Leathem's Pick of Evolution's All-Time Greatest Hits

A purely subjective evaluation!

The Origin of Life and the First Cells

Current Standpoint

primitive atmosphere
H_2O, N_2, H_2, CO, H_2S 1

small- and medium-sized molecules
sugars, purines, pyrimidines, amino acids, lipids 2

large molecules
polysaccharides, nucleic acids, proteins 3

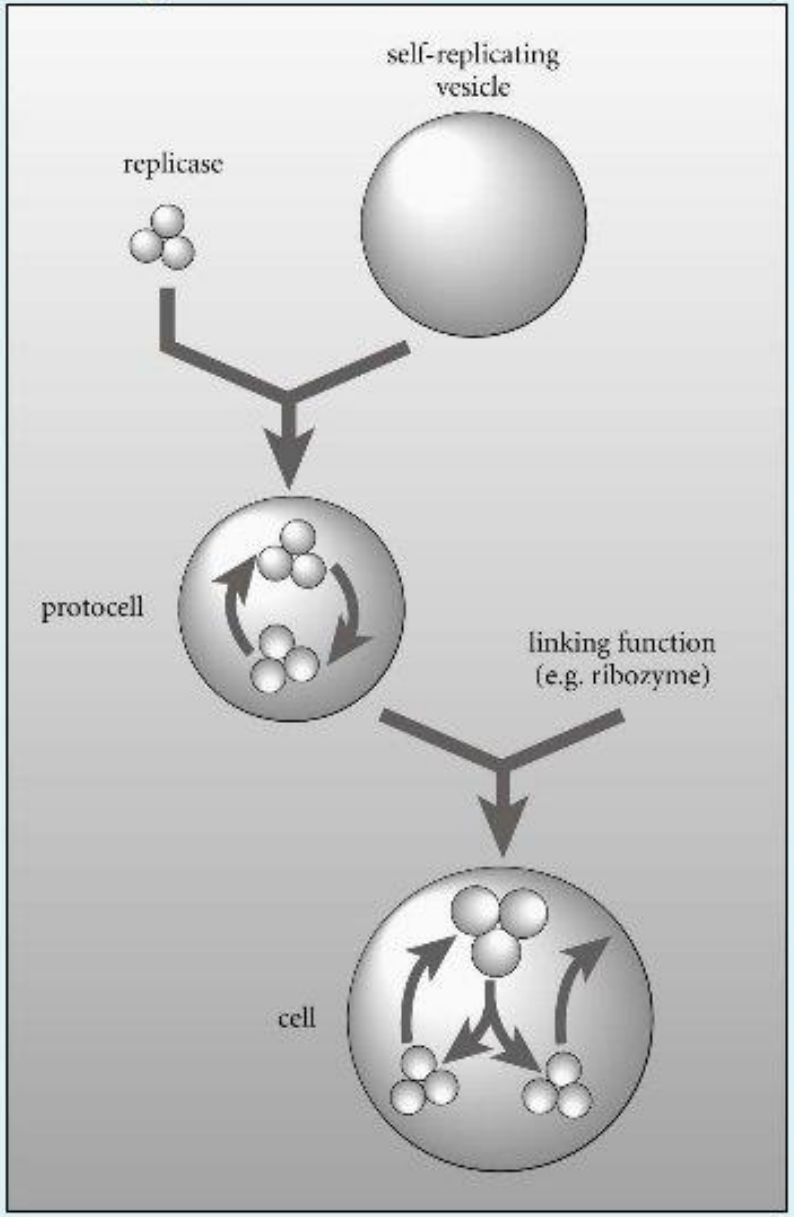
membrane → "protocells" 4

genetic mechanism; ATP system → prokaryotes 5 — c. 3500 Ma

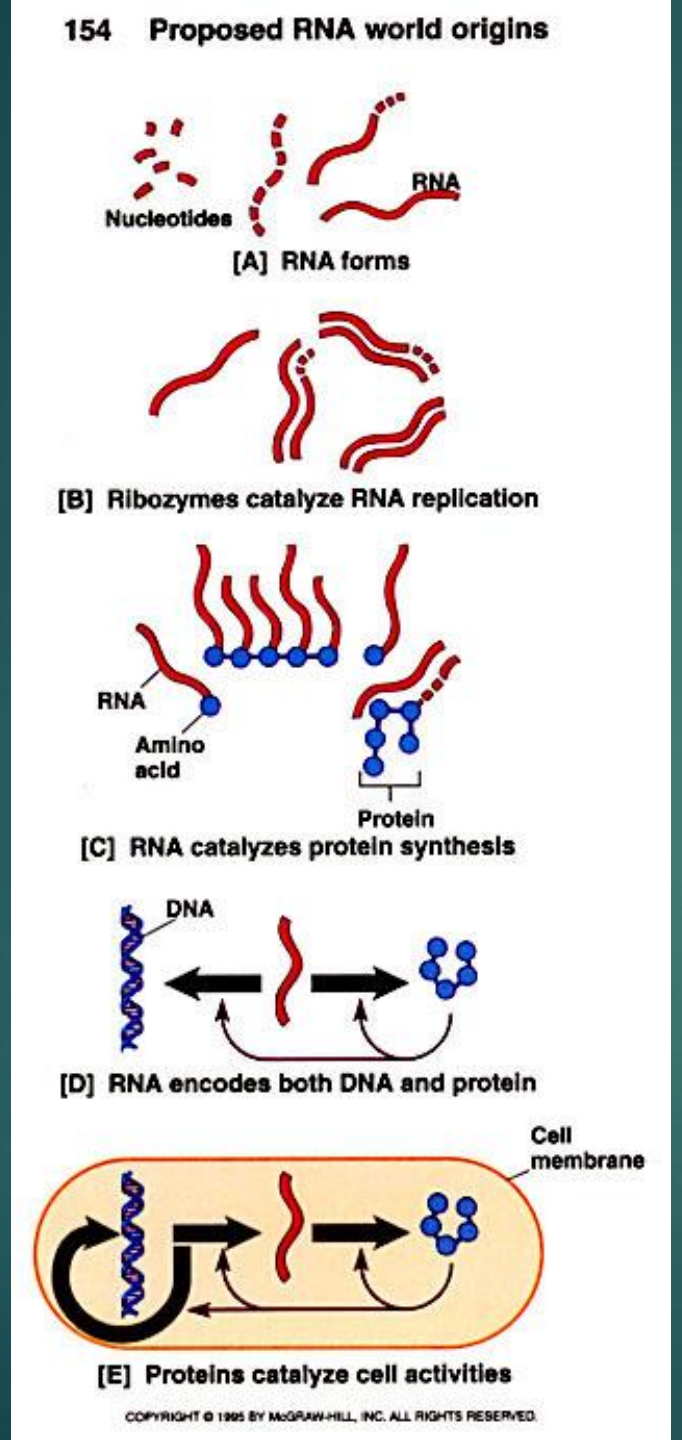
organelles → eukaryotes 6 — c. 1600–900 Ma

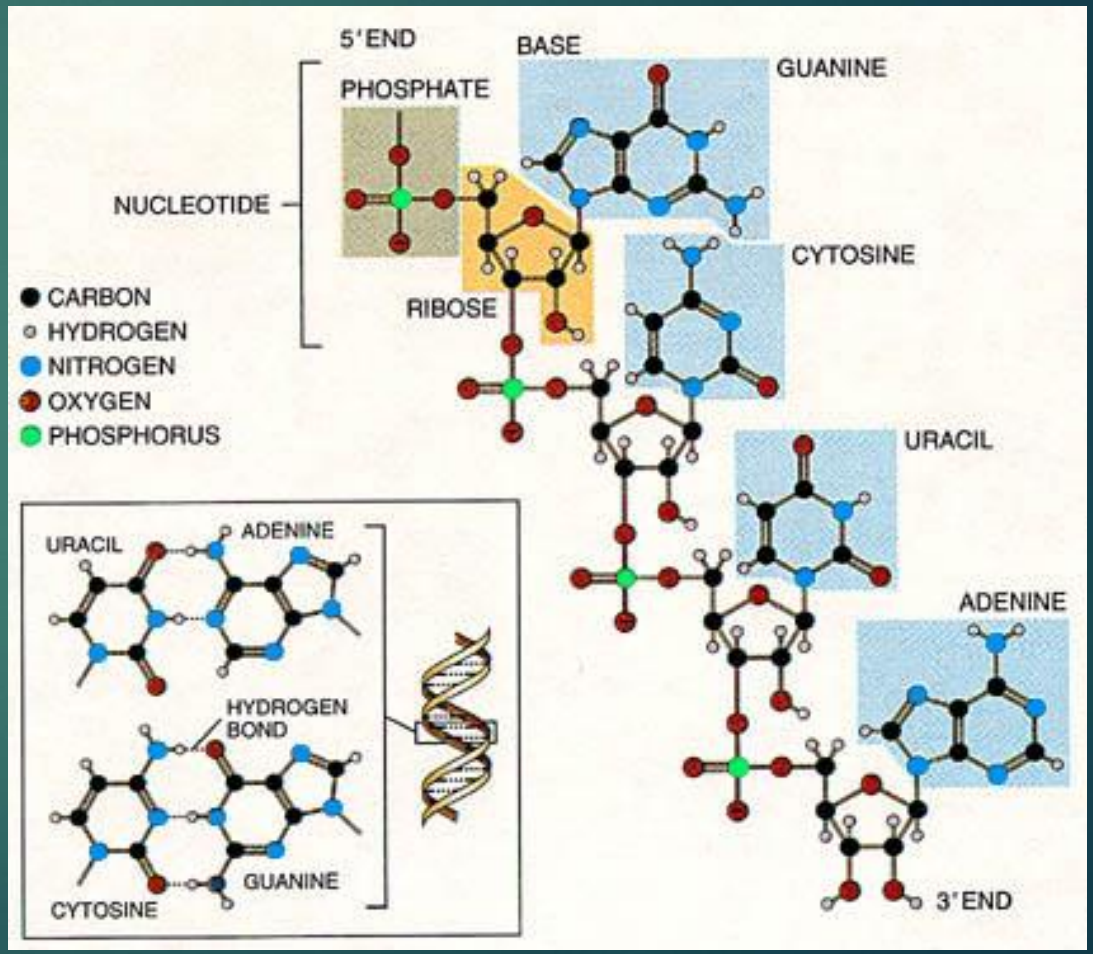
distinct tissue layers → multicellular organisms 7 — c. 1260–950 Ma

Benton & Harper (2009)

