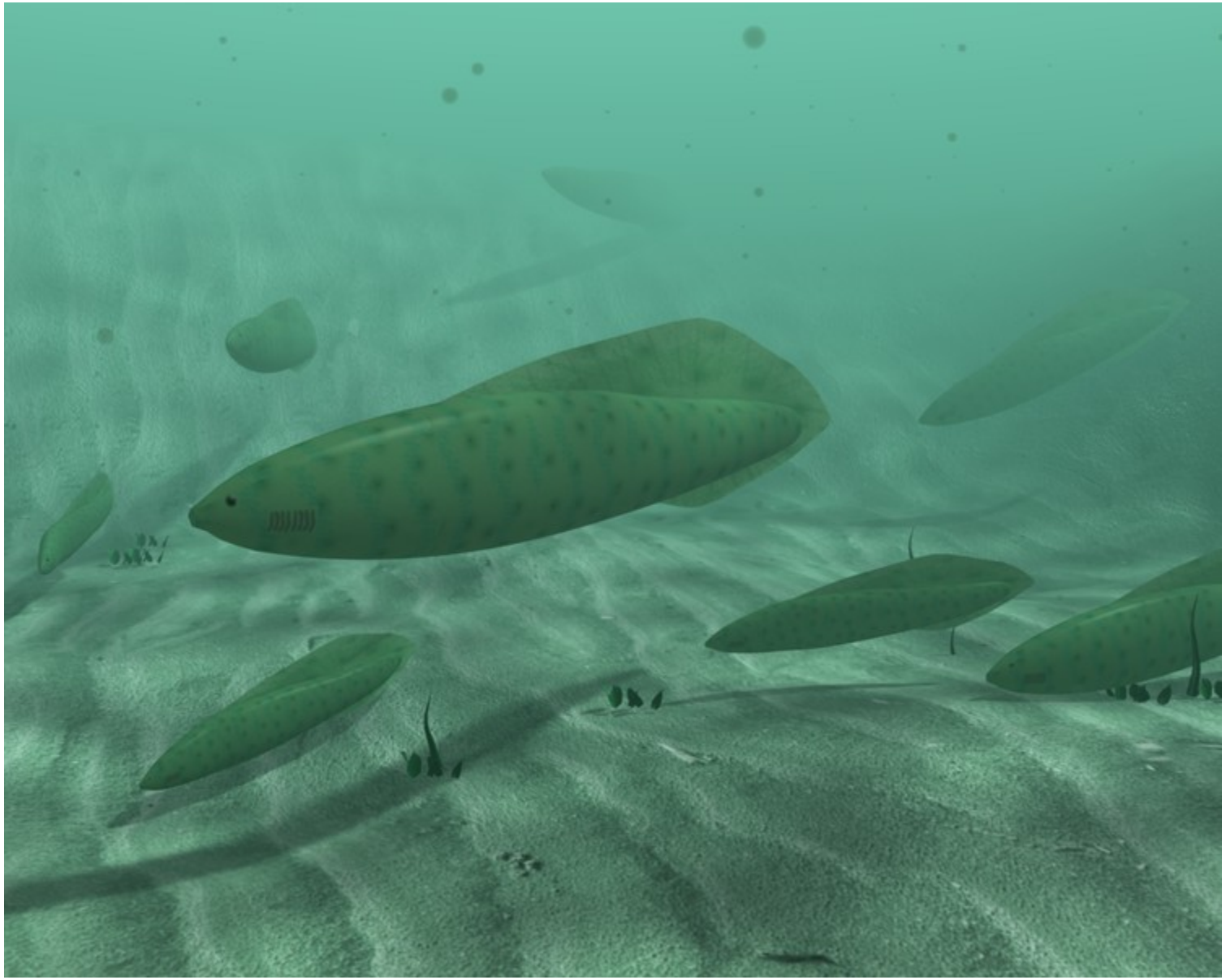
Subphylum Vertebrata

- Subphylum Vertebrata has several divisions you need to be familiar with:
  - Superclass Agnatha – Jawless Fish;
    Ostracoderm (fossil)
  - Superclass Gnathostomata
    - Class Placodermi – First Jawed Fish (Fossils)
    - Class Chondricthyes – Cartilagenous Fish; Sharks; Rays
    - Class Osteichthyes
      - Subclass Actinopterygii – Ray-finned Fish; Goldfish; Sea Horse
      - Subclass Sarcopterygii – Lobe-finned Fish; Coelocanth

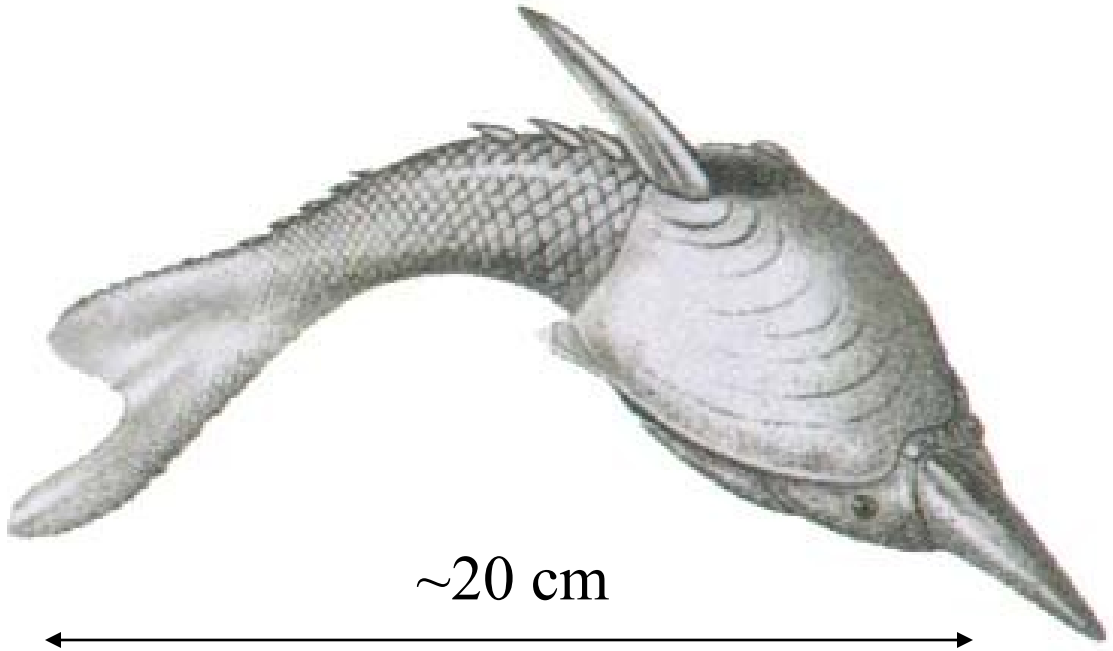
Vertebrata

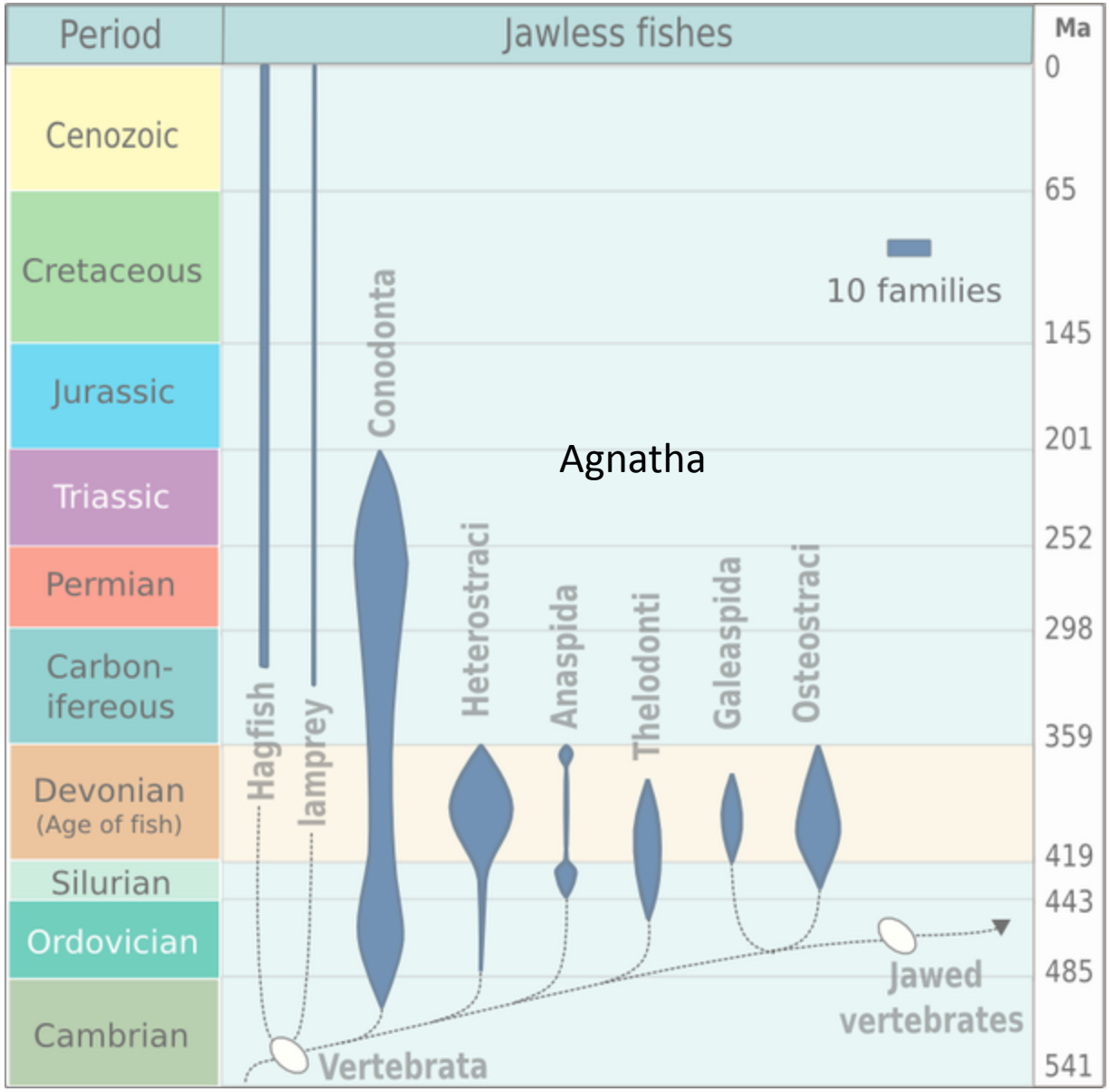
Vertebrates originated about **525 million years ago** during the **Cambrian explosion**, which saw the rise in organism diversity. The earliest known vertebrate is believed to be the ***Myllokunmingia***.[1] Another early vertebrate is ***Haikouichthys ercaicunensis***. Unlike the other fauna that dominated the Cambrian, these groups had the basic vertebrate body plan: a notochord, rudimentary vertebrae, and a well-defined head and tail.[17] All of these early vertebrates lacked jaws in the common sense and relied on filter feeding close to the seabed.[18] A vertebrate group of uncertain phylogeny, small-eel-like conodonts, are known from microfossils of their paired tooth segments from the late Cambrian to the end of the Triassic

Haikouichthys ercaicunensis



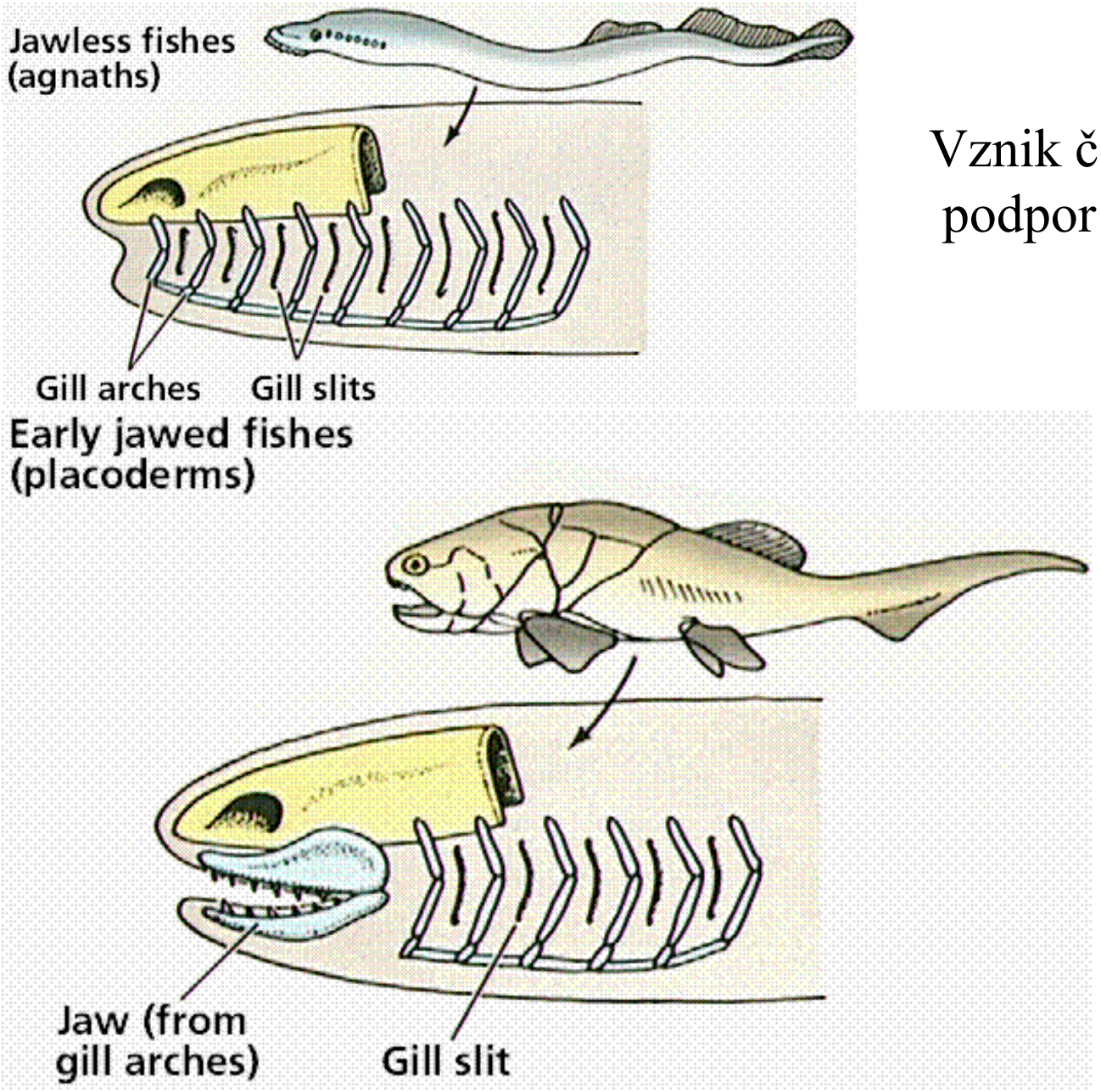
Devonian Jawless Fish




Period
Jawless fishes
Ma
Cenozoic
Cretaceous
Jurassic
Triassic
Permian
Carbon-
iferous
Devonian
(Age of fish)
Silurian
Ordovician
Cambrian
0
65
145
201
252
298
359
419
443
485
541
10 families
Agnatha
Hagfish
lamprey
Conodonta
Heterostraci
Anaspida
Thelodonti
Galeaspida
Osteostraci
Vertebrata
Jawed
vertebrates

CONODONTS

- conodonts are small tooth shaped structures
  - have been found in fossil record for many years
  - important biostratigraphically
  - made of phosphate (like most vertebrate bones)
  - Ordovician conodont over 1 foot long (1995)
  - probably a predator in Chordata



