen in other vertebrates
- Two groups: dipnoi and Crossopterygians
- rhipidistia, coelacanths,
- Their scales are covered by cosmine
- Early fishes had double dorsal fins and heterocircal tails; in later species dorsal fins were reduced and caudal fin became symmetrical
- Rhipidistian jaws carried labyrinthodont teeth, characterised by complex infolding of a tooth wall around a central pulp cavity
- Rhipidistian gave rise to amphibians during the Devonian and became extinct in the early Permian
- Coelacanths arose in the middle Devonian and were supposed to go extinct in late Cretaceous. However, in 1938 an unusual lobe finned fish was caught in the Indian Ocean and was identified as a coelacanth and named *Latimeria* (living fossil)

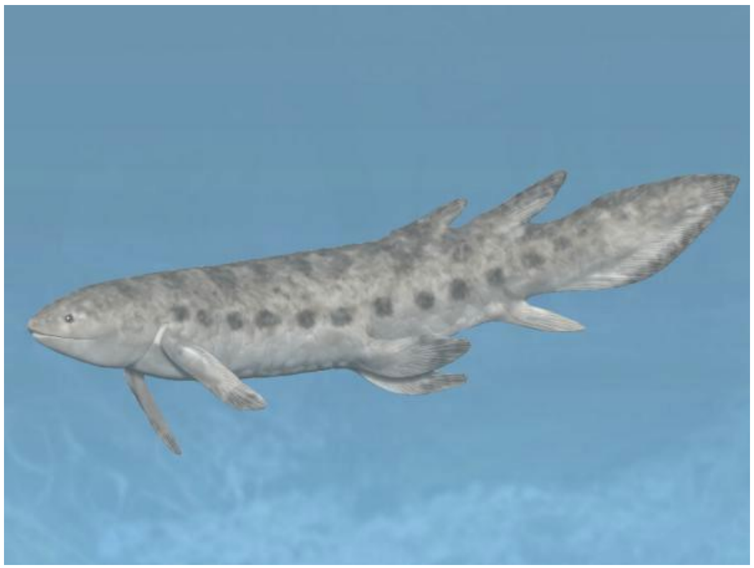
Subclass Sarcopterygii

- Lungfishes (dipnoi) were particularly diverse in the Devonian and still exist today with three genera
- Some lungfishes are marine but most occupy fresh water
- With pair of lungs dipnoans can breath during periods when oxygen levels in the water fall or when pools of water evaporate during dry seasons
- With time they elaborated crushing toothplates and developed special hypermineralised dentine increasing the crushing power of the jaws
- The body shape also changed becoming more symmetrical

Dipterus
A devonian lung fish

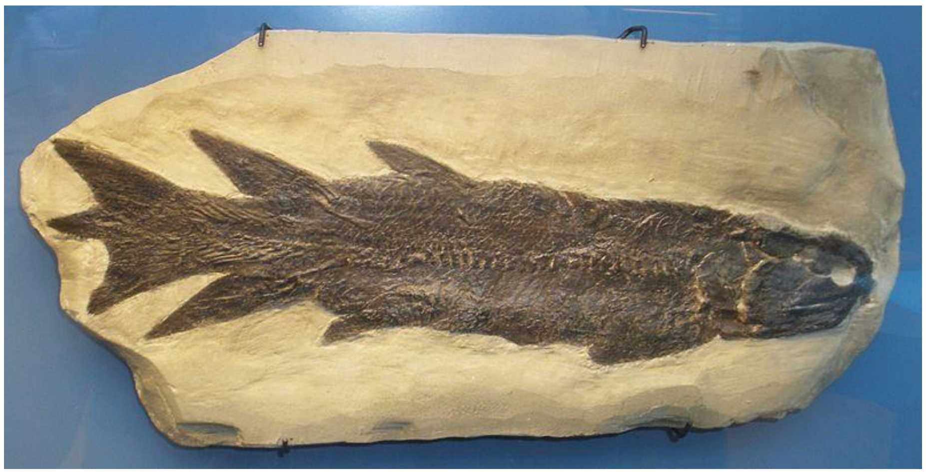
Dipterus valenciennensi,

Museum fur Naturkunde Berlin



Dipterus

Eusthenopteron
Crossopterygians (Devonian)



Eusthenopteron foordi

Eusthenopteron

Crossopterygians

1. Rhipidistia – The ancestral group of Amphibia
2. Coelacanths – Crossopterygians who invaded the sea led to the Coelacanths . Coelacanths were considered extinct and are now considered living fossils after catching one in 1938 off the coast of Madagascar.

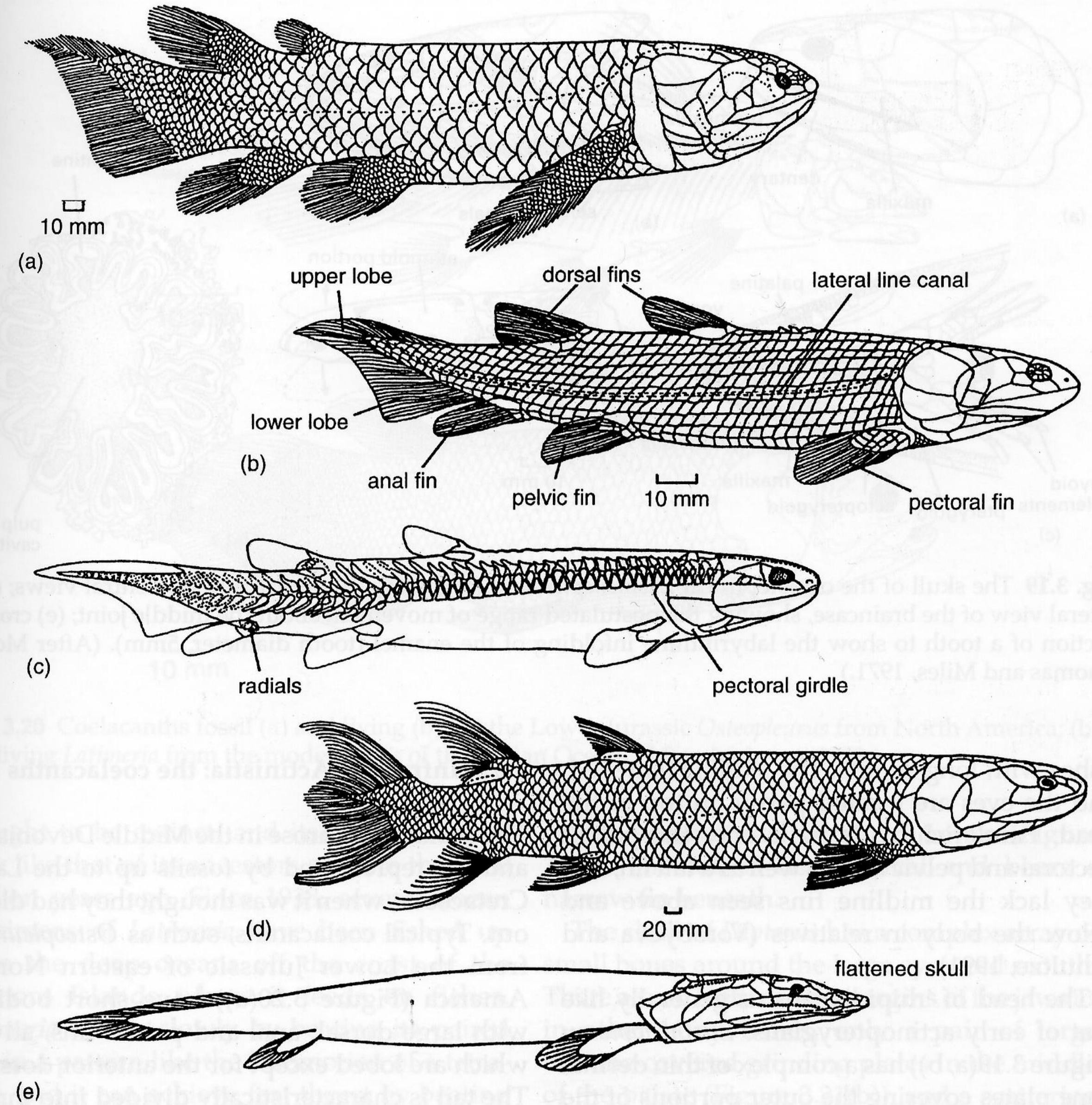


Fig. 3.18 Diversity of 'rhipidistians', a porolepiform (a), two osteolepiforms (b–d), and a panderichthyid (e): (a) lateral view of *Holoptychius*, (b, c) lateral views of *Osteolepis*, with and without scales, (d) lateral view of *Eusthenopteron*, (e) lateral view of *Panderichthys*. [Figure (a) after Andrews, 1973; (b, d) after Moy-Thomas and Miles, 1971; (c) after Andrews and Westoll, 1970a; (e) modified from Vorobyeva and Schultze, 1991.]

Latimeria

Latimeria, a modern Coelacanth. The tail resemples the one of Eusthenopteron

- Their most recent and advanced group, the teleosts: arose in the late Triassic, had homocercal tails, circular scales without ganoin, ossified vertebrae, skull with complex jaw mobility allowing rapid capture and manipulation of food

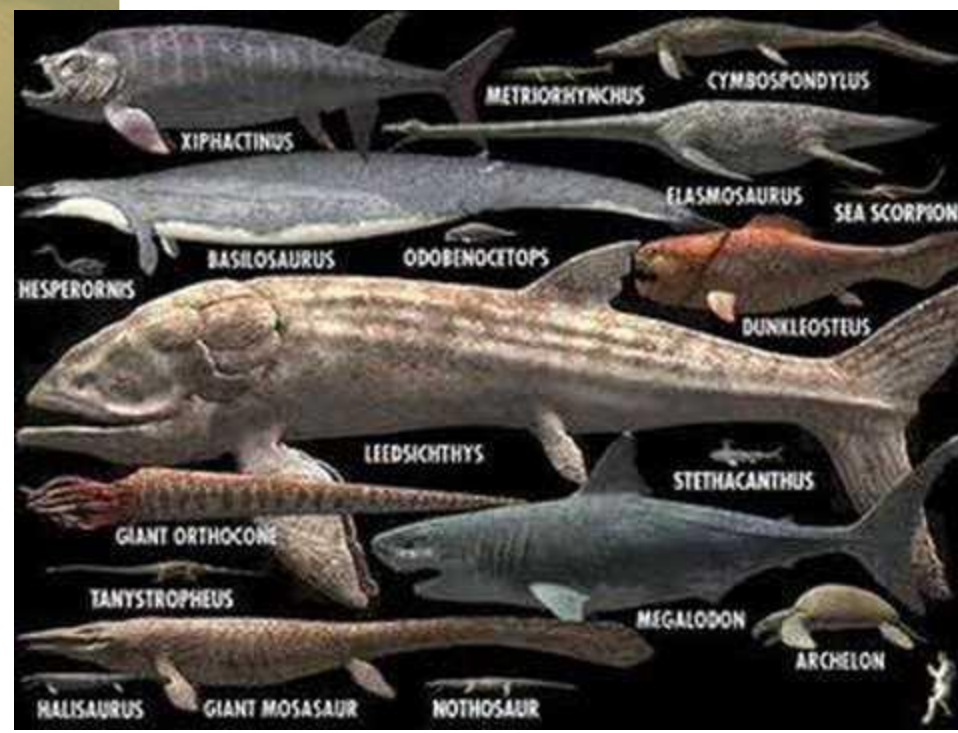
Teleostei

- Εμφανίστηκαν στο Κρητιδικό.
- Τα κυρίαρχα ψάρια στον κόσμο σήμερα.
- Their most recent and advanced group,
- arose in the late Triassic, had homocercal tails, circular scales without ganoin, ossified vertebrae, skull with complex jaw mobility allowing rapid capture and manipulation of food, posses swim bladder

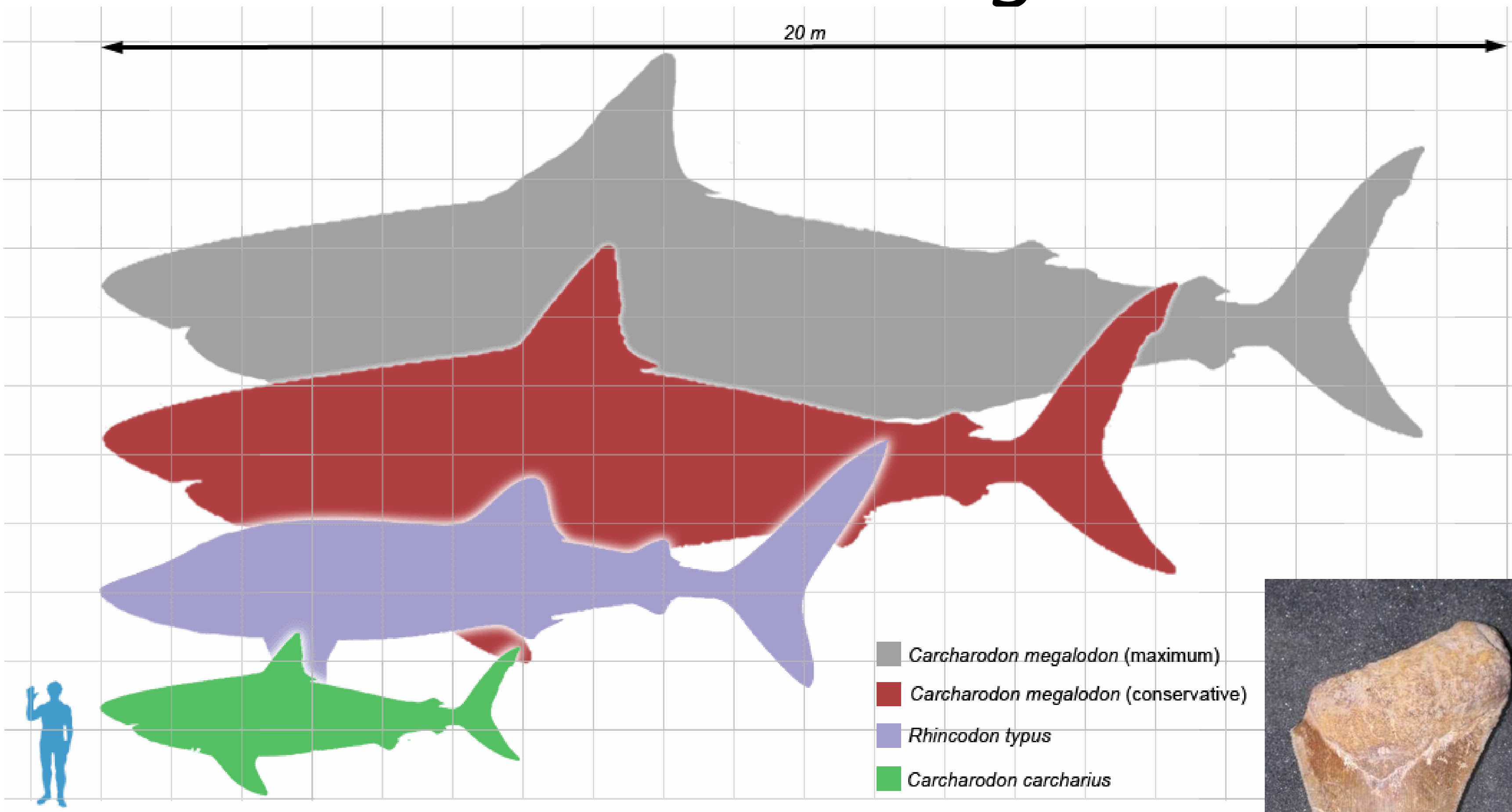
The largest fishes

Leedsichthys up to 15-16 m in length!

