Milestones in Life's Evolution

1.Formation first life

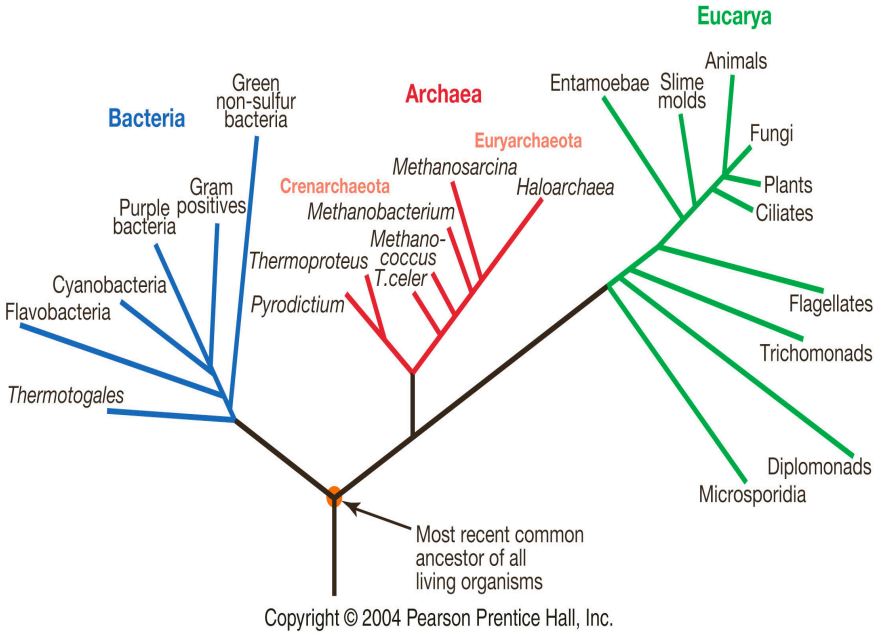
2. Diversification of life-lateral gene transfer

3. Evolution Eukaryotes-symbiosis

4. Evolution of metazoans

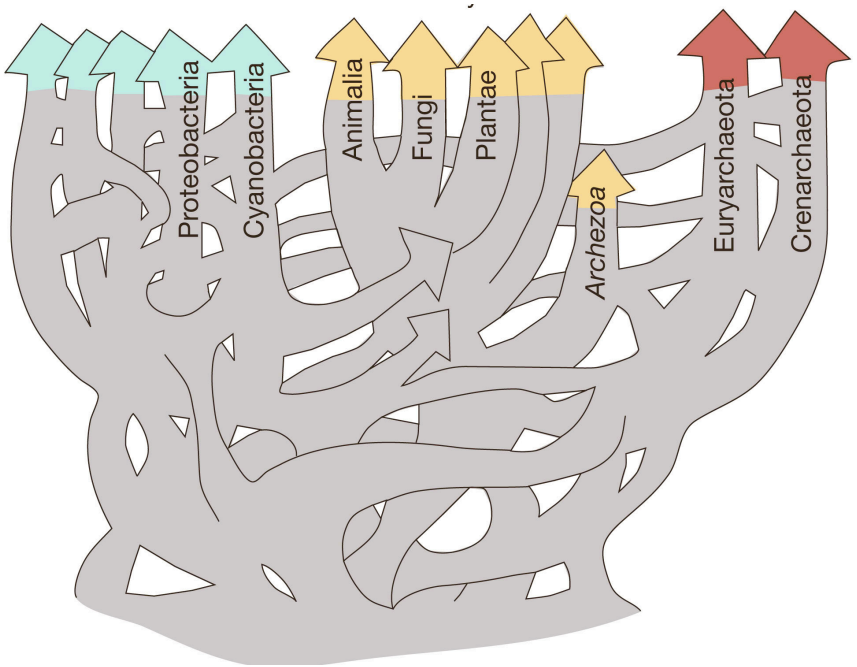
5. Ediacarans

6. Cambrian Explosion and formation of phyla



Horizontal Gene Transfer

Making a mockery of traditional views on microbial genetics - and trees?



There was a long time when not much happened

Origin of life - 3.5 billion bp?

