A Brief History of Slime: 550 Million Years of Mollusks

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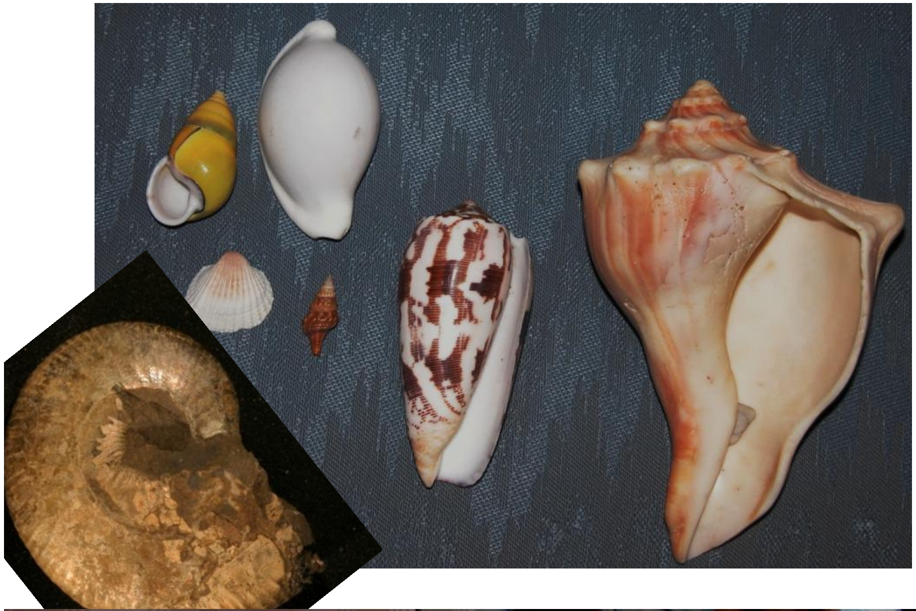
What is a mollusk?

- Snails, slugs, clams, octopi, squid, *etc.*
- Common characteristics
  - Soft body (*mollis*)
  - Shell
  - Muscular foot
  - Radula-usually ribbon-like, toothed feeding structure
- *Physella acuta* foot and radula in action

Why care about mollusks?

- Minimal direct Biblical mention, but products (pearls, purple dye) important
- Other human importance-food, ornament, food chain, water filtering, environmental structure, parasites, *etc.*
- High level of conservation concern; high risk from global warming and acidification
- Very diverse in numbers, form, and behavior
- As God made a lot of them, they're worth understanding and protecting.



Tennessee had the second highest freshwater mollusk diversity in the world (after Alabama)

> 115 mussel species

~ 100 freshwater snails

Diverse temperate landsnail fauna.

State fossil is a bivalve, *Pterotrigonia thoracica*

Damming rivers, pollution, and poor land use have drastically altered habitats, facilitating boat travel and producing electricity but exterminating many species and imperiling many more.

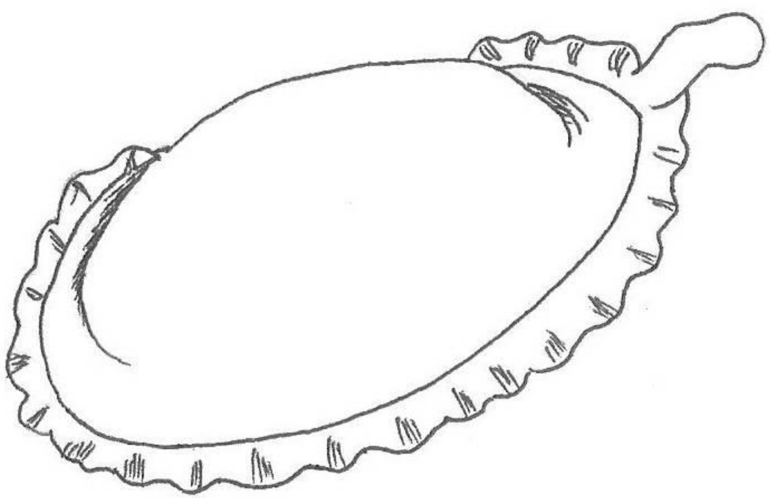
The shoals at Muscle Shoals, with 70 species of mussels and many snails as well, delayed the Union advance up the Tennessee River. Now they are drowned by lakes.

