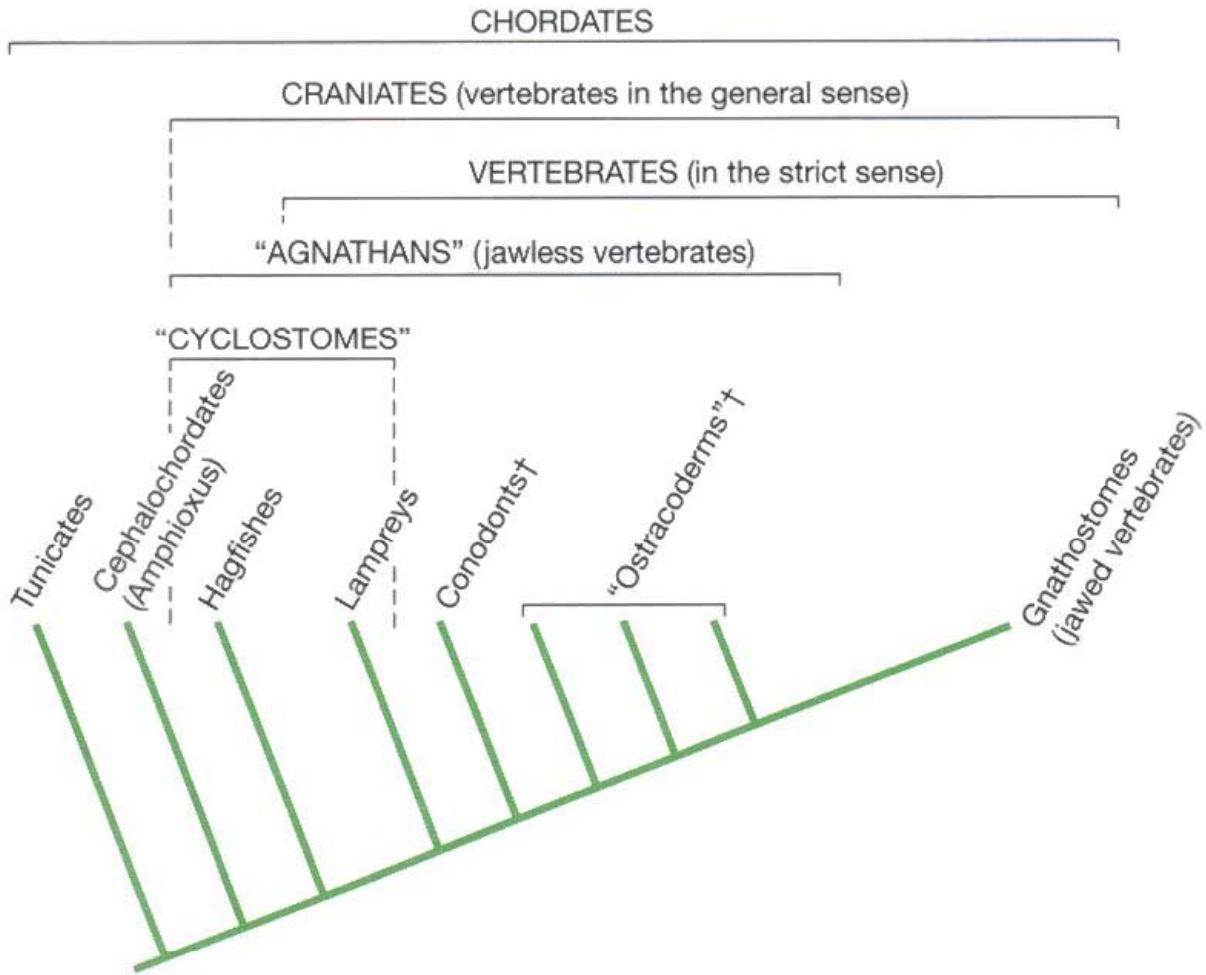
From Jawless Vertebrates to Jawed Fishes

Textbook Chapter 3,
Learn: Table 3.2;

Figs. 3-4; 3-8; 3-9; 3-15; 3-16;

Phylogenetic placement of jawless vertebrates



Generalities about jawless vertebrates

- Vertebrates evolved in marine environment.
- Jawless vertebrates are known from Cambrian
- Earliest jawed vertebrates are known from Ordovician
- Early Cambrian vertebrates lacked bone, and hagfishes lack bone.
- Conodonts are fossils from Cambrian, that have bone and enamel, derived traits shared with all vertebrates.

Environment experienced by jawless vertebrates

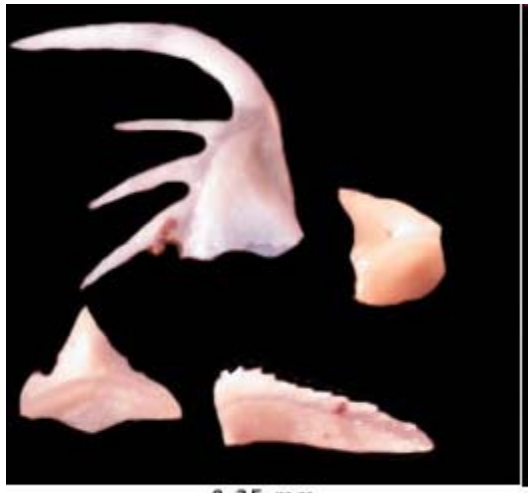
Cambrian
Ordivician
Silurian

550 to 425 mya

- Jawless fishes and earliest jawed fishes were very abundant in oceans by Silurian
- Evidence for marine origin:
  1. all sister groups to vertebrates were marine origin;
  2. earliest fossils are from marine sediments;
  3. body fluids of nonvertebrate chordates, and;hagfishes, are in same concentration as surroundings (i.e. seawater).

Conodonts

- Know they existed, what they are:
  - Conodonts are difficult to place phylogenetically.
  - They existed Late Cambrian to Late Triassic
  - They were jawless, elongate, eel-like, swimmers, probably carnivores.
- Why care about Conodonts?
  - Earliest fossils with tooth-like structures with enamel and cellular bone.
  - These are features shared by all vertebrates and found in no other group (synapomorphies), thus Conodonts are part of Vertebrata and part of early evolution of vertebrates.

