FOSSILS and FOSSILIZATION

part 4 – Life Forms: Eukarya (Fungi and Animals)

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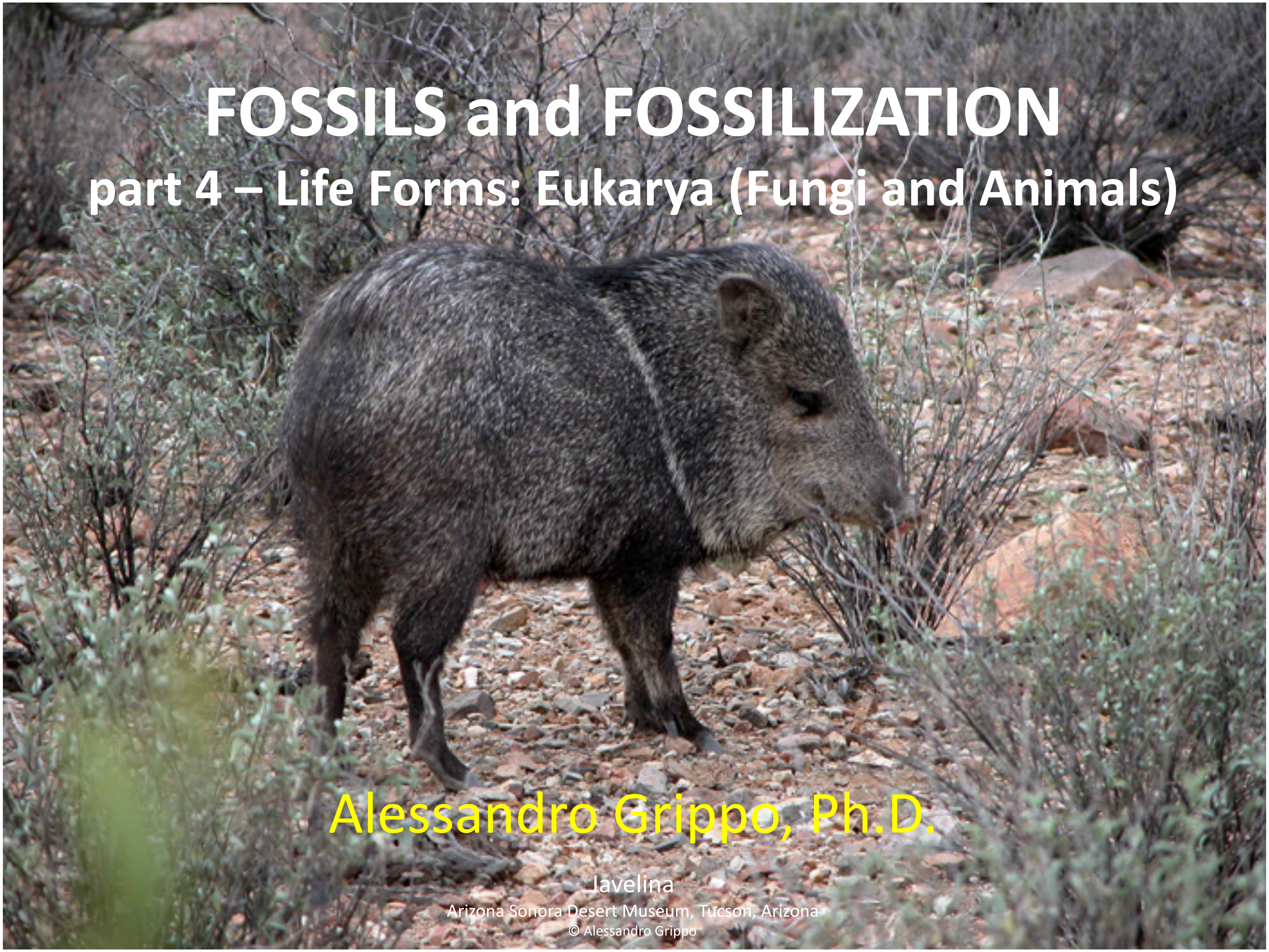


Javelina
Arizona Sonora Desert Museum, Tucson, Arizona

Life Forms: a Summary

Life on Earth is divided in three Domains

- **Archaea**
  - Prokaryotes
- **Bacteria**
  - Prokaryotes
- **Eukarya**
  - Eukaryotes

- All life forms are formed by cells containing DNA
- Prokaryotic cells lack internal organization
- Eukaryotic cells present internal structuring

Fungi vs. Animals

- While Plants are Producers, both Fungi (or Mushrooms) and Animals are Consumers

- Animals (like us) mostly digest food outside their cells but inside a body cavity, then absorb the products