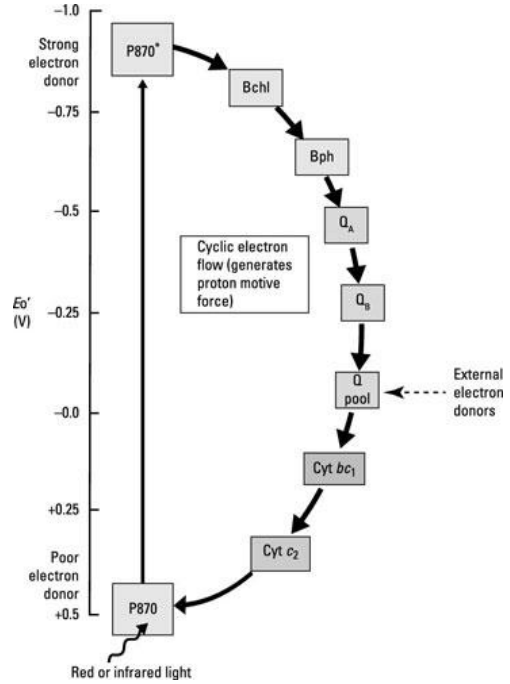


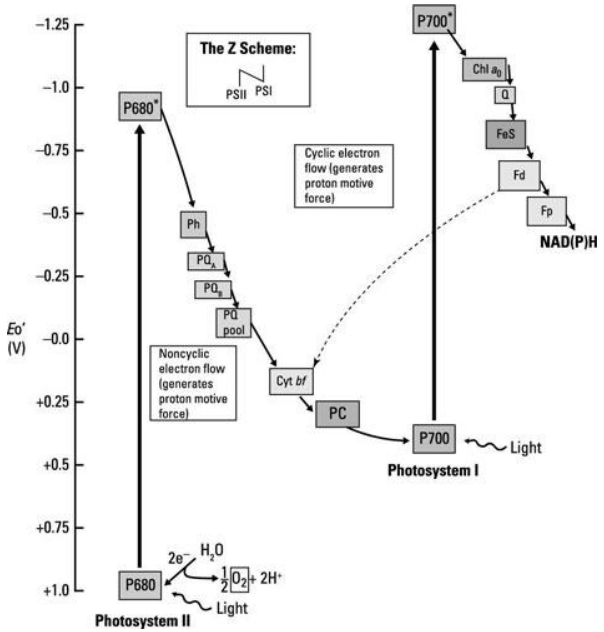
RNA World Hypothesis





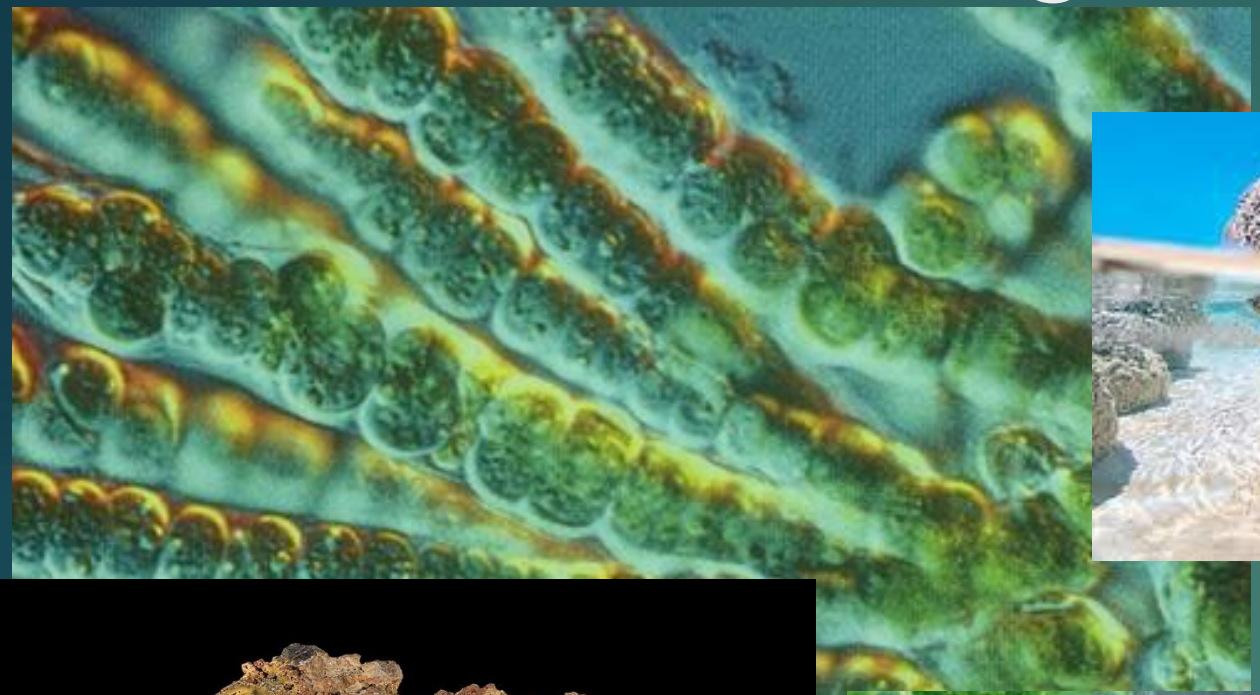
Photosynthesis

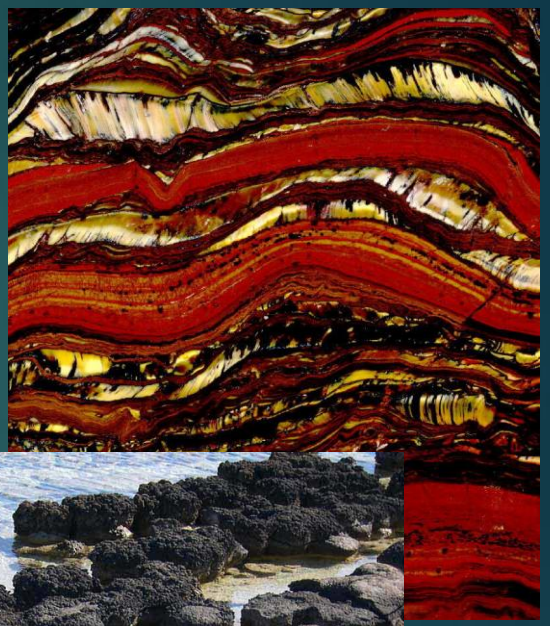


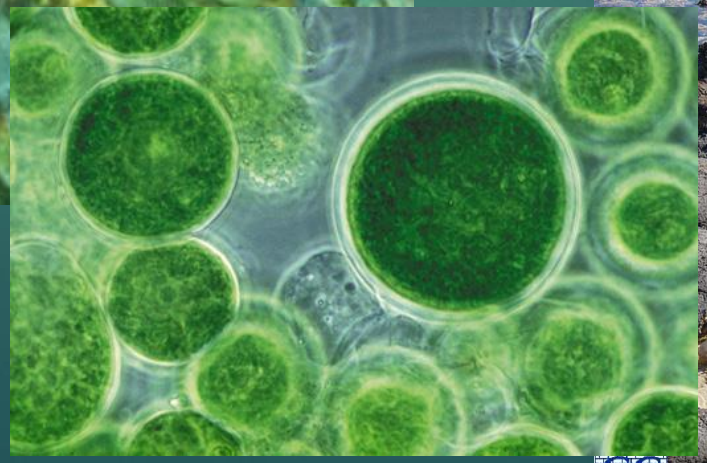


- The first cells to carry out photosynthesis did not use oxygen in energy-producing reactions.
- Early photosynthesis probably used H_2S, as it was abundant and requires less energy to oxidize than water
  - $6CO_2+12H_2S+h\nu \rightarrow C_6H_{12}O_6+6H_2O+12S$
  - This method predominated for millions of years
- Many organisms today are anaerobic, and even find oxygen toxic.
  - They use other sources for energy such as hydrogen sulfide
- But eventually some organisms developed a second photosystem that could use water (H_2O) instead of H_2S, producing oxygen rather than sulfur as the end product and gleaning more energy.

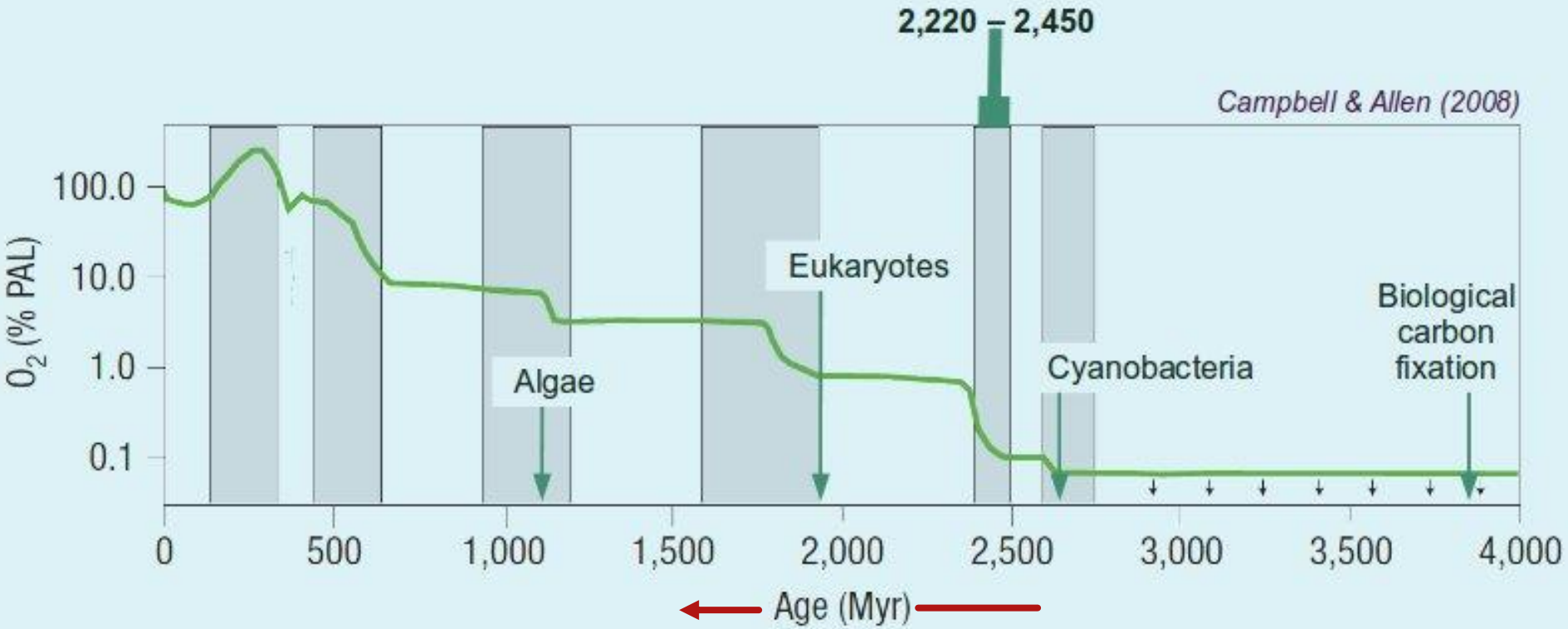
Earliest life: blue-green algae







Great Oxidation Event



Oxygen Source

Photosynthesis

Alternative metabolisms?

Oxygen Sinks

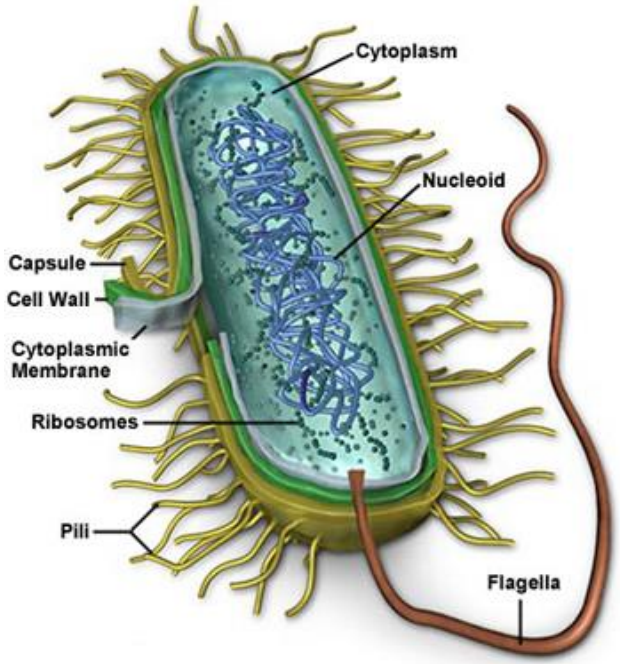
Oxidation of volcanic gases

Oxidation of terrestrial minerals

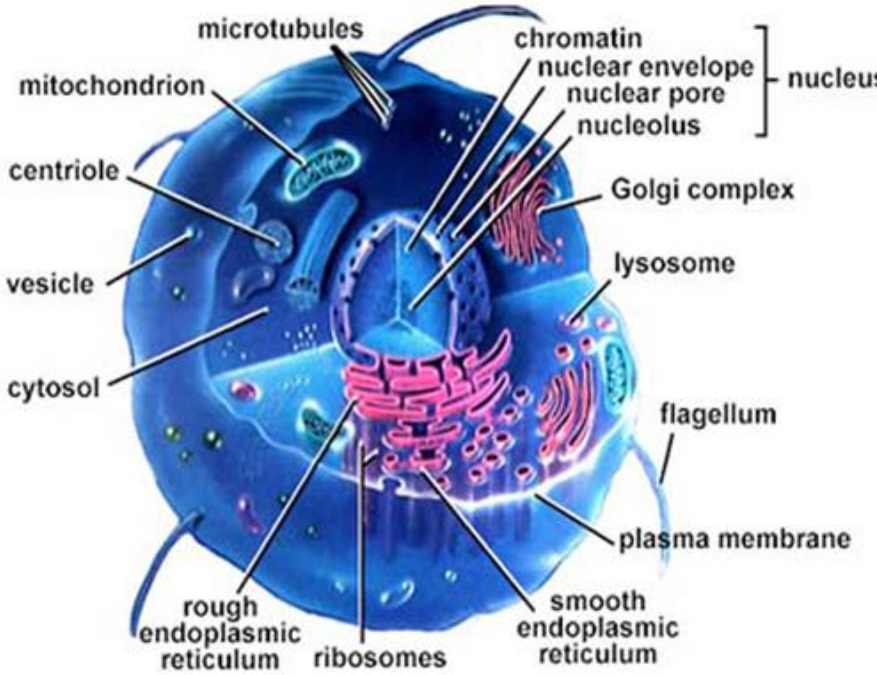
Oxidation of diagenesis prods.

Eukaryotes

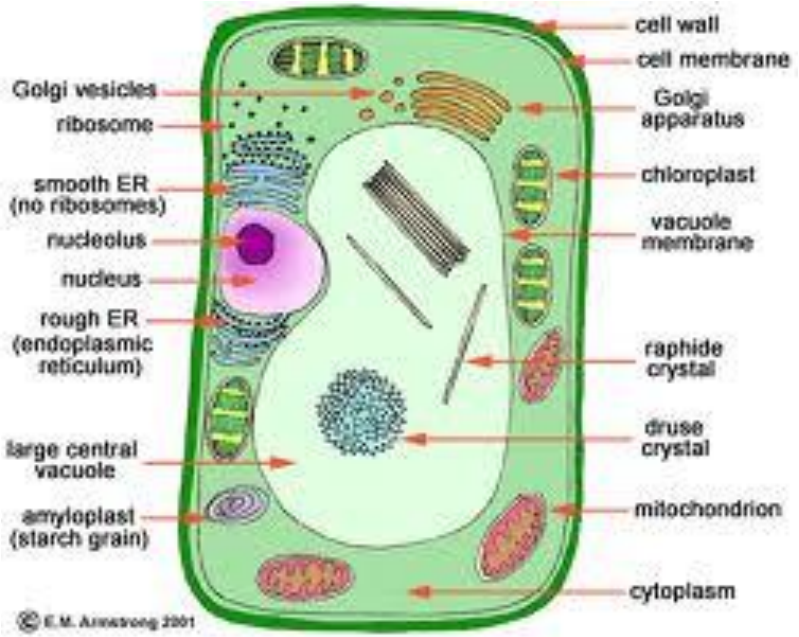
Prokaryotes and Eukaryotes

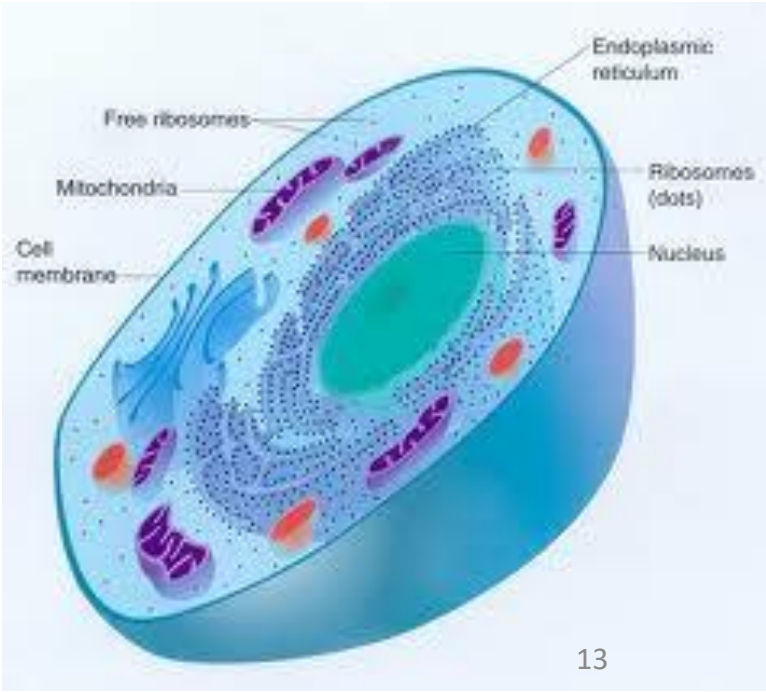


prokaryotic cell (bacteria)



