Paleontology

The study of ancient life
as it is recorded in the rock record

Biology + Geology

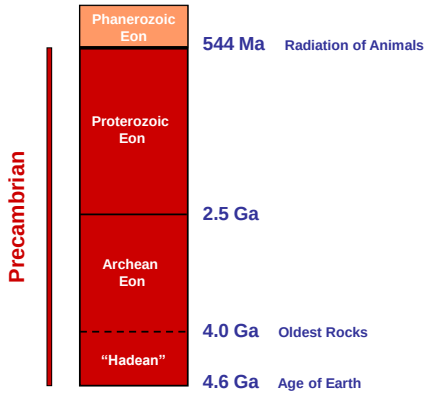
Paleontology

The study of ancient life
as it is recorded in the rock record

Biology + Geology

Great contribution = ***"Deep Time"***

Only way to study long-term
processes of evolution



Body Plan =

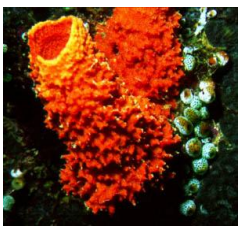
The shape or anatomy of an animal –

How it is put together

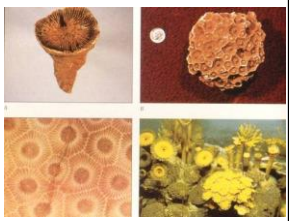
Phylum =

A major type of animal, defined by its body plan

Sponges



Corals



Bryozoans

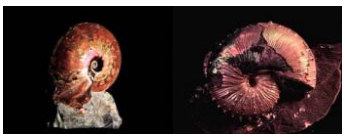




Brachiopods

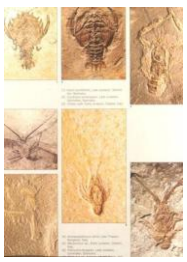

Molluscs



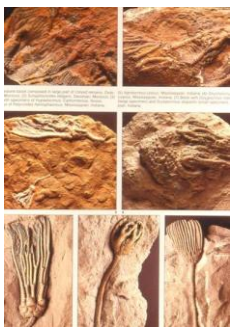



Arthropods





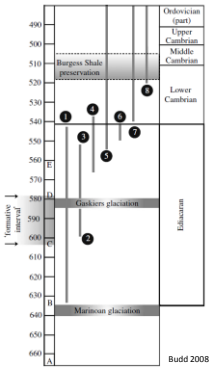
Echinoderms



Chordates


Key Fossil Data for Origin of Metazoans

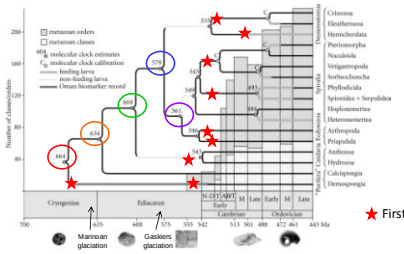
1. Large spiny acritarchs (may be animal egg cases?)
2. Doushantuo embryos - older estimate
3. Doushantuo embryos - younger estimate
4. Ediacaran fauna
5. Trace fossils
6. First shells, *e.g., Cloudina* and *Namacalathus*
7. Small shelly fauna
8. Trilobites



Key molecular clock splits

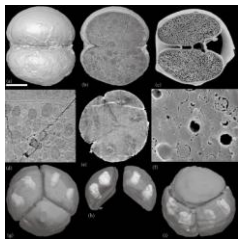
(Peterson *et al.* 2005)

Split	Date
All metazoans	664 Ma
Sponges-Eumetazoans	634 Ma
Radiata-Bilateria	604 Ma
Protostomes-Deuterostomes	579 Ma
Spiralia-Ecdysozoa	561 Ma



Late Precambrian Animal Fossils

Fossil embryos from ~580 Ma Doushantuo Fm (arthropod-like)



