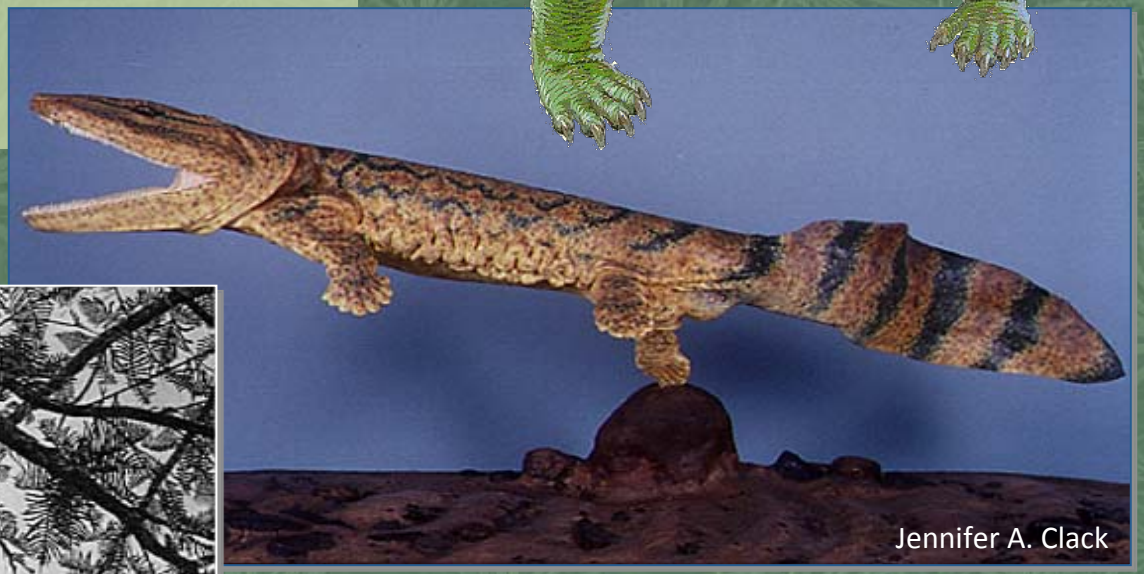
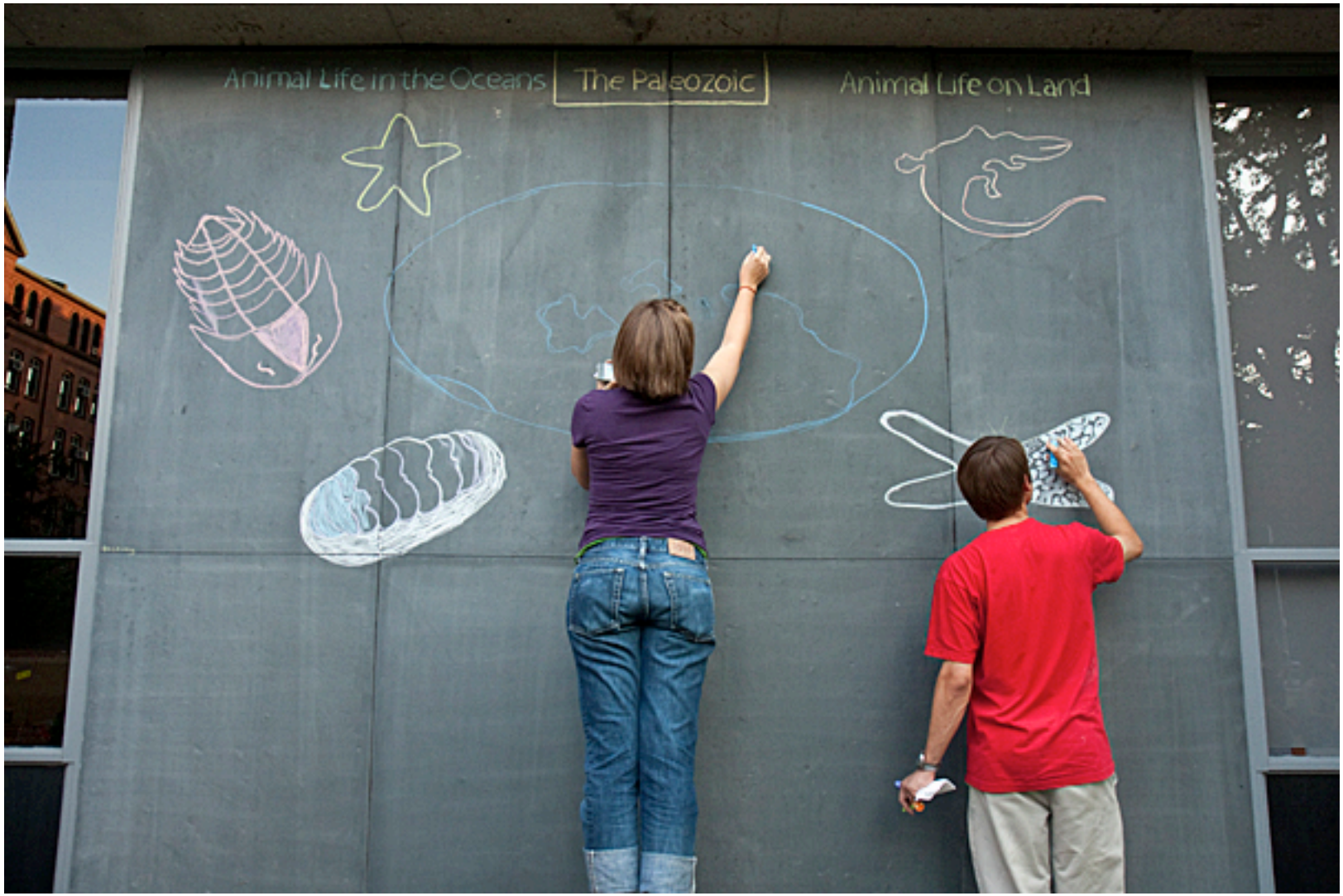
Paleozoic oceans
Jawless and jawed fishes
Life on land
Plant life an coal
Terrestrial vertebrates
Amniotes
Synapsids



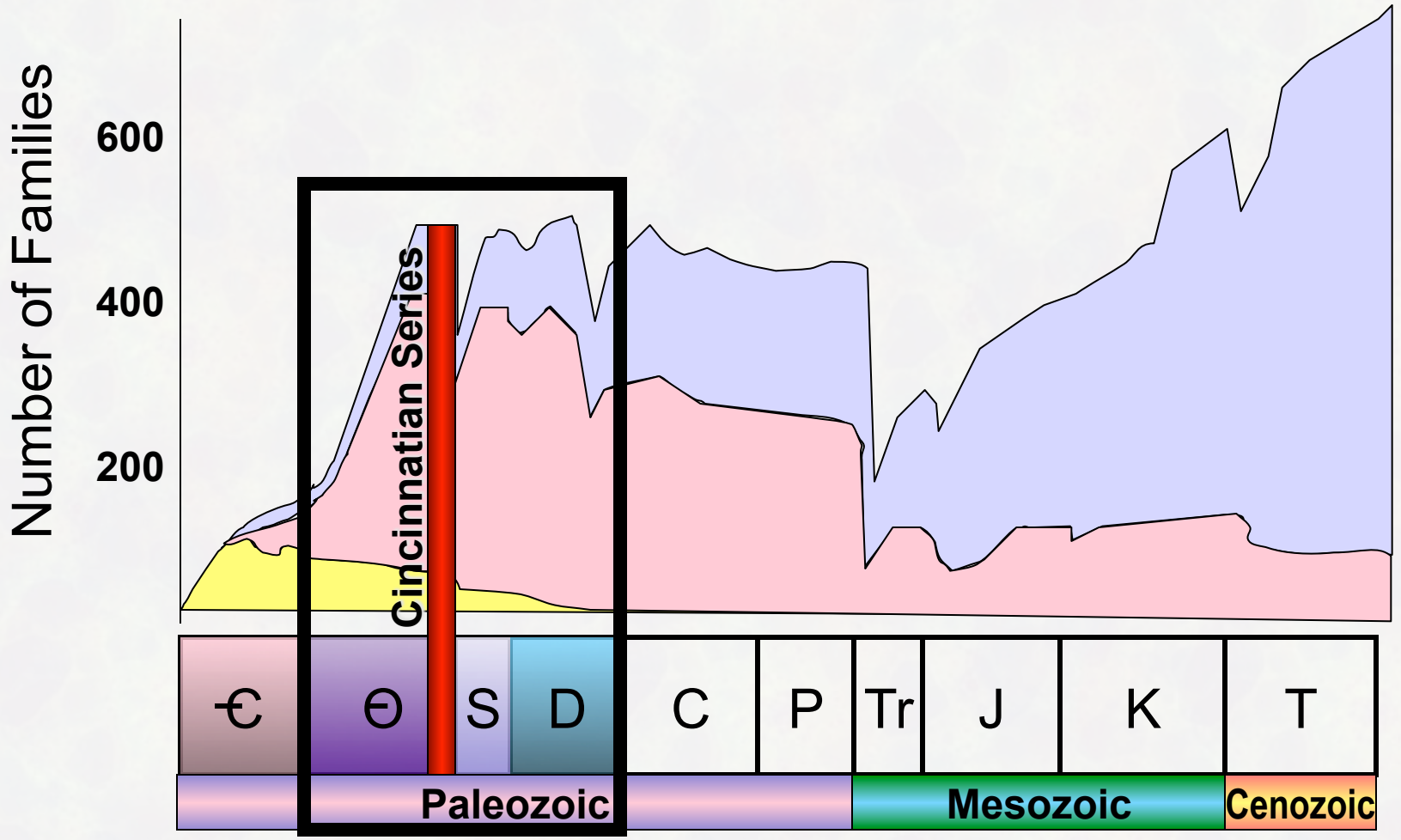
Paleozoic Earth History

The Paleozoic was a dynamic time for life, with evolution of new organisms followed by mass extinctions. Plant, insect and vertebrate species diversified into the terrestrial realm by the mid-Paleozoic, and were very diverse by the end of the Paleozoic.