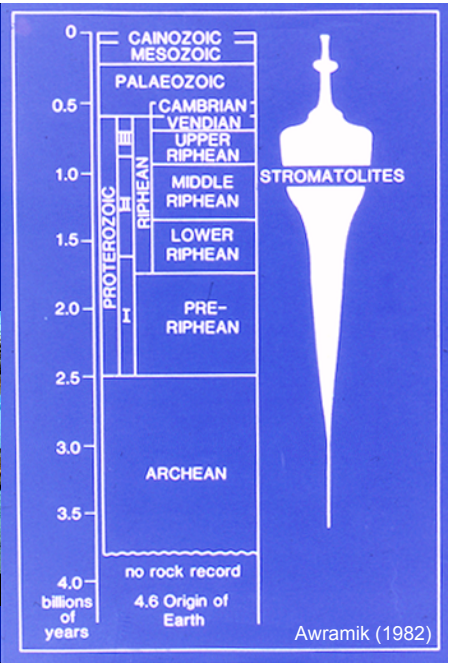
Origin of Eucaryotes - 2.2 billion bp?

Origin of metazoans - 700 million bp?

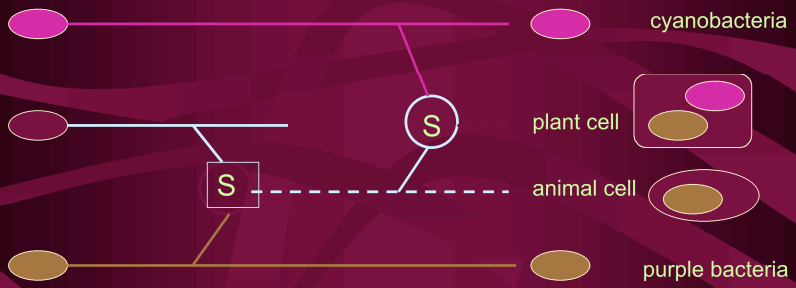
Neoproterozoic

- Few animals
- Some horizontal burrowing
- Microbialites, precipitates
- BIFS
- Equatorial glacial tillites

Stromatolites
Shark Bay, Aust.



Serial Endosymbiosis Hypothesis (Lynn Margulis)



Evidence for Origin of Mitochondia and Chloroplasts As "Slave Bacteria"

Mitochondria and Chloroplasts are of similar size as bacteria.

Mitochondria and Chloroplasts have complex double membrane systems, similar to bacteria.

Mitochondria and Chloroplasts are somewhat self-contained, as if they derived from functional cells.

Mitochondria and Chloroplasts divide by binary fission, similar to bacteria.

Biologists are almost certain that eukaryotes evolved from prokaryotes because:

1. **Both use RNA and DNA are the genetic material**
2. **Both use the same 20 amino acids**
3. **Both have ribosomes and DNA and RNA**
4. **Both have a lipid bilayer cell membrane.**
5. **Both use L amino acids and D sugars**

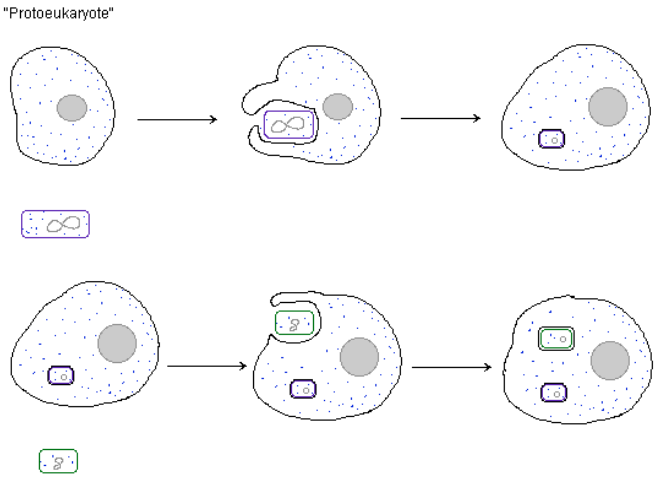
Biologists are also almost certain that eukaryotes evolved only once (i.e., are monophyletic- descendants of a single common ancestor) Because they all share:

1. microtubules (composed of the protein tubulin) and actin molecules-

* **cytoskeleton for support or intracellular transport.-**
* **flagella (or cilia)**

2. DNA in chromosomes (intertwined with histone protein)
3. membrane-bound organelles.

Endosymbiosis - Origin of Mitochondria and Chloroplasts



Some of these cells also engulf and keep blue-green algal cells which become chloroplasts.