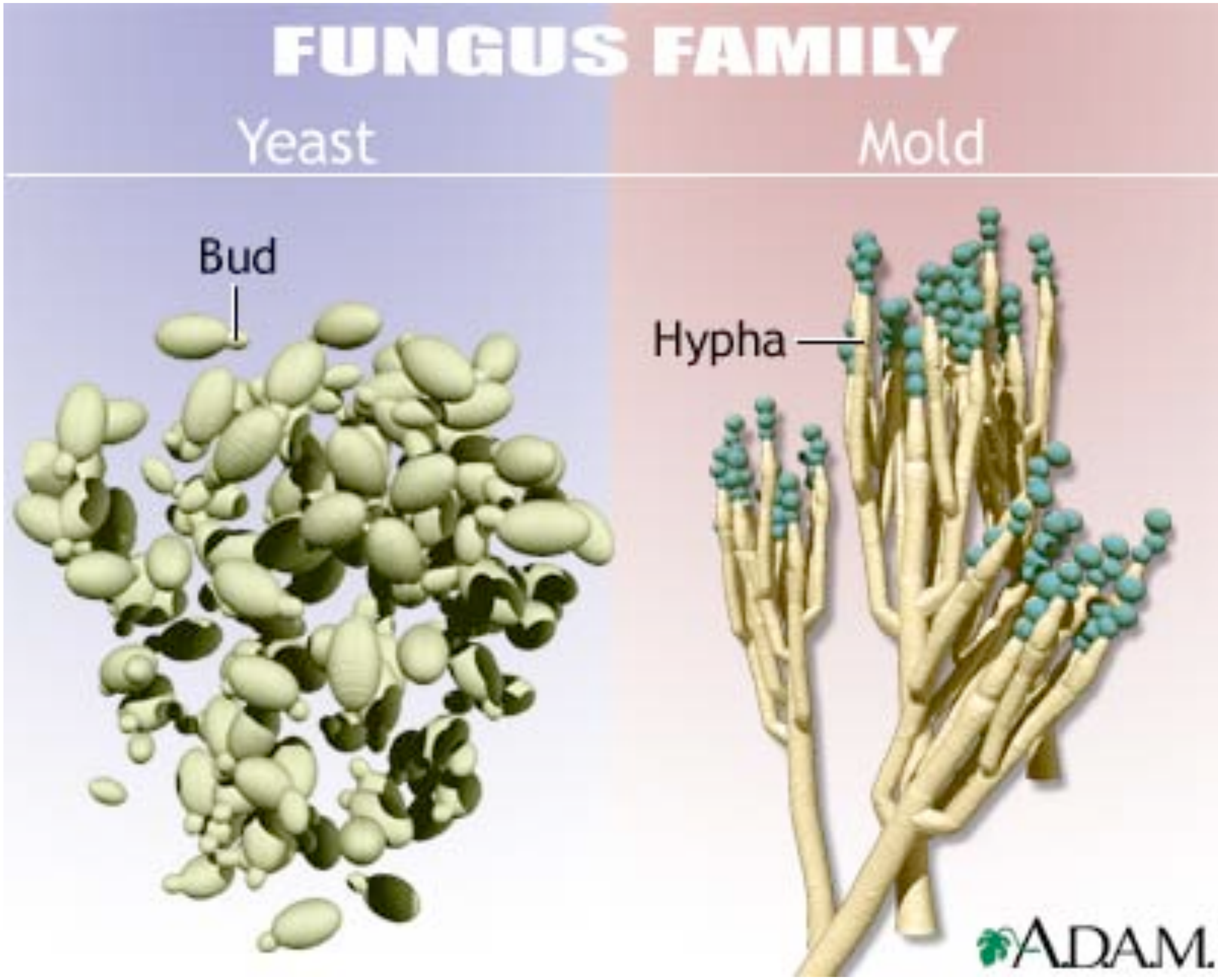
- Fungi release enzymes to break down food in the environment, and then absorb it into their cells

3. Fungi

- Fungi are decomposers that absorb most of their food from dead organisms (typically from wood, bark, dead leaves)

- Mushrooms have filamentous cells, sometimes packed tightly into bundles

- Some fungi, including yeasts, have turned unicellular form multicellular ancestors



FUNGUS FAMILY
Yeast
Mold
Bud
Hypha
A.D.A.M.

Mushrooms




Fossil Fungi

- Fungi have no hard parts, so they have a poor fossil record
- Still, fungi spores have been recorded after mass extinction events
- Some giant fungi have been recovered in 400 my old sediments (Devonian)

Miocene perithecium (mushroom) Nevada from http://www.ucmp.berkeley.edu/fungi/fungifr.html

4. <u>Animals</u>

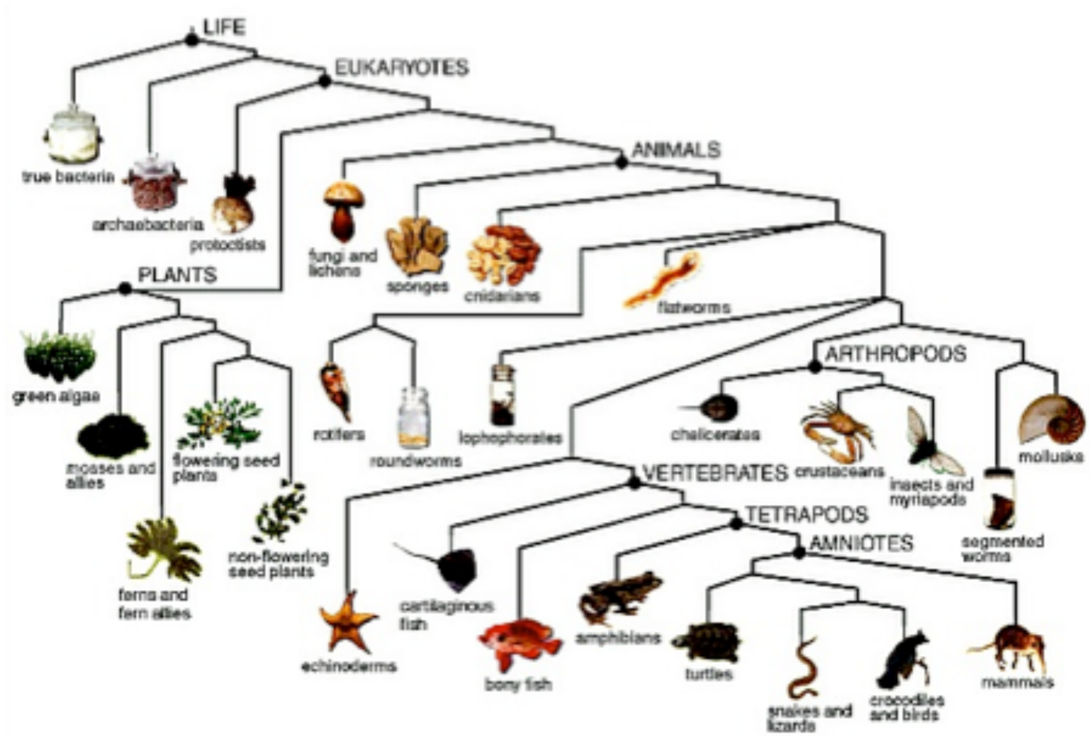
- Multicellular consumers
- Most posses bodies formed of tissues

- Clues for evolutionary relationships come from
  - fossil record
  - patterns of embryonic development
  - gene sequencing

Animals

- Animals are divided into groups based on a variety of characteristics
- A convenient way to classify animals is between vertebrates (with a backbone) and invertebrates (without a backbone)
- Among invertebrates, only sponges lack tissues