***Xiphactinus audax**, up to 6-7 m.*



Carcharodon megalodon



What we check in fossil fishes

- Body shape
- Scale type
- Skeletal elements
  - Otoliths
  - Type and number of vertebrae
  - Type and number of fins

Skeleton of a teleost fish

- Cranial Skeleton
- Postcranial Skeleton

  Axial Skeleton

  Appendicular Skeleton

  - Shoulder girdle
  - Pelvic girdle

  Dorsal and ventral fins

The first tetrapods

- The first tetrapods arose during the Devonian
- Radiated extensively during Carboniferous and Early Permian
- They evolved from the sarcopterygian group Rhipidistia
- Small semi-aquatic forms, as well as larger carnivorous forms, of which some as adults could live fully terrestrial lives
- They belong to the class Amphibia

- The class Amphibia as it is used excludes many descendant groups
- The term amphibian is related to the double mode of life of living forms (frogs, salamanders etc.) both in water and on land
- The modern groups of amphibians arose in the Triassic

Problems of life on land

- Weight and structural support
- Physiology of breathing air
- Lomomotion
- Feeding
- Sensing prey and predators
- Water balance
- Reproduction

Anatomical changes for the transition from water to land

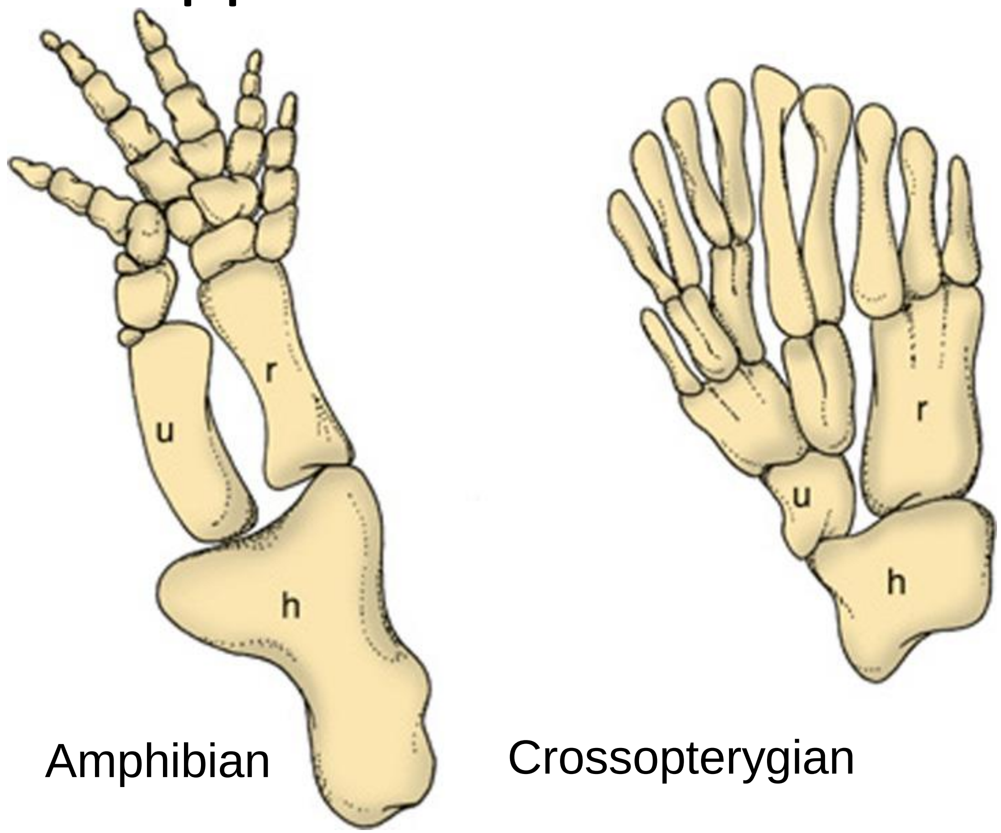
1. Development of a three chambered heart to feed the lungs with blood.
2. The bones of the appendages (fins) have been changed to support the body above the ground.
3. The spine has changed to become stronger and more flexible.
4. The airways of the fish became Eustachian tubes and inner ear.
5. The bones of the ear have changed to work better in the air (creating an anvil).
6. Tympanic membrane covered a forage in the skull

Origin of amphibians from Crossopterygians

1. Arrangement of the bones of the amphibian appendages and the fins of the Crossopterygians.
2. The shape of the skull bones
3. The structure of the teeth
4. The bones of the spine in the first forms.

Similarities of Crossopterygians - Amphibians

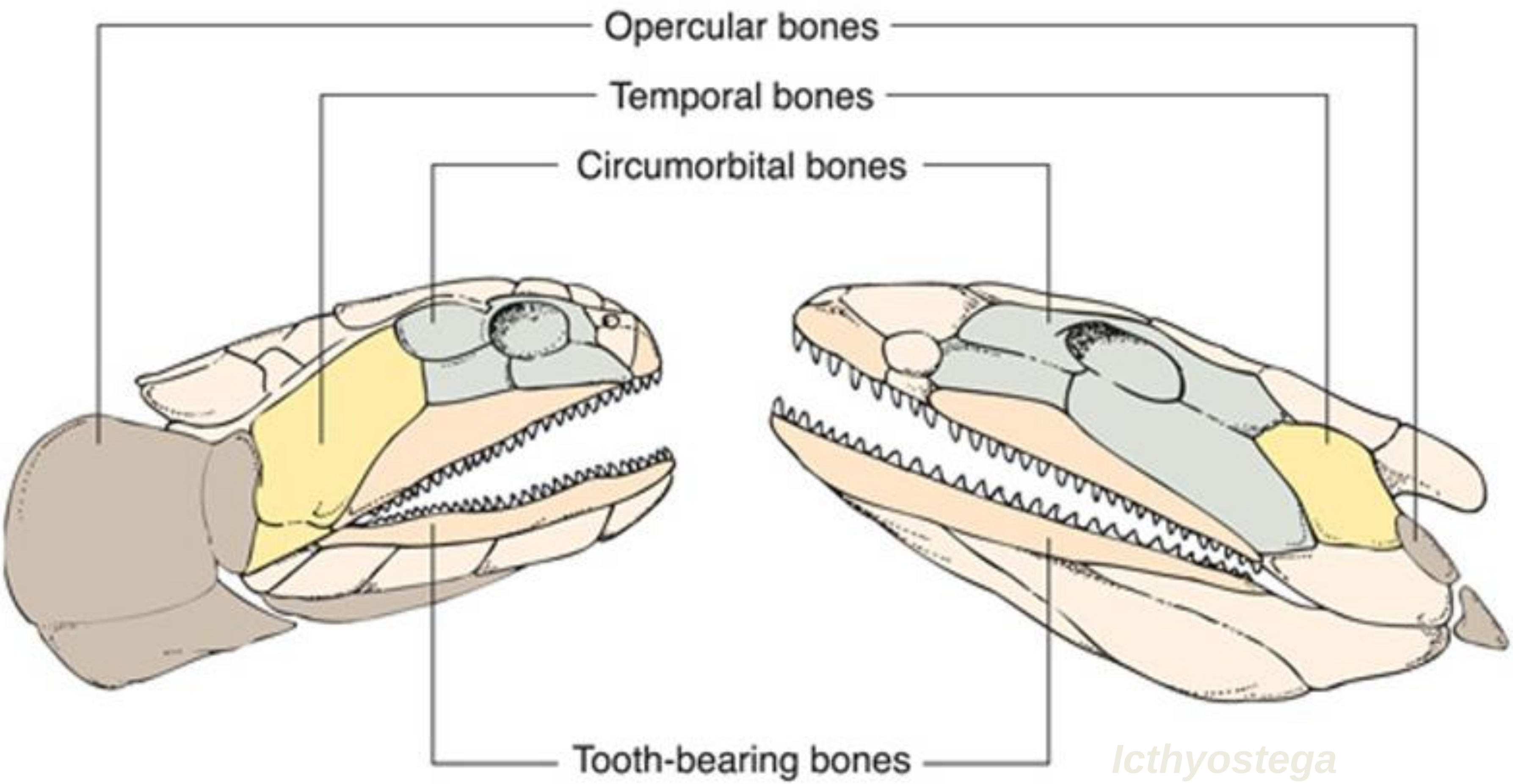
1. The same appendicular bones



r = Radius *u = Ulna* *h = Humerus*

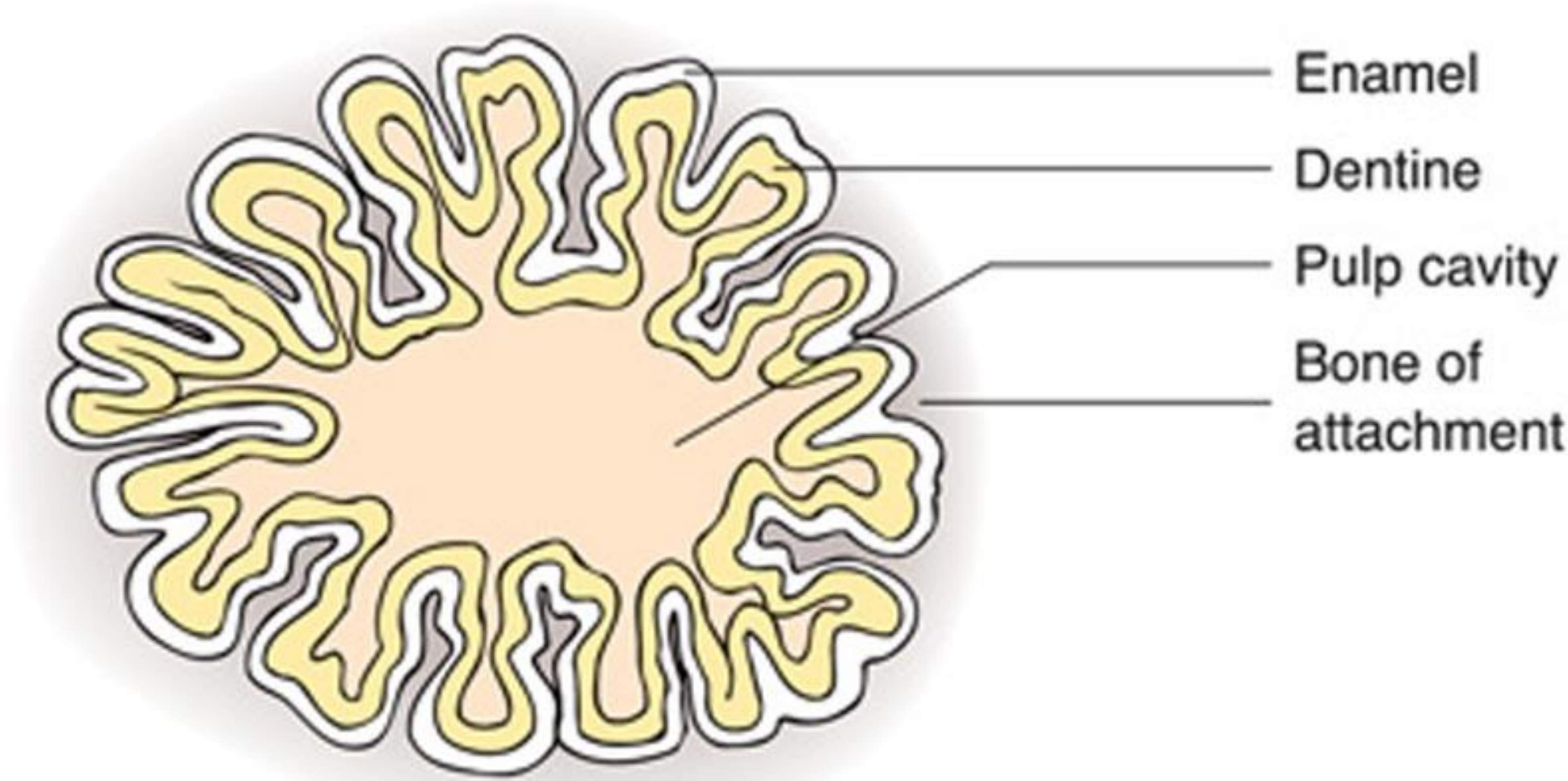
Similarities of Crossopterygians - Amphibians

2. The same cranial bones



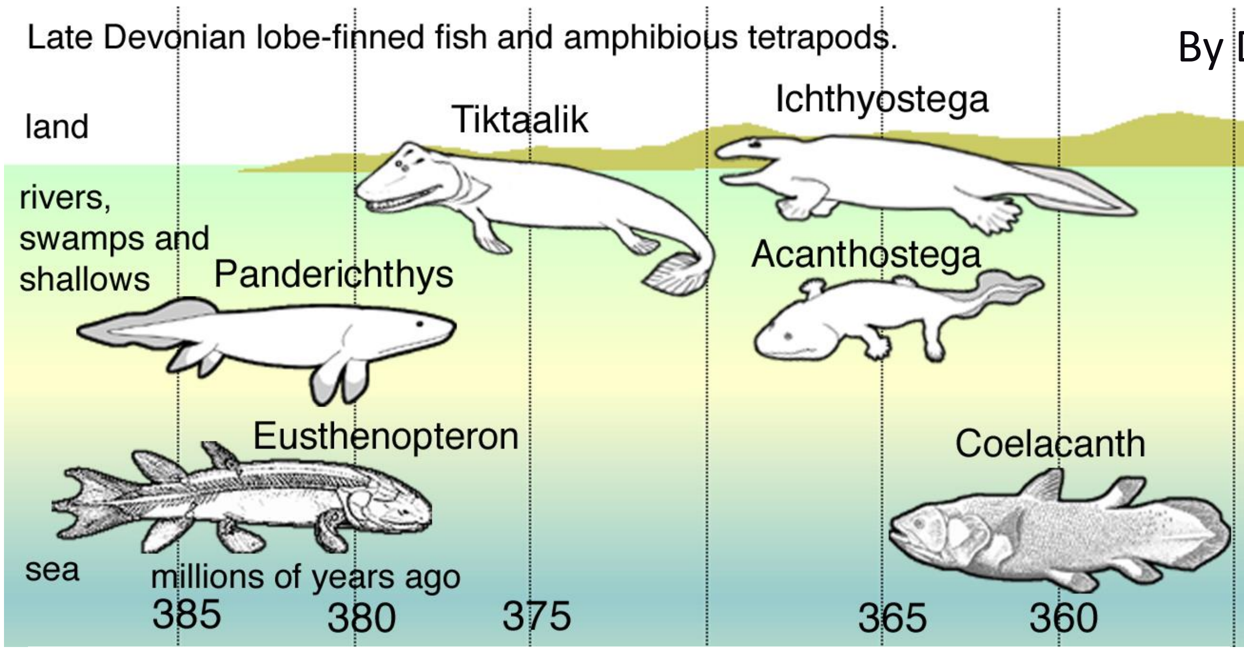
Similarities of Crossopterygians - Amphibians