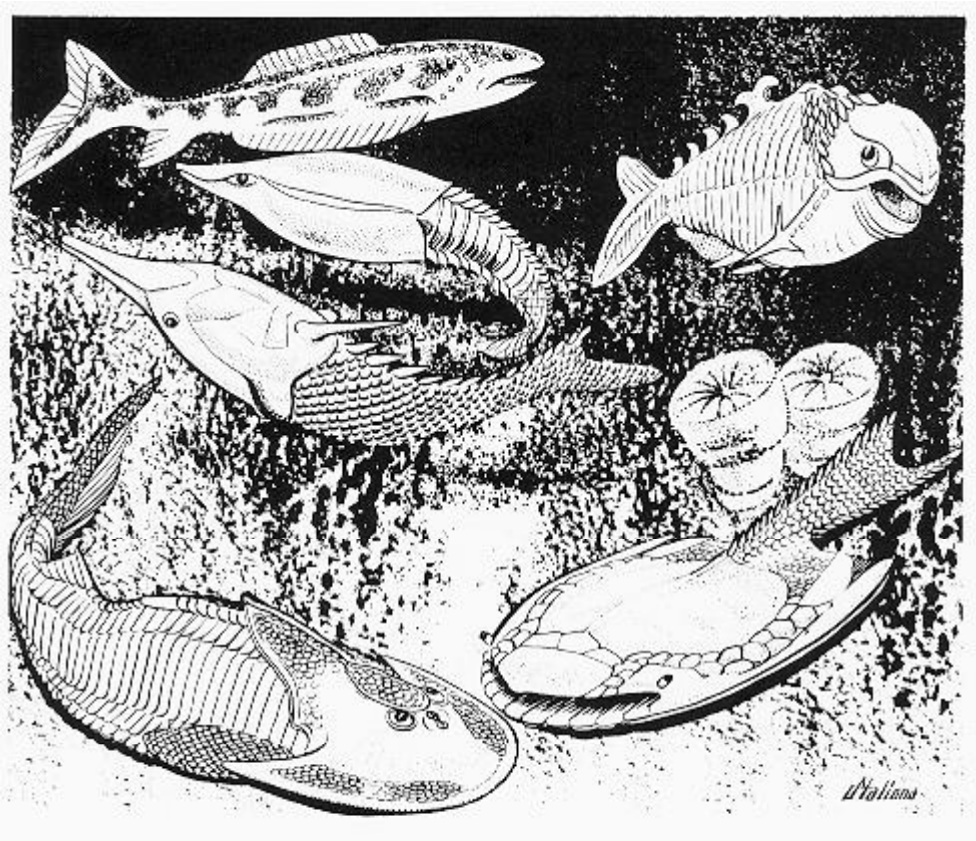


Ostracoderms

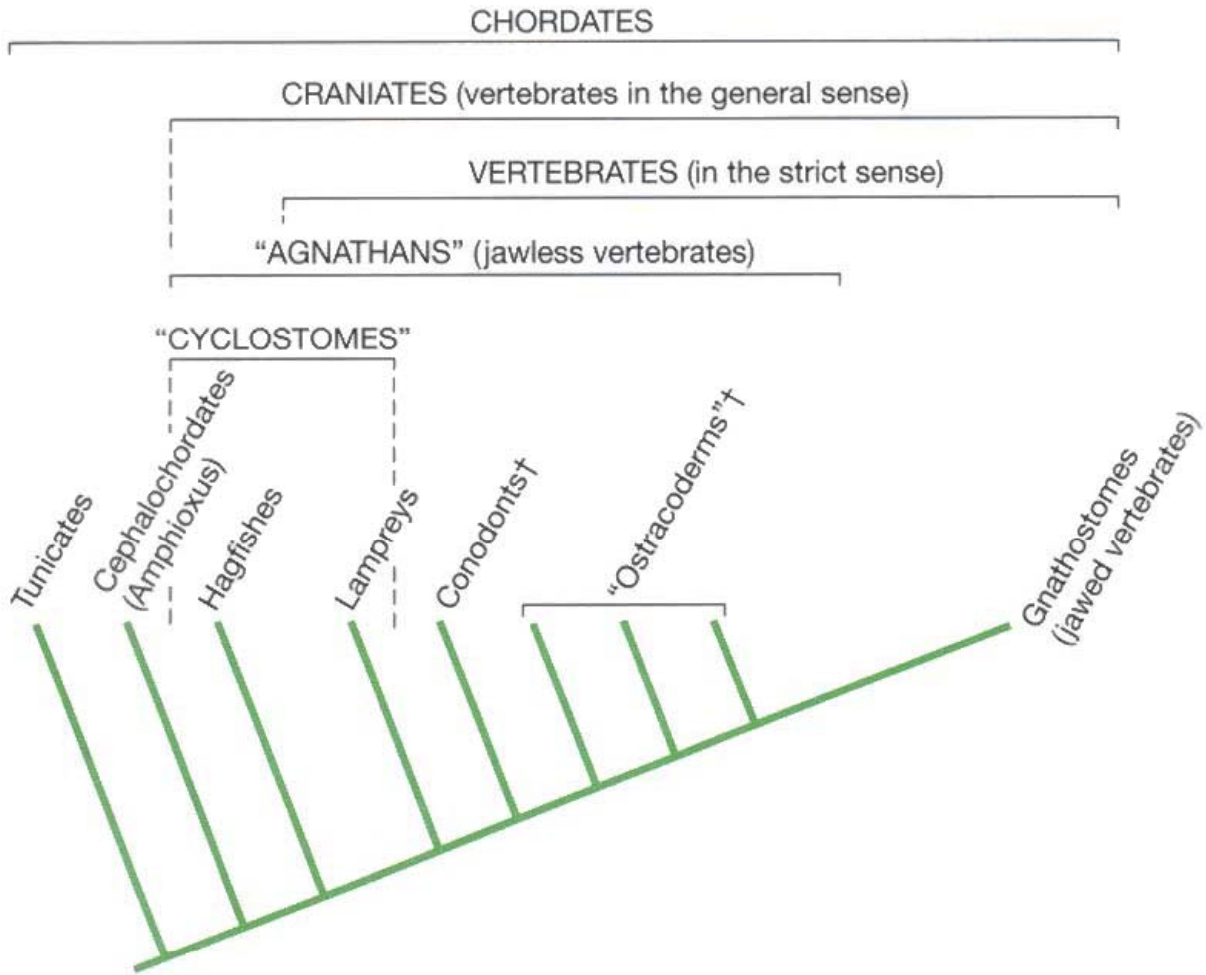
- Early jawless vertebrates from Cambrian, 500 mya
- They were nothing like lampreys, the exant jawless vertebrates
- They were fish-like, covered with bony exoskeletons
- They were diverse, occurred worldwide.

Ostracoderms (continued)

- "muscular pump" filter-feeding mechanism instead of cilia as in protochordates.
- improved filter-feeding allowed collection of larger food items and led to evolution of increased body size (up to 30 cm).
- improved mobility due to their vertebral columns and flexible skeletons.