When did metazoans first appear?

18S rDNA studies strongly indicate that "Porifera" is paraphyletic. This suggests that the last common ancestor of all living animals, estimated by molecular clocks to have evolved ~ 650 mya, was benthic and suspension fed, primarily upon bacteria.

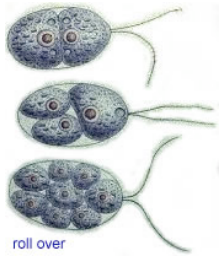
Oldest Known Eukaryote Fossils:
Grypania spiralis
carbonized algal structures 2 mm wide and 10 cm long
Found in rocks 2.1 Ga in Michigan and
abundantly in rocks 1.4 Ga in China, Montana and Michigan

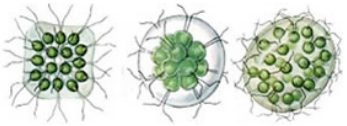
The slime molds are **temporary metazoans**.

The steps to true metazoans remain to be completed defined, but an important event is the development of permanent adhesions and distinct cell types.

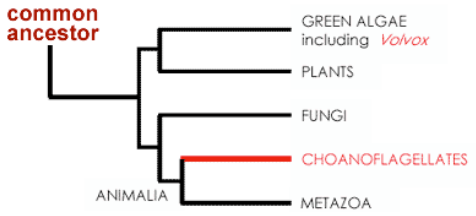
There are a number of **colonial eukaryotes** that contain multiple cell types; specifically cells that possess a motile **flagella** and those that do not.

The flagellum is a motile organelle that is used to move the organism or to move fluid around the organism.





These cells are held together by a gelatinous matrix into loose colonial groups.



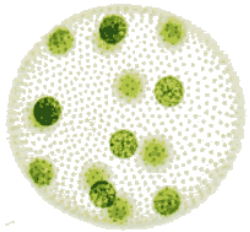
These organisms have cells that are characterized by a single **flagellum** surrounded by a distinctive **collar**.

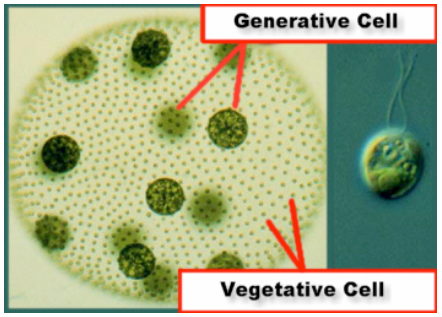
Choanoflagellates can exist in simple colonial forms.

The collar cells are located on the periphery of cell aggregate, while ameobiod cells are located in the interior.

The most primitive metazoans, the sponges or **porifera**, contain cells that are very similar in structure to choanoflagellate

They can be regularly organized, as in a *Volvox*.





They can reproduce asexually, by forming daughter colonies that develop within the mother.

There is also a sexual cycle, mediated by the formation and fusion of gametes.

When did metazoans first appear (genetic approach)

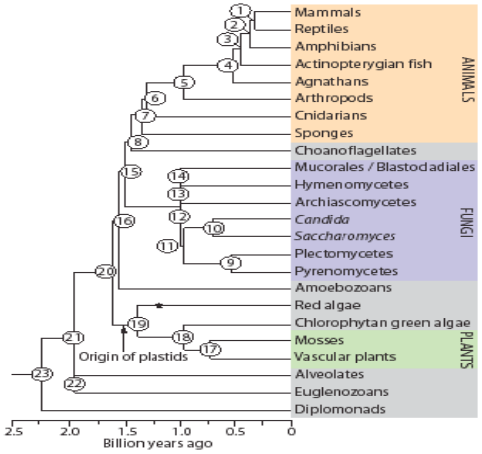


Figure 2
A timescale of eukaryote evolution. The times for each node are taken from the summary times in Table 1, except for nodes 1 (310 Ma), 2 (360 Ma), 3 (450 Ma), and 4 (520 Ma), which are from the fossil record [25]; nodes 8 (1450 Ma) and 16 (1587 Ma) are phylogenetically constrained and