The Tree of Life



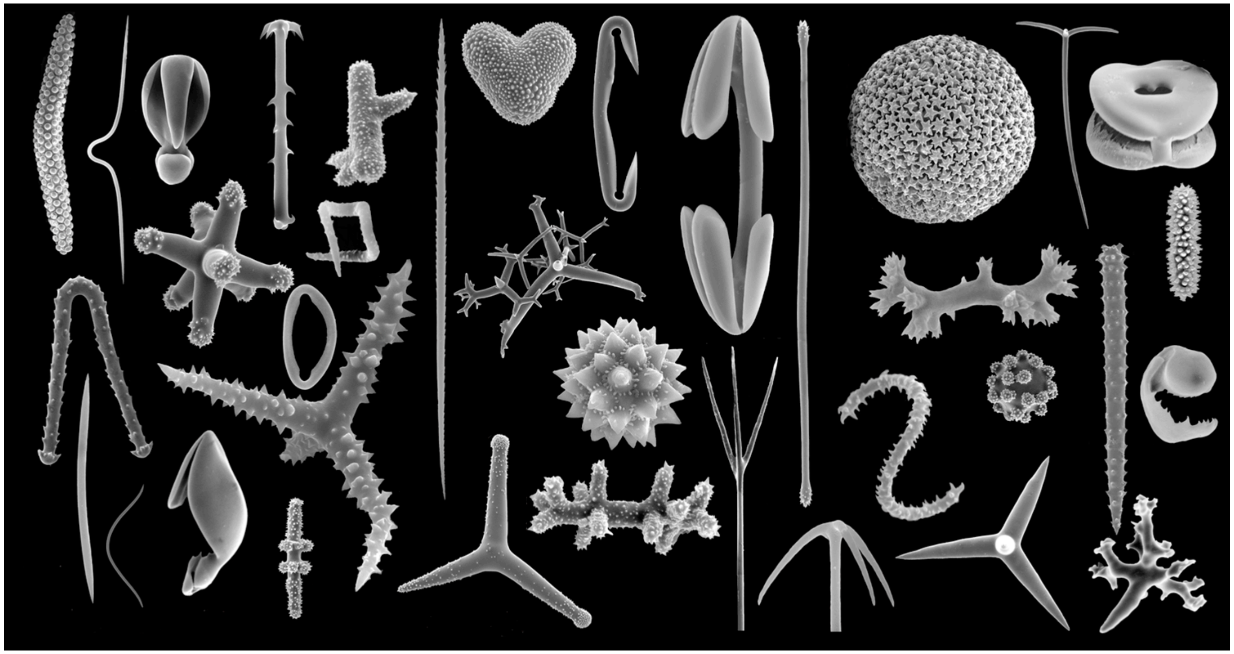
Sponges

- Simplest animals
- Phylum: Porifera
- Most live in the ocean, some in lakes
- All are suspension feeders

- Sponges either have
  - a supporting skeleton made of organic matter (bath sponges)
  - $CaCO_3$ or SiO_2 *spicules*

Fossil Sponges

Both skeletons and spicules give sponges a conspicuous fossil record that extends back to the Late Proterozoic



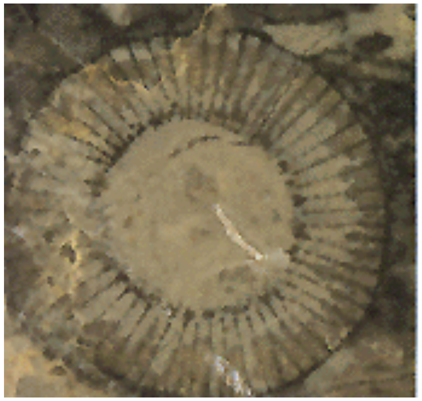
Fossil Spicules and Sponges

Sponges from the past:

Archaeocyathids

- Extinct group of sponges
- Geologically brief but spectacular history
- Appeared in the Lower Cambrian, evolved rapidly, but disappeared a few million years later, by Middle Cambrian
- Played a dominant role in building the first ever reefs

Above: Archaeocyathids model (Melbourne Museum, Australia)
Below: Fossil Archaeocyathids



Cnidarians

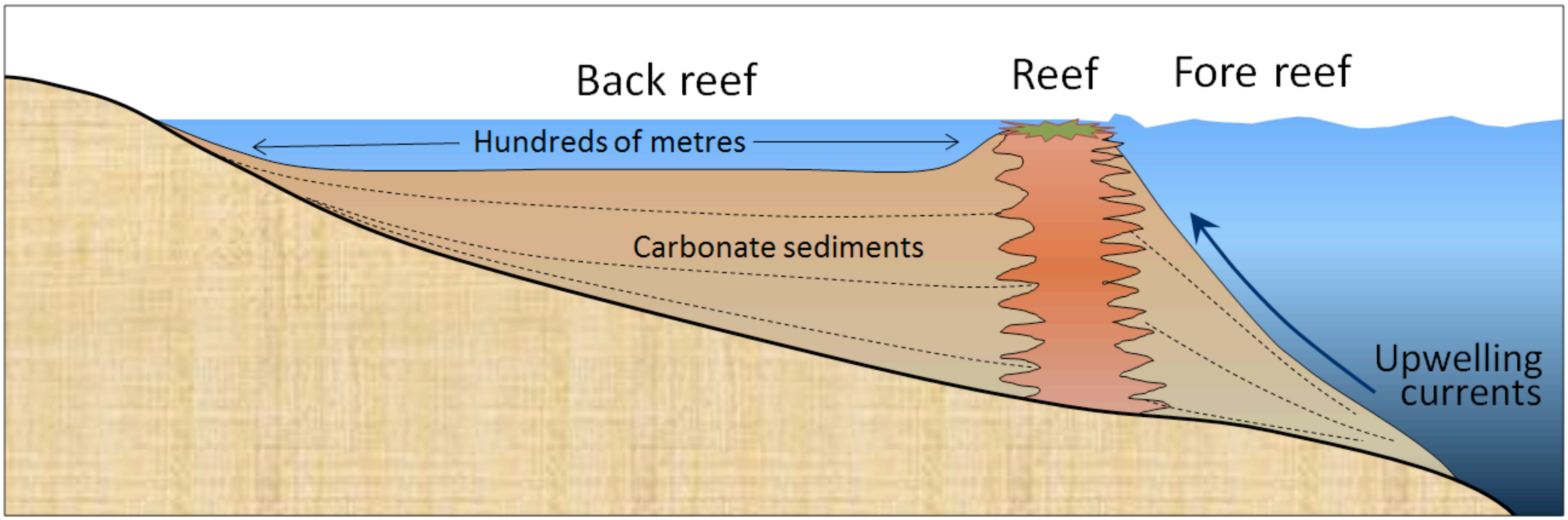
- Jellyfishes, corals, and their relatives
- Most are marine
- Carnivores, they catch small animals with their tentacles, armed with stinging cells
- Radial symmetry