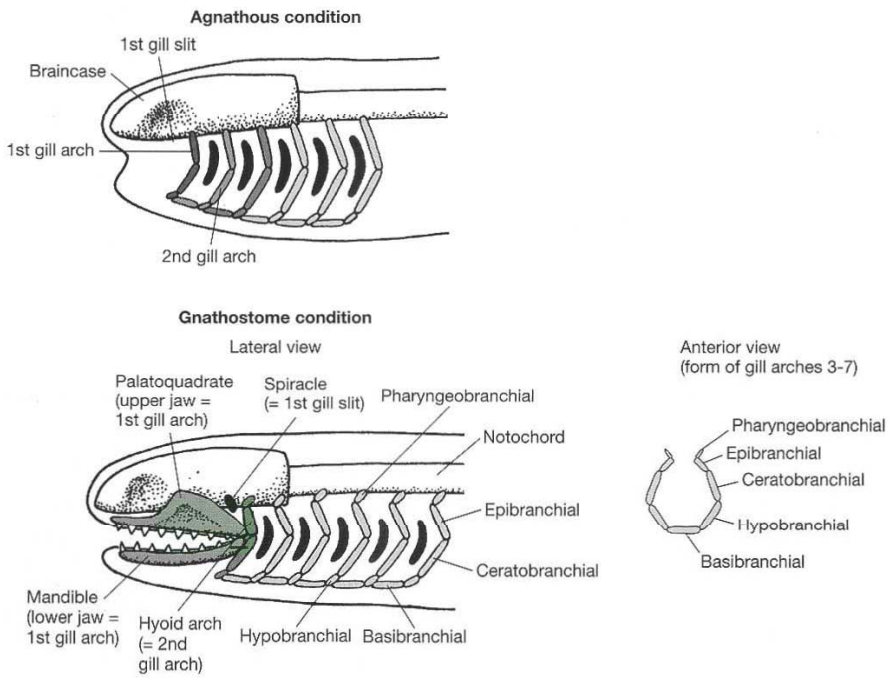


Phylogenetic placement of jawless vertebrates



Transition to Jawed Vertebrates

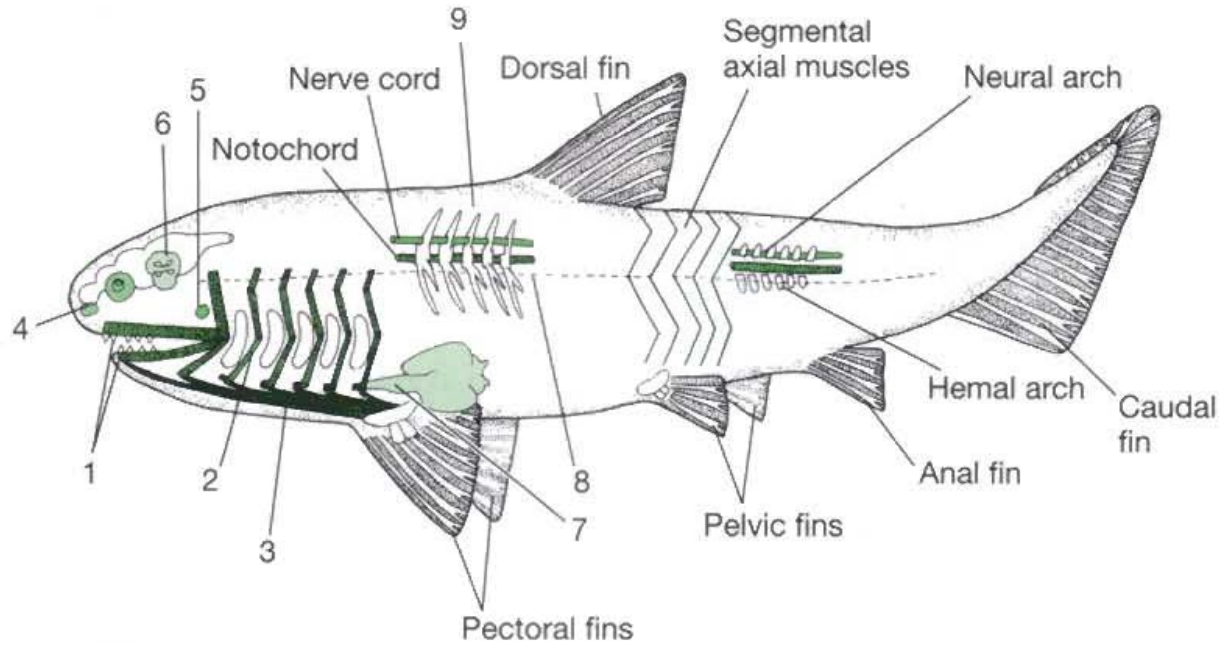
- What's good about having jaws?
- Romer: "…greatest advancement in vertebrate history was development of jaws and consequent revolution in mode of life of early fishes."
- Jaws are derived from branchial arches.
  - Understand figure 3-8.



- Gill arches in agnathous condition:
  - Support cranium;
  - Support gills;
- Gnathostomes:
  - 1st gill arch makes upper and lower jaws;
  - 2nd gill arch makes hyoid;

Transition to Jawed Vertebrates

- What's good about having jaws?
- Grasping, manipulating objects
    - Not only prey, but all kinds of behaviors
  - Add teeth
    - For cutting or grinding or both
  - New food resources become available, or they can be more efficiently exploited;
  - Wider range of body sizes can exist;
  - In short, many ecological niches can be exploited that were not filled before, and clades diversify to fill them.



▲ **Figure 3–9** Generalized jawed vertebrate (gnathostome) showing derived features compared to the jawless vertebrate (agnathan) condition.

Legend: 1. Jaws (containing teeth) formed from the mandibular gill arch. **2.** Gill skeleton consists of jointed branchial arches, and contains internal gill rakers that stop particulate food from entering the gills. Gill musculature is also more robust. **3.** Hypobranchial musculature allows strong suction in inhalation and suction feeding. **4.** Two distinct olfactory bulbs, leading to two distinct nostrils. **5.** Original first gill slit squeezed to form the spiracle, situated between mandibular and hyoid arches. **6.** Three semicircular canals in the inner ear (addition of horizontal canal). **7.** Addition of a conus arteriosus to the heart, between the ventricle and the ventral aorta. (Note that the position of the heart is actually more anterior than shown here, right behind the most posterior gill arch.) **8.** Horizontal septum divides trunk muscle into epaxial (dorsal) and hypaxial (ventral) portions. It also marks the position of the lateral line canal, containing the neuromast sensory organs. **9.** Vertebrae now have centra (elements surrounding the notochord) and ribs, but note that the earliest gnathostomes have only neural and hemal arches, as shown in the posterior trunk.

