What Can Fossils Tell Us?

by

Der Proff

My Family Tree

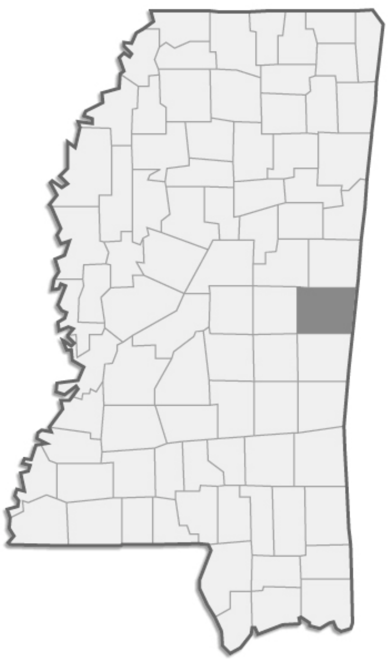
Calvin T. Rush — **Mary E. Fortner**

May Rush — **Charles B. Smith**

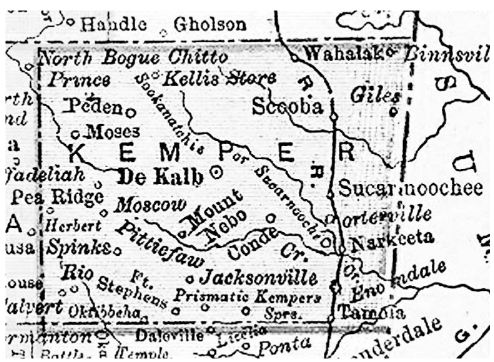
Howell Gwin — **Elizabeth Smith**

May Rush Gwin — **Roger Waggoner**

Ben Waggoner

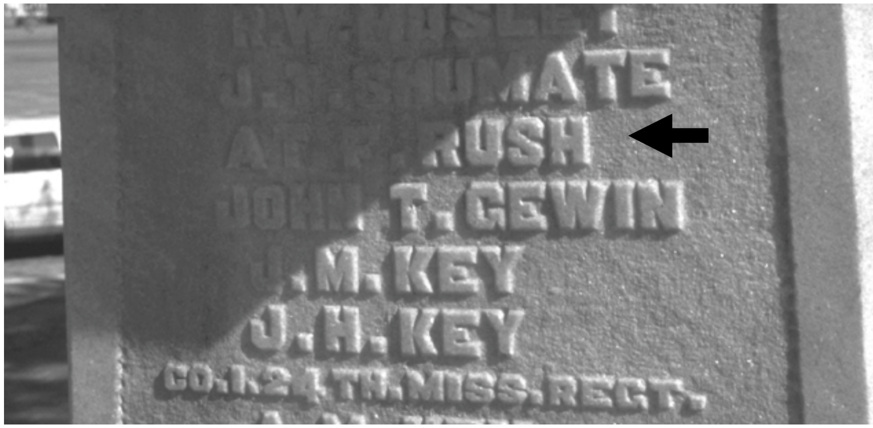


Kemper County, Mississippi

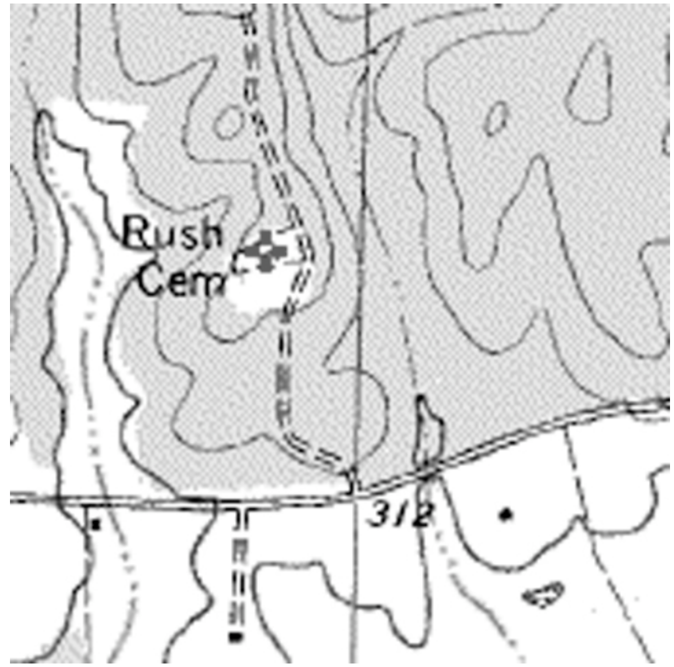


Kemper County
Civil War
Memorial

DeKalb, MS



Name “A.T. F. Rush” on Civil War Memorial
(Company I, 24th Mississippi Regiment)



Just about ten miles south of DeKalb, along a country road off State Hwy 39, is Rush Cemetery.

View of Rush Cemetery

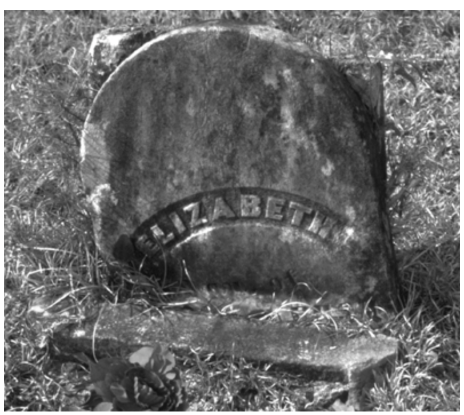
James Calvin
Rush
son of William C.
and Elizabeth S.
Rush

(1845-1862)

R. R. Rush
(1857-1935)

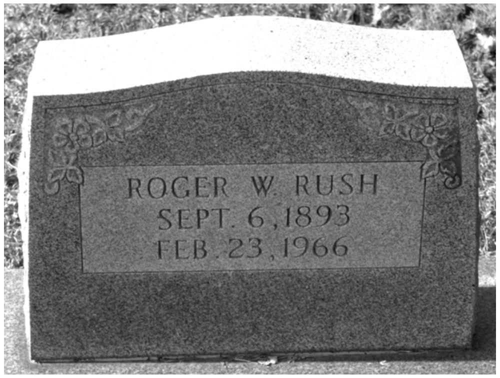
Patience Rush
"consort of
Benjamin T. Rush"
(1825-1874)

Some of the tombstones were broken or weathered—I can't tell who they are or when they lived. . .