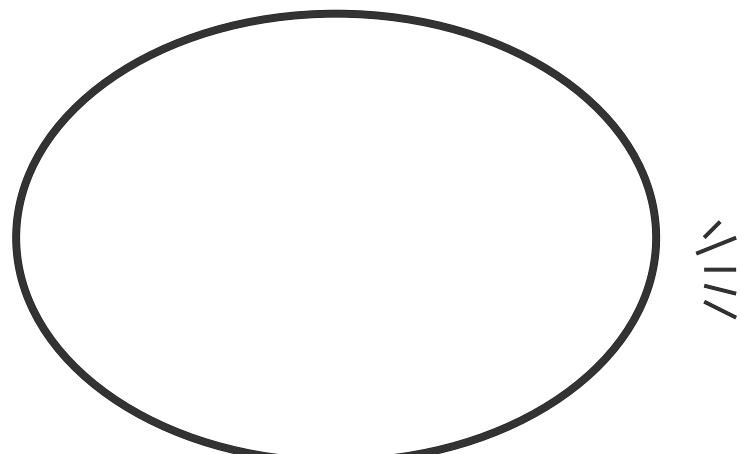
Genetics, Paleobiology, and the History of Mollusks

- With their shells, they have a good fossil record- useful to understanding the histories of mollusks, of life, and of the earth
- From modern specimens, we can sequence DNA as another clue to their history

Origins?

- *Kimberella* –latest Precambrian (Ediacaran), ca. 550 million years ago
- Initially thought to be a jellyfish-like animal
- No fairy godmother to transform *Kimberella* into a princess, but better-preserved material led to transformation in its identification-an early mollusk or relative
- Associated with oval traces (**foot**) and scratches (**radula** feeding)