TABLE 3.2 Derived Features of Gnathostomes "gnath" means jaws + "stoma" means mouth

Cranial Characters

1. Cranium enlarged anteriorly to the end in a precerebral fontanelle.
2. Cranium elongated posteriorly, so that one or more occipital neural arches are incorporated in the rear of the skull.
3. Development of a postorbital process on the cranium, separating the functions of supporting the jaws and enclosing the eyes.
4. Intrinsic musculature in the eye for focusing the lens.

Internal Anatomical Characters

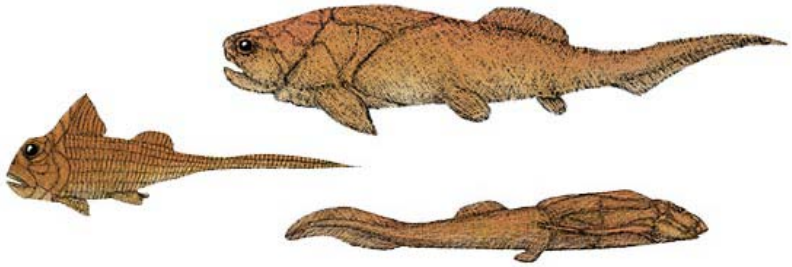
5. Atrium lies posterodorsally (versus laterally) to ventricle.
6. Renal portal vein present.
7. Spiral valve primitively formed within intestine.
8. Pancreas with both endocrine and exocrine functions.
9. Distinct spleen.
10. Kidneys formed only by more posterior sections in adult (mesonephros and metanephros).
11. Male gonads linked by ducts to excretory (archinephric) duct.
12. Female gonads with distinct oviducts.
13. Two (versus one) contractile actin proteins (one specific to striated muscle and one specific to smooth muscle).

Sensory Characters

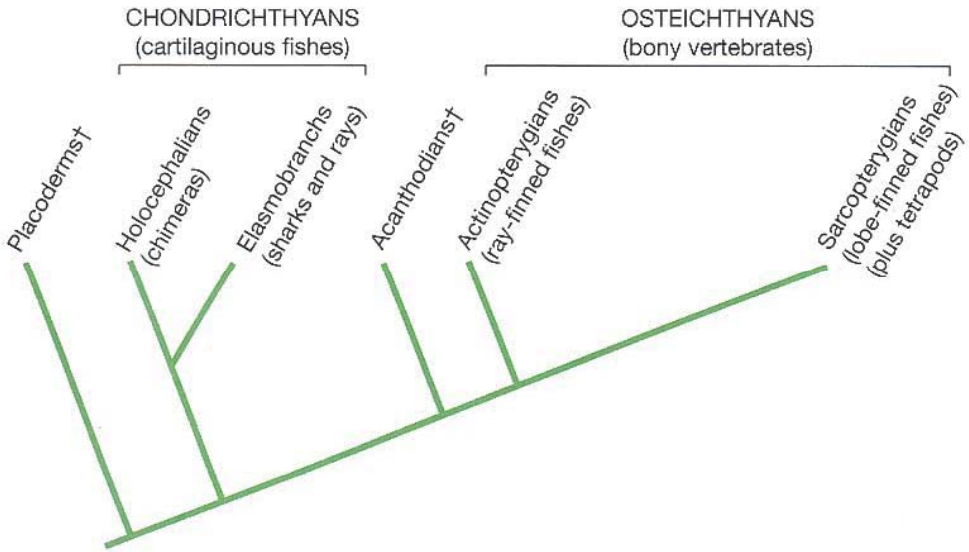
14. Nerves enclosed in myelinated sheaths.
15. Large, distinct cerebellum in the hind brain.
16. Two distinct olfactory tracts leading to widely separated olfactory bulbs.
17. Thicker spinal cord with "horns" of gray matter in section.
18. Dorsal and ventral spinal nerve roots linked to form compound spinal nerves.
19. Unique and evolutionarily conservative pattern of head lateral line canals (lost in some adult amphibians and amniotes).
20. Lateral line on trunk region flanked or enclosed by specialized scales (lateral line lost in some adult amphibians and amniotes).
21. Third (horizontal) semicircular canal.

Placoderms, the first jawed fishes

http://www.devoniantimes.org/who/images/R-placoderms.jpg



- placo (plate) + derm (skin) Armored Fishes.
- Sister clade to Chondrichthyians and to all other gnathostomes
- Silurian to end of Devonian
- Paired fins
- Very diverse, all kinds of life histories