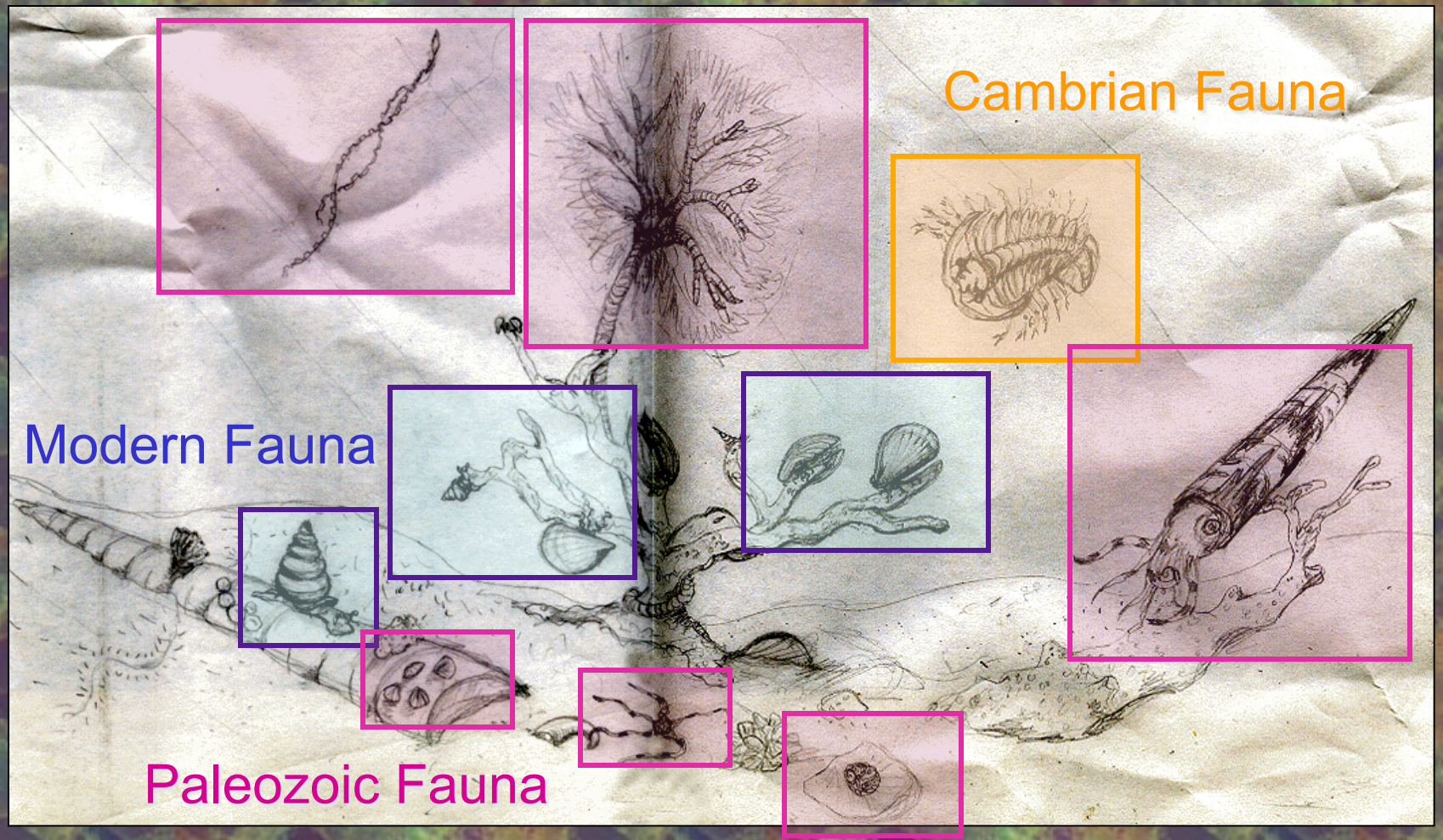
http://news.harvard.edu/gazette/story/2010/08/time-travel-in-chalk/ Jon Chase/Harvard Staff Photographer

Jack Sepkoski's Three Evolutionary Faunas



Decline of Cambrian weirdness, rise of Paleozoic phyla.

Cincinnatian Ocean



Reconstruction of a shallow water community in the Cincinnati region, approximately 440 Ma.

Cambrian Fauna

Trilobite

Member of an extinct superclass of arthropods.

No modern descendants, last common ancestor with the rest of the arthropods probably in the Precambrian.

http://www.uky.edu/OtherOrgs/KPS/

Bryozoans

Bryozoans are found in many marine environments throughout time. Both major classes are present in modern oceans.

The most common bryozoan order in the early Paleozoic is extinct and has no modern descendants.

Paleozoic Fauna

Brachiopods

Brachiopods were the most abundant shelled epifauna for much of the Paleozoic. Four orders are found in modern oceans, but each order has low diversity.

Most brachiopod orders left no descendents, but 3 of the 4 modern orders are present in the Cincinnatian.

http://www.whoi.edu/science/B/people/khalanych/evodevo2001/

http://www.uky.edu/OtherOrgs/KPS/

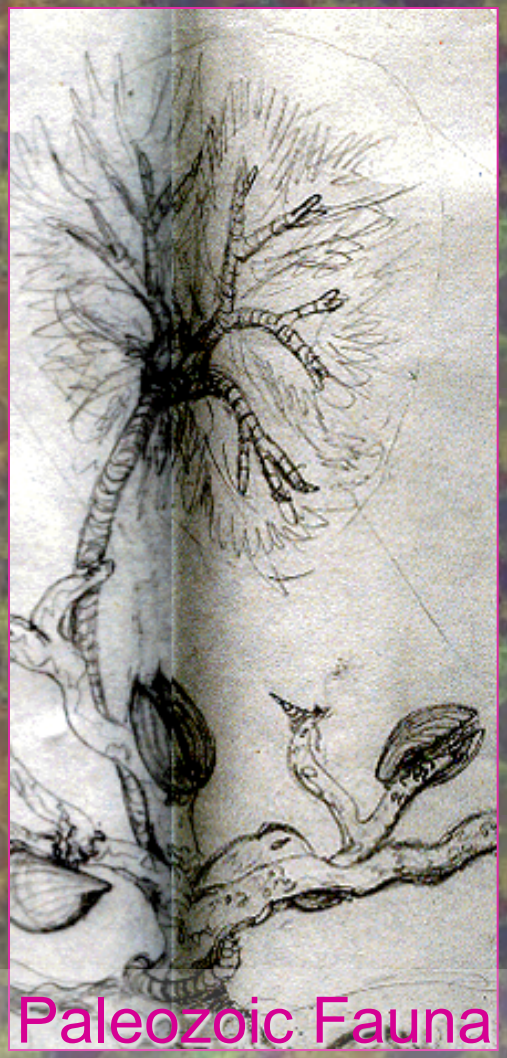
Starfish

Brittle stars (like this one) and starfish are another successful group. Modern starfish are similar in appearance to ancient starfish.

Descendants of this class are common in all marine environments, and the brittle stars are probably the most abundant animals on the deep sea floor.

http://www1.newark.ohio-state.edu/Professional/OSU/Faculty/jstjohn/Cool%20Fossils/Caesar-Creek-starfish.htm

http://oceanexplorer.noaa.gov/explorations/islands01/log/sep4/sep4.html



Paleozoic Fauna

Crinoid

A very successful group of Paleozoic echinoderms.

Modern crinoids are descendants of one very small group that survived the end-Paleozoic extinction. Most ancient taxa have no modern descendants.

http://www.uky.edu/OtherOrgs/KPS/

Paleozoic Fauna

Edrioasteroids

Weird little echinoderm that looks like a “starfish on a bun.”

Relationship to modern echinoderms uncertain, this extinct class may not have modern descendants.

Paleozoic Fauna

Graptolite

A hemichordate - first cousin to chordates (which include vertebrates).

Relationship to modern hemichordates unknown, but this extinct class probably has no descendants.

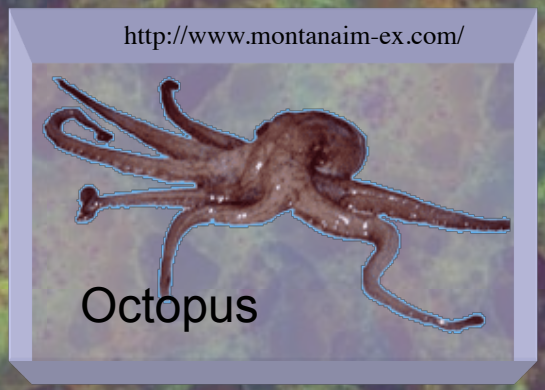
http://www.lakeneosho.org/More4.html

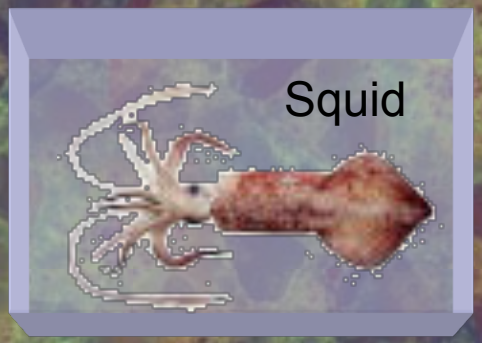
http://www.science.uwaterloo.ca/earth/geoscience/graptol.html

Shelled Cephalopod

Related to modern *Nautilus*, cuttlefish, squid, and octopi. Ancestor of later cephalopods, but perhaps not modern groups.

Ranged in size from 1 cm to 5-6 m.





Bivalves

Outstandingly successful group of mollusks found throughout the Paleozoic, Mesozoic, and Cenozoic.

This is *Ambonychia*, a taxon we'll see again. It is related to modern pin shells, oysters, ark shells, although the genus itself probably has no descendants.

Gastropods

Another spectacularly successful group of mollusks. Many early Paleozoic snails are very similar to some modern snails.

The order to which these belong continued to diversify steadily through 500 Ma.