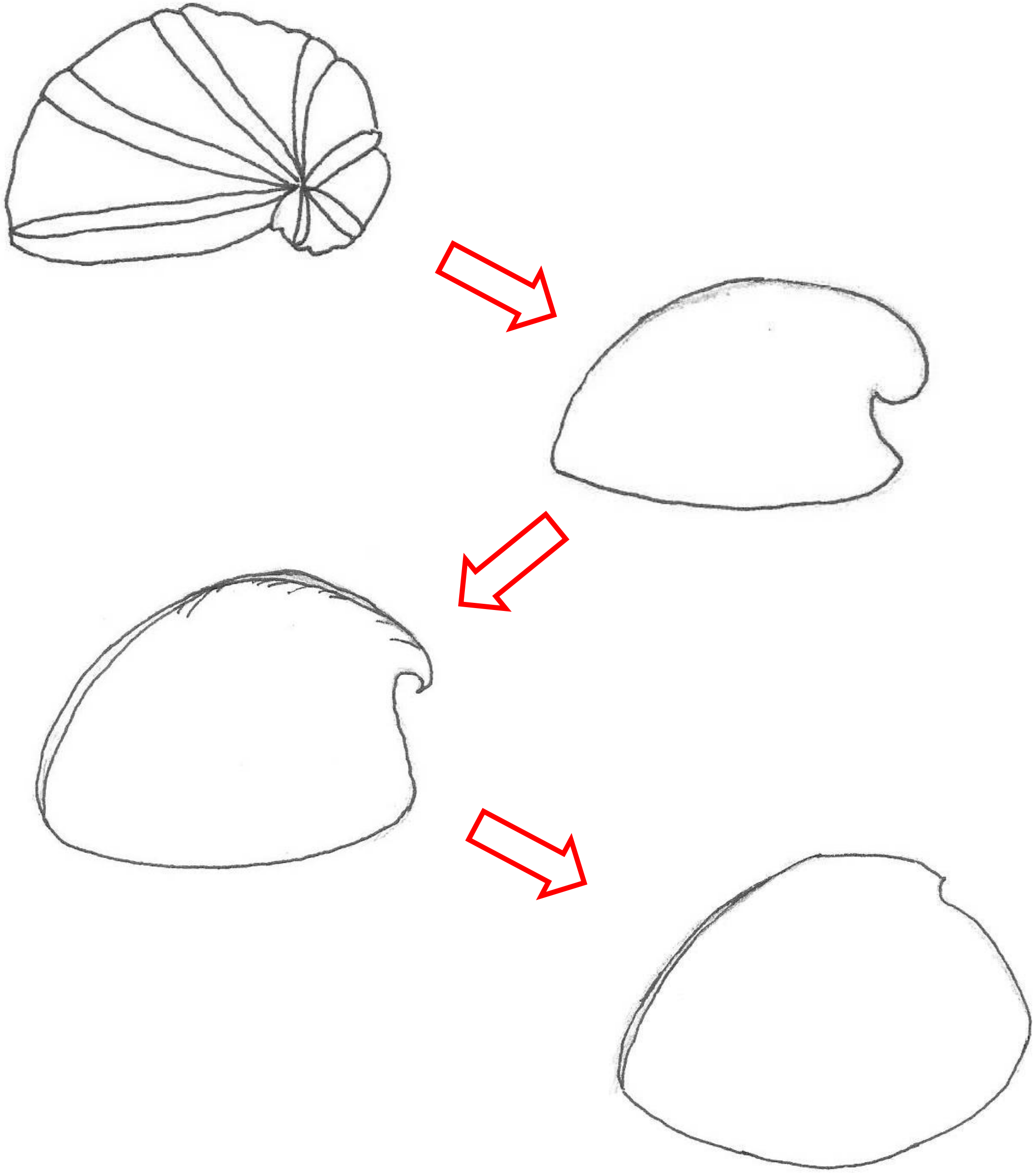
Cambrian

- Mineralized shells become common in the earliest Cambrian, including some mollusk-like forms
- Some had multiple small shells, perhaps a transition from *Kimberella*-like organic shell to a mineral shell, somewhat like modern (and ancient) chitons

- Many relatively generic early mollusks have cap-shaped shells
- Good fossil transitions are present between cap-shaped shells and some of the major classes of mollusks

Cap-shape to clam transition

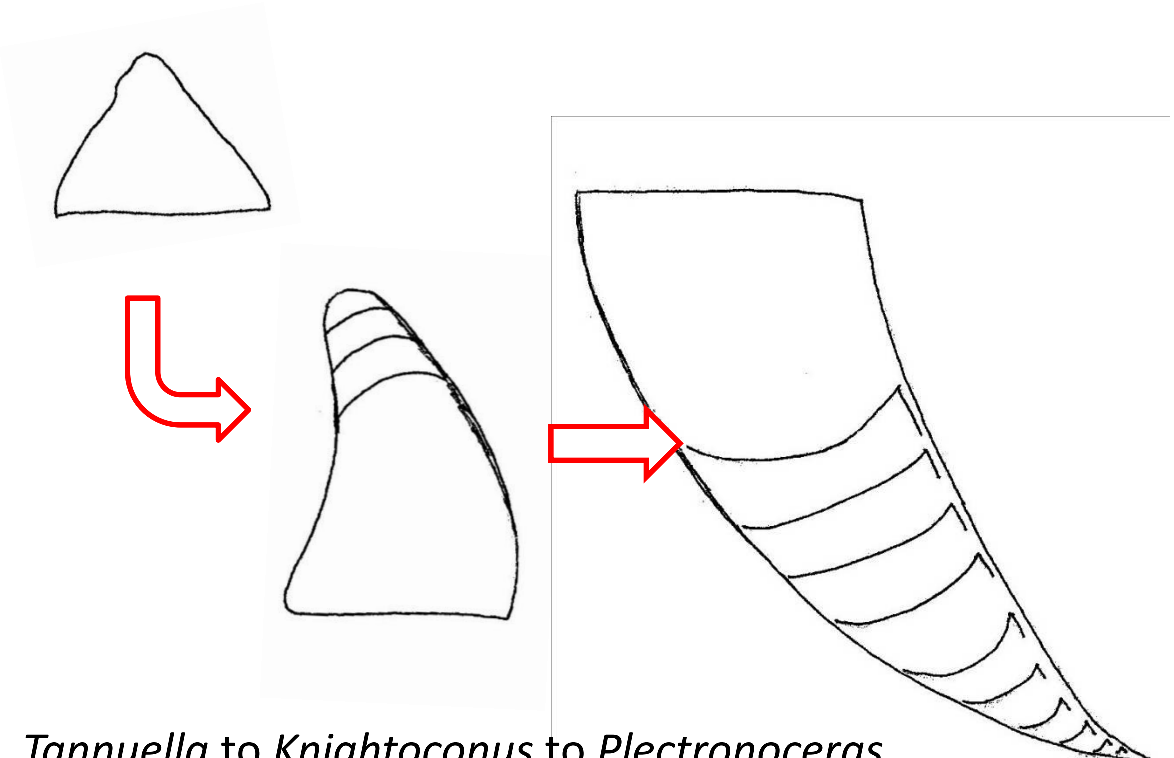
- Less coiled
- More narrow
- Increasing flexibility along the back (note dorsal groove on lower two)