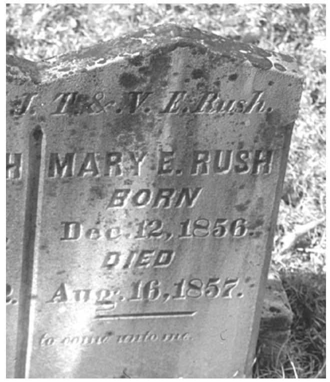


Others are missing information, such as birth and death dates. . . .

Others *can't* be my ancestors, because they died too young, or were born too late. . .



Roger W. Rush
(1893-1966)
younger than my great-grandmother

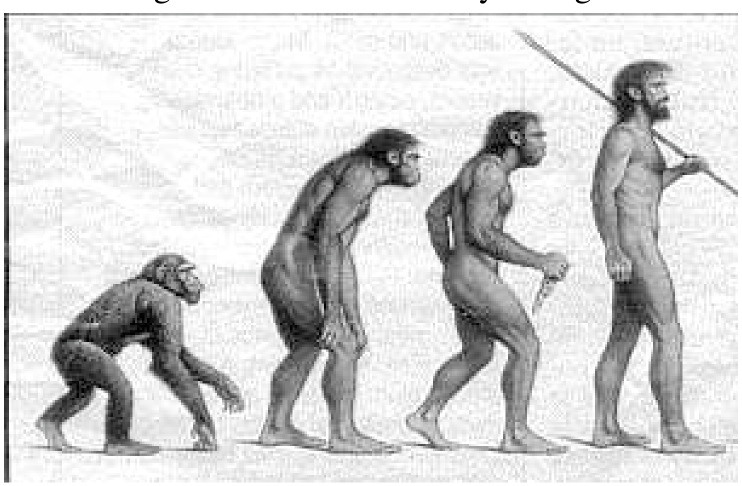


Mary E. Rush
(1856-1857)
died in infancy

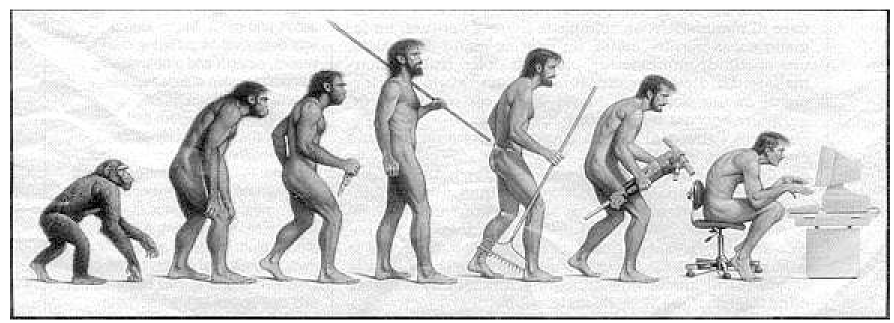
OK, so what?

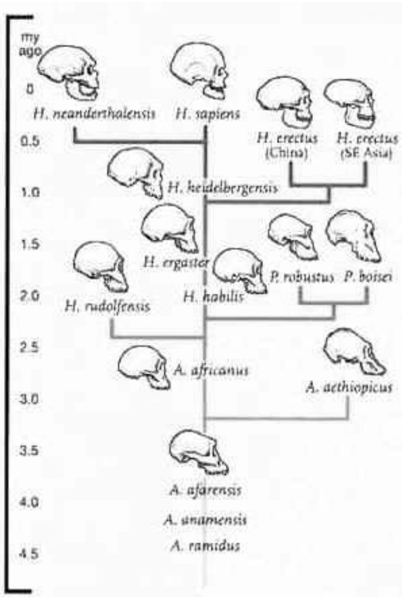
- Most of the Rush family members in Rush cemetery are *not* my ancestors—they'd be distant cousins, great-great-great uncles/aunts, etc.
- Human families don't form straight, continuous lines of descent. *They branch.*
- We see the same thing in looking at the fossil record. It *branches*.

This is why diagrams like the infamous "March of Progress" are fundamentally wrong. . .



. . . although I admit they can be rather droll. . .



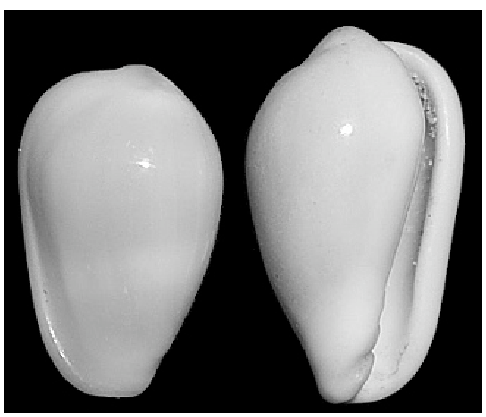


Diagrams like this one do a better job of conveying how evolution works. Note that most of the species shown are *not* directly ancestral to our own species (top center).