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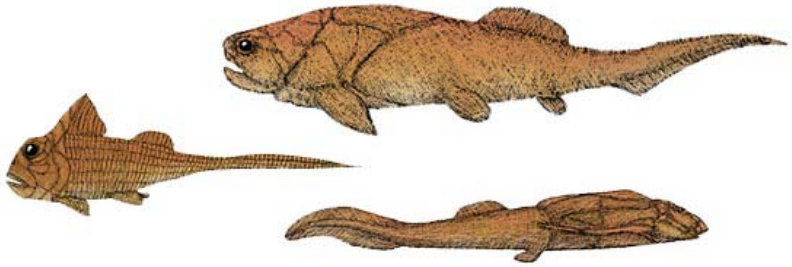
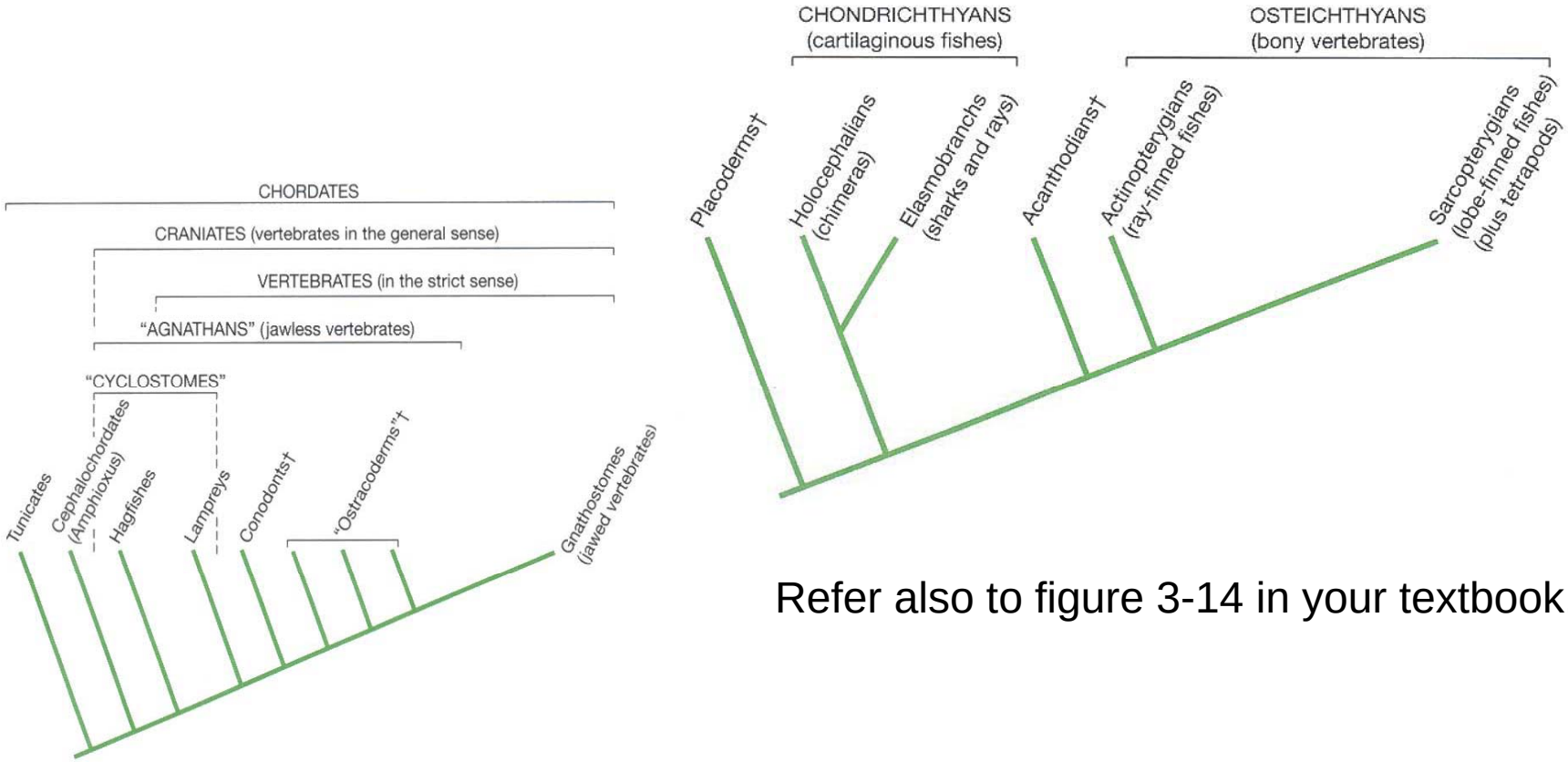
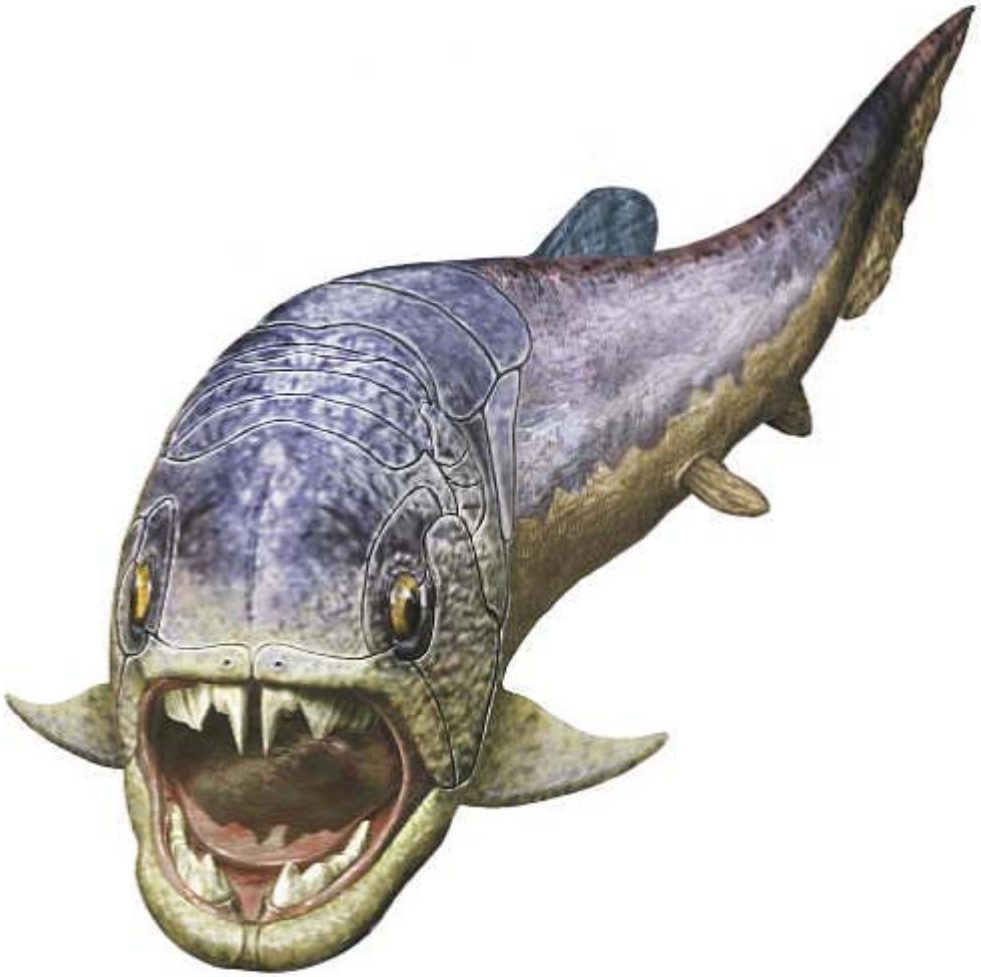




Refer also to figure 3-14 in your textbook.

Dunkleosteus, a predatory placoderm, was 30 feet long.



http://www.dkimages.com/discover/Home/Science/Earth-Sciences/Palaeontology/Prehistoric-Animals/Fish/Placoderms/Dunkleosteus/Dunkleosteus-2.html