Anabarella (top) to *Watsonella* (bottom). *Watsonella* had a bi-valved larval shell. After Gubanov *et al.*, 1999. Lethaia 32:155-7.

Cap-shape to cephalopod transition

- Taller
- Adding chambers
- Finally adding a tube connecting the chambers (to control gas and fluid and thus buoyancy)



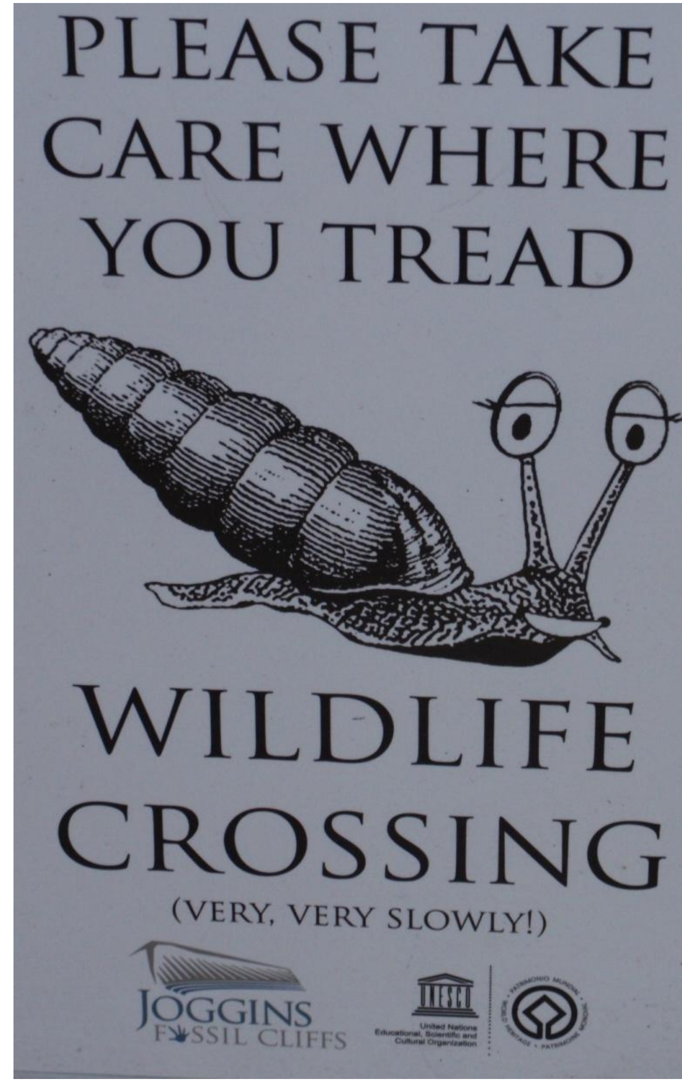
Tannuella to *Knightoconus* to *Plectronoceras*

Modern *Nautilus*, showing chambers and connecting tube

Post-Cambrian Paleozoic

- Cephalopods become major large swimming predators
- Freshwater, land invaded
- Some groups die out, but mollusks generally survive well
- Further diversification within classes

Devonian cephalopods



The oldest land snail (which probably did not have eyes on the ends of tentacles) is a mascot at the Joggins Fossil Cliffs World Heritage site

Mesozoic

- While dinosaurs diversified on land, ammonites and large bivalves were important in the oceans; these all went extinct with the K/T
- Major groups of modern snails and clams began to diversify; they survived