- Corals are important because they left an excellent fossil record

From top left, clockwise:
Australian Box Jellyfish, Sun Coral, section of a coral reef, Australia’s Great Barrier Reef

Barrier Reefs

a simplified profile



Barrier Reefs

where do they form

- All these conditions should be met for optimal development:
  - Shallow waters
    - many reef-building corals symbiotically host algae, so sunlight is required; depth of photic zone is 100 m
  - Warm waters
    - warm, shallow waters lose CO_2 to the atmosphere, making it easier for $CaCO_3$ to form
  - Crystal-clear waters
    - sand and mud would kill corals
    - too many nutrients would attract too many animals that would destroy the reef

$CaCO_3$ equilibrium in water

a reminder

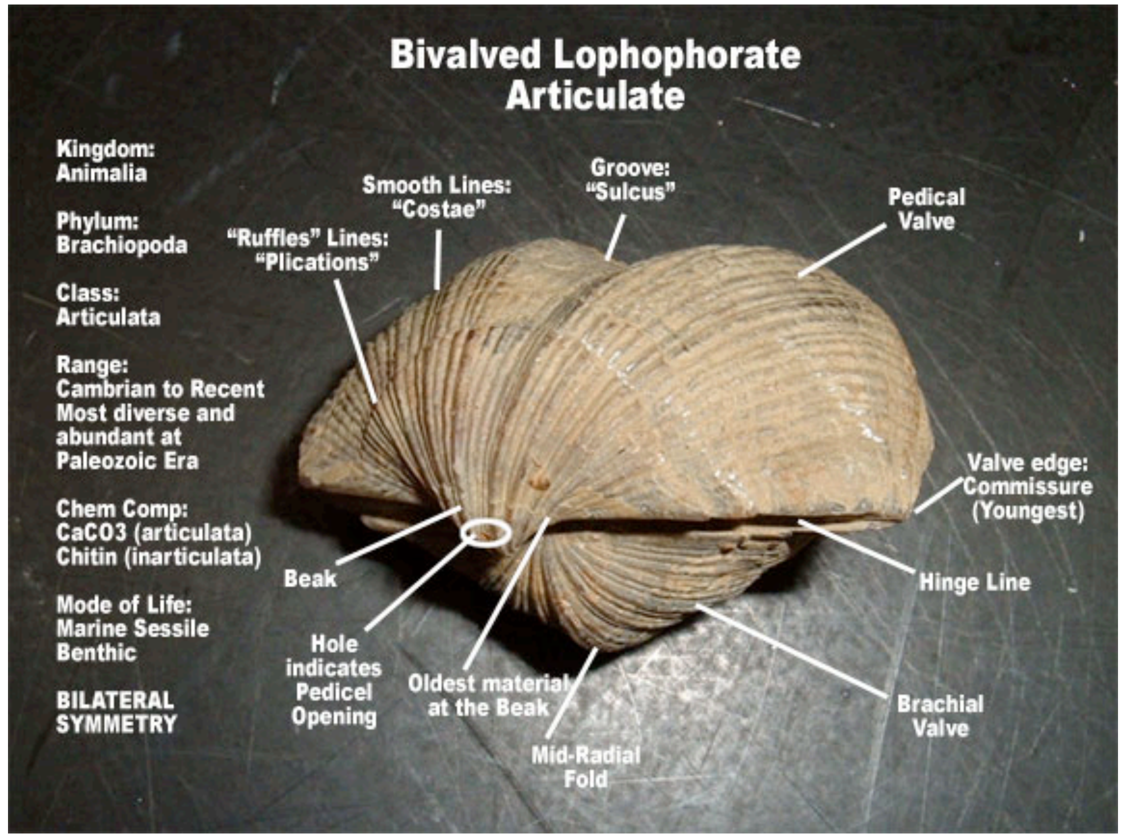
- $H_2O + CO_2 + CaCO_3 \rightleftharpoons Ca^{2+} + 2HCO_3^-$
- More CO_2 in water causes dissolution of calcite
- Less CO_2 in H_2O causes formation of calcite
- CO_2 leaves water
  - at low pressures
  - at high temperatures
- Low pressure and high temperatures are found in shallow, tropical oceans. That is where coral thrives, if they are far away from sand and mud (which are brought to the ocean by rivers)

Reef Corals

- So, reef corals imply clear, warm, and shallow marine waters
- Most reef builders today live at depths of 15 m (45 ft) or less
- Optimum temperature between 25°C (77°F) and 29°C (85°F)
- As a consequence, most are found today between 30°N and 30°S of latitude
- In the geologic past, corals lived in polar areas. Implications?
- Corals have been important members of the biosphere since the Ordovician

Brachiopods

- Similar to clams, their shall is divided into two halves (valves) that are not identical
- Range from late Proterozoic to the present. Uncommon today but are the most conspicuous fossil in Paleozoic rocks
- They can be articulate (with teeth along the hinge between valves) or inarticulate



Brachiopods

Brachiopods

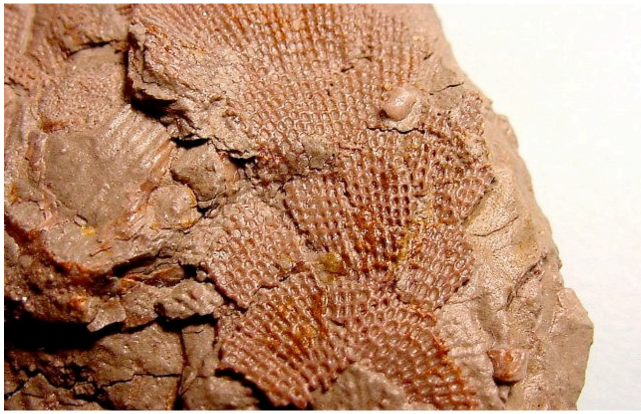
Lingula

- *Lingula* is still alive today
- Part of a group that originated in the Paleozoic
    - it is considered to be a *Living Fossil*
- *Lingula* lives in fresh sediment, anchored to it by fleshy stalks