A fossilized school of placoderms

http://www.kingtutexhibit.com/images/pics2/pic49.jpg

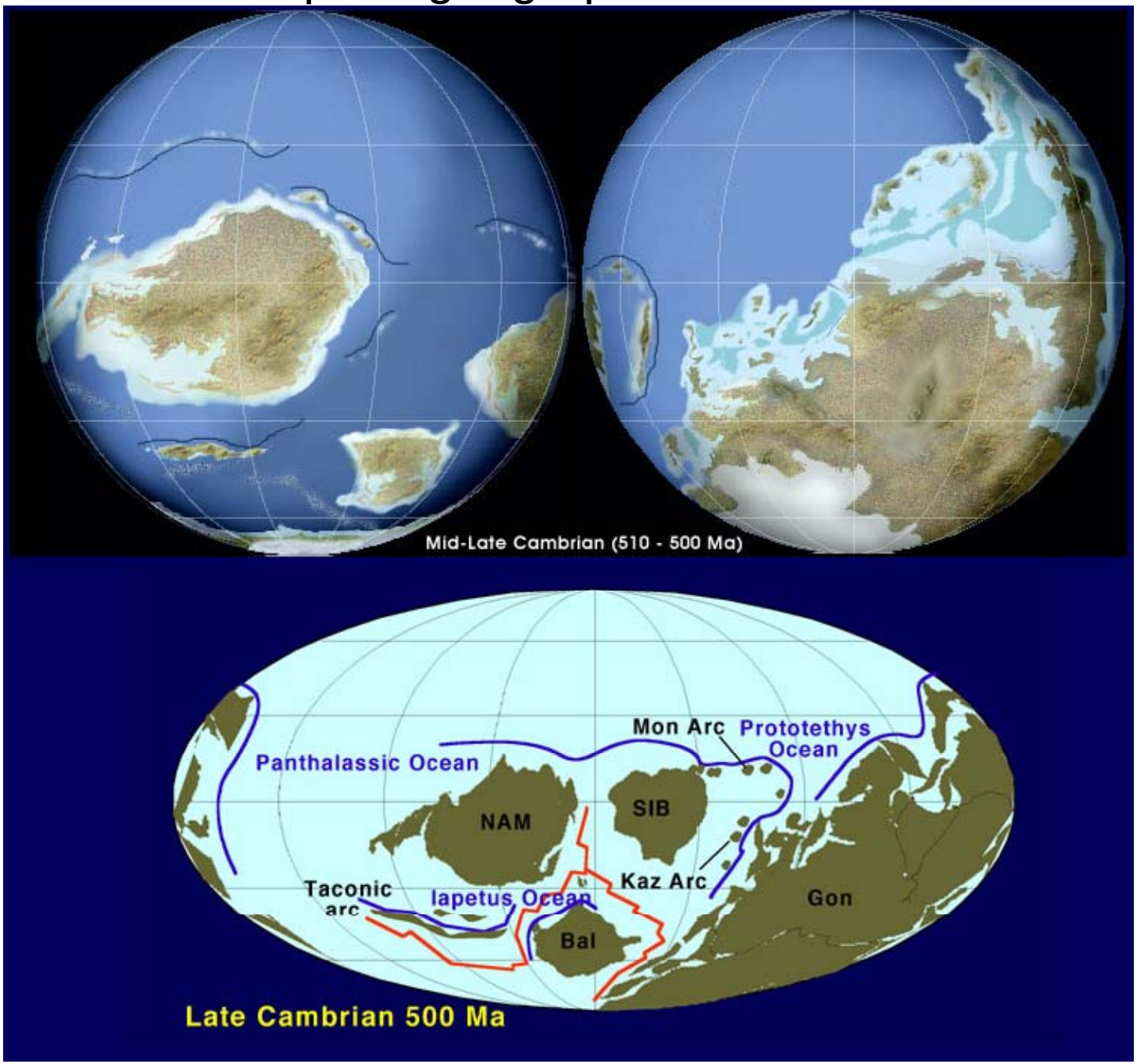
Paleozoic Ecology

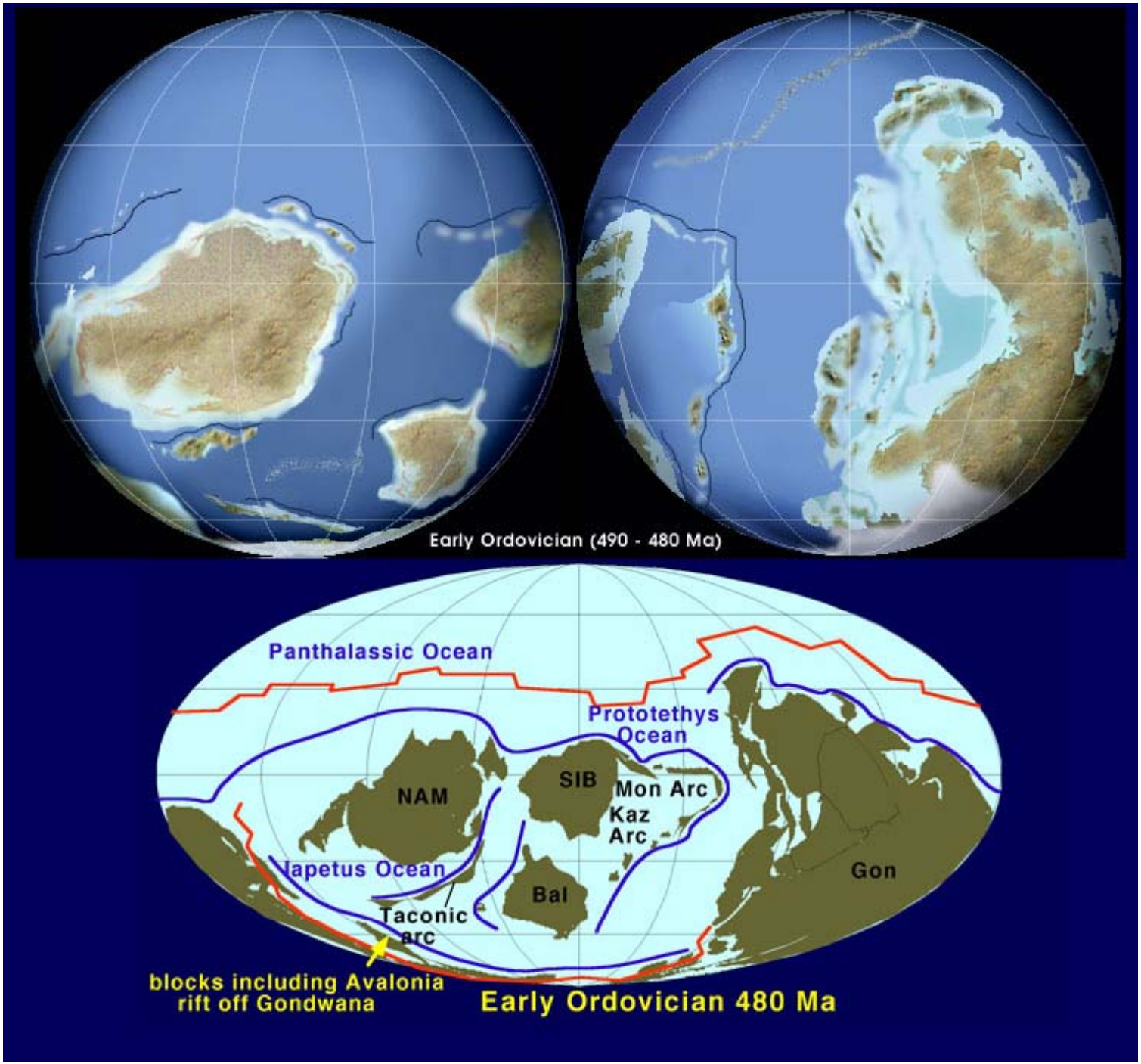
- Continental position affects:
  - Weather
  - Currents
  - Distribution of habitats
- Fragmentation and coalescence of land masses sets the stage for diversification of lineages.