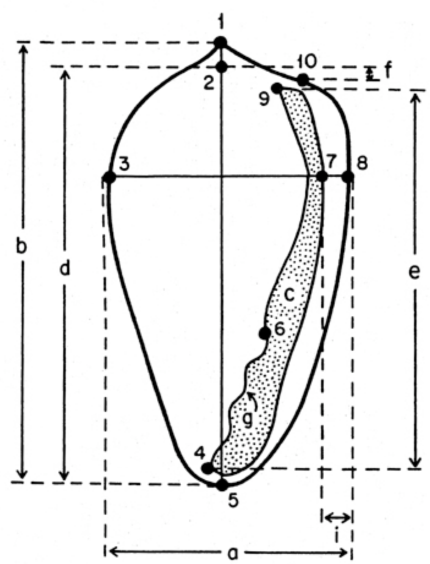
"Punk Eek"

- How fast do new species form?
  - In the 1970s, Stephen Jay Gould and Niles Eldridge devised a theory called "punctuated equilibrium" (or "punk eek", if you want to be informal)
  - This is a theory about the *rate* of species formation—Gould and Eldredge argued that new species come into existence relatively quickly
  - Usually you would not expect to see direct fossil evidence for one species changing into another. . .

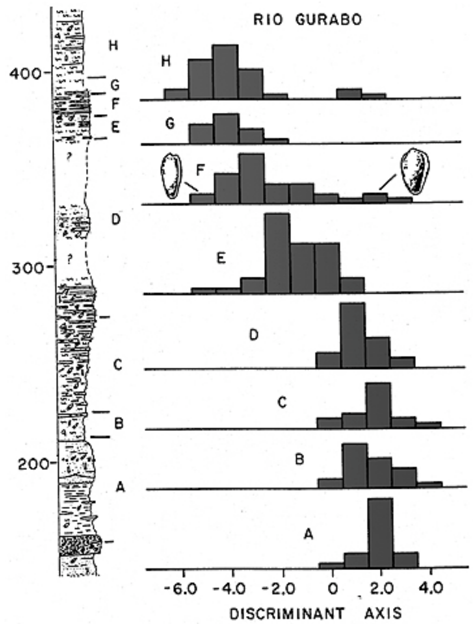
But sometimes you can document a species transition! A former fellow grad student, Ross Nehm, demonstrated one in marine snails known as marginellids.



A living marginellid species, *Prunum carneum*

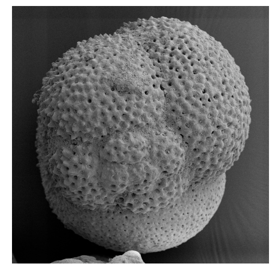


Nehm made a number of measurements on many fossil marginellid shells from Costa Rica, and combined the measurements into a single number per shell that expressed most of the variation in his samples (a technique called *principal components analysis*).



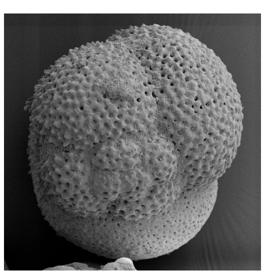
And here's what the variation over time looks like in a series of samples of fossils (graphed as a stack of histograms). At the bottom: a broad species called *Prunum coniforme*. At the top: a slender species called *Prunum christineladdae*. In between, a gradual transformation.

Foraminifera

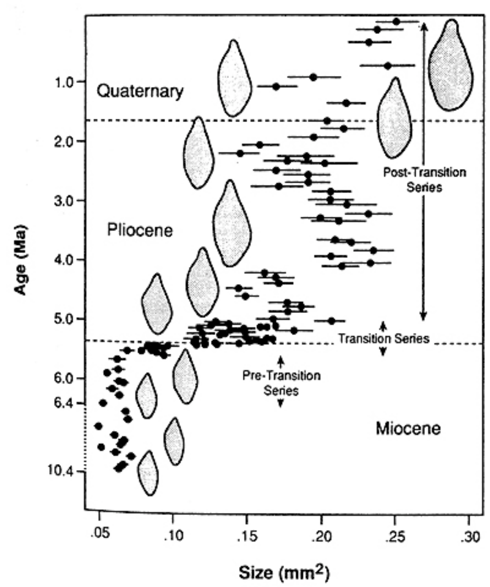


- Planktonic or benthic marine protists
- Amoeba-like bodies
- Secrete a *test*—a shell-like covering, typically calcareous (chalky) or agglutinated (made of small sediment grains glued together)
- Test perforated with tiny holes, or *foramina*

Why Foraminifera?



- Forams are extremely abundant in oceans
- Pelagic (floating) forams die and constantly sink to the bottom, creating thick layers of "foram ooze" in some regions
- Drilling samples of deep-sea sediments lets us trace evolutionary changes in very fine detail

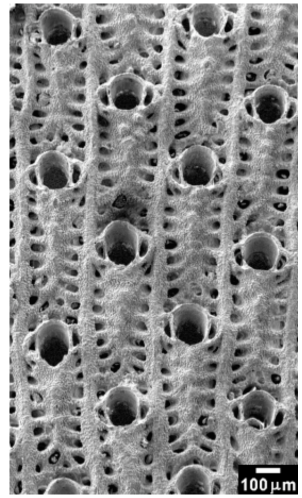


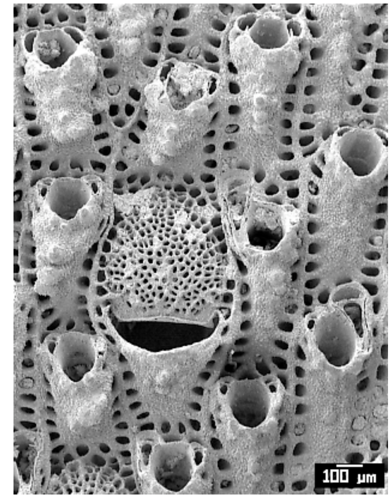
The transition from the foram species *Globorotalia plesiotumida* (bottom) to *Globorotalia tumida* (top) involved a "sudden", but still continuous, increase in size between about 5.5 and 6.0 million years ago. (Graph shows size ranges and mean sizes of samples.)