Bryozoans

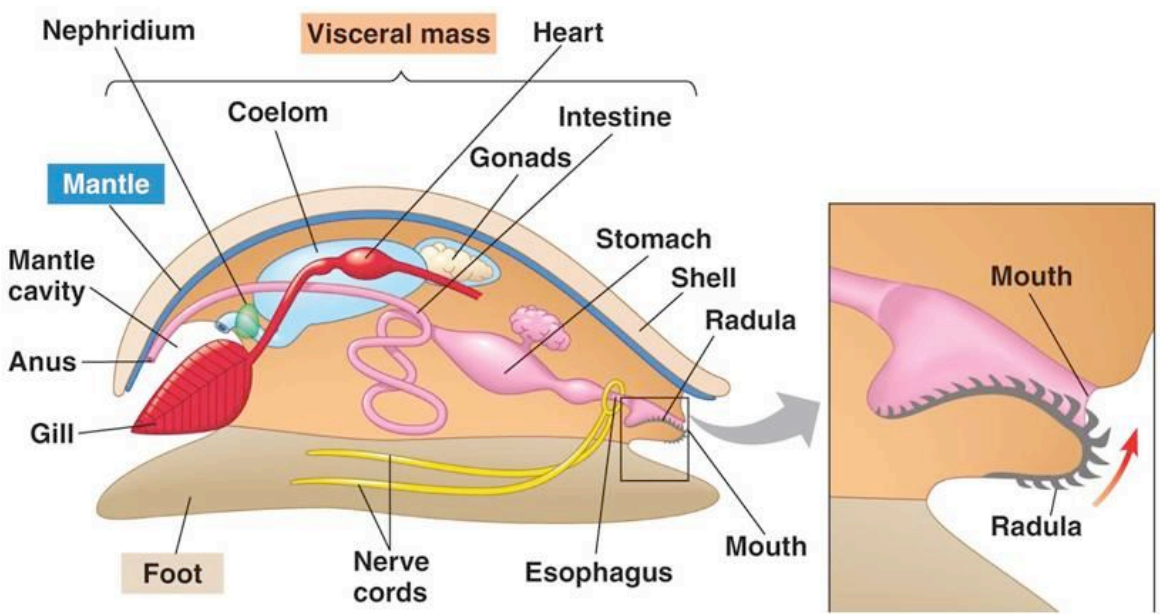
- Animals that grow by budding, in colonies
- Look moss-like
- As Brachiopods, Bryozoans have a *lophophore*
  - a lophophore is a horseshoe-shaped feeding structure bearing tentacles
- Many bryozoans have a calcified skeleton
- Fossil record since Late Cambrian

Above: living Bryozoan. Notice the horseshoe shape
Below: fossil Bryozoan. Every pit is the location of a single individual



Mollusks

- Most mollusks have an external $CaCO_3$ shell
- Shell is secreted by a *mantle*, a fleshy, sheet-like organ
- A muscular portion of the body, the *foot*, is used for motion. Foot is modified in tentacles in some species (squid, cuttlefish)
- Respiration occurs in *gills*
- Well-developed circulatory organs, digestive glands and nervous system are evidence of advanced development
- Many use a file-like structure called *radula* for feeding



Mollusks

important groups

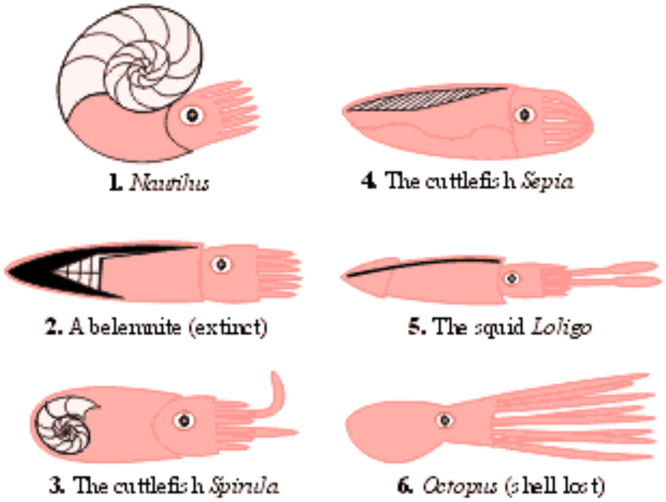
- Monoplacophorans
  - early ancestors of all other mollusks
- Bivalves
  - shells divided in two valves
  - suspension feeders or burrowers
  - clams, mussels, oysters, scallops, etc.
- Gastropods
  - evolved directly from Monoplacophorans
  - shell coiling in 3-D
  - mostly marine, some grazers, suspension feeders, carnivores
  - snails, slugs
- Cephalopods
  - swimmers, they have eyes, and move by jet propulsion
  - predators
  - squids, octopuses, chambered nautiluses, ammonites (extinct)

Cephalopods from the past:

Ammonoids and Belemnoids

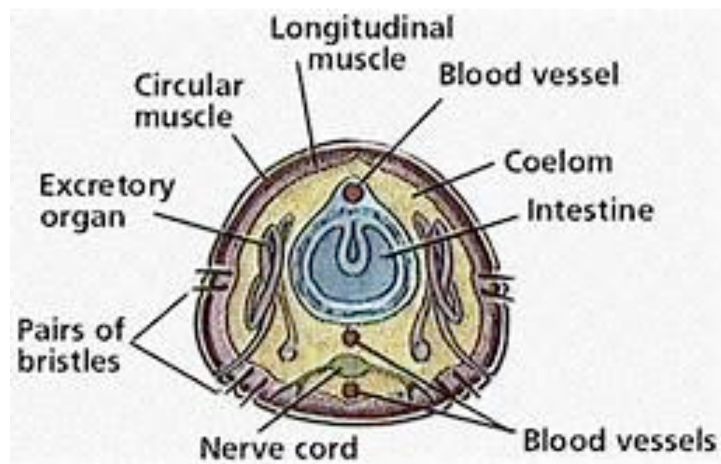
- **Ammonoids** are related to Nautiloids
  - Became extinct at the end of the Cretaceous
  - Evolved very rapidly during Paleozoic and Mesozoic
  - Used as fossil index (or fossil guide)

- **Belemnoids** have an internal shell
  - Useful index fossils for Jurassic and Cretaceous



Segmented Worms

- Complex worms with bodies divided into segments
- They have a fluid-filled body cavity
- Poor fossil record



Arthropods

- 80% of living animals are arthropods
  - Crustaceans (lobsters, crabs, ostracods, etc.)
  - Trilobites (now extinct, but very important during the Paleozoic)
  - Spiders
  - Insects
  - Centipedes, and more