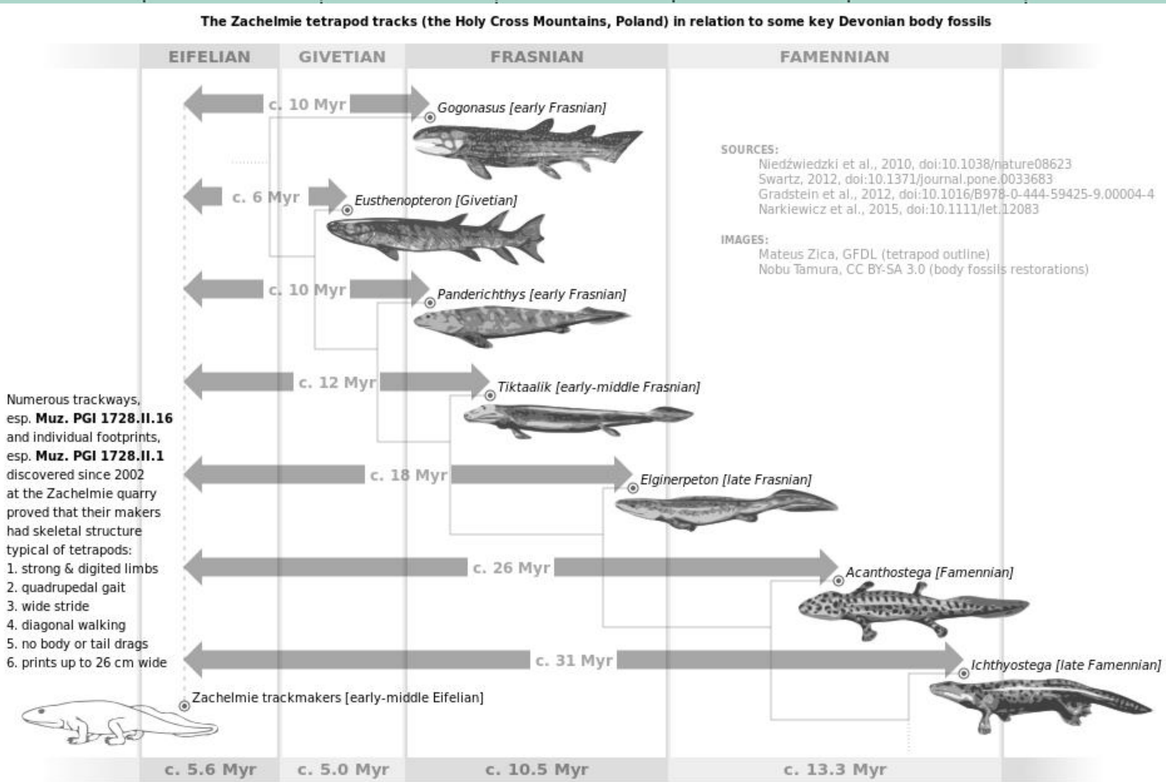
3. Same teeth structure



Τομή δοντιού κροσσοπτερύγιου

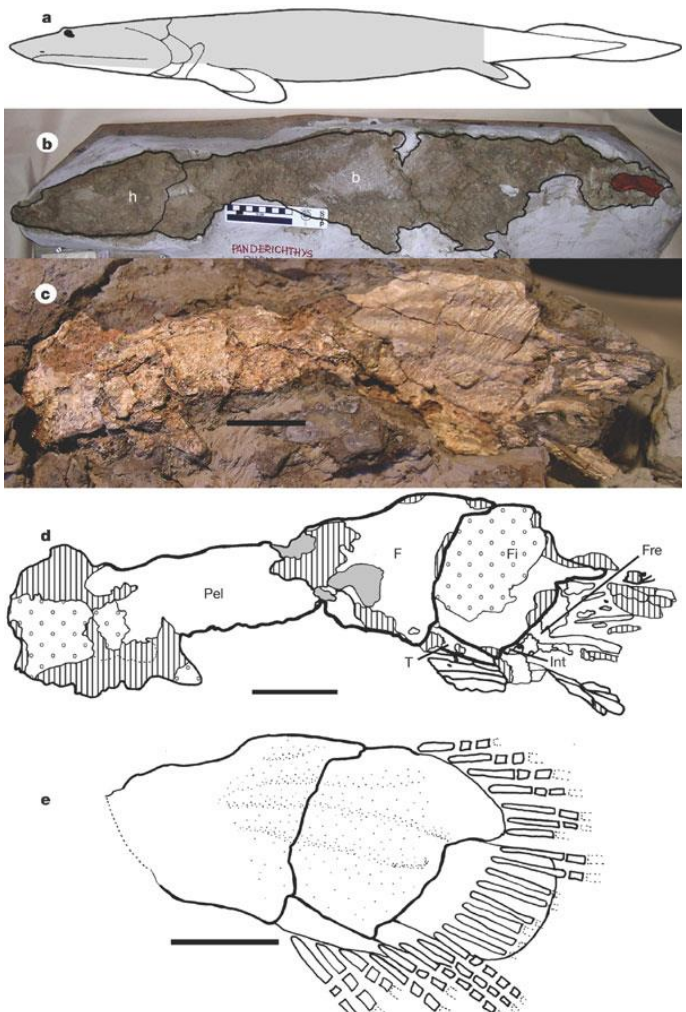
By Dave Souza

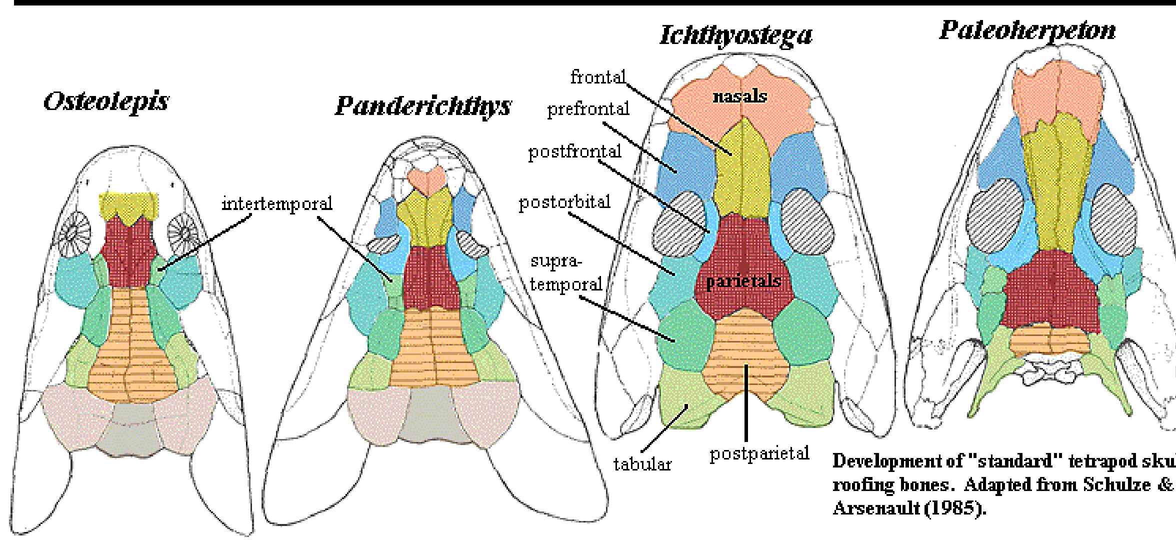




By Nobu Tamura

Panderichthys rhombolepis





Development of "standard" tetrapod skull roofing bones. Adapted from Schulze & Arsenault (1985).

Tiktaalik roseae

- Age: 375 my
- Transitional ancestral form that led to Amphibia

How many fingers?

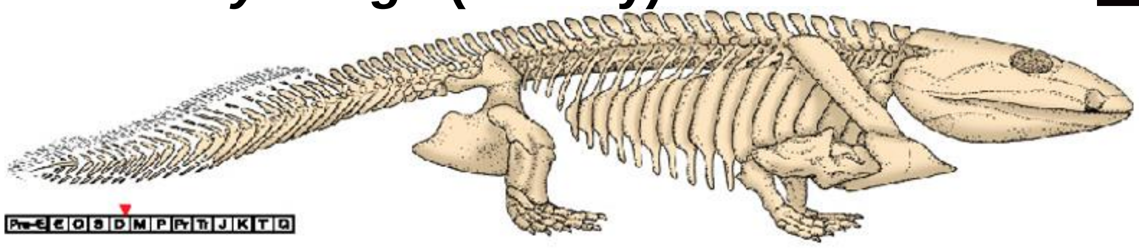
- Until recently it was considered as granted that tetrapods had always fingers and toes.
- In *Acanthostega* and *Ichthyostega* although most features are similar to later tetrapods there are a few startling differences. Recent work has shown that *Acanthostega* had eight fingers and *Ichthyostega* seven toes. In the latter the number of phalanges in each toe also varies (3,4,2,3,4,4,3)
- This is also supported by reports of six fingers and toes in *Tulerpeton.*
- It seems that during the Late Devonian six, seven or eight digits were freely produced in tetrapods, and only at the beginning of the Carboniferous the number was fixed to five

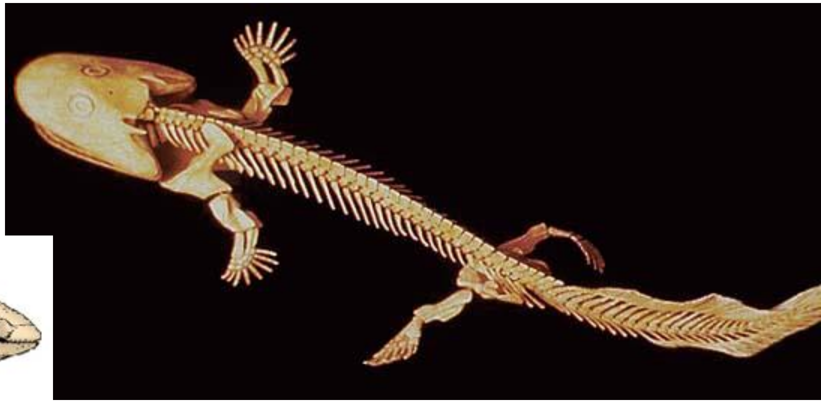
The first amphibia

- *Sinostega pani* το πρώτο αμφίβιο από Κίνα.

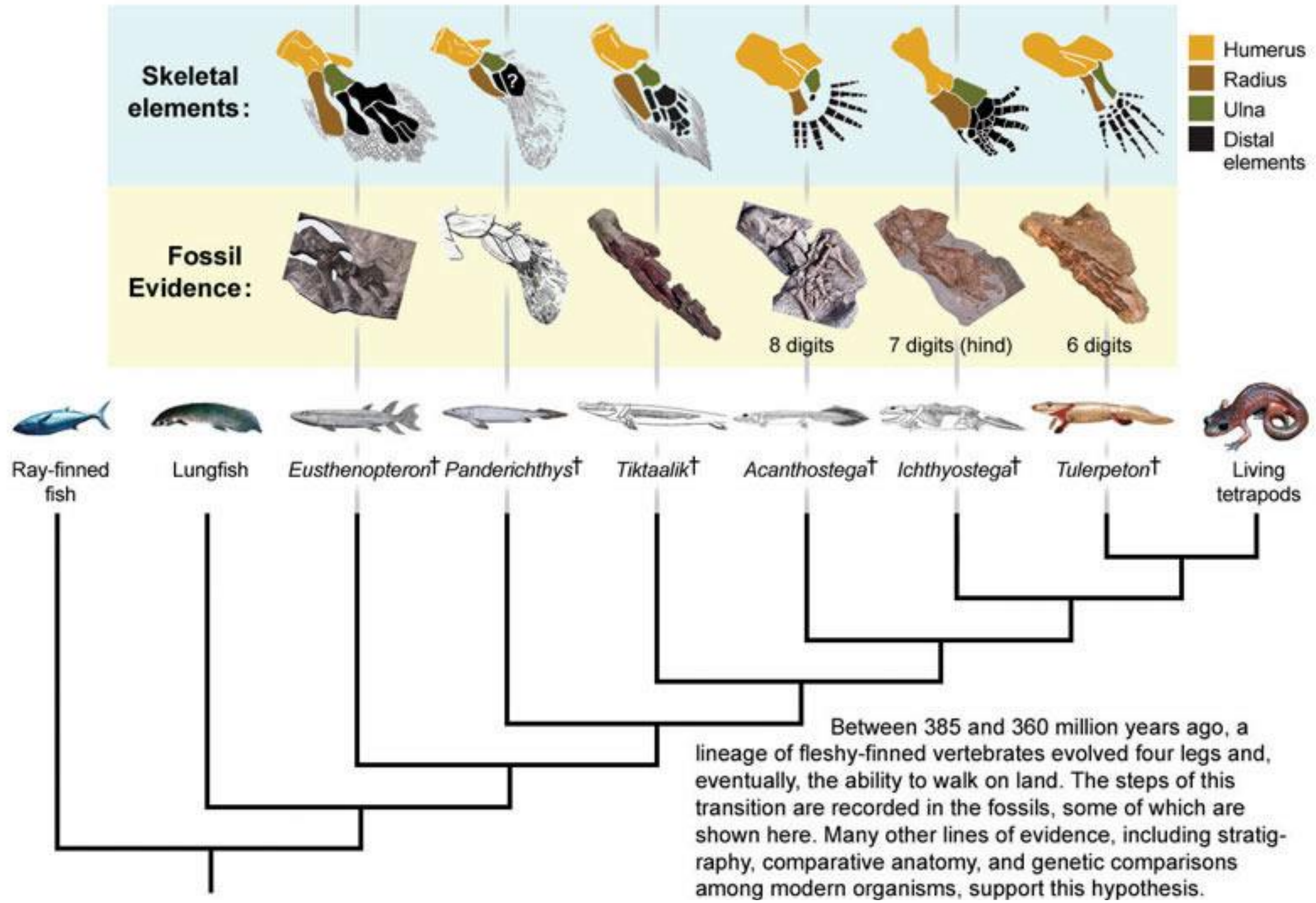
- ***Acanthostega***
- **(360 my)**

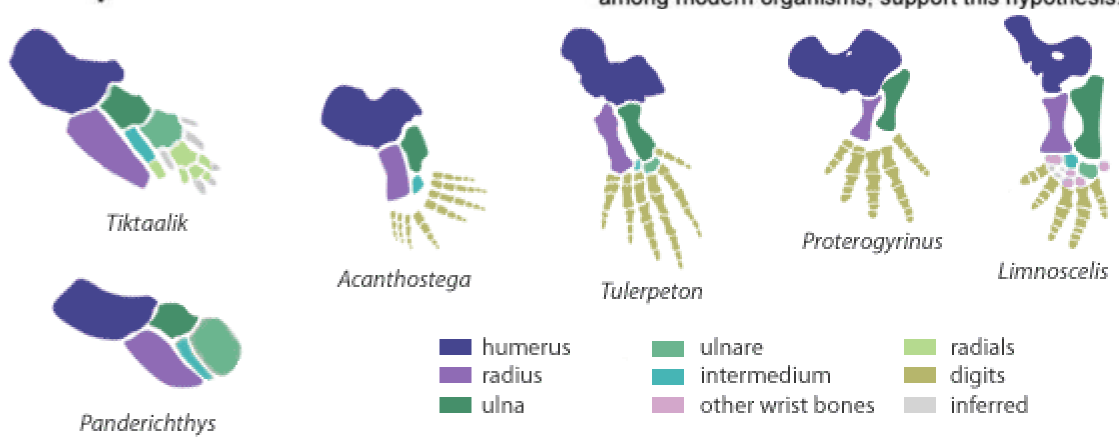
***Icthyostega* (367 my)**





Evidence of Macroevolution—The Origin of Tetrapods



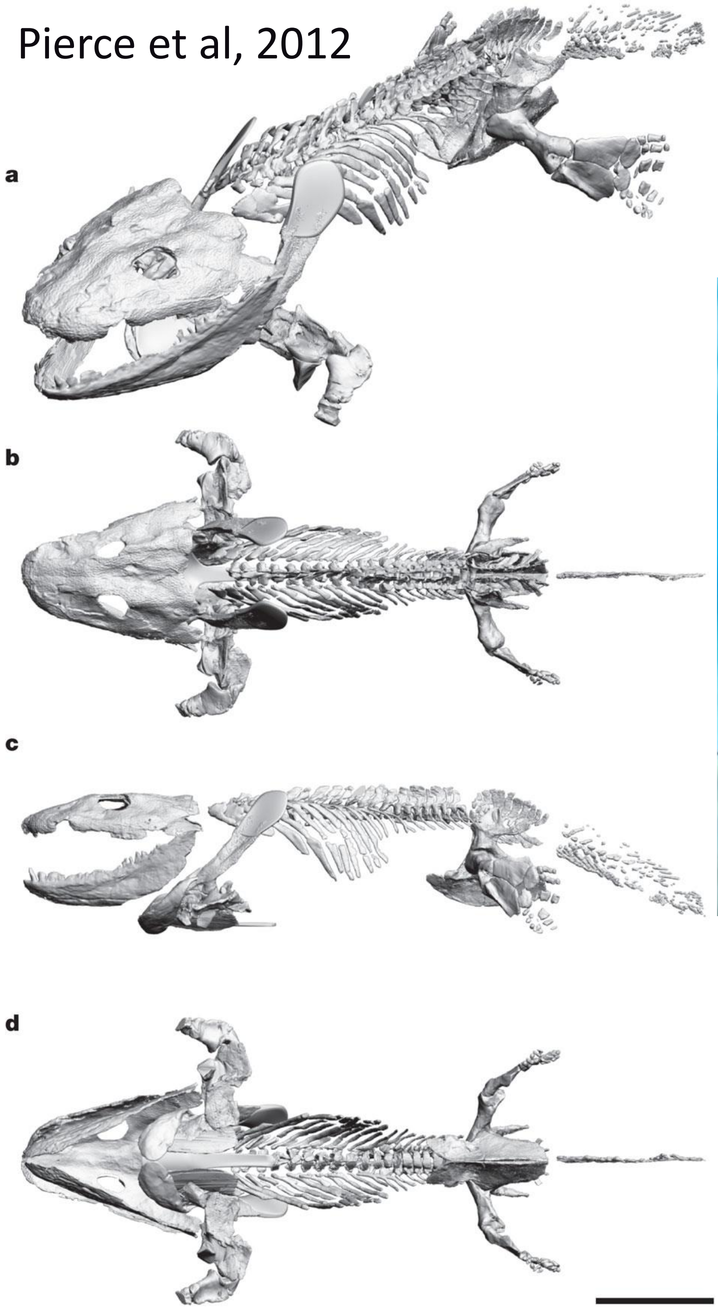


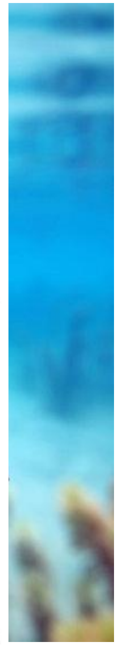
Icthyostega

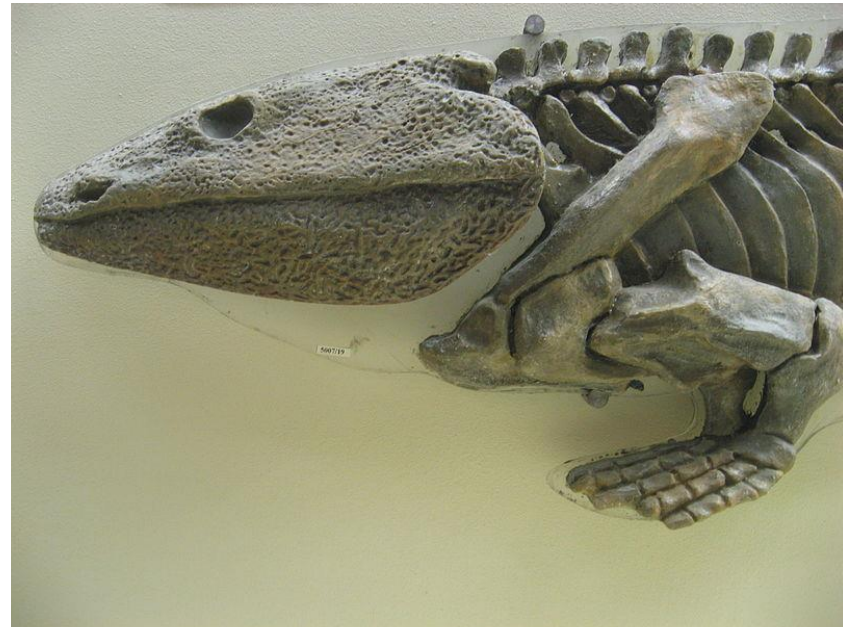
- Fish features:
  - Scales
  - Same skull structure
  - «loose» fishlike vertebral column.
- New features:
  - Front limb with 5 fingers
  - Pelvic and shoulder girdle that allowed walking on land.