Vznik čelistí z žaberních podpor

KINGDOM: **ANIMALIA**
PHYLUM: **CHORDATA**

CRANIATA (vertebrates) *CAMB.*

CLASSES: **CONODONTA*** *CAMB.*

AGNATHA (jawless fish) *CAMB.*

Gnathostomata

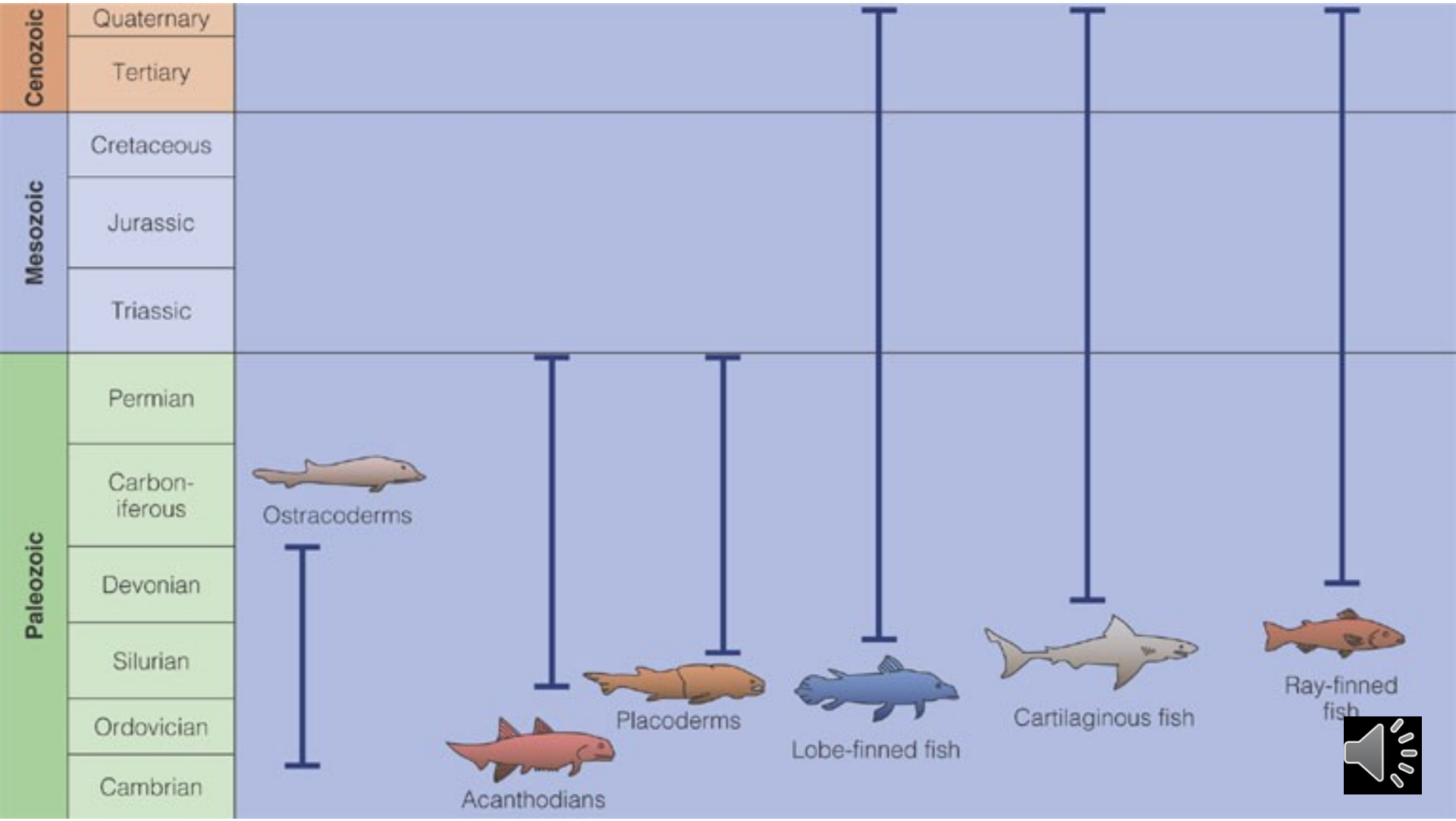
ACANTHODI (spiny sharks)* *SIL.*
PLACODERMI (armored fish)* *SIL.*
CHONDRICHTHYES (cartilaginous sharks) *DEV*
OSTEICHTHYES (bony fish) *SIL.*

- Subclass Actinopterygii (paprskoploutví)
- Subclass Sarcopterygii (nozdratí)

AMPHIBIA (amphibians) *DEV.*
REPTILIA (reptiles) *CARB.*
AVES (birds) *JURASSIC*
MAMMALIA

(mammals) *TRIASSIC*

Geologic Ranges of Major Fish Groups

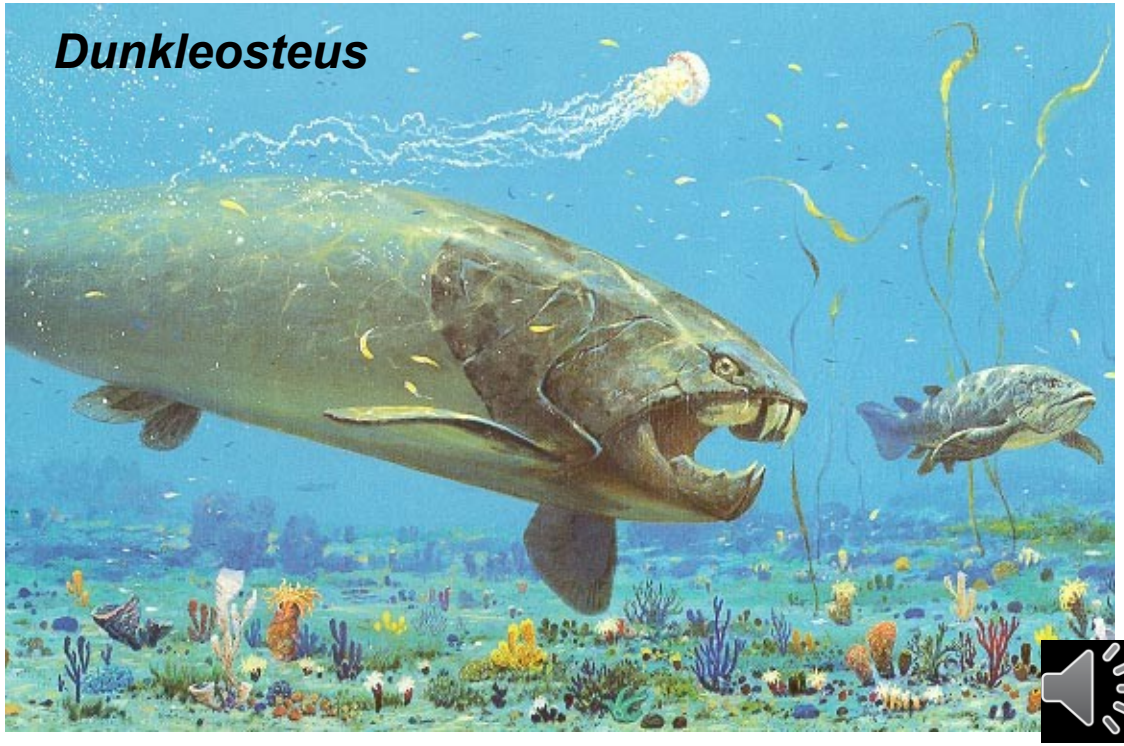


EARLY PALEOZOIC LIFE

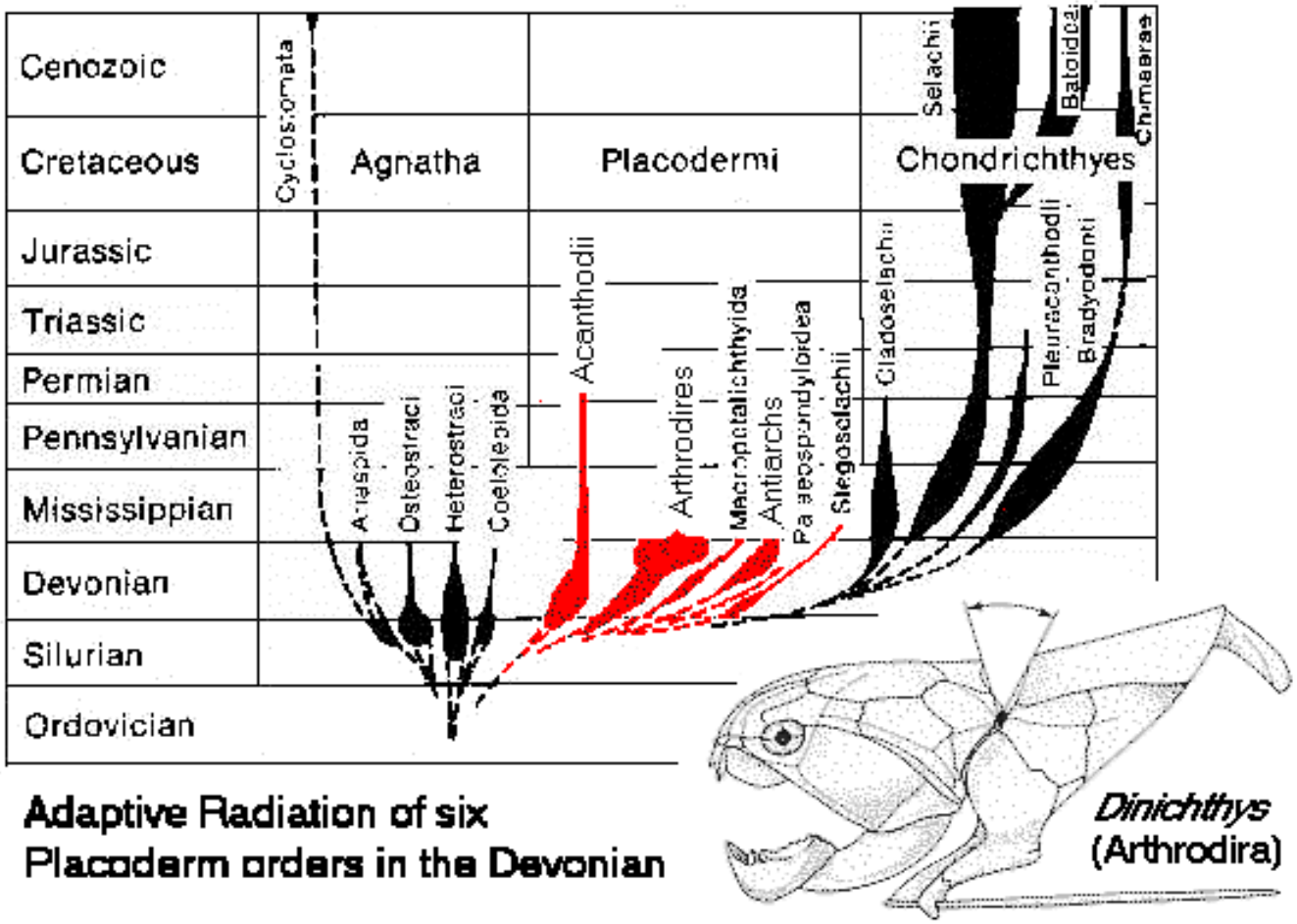
Vertebrates

Fish

Placodermi (Placoderms)



Placodermi

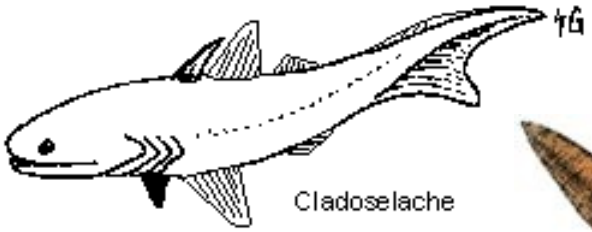

Cenozoic
Cretaceous
Jurassic
Triassic
Permian
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cyclostomata
Agnatha
Placodermi
Chondrichthyes
Selachi
Batoidea
Chimaeras
Acanthodii
Arthrodires
Antiarchs
Cladoselachii
Pleuracanthodii
Bradyodonti
Arthrodira
Osteostraci
Heterostraci
Coelolepida
Stegoselachii
Adaptive Radiation of six
Placoderm orders in the Devonian
Dinichthys
(Arthrodira)

EARLY PALEOZOIC LIFE

Vertebrates

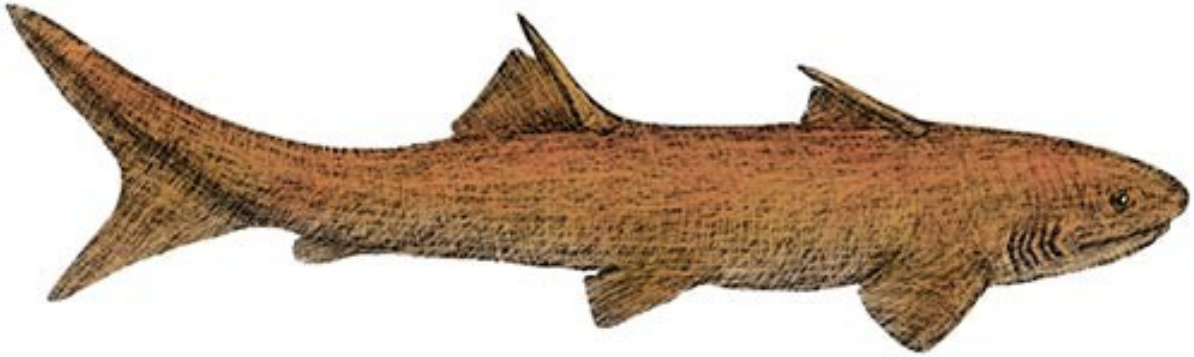
Fish
Acanthodii (Acanthodians)
Early jawed fish
Late Silurian to Permian

Chondrichtyes -Paryby



First sharks

Elasmobranchii - žraloci



Ctenacanthus sp, a Late Devonian and Carboniferous shark

The very earliest signs of sharks are minute fossil **scales** and teeth which are found in rocks from the late **Silurian to early Devonian** period {around 400 million years ago). It becomes more and more difficult, however, to identify shark scales in older rocks because they closely resemble those from jawless fishes called the lodonts, which lived at the same time. Only microscopic differences separate shark and the lodont scales, and the two kinds seem to become more and more alike the further one goes back.

OSTEICHTHYES (bony fish) *SIL.*

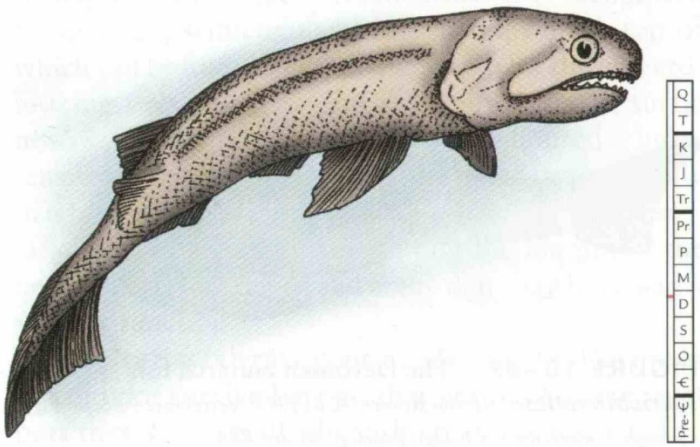
- **Subclass Actinopterygii (paprskoploutví)**
- **Subclass Sarcopterygii (nozdratí)**

Actinopterygii

Chondrostei - chrupavčití

well represented by the genus *Cheirolepis* (Fig. 10–71). From such fishes as these evolved the more advanced bony fishes during the Mesozoic and Cenozoic.

The second category of bony fishes, the Sarcopterygii, is characterized by fishes with sturdy, fleshy lobe-fins and a pair of openings in the roof of the mouth that led to clearly visible external nostrils.



Sarcopterygii -nozdratí

Mezi charakteristické hlavní znaky těchto tzv. *živých fosílií* patří vyvinutí choanů (vnitřních nozder), které umožňují vdechování atmosférického vzduchu se zavřenou tlamou. A také rozvinuté plicní dýchání

podtřída lalokoploutví (Coelacanthimorphes)

podtřída dvojdyšní (Dipnoi)

Původ obojživelníků, a tedy všech čtyřnožců, je zahalen tajemstvím. K předkům obojživelníků mohly patřit lalokoploutvé ryby dýchajících vzduch, jejichž ploutve se postupně přeměnily na končetiny schopné podpírat tělo. Možná se však obojživelníci vyvinuli z ryb dvojdyšných (Dipnoi). Fosilní záznam je ale poměrně kusý a je obtížné rozhodnout, jestli je daný živočich ještě rybou nebo už obojživelníkem

Dipnoi

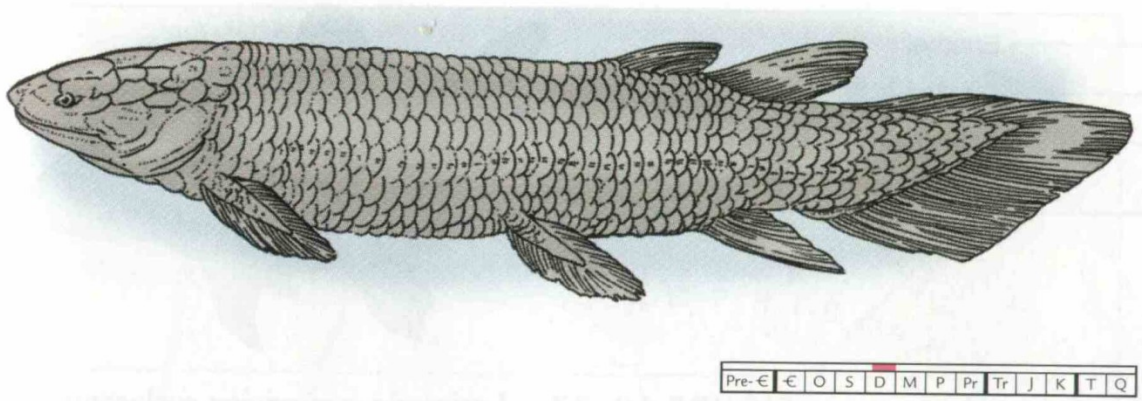
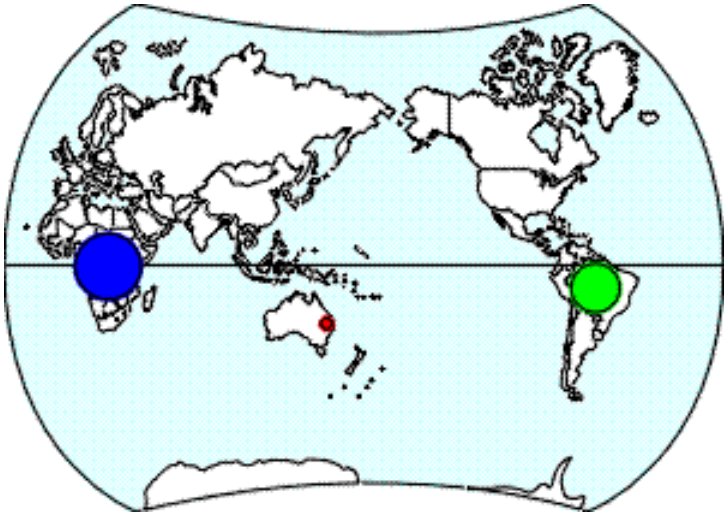
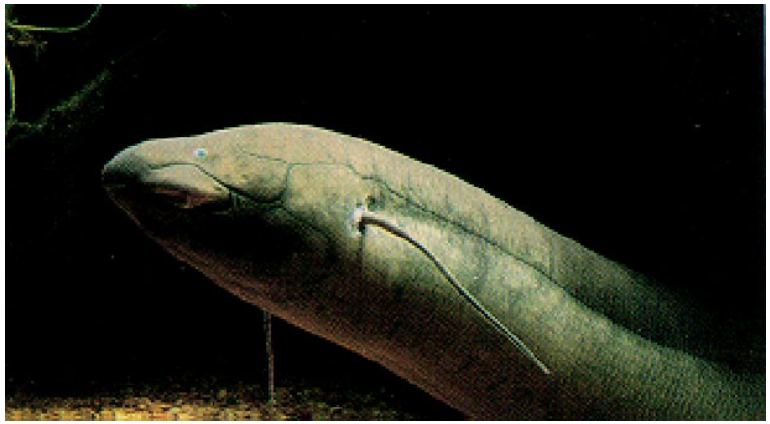


FIGURE 10–72 *Dipterus,* a Devonian lungfish.