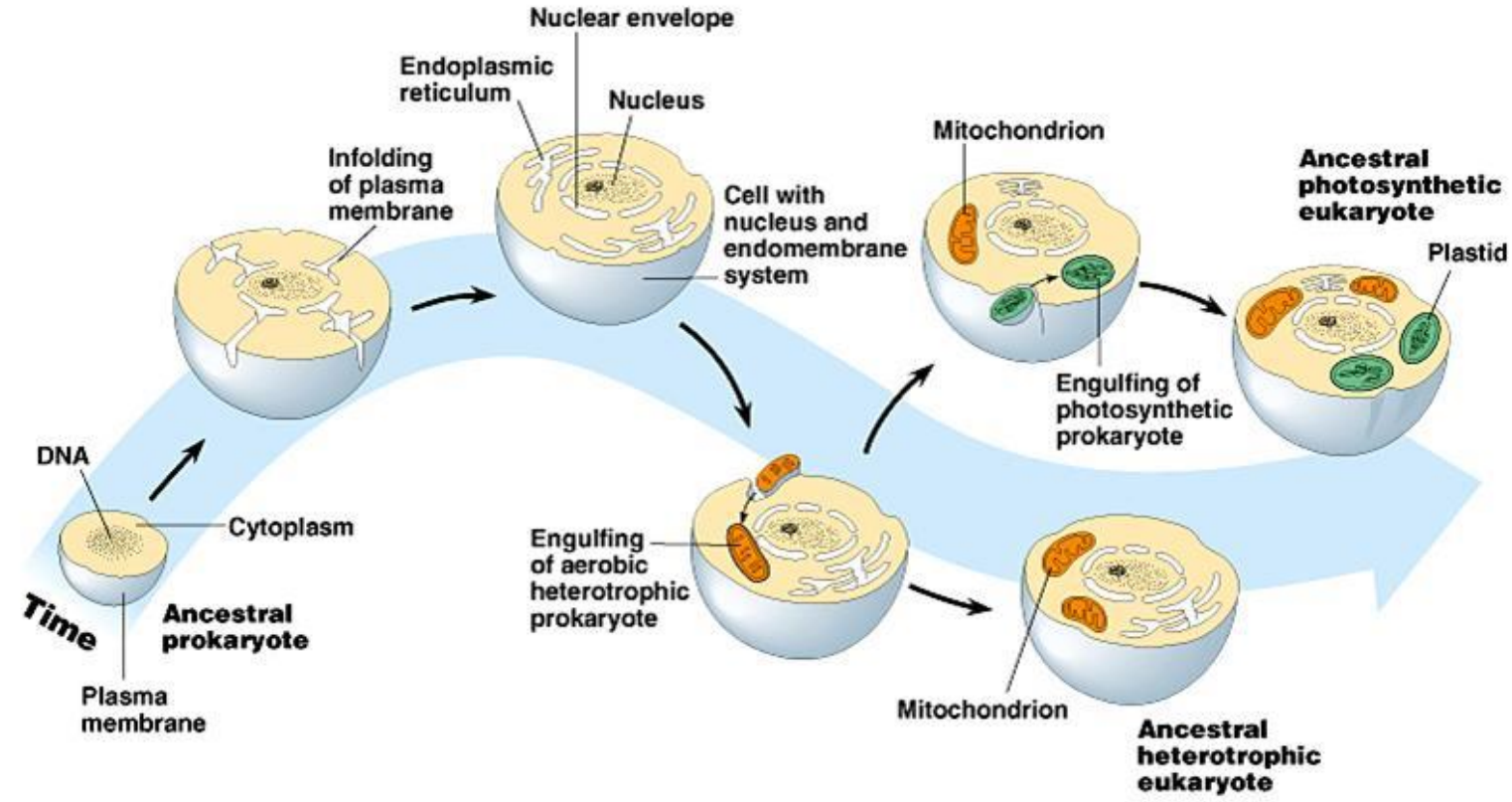
eukaryotic cell (protists, fungi, animals, plants)





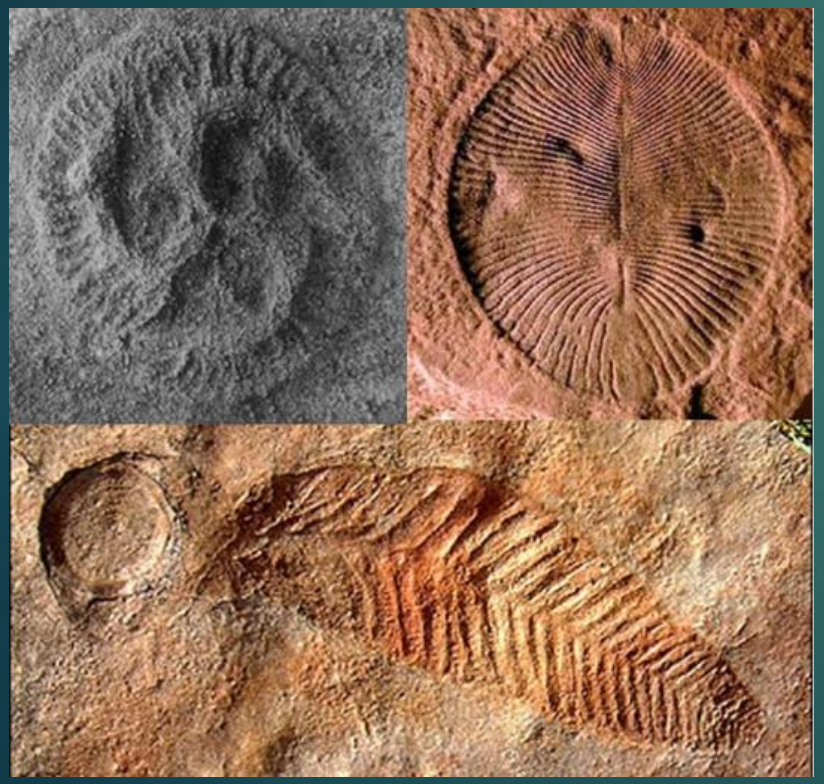
Eukaryotes: A Matter of Endosymbiosis

- Lynn Margulis originated the theory by observing that certain eukaryotic organelles (mitochondria and chloroplasts) are unique among organelles in that they have their own membrane and their own DNA and reproduce independently of the host cell.



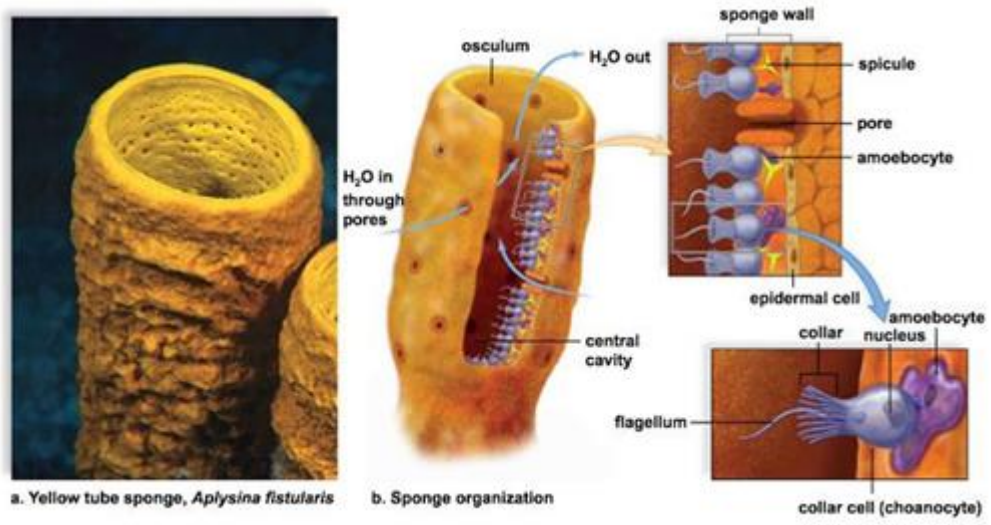
Multicellularity

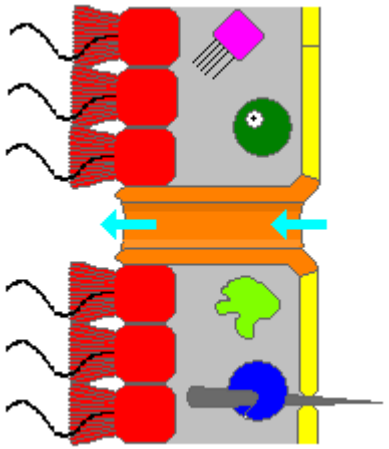
Ediacaran life: 550 MYA: Precursors to Cambrian explosion or aberrations?