Icthyostega 2

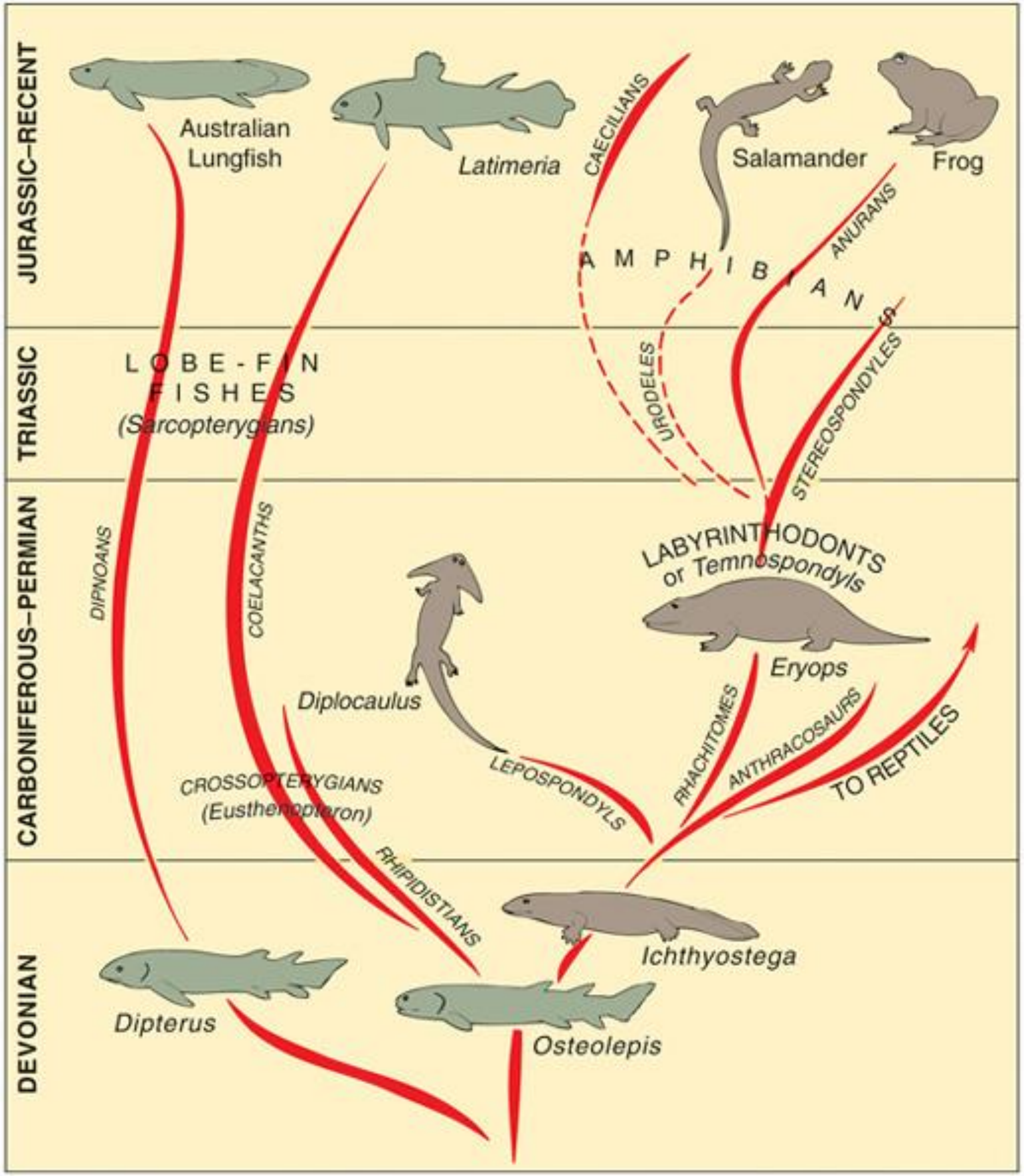
Pierce et al, 2012



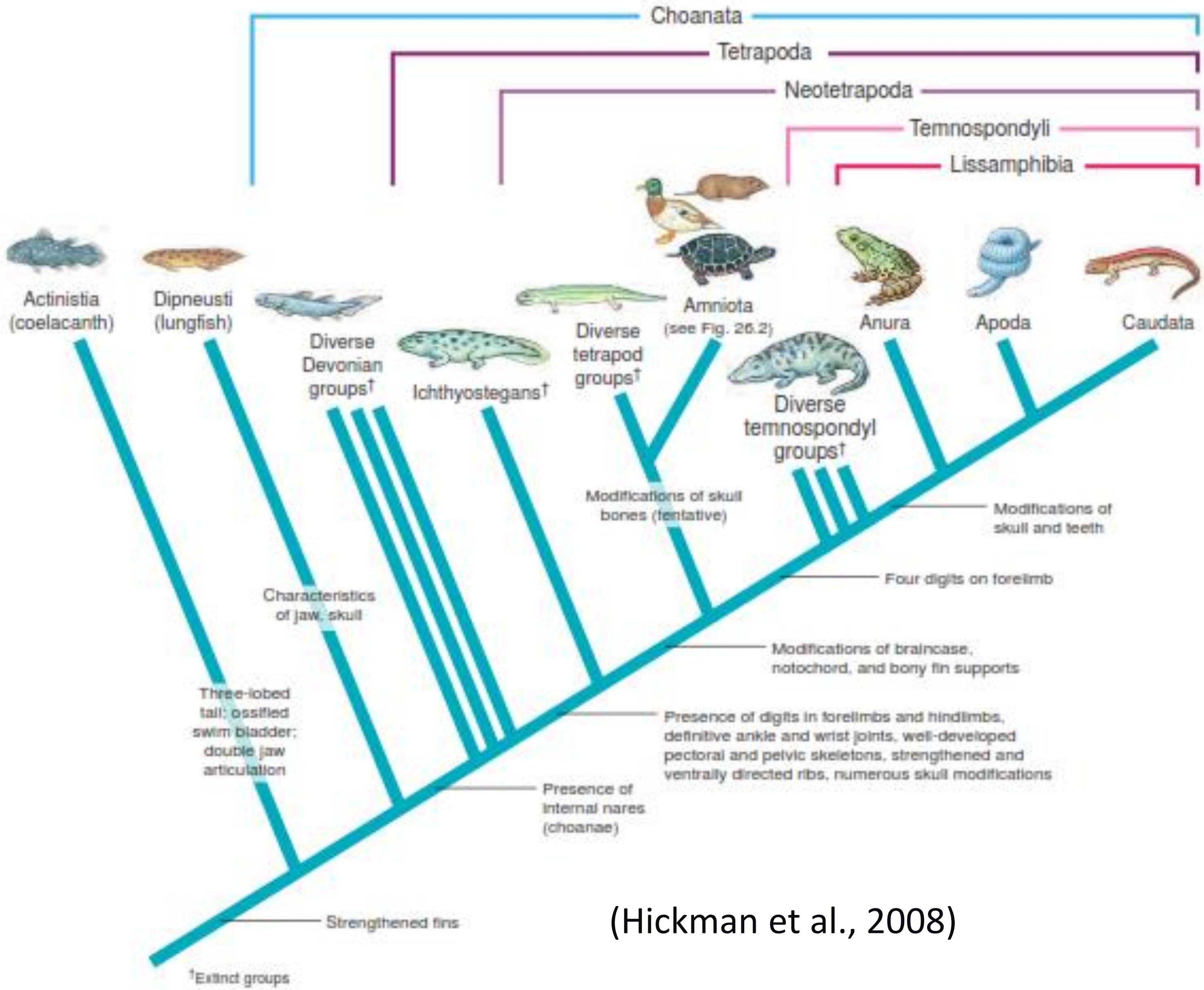




Icthyostega skeleton

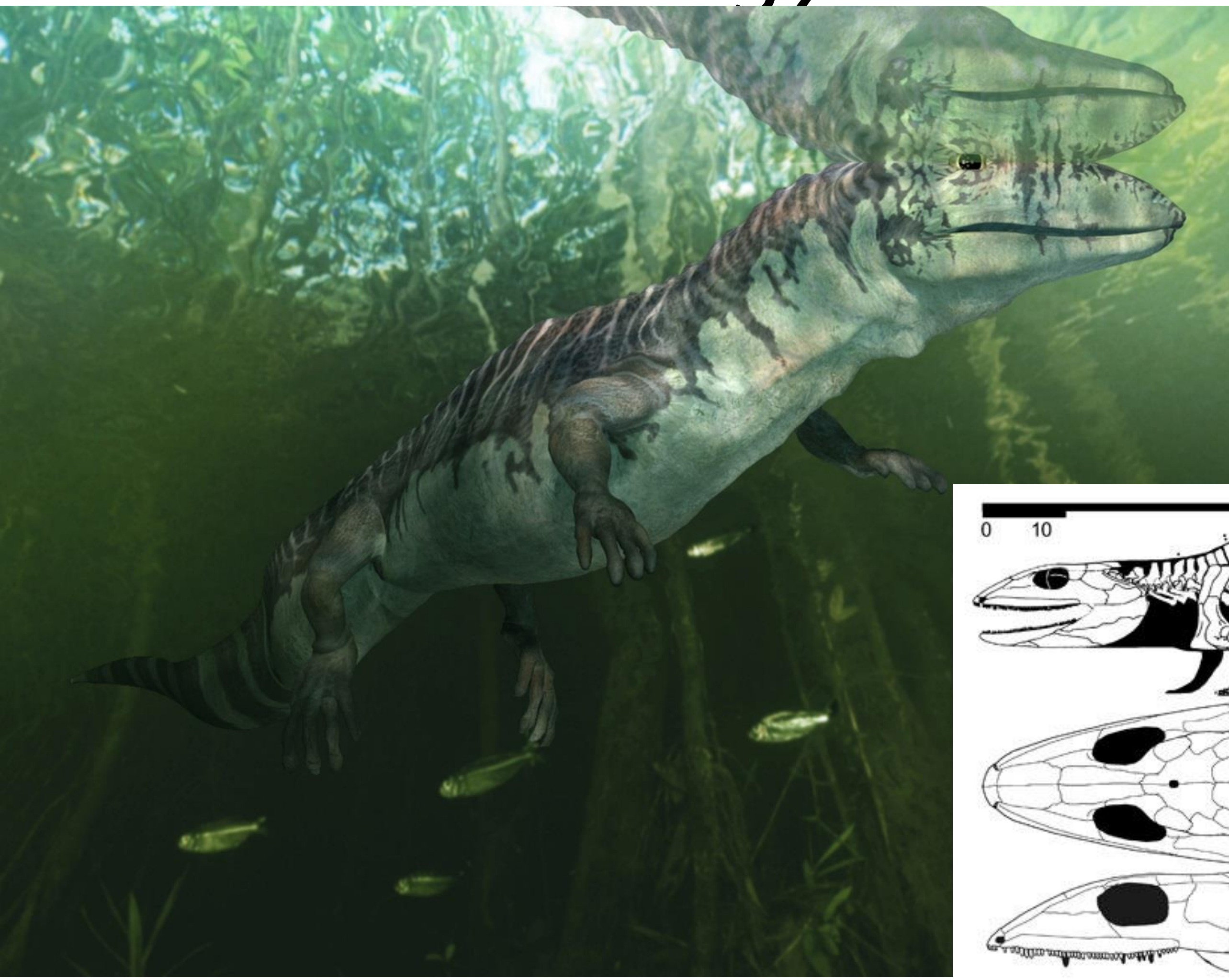


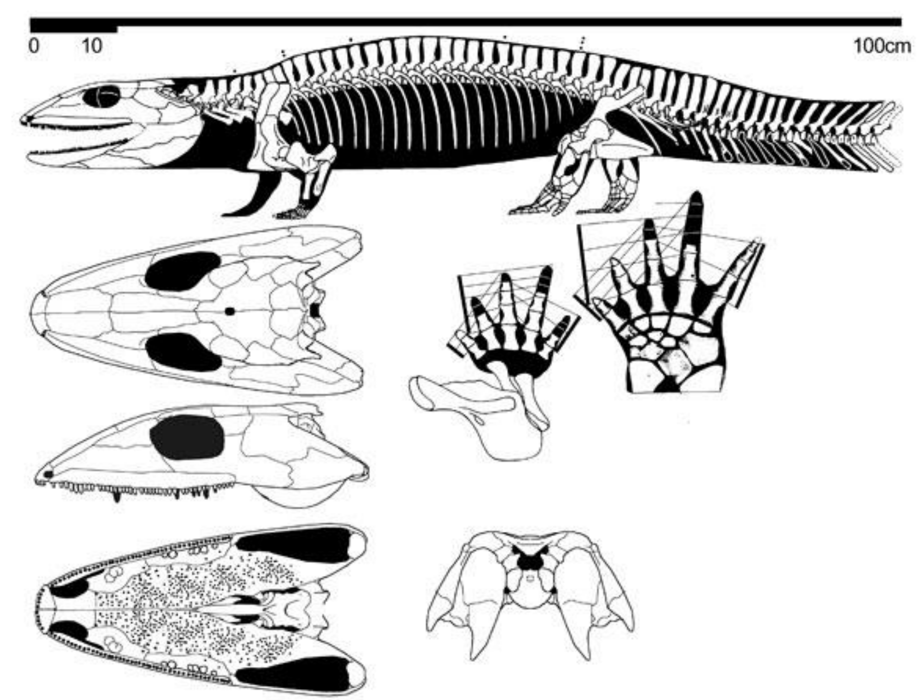
JURASSIC–RECENT
TRIASSIC
CARBONIFEROUS–PERMIAN
DEVONIAN
Australian Lungfish
Latimeria
CAECILIANS
Salamander
Frog
AMPHIBIANS
ANURANS
URODELES
STEREOSPONDYLES
LOBE-FIN FISHES
(Sarcopterygians)
DIPNOANS
COELACANTHS
LABYRINTHODONTS or Temnospondyls
Eryops
Diplocaulus
RHACHITOMES
ANTHRACOSAURS
TO REPTILES
LEPOSPONDYLS
CROSSOPTERYGIANS
(Eusthenopteron)
RHIPIDISTIANS
Ichthyostega
Dipterus
Osteolepis



(Hickman et al., 2008)