Resolution?

- From the point of view of a paleontologist, 10,000 - 100,000 years is a brief instant
  - The transition from one species to the next is often so "fast" that it can't be seen clearly in the fossil record
- From the point of view of a worker on modern organisms, 10,000 - 100,000 years is unbelievably long
  - Whether a pattern looks "gradual" or "punctuated" may well depend on the observer's choice of timescale

This may be seen in Alan Cheetham's very well-documented study of an organism called *Metrarabdotos*, a *bryozoan* (colonial "moss animal")





Fossil species of *Metrarabdotos*, sampled from Central America, show a punctuated evolutionary pattern.

EOLSS - PATTERNS AND RATES OF SPECIES EVOLUTION

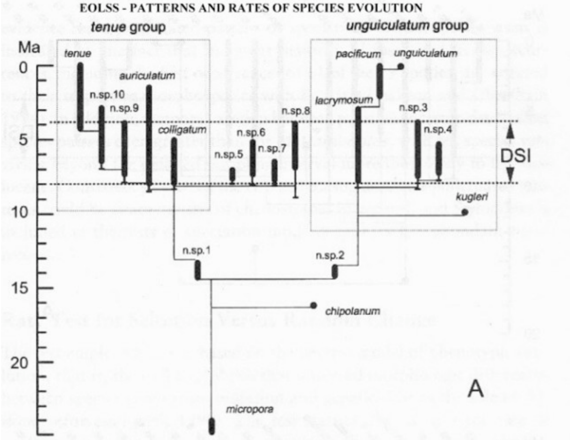
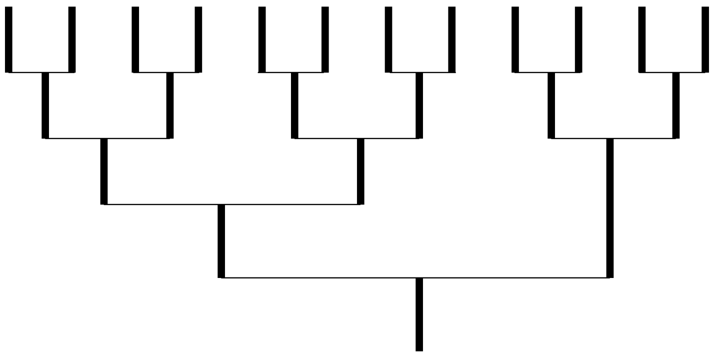


Fig. 6. Punctuational speciation in the bryozoan Metrarabdotos. The fossils show that Metrarabdotos radiated dramatically between 8 and 4 million years ago, and several species arose apparently rapidly, within the Dominican Sampling Interval (DSI), a particularly well sampled sequence. Based on the work of Cheetham and Jackson.

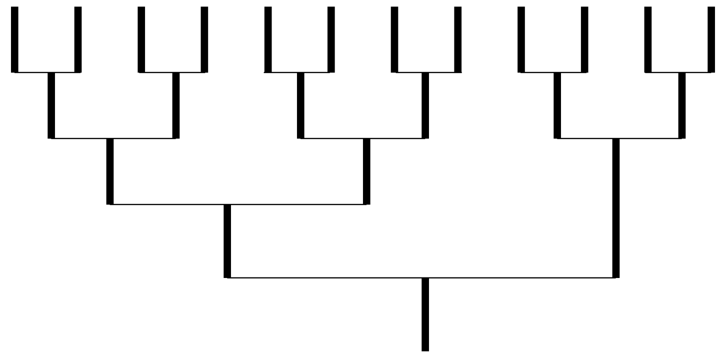
Missing links?

- "Punk eek" is often taken by creationists as an admission that the fossil record provides no evidence for evolutionary transitions.
  - HOWEVER: "punk eek" is a statement about *speciation* as seen (or not seen) in the fossil record
  - Transitions between species may be rare, but transitions between larger groups are well documented.

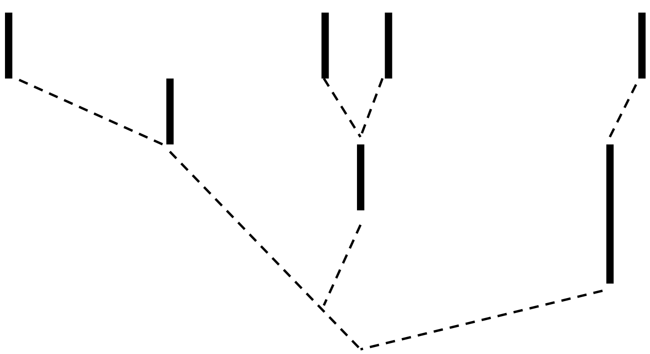
Take this sample "family tree" of a group of organisms. . .



Unless you're very lucky, most of these won't fossilize, or won't be found as fossils yet. If we only have, say, seven of these species, then the tree might look like this:



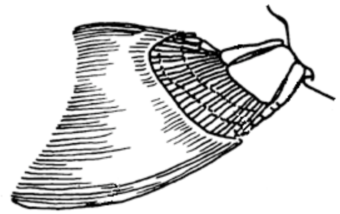
Yet we could still identify some larger-scale lineages within the group, even if most of the links are missing!



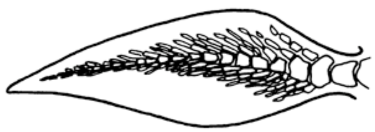
What are Sarcopterygii?