An Antarctic Cretaceous trigonid; living species only occur around Australia

Cretaceous ammonite

Cenozoic

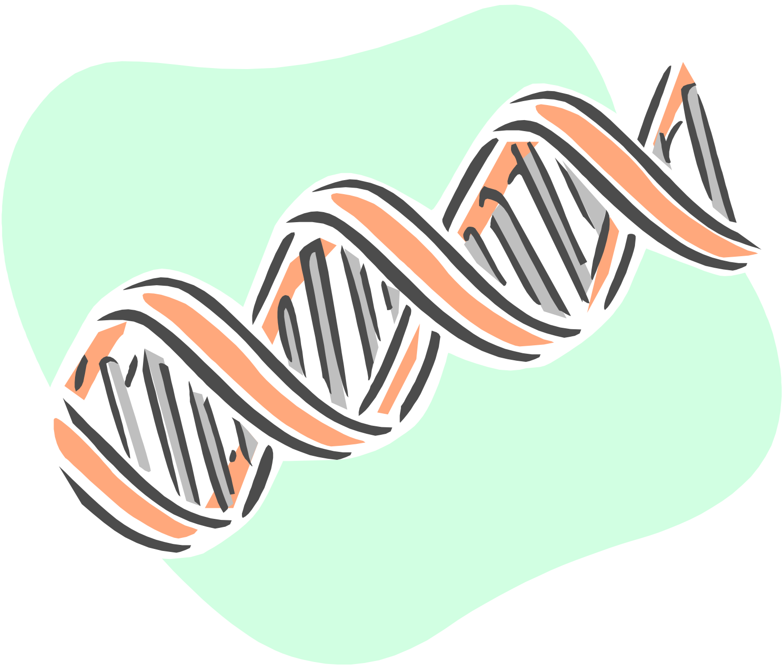
- High turnover at species level-the original basis for Lyell's divisions into Eocene, Miocene, Pliocene
- Reflect global plate tectonic and climate changes, such as isolation and cooling of Antarctica, formation of Panamanian and Suez isthmuses
- Increasingly modern forms evolve

Large predatory snails from the Neogene of Florida, related to the modern horse conch

Predatory drilling snails like this murex become common

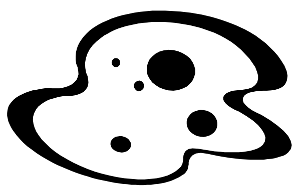
Genetic Evidence on Mollusk History

- Mollusks not as high a priority as main lab animals- just now getting the first fairly complete genomes
- Major genetic patterns tie into anatomical and developmental features for broad-level relationships



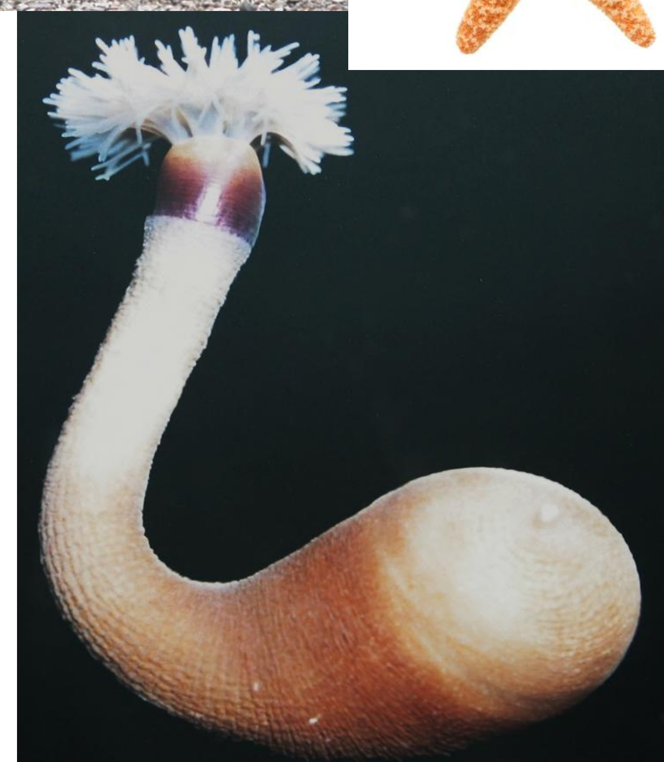
Mollusk relationships to other organisms

- DNA similarities, posteriorly flagellated mobile cells, and a triple-gene fusion unite animals, fungi, slime molds, some amoebas, and choanoflagellates