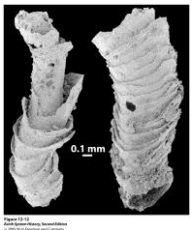
Synchrotron-radiation X-ray tomographic images

Late Precambrian Animal Fossils

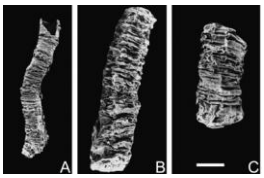
Trace fossils – "worm" trails – by 555 Ma
(<1 mm diameter)

Late Precambrian Animal Fossils

First shelled things by 550 Ma
= origin of animal biomineralization



Cloudina **– annelid worm tube?**
(0.8-1.5 cm long)

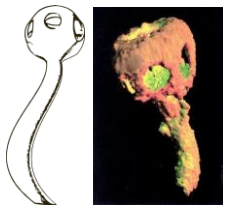


Sinotubulites **– annelid worm tube?**
(up to 2 cm long)

Late Precambrian Animal Fossils

First shelled things by 550 Ma
= origin of animal biomineralization

Namapoikia **– sponge or coral?**



Namacalathus **– lightly calcified cnidarian?**
(up to 3 cm long)

Key molecular clock splits

(Peterson *et al.* 2005)

Split	Date
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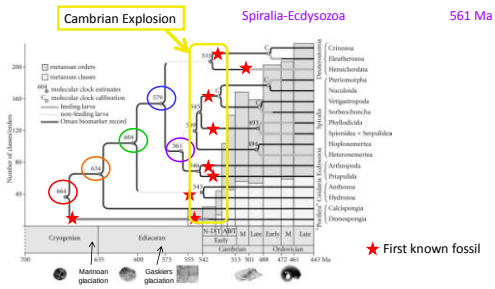


So what is the Cambrian Explosion?

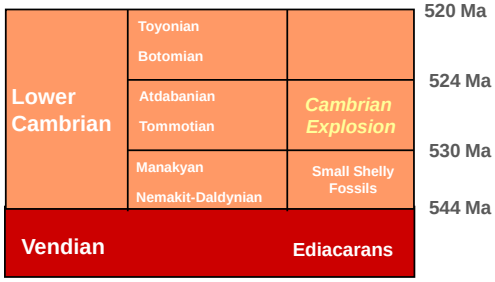
The first appearance / radiation of **Bilateria** in the fossil record

(*e.g.*, molluscs, brachiopods, annelids, arthropods, echinoderms, and chordates)

= The invention of bilaterian body plans

Precambrian – Cambrian boundary in Siberia

Timing of the Cambrian Explosion



Most animal phyla appear in fossil record within 6 million years!

The Appearance of Modern Animals

Why did it happen?

Why did it happen when it did?

Mass extinction of mysterious Ediacarans emptied the ecosystem?

The Appearance of Modern Animals

Why did it happen?

Why did it happen when it did?

Changes in seawater chemistry allowed animals to grow skeletons for first time?

The Appearance of Modern Animals

Why did it happen?

Why did it happen when it did?

Finally enough oxygen in atmosphere to support larger, more active life forms?

The Appearance of Modern Animals

Why did it happen?
Why did it happen when it did?

Finally evolved ability to grow larger?
(origin of set-aside cells, sufficient atmospheric oxygen)

The Appearance of Modern Animals

Why did it happen?
Why did it happen when it did?

All of the above?

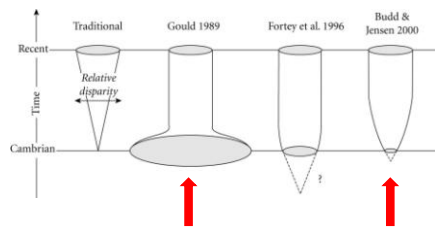
The Appearance of Modern Animals

Why did it NEVER happen AGAIN?

External – never an empty enough ecosystem?

Internal – development becomes canalized?