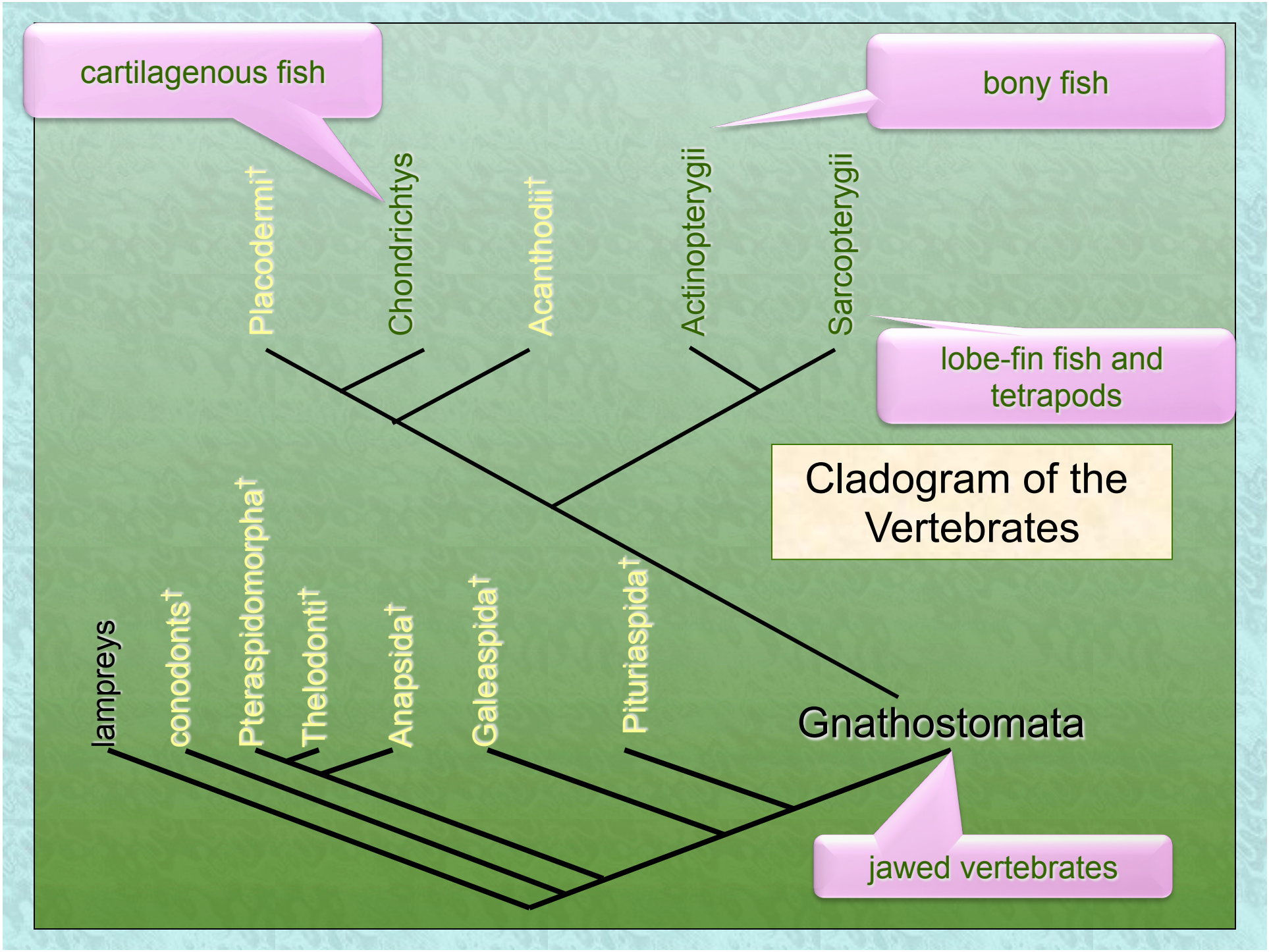
Ordovician Ocean

Eon	Era	Period	Age
PHANEROZOIC	CENOZOIC	Neogene	
		Paleogene	67 Ma
	MESOZOIC	Cretaceous	
		Jurassic	
		Triassic	270 Ma
	PALEOZOIC	Permian	
		Pennsylvanian	
		Mississippian	
		Devonian	
		Silurian	
		Ordovician	
		Cambrian	540 Ma
PROTEROZOIC			2,500 Ma
ARCHAEN			3,800 Ma
HADEAN			

Note that there are no *fish* in this reconstruction

In contrast to the highly developed communities of invertebrates (including the largest predators of the Ordovician), the *vertebrates* were rather incompetent, clunky creatures.

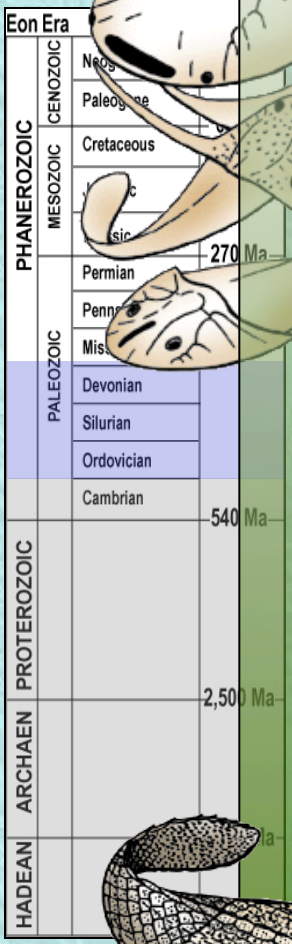
http://hannover.park.org/Canada/Museum/cobalt/FSLIDE4.HTM


cartilagenous fish
bony fish
Placodermi†
Chondrichtys
Acanthodii†
Actinopterygii
Sarcopterygii
lobe-fin fish and tetrapods
Cladogram of the Vertebrates
lampreys
conodonts†
Pteraspidomorpha†
Thelodonti†
Anapsida†
Galeaspida†
Pituriaspida†
Gnathostomata
jawed vertebrates

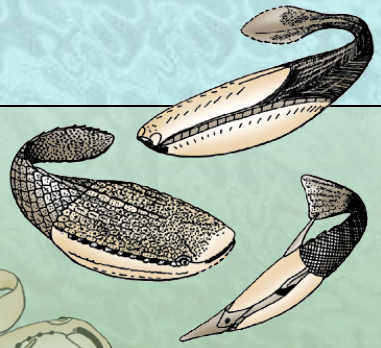
Key features of Early Paleozoic "Agnatha" (jawless fish)

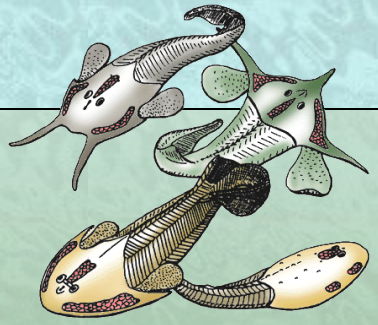
Absent:
hinged jaws, paired fins

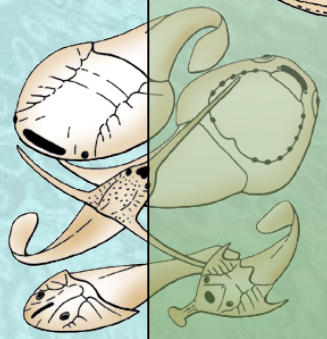
Present:
bony scales and plates in skin, cartilaginous skeleton, embryonic notochord in adult, seven or more paired gill pouches, pineal eye, external fertilization



http://tolweb.org/

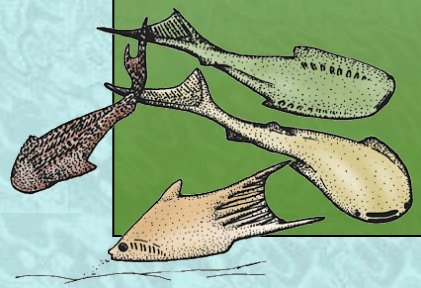




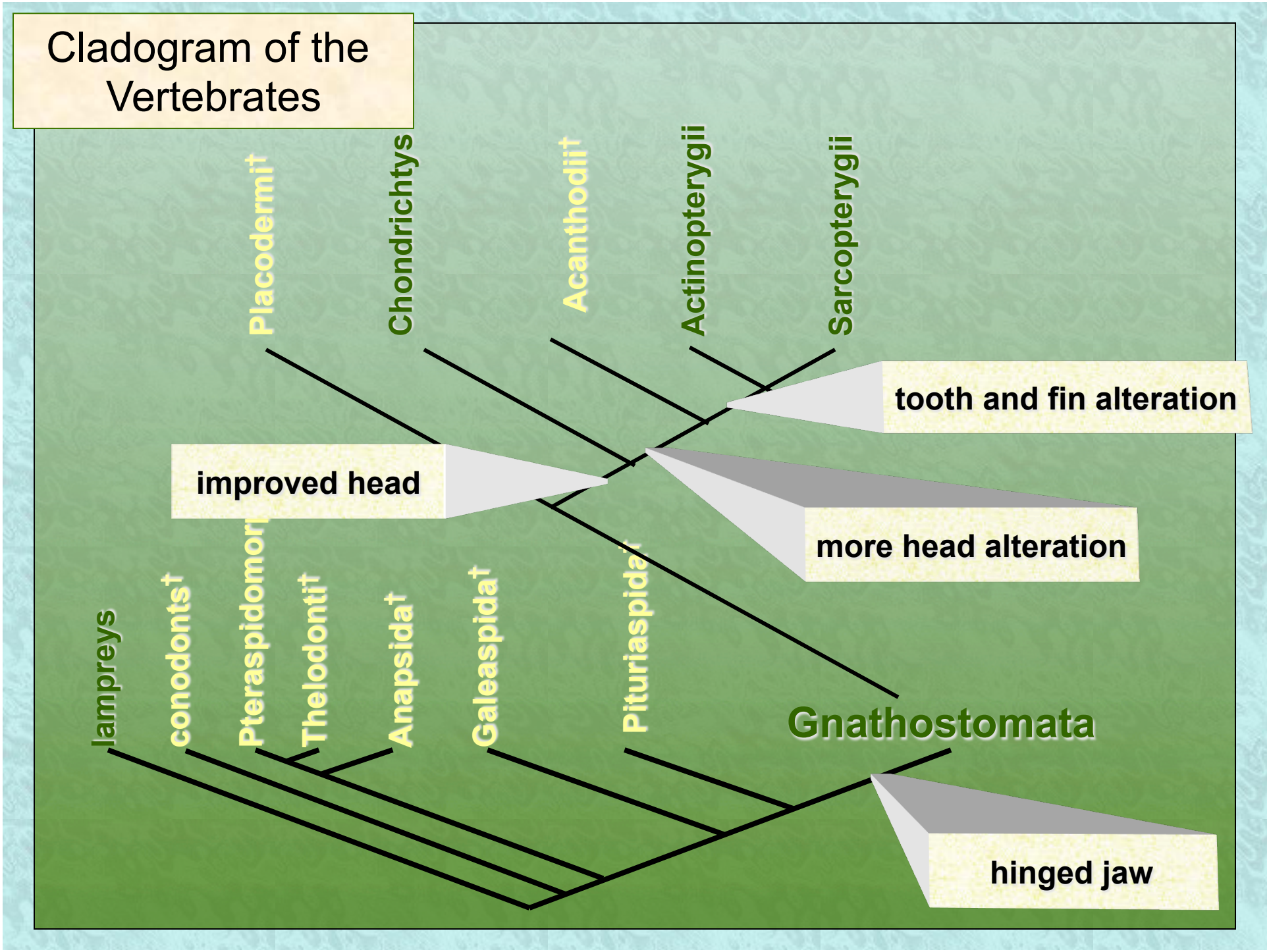


By the end of the Devonian, the jawless fish were in decline - losing out to more advanced fish with jaws and better fins