Neoceratudos forsteri



Protopterus ssp

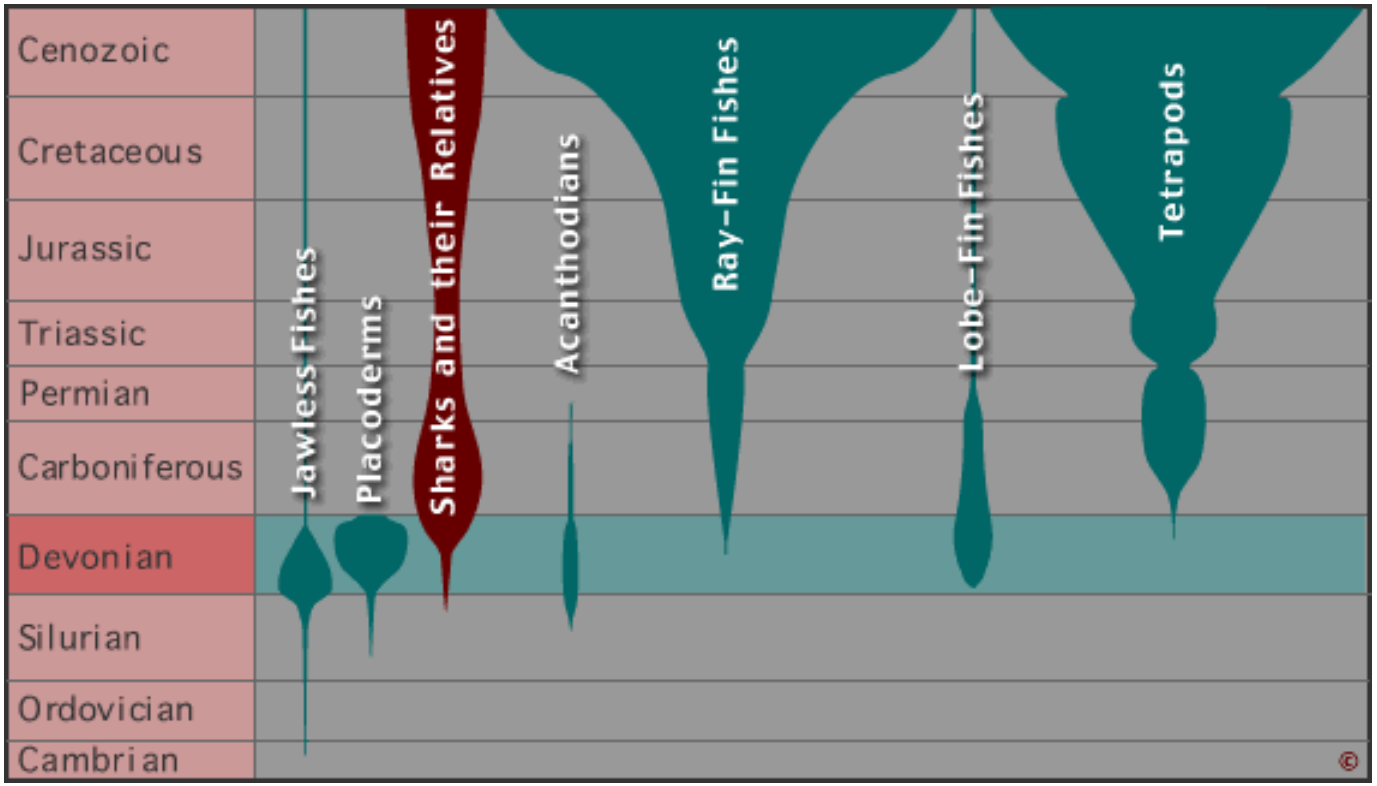


Lepidosiren paradoxa

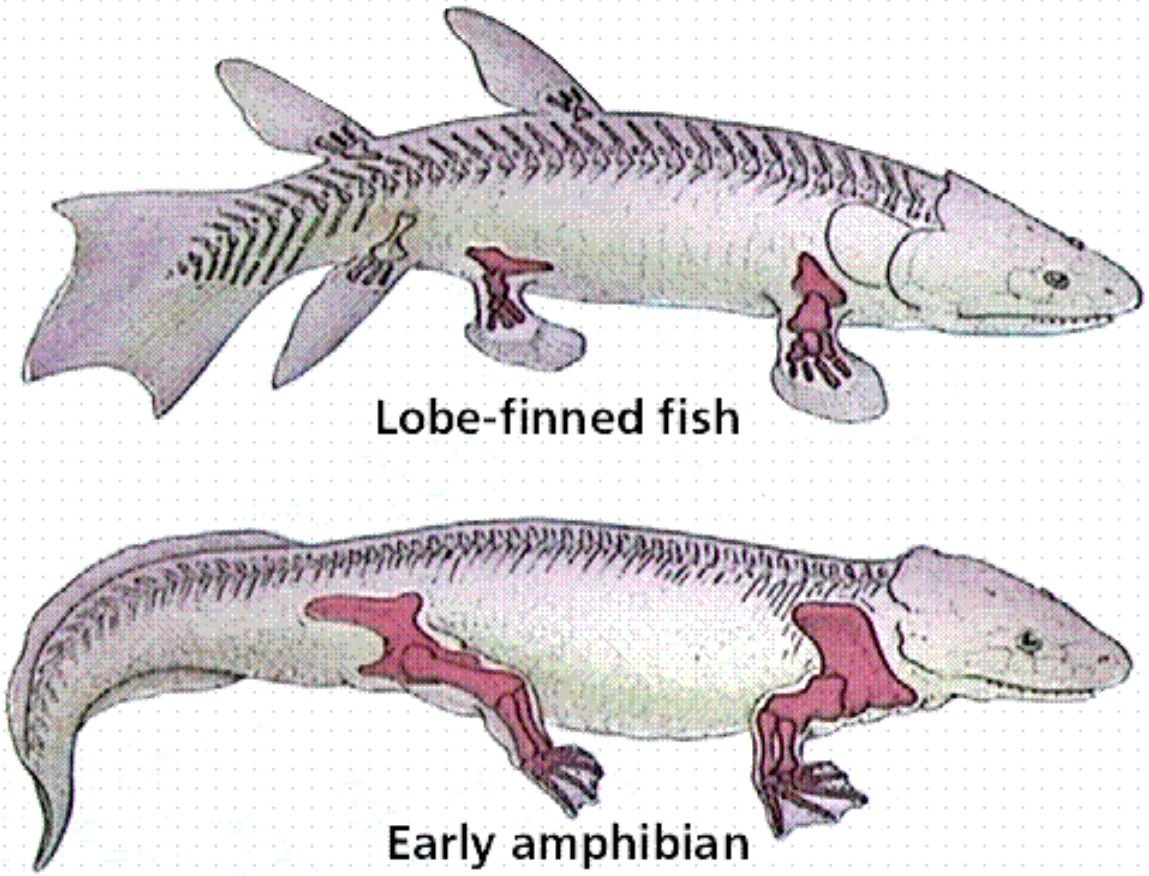
lalokoploutví (Coelacanthimorphes)

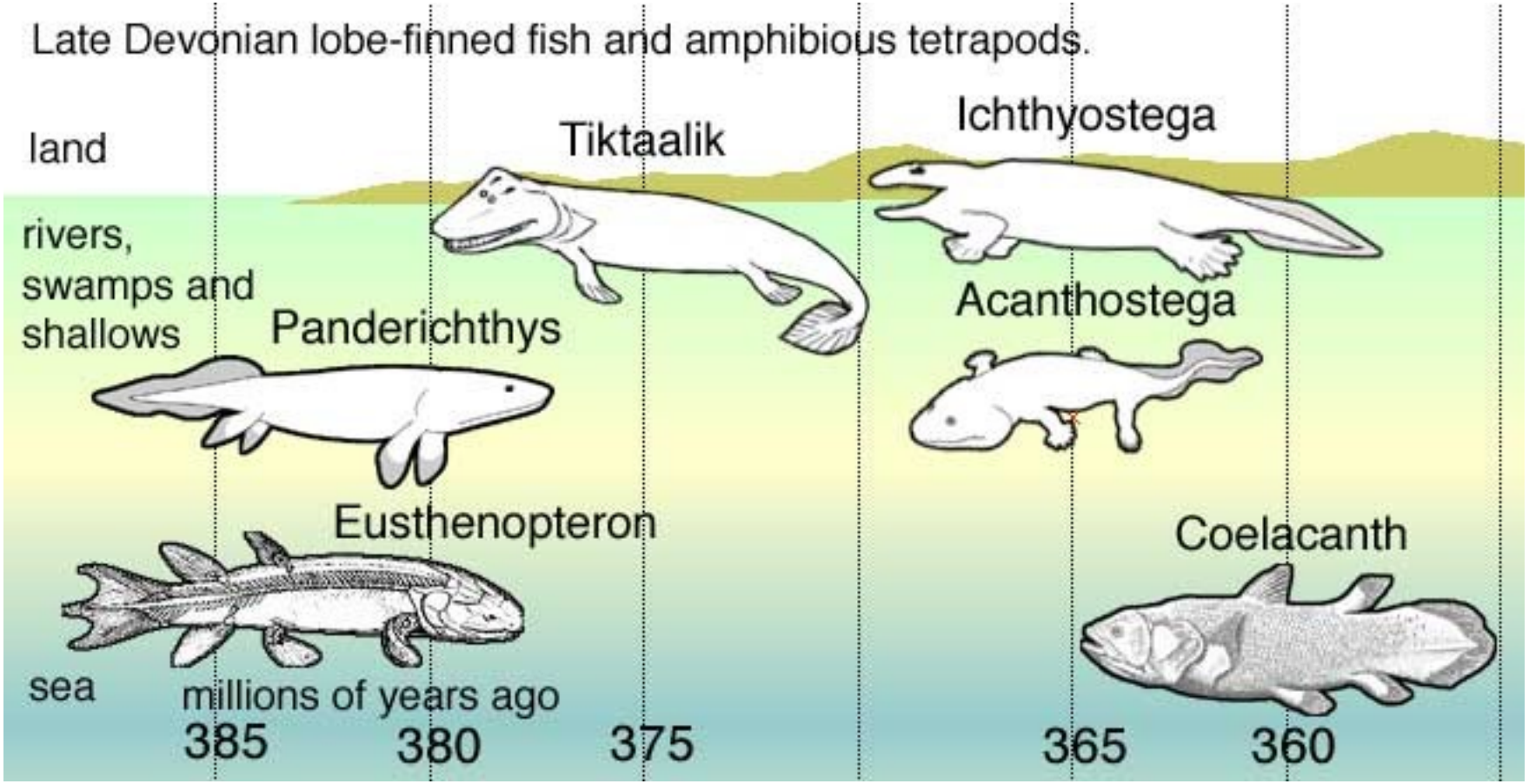
Eusthenopteron

Latimeria chalumnae



Tiktaalik roseae lived approximately 375 million years ago. Paleontologists suggest that it is representative of the transition between non-tetrapod vertebrates (fish) and early tetrapods such as *Acanthostega* and *Ichthyostega*, known from fossils about 365 million years old. Its mixture of primitive fish and derived tetrapod characteristics led one of its discoverers.
***Tiktaalik roseae*, has a skull, a neck, ribs and parts of the limbs** that are **similar to four-legged animals** known as tetrapods


Lobe-finned fish
Early amphibian


Late Devonian lobe-finned fish and amphibious tetrapods.
land
rivers, swamps and shallows
sea
Tiktaalik
Ichthyostega
Acanthostega
Panderichthys
Eusthenopteron
Coelacanth
millions of years ago
385
380
375
365
360

Amphibia

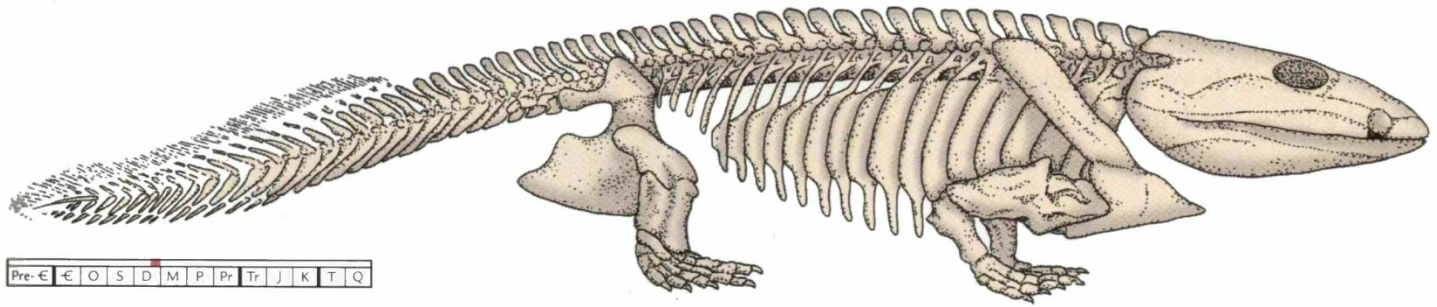


FIGURE 10–79 The skeleton of *Ichthyostega* still retains the fishlike form of its crossopterygian ancestors. *(From Levin, H. L. 1975.* Life Through Time. *Dubuque, IA: William C. Brown Co.)*