- Bony vertebrates are divided into two major groups: *Actinopterygii* (ray-finned fish) and *Sarcopterygii* (lobe-finned fish and descendants)
- Sarcopterygii have the following features:
  - fleshy lobe supports fin
  - single series of bones supports fin (*monaxial support*)
  - skull is never as kinetic as in ray-finned fish (i.e. the skull bones have many fewer joints and ranges of movement)

Monaxial fins. . .

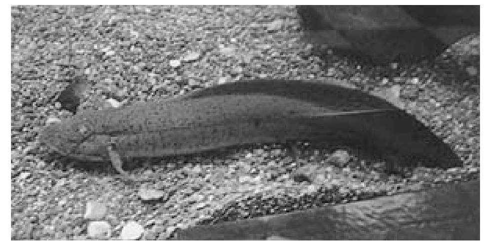


Compare this shark fin, with three supports attached to the limb girdle (*tribasic* fin). . .



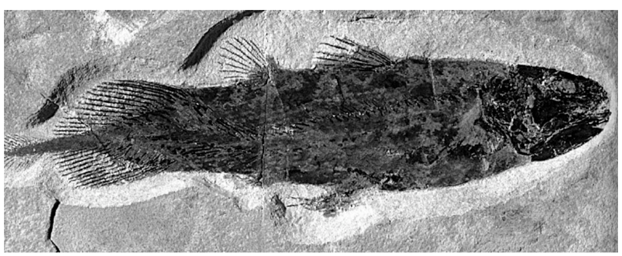
. . . with this lungfish fin, which is attached to the limb girdle and supported along its length by a single row of bones.

A typical *actinopterygian*: the squirrelfish



A *sarcopterygian:* the South American lungfish

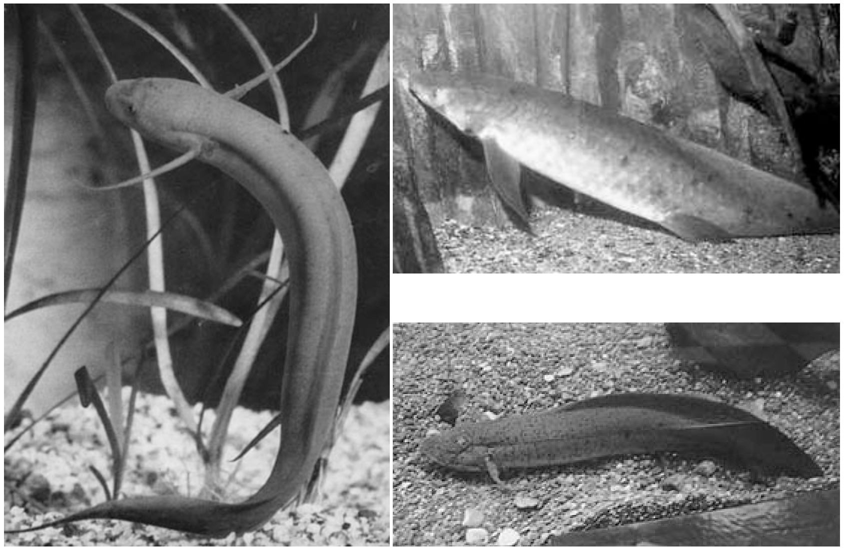
Sarcopterygians include lungfish and coelacanths, both with long fossil records. . .



Caridosuctor, a coelacanth. 320 million years old; Bear Gulch, MT

Scaumenacia, a lungfish. 370 million years old; Escuminac Bay, Québec

And a live coelacanth—posing with the wife of a dude that your prof went to grad school with.

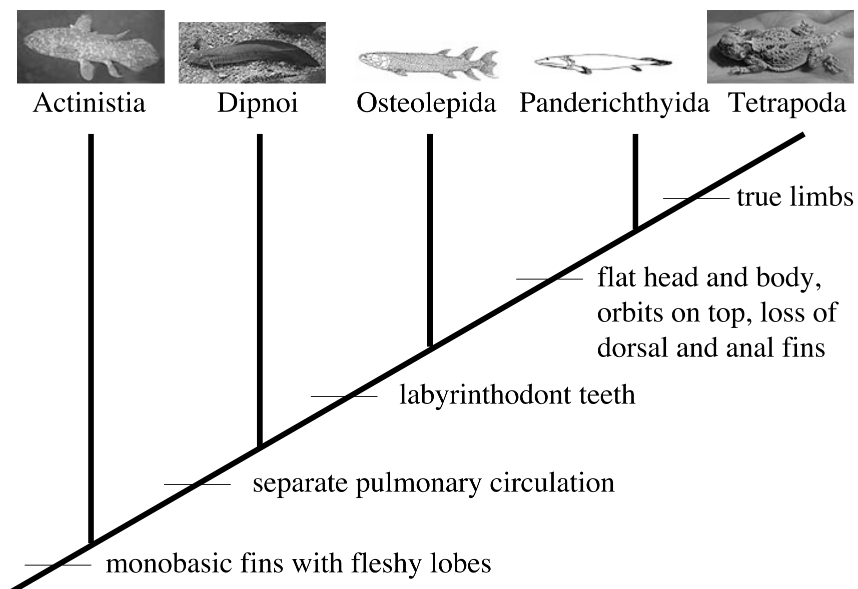


Living lungfishes

(Left: African. Upper right: Australian. Lower right: South American.)

Now what?