Mollusks are triploblast bilaterians

- Unlike simpler animals, mollusks and many others have 3 basic cell layers, bilateral symmetry, and DNA similarities

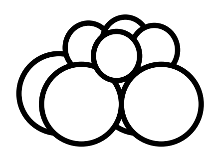


Clockwise from lower left: bivalve and gastropod mollusks, tardigrade, vertebrate, echinoderm, sipunculid (Tardigrade and sipunculid photos from Smithsonian exhibit)

Mollusks are Protostomes



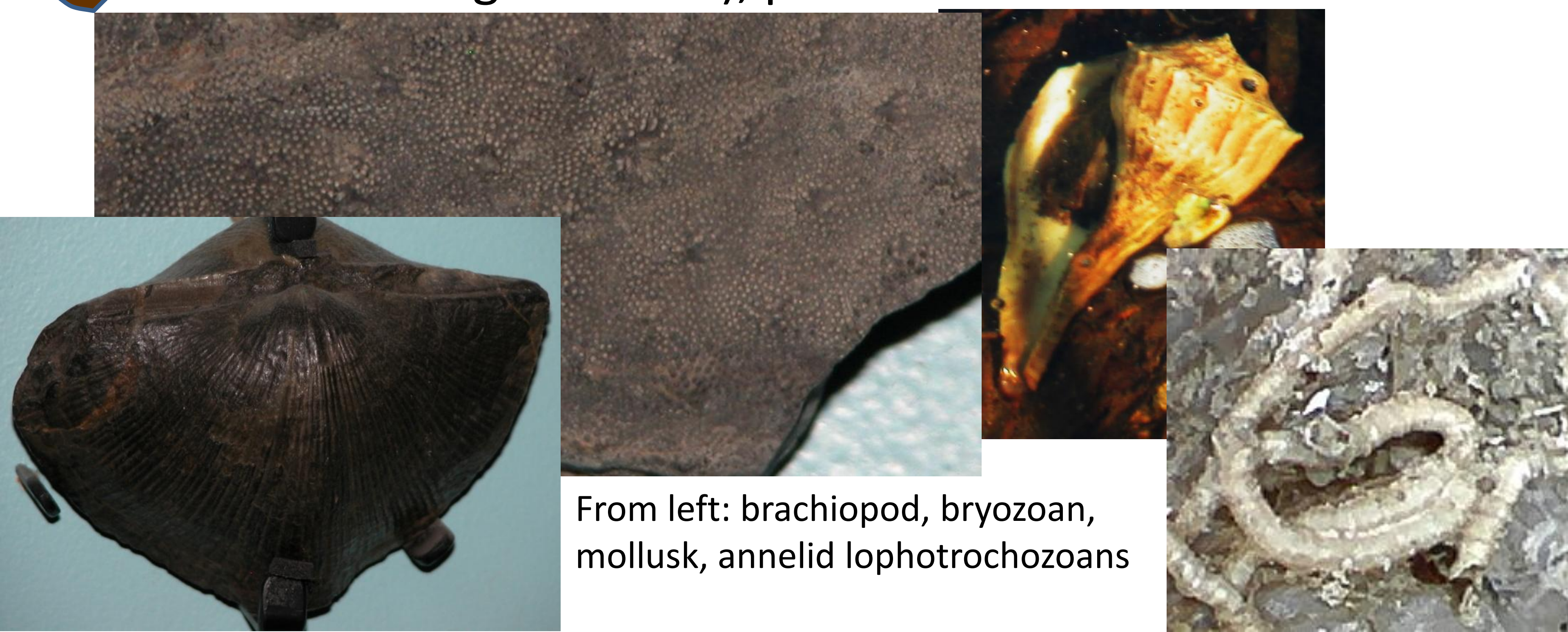
- Most invertebrates, including arthropods, mollusks, most worms, *etc.*
- Initial opening in development becomes **mouth** (not anus)
- Developing cells divide in **spiral** pattern (not radial)
- Cell fate fixed **immediately** (versus much later)
- Molecular similarities