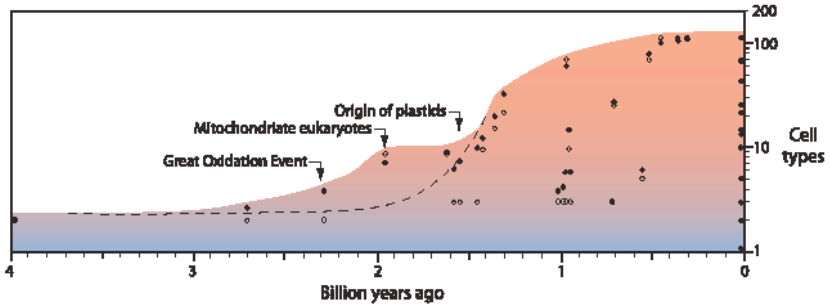
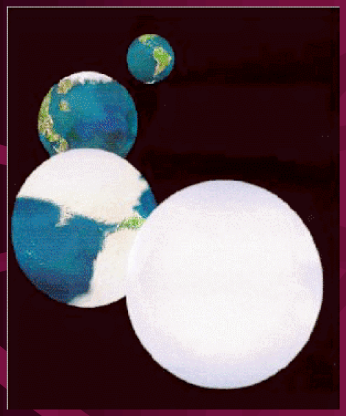


Figure 3
Increase in the maximum number of cell types throughout the history of life. Data points at time zero are from living taxa [1-3,50]; earlier data points were estimated with squared-change parsimony (solid circles) and linear parsimony (hollow circles) [51] using the molecular timetree (Fig. 2). The origin of life and divergence of archaebacteria and eubacteria were set at 4000 Ma and the origin of eukaryotes at 2700 Ma [27,28], although earlier values for those events would not affect the overall trend. We follow McShea [4] in using maximum values at any given time and assuming that decreases do not occur. Dashed line shows an alternate (conservative) interpretation based on uncertainty as to the level of complexity of ancestors of early branching eukaryotes.

The Snowball Earth

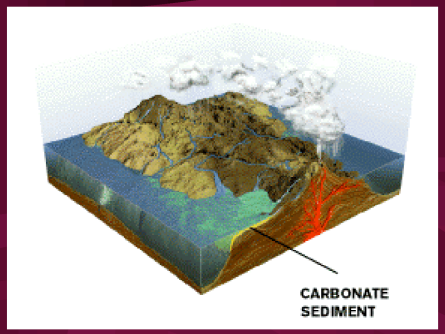


Snowball Earth Model:
Runaway Icehouse Effect
Paul Hoffman and Daniel Schrag, 1998

In most extreme scenario, almost entire Earth frozen Over

Up to 4 major snowball events between 750 and 580 Ma

From Freeze to Fry



As tropical oceans thaw, seawater evaporates and works along with carbon dioxide to produce even more intense greenhouse conditions.
Surface temperatures soar to more than 50 ºC driving an intense cycle of evaporation and rainfall.
Torrents of carbonic acid rain erode the rock debris left in the wake of the retreating glaciers.
Swollen rivers wash bicarbonate and other ions into the oceans, where they form carbonate sediment.

Possibilities/questions posed by timing of earliest complex metazoan and Snowball Earth

1. Metazoans evolved from unicellular eukaryotes REALLY fast (580 to 575 million years provides only 5 million years for this to occur)

2. Metazoans evolved before or during Snowball Earth (perhaps just no record up until 575 Ma) ?
   If so, how did they survive on ice-covered Earth ?

3. Perhaps Snowball Earth wasn't as severe as originally asserted by Hoffman and Schrag (to permit survival of life) ?
   Perhaps a fair amount of open ocean at equator ?

Result: Snowball Fight !
Many geologists in favour of Snowball Earth concept
BUT many against !

The Cambrian Explosion

A profound change in the *tempo* of evolution then prevailing on Earth.