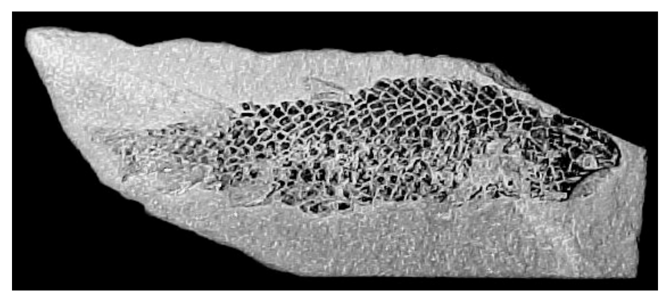
- Starting about 390 million years ago, a lineage of lobefins (that was neither coelacanth nor lungfish) began changing in ways that would later prove useful on land:
  - development of free digits
  - increased mobility of limb joints
  - pelvic girdle attaching to spinal column
  - pectoral girdle becoming free from its attachment to the skull
  - vertebrae develop stronger interlinkages (*zygapophyses*)

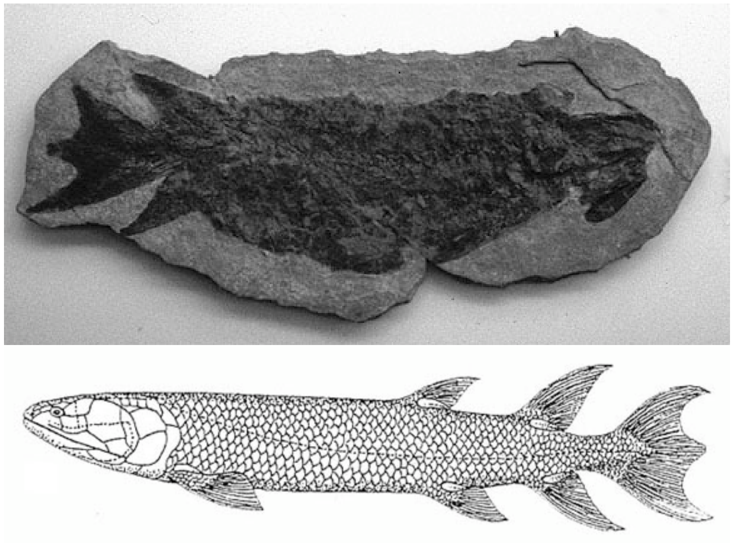


Cladogram (somewhat simplified) of the Sarcopterygii

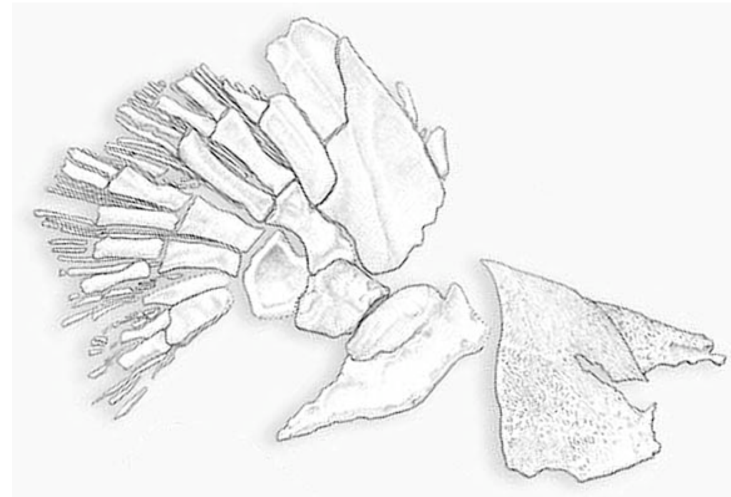
Osteolepiformes

- Extinct group of lobe-finned fish
  - *Labyrinthodont* teeth — teeth in cross-section show complex infoldings
  - No postaxial bones in the lobe fin





Eusthenopteron: fossil and reconstruction (Devonian; Quebec)