- Evolved from segmented worms

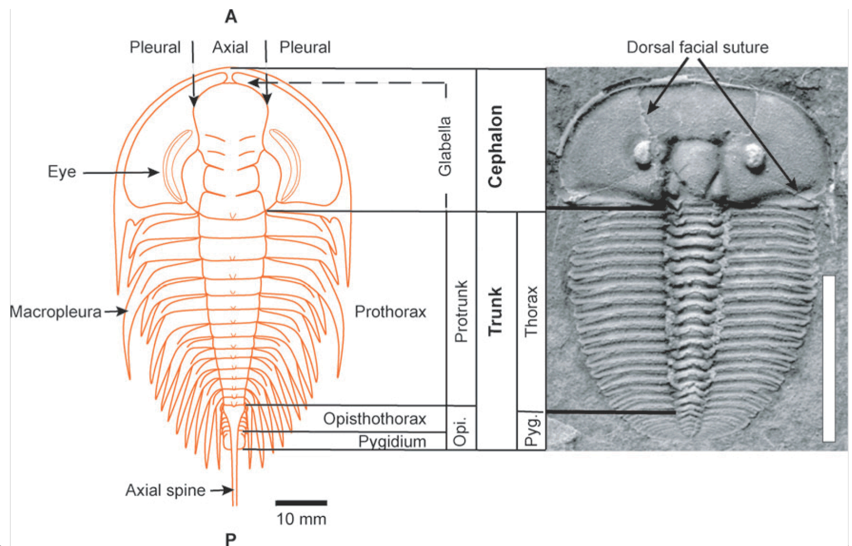
- Body protected by *exoskeleton* of organic material (chitin), sometimes strengthened by $CaCO_3$

- Many arthropods molt, or shed their stiff exoskeleton to build a bigger one with growth

- Except for a few groups, the fossil record is scant

Trilobites

- Extinct marine arthropods
- Subject to rapid evolution during the Paleozoic
- Very common during the Cambrian, they became extinct at the Permian/Triassic boundary
- Three lobes
- Developed advanced eyes



Crustaceans

- Crustaceans (crabs and lobsters) have a poor fossil record because their exoskeleton is made of chitin, with some occasional $CaCO_3$
- Still, they extend back to early Paleozoic

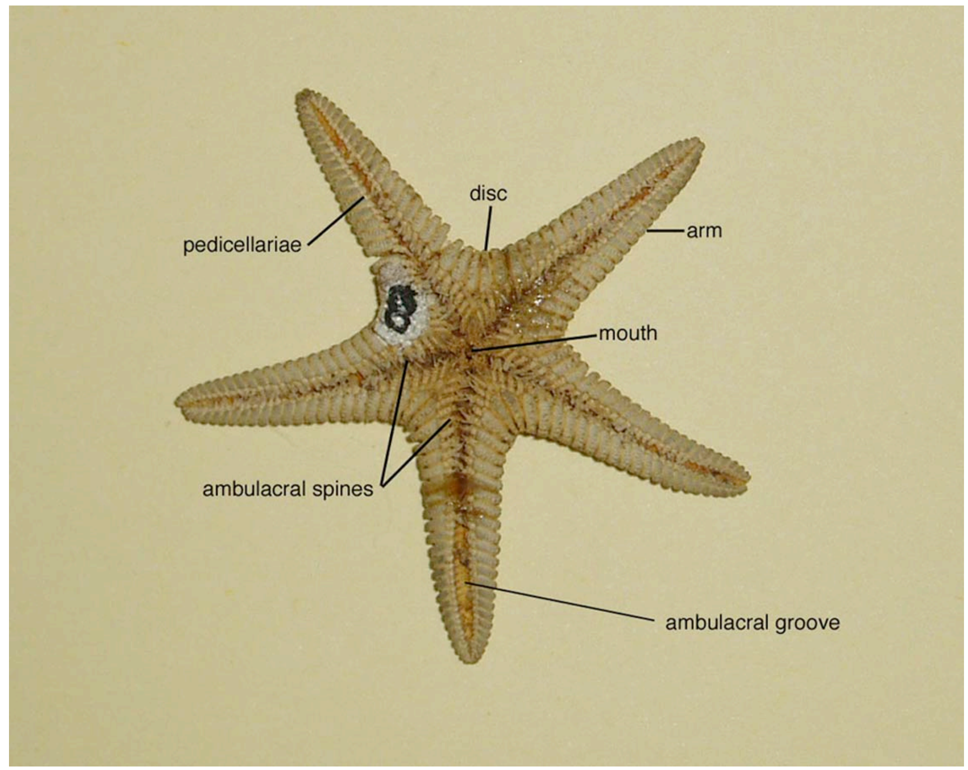
Insects

- Insects include most of the animal species on Earth
- Almost none lives in the ocean
- Almost all have wings
- Very important for fertilization of angiosperms
- Scant fossil record, begins from the first flowering plants



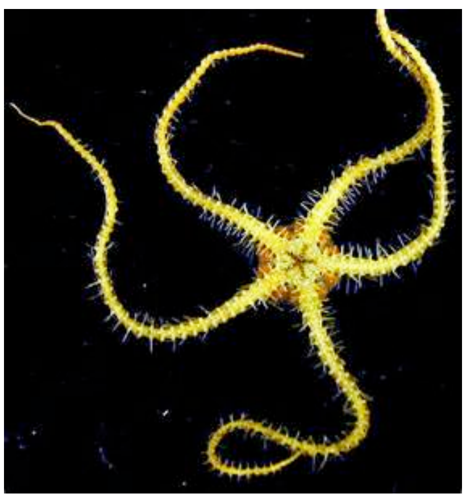
Echinoderms

- Highly developed animals
- Pentamerous (five folds) symmetry
- Skeleton often knobby or studded with spines
- Tube feet
- All are ocean dwellers
- Most have internal $CaCO_3$ skeleton
- Calcite plates readily fossilize in sediment
- Since Lower Paleozoic



Common Echinoderms

- Asteroidea (Sea Stars)
- Echinoidea (Sea Urchins)
- Ophiuroidea (Brittle Stars)
- Crinoidea (Sea Lilies)
- Holothuroidea (Sea Cucumbers)