Proterogyrinus shceelei





Anthracosauria, the clade towards Amniota

Eryops megacephalus

Temnospondyli the clade that led to Lisamphibians

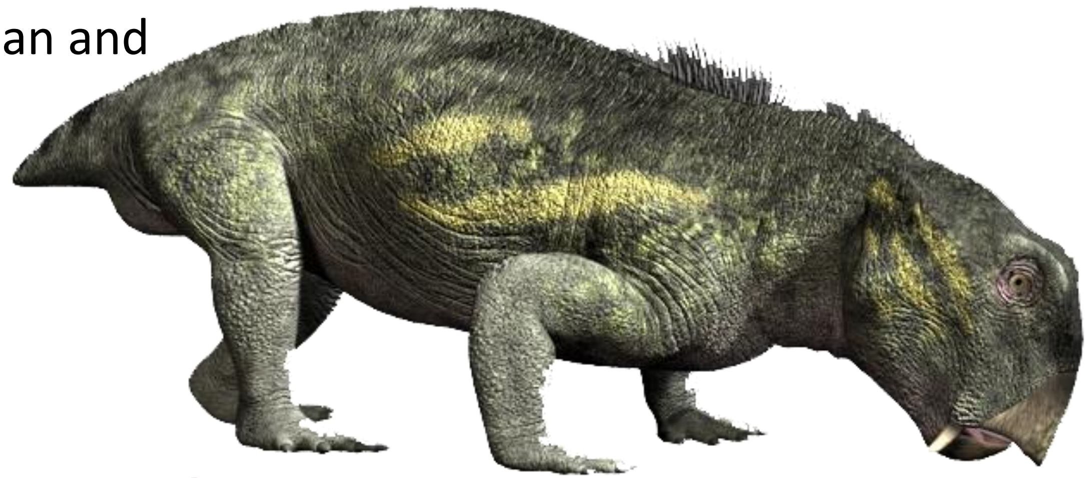
Cacops aspidephorus

Field Museum,

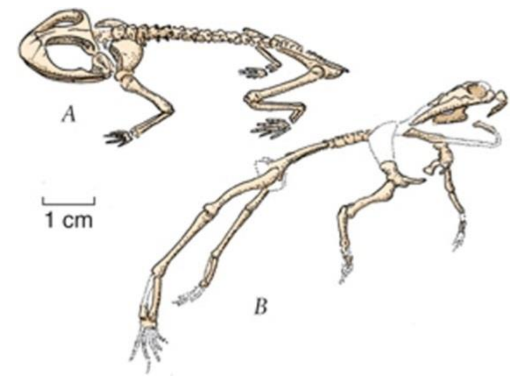
Small amphibian of the Late Permian.

Lystrosaurus

Large amphibian of Late Permian and Triassic



Lisamphibians



- Order Anura (Late Triassic– Recent) frogs and toads, the ilia project anteriorly and the posterior vertebrae are fused into a rod called urostyle, forming a strong pelvic basket
- Order Urodela (Late Jurassic – Recent)

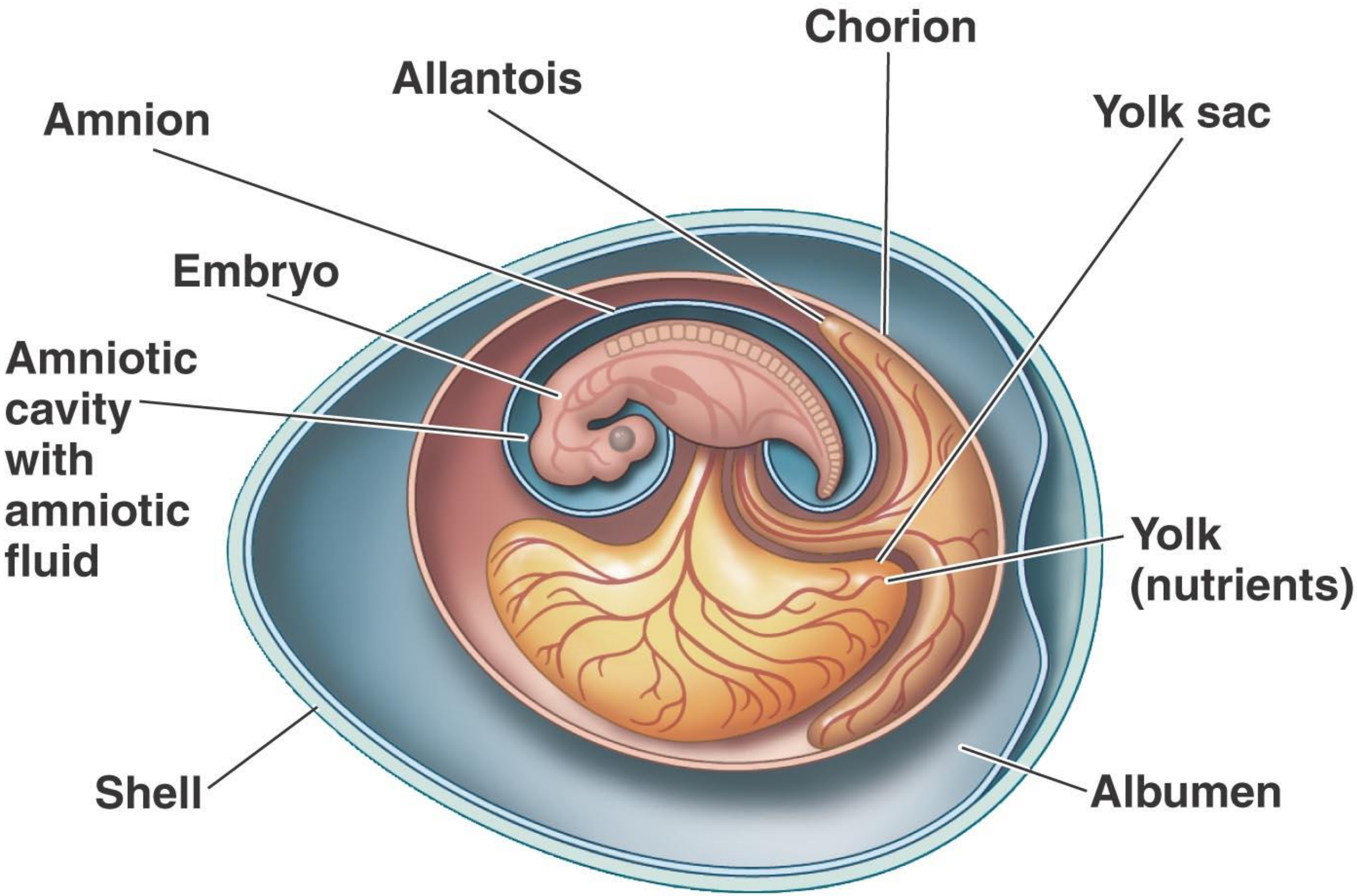
  Newts and salamanders
- Order Gymnophiona (Early Jurassic – Recent)

  Caecilians, strange, little, legless, earthworm-like amphibians

Vertebrates

- Non-amniotic vertebrates - Egg without cover that is fertilized externally. It must be either in liquid or in water for reproduction.
  - Fish
  - Amphibia
- Amniotes. Internal fertilization and amniotic egg. No water needed for reproduction.
  - Reptiles
  - Birds
  - Mammals

Amniotic egg



It's importance

- It allowed the possibility to live away from the water.
- It allowed vertebrates to live in different types of terrestrial environments.
- The amniotic egg evolved during the Carboniferous.
  The first fossilized eggs at L. Permian.

- Amphibians such as Seymouria (Permius), present mixed characters of amphibians and reptiles. A primitive amphibian that looked like Seymouria was probably the ancestor of the reptiles.

Reptiles

- The first entirely terrestrial tetrapods
  Age: Late Carboniferous - today.
  The oldest fossils in the genera Hylonomus and Paleothyris (310 my) in Canada in fossilized hollow trees full of sediment. Length 24 cm and looked like lizards.

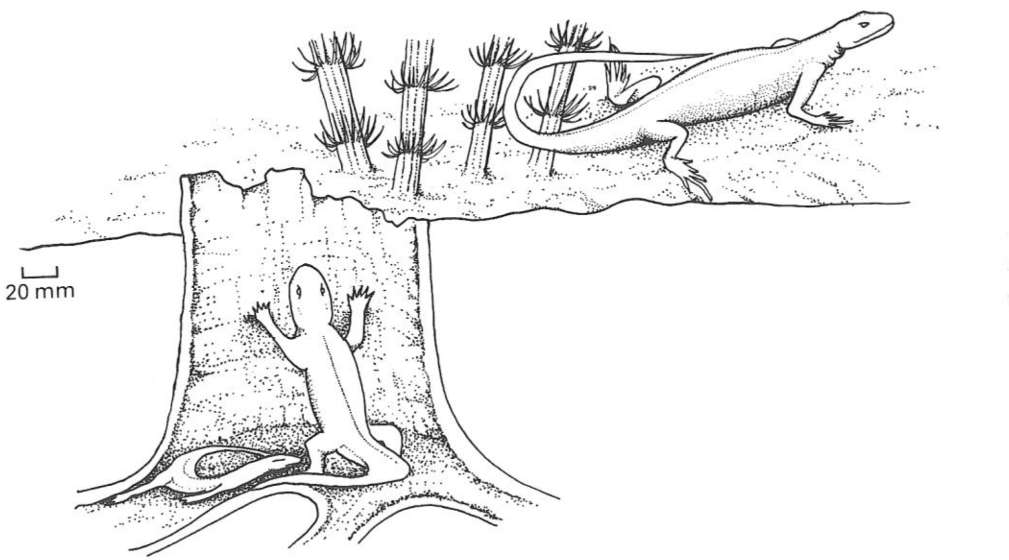
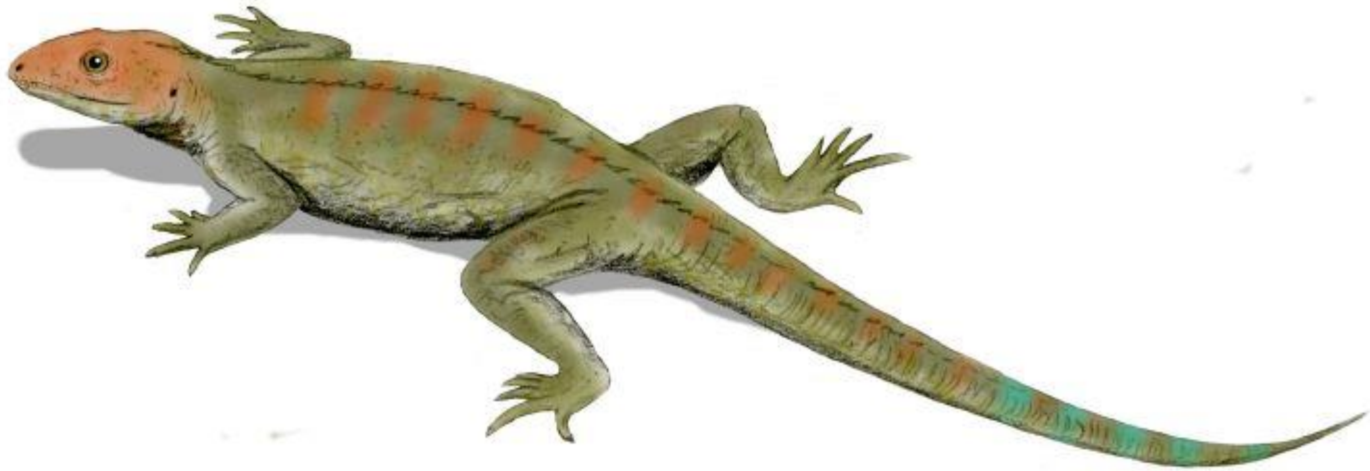
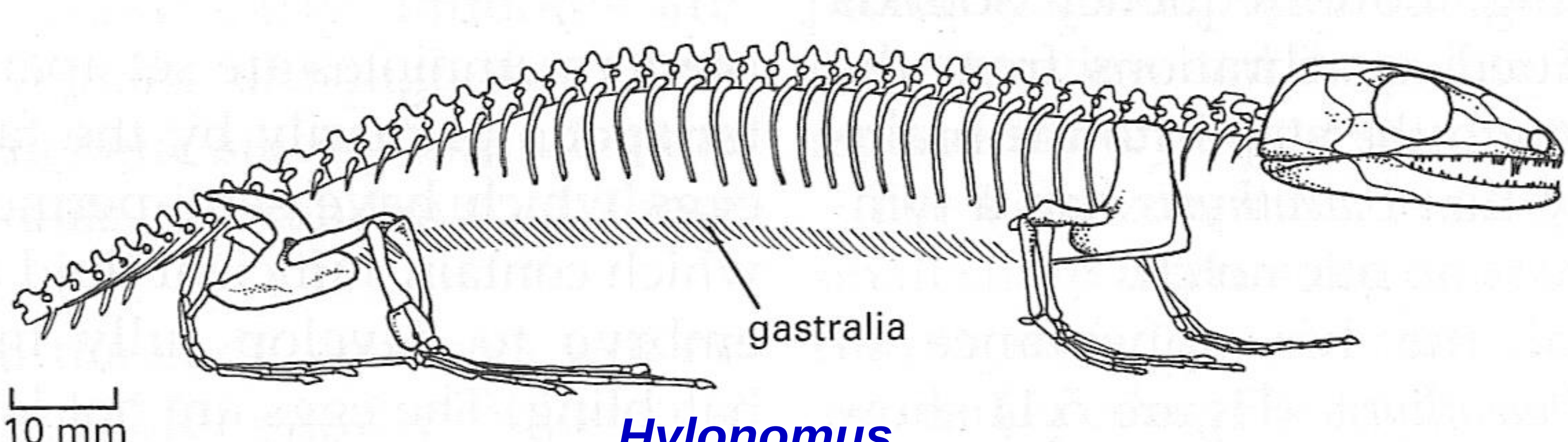


Fig. 5.1 The mode of preservation of the early amniotes *Hylonomus* and *Paleothyris* which were trapped in hollow tree stumps in the mid Carboniferous of Nova Scotia. (After Carroll, 1970 and other sources.)

