Milestones in the first 3 billion years of life

- Origin of life - before 3.8 Ga
- Origin of eukaryotes - before 1.4 Ga; before 2.7 Ga?
- Origin of multicellularity - 600-800 Ma?
- Origin of skeletons - 550 Ma?
- The Cambrian Explosion - 550-544 Ma?

When did the first multicellular eukaryotes arise?

- Body fossils
  - “good” fossil evidence at 600-800 Ma
  - Questionable fossil evidence earlier (but stay tuned)

- Molecular clocks
  - Wide variety of dates (600-1500 Ma)
  - Most dates focus on 800-1000 Ma
Grypania, ca. 2.1 Ga from Michigan

Eukaryotic (triploblastic)
Traces, India

1.0 or 0.6 Ga

From Seilacher et al.
Multicellular algae (?), Proterozoic (ca. 800 Ga), Montana and NW Canada
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**Table 1. Recent molecular data estimates of the protostome-deuterostome split**

<table>
<thead>
<tr>
<th>date estimate</th>
<th>sequence data</th>
<th>calibration date [Myr ago]</th>
<th>study</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200</td>
<td>18S, 18S</td>
<td>&gt;15 dates (mostly vertebrate)</td>
<td>Wray et al. (1996)</td>
</tr>
<tr>
<td>730, 850</td>
<td>21 protein coding (mitochondrial and nuclear)</td>
<td>six dates (vertebrate: 100-450)</td>
<td>Feng et al. (1997)</td>
</tr>
<tr>
<td>670, 736</td>
<td>16 protein coding (mitochondrial and nuclear)</td>
<td>more than eight dates</td>
<td>Ayala et al. (1998)</td>
</tr>
<tr>
<td>630</td>
<td>50 genes</td>
<td>one date (fish-tetrapod: 430)</td>
<td>Lynch (1999)</td>
</tr>
</tbody>
</table>

Important points about the origin of skeletons

• It really seems to have happened no earlier than ca. 550-600 Ma
• Not just skeletonizing formerly soft-bodied critters; skeletons make new body plans possible.
• Causes? Genetic innovation vs. environmental causes

The oldest known skeletonized organism

*Cloudina* – ca 550 Ma
**Namacalathus**, a calcified metazoan
550-543 Ma
Namibia

From Grotzinger et al., 2000
*Paleobiology* 26(3)

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The Cambrian Explosion

The relatively sudden appearance and diversification of almost all of the phyla (all but Bryozoa) in the early Cambrian.

This event began around 550 million years ago and lasted no more than 20-30 million years.

The Linnean Hierarchy

- phylum
- class
- order
- family
- genus
- species
Major phyla of the fossil record

- Porifera – sponges
- Cnidaria – corals etc
- Arthropoda – arthropods
- Echinodermata – echinoderms
- Brachiopoda – brachiopods
- Bryozoa – bryozoans
- Mollusca – mollusks
- Chordata – vertebrates etc.

Key Faunas Before/After the Cambrian Explosion:

- Burgess Shale (505 Ma)
- Chengjiang (520 Ma)
- Small Shellies (Manykaian Stage) (544-530 Ma)
- Ediacara (575-545 Ma)
- Doushantuo embryos (580-570 Ma)
The Ediacara Biota

- Mawsonites
- Dickensonia
- Tribrachidium
- Parvancorina
- Cyclomedusa

Ediacara Hills, Australia
The Ediacara Biota

Spriggina

Charnia

Ediacara fronds:
Comparison with living Pennatulacean Cnidarians
The “traditional” interpretation of Ediacara
(from Glaessner (1984))

“Traditional” reconstructions
of the Ediacara Biota
A radical alternative interpretation of the Ediacara Biota: Vendobionta (From Seilacher, 1989)

**Seilacher’s hypothesis**

- Ediacaran organisms (“vendobionts”) represent an independent origin of “animal-grade” multicellular eukaryotes
- Vendobionts were immobile and possibly photosynthetic, photosymbiotic, chemosynthetic, or chemosymbiotic
- They are not ancestral to any Phanerozoic forms
- Ediacaran organisms all became extinct just before the Cambrian-Precambrian boundary
So is Seilacher correct?

... probably not completely

- Ediacaran forms now known from Cambrian
- Taphonomy and new Ediacaran fossils show greater resemblances to Phanerozoic/modern forms possible
- More detailed analysis of Ediacaran morphology suggests closer affinities to Phanerozoic/modern forms
- But... there are still a lot of Problematica in Ediacara.
Why Seilacher’s hypothesis is important

• Tests our assumptions
• Implications for extraterrestrial life


Length ca. 5 cm)
The latest on Ediacara… 2005

• There may be actual bilaterians among the Ediacaran biota
• There are at least 3 biostratigraphically recognizable assemblages:
  – Avalon 575-565 (e.g., Mistaken Point, Newfoundland)
  – Nama 565-550
  – White Sea 550-545

The Ediacara Biota at Mistaken Point, Newfoundland

http://geol.queensu.ca/museum/exhibits/ediac/mistaken_point/mistaken_pt.html
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Doushantuo embryos


Bengtson & Zhao 1997, a SEM image depicting a suggested metazoan embryo—possibly Olszewskia multivesiculata—at approximately the 256-cell stage.