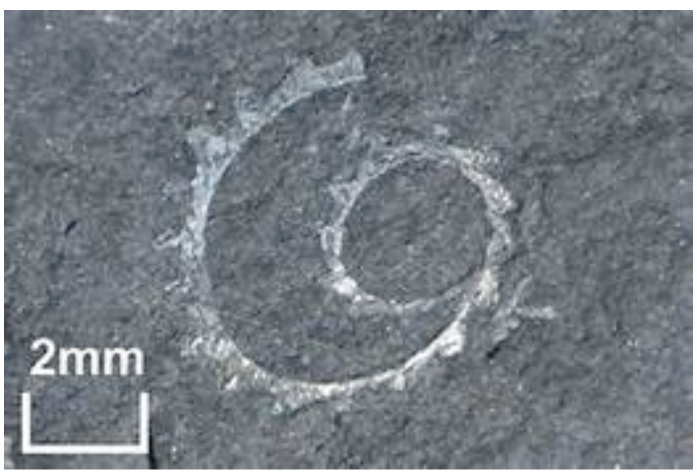
Fossil Echinoderms

Graptolites

- extinct organisms classified as primitive members of Phylum Chordata

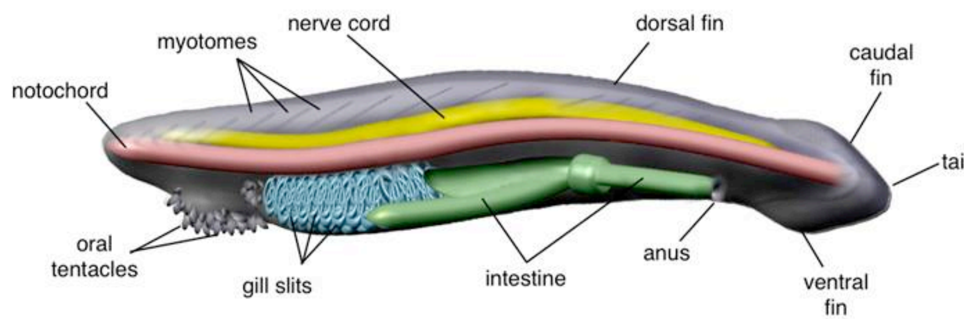
- microscopic, suspension-feeding individuals living in colonies
- skeleton made of chitin
- usually preserved as carbon films in black shales

- known from Cambrian to Mississippian
- very important for Ordovician and Silurian
- worldwide distribution and very rapid evolution make them the ideal fossil index for Early Paleozoic

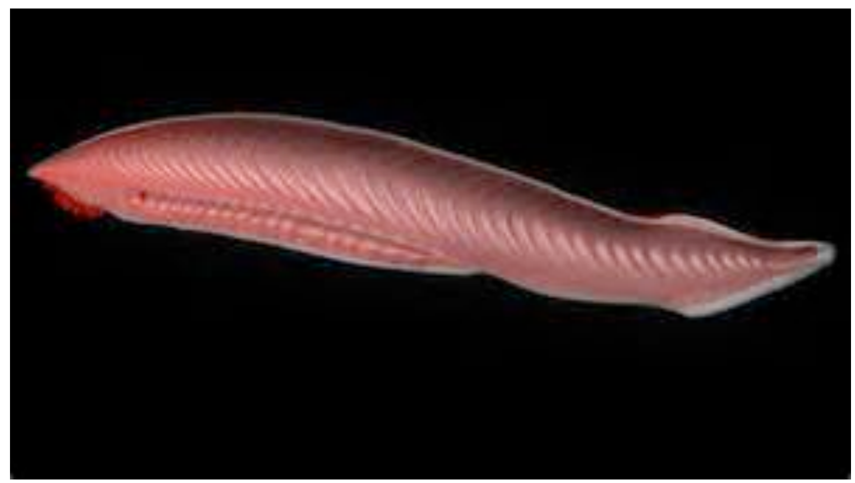


Chordates

- Animals with a "chord", a longitudinal support structure
  - flexible notochord in tunicate larvae and lancelets
  - vertebral columns in vertebrates (like us)



- Also:
  – nerve chord
  – gill slits in the pharynx
  – post-anal tail
  – unique blood circulation



A lancelet

Conodonts

- Conodonts are the chewing apparatus of soft-bodied creatures, similar to lancelets
- For a long time only teeth were found, and this was a mysterious fossil
- Despite that, the fossil is diagnostic for Cambrian to Triassic rocks

Fishes

- Fishes appeared in the Cambrian
- At first they were jawless
- Then they developed jaws: more effective as predators
- Early fishes had a cartilage skeleton (sharks still do)
- Some developed an outer bony armor
- Others developed a bony internal skeleton
  - their descendants include most fishes of the modern world