1. *Ediacaran Fauna* 580- 550 mya

***R.C. Sprigg*-- studying old lead mines in the Ediacaran Hills of south Australia**

***Martin Glaesner* - placed Ediacarans in modern Phyla**

A. Seilacher* - Placed them in new phyla - *Vendozoa

***Greg Retallick* - recognized them as fungi**

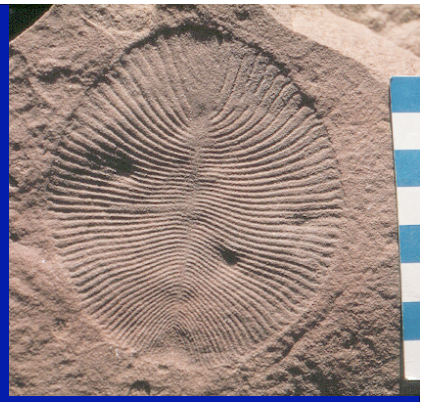
2. *Trace fossils* - 560 onward

3. *"Small Shelly Fossils"*, or "SSF"s -- 545 mya.

4. "*Cambrian fauna*" - 530 mya --Trilobites, brachiopods, and a host of newly evolved mollusks and echinoderms

Neoproterozoic

- Few animals
- Some horizontal burrowing
- Microbialites, precipitates
- BIFS
- Equatorial glacial tillites

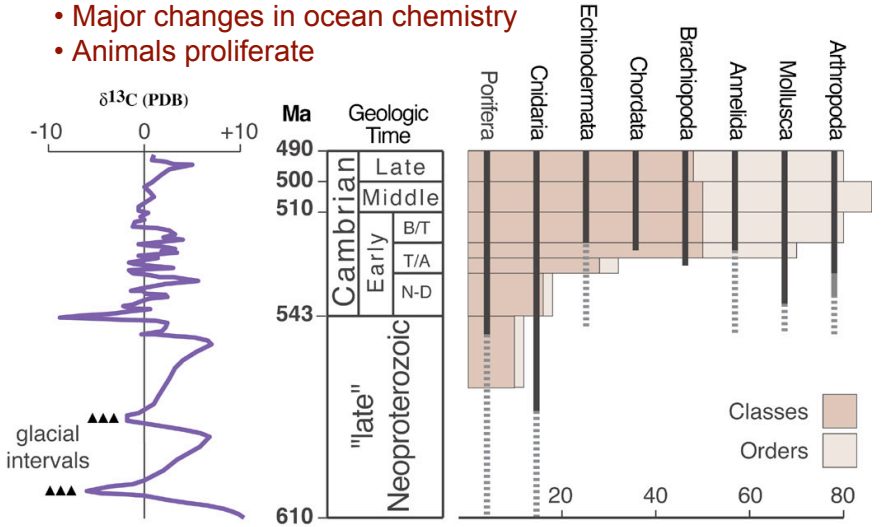


Dickinsonia costata
Rawnsley Quartzite
Nilpena Pound, Aust.

Glacial Dropstone
Rapitan BIF
(Photo: P. Hoffman)

Neoproterozoic-Cambrian

- Major changes in ocean chemistry
- Animals proliferate



(adapted from Knoll et al., 1999, Science v. 284)