Arthropod, annelid, mollusk, and spiral cell cleavage

Mollusks are not ecdysozoans

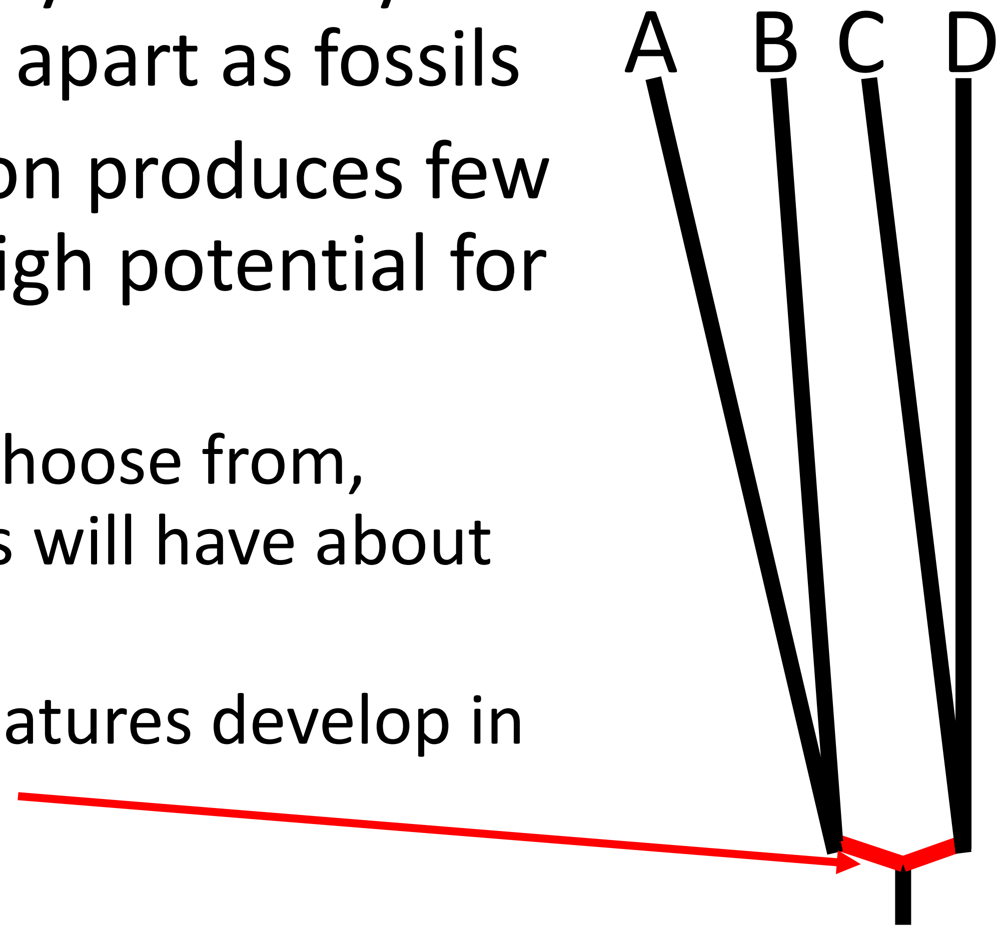
- Lophotrochozoans plus platyzoans-no molting; often similar larval forms.
- Mollusks are lophotrochozoans, which are generally larger, have a schizocoel body cavity; many have shells and/or lophophore (special arrangement of feeding tentacles), plus molecular similarities



From left: brachiopod, bryozoan, mollusk, annelid lophotrochozoans

Relationships of lophotrochophoran phyla and of mollusk classes remain poorly resolved

- Ancestral forms probably relatively generic-not easy to tell apart as fossils
- Relatively rapid radiation produces few synapomorphies and high potential for long-branch problems
  - With only A, C, G, T to choose from, random DNA sequences will have about 25% similarity
  - Relatively few shared features develop in the short time intervals



Several details of mollusk evolution are well-resolved

- Are true oysters closer to pearl oysters or scallops?