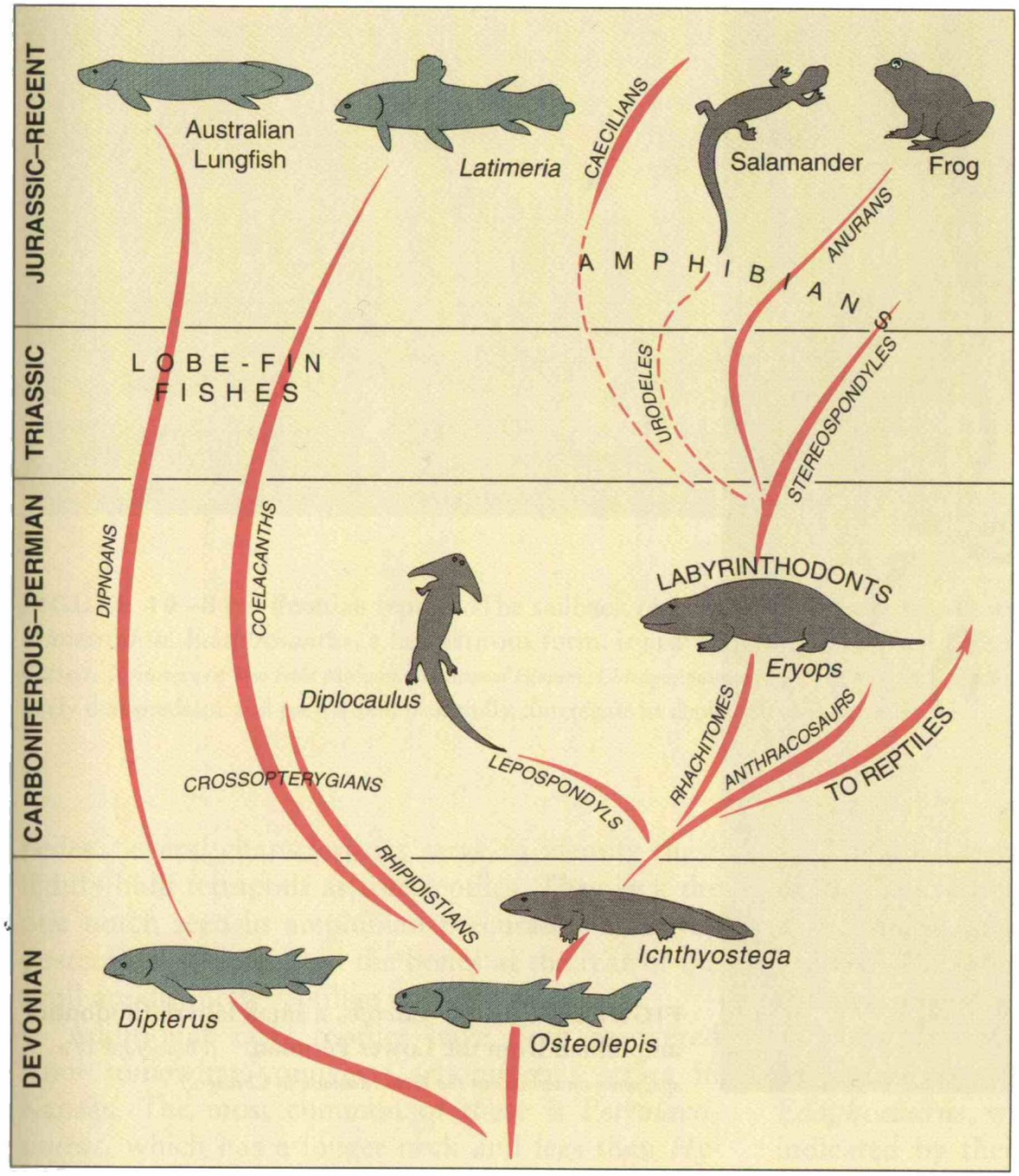


FIGURE 10–78 The evolution of amphibians and lobe-fin fishes. *(From Colbert, E. H., and Morales, M. 1991. Evolution of the Vertebrates, 4th ed. New York: John Wiley. With permission of the author, artist Lois Darling, and the publisher.)*

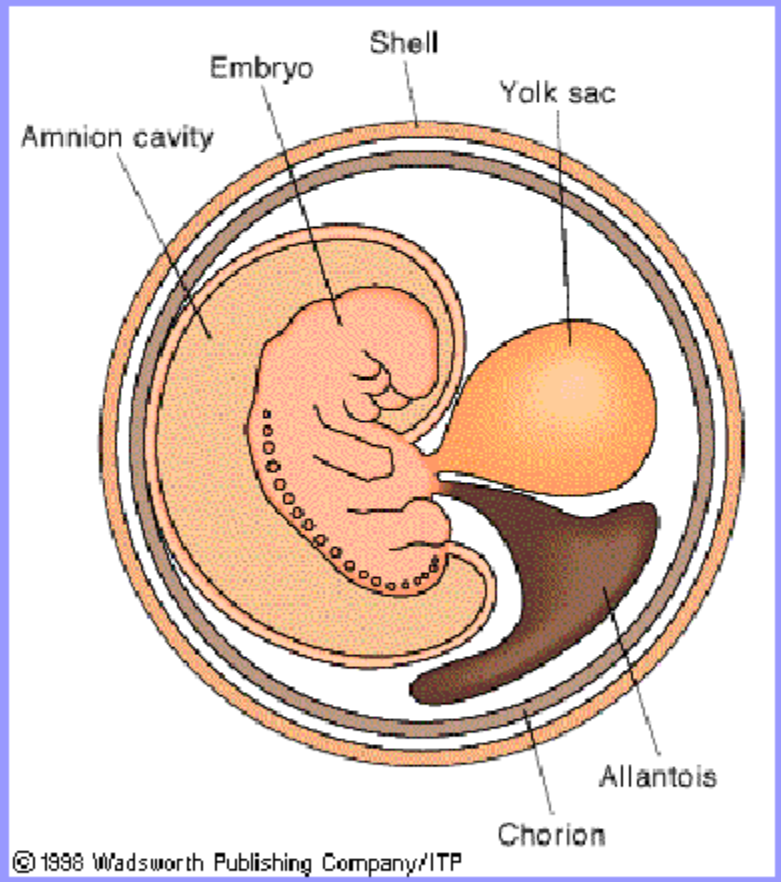
Amphibia – Labyrithodonts. Carboniferous – age of amphibians.

Discosauriscus

Eryops 2m-lower Permian

Evolution of the Reptiles - The Land is Conquered

- The evolution of the amniote egg freed reptiles from the constraint of returning to water to reproduce
  - amnion - liquid filled sac surrounding the embryo
  - allantois - waste sac
  - a tough shell protects the developing fetus
  - reptiles were able to colonize all parts of the land



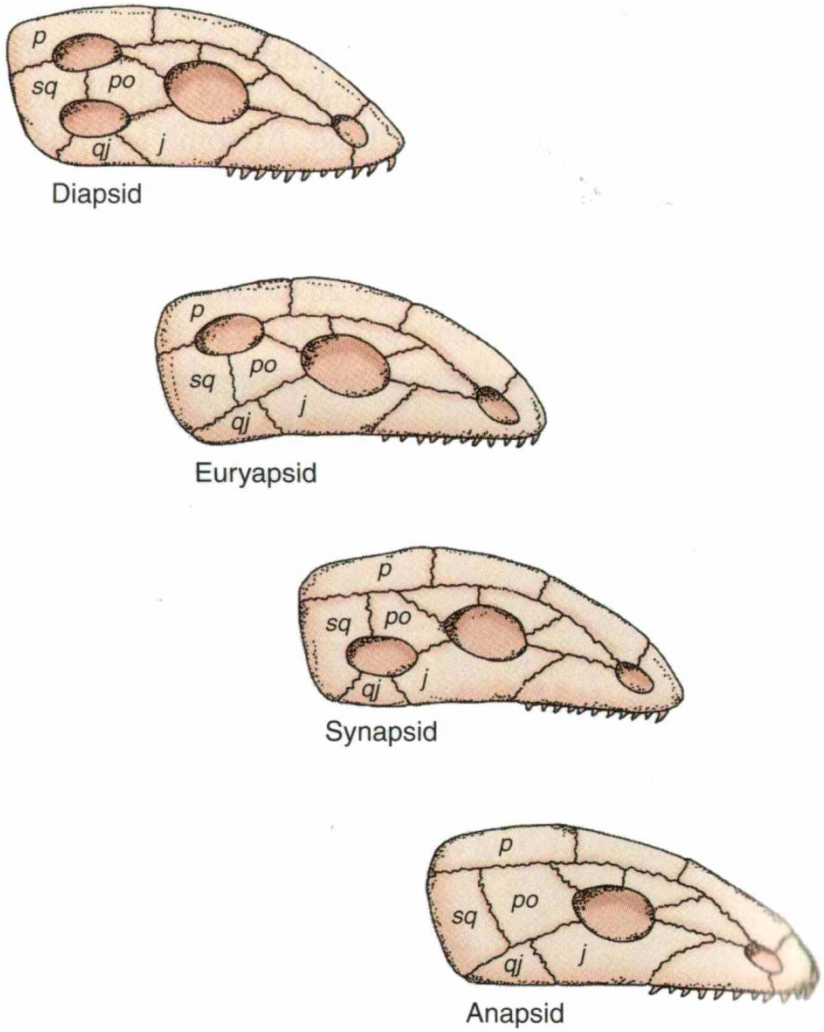


FIGURE 12–23 Reptile skull types. *(p,* parietal; *sq,* squamosal; *po,* postorbital; *j,* jugal; *qj,* quadratojugal.)

In which of the above groups are dinosaurs placed?

Reptiles

Cotylosauria (anapsids) - first reptiles in middle Carboniferous)

Pelycosauria mammal-like reptiles, synapsids, first in Late Carboniferous, extinct in middle Permian

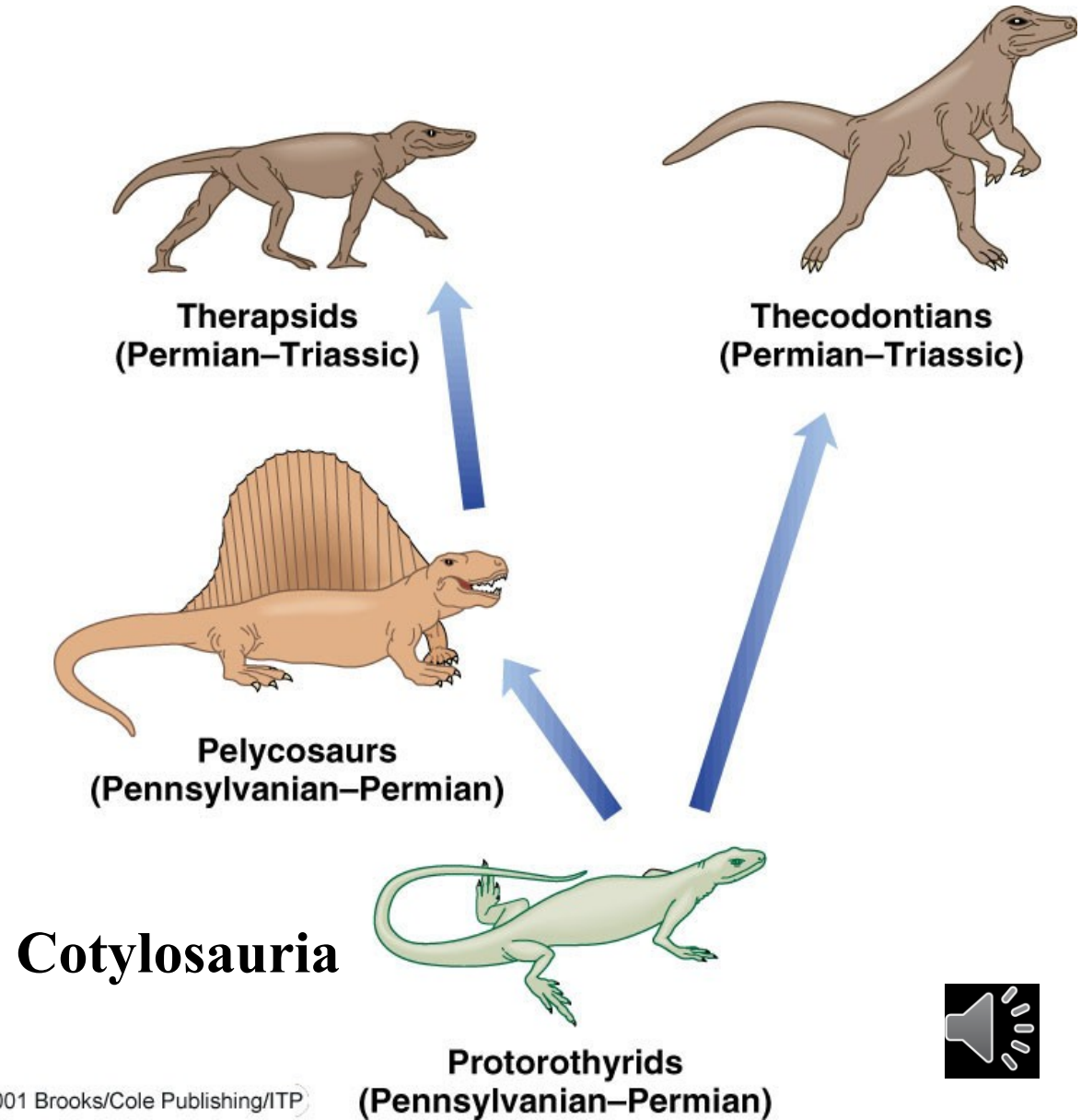
Therapsida – synapsids, predecessors of mammals, middle Triassic

First diapsids – late Carboniferous
Thecodonts, ancestors of dinosaurs – late Permian

Notosaurs (euryapsids),

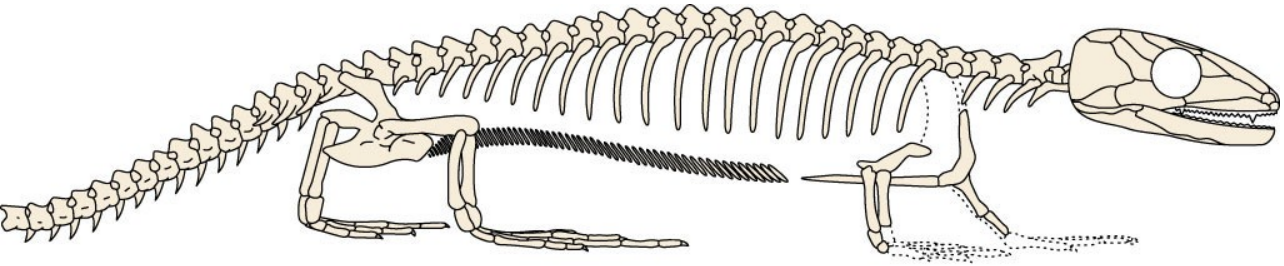
Paleozoic Reptile Evolution

- Evolutionary relationship among the Paleozoic reptiles



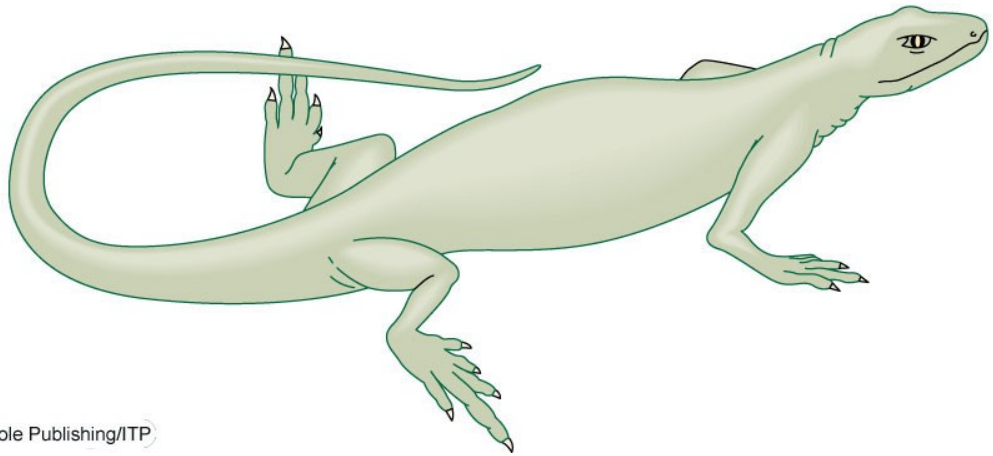
One of the Oldest Known Reptiles

- Reconstruction and skeleton of *Hylonomus lyelli* from the Pennsylvanian Period