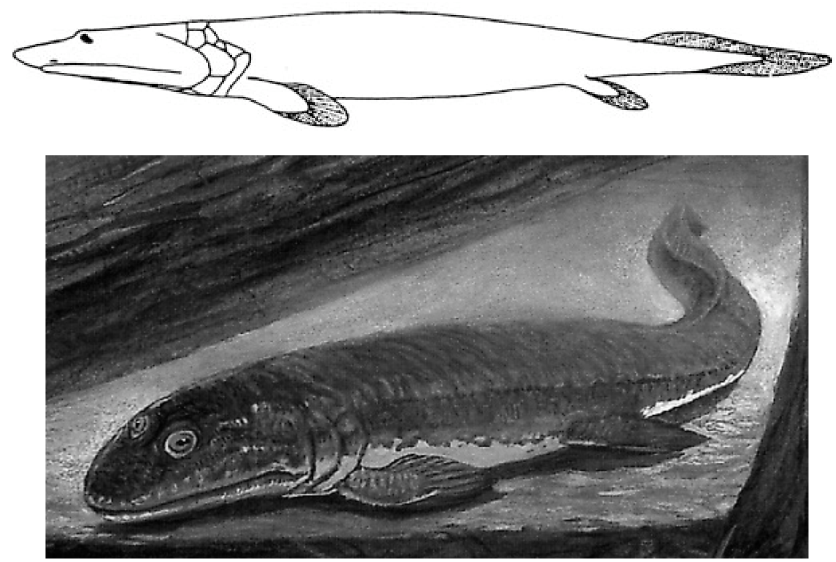


Pectoral fin of the 380 million-year-old fish *Sauripterus*

Panderichthyids

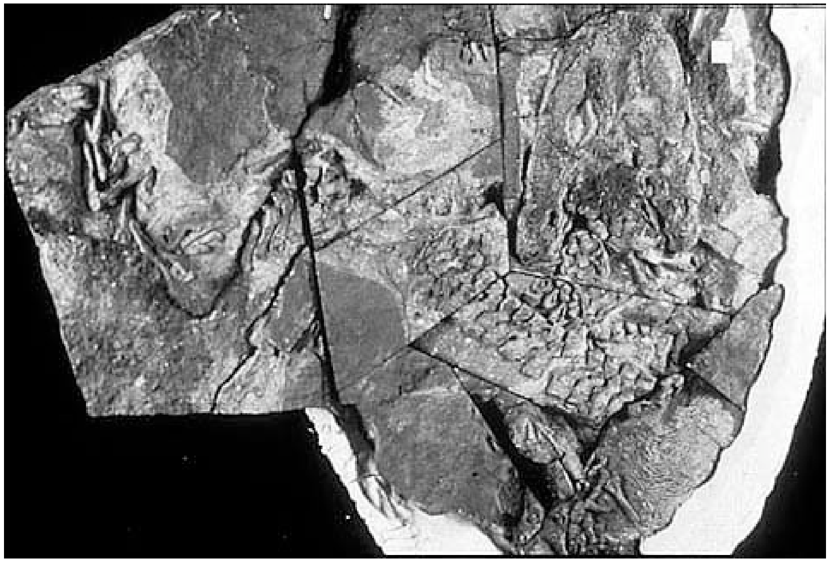
- Extinct group of lobe-finned fish; most are known only from fragments, but a few are known as complete specimens
- Even more tetrapod-like characters:
  - flattened skull with snout
  - eyes on top of head
  - no dorsal fin or anal fin
  - reduced tail fin

Panderichthys: two reconstructions

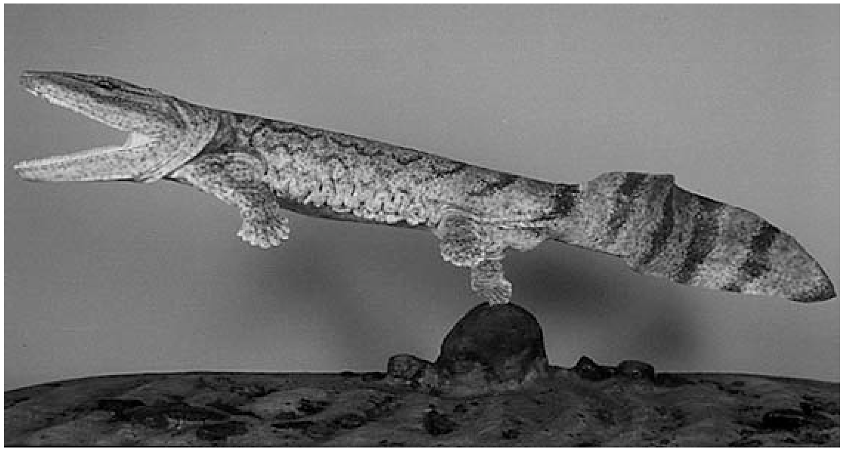


Acanthostega

- First complete tetrapod with free digits
  - Eight digits on each hand
- Retained "fishy" characters:
  - gills
  - tail fin
  - partial connection between skull and pectoral girdle
  - lateral line
  - ulna shorter than radius
- 380 million years old; found in Greenland

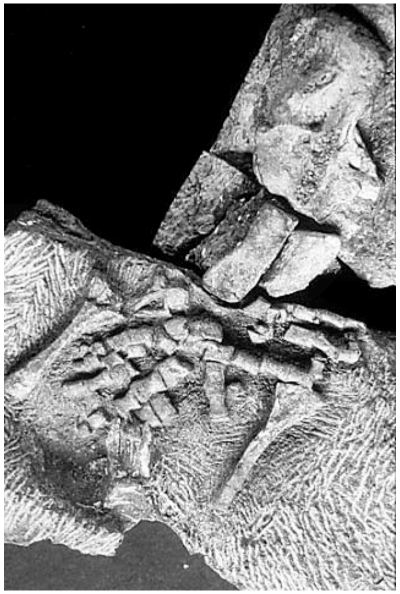


Acanthostega: fossil. . .



. . . and reconstruction

The limbs were probably not strong enough to support *Acanthostega* on land!

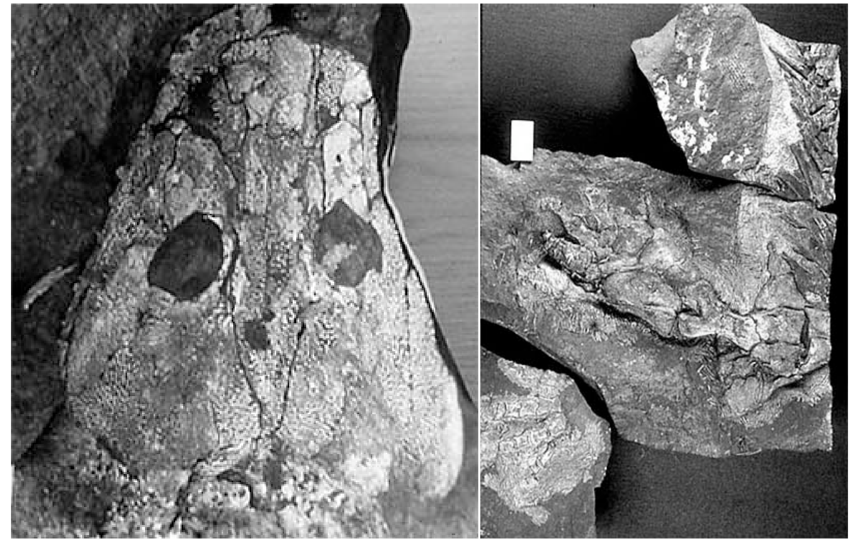


Left forelimb of *Acanthostega*

Images plagiarized from the excellent Tree of Life Website. . .