Paleozoic climates and continental drift

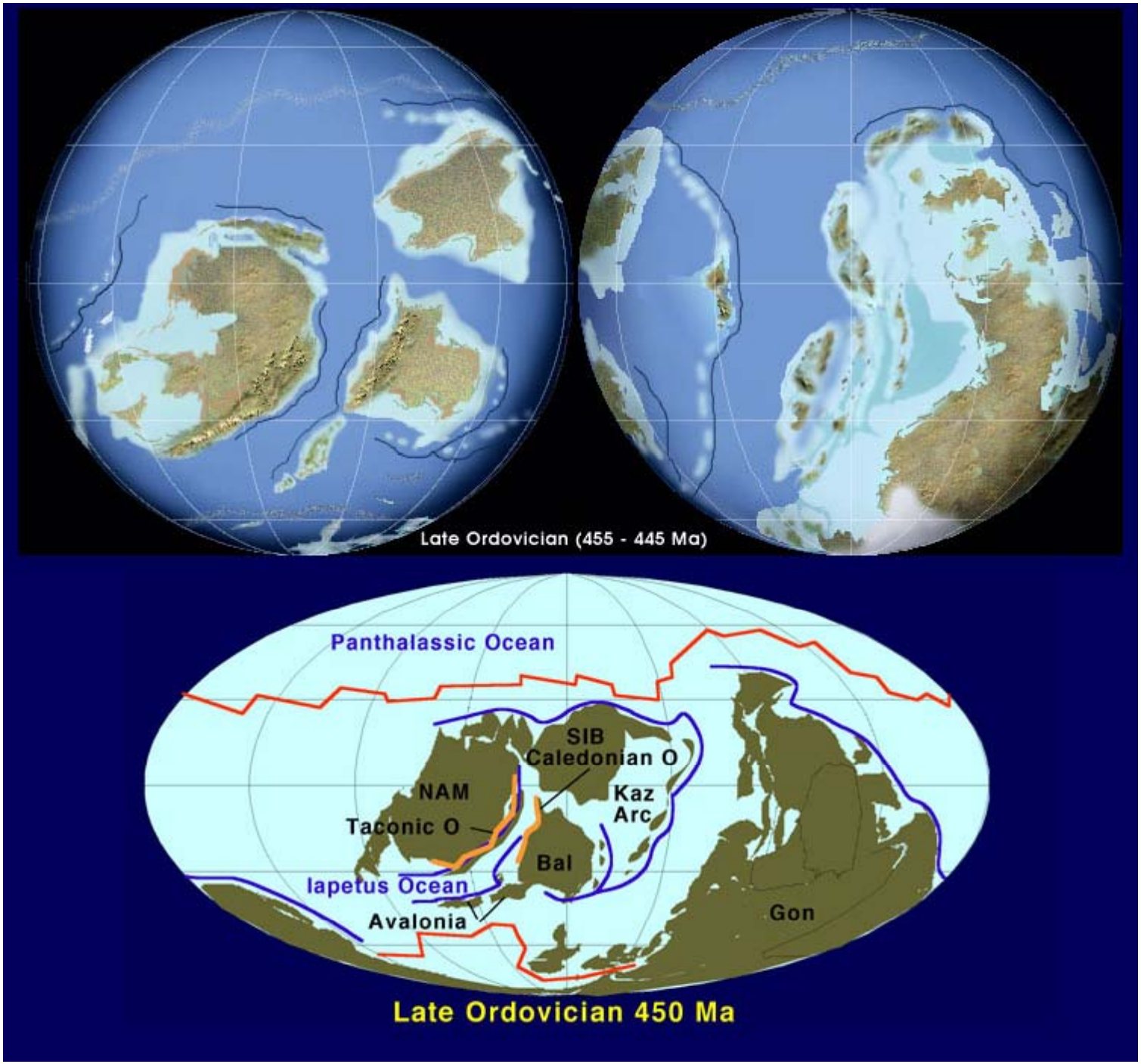
- There were 6 continents, different from those today.
- The 2 notable ones to remember: Laurentia and Gondwana.
- Note position of these supercontinents in relation to equator and poles.
- Cambrian and Ordivician
  - Sea levels were high,
  - CO2 was high,
  - Climate was hot, dry on land
    - Probably inhospitable to land plants, and hence higher trophic groups.