A Jawless Fish

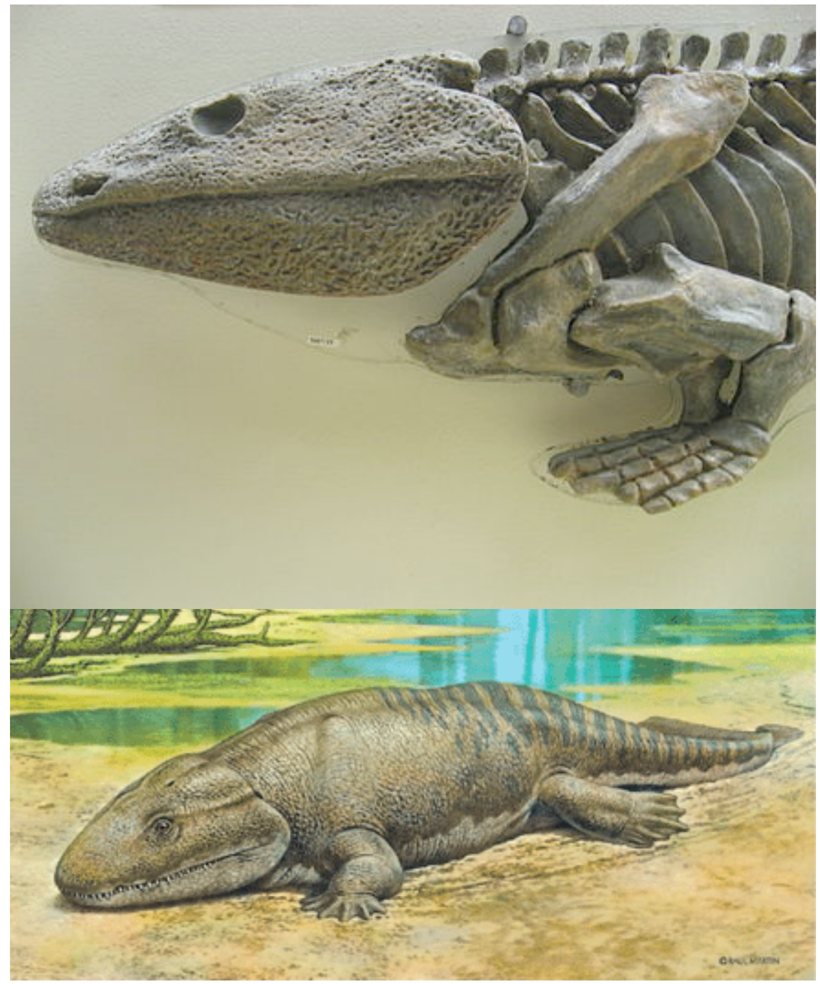
Fishes

- In the Paleozoic, bony fishes evolved in two groups:
  - Ray-finned fishes
    - Fins supported by thin bones radiating outward
    - Dominant fishes of modern seas, lakes, rivers
  - Lobe-finned fishes
    - Fleshy fins supported by a complex assembly of heavy bones
    - Very few found today, among them the coelacanth
    - Ancestors of four-legged land animals (tetrapods)

the
Coelacanth

Amphibians

- First tetrapods to spend adult life on land
- Appeared during the Devonian (*Ichtyostega*)
- True amphibians appeared in the Carboniferous
- Had to lay eggs in water and spend early life there
  - today: frogs are amphibians whose juveniles, tadpoles, live in water and swim with fishlike tails



Above: *Devonian Ichtyostega* from Moscow Paleontological Museum
Below: reconstruction of *Ichtyostega*

Amphibians: the life cycle of a frog

Reptiles

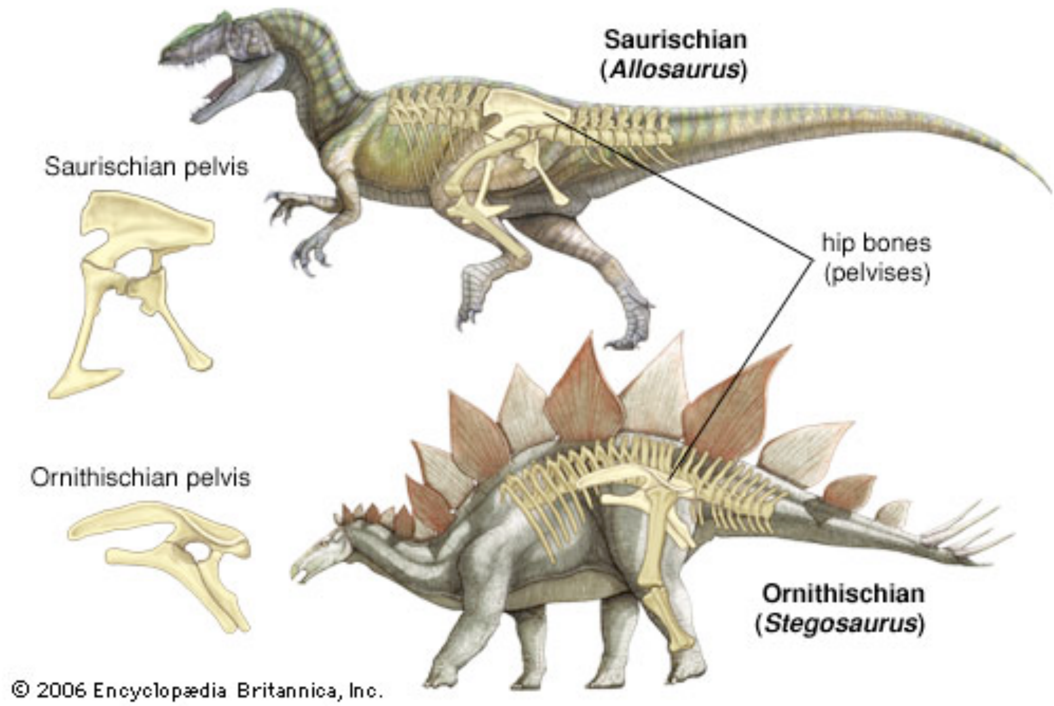
- Evolved from amphibians by developing the egg
- The egg works as a protective shell that keeps the embryo moist
- Eggs allowed reptiles to expand on dry lands:
  - there was no need to get back in water for reproduction and early development (like for frogs)

Reptiles

- Many reptiles are now extinct (for instance, dinosaurs and more)
- Among surviving reptiles: snakes, crocodiles, turtles, lizards
- Reptiles' body temperature is function of the environments

Dinosaurs

- Related to reptiles
- Became extinct in a great mass extinction at the end of the Mesozoic
- Saurischia (reptile-like) vs. Ornitischia (bird-like)
- Birds descend from Saurischia



Birds

- Evolved from, and classified as, dinosaurs (Saurischia)
- Endothermic (warm blooded)
- Developed feathers
  - good for flight
  - good for thermal insulation
- Developed hollow bones
- Robust breast muscles, big heart, efficient respiratory system
  - all these good for flying

Archaeopteryx

Birds

Mammals

- Mammals appeared during the Mesozoic (they coexisted with Dinosaurs)

- Descended from mammal-like reptiles from Permian and Triassic

- Characteristics:
  - endothermic
  - body hair for insulation (except whales)
  - sweat glands for cooling
  - four-chambered heart
  - most bear live young and feed them milk from mammary glands
  - have highly differentiated teeth
  - have advanced features for locomotion

Mammals

- Three groups of mammals are alive today, all with histories extending back to the Mesozoic:
  - Monotreme mammals
    - retain ancestral characteristics: they lay eggs
    - Platypus, Echydna


Mammals

– Marsupial mammals

- bear immature live young that grow in a pouch
- suckle milk within the pouch
- found mostly in Australia and parts of South America




Mammals

- Placental mammals
  - include vast majority of living mammal species (us too!)
  - newborn offsprings are larger and more mature than those of placental
  - placental mammals expanded only in the Cenozoic, after dinosaurs' extinction
  - marsupials developed in Australia because there were no early placentals (that is function of plate tectonics: Australia detached from Gondwana before early placental evolution)

Fossils and Fossilization
Life Forms: Protists and Plants

The End