The Cambrian Explosion

And the Pre-Cambrian Fuse

Multicellular Fossil Record

Phosphatized metazoan embryos
Doushantuo Fm., China
614 Ma

- Preserved by replacement of soft tissue by phosphate minerals.
- Appear to represent the embryos of jellyfish and possibly worms.
Phosphatized metazoan embryos
Latest Proterozoic

Cnidarian (jellyfish)
Polyp stage

Phosphatized metazoan embryos
Latest Proterozoic

First indisputable multicellular animals - Ediacaran Fauna

- Large, multicellular, but no skeletons or shells.
- Preserved as impressions in sandstones - possibly by overgrowth of bacterial mats.
- Appear after the end of the snowball Earth ice ages.
- Global in distribution.
- Several competing theories:
  - Early versions of modern phyla (corals, molluscs, worms).
  - Extinct group of animals NOT related to any modern phyla (Vendozoa - sensu Seilacher)
  - NOT animals at all - lichens (algae-fungus)
  - All of the above!
Ediacaran metazoans - Cnidarians (Jellyfish?)

Eoporpita

Cyclomedusa

Ediacaran metazoans - worm?

Dickensonia

Ediacaran metazoans - mollusc?

Kimberella
Ediacaran metazoans

Spriggina

Ediacaran metazoans - echinoderm?

Tribrachidium

Mistaken Point, Newfoundland
The Ediacaran Period (635-542 Ma)

Ediacaran Fauna

The Ediacaran Period (635-542 Ma) marks a significant time in Earth's history, characterized by the appearance of complex multicellular organisms. This period is named after the Ediacara Hills of South Australia, where some of the earliest known multicellular fossils were discovered. The Ediacaran fauna includes a diverse array of organisms, ranging from simple bilateral animal-like forms to more complex, likely bilaterally symmetrical creatures. The period is critical in understanding the evolutionary transition from simple to more complex life forms.
Ediacaran Mass Extinction?

- Ediacaran fossils become rare to non-existent by the end of the Proterozoic.
- Possible that Ediacaran animals went extinct.
- Alternative explanation: conditions for preserving the soft-bodies of the Ediacara were eliminated, creating an apparent mass extinction.
  - Loss of bacterial mats due to grazing by metazoans?

Mineralized shells

- Rare in the Proterozoic.
- Difficult to interpret.
- *Cloudina* - simple tube-like structure
- Enigmatic things from Namibian limestones.
Nama Group, Late Neoproterozoic, Africa

Small, calcareous fossils - but of what?
The Phanerozoic Eon begins!

- The beginning of the Cambrian dated at 542 Ma.
- Marked by appearance of a distinctive trace fossil.
- Followed by first appearance of abundant, tiny mineralized shells (hard to identify - most are probably plates from larger animals).
- Followed by large fossils of identifiable shelly marine animals (trilobites, echinoderms, molluscs, etc.).
- Phanerozoic = “visible life”
The first small shelly fossils appear more than 10 million years later.

**Trichophycus pedum**
Small shelly fossils from the Tommotian Stage of the Early Cambrian.

Trilobites  
Archaeocyathids  
Hyolithids  
Brachiopods  
Echinoderms  

Small shelly fossils  
*Trichophyctus pedum*  

Atababanian Stage  

Cambrian Arthropods
The “Cambrian Explosion”

- Geologically “sudden” appearance of skeletonized animal life.
- Fossil evidence from the Precambrian suggests at least 70 million years of prior animal evolution!
- What triggers the Cambrian radiation of animal phyla?
  - Atmospheric oxygen reaches a critical level?
  - Evolutionary “arms race” between predators and prey?
  - Evolutionary novelty triggers adaptive radiation (ability to make mineral shells, new developmental genes)?

### Ordovician

- **Late Cambrian**
- **Middle Cambrian**
  - **Botomian**
  - **Atdabanian**
  - **Pombokian**
- **Early Cambrian**
  - **Manykaian**

### Cambrian Lagerstatten (preservational window)

- **Burgess Shale**, Canada
- **Chengjiang Fm**, China

### Burgess Shale

- Discovered in 1909
- Charles D. Walcott
- Near Banff, B.C.
- Canadian Rockies
Ottoia - priapulid worm

Profile of Mt. Field showing stratigraphy and position of Burgess Shale (BS) within the Stephens Formation.

Burgess Shale animals with normally fossilizable hard parts.

Hyolithus - mollusk

Monoplacophoran - mollusk
Crinoid - echinodermata

Oleneloides - trilobite

Burgess Shale Lagerstatte, Middle Cambrian, British Columbia, Canada

Sponges - Porifera

Vauxia
Phylum Onychophora

Ayshea pedunculata

Phylum Arthropoda

Halucingena - onychophoran

Marrella splendens

Phylum Arthropoda
Canadaspis - arthropod

Canadia - annelid worm

Eldonia - holothurian echinoderm

Waptia - Crustacean arthropod

Wiwaxia - annelid worm??

Opabina - incertae sedis
Anomalocaris - one meter long Early Cambrian predator

Pikaia gracilens
Phylum Chordata
Chengjiang Formation - Early Cambrian (530 ma), China

*Haikouichthys*

- Definitely a chordate
- Might be a proto-vertebrate (evidence for gill slits, brain, eyes)
- Possible ancestor of all vertebrates that evolve throughout the Phanerozoic (for which we have an excellent fossil record!)