- Pearl oysters
  - Similar juvenile shell
  - Tend to sit on the left
- BUT Inner shell aragonite, pearly
  - Tentacles less developed

- Scallops (and relatives)
  - Inner shell calcite, not pearly
  - Well-developed tentacles
  - Often cemented
- BUT Juvenile shell less similar
  - Tend to sit on the right

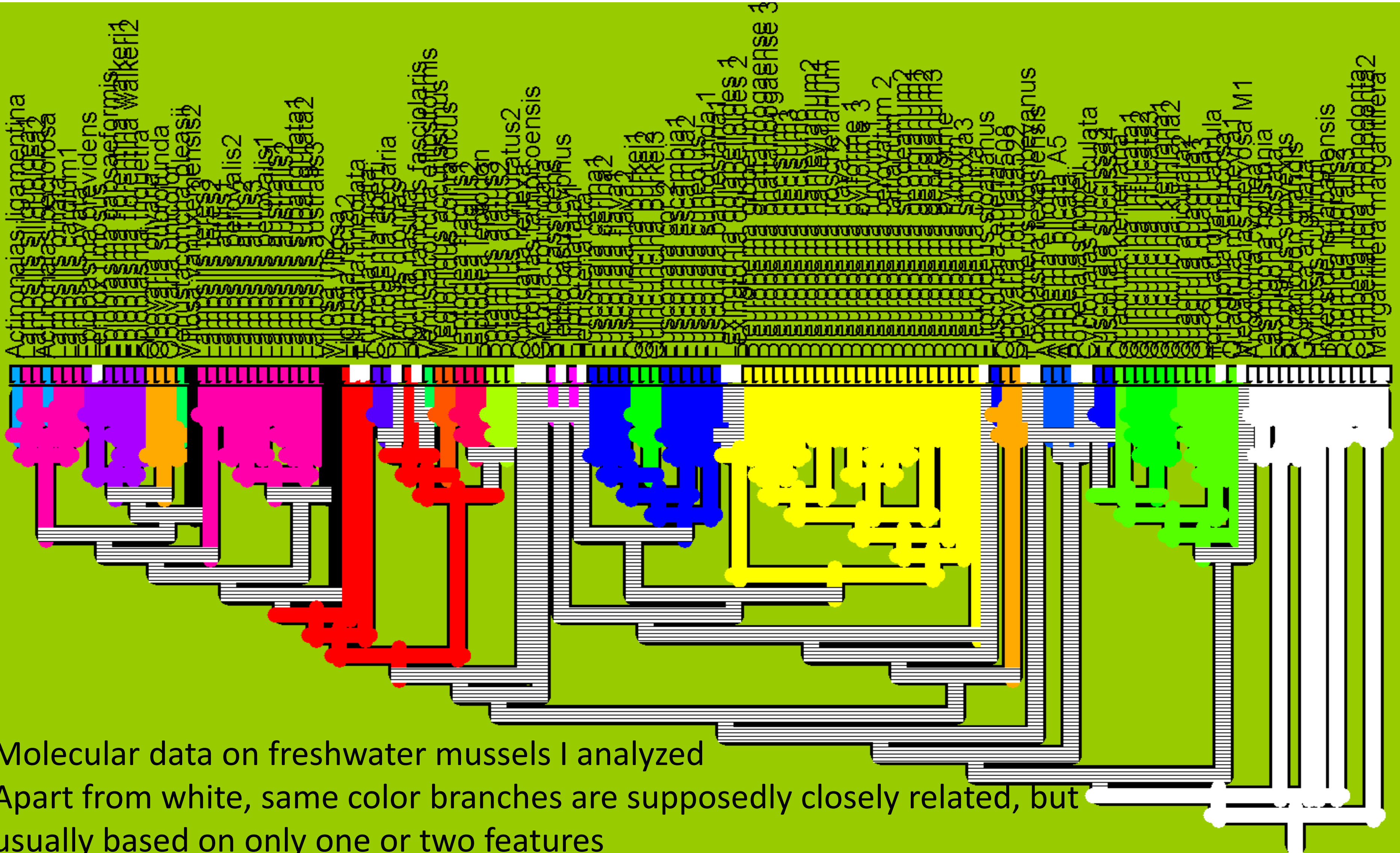
New data resolves it

- DNA: Pearl oysters, true oysters are very similar
- Fossil record-First oysters had pearly aragonite insides, after the scallops had already changed to calcite



Problems

- Often too much emphasis has been placed on a single feature or analysis



Molecular data on freshwater mussels I analyzed
Apart from white, same color branches are supposedly closely related, but usually based on only one or two features

Conclusions

- Mollusks are a fascinating, important, and sometimes imperiled part of creation
- We have much data, but also much to do, in understanding the means by which they were made

Extinct *Epioblasma* mussels form Tennessee. The odd shape helped it grab a fish and infect it with parasitic larvae.

Acknowledgements

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