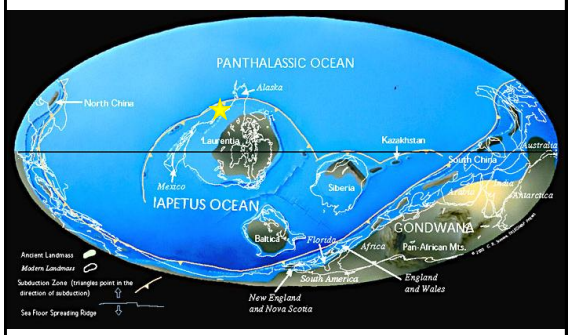
Models for the Cambrian Explosion



Key issue = does disparity peak early?
(disparity = number of body plans)

The Burgess Shale Fauna

- Middle Cambrian (515 Ma) of British Columbia
- Discovered in 1909 by Charles Doolittle Walcott, Secretary of the Smithsonian Institution
  - *Claimed specimens were primitive members of modern animal phyla*



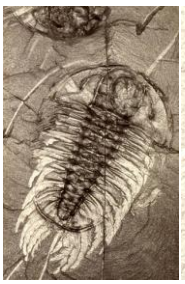
Charles Doolittle Walcott
1909

The quarry

The Burgess Shale quarry

The Burgess Shale Fauna

- Starting in 1960s, restudied by Harry Whittington, Derek Briggs, and Simon Conway Morris
  - Radical re-interpretation – many of these animals are unique!



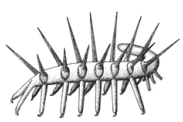
Olenoides
trilobite

Sanctacaris
chelicerate

Haplophrentis
hyolith

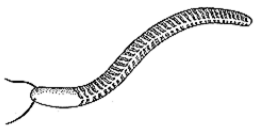
Aysheaia

onychophorans



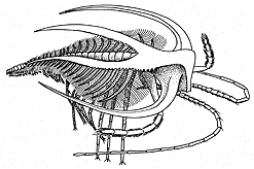
Hallucigenia

Pikaia
chordate



Marrella
trilobite?

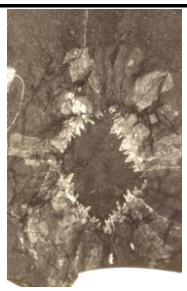
No…

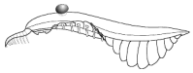


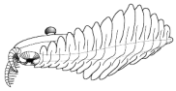
In fact, in the Burgess Shale, at least 12 different arthropod groups are present!

And there are other things whose classification is unclear!

Anomalocaris



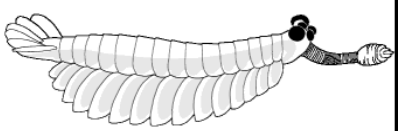




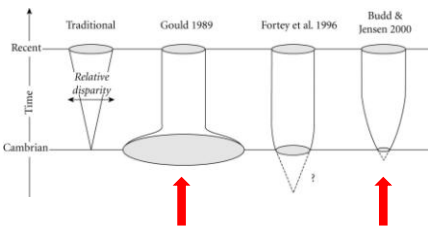
Anomalocaris

The top Burgess predator!

Opabinia

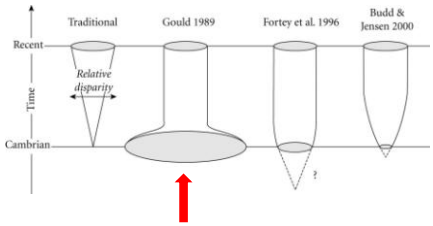


Models for the Cambrian Explosion



Key issue = does disparity peak early?

Models for the Cambrian Explosion



Yes, it does!

So What?

Cambrian faunas show a greater number of body plans than modern faunas…

…so why did crustaceans "win" while *Anomalocaris* disappeared?

Are modern groups ***superior****?*

So What?

No! – we see no obvious selective advantage of survivors over Cambrian oddballs…

Modern body plans are the lucky winners of the Cambrian lottery.

The long-term history of life is not (entirely) predictable from the Darwinian struggles of individuals!