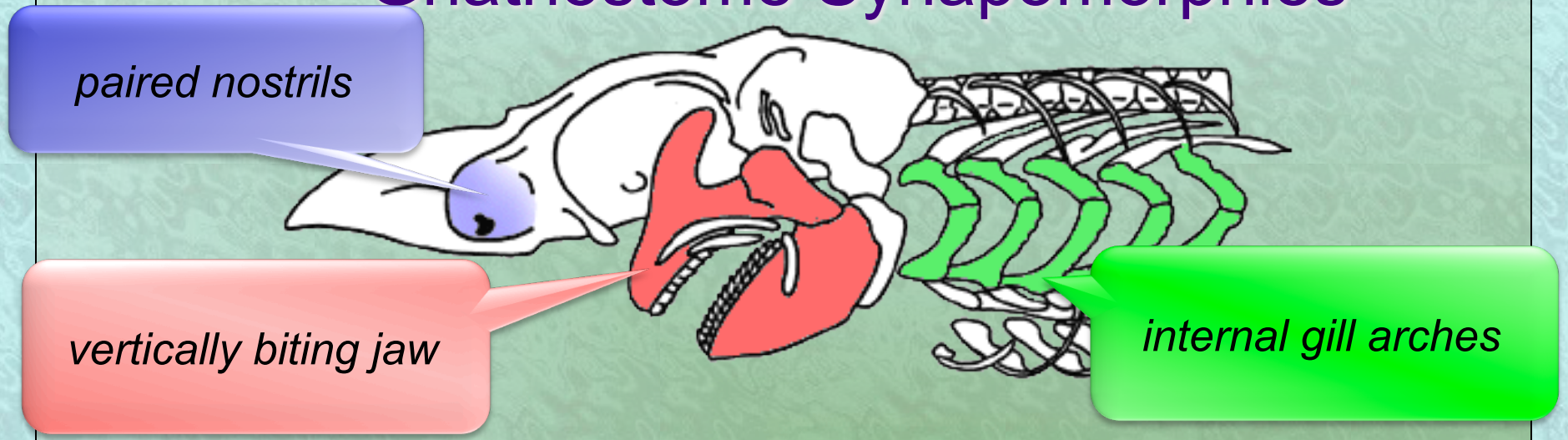
Gnathostomata!



Eon	Era	Period	Age
PHANEROZOIC	CENOZOIC	Neogene	
		Paleogene	67 Ma
	MESOZOIC	Cretaceous	
		Jurassic	
		Triassic	270 Ma
	PALEOZOIC	Permian	
		Pennsylvanian	
		Mississippian	
		Devonian	
		Silurian	
		Ordovician	
		Cambrian	540 Ma
PROTEROZOIC			2,500 Ma
ARCHAEN			3,800 Ma
HADEAN			


Cladogram of the Vertebrates
Placodermi†
Chondrichtys
Acanthodii†
Actinopterygii
Sarcopterygii
tooth and fin alteration
improved head
more head alteration
lampreys
conodonts†
Pteraspidomor
Thelodonti†
Anapsida†
Galeaspida†
Pituriaspida†
Gnathostomata
hinged jaw

Gnathostome Synapomorphies

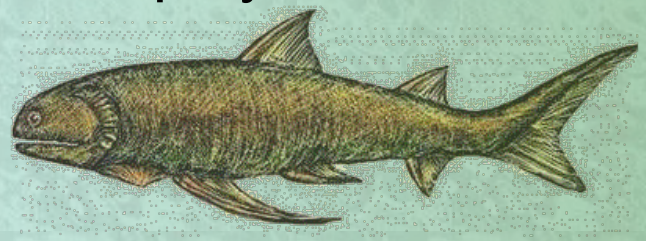


- **Pelvic fins**, the paired fins or limbs situated just in front of the anus
- **Interventrals and basiventrals in the backbone**. These are the elements of the backbone which lie under the notochord, and match the basidorsals and interdorsals respectively.
- **Horizontal, semicircular canal** in the inner ear

Gnathostome Taxa

Acanthodii†

Spiny fishes



Chondrichthys

Cartilaginous fishes

Placodermi†

Armored fishes

"Osteichthys"

Actinopterygii

Sarcopterygii

lobe-finned fish

tetrapods

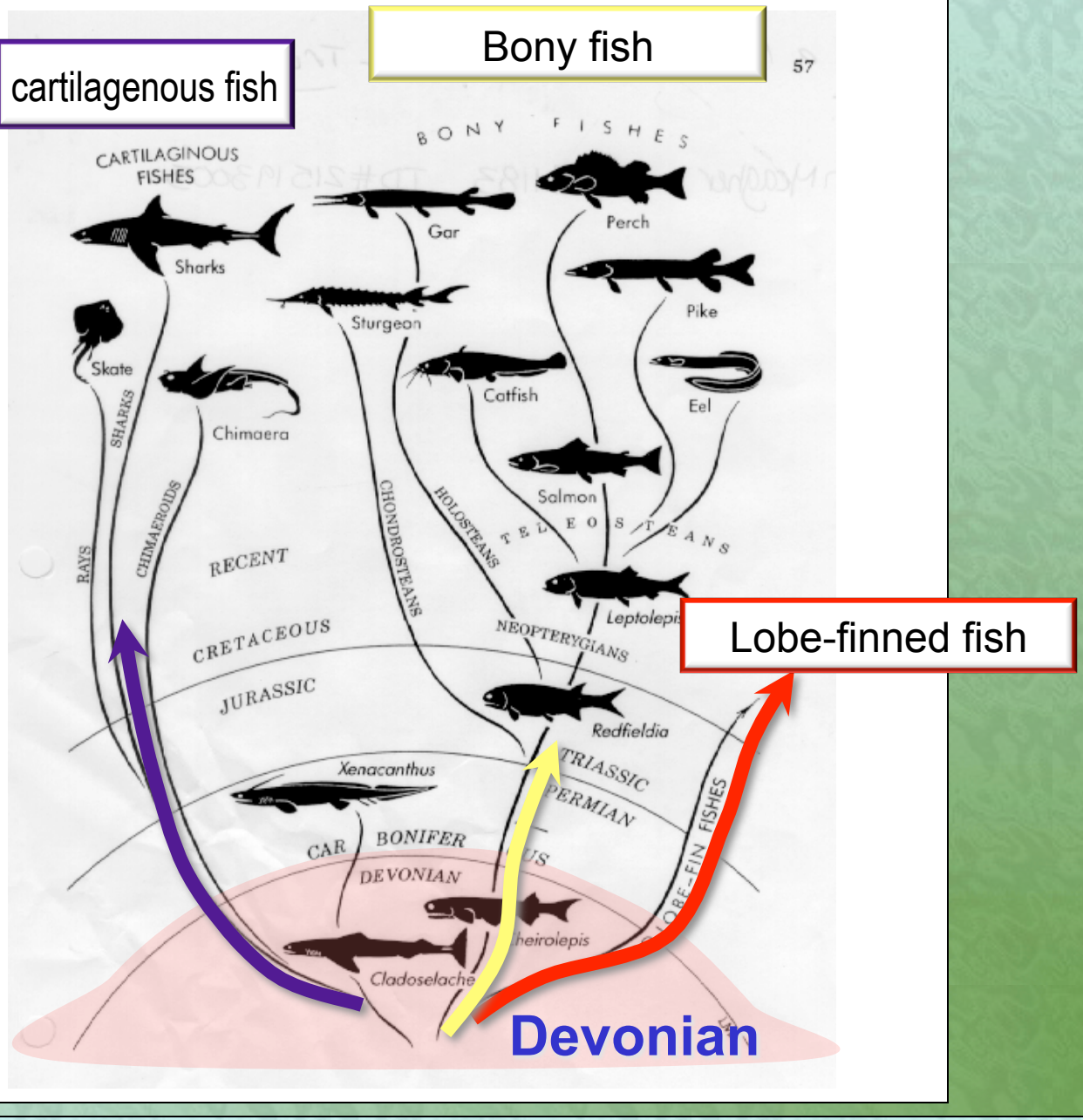
http://www.auburn.edu/academic/classes/zy/0301/Topic3b/acanthodian1.jpeg

Placodermi†

The most fea derm species to the left may top of the food chain.

There were many smaller species of placoderms as well, including some that lived in freshwater.

http://www.ucmp.berkeley.edu/vertebrates/basalfish/placodermi.html



http://www.biology.ucsc.edu/classes/bio137/thetree.GIF

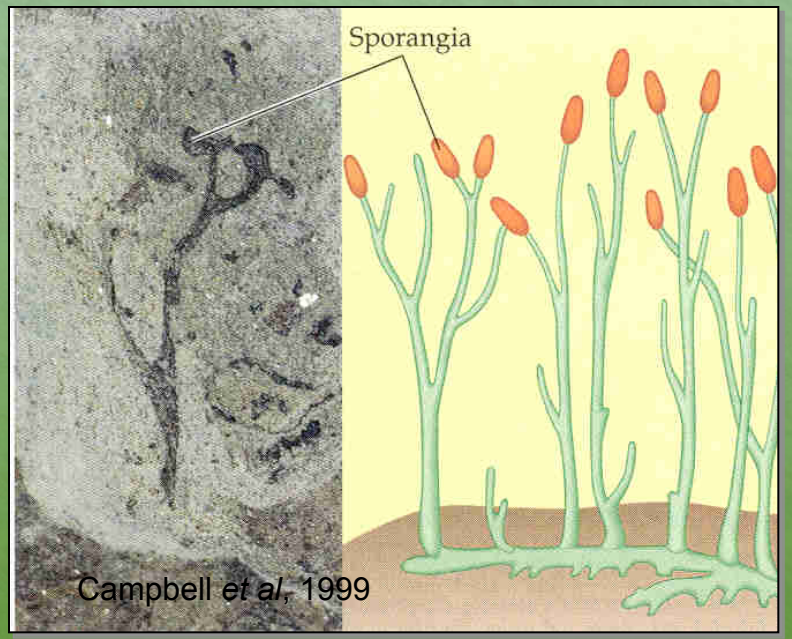
Land Plants

By the end of the Silurian, simple plants were well established on land.

This plant is one of the earliest - a simple branching plant called *Cooksonia*.