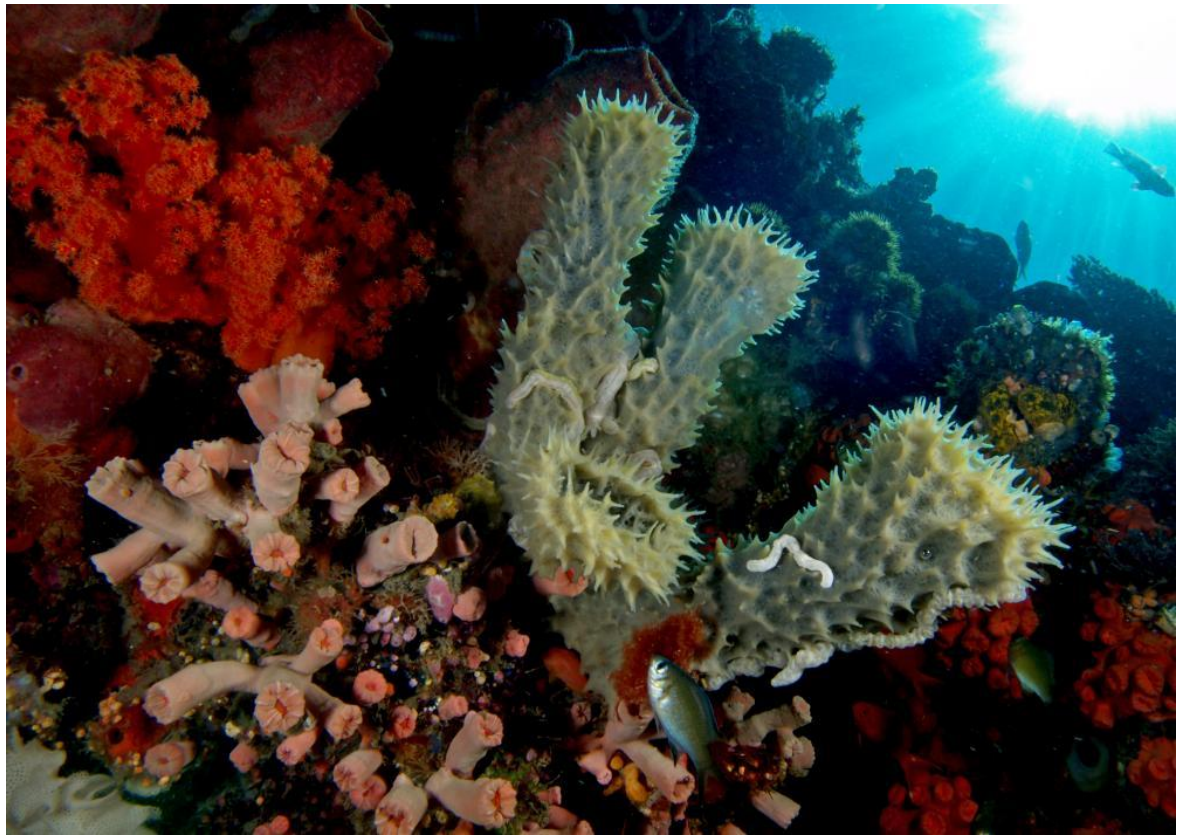


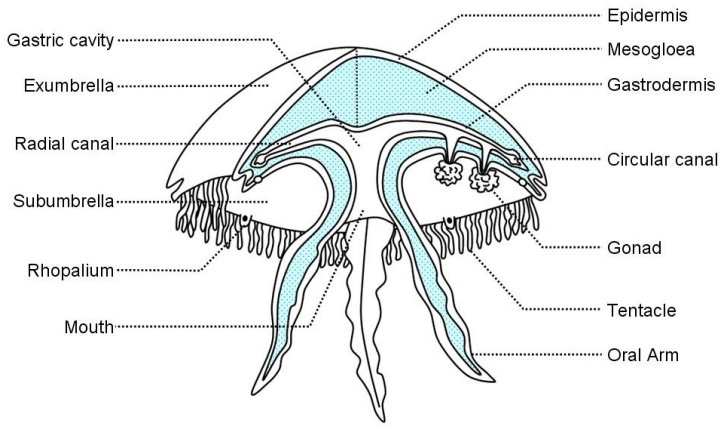
Tissues

Sponges don’t have tissues

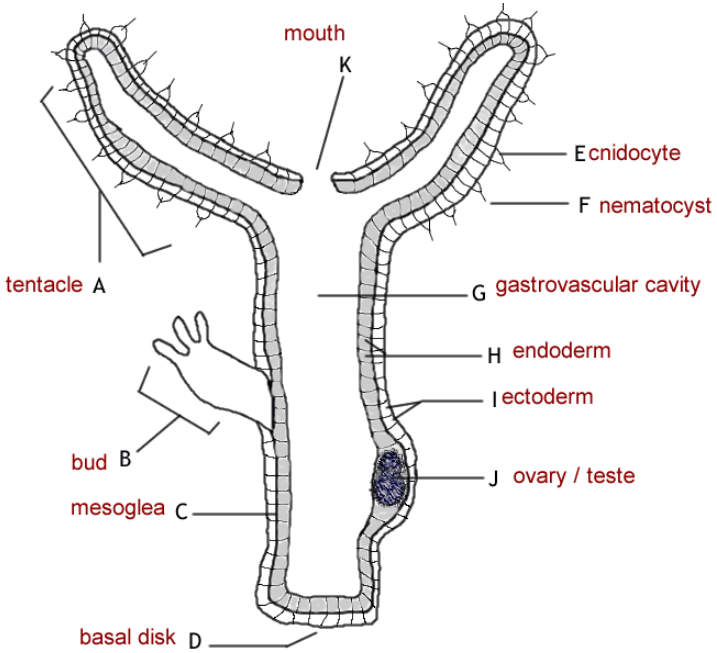


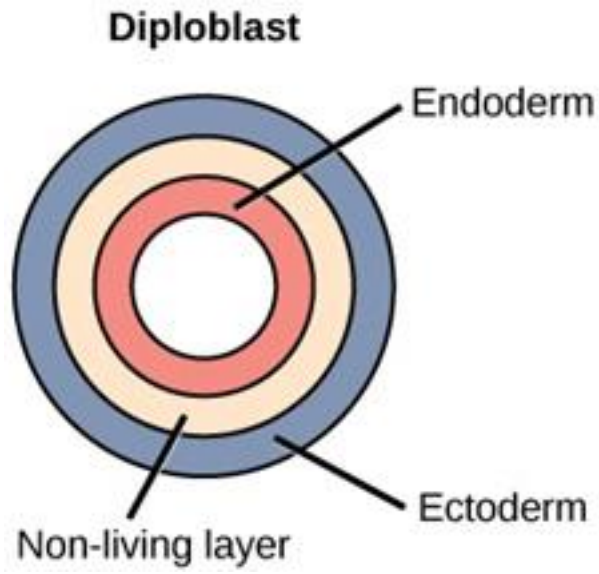




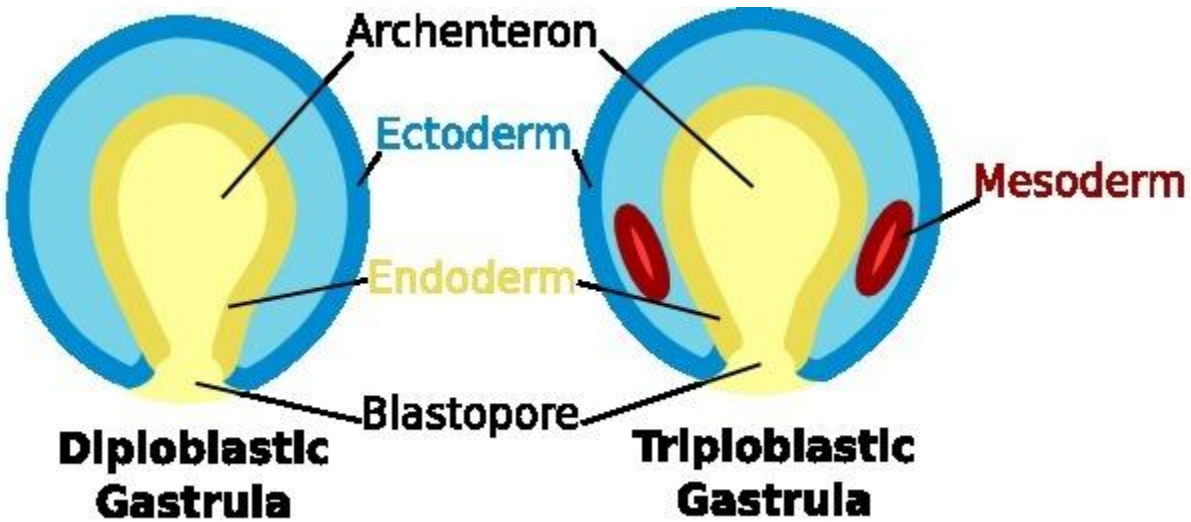


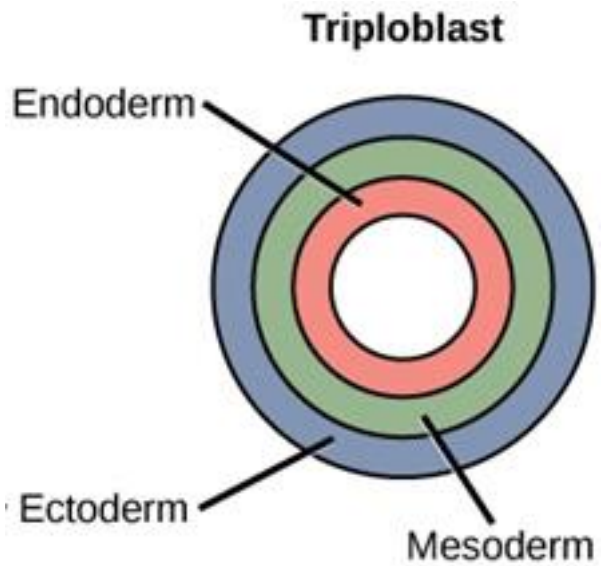
Aurelia medusa – cutaway diagram





Two tissue layers

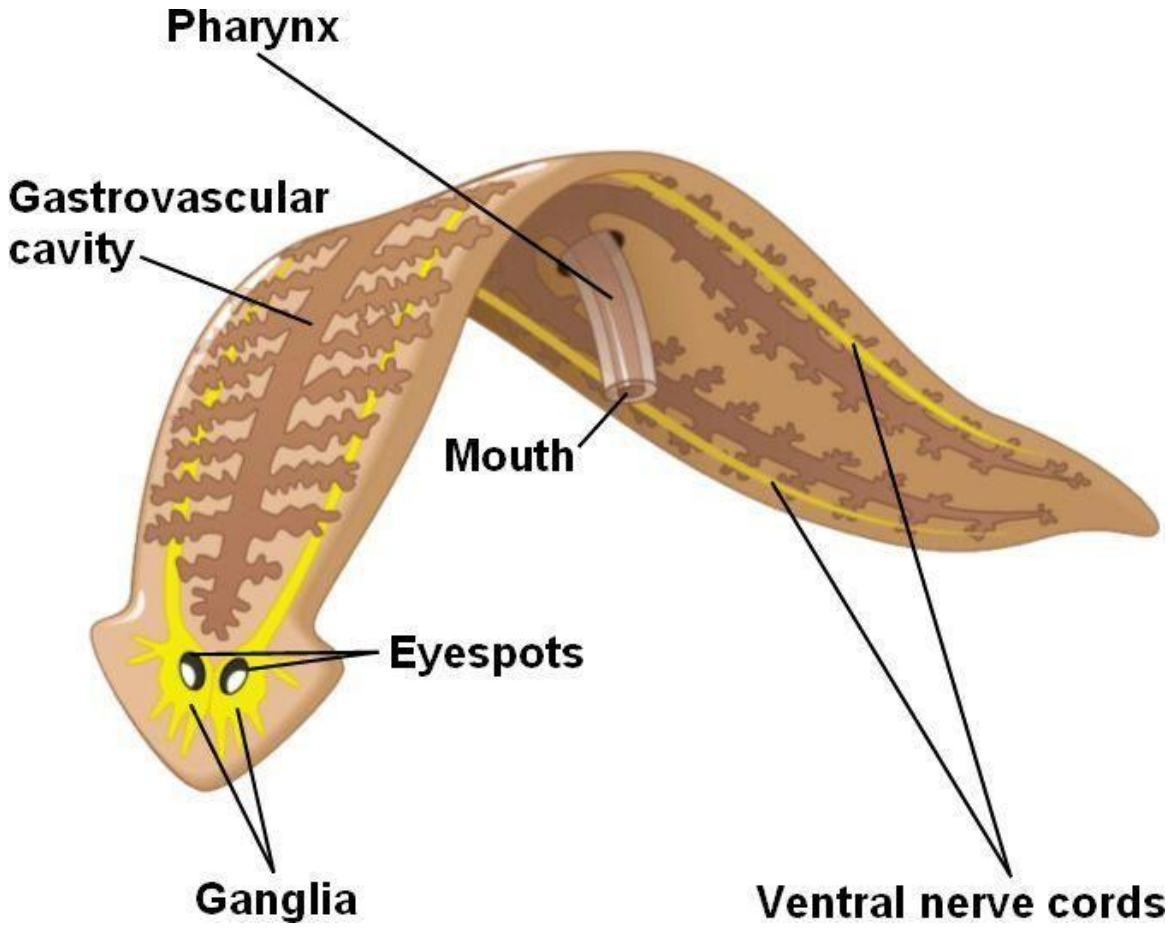


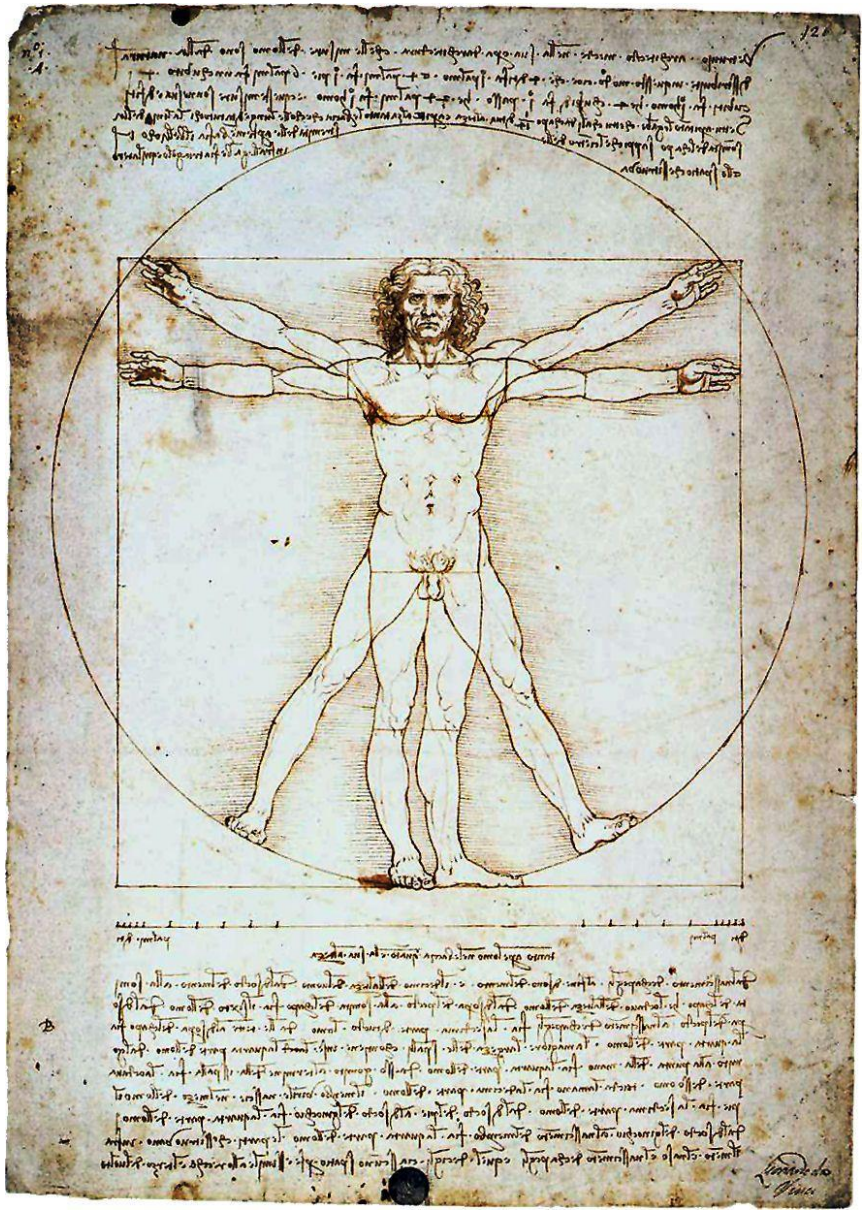


Three tissue layers

Bilateral Symmetry

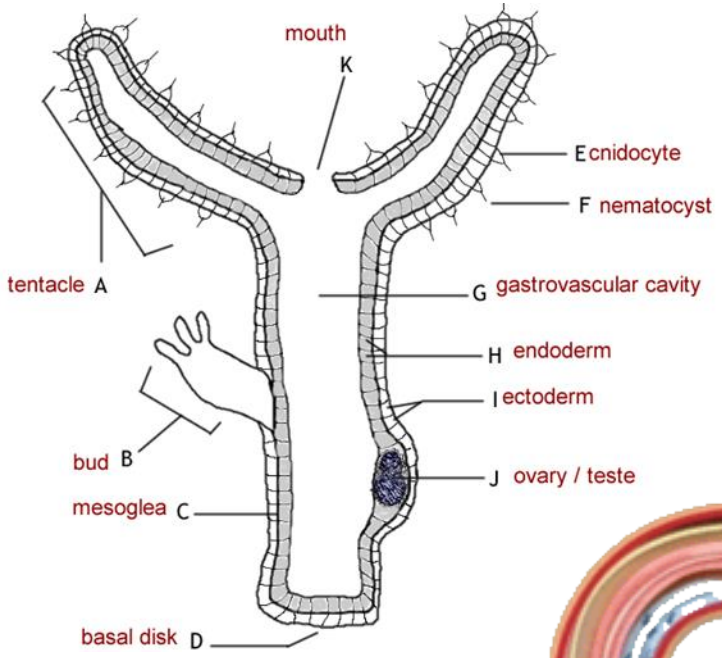
Bilateral symmetry

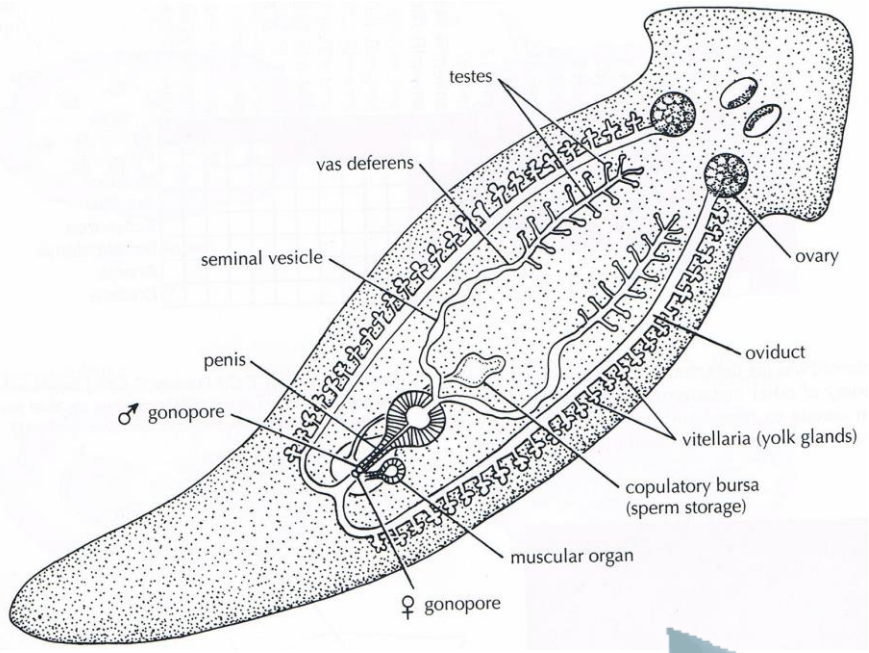


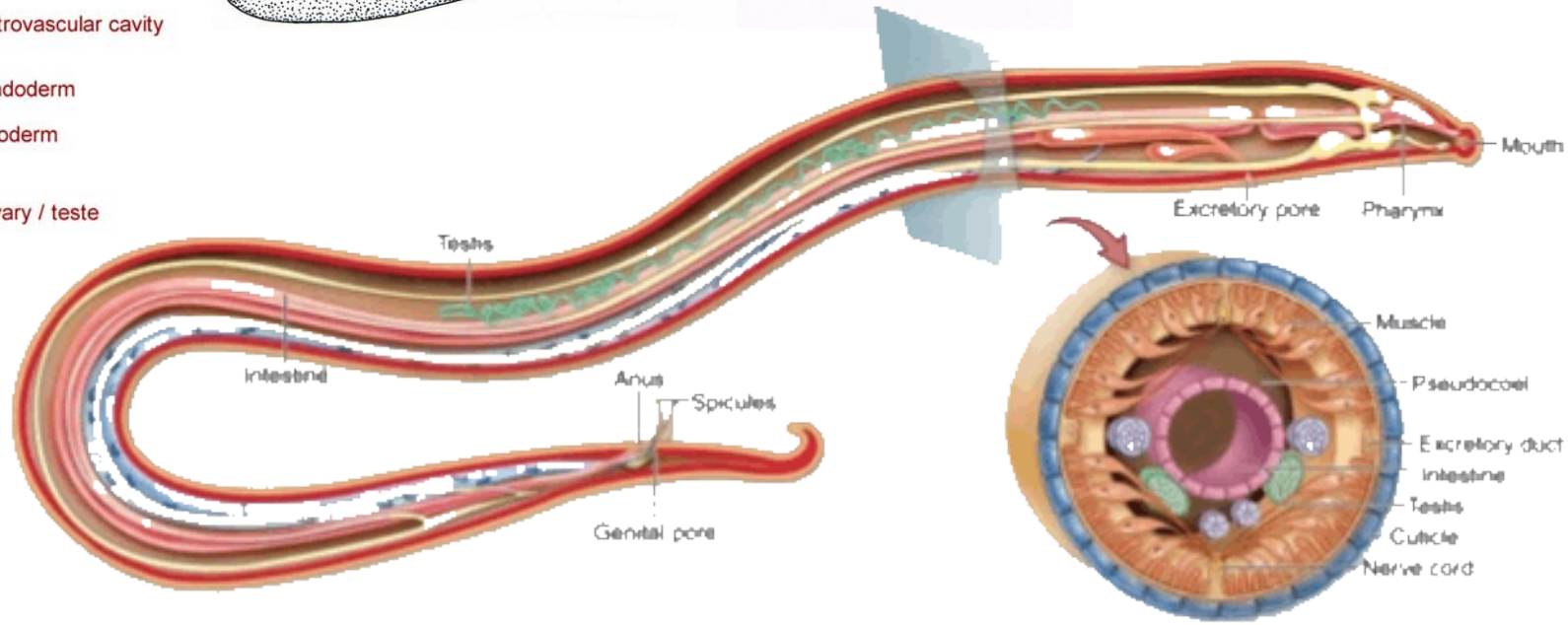


An Anus

An Anus

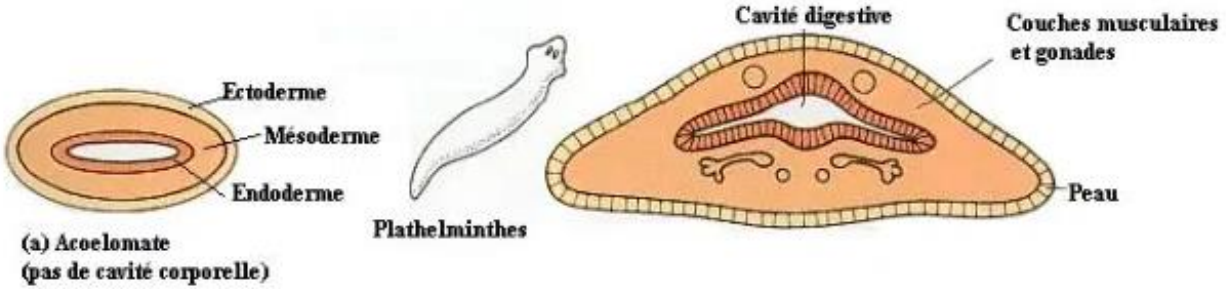

mouth
K
E cnidocyte
F nematocyst
tentacle A
G gastrovascular cavity
H endoderm
I ectoderm
bud B
J ovary / teste
mesoglea C
basal disk D

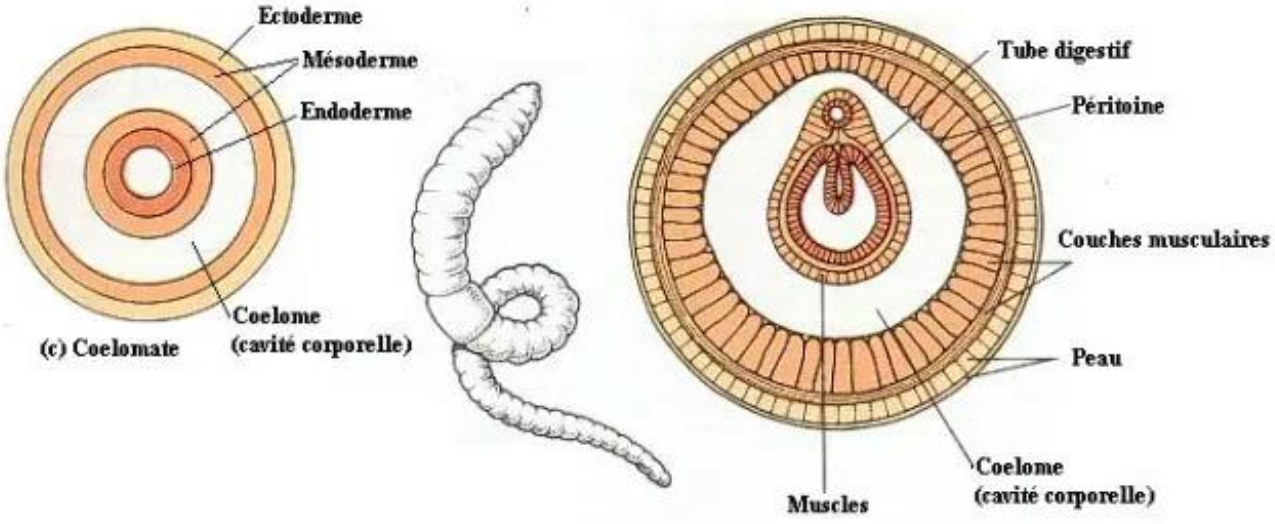

testes
vas deferens