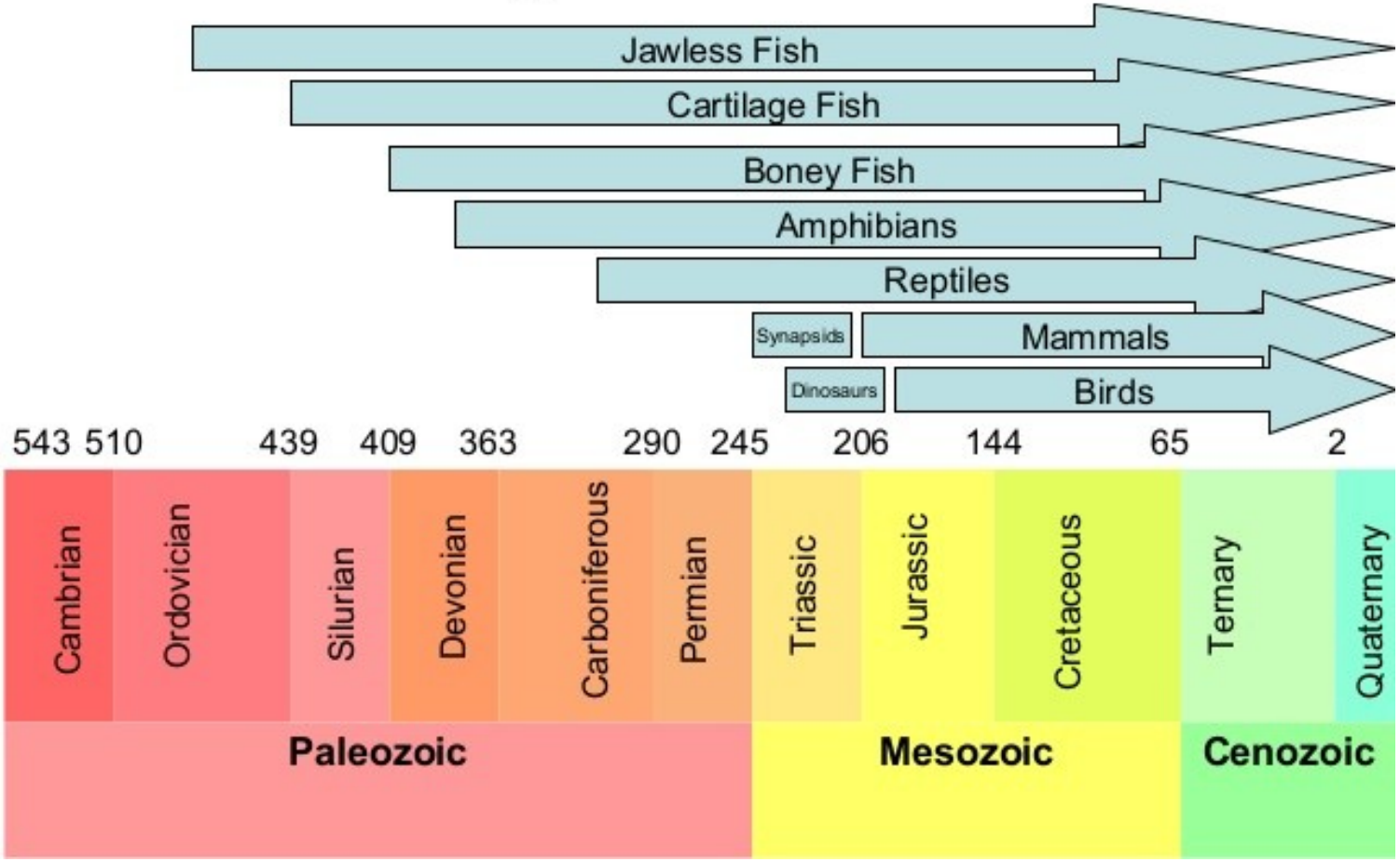


– *Hylonomus lyelli* was about 30 cm long

Cotylosauria



Geological Timescale



Pelycosauria

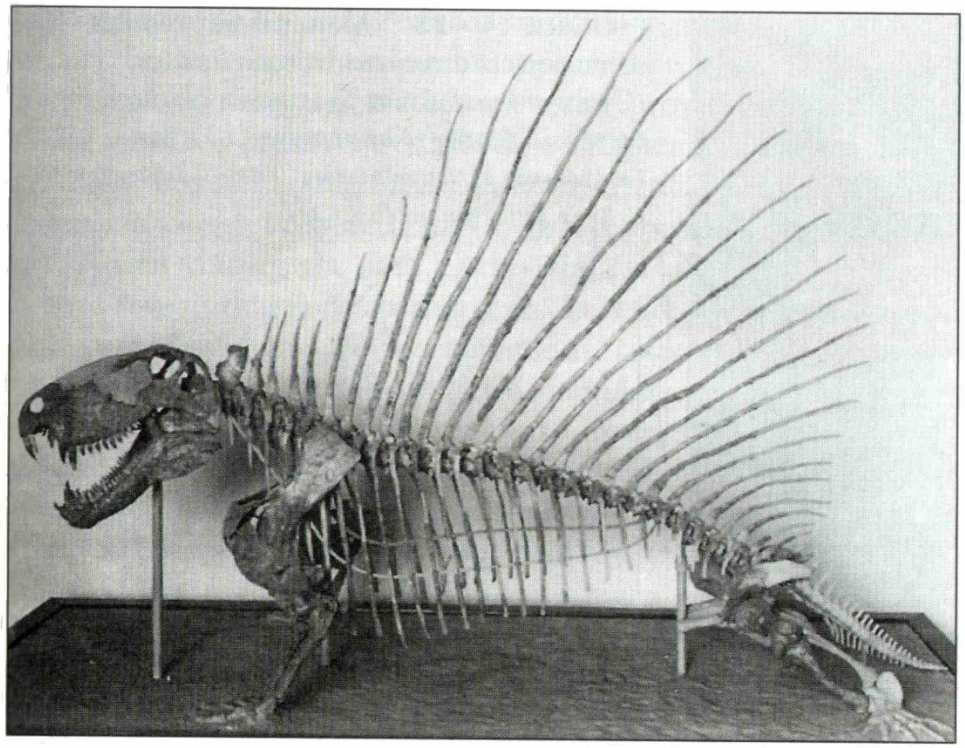
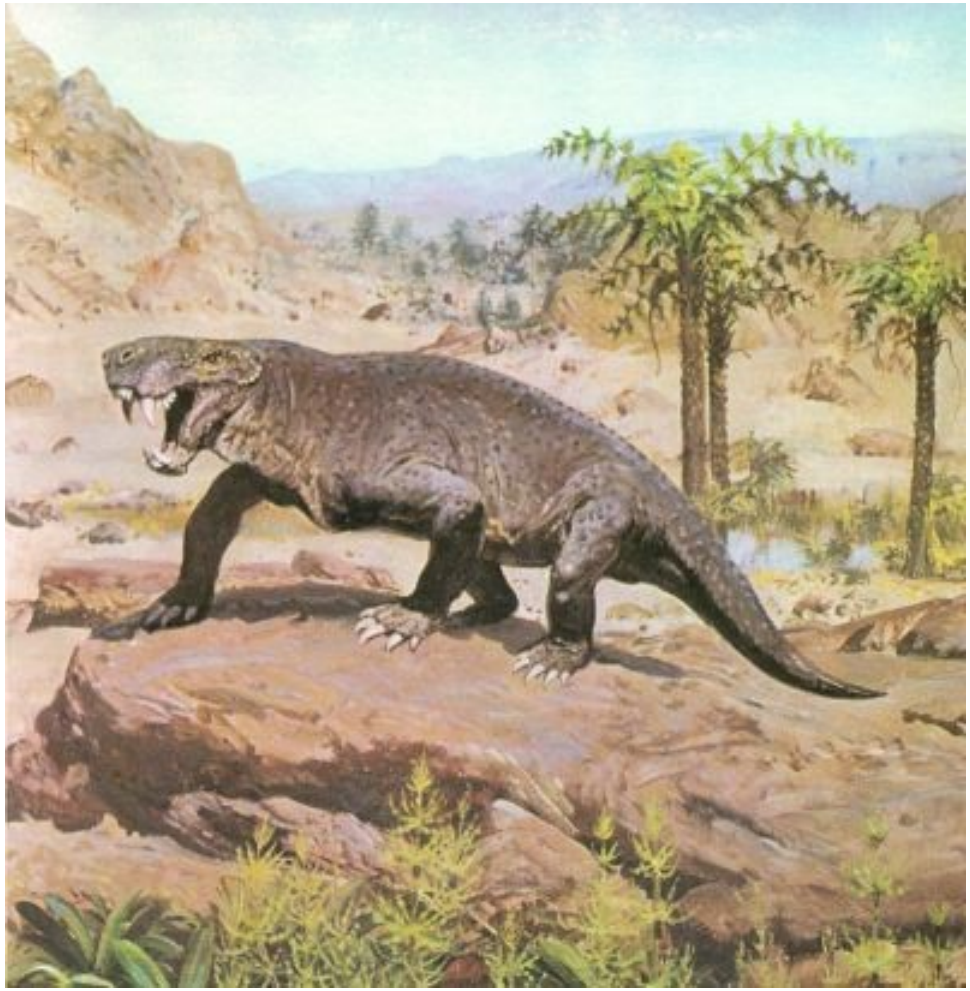


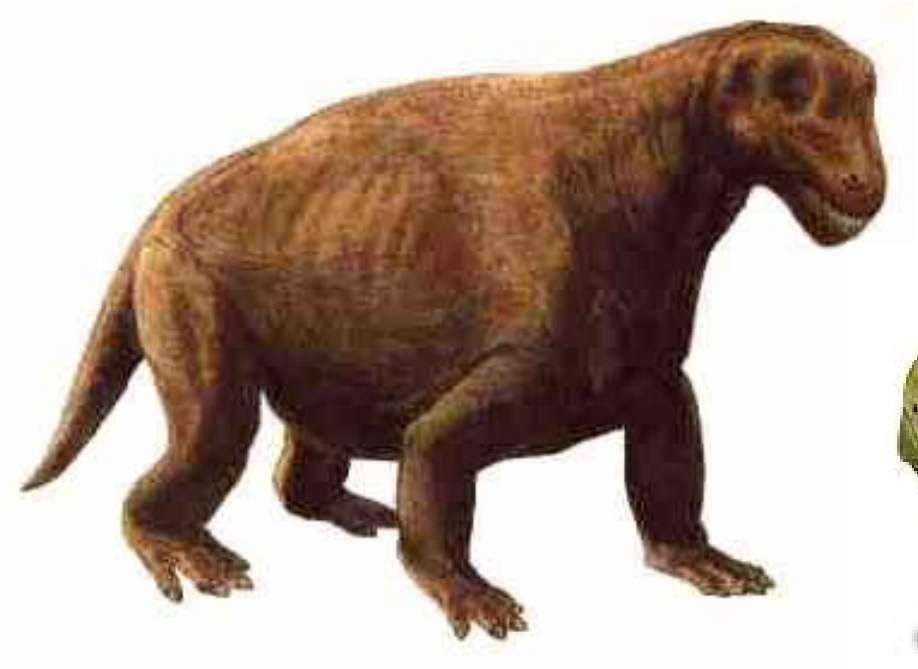
FIGURE 10–82 Mounted skeleton of the Permian "sail-reptile" *Dimetrodon gigas*. The tail was actually somewhat longer. *(Courtesy of the U. S. National Museum of Natural History, Smithsonian Institution.)*

Therapsids

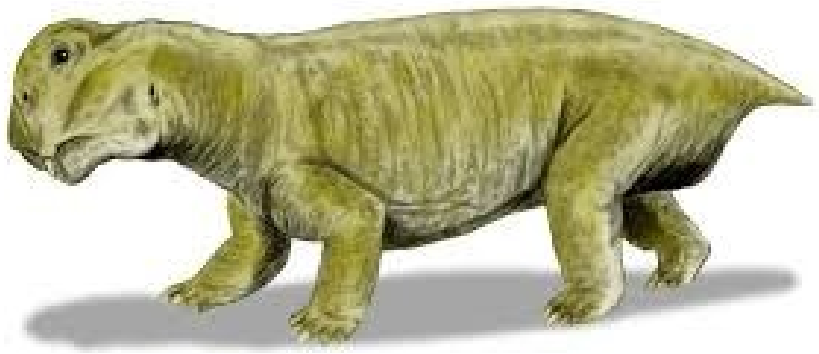


Der Sauroctonus wies bereits ein mächtiges, differenziertes Gebiss auf und wird eines der großen Raubtiere des Perms gewesen sein.(Werk des Künstlers Z. Burian)

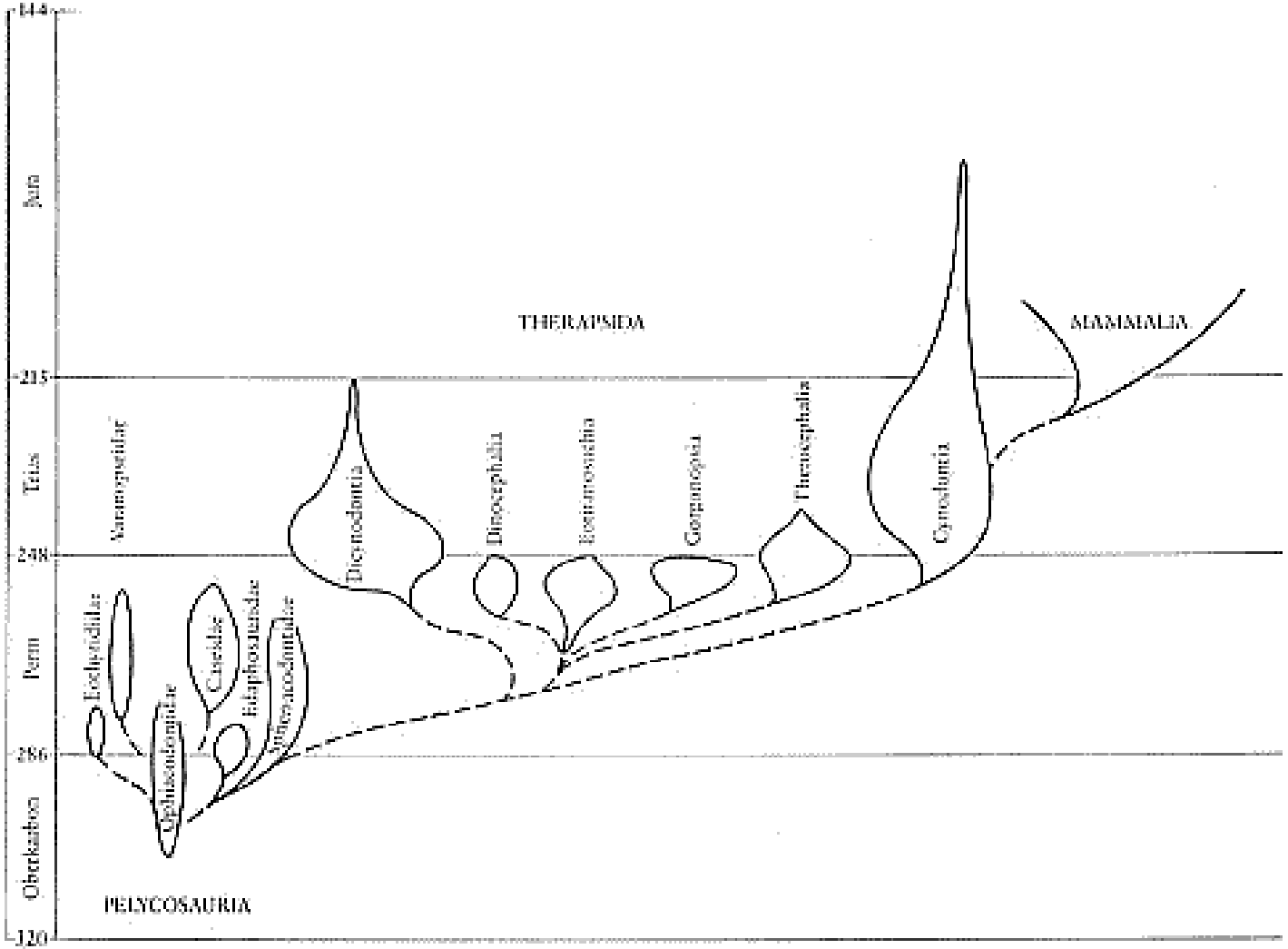
The bear-sized gorgonopsid *Inostrancevia alexandri* assaulting the ox-sized armoured pareiasaur herbivore *Scutosaurus karpinski*