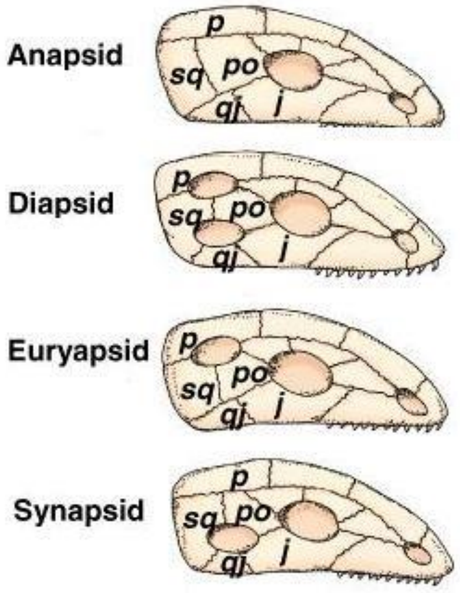


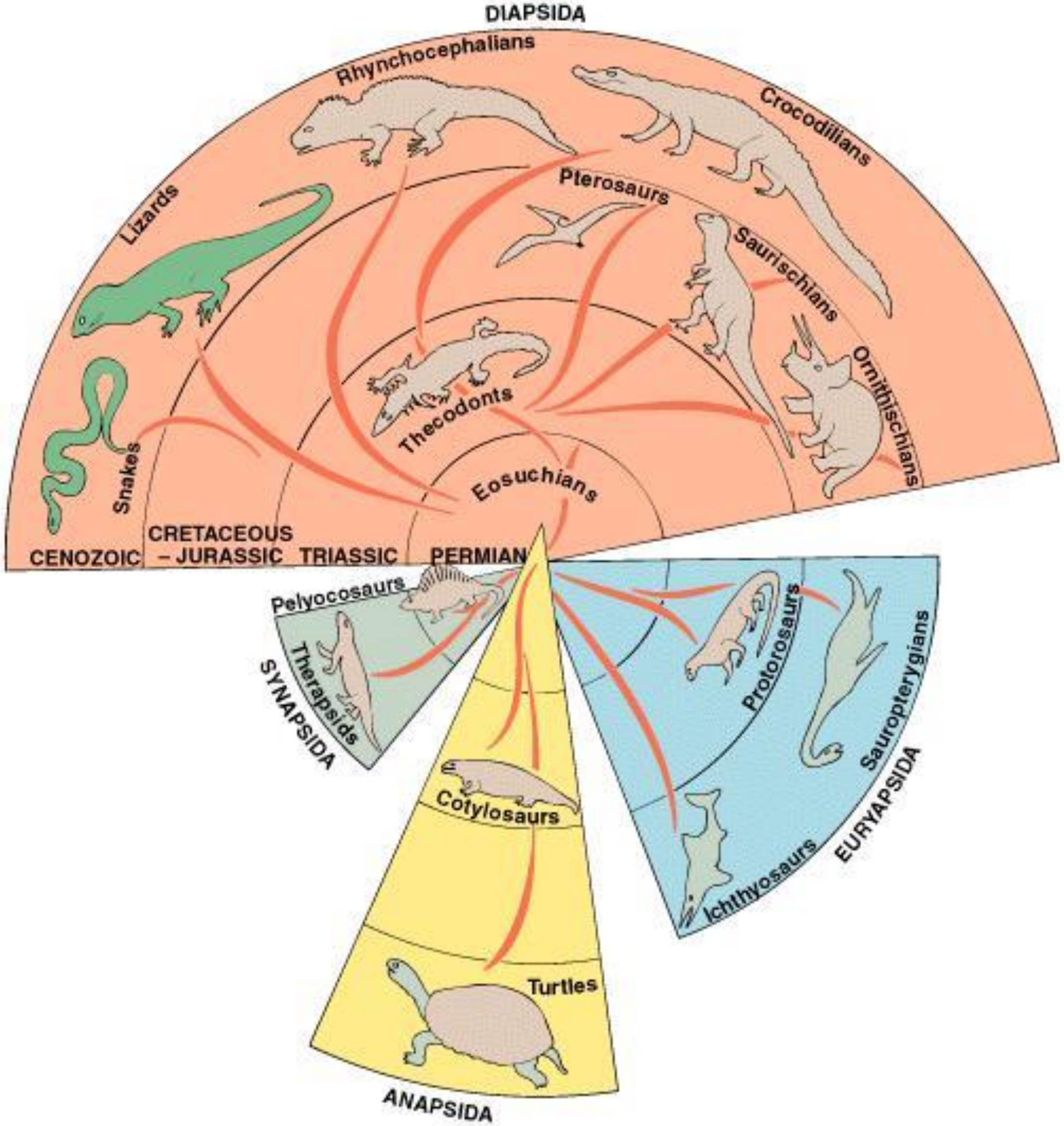


Hylonomus

Vertebrate skulls

- Anapsid (with no temporal fenestrae) - amphibians, first reptiles, and turtles.
- Diapsid (with two temporal fenestrae) - dinosaurs, pterosaurs, birds, and modern reptiles (except turtles).
- Euryapsid (with one upper temporal fenestra) - Marine reptiles (plesiosaurs, icthyosaurs).
- Synapsid (with one lower temporal fenestra) - pelycosaurs, therapsids, and mammals.




DIAPSIDA
Rhynchocephalians
Crocodilians
Lizards
Pterosaurs
Saurischians
Ornithischians
Thecodonts
Snakes
Eosuchians
CENOZOIC
CRETACEOUS
– JURASSIC
TRIASSIC
PERMIAN
Pelycosaurs
Therapsids
SYNAPSIDA
Protorosaurs
Sauropterygians
EURYAPSIDA
Ichthyosaurs
Cotylosaurs
Turtles
ANAPSIDA

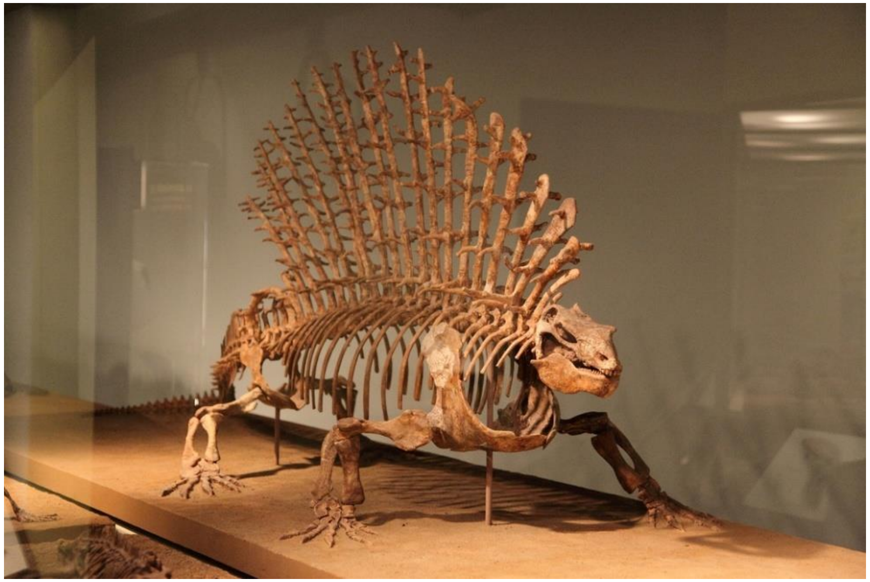
Synapsids

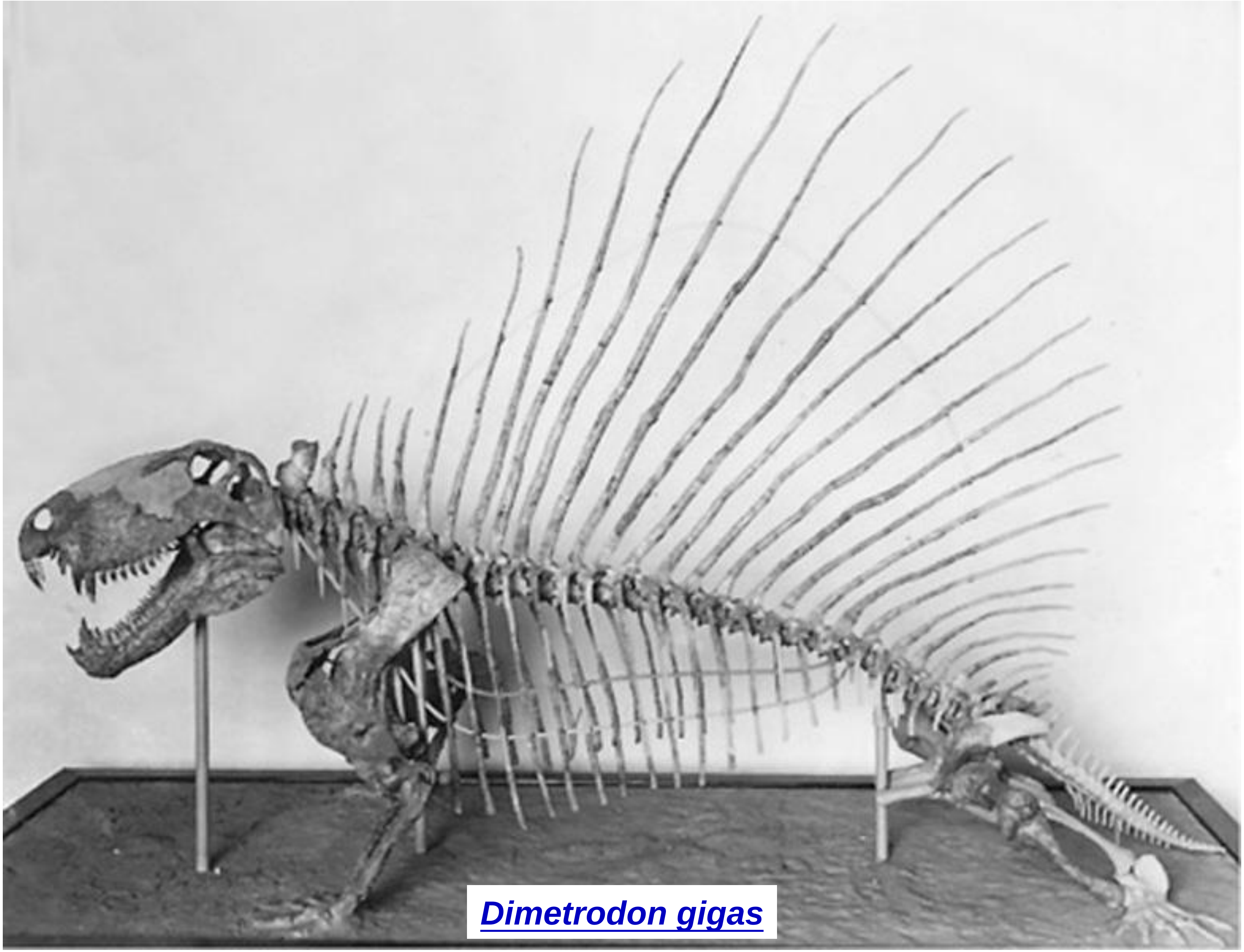
- They distinguished from the rest of the reptiles in the Late Carboniferous .
- The dominant terrestrial vertebrates of the Permian.
- Also known as "mammal-like" reptiles, different from all other reptiles.
- They include the pelycosaurs and the therapsids.

Pelycosaurs

- They are characterized by the developed "fins" on their backs, which are supported by vertebral spines. They probably functioned as temperature regulators.
- Carnivores (*Dimetrodon*) and herbivores (*Edaphosaurus)*

Edaphosaurus pogonius, Field Museum





Dimetrodon gigas

Dimetrodon και *Edaphosaurus*, ερπετά του Περμίου.

Therapsids

Age: Permian – Triassic

Medium size with mammalian characteristics:

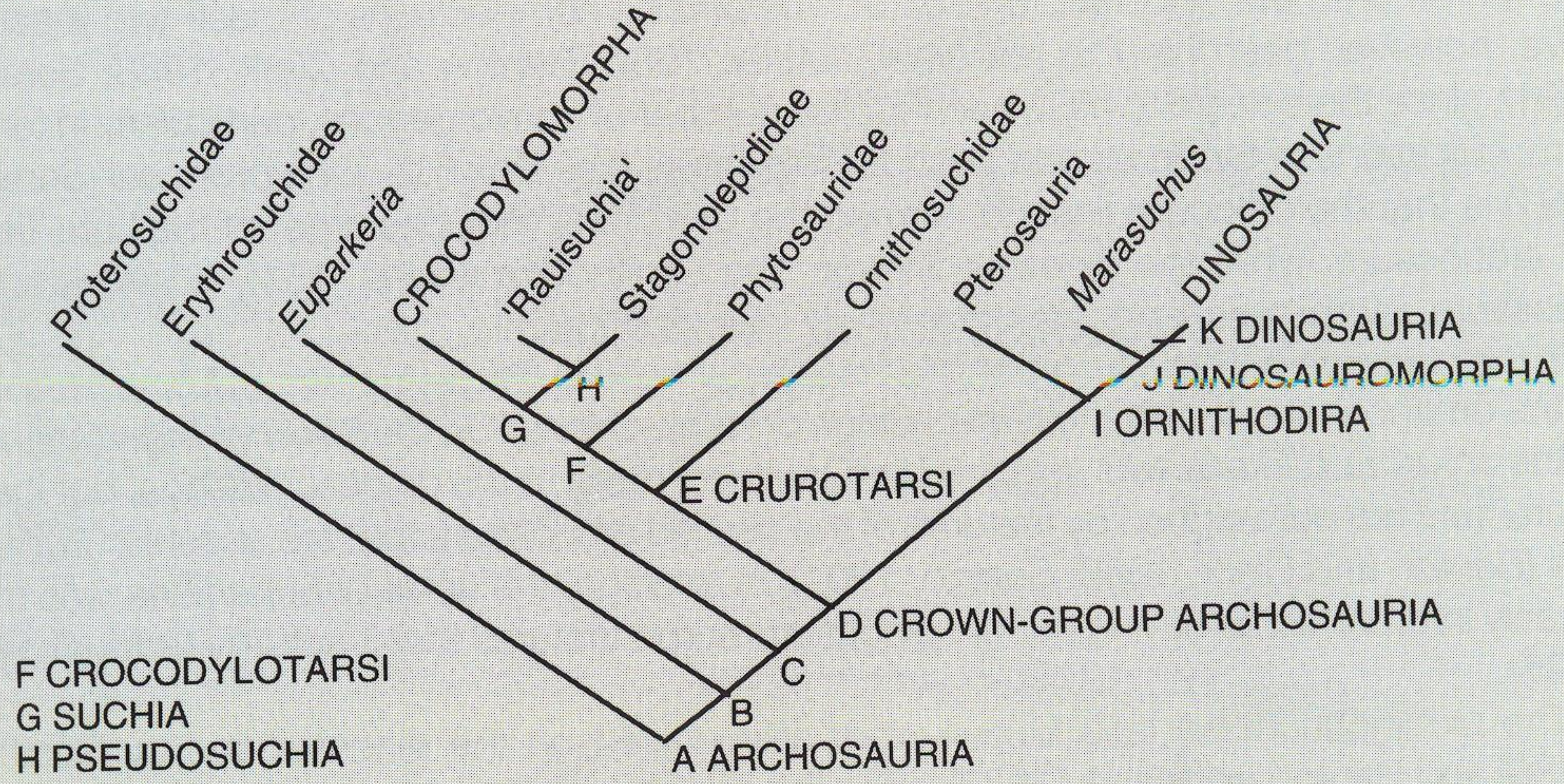
1. Fewer bones in the skull
2. Jaw structure like mammals
3. Differentiated teeth (incisors, canines, molars)
4. limbs placed under the body
5. Reduced ribs
6. Articulation between the skull and the atlas with two tubercles
7. Bony palate that allowed breathing during chewing
8. Holes for "whiskers" in the muzzle (so hairs)

Cynognathus

Cynognathus crateronotus, από το Τριαδικό της Ν. Αφρικής.

Reptiles

- Great diversity in the Mesozoic.
- Many new groups appeared in the Mesozoic, dominating in land, sea and air.
- The most interesting group of the Mesozoic was the archosaurs, a group of diapsids that included the crocodiles, the pterosaurs, the dinosaurs, and the Thecodonts.


Proterosuchidae
Erythrosuchidae
Euparkeria
CROCODYLOMORPHA
'Rauisuchia'
Stagonolepididae
Phytosauridae
Ornithosuchidae
Pterosauria
Marasuchus
DINOSAURIA
K DINOSAURIA
J DINOSAUROMORPHA
I ORNITHODIRA
H
G
F
E CRUROTARSI
D CROWN-GROUP ARCHOSAURIA
C
B
A ARCHOSAURIA
F CROCODYLOTARSI
G SUCHIA
H PSEUDOSUCHIA

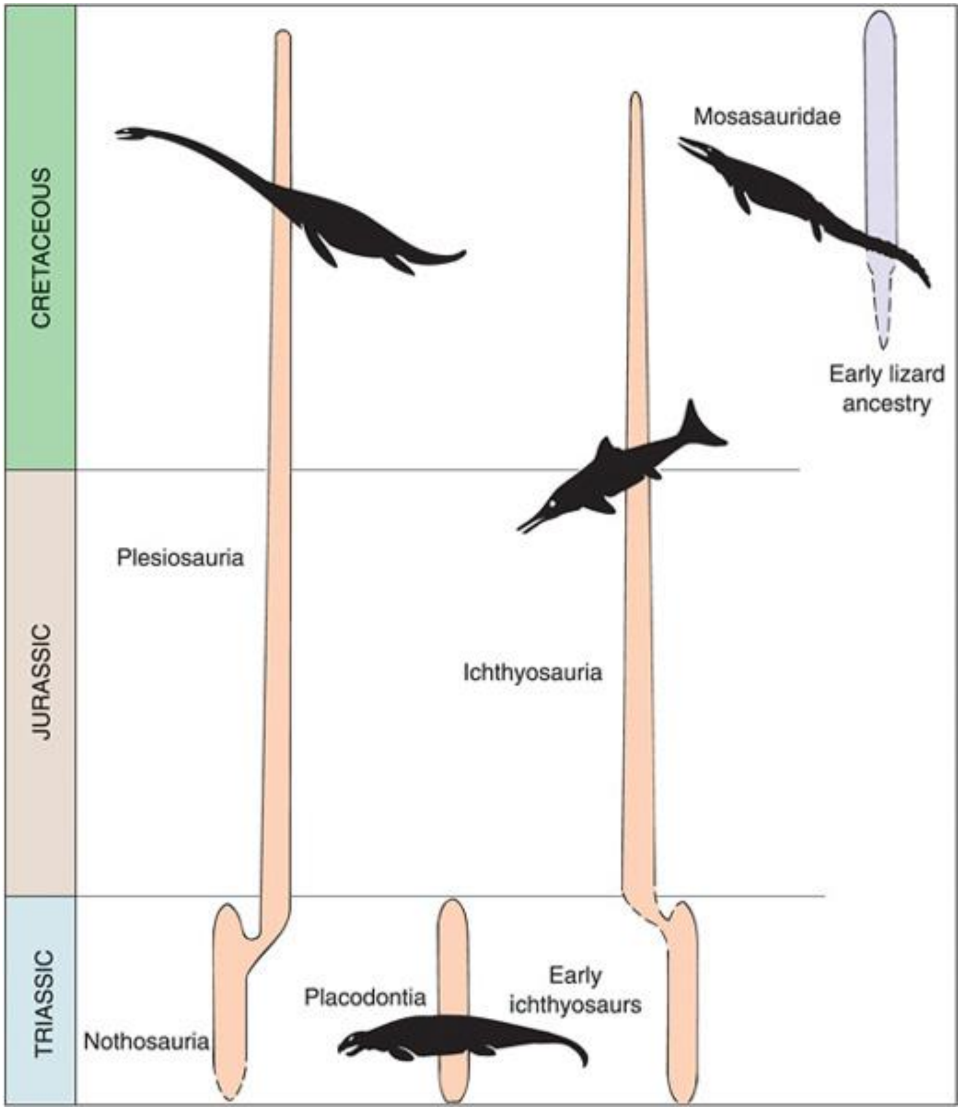
Reptiles colonize the sea

- Many reptile groups have successfully adapted to the marine environment.
- Settlement seems to have worked as a retrograde adaptation since reptiles were the first tetrapods that developed adaptations to live exclusively on land without having to return to the water for reproduction.
- In this case reptiles as predators have settled in the sea to exploit the abundance of food.
- They fed on ammonites, sharks, osteicthyans and other animals inhabiting the seas.