seminal vesicle
ovary
oviduct
penis
♂ gonopore
vitellaria (yolk glands)
copulatory bursa
(sperm storage)
muscular organ
♀ gonopore

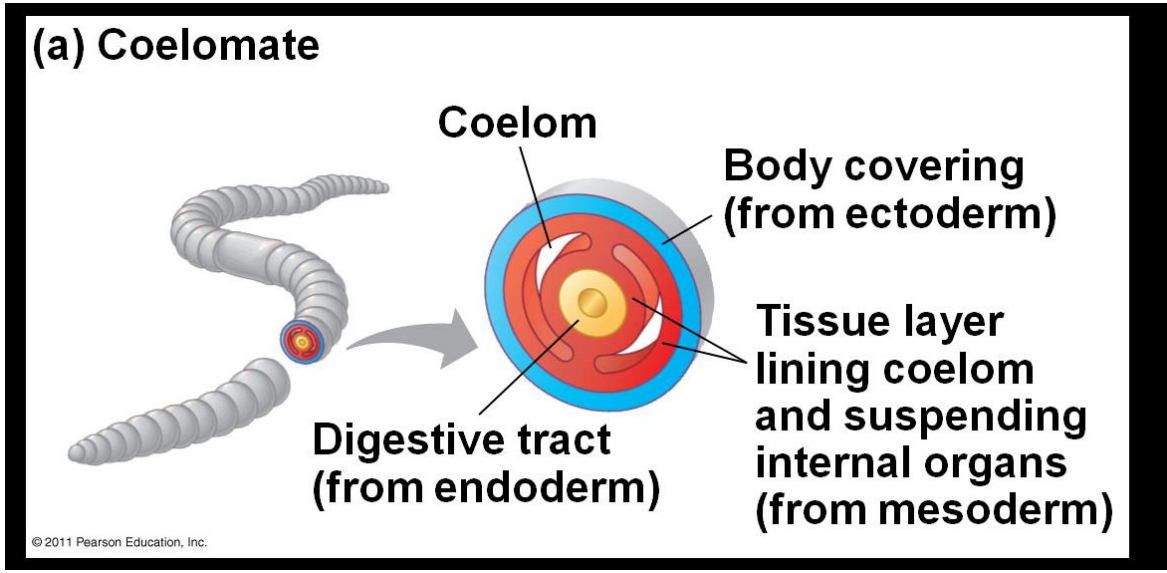

Mouth
Excretory pore
Pharynx
Testis
Intestine
Anus
Spicules
Genital pore
Muscle
Pseudocoel
Excretory duct
Intestine
Testis
Cuticle
Nerve cord

Coelomb

Coelomb


Ectoderme
Mésoderme
Endoderme
(a) Acoelomate
(pas de cavité corporelle)
Plathelminthes
Cavité digestive
Couches musculaires
et gonades
Peau


Ectoderme
Mésoderme
Endoderme
Coelome
(cavité corporelle)
(c) Coelomate
Tube digestif
Péritoine
Couches musculaires
Peau
Coelome
(cavité corporelle)
Muscles


(a) Coelomate
Coelom
Body covering
(from ectoderm)
Tissue layer
lining coelom
and suspending
internal organs
(from mesoderm)
Digestive tract
(from endoderm)
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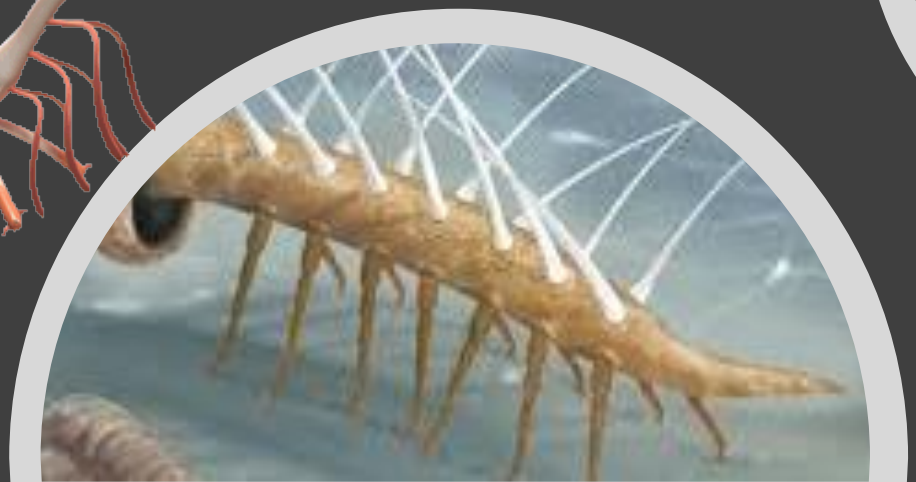
Predation