http://jan.ucc.nau.edu/~rcb7/paleogeographic.html

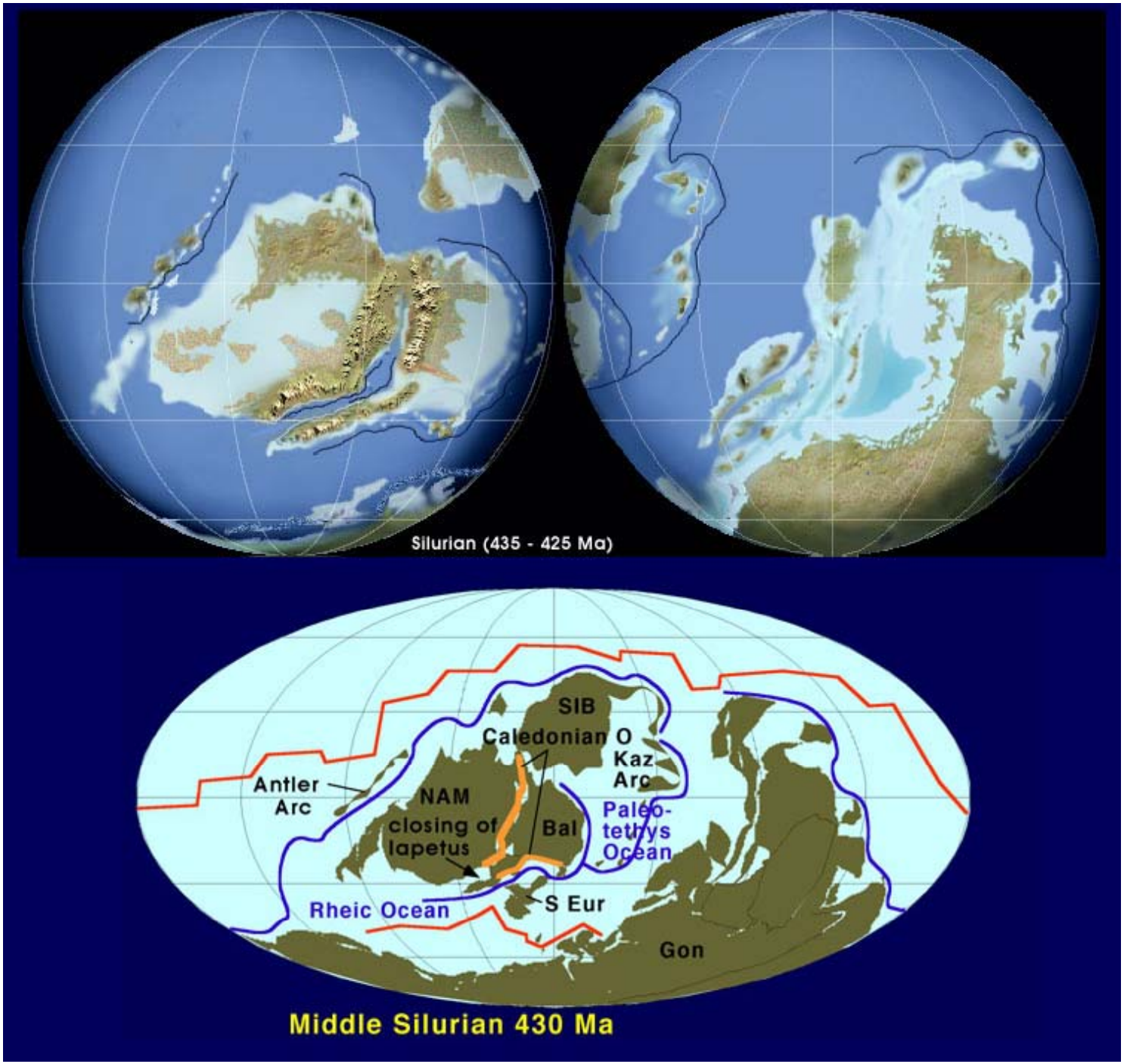


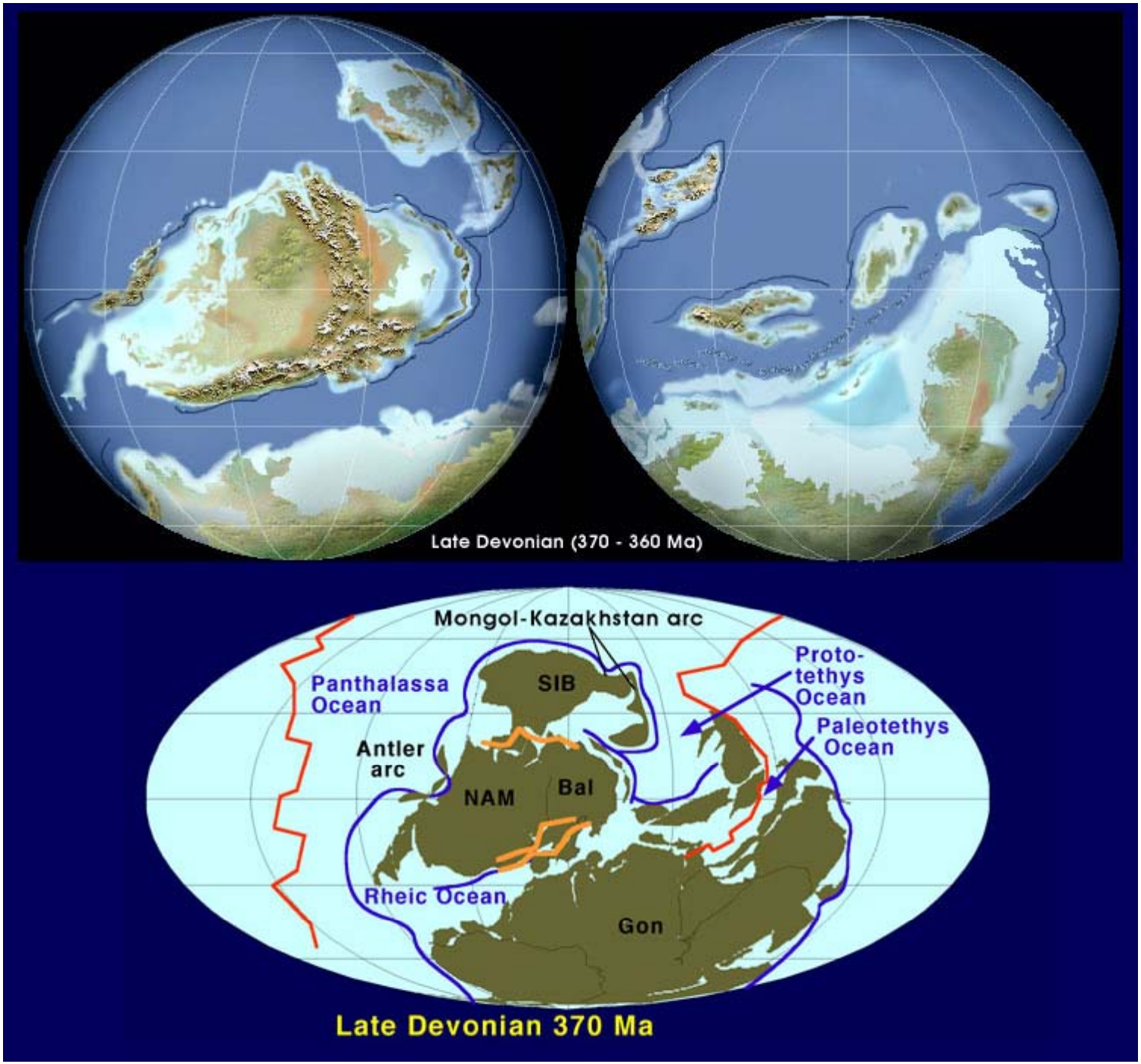

Early Ordovician (490 - 480 Ma)
Panthalassic Ocean
Prototethys Ocean
NAM
SIB
Mon Arc
Kaz Arc
Iapetus Ocean
Bal
Gon
Taconic arc
blocks including Avalonia rift off Gondwana
Early Ordovician 480 Ma

Glaciation
and cooling



Cooling has set stage for terrestrial ecosystems by the Silurian




Late Devonian (370 - 360 Ma)
Mongol-Kazakhstan arc
Panthalassa Ocean
SIB
Proto-tethys Ocean
Paleotethys Ocean
Antler arc
NAM
Bal
Rheic Ocean
Gon
Late Devonian 370 Ma