Marine reptiles

- Adaptations to the marine environment included:
- Flat finned limbs
- Hydrodynamic bodies
- Modified lungs for greater efficiency
- Reproductive adaptations in some groups to give birth in the sea (ovoviviparous).
- Others like sea turtles have returned to land to give birth.

Marine reptiles



1. Prolacertiformes
2. Pachypleurosauria
3. Nothosauria
4. Placodontia
5. Plesiosaurs,
6. Icthyosaurs
7. Mosasaurs
8. Crocodiles
9. Marine turtles

Marine reptiles

1. Prolacertiformes
2. Pachypleurosauria
3. Nothosauria
4. Placodontia (wide teeth to crush shells of mollusks). They lived only in the Triassic The first reptile that returned to the sea was Mesosaurus in the early Permian

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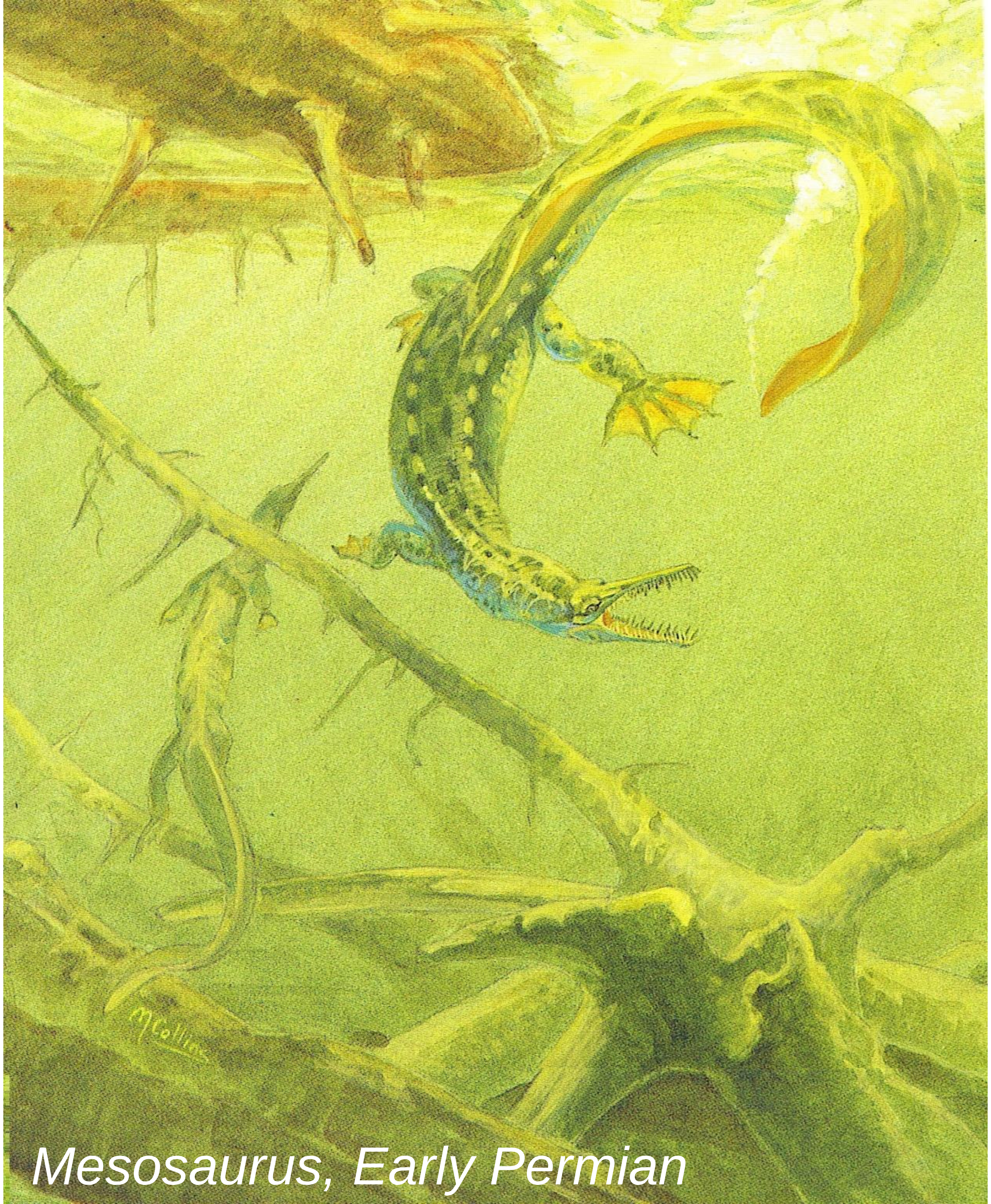
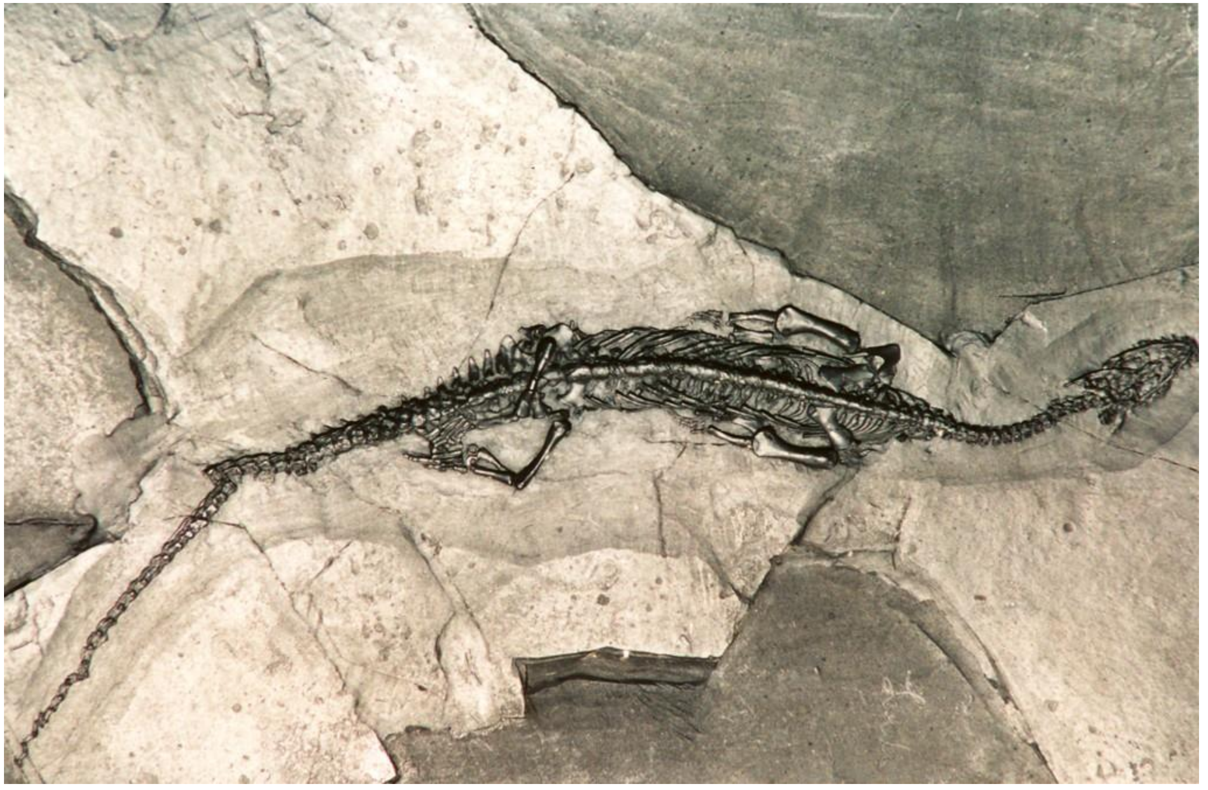


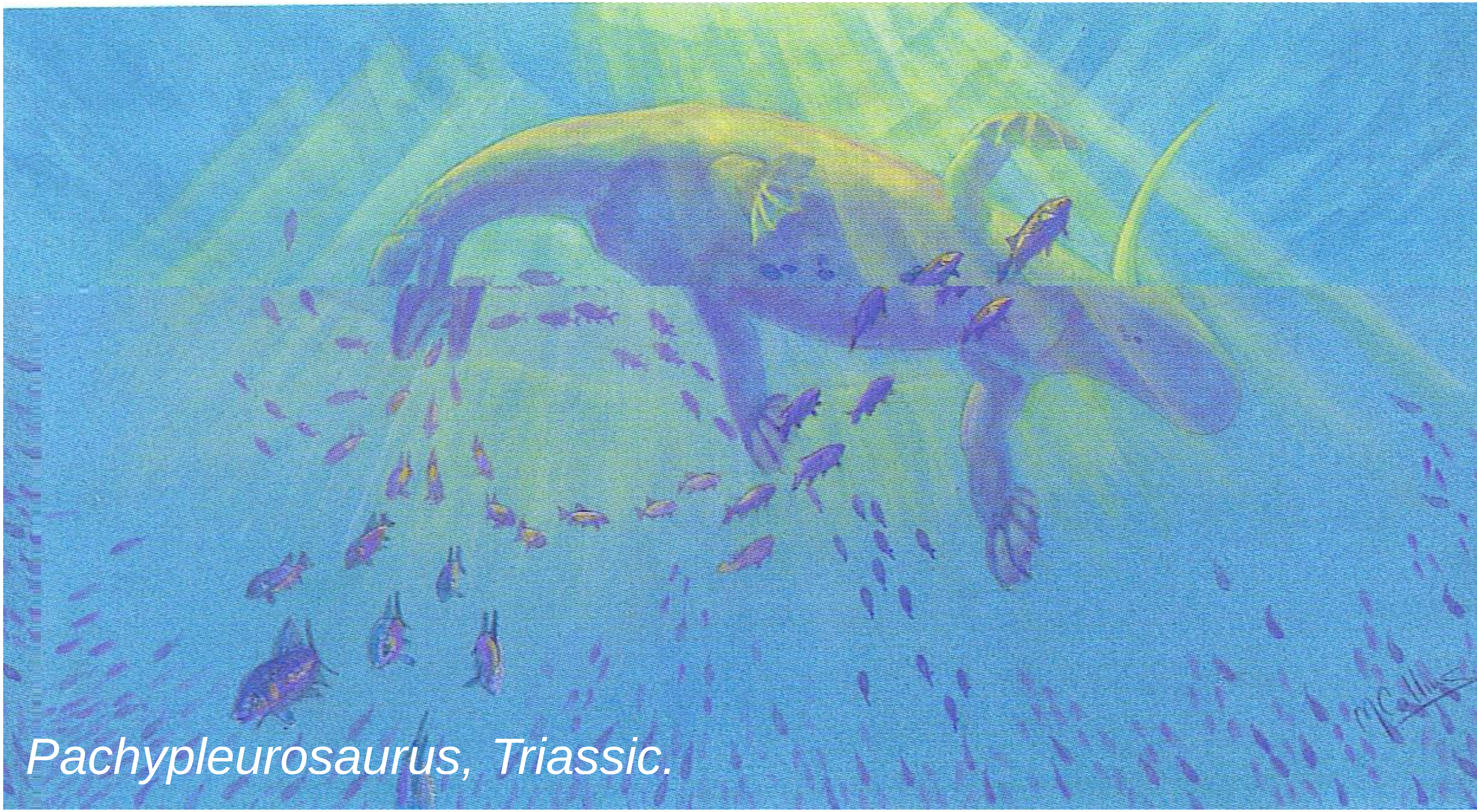
Mesosaurus, Early Permian

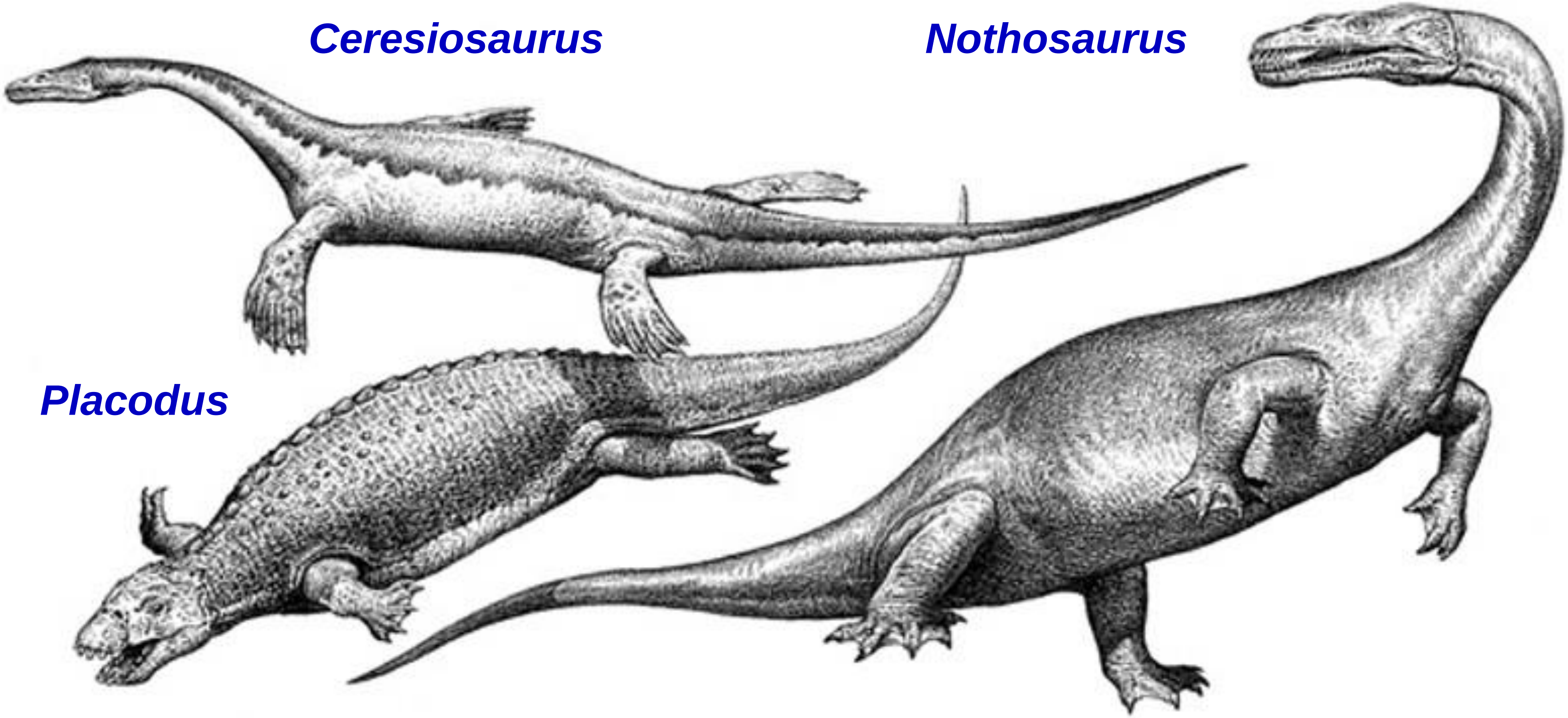
Tanystropheus, Prolacertiform reptile of the Triassic