Eon	Era	Period	Age
PHANEROZOIC	CENOZOIC	Neogene	
		Paleogene	67 Ma
	MESOZOIC	Cretaceous	
		Jurassic	
		Triassic	270 Ma
	PALEOZOIC	Permian	
		Pennsylvanian	
		Mississippian	
		Devonian	
		Silurian	
		Ordovician	
		Cambrian	540 Ma
PROTEROZOIC			2,500 Ma
ARCHAEN			3,800 Ma
HADEAN			

http://www.eurypterids.net/



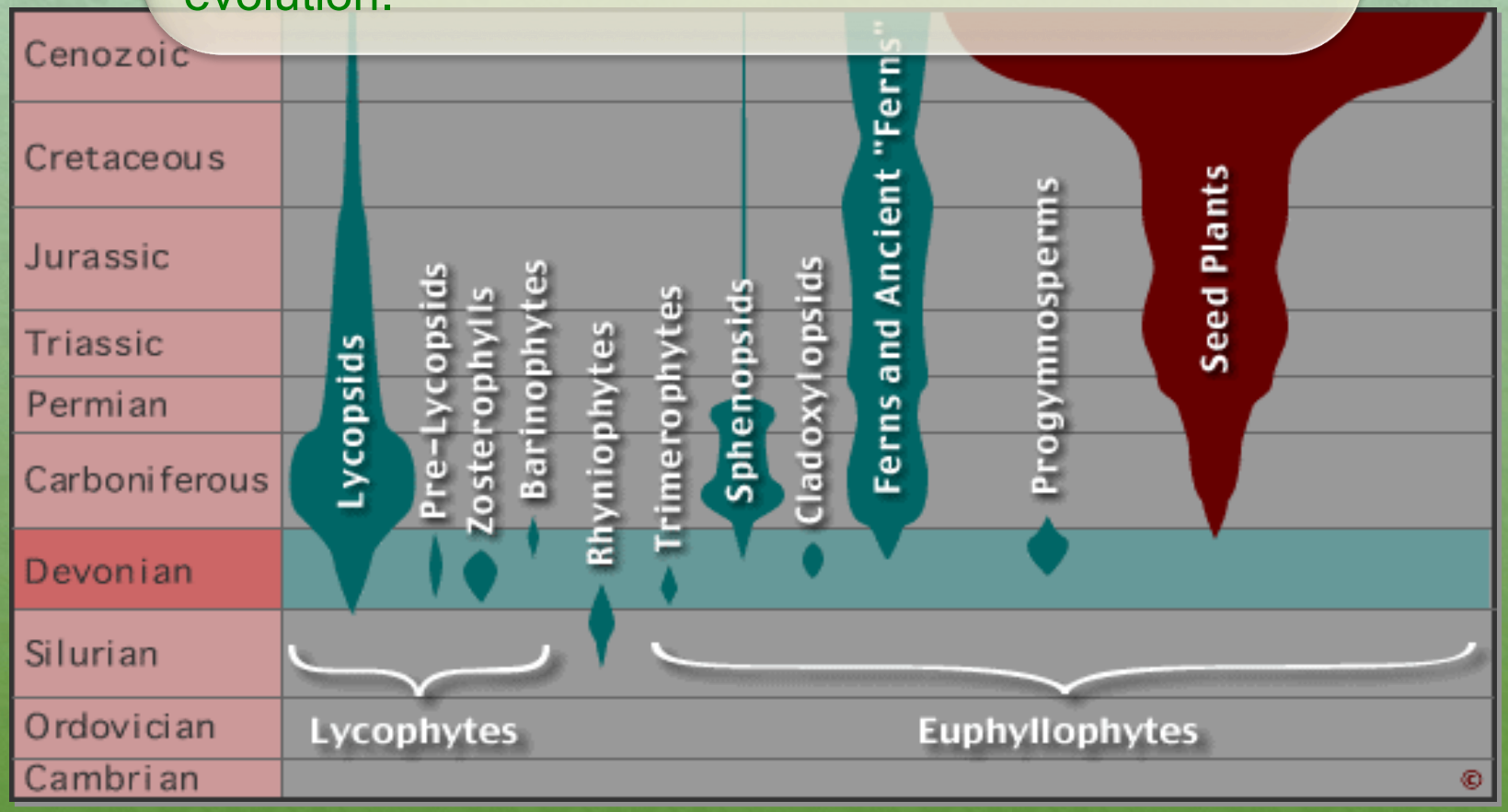
Campbell *et al*, 1999

http://www.earth.rochester.edu/ees201/Lippert/

Land Plants

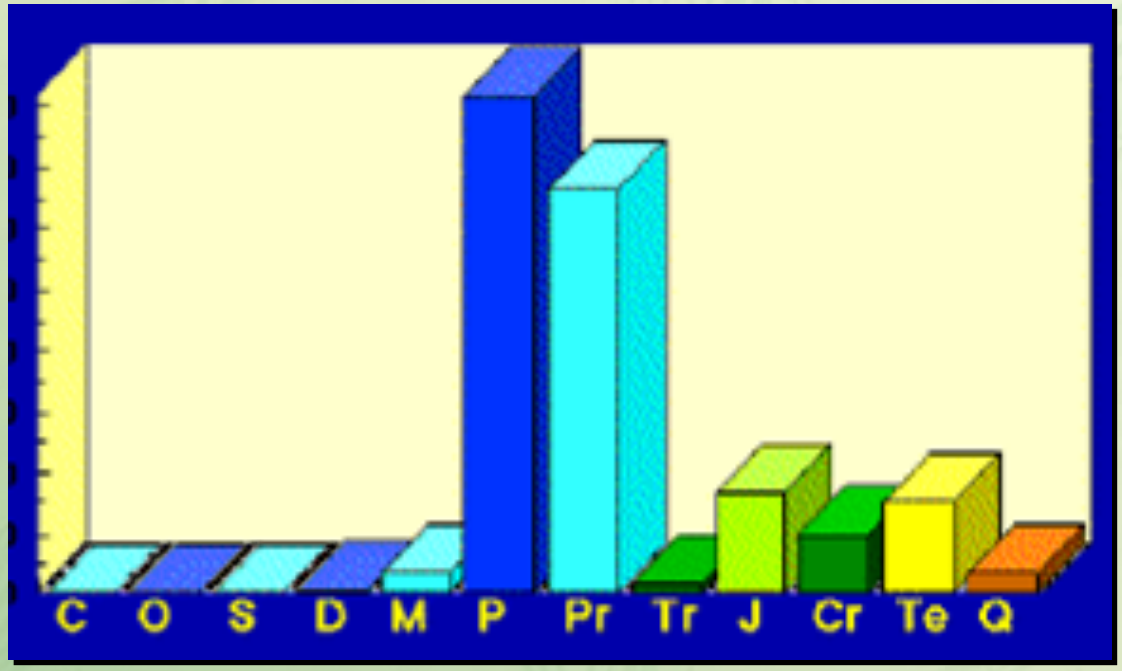
Starting in the late Devonian, plants with seeds diversified on land.

As with both vertebrates and invertebrates, the weird plant taxa petered out soon after their evolution.



http://www.mdgekko.com/devonian/who/pages/lyginopterids.html

Carboniferous - The Age of Coal



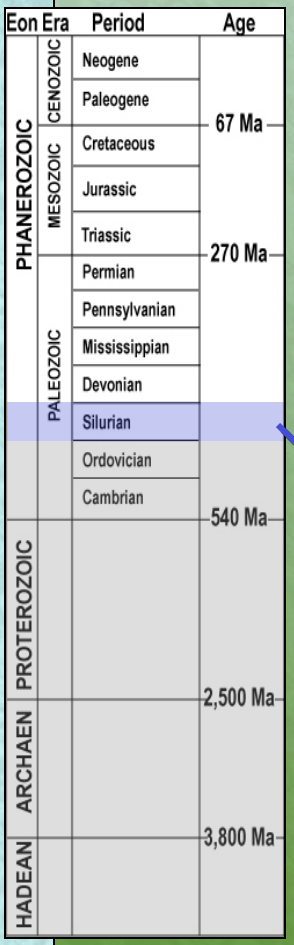
Most of Earth's economic reserves of coal were deposited in the Carboniferous and Permian Periods.

By dumb luck, most of these deposits are located in modern North America and Europe - a historical accident with obvious socio-economic consequences.

http://earthsci.org/energy/coal2/peat.gif

Land Insects

The massive diversification of insects in the late Paleozoic began with a rather inconspicuous little group of “bristletails” that came ashore during the Silurian.