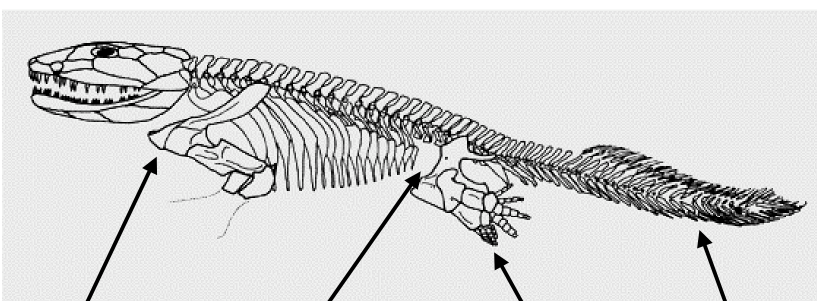
Ichthyostega

- Much like *Acanthostega*, but. . .
  - stronger limbs; radius and ulna of equal length
  - no gills in adult
  - reduced number of skull bones
- Still retains panderichthyid-like skull, tail fin, labyrinthodont teeth, lateral line
- First tetrapod known that was capable of life on land



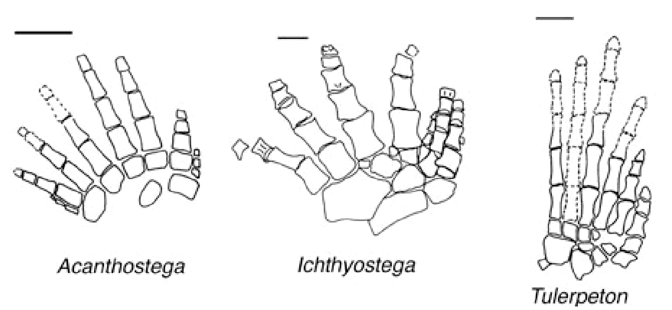
skull hind limb

Ichthyostega: fossils. . .

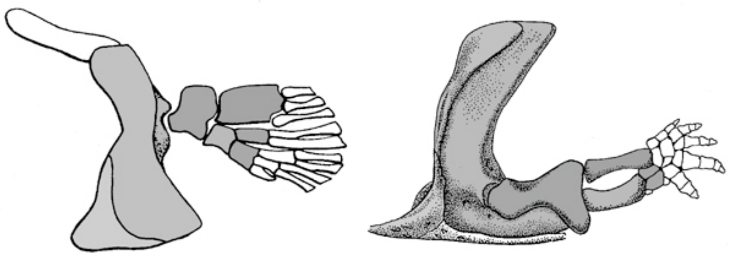


. . . and reconstruction.

Hands of *Acanthostega*, *Ichthyostega*, and a less complete relative called *Tulerpeton*. . .



Left: fin skeleton of a fossil lobefinned fish.
Right: arm bones of an early land vertebrate.



humerus (forearm)
radius (arm)
ulna (arm)
carpals (wrist)

scapula (shoulder)
cleithrum
clavicle

Why???

- "Old Story"
  - Lobe-finned fish were living in habitats that dried up, and / or that ran low on food.
  - Those that survived were the ones that could crawl to new ponds. This created selective pressure for the development of sturdy limbs.
  - Certain living fish do this (e.g. "walking catfish")—they're not closely related to land vertebrates, but at least may be analogues. . .

An Asian "walking catfish" is able to travel to a new pond, if its old one either dries up or runs out of food. . .

The "Old Story" (as drawn by cartoonist Larry Gonick)

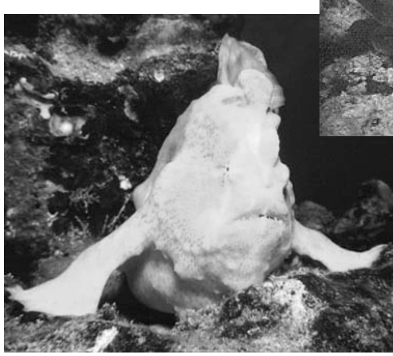
Problems with the “Old Story”

- Living Australian lungfish do live in habitats that dry up, but they don’t crawl out. Instead, they burrow into the mud and *estivate* (enter a state of “suspended animation”).
- *Acanthostega* probably never left the water anyway, but it had fully formed limbs.
- A fish that can crawl back to a pond has enabled itself to remain a fish—why would such an animal evolve into a land-dweller?

The “New Story”

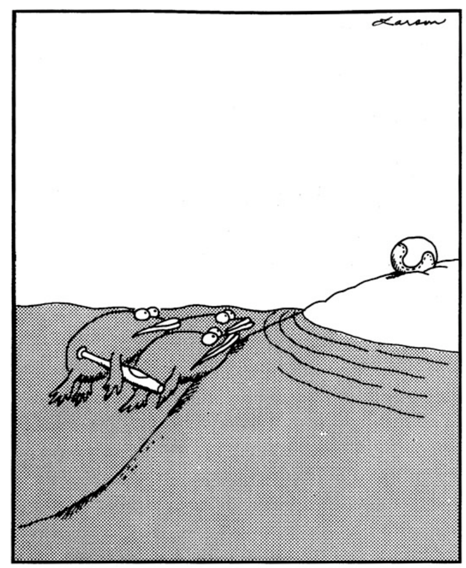
- *Acanthostega* and others had fully formed limbs, but probably never left the water.
- Limbs were useful “after the fact” for moving on land, but they originally had a different function.
- “Fish with legs” may have used their limbs for pushing off the bottom of the lakes they lived in. Certain living fish do this today.

“Galloping frogfish”: a living analogue for the “New Story”



Frogfish use their modified pectoral fins to prop themselves up and push themselves around on the bottom. Frogfish can even “gallop” in short bursts (like the fish above is doing).

But then again, maybe this was the reason.



Great moments in evolution