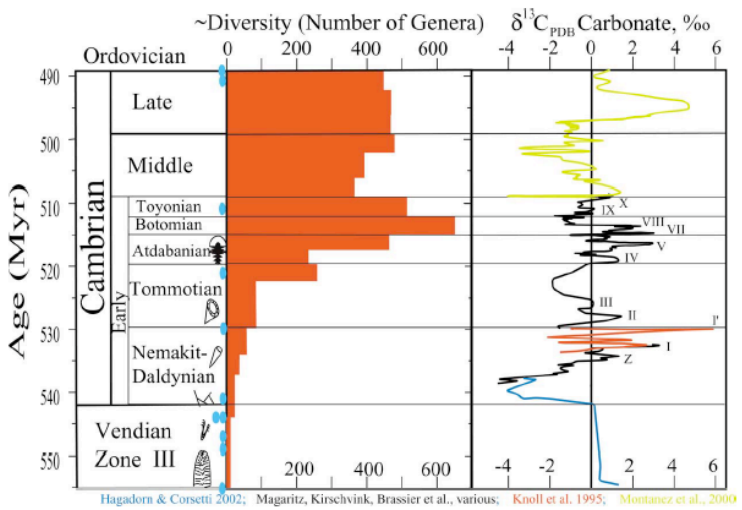


Fig. 1. Age constraints, biological diversity, and variations in inorganic carbon isotope ratios for Late Vendian and Cambrian time. Blue ovals along the left indicate the stratigraphic location of volcanic ashes that have been dated using U/Pb on zircon. Carbon isotope values from carbonate were compiled as follows: Blue curve from Corsetti and Hagadorn [18,19,42]; Black are the original data from Siberia [9,11,75,76]; red is the sub-Tommotian gap filled by Knoll et al. [65]; and Green is from the compilation of Montanez et al. [79].

Phyla are categories of animals and plants just beneath that of the Kingdom, and they themselves a re composed of as series of Classes. The animal phyla are each defined as being composed of species with quite different basic body plans.

Causes of the Cambrian Explosion **: Environment or evolution?**

1. Environmental causes

A. Oxygen reached some critical threshold value

B. Nutrients became available in large amounts

C. Temperatures ameliorated following the late Precambrian glaciation

D. Inertial Interchange Event

E. Opening of new habitat: transgression, rifting of Rodinia

Four biological *prerequisites* necessary for the Cambrian event

a. Life itself

b. Attainment of oxidative metabolism (the ability to live and grow in the presence of oxygen)

c. Evolution of sex,

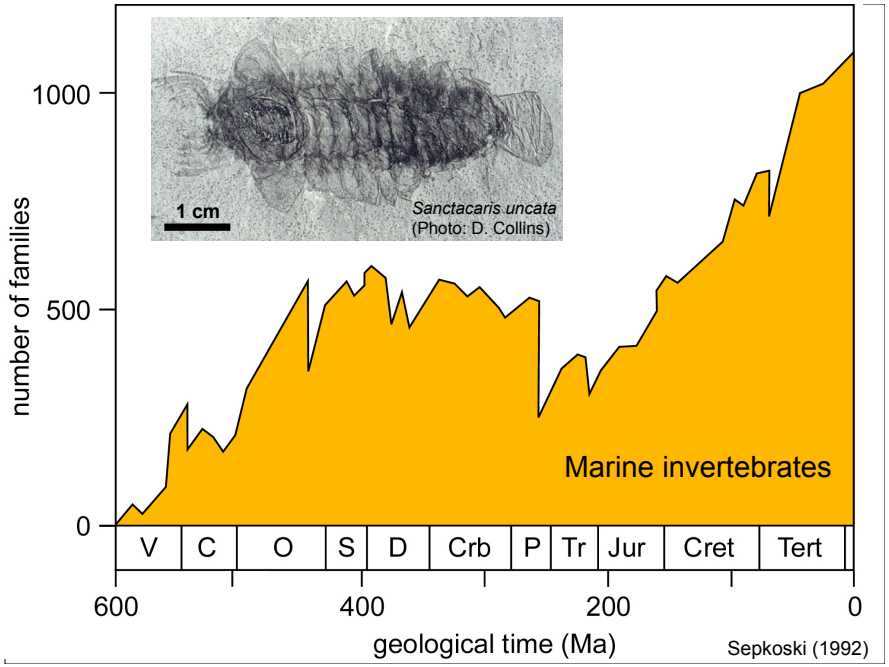
d. an appropriate protozoan ancestor. Cloud states that attaining all of these took nearly 4 billion years - 85% of Earth history.