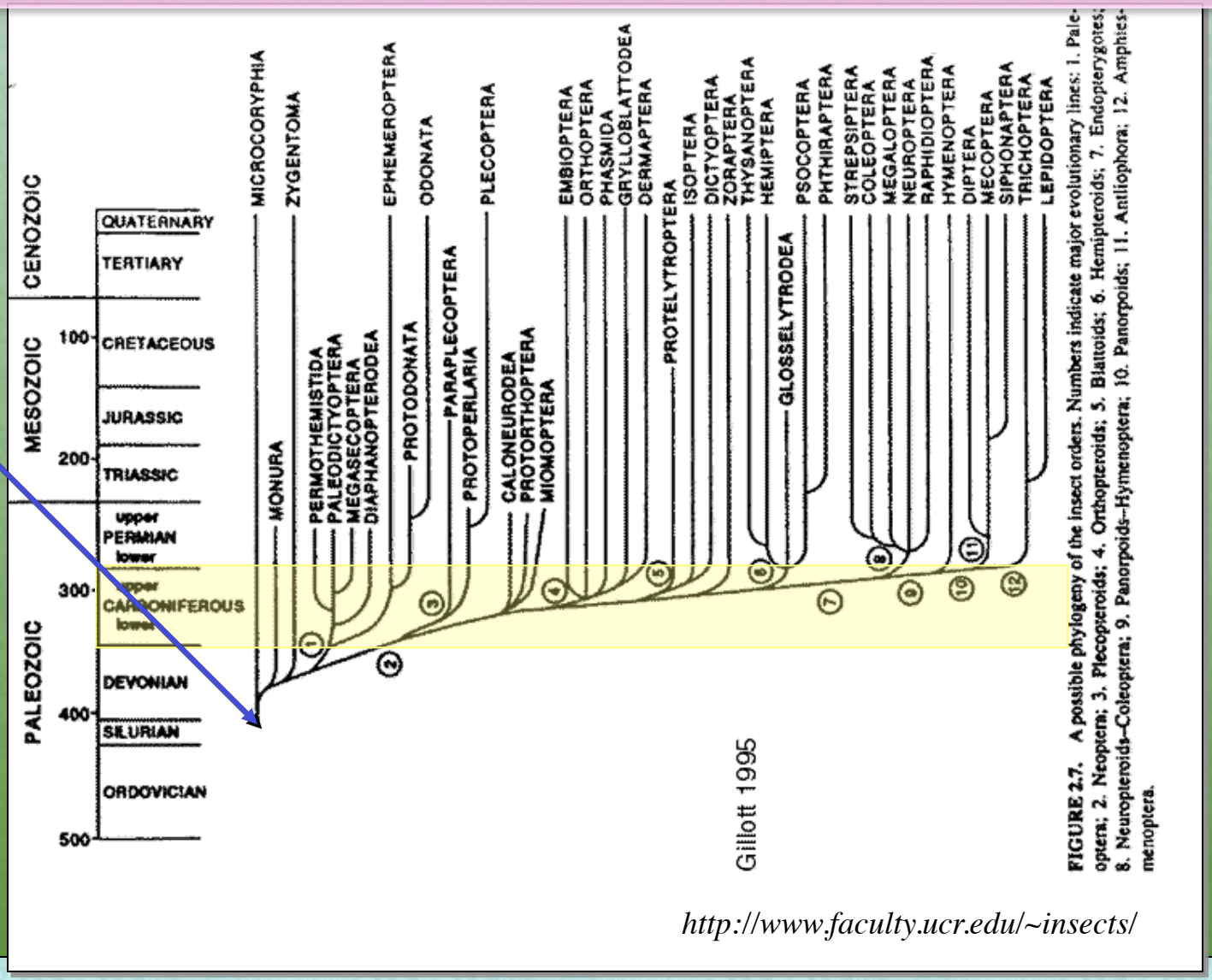
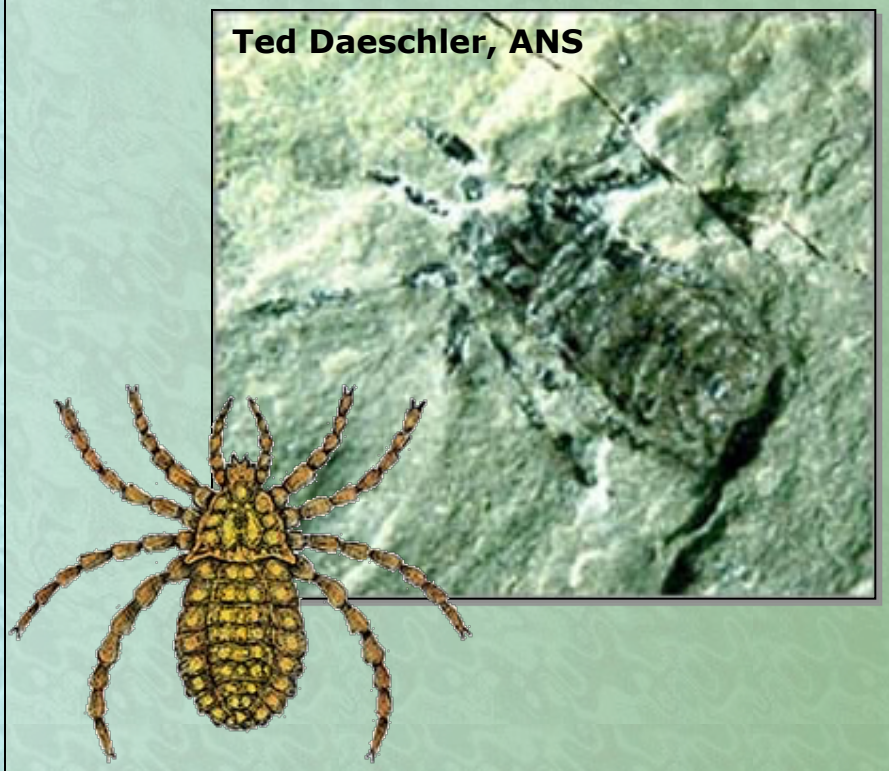


FIGURE 2.7. A possible phylogeny of the insect orders. Numbers indicate major evolutionary lines: 1. Paleoptera; 2. Neoptera; 3. Plecopteroids; 4. Orthopteroids; 5. Blattoids; 6. Hemipteroids; 7. Endopterygotes; 8. Neuropteroids–Coleoptera; 9. Panorpoids–Hymenoptera; 10. Panorpoids; 11. Antliophora; 12. Amphiesmenoptera.

http://www.faculty.ucr.edu/~insects/

Land Bugs

Insects and arachnids followed plants onto land, and were well established by the Devonian. Fish followed bugs into shallow water, and bugs featured prominently in vertebrate evolution as a rich food source from that time on.



Gigantocharinus

Devonian arachnid about the size of a small tick.

Early arachnids probably sucked the juices out of plants, developing predatory (spiders) and parasitic (mites and ticks) behaviors later.

http://www.mdgekko.com/devonian/who/pages/lyginopterids.html

Insect Life on Land

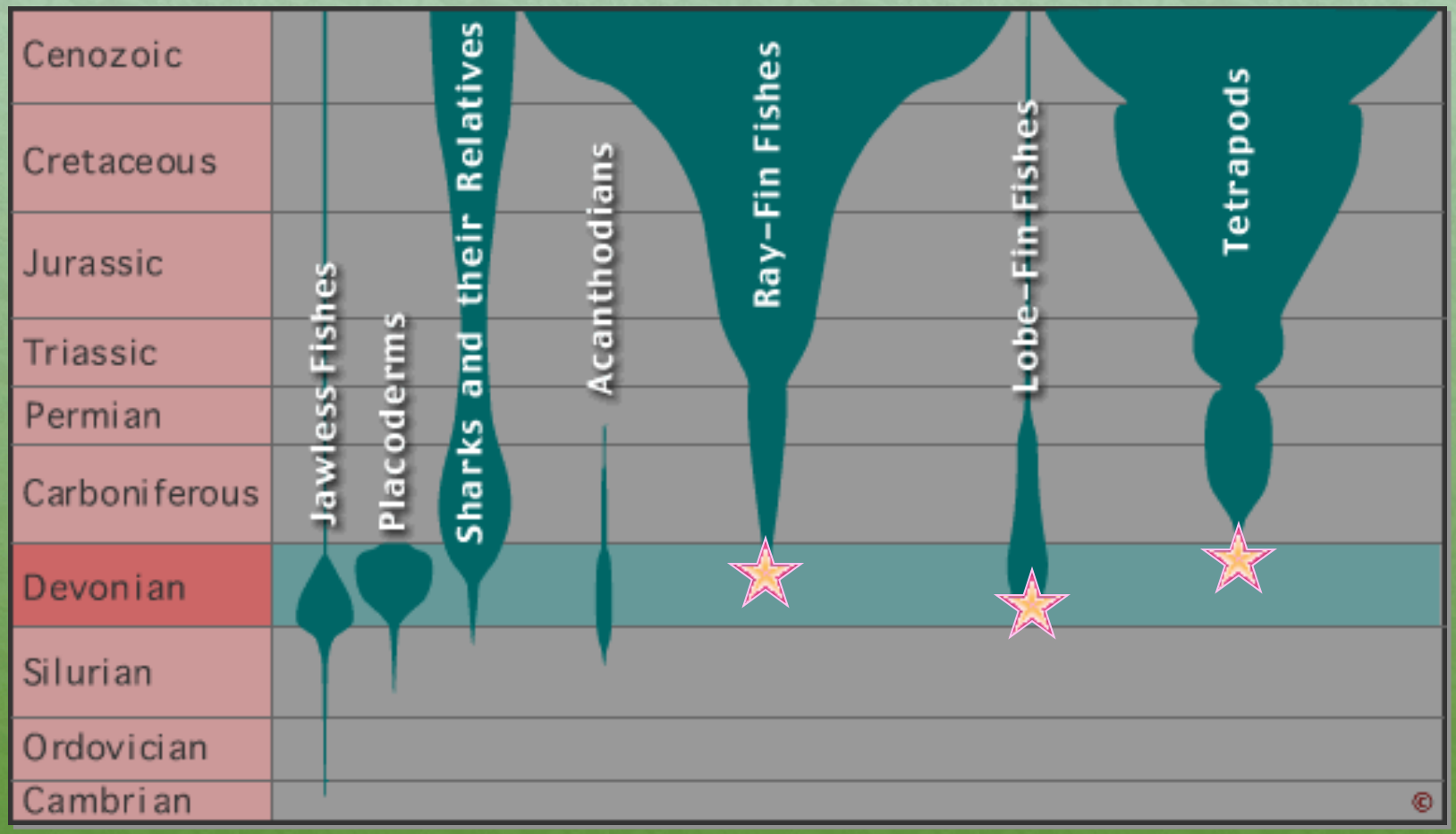
Respiration

Very large insects were found in Paleozoic forests, perhaps indicating unusually high levels of atmospheric oxygen, or perhaps not…

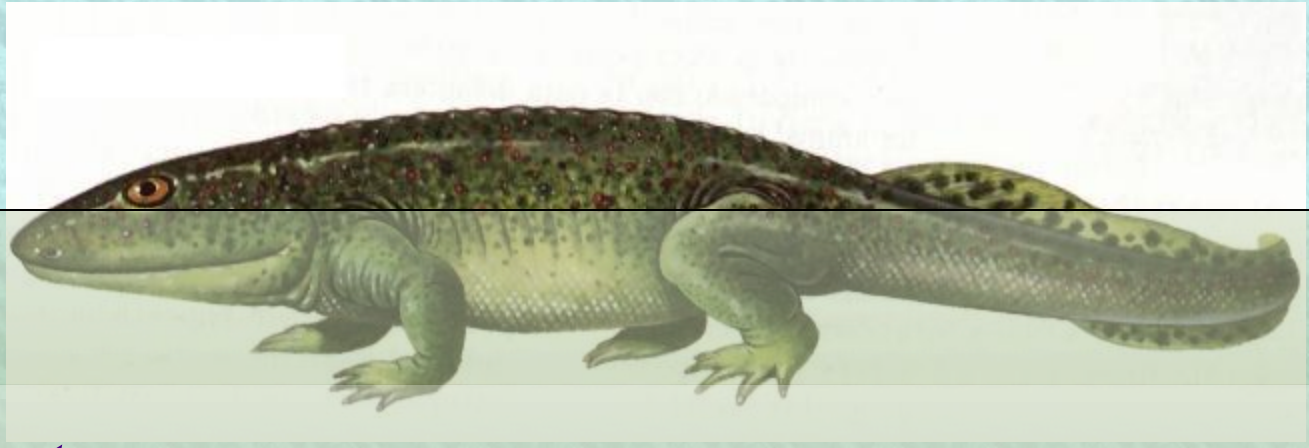
http://www.windsofkansas.com/lifesize.html

Vertebrates

Actinopterygians (ray-fin fishes) and lobe-fin fishes (and their sister group, the tetrapods) appear in the Devonian.