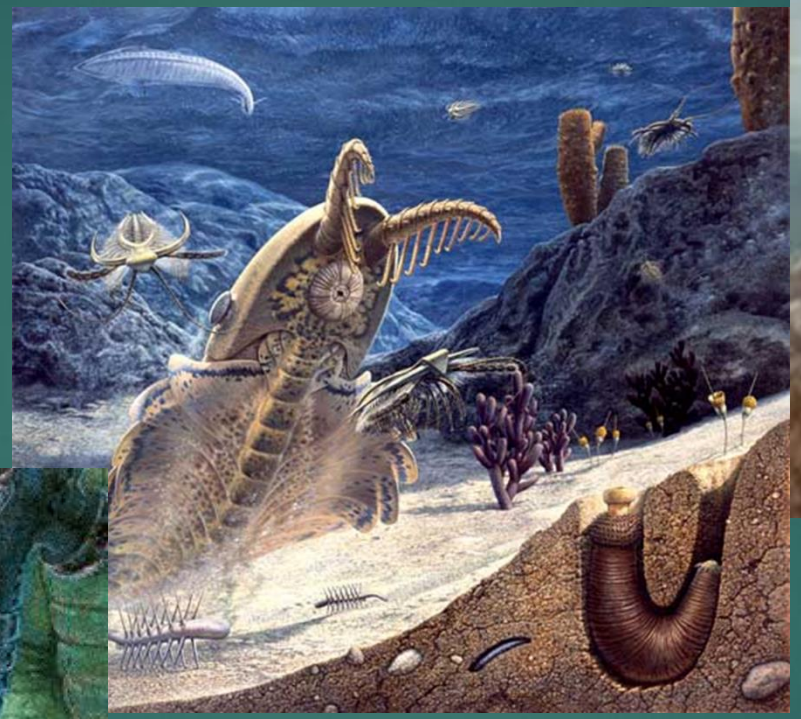
Burgess Shale

- Some 30 million years after the Ediacarans we find another strange group of animals from the Middle Cambrian. Again, these creatures seem to have left no descendants. But we've come a long way from the first eukaryotes! They are motile, active swimmers with sense organs and hard parts. We have both predators and prey, a powerful driving force of evolution.

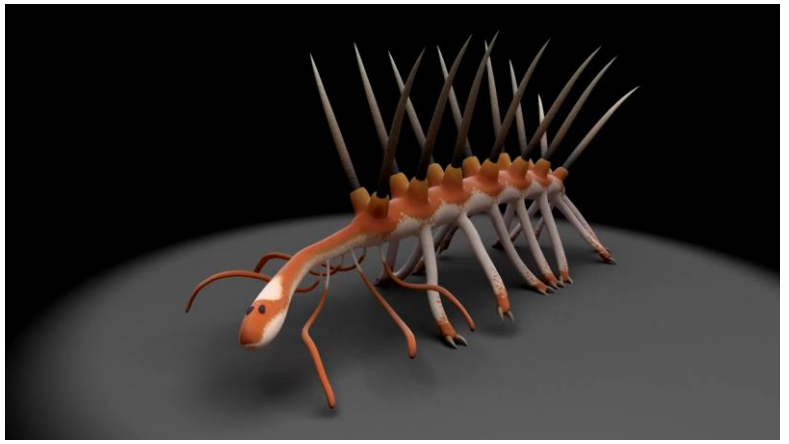


Cambrian Burgess Shale Organisms: Another False start??

ca 505 Million Years Ago



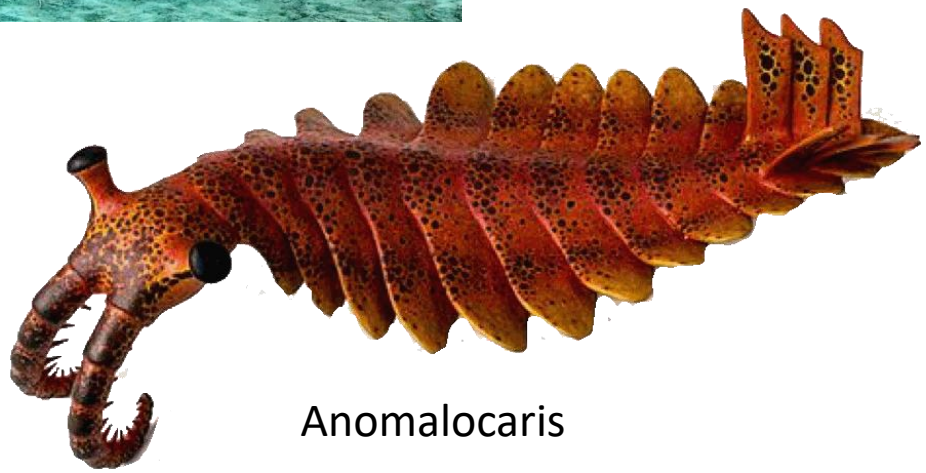
Invertebrates of the Cambrian



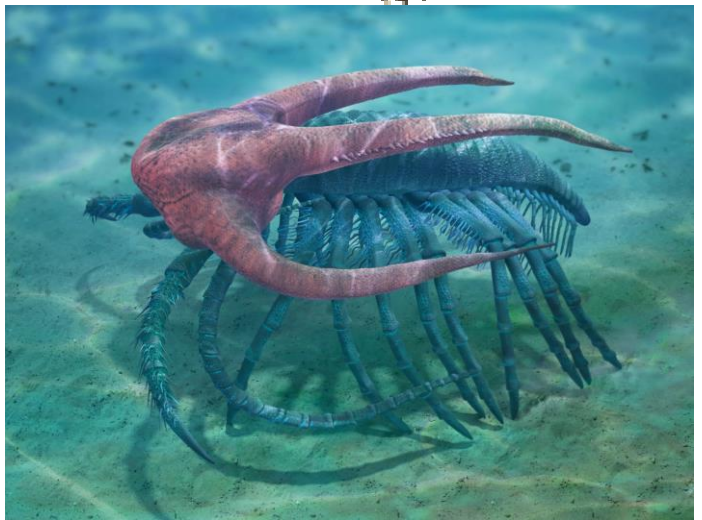
Hallucigenia

Wiwaxia

Opabina



Anomalocaris



Marrella

Other major invertebrates of the Cambrian

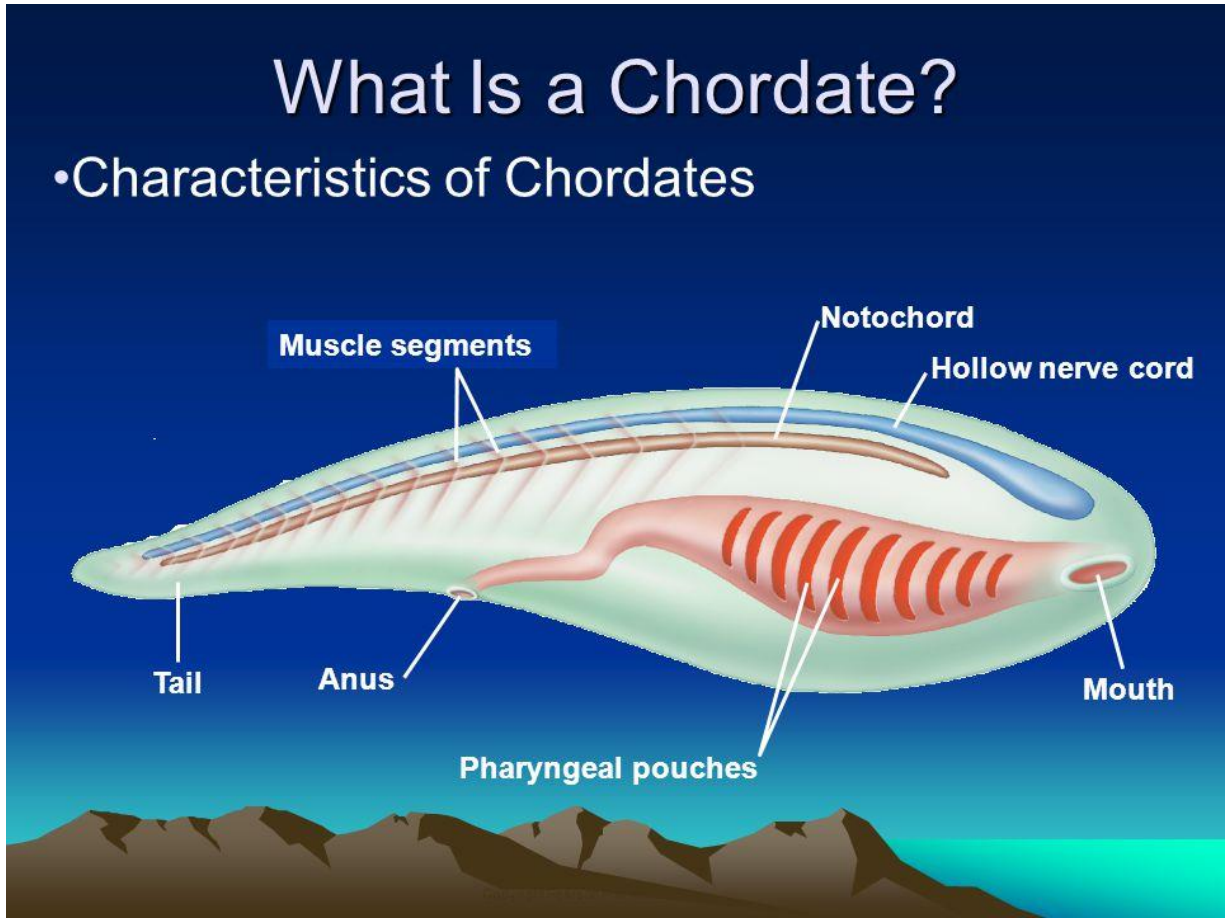
Cambrian: the Age of the Trilobites

- Perhaps the most charismatic animal of the early Cambrian is the Trilobite
- First appear in the fossil record around 521 MYA, and lasted until a major extinction at the end of the Permian, 252MYA, a run of nearly 300 million years.
- They are the earliest known arthropods.
- Trilobites had many lifestyles; some moved over the sea bed as predators, scavengers, or filter feeders, and some swam, feeding on plankton.
- Over 50,000 species are recognized
- They are probably most closely related to spiders (like horseshoe crabs).

Internal Skeleton (Chordates and Vertebrates)

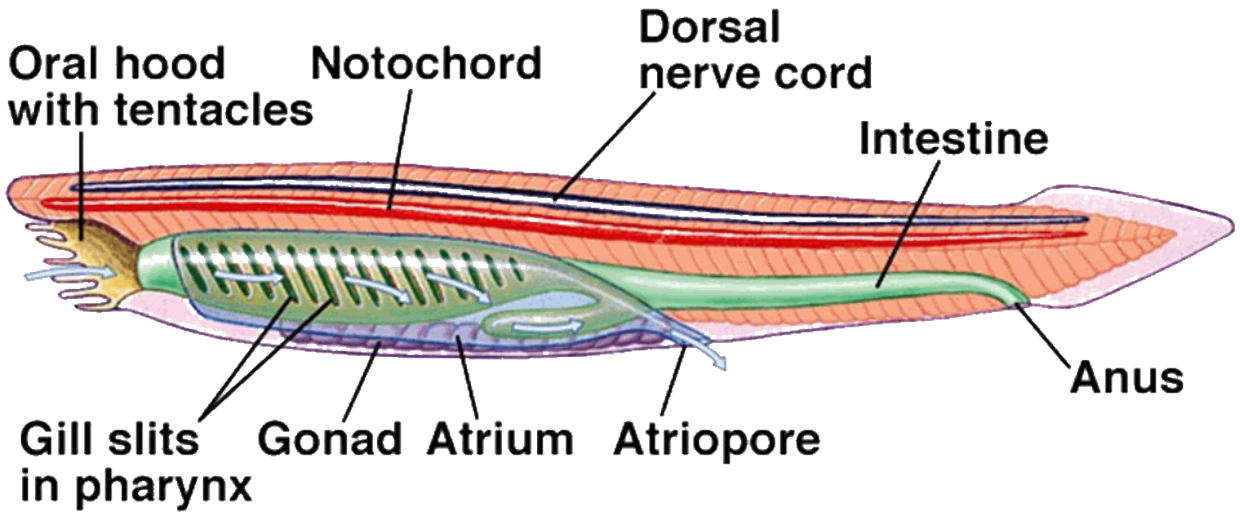
The First Chordates (Phylum Chordata)

- Chordates (our phylum) first appeared in the Cambrian, 525MYA.