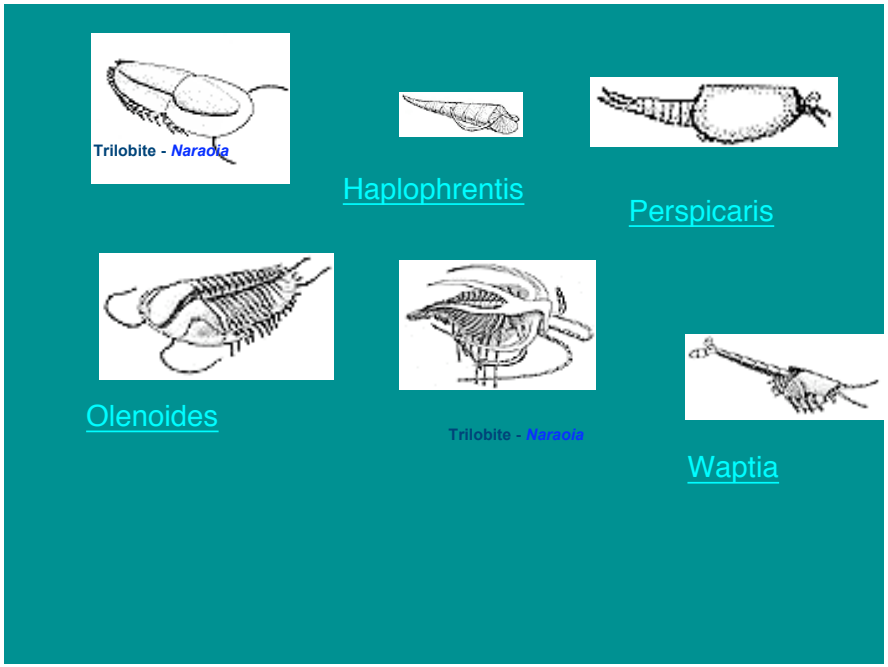
Triggers .

1. The advent of precipitated skeletons

2. Evolutionary thresholds were attained allowing large animal size

3. The Predation hypothesis





Enigma of Evolution

- Of the three Domains of life (Archaea, Bacteria, Eucarya) only the latter have exploited evolutionary change involving wholesale experimentation in new morphology and body plans. Why not the other two?
- Why no new phyla since the Cambrian Exlosion

Explain this (and you get a 4.0)

- "The fossil record of the last 3.5 billion years shows not a gradual accumulation of biological form, but a relatively abrupt transition from body plans of single cells to those of a rich diversity of animal phyla." (Erwin, Valentine, Jablonski, 1997). Evolution thus did not gradually create complex metazoans. They evolved quickly, due to a set of environmental conditions quite different from those which allowed the evolution of life in the first place.

Diversity and Disparity

- Diversity: number of taxa - species
- Disparity: number of body plans-morphology
- What is history of each since the start of the

Cambrian? The big fight: Steve Gould vs. Simon Conway Morris.