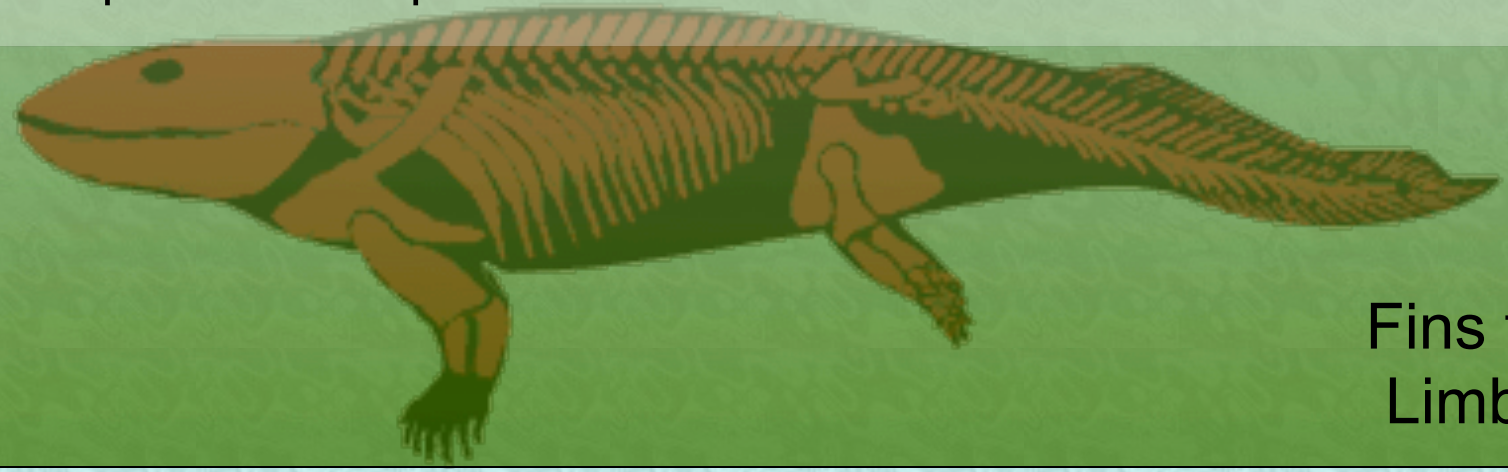
http://www.mdgekko.com/devonian/opportunity/opportunity.html



Ichtyostega

This genus is considered the first tetrapod, even though it probably did not walk (like the reconstruction above).

Some experts consider *Icthyostega* to be the first amphibians. Others believe it should still be classified with the lobe-fin fish. In other words, this is a perfect example of a transition animal.

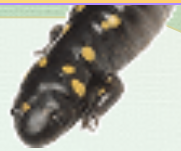


Fins to Limbs

http://www.geocities.com/torosaurio/crdebunk/Icthyostega.html

Tetrapods



Amniotes

There are four major groups of tetrapods:

- Amphibians (partial land-dwellers) - large, paraphyletic and probably polyphyletic group including modern and ancient forms.
- Diapsids - reptiles and birds
- Synapsids - mammals and mammal-like reptiles
- Anapsids - turtles and relatives

The aminiotes can be distinguished from each other by the structure of their skulls - particularly the number and placement of cranial openings behind the eyes.




Vertebrate Life on Land

Reproduction

Amphibians usually lay their eggs in water, and can have external fertilization of eggs. This dependence on water prevents most amphibians from ever being fully terrestrial.

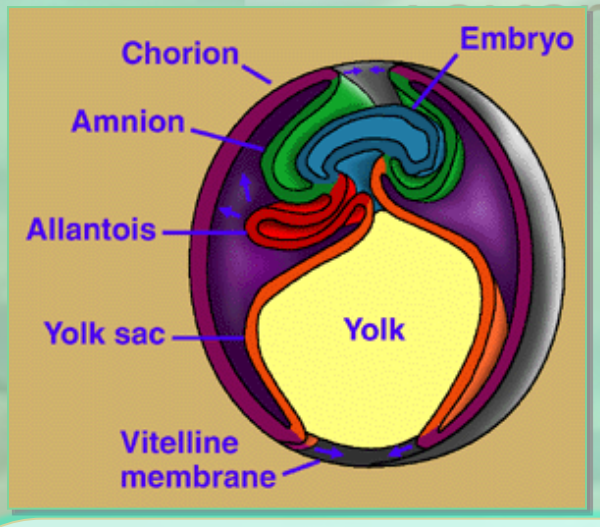
All other terrestrial vertebrates are called “amniotes” because they reproduce with internal fertilization producing a very special egg - the amniotic egg.

Amphibian eggs

Turtle eggs

http://sepwww.stanford.edu/sep/jon/family/aac/2002/amphib/ http://tolweb.org/ http://www.turtletimes.com/

Vertebrate Life on Land



The amniotic egg is a self-contained little life pod that supplies the developing embryo with nutrients and gasses while separating wastes and maintaining a fluid environment.

The egg contains regions and membranes specializing in various tasks, including the:

- Amnion - contains buffering amniotic fluid
- Allantois - controls gas exchange and removes waste from embryo
- Yolk sac - provides food for embryo
- Chorion - enclosing membrane controlling gas and fluid exchange with external environment

Egg-laying amniotes also enclose the egg in a leathery or hard shell.

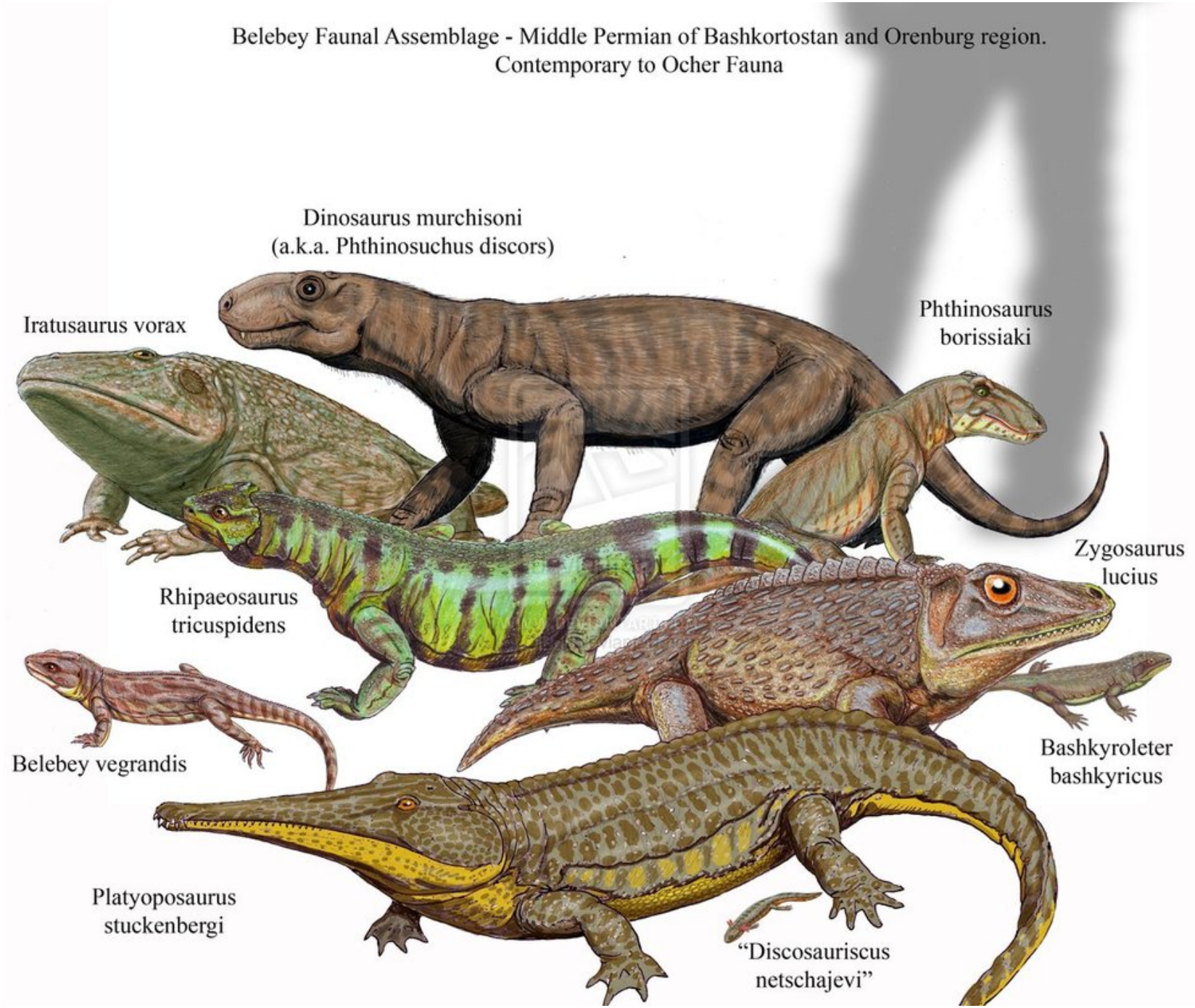
Diapsids

Hylonomus, a primitive reptile, leaps up for an insect in a coal forest in Nova Scotia during the Carboniferous, some 350 million years ago.