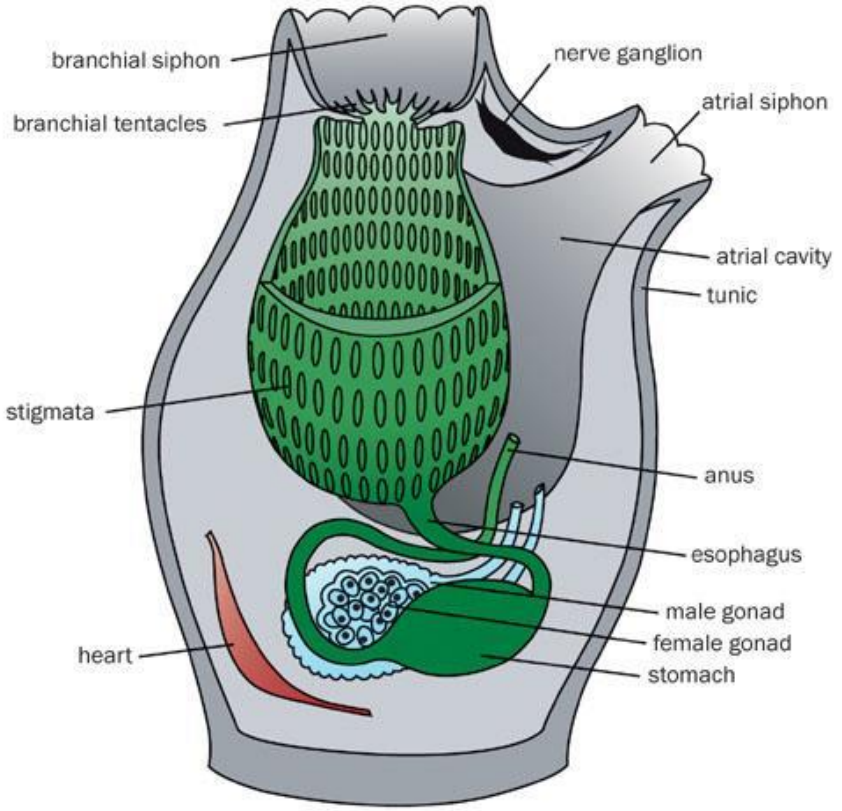
Invertebrates, Chordates and Vertebrates

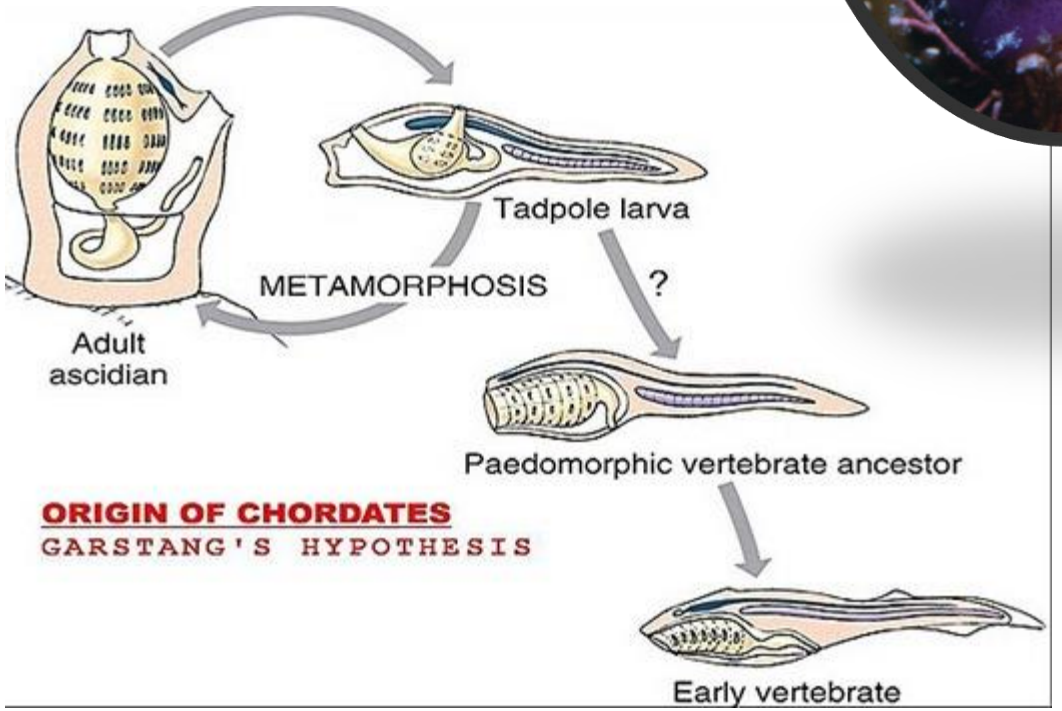
- Invertebrates are all animals that are not chordates
  - Generally, invertebrates, if they have hearts, have dorsal hearts; if they have a nervous system it is usually ventral.
- All vertebrates are chordates, but not all chordates are vertebrates.
  - Chordates:
    - Dorsal notochord
    - Dorsal nerve chord
    - Ventral heart
    - Post-anal tail
  - Vertebrates:
    - Dorsal spinal column (articulated) and skeleton

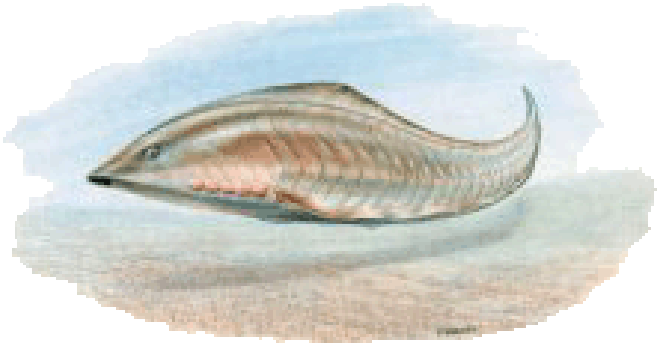


Amphioxus: archetypal chordate

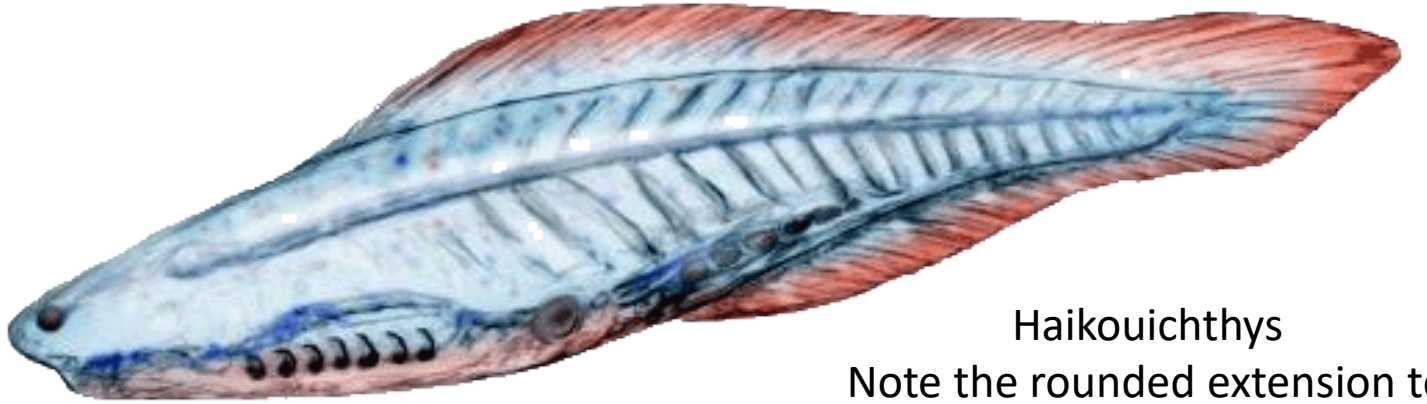
Origin of the Chordates



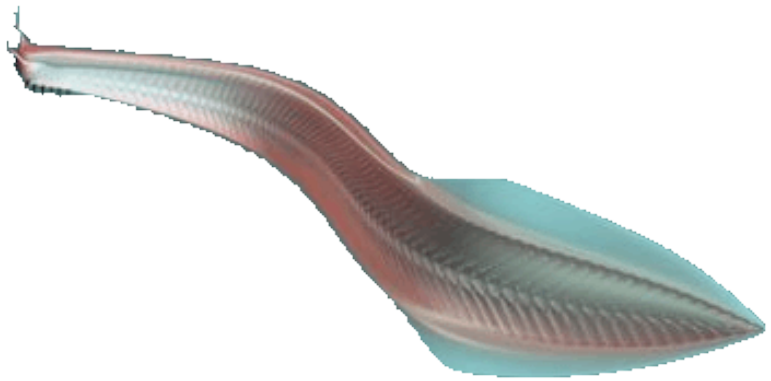




Myllokunmingia
Possibly the oldest vertebrate: showed gill bars and primitive vertebral elements



Haikouichthys
Note the rounded extension to the head bearing sensory organs



Pikaia
Primitive chordate, similar to Amphioxus

Early and primitive agnathan vertebrates of the Early Cambrian (530MYA)

Note: these organisms were less than an inch long.

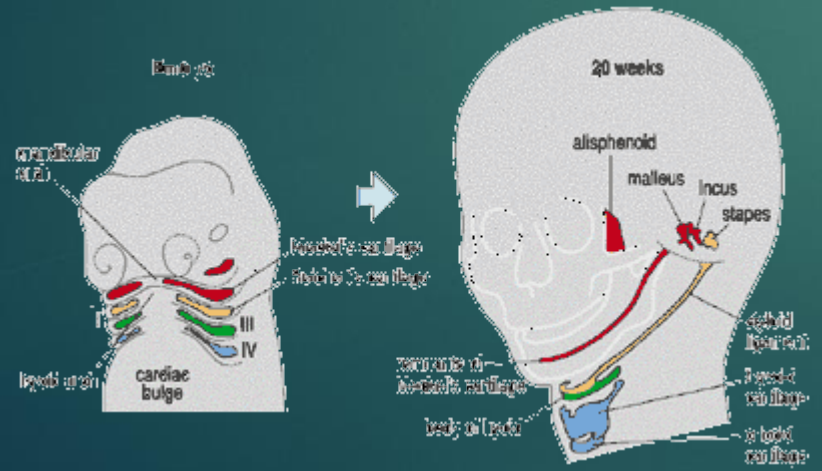
Vertebrates of the Silurian

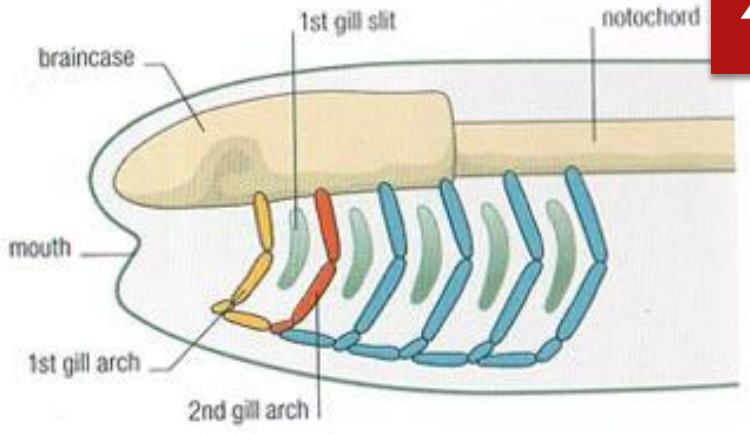
By the end of the Cambrian fish had arisen. They were jawless fish called conodonts. As the Ordovician progressed, heavily armored fish called placoderms appeared. Some placoderms reached 30 feet long. By the Silurian fish had developed jaws.

Jaws

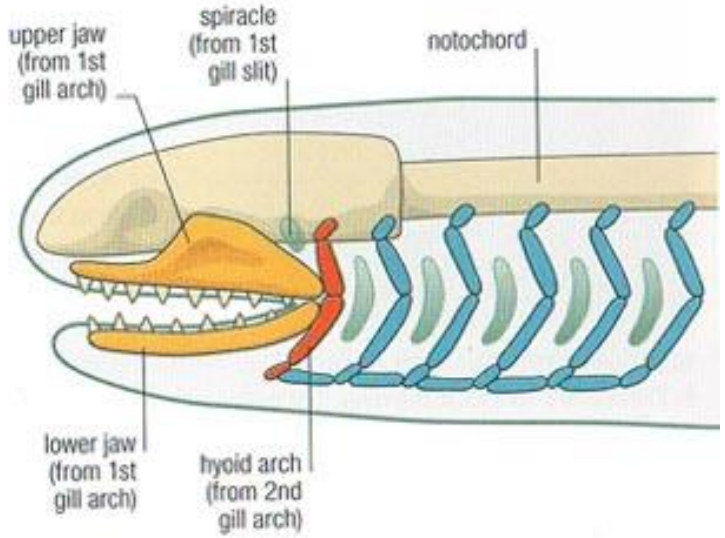
Evolution of Jaws

- By the Silurian, some 440 MYA, the early gill arches of fish had evolved into jaws, a major advance in predation.
- These gill arches today form your middle ear bones.