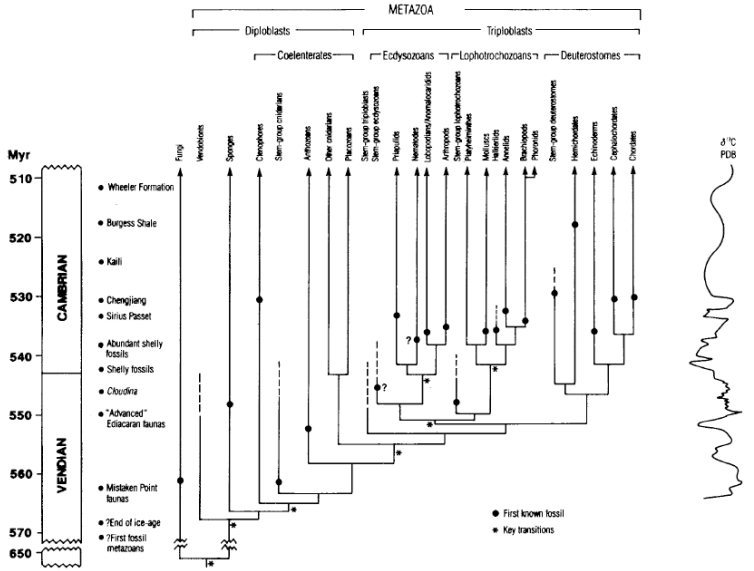
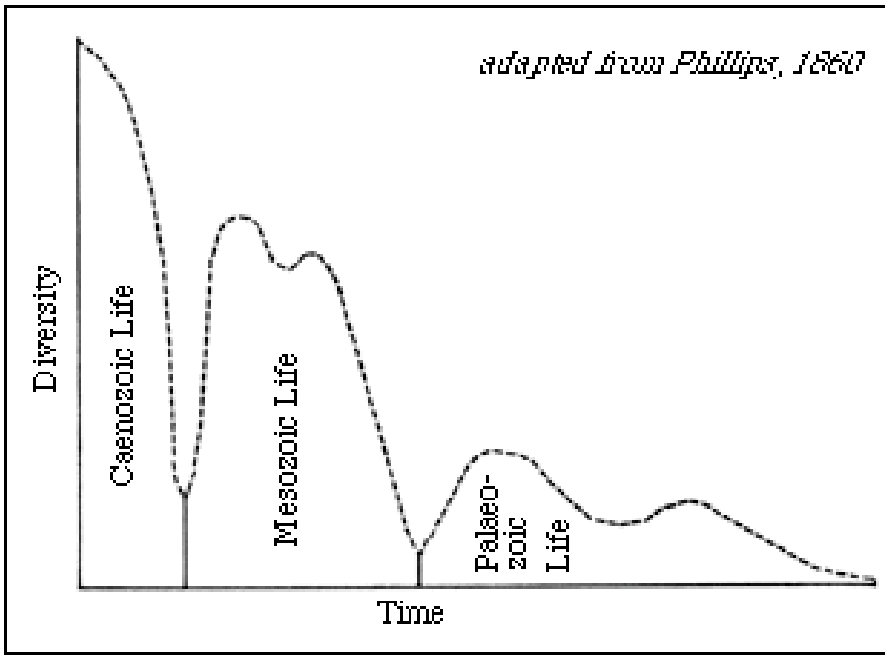
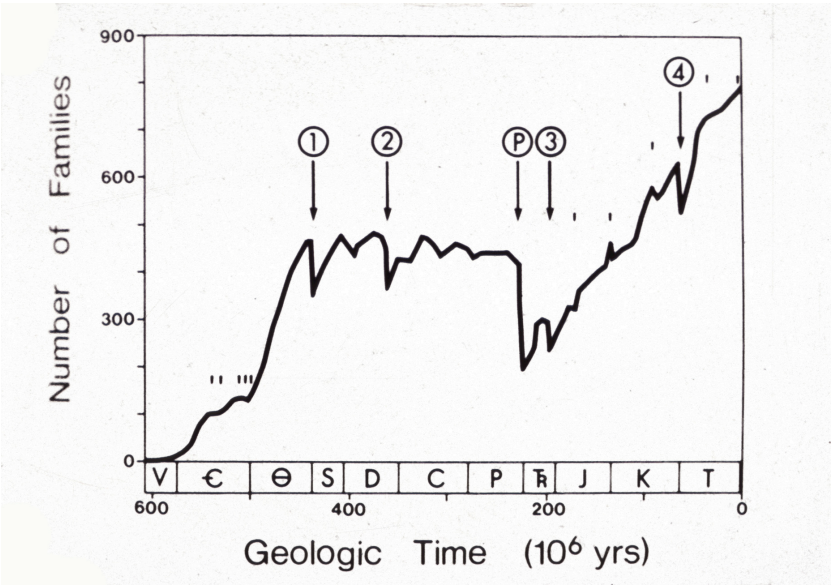


Fig. 1. Principal events across the Vendian-Cambrian boundary, spanning an interval of approximately 60 Myr (570–510 Myr), in the context of the early evolution of metazoans. On the left are denoted a series of important fossil assemblages, e.g., Burgess Shale, and various other significant events, e.g., cessation of ice age. To the right is the carbon isotope curve (redrawn from ref. 4), which provides an independent tool for correlation by chemostratigraphy and may also indicate substantial changes in ocean state with possible implications for evolutionary diversification. The evolutionary framework is largely based on molecular


adapted from Phillips, 1860
Diversity
Caenozoic Life
Mesozoic Life
Palaeo-
zoic
Life
Time


Number of Families
900
600
300
0
1
2
P
3
4
V
€
Θ
S
D
C
P
Tr
J
K
T
600
400
200
0
Geologic Time (10⁶ yrs)