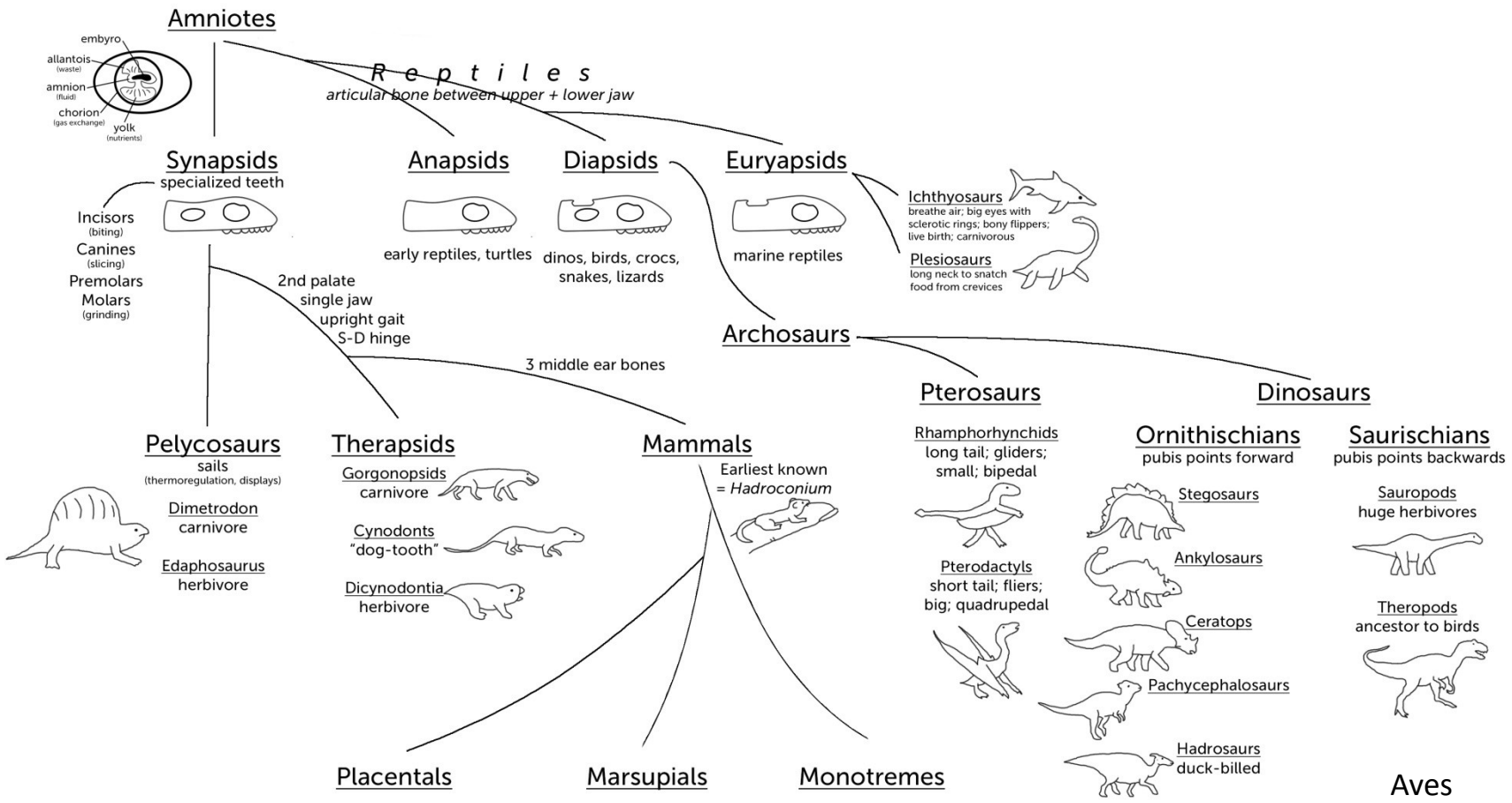


Moschops



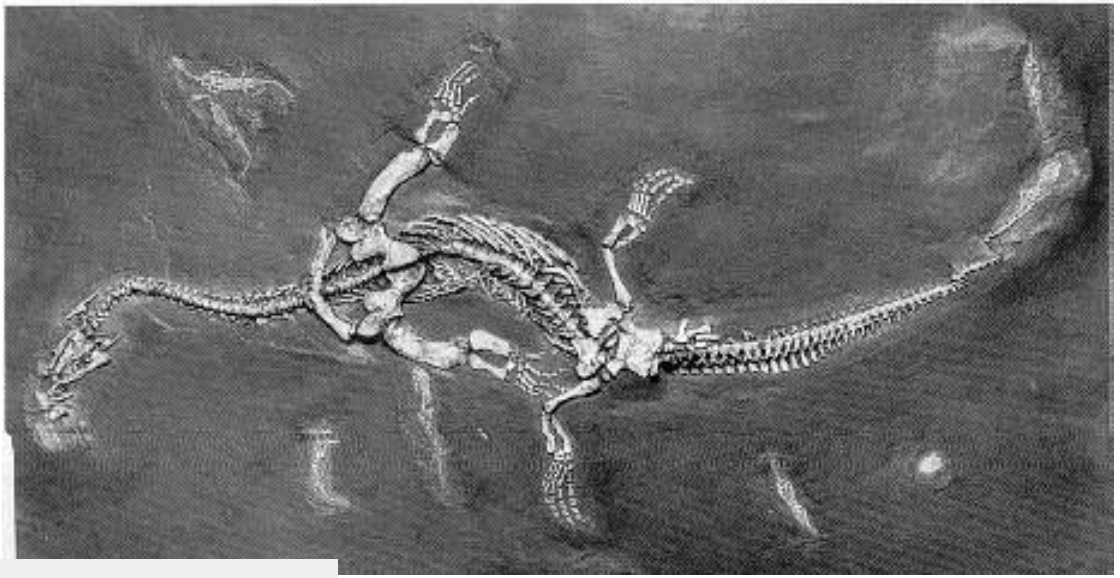
Lystrosaurus

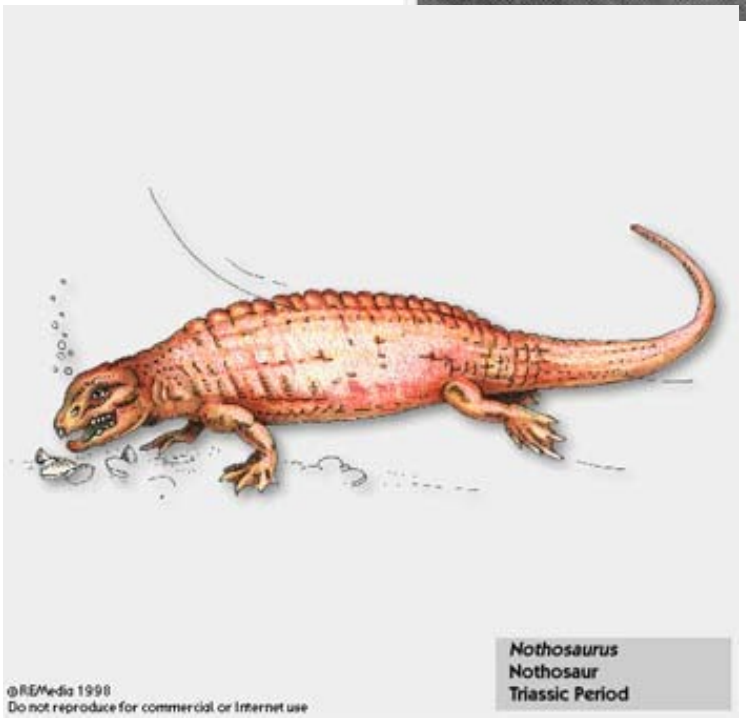

Jura
Trias
Perm
Oberkarbon
215
248
286
320
THERAPSIDA
MAMMALIA
PELYCOSAURIA
Varanopseidae
Dicynodontia
Biarmosuchia
Gorgonopsia
Therocephalia
Cynodontia
Ophiacodontidae
Caseidae
Edaphosauridae
Sphenacodontidae

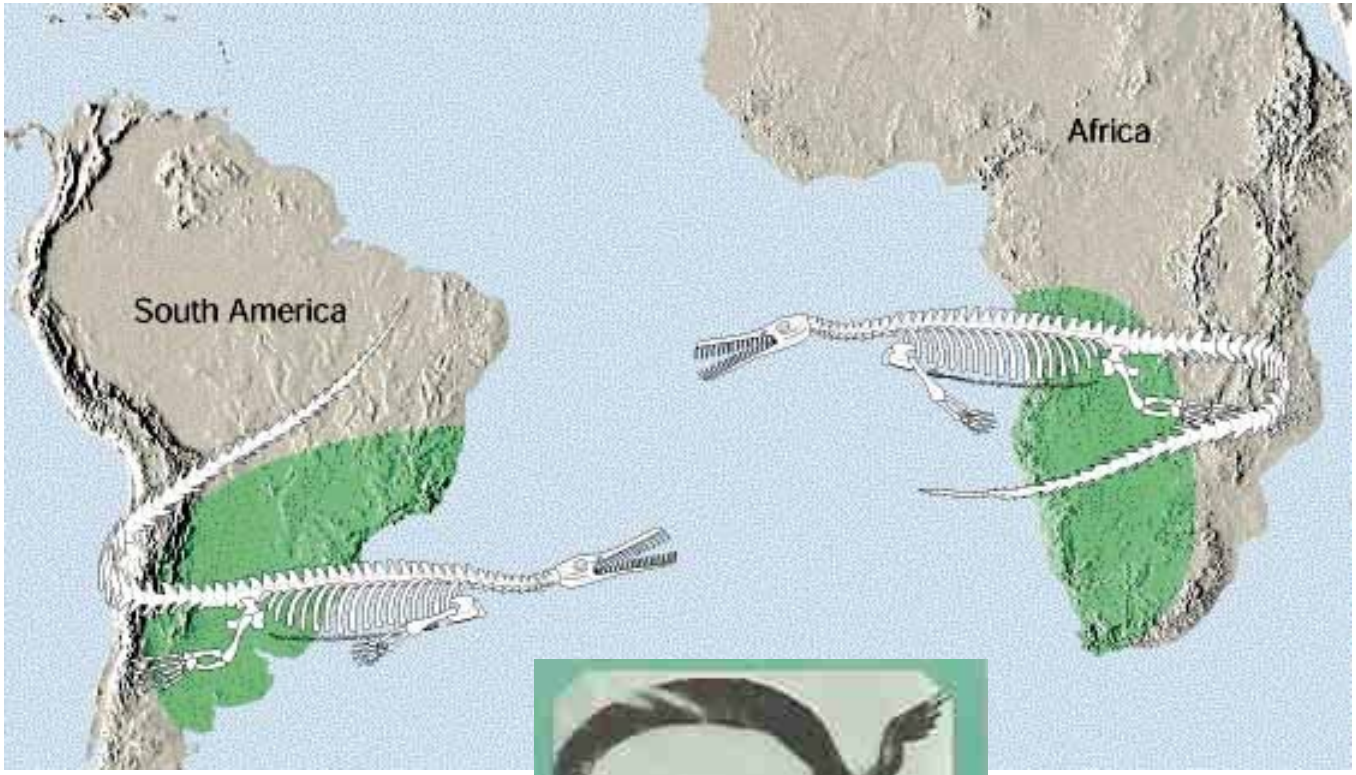

Amniotes
embyro
allantois
(waste)
amnion
(fluid)
chorion
(gas exchange)
yolk
(nutrients)
Reptiles
articular bone between upper + lower jaw
Synapsids
specialized teeth
Incisors
(biting)
Canines
(slicing)
Premolars
Molars
(grinding)
Anapsids
early reptiles, turtles
Diapsids
dinos, birds, crocs, snakes, lizards
Euryapsids
marine reptiles
Ichthyosaurs
breathe air; big eyes with sclerotic rings; bony flippers; live birth; carnivorous
Plesiosaurs
long neck to snatch food from crevices
2nd palate
single jaw
upright gait
S-D hinge
3 middle ear bones
Archosaurs
Pterosaurs
Dinosaurs
Pelycosaurs
sails
(thermoregulation, displays)
Dimetrodon
carnivore
Edaphosaurus
herbivore
Therapsids
Gorgonopsids
carnivore
Cynodonts
"dog-tooth"
Dicynodontia
herbivore
Mammals
Earliest known
= Hadroconium
Rhamphorhynchids
long tail; gliders; small; bipedal
Pterodactyls
short tail; fliers; big; quadrupedal
Ornithischians
pubis points forward
Stegosaurs
Ankylosaurs
Ceratops
Pachycephalosaurs
Hadrosaurs
duck-billed
Saurischians
pubis points backwards
Sauropods
huge herbivores
Theropods
ancestor to birds
Aves
Placentals
Marsupials
Monotremes

Euryapsida

Notosaurs -



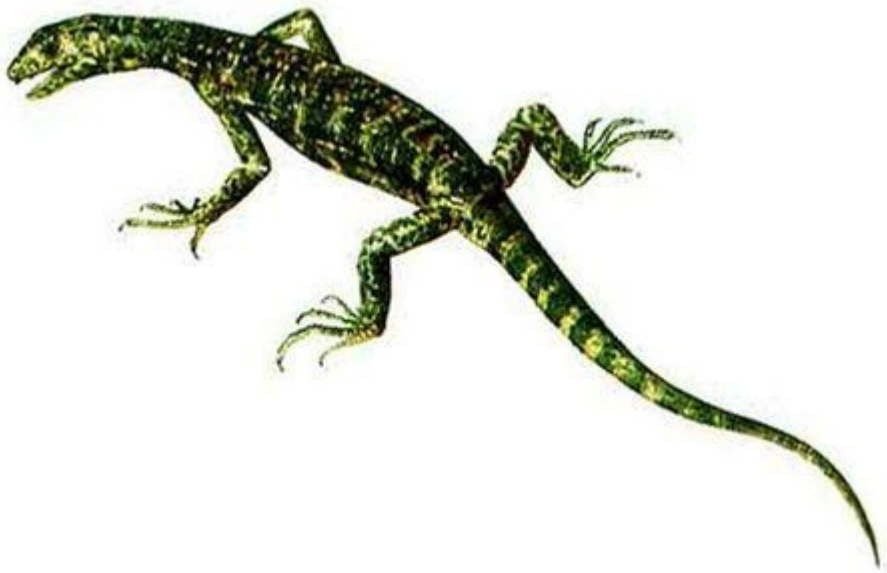



Africa
South America


19
MESOSAURUS

Diapsida

insectivorous lizard-like diapsid reptiles,
Petrolacosaurus was a small, 40-centimetre (16 in) long, reptile, and the earliest diapsid known. It lived during the late Carboniferous period