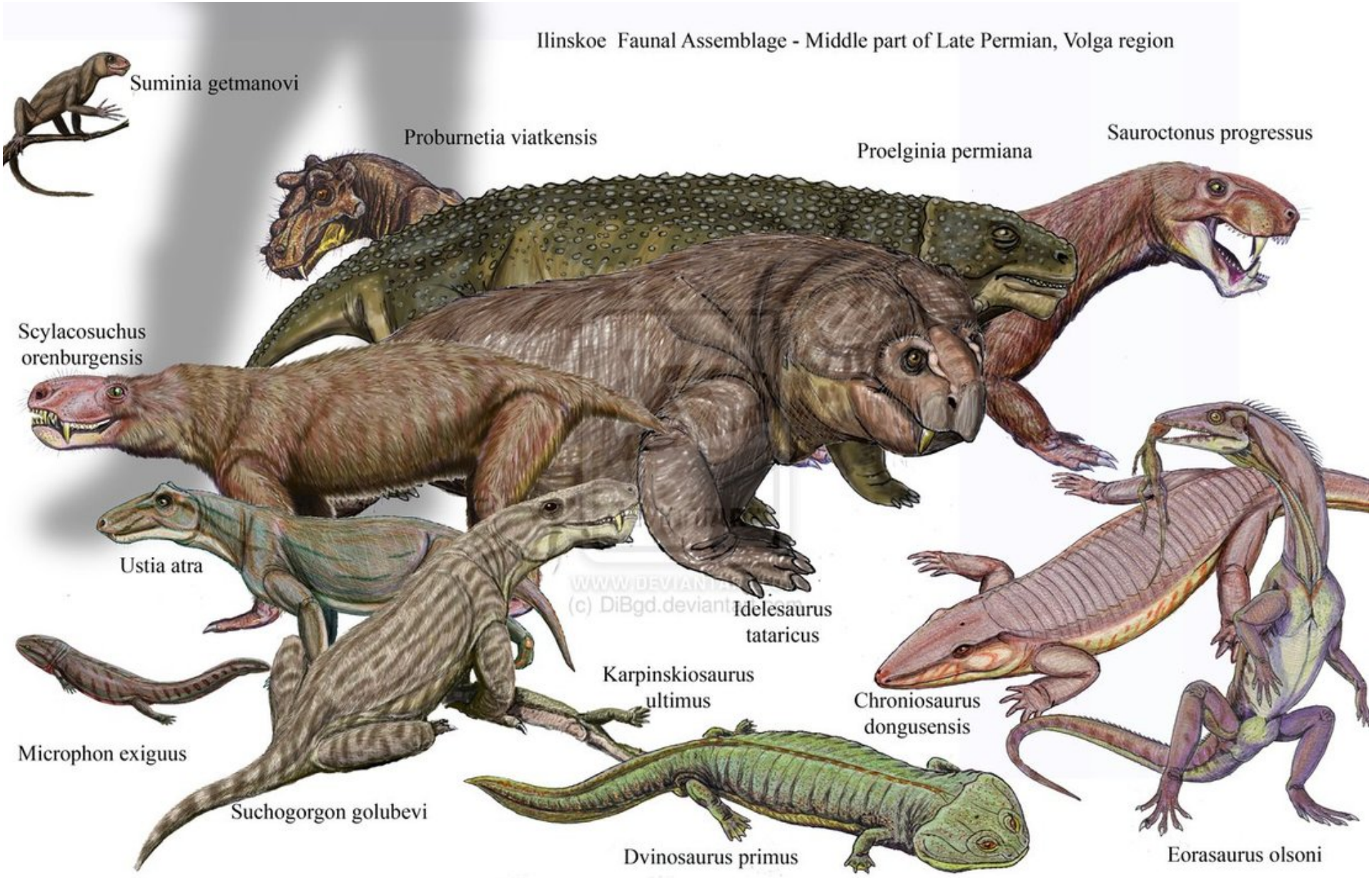
http://gallery.in-tch.com/~earthhistory/

Synapsids

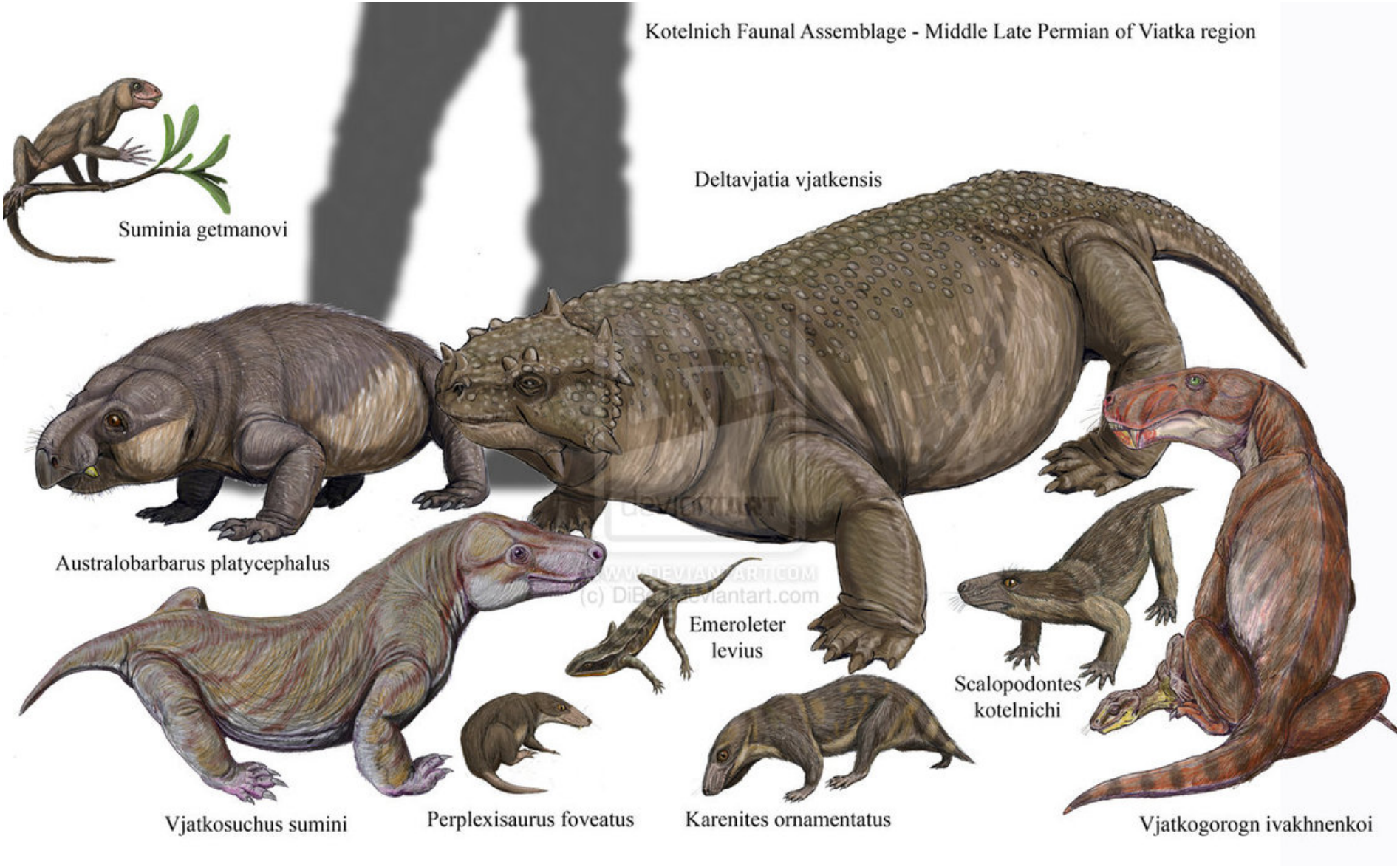
Synapsids - Mammals and their relatives, includes the first very large land animals to evolve on Earth.



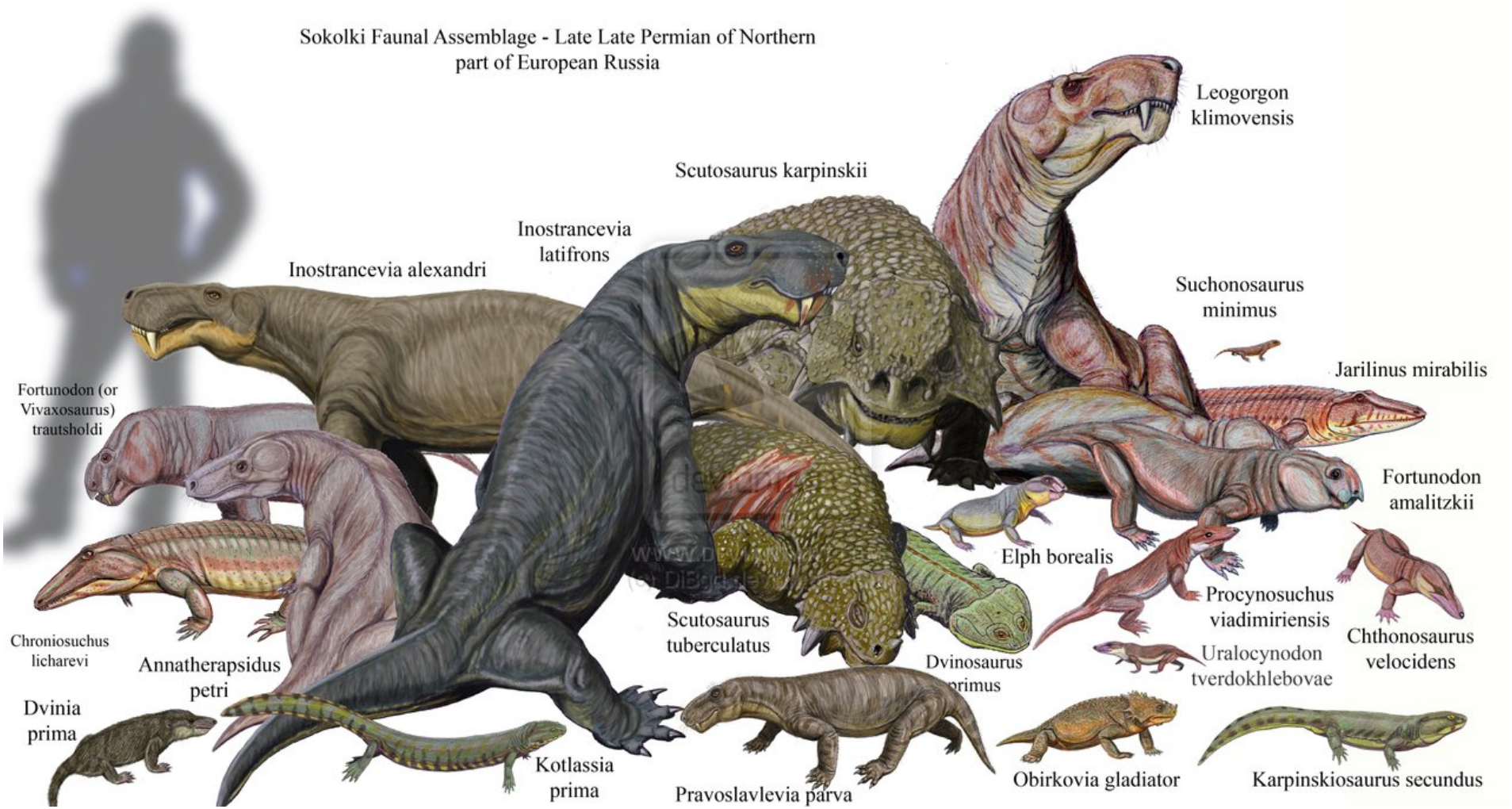
http://dibgd.deviantart.com/art/Belebey-faunal-Subassemblage-341983097



http://dibgd.deviantart.com/art/Ilinskoe-Faunal-Assemblage-350664662



http://www.deviantart.com/art/Kotel-nich-faunal-assemblage-340015179



http://dibgd.deviantart.com/art/Sokolki-Faunal-Assemblage-356905273