AGNATHOUS (JAWLESS) VERTEBRATE

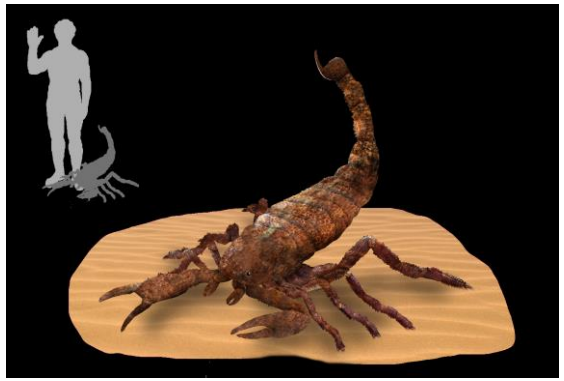


GNATHOSTOME (JAWED) VERTEBRATE

Migration from Sea to Land

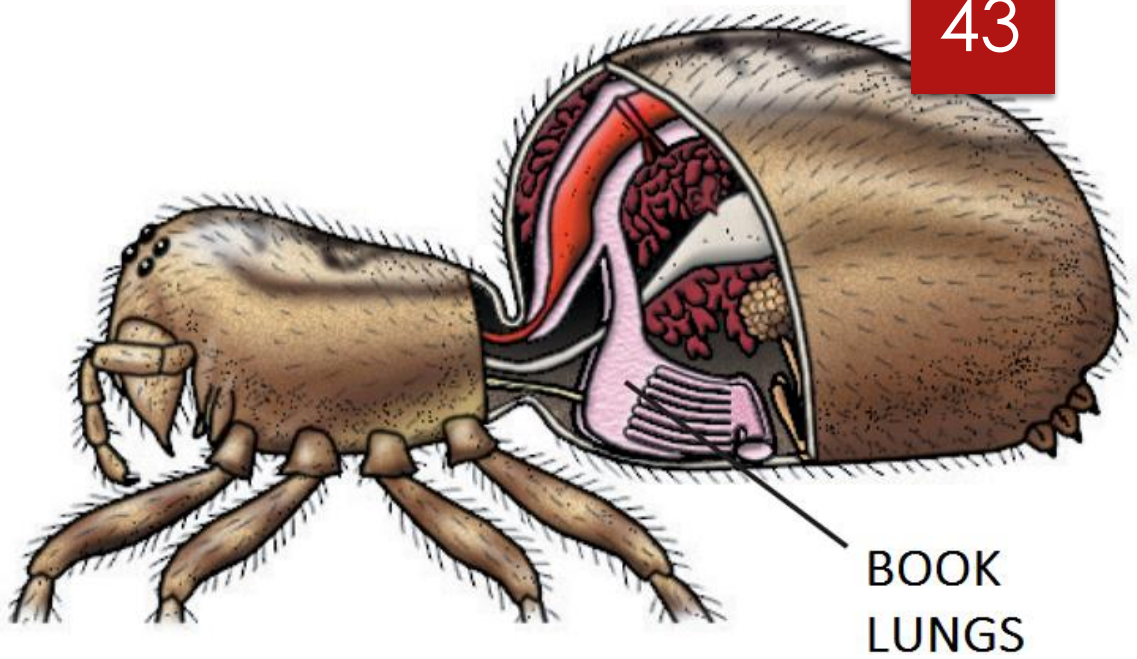
Invasion of the Land

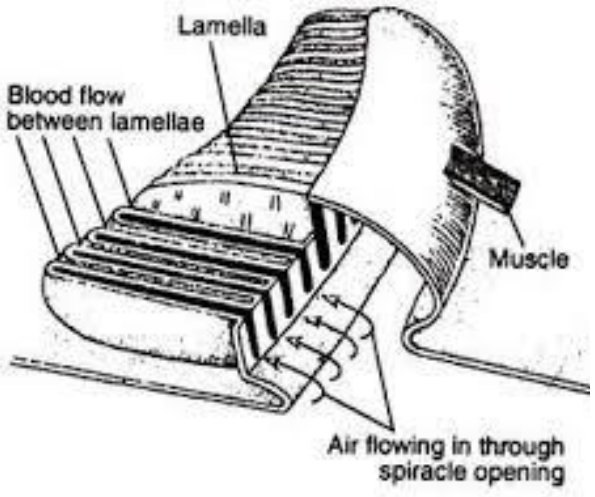
- The first terrestrial animals were arthropods: centipedes, millipedes and scorpions (arachnids).
- While land plants provided food, the main problems to be overcome were desiccation and gravity.



Arthropod Adaptations to Land

- Desiccation: chitinous exoskeleton
- Respiration: book lungs
- Mobility: jointed legs





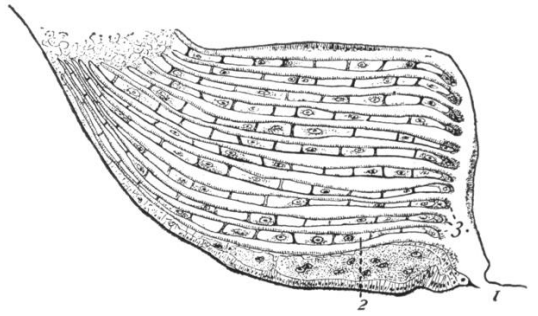
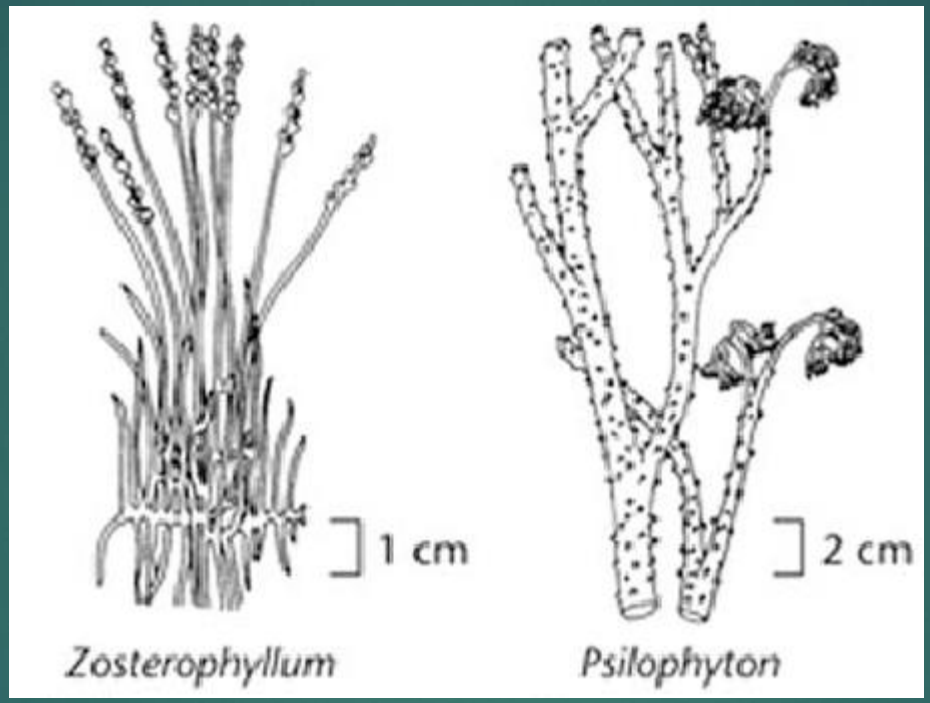


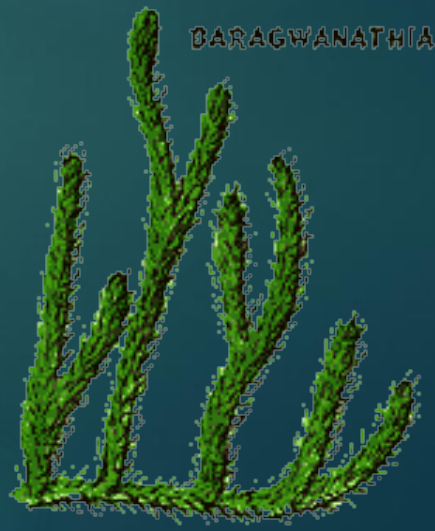
Fig. 18.111: Sectional view of a book-lung.

Plants of the Silurian

Cooksonia date from the middle of the Silurian until the end of the Early Devonian.



Rhyniophytes



The Silurian saw the emergence of vascular land plants. They are considered to have arisen in fresh-water, where algae developed spores to allow pool-to-pool dispersion. Most were only a few centimeters high and confined to wet areas.

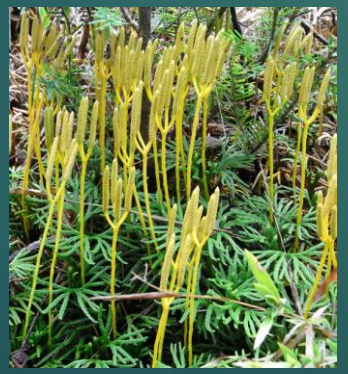
Plants of the Carboniferous

- For the first 10 million years (350-340 MYA) lycophytes and seed ferns dominate coastal swamps; Horsetails lined streams, along with sphenopsids.
- By 320 MYA conifers and glossopterids appear; lianas and epiphytes appear in forests dominated by lycopsids, cordalites and seed plants. Small ferns provide ground cover (no grasses).

glossopterid

cordaite

Carboniferous lycophyte



Modern lycophyte

lycopsids

Carboniferous horsetail

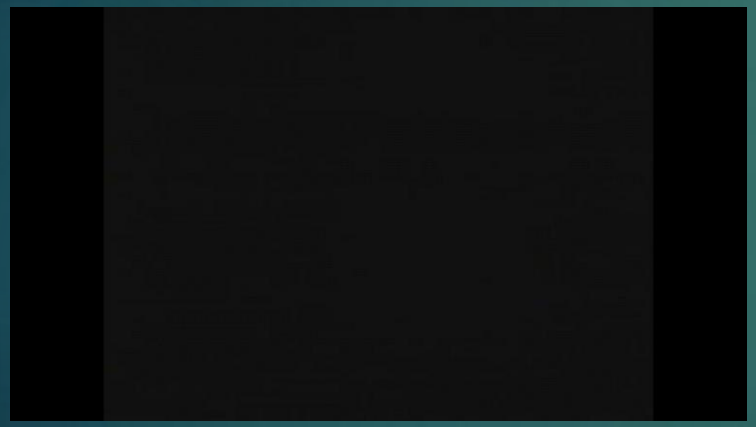
Animals of the Carboniferous

EarlyTetrapods Explore Mississippian Riverbanks
Acanthostega (foreground) and Ichthyostegans

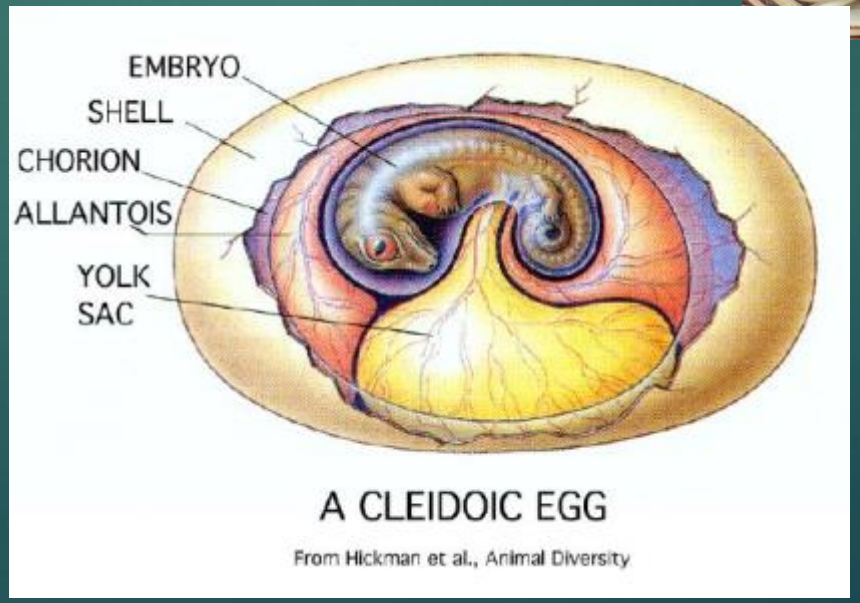
The Cleidoic Egg

Rise of the Reptiles: Cleidoic Egg

A major adaptation for terrestrial living, the cleidoic egg arose in the Carboniferous. It enabled reptiles to become completely independent of water for reproduction.



Amphibian (frog) development



Homeothermy

Rise of the Mammals

- The first amniotes arose in the middle Carboniferous. Within a few million years, two important amniote lineages became distinct: synapsids from which mammals descended, and diapsids from which lizards, snakes, crocodilians, dinosaurs, and birds are descended. The earliest known fossils of synapsids date from about 320 to 315 million years ago.

Lystrosaurus, 200 MYA

The Cenozoic: The Age of Mammals

- The Cenozoic began in a "nuclear winter", cold in dark, with only 5% of species left alive to repopulate a dark and cold earth.
- By the Paleogene the temperature had warmed to 55°C, with tropical forests and deserts inland.
- Later in the Neogene the climate cooled, leading to large furry mammals like the wooly mammoth.
- The Quaternary (present period) has been characterized by a series of glaciations.

Mammals of the Paleogene, 65 to 23 MYA

coryphodon

uintatherium

Andrewsarchus

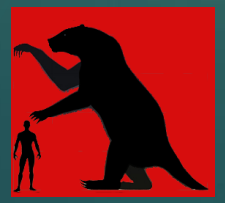
arsinoitherium

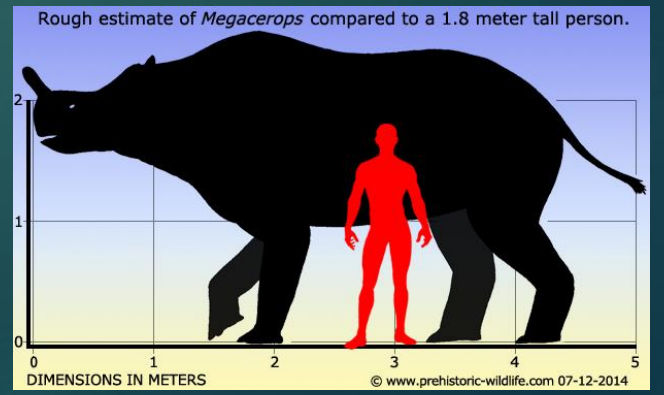
Mammals of the Paleogene

Magistotherium

megacerops

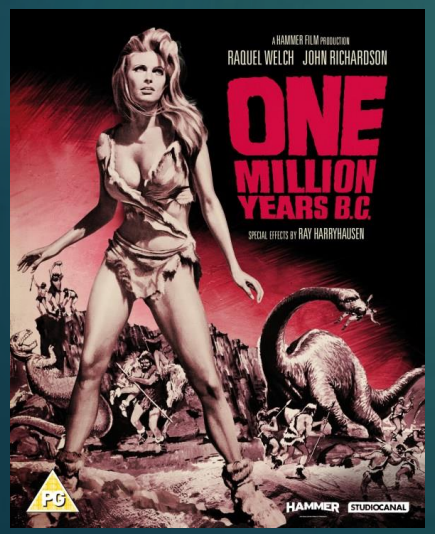
megatherium





Megafauna of the Pleistocene

2,580,000 to 11,700 years ago,



What's Next??

We haven't stopped evolving, so where might we go from here?

Will our destiny be governed by natural selection or by genetic engineering?

Do we guide our development or let "nature take its course?