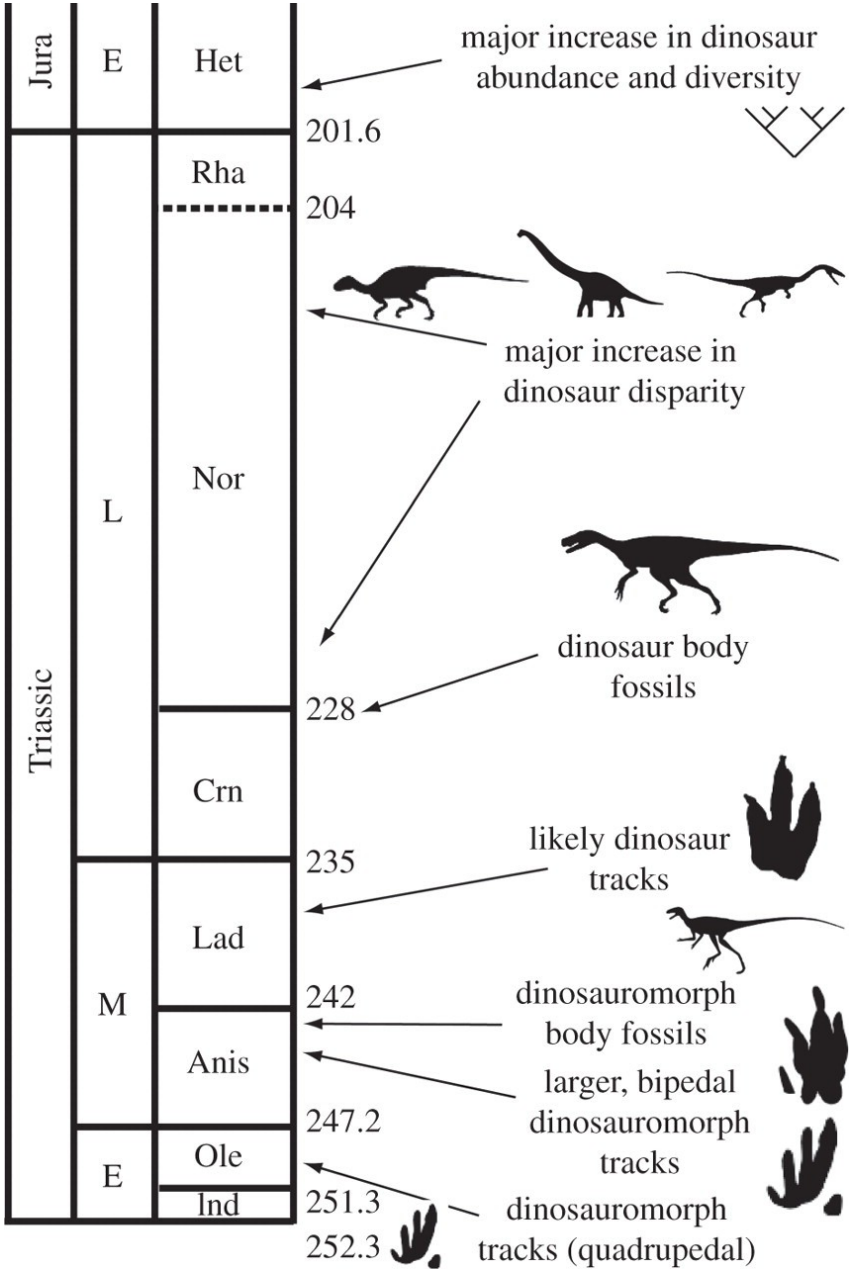


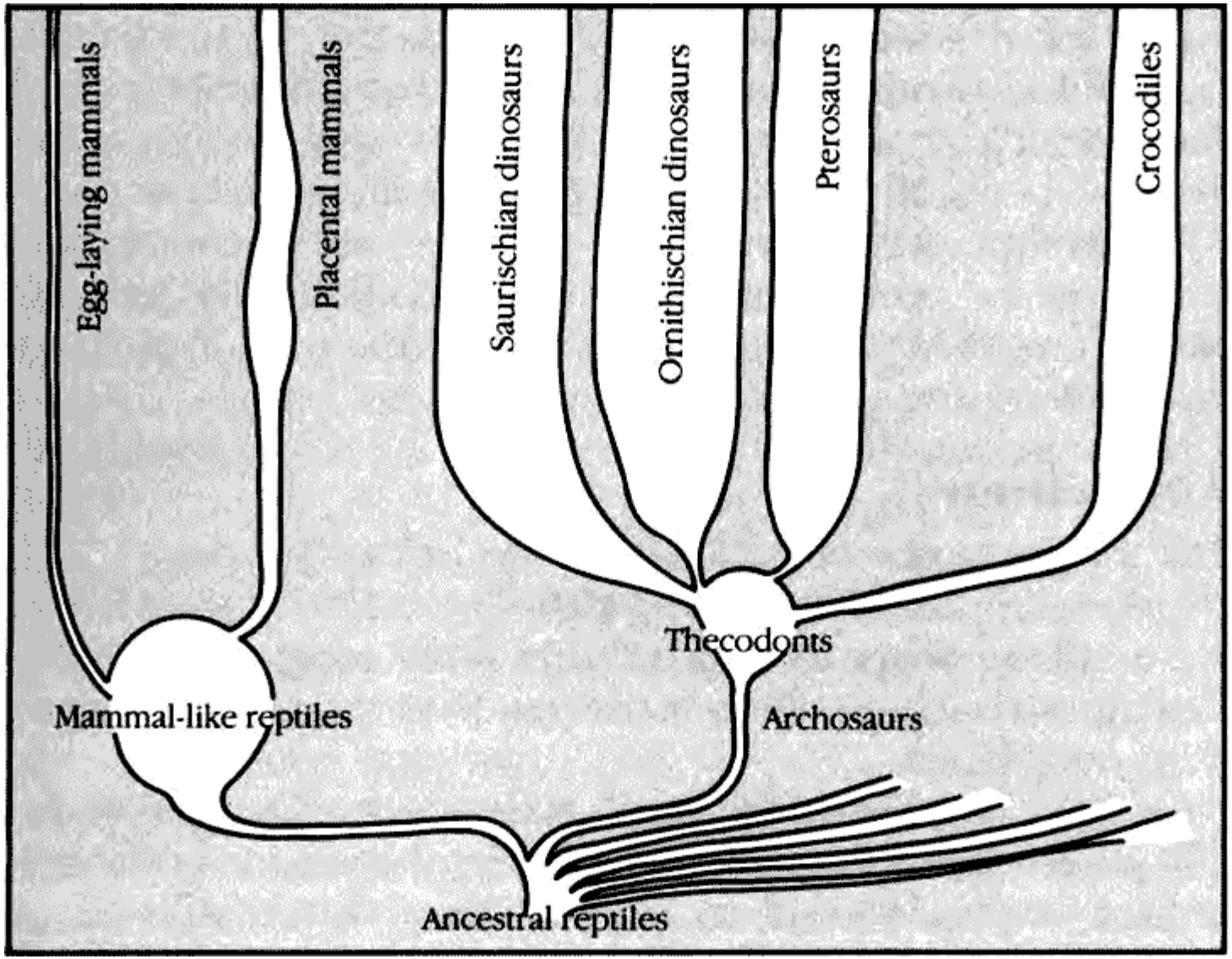
Thecodonts

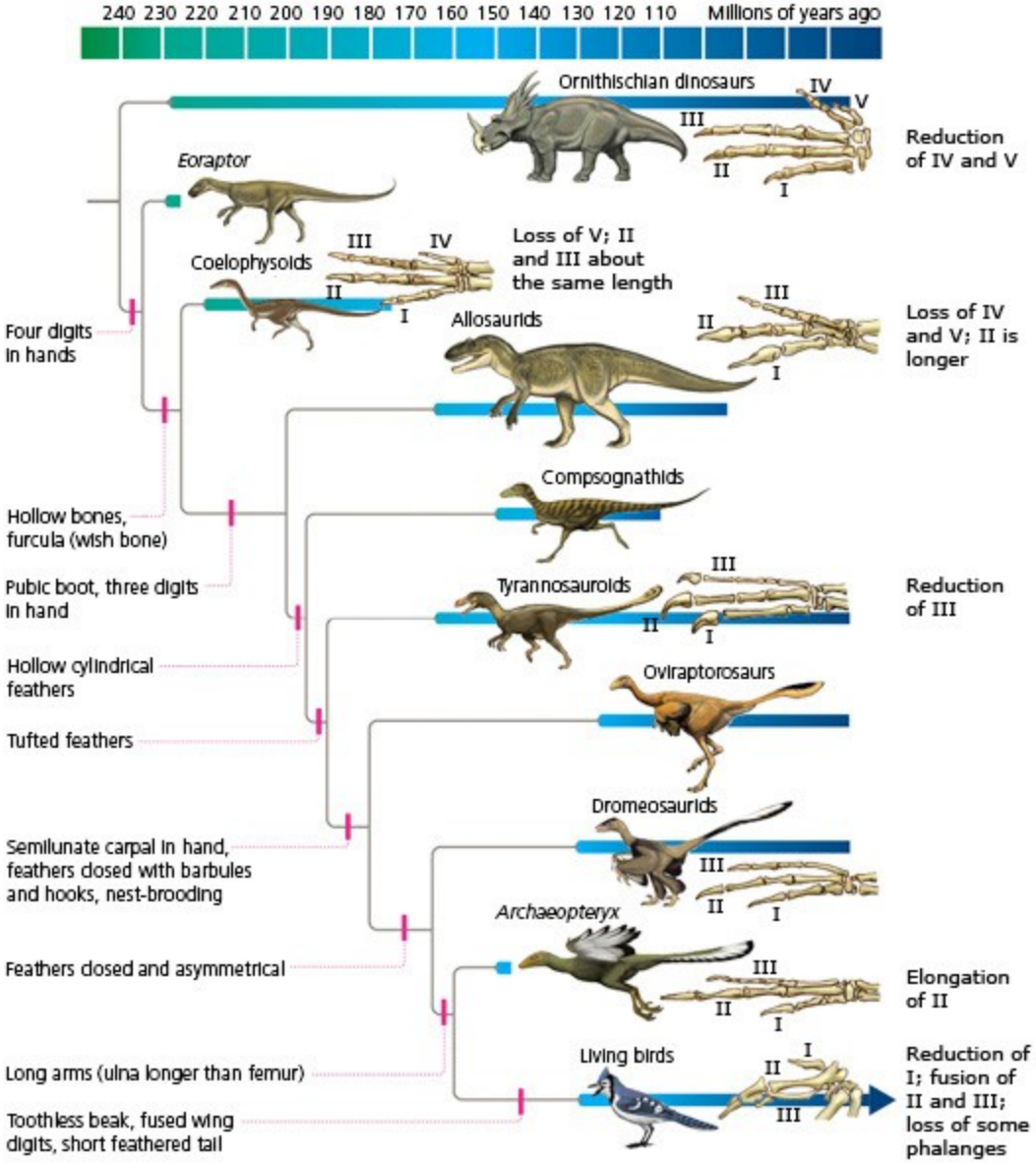
give rise to crocodilians, dinosauria, & pterosaurs

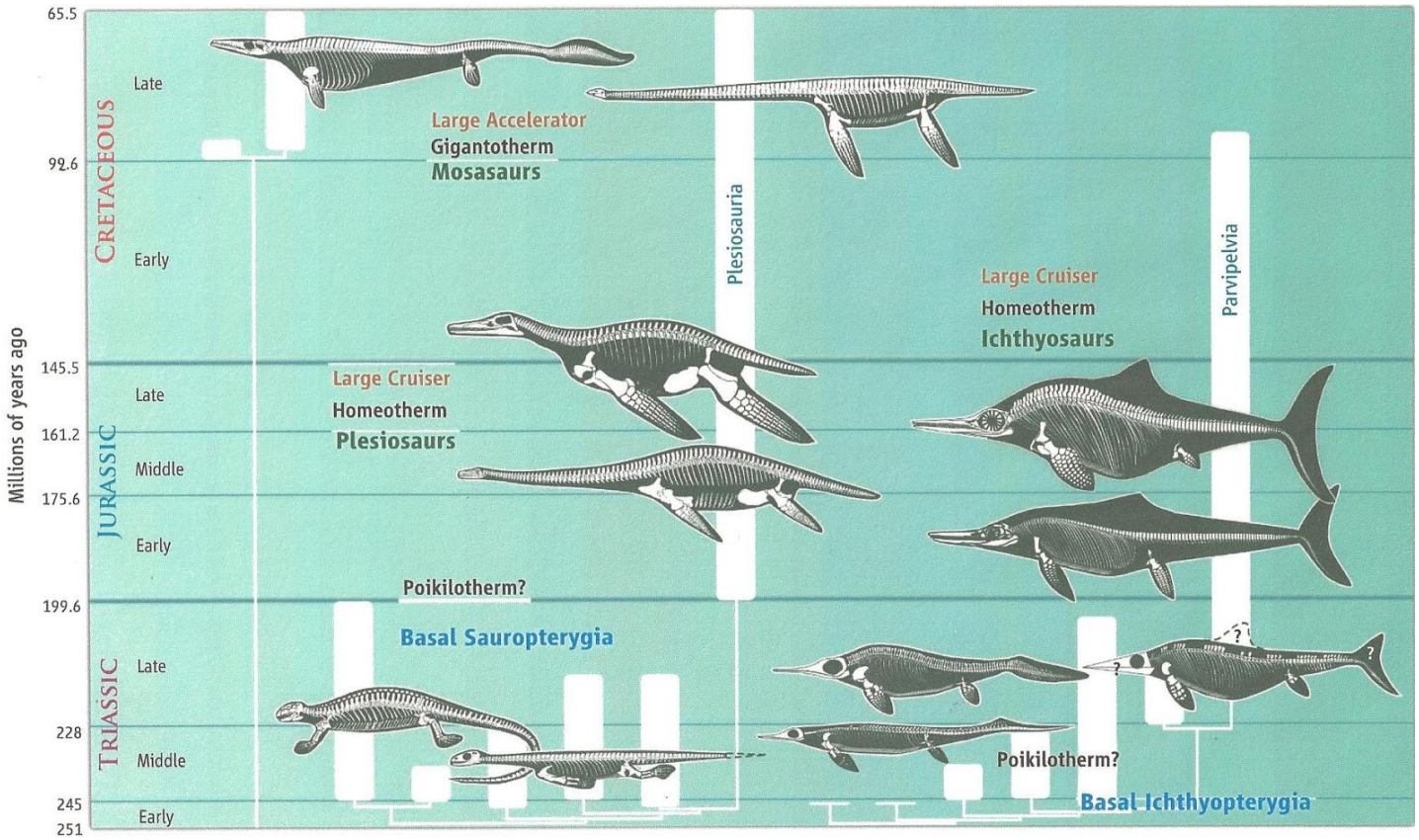
Theropods' ancestors: Known for being smaller, long tails, short forelimbs.
Some scientists hypothesize that this group includes the small, lizard-like, flying reptiles.

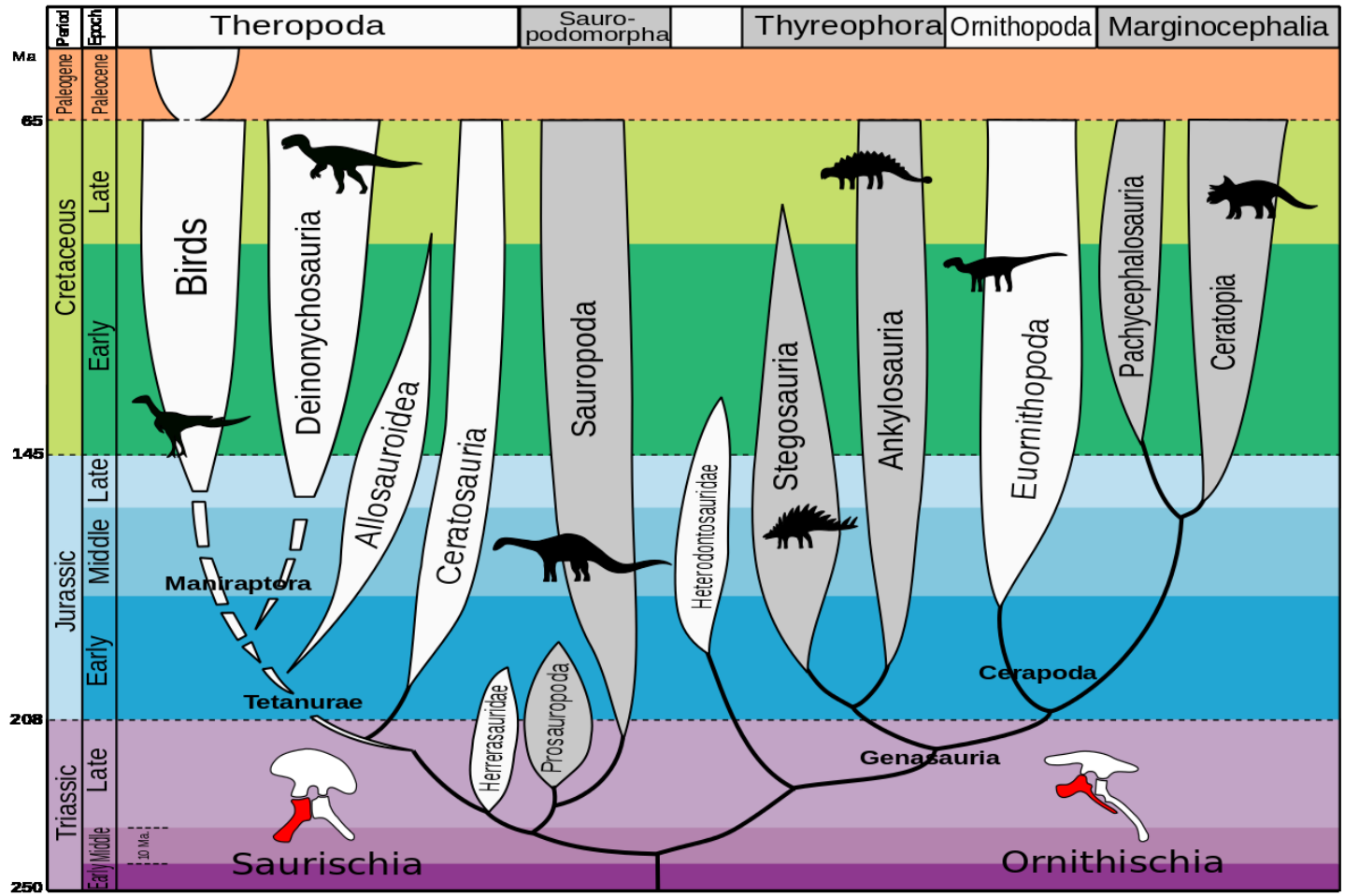
These were around before Theropods.

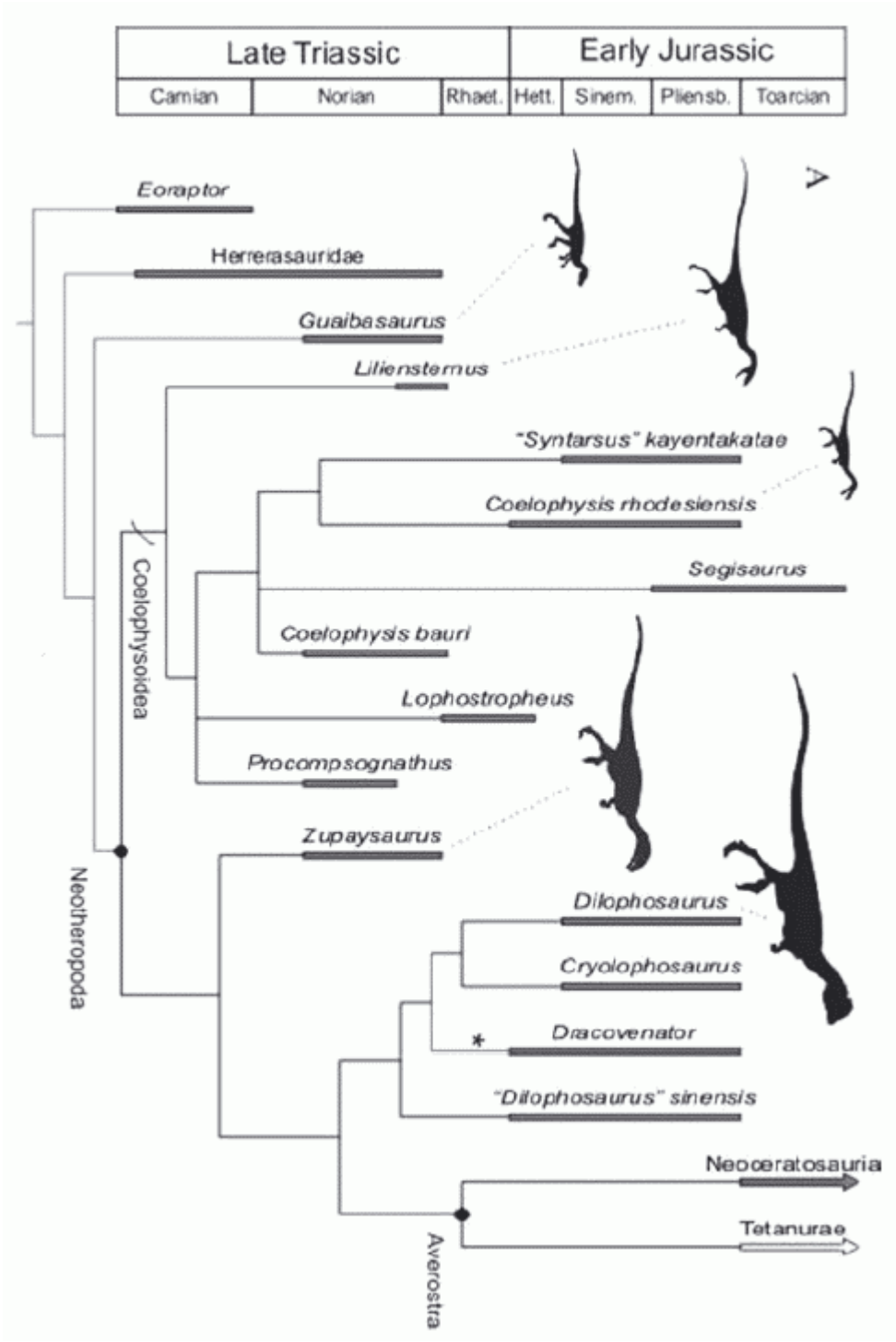

Jura
E
Het
major increase in dinosaur abundance and diversity
201.6
Rha
204
major increase in dinosaur disparity
L
Nor
dinosaur body fossils
228
Crn
likely dinosaur tracks
235
Lad
242
dinosauromorph body fossils
M
Anis
larger, bipedal dinosauromorph tracks
247.2
Ole
E
Ind
251.3
252.3
dinosauromorph tracks (quadrupedal)
Triassic