Pachypleurosauria



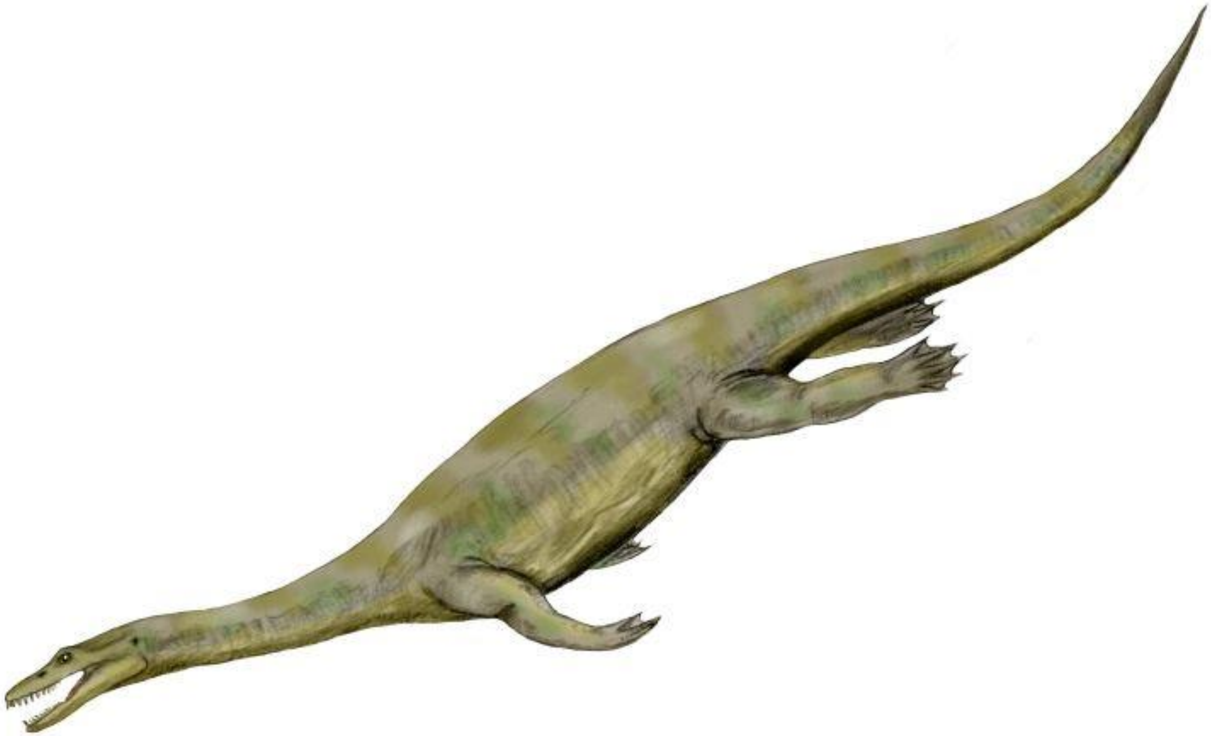
Pachypleurosaurus edwarsi


Pachypleurosaurus, Triassic.



Triassic Nothosauria and Placodontia

Nothosauria



Nothosaurus mirabilis,
Triassic

5. Plesiosaurs

- They evolved from the Nothosauria
- They fed mainly with fish and invertebrates.
- Two forms, one with a short and wide body with an extremely long neck with a small head, and one with a large, sturdy body with a short neck and a large head with strong jaws (Pliosaurs)
- They reached a length of 14 meters.
- Large, with many bones, fin shaped limbs.

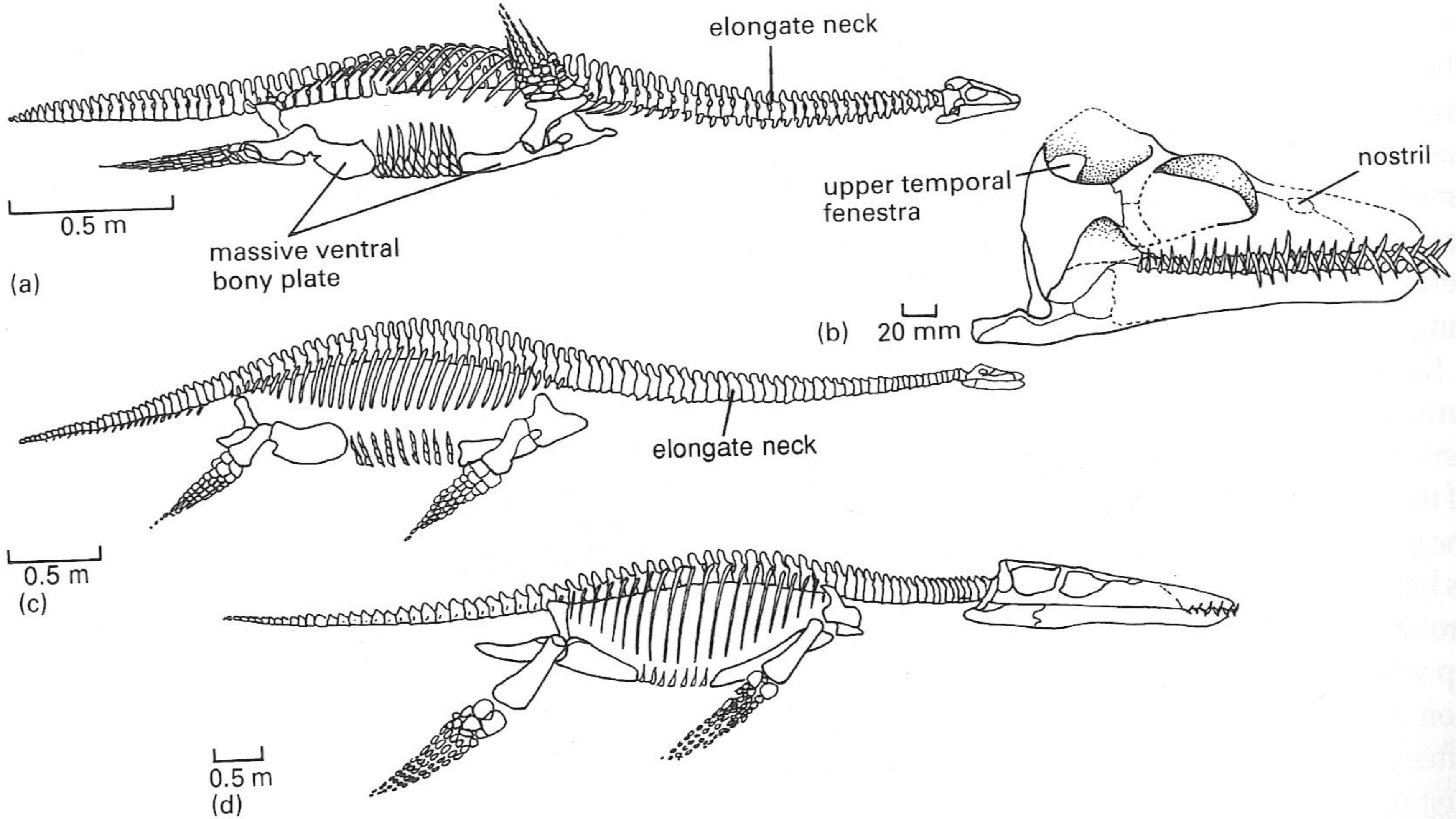
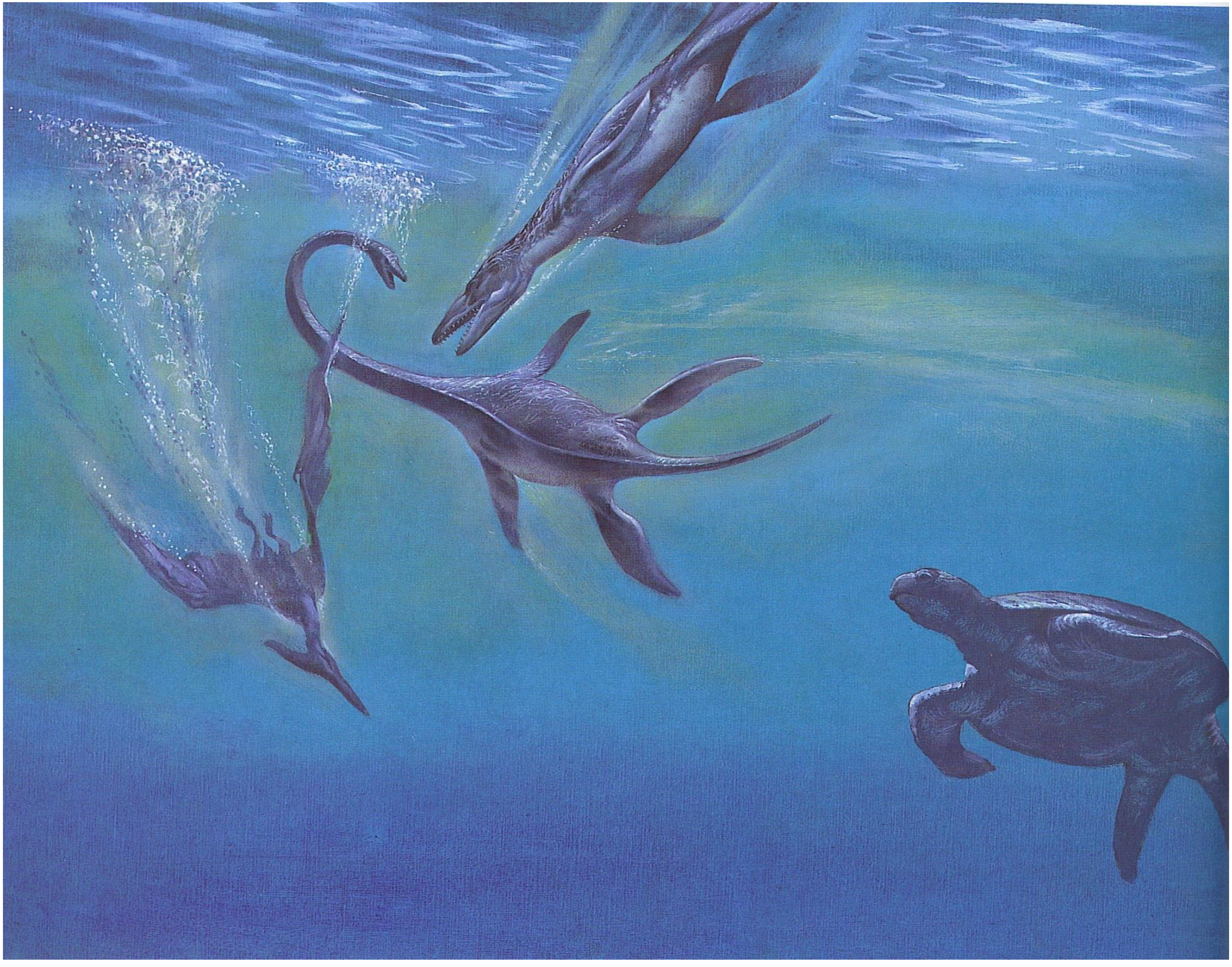


Fig. 8.30 The plesiosaurs: (a, b) the Late Jurassic cryptoclidid *Cryptoclidus*, skeleton in swimming pose and skull in lateral view; (c) the Late Jurassic elasmosaur *Muraenosaurus*; (d) the Late Jurassic pliosaur *Liopleurodon*. [Figures (a, b) after Brown, 1981; (c, d) after Robinson, 1975.]

Κρητιδικός πλησιόσαυρος



6. Icthyosaurs

- The most fish-like reptiles of the Mesozoic
- They look like dolphins but with vertical rather than horizontal tail fins.
- Top predators in the oceans
- Large eyes to locate prey.
- Ability to maneuver and control buoyancy
- They gave birth to youngs and not eggs
- Length from 1-14 meters

Large Jurassic Icthyosaur, *Grendelius*

An icon of the Jurassic, and one of the most astounding fossils of all time. Here a female ichthyosaur, about 10 ft (3 m) long, is fossilized apparently in the process of giving birth. Three tiny skeletons may be counted inside her rib cage, and a fourth lies outside her body. This is one of fifty or more mothers with embryo young that have been found in the

7. Mosasaurs

- Only in Cretaceous
- They reached a length of 15 m
- Largest lizards they've ever livedrelated to the modern barons (they had a common ancestor).
- Probably toppredators
- They attacked ammonites, as evidenced by bite marks in ammonite shells.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8. Crocodiles

- They evolved in the Triassic as land animals
- It was the last important group of marine reptiles of the Triadic that evolved.
- Some got adapted to the marine environment in the Lower Jurassic.
- In the Cretaceous Rare.
- Fast swimmers.
- They have evolved from the Archosaurs, relatives of dinosaurs.

9. Marine Turtles

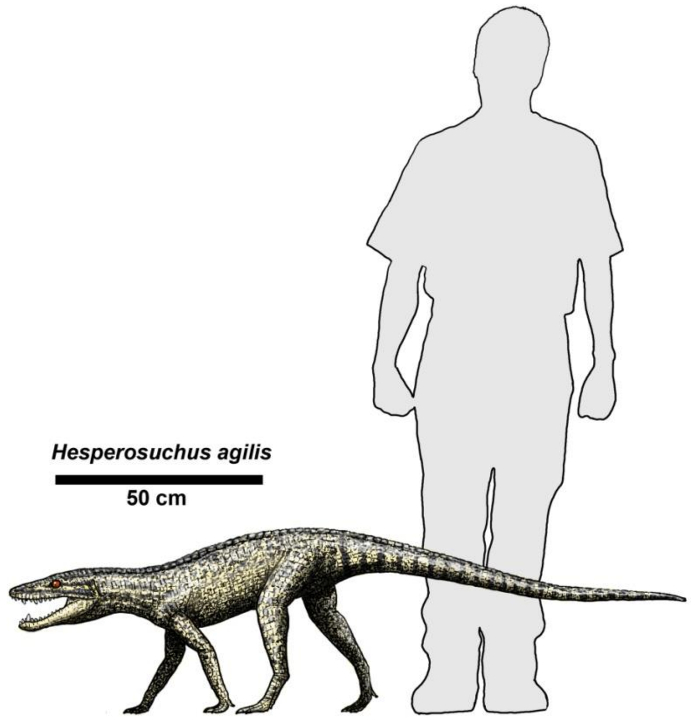
- Evolved in the Cretaceous
- Reached 4 m in length such as the genus *Archelon*


Protostega gigas, Κρητιδικό
© Pamela Gore 1996

Lower Archosaurs (Thecodonts)

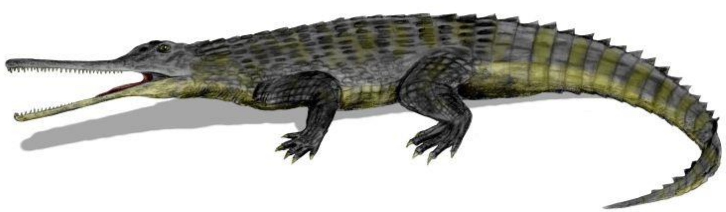
- The Archosaurs are diapsid reptiles of the Triassic. They are divided into two groups:
  - Lepidosauria (lizards, snakes, etc.)
  - Archosauria (Dinosaurs, Pterosaurs, Crocodiles and Birds)
- Small agile reptiles with long tails and short forelimbs.
- Several of them were bipedal. This meant that the front ends were released and could be used for other activities such as catching prey and later using them for flight.

Hesperosuchus



Hesperosuchus agilis
lower archosaur

Phytosaurs



Rutiodon carolinensis,
L. Triassic

- Some Archosaurs returned to the tetrapod locomotion and evolved into:
  Armoured terrestrial carnivores, or
  Crocodylomorph aquatic reptiles the Phytosaurs.
- Their skull was elongated with sharp teeth, and most likely fed with fish.
- They lived in the Late Triassic

Phytosaurs and Crocodiles

- A clear difference between them is the position of the nostrils.
  - In crocodiles they are placed at the edge of their muzzle.
  - In Phytosaurs they were placed right in front their eyes.