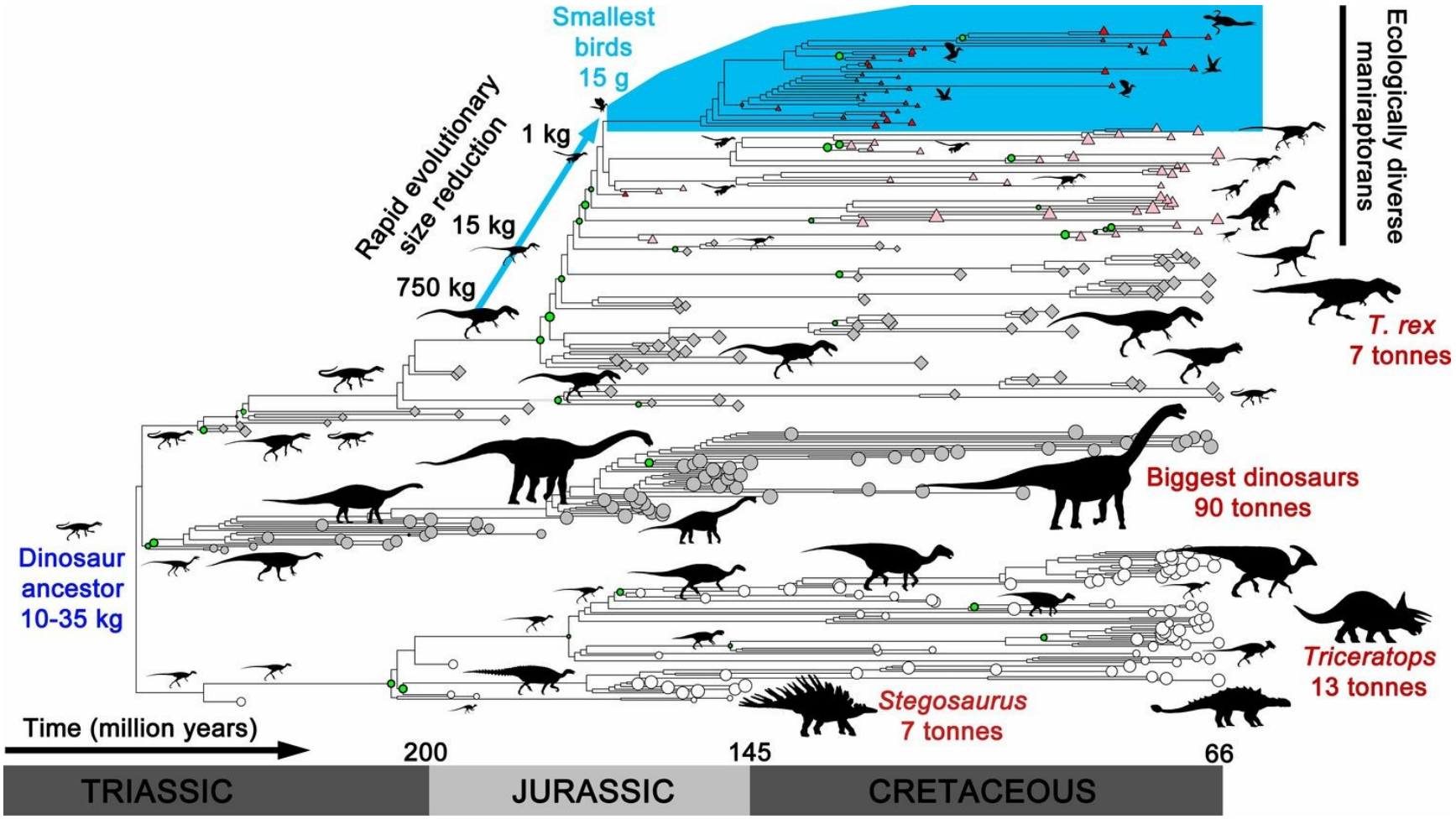

Egg-laying mammals
Placental mammals
Saurischian dinosaurs
Ornithischian dinosaurs
Pterosaurs
Crocodiles
Thecodonts
Mammal-like reptiles
Archosaurs
Ancestral reptiles

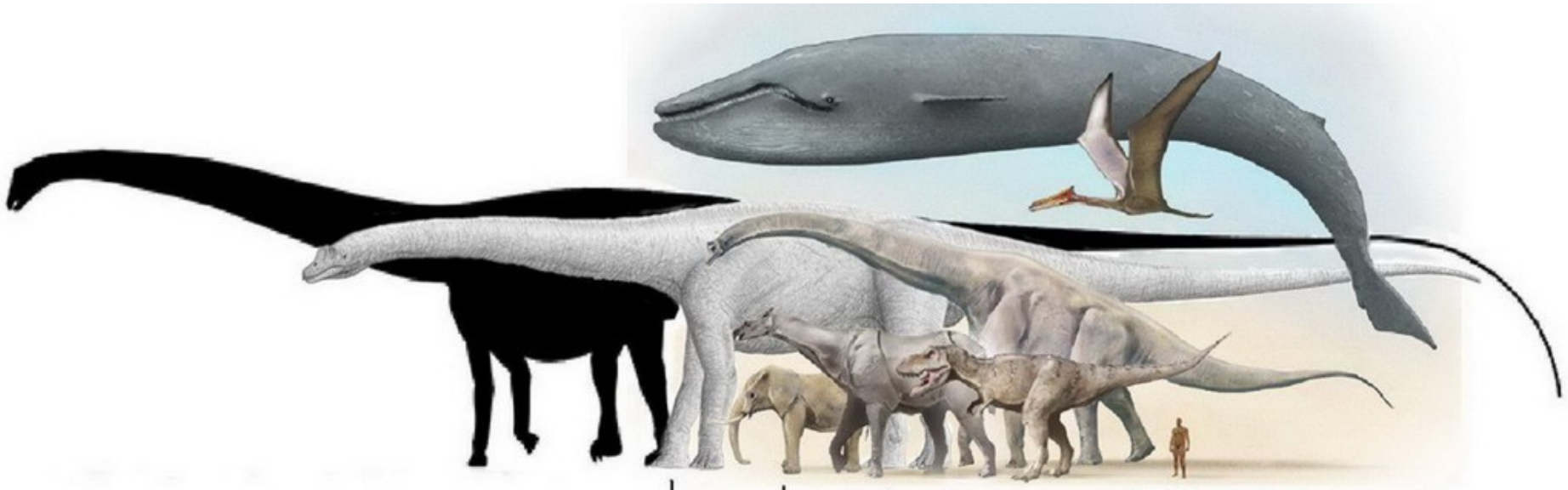

240 230 220 210 200 190 180 170 160 150 140 130 120 110 Millions of years ago
Ornithischian dinosaurs
IV
V
III
II
I
Reduction of IV and V
Eoraptor
Coelophysoids
III
IV
II
I
Loss of V; II and III about the same length
Four digits in hands
Allosaurids
III
II
I
Loss of IV and V; II is longer
Compsognathids
Hollow bones, furcula (wish bone)
Pubic boot, three digits in hand
Tyrannosauroids
III
II
I
Reduction of III
Hollow cylindrical feathers
Oviraptorosaurs
Tufted feathers
Dromeosaurids
III
II
I
Semilunate carpal in hand, feathers closed with barbules and hooks, nest-brooding
Archaeopteryx
III
II
I
Feathers closed and asymmetrical
Elongation of II
Long arms (ulna longer than femur)
Living birds
I
II
III
Reduction of I; fusion of II and III; loss of some phalanges
Toothless beak, fused wing digits, short feathered tail


Millions of years ago
65.5
92.6
145.5
161.2
175.6
199.6
228
245
251
CRETACEOUS
Late
Early
JURASSIC
Late
Middle
Early
TRIASSIC
Late
Middle
Early
Large Accelerator
Gigantotherm
Mosasaurs
Plesiosauria
Parvipelvia
Large Cruiser
Homeotherm
Ichthyosaurs
Large Cruiser
Homeotherm
Plesiosaurs
Poikilotherm?
Basal Sauropterygia
Poikilotherm?
Basal Ichthyopterygia


Period
Epoch
Theropoda
Sauro-
podomorpha
Thyreophora
Ornithopoda
Marginocephalia
Ma
Paleogene
Paleocene
65
Cretaceous
Late
Early
Birds
Deinonychosauria
Allosauroidea
Ceratosauria
Sauropoda
Stegosauria
Ankylosauria
Euornithopoda
Pachycephalosauria
Ceratopia
145
Jurassic
Late
Middle
Early
Maniraptora
Heterodontosauridae
Tetanurae
Herrerasauridae
Prosauropoda
Cerapoda
208
Triassic
Late
Middle
Early
10 Ma.
Genasauria
Saurischia
Ornithischia
250


Late Triassic
Early Jurassic
Carnian
Norian
Rhaet.
Hett.
Sinem.
Pliensb.
Toarcian
A
Eoraptor
Herrerasauridae
Guaibasaurus
Lilienstemus
"Syntarsus" kayentakatae
Coelophysis rhodesiensis
Segisaurus
Coelophysis bauri
Coelophysoidea
Lophostropheus
Procompsognathus
Zupaysaurus
Neotheropoda
Dilophosaurus
Cryolophosaurus
Dracovenator
*
"Dilophosaurus" sinensis
Neoceratosauria
Tetanurae
Averostra


Smallest
birds
15 g
Rapid evolutionary
size reduction
1 kg
15 kg
750 kg
Ecologically diverse
maniraptorans
T. rex
7 tonnes
Biggest dinosaurs
90 tonnes
Dinosaur
ancestor
10-35 kg
Triceratops
13 tonnes
Stegosaurus
7 tonnes
Time (million years)
200
145
66
TRIASSIC
JURASSIC
CRETACEOUS



Amphicoelias
150 million years ago
58-62 m length
122-130 tones

Bruhathkayosaurus
70-65 million years ago
40-44m length
200-220 tones

African Elephant
3 meters height
6 tones

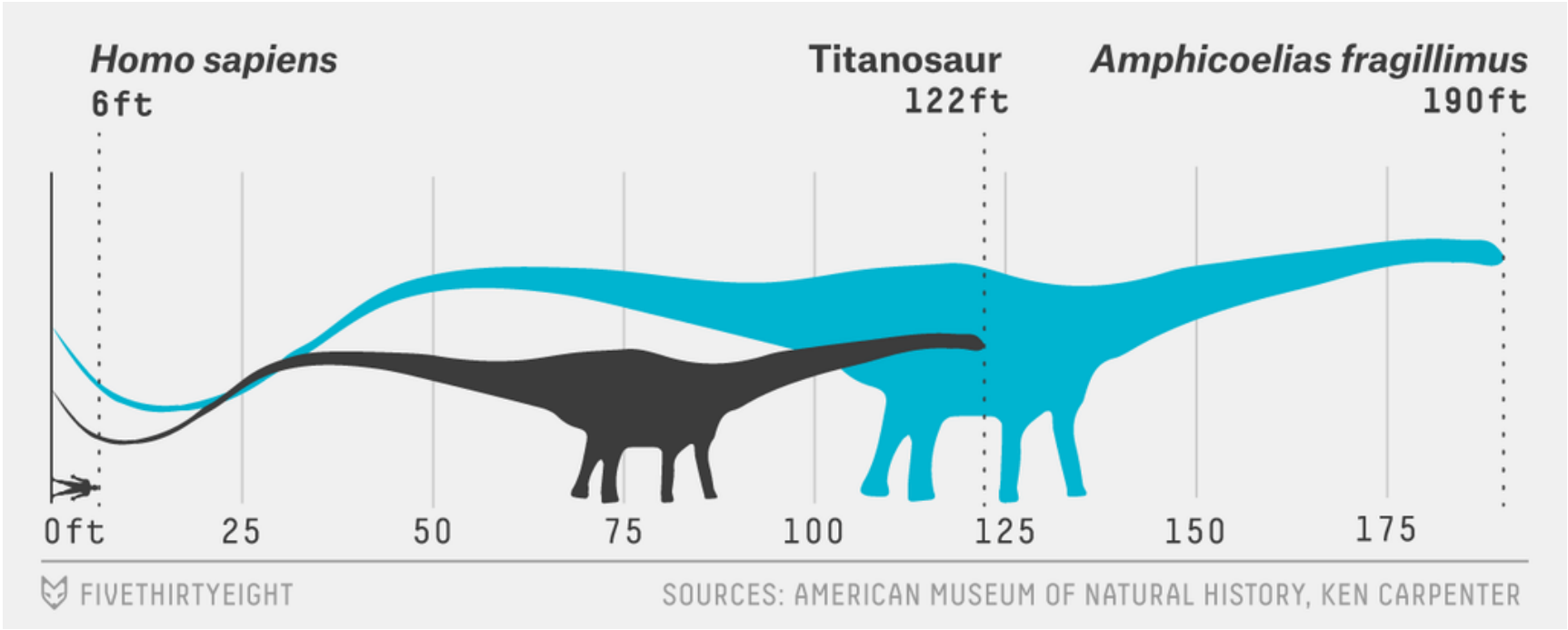
Indricotherium
37-32 million years ago
5.2m tall
8.2m length
15tones

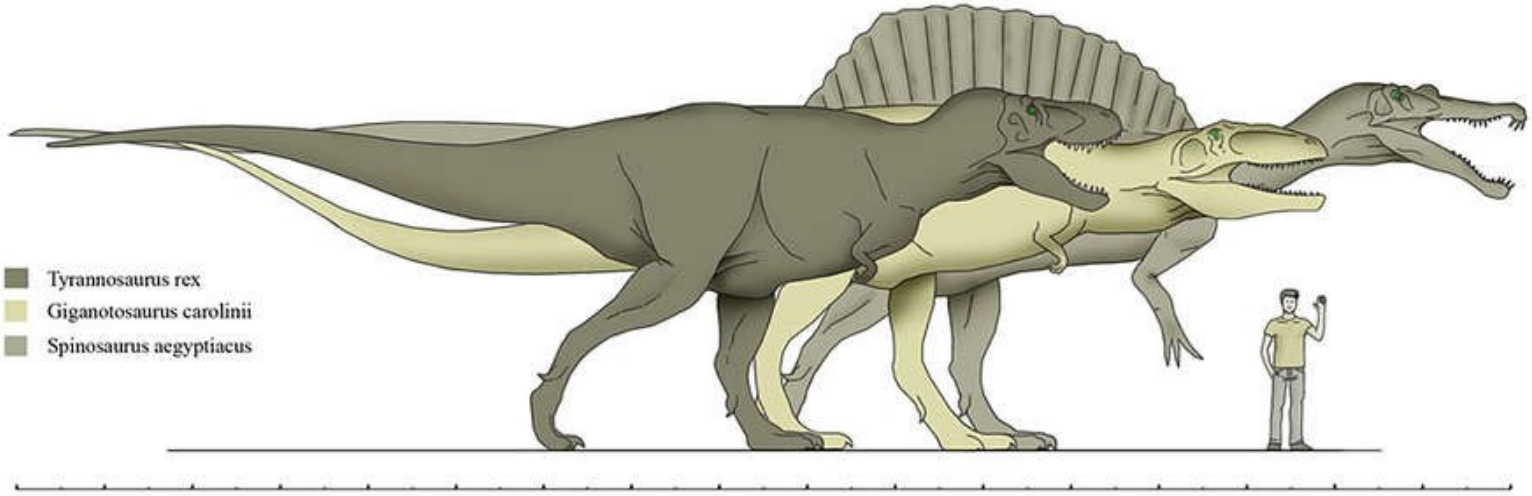
T-rex
68-65 million years ago
5-6 tones weight
13 meters length

Brachiosaurus
100-110 million years ago
60-70 tones weight
13m height
25m length

Homo Sapiens
2m hight

Blue Whale
33.5 m length
180 tones


Homo sapiens
6ft
Titanosaur
122ft
Amphicoelias fragillimus
190ft
0ft
25
50
75
100
125
150
175
FIVETHIRTYEIGHT
SOURCES: AMERICAN MUSEUM OF NATURAL HISTORY, KEN CARPENTER


Tyrannosaurus rex
Giganotosaurus carolinii
Spinosaurus aegyptiacus