1.9
Origin of the major eukaryotic groups

1.0
Eukaryotic cells abundant

0.6
Invasion of the land

0.002
Ancestral humans Diversification of mammals

BYA

ORIGIN OF THE EVOLUTION OF SEX (Meiosis)

ORIGIN OF THE NUCLEUS AND ORGANELLES

EVOLUTION OF COMPLEX LIFE FORMS

Origin of Multicellularity: A major transition in history of life

- Evolved independently in different lineages
- Extant organisms provide clues about origin of multicellularity

Bacterial Aggregates

Slime Mold
THE PROTEROZOIC ERA: 2.5 BYA TO 543 MYA

- Most of this era was characterized by prokaryotes and eukaryotic algae.
- First evidence of multicellular animal life appeared less than 1 BYA (But see the next slide)
- Oldest fossils of multi-cellular animals are 640 million years old.
  - The best-known Precambrian animals are the EDIACARAN FAUNA.
    - Soft-bodied, lacking skeletons.
    - Crep or stood upon the sea floor.
    - Most don’t fit into modern Phyla.

Oldest fossils of multicellular life date back 2.1 billion years

Unclear where they fit in the tree of life

Discovery of Possible Earliest Animal Life Pushes Back Fossil Record - 650 million years ago

Evidence from biomarkers and molecular clocks points to the existence of sponges tens of millions of years before their earliest fossil remains. Fossils from South Australia may narrow that gap.

Possible animal-body fossils in pre-Marinoan chertstones from South Australia.

Maloof et al. 2010 Nature Geoscience 3, 653 - 659
Earliest animal tracks date to **585 million** years ago

**Ediacaran Fossils:**

- Large diversity of forms with unknown affinities to more recent fossil groups found between 580-541 mya

**Cellular and Subcellular Structure of Neuronal Axon Animal Embryos**
Animal embryos or animal relatives?

EARLY METAZOAN EMBRYOS
From the Doushantuo Formation, Southern China

570 MYA

FROM: Xiao et al. 1998 Nature

Evolution of Ediacaran fauna
PALEOZOIC ERA: CAMBRIAN PERIOD (541 to 500 MYA)

- The "Cambrian Explosion" started about 530 MYA.
- Almost all of the modern phyla and classes of skeletonized marine animals suddenly appear in the fossil record.
- This explosion may have occurred in 30 MY or maybe as little as 5-10 MY (according to the fossil record).
- The most amazing record of this period appears in the BURGESS SHALE, ~505 MYA which is near Banff, BC, Canada.
- Almost all of the fundamentally different animal body plans were present by the end of the Cambrian.
- Cambrian ended with a mass extinction.
Clues about ancient ecology and behavior from the fossil record

Hallucigenia

Behold......

The Sea Pig
Anomalocaris

A suspension-feeding anomalocarid from the Early Cambrian

Marrella

Side view of Marrella. Drawn by Marianne Collins.

Marrella
Pikaia

8.1. Pikaia, the world's first known chordate, from the Burgess Shale. Note the features of our phylum: the notochord or stiffened rod along the back that evolved into our spinal column, and the paired muscle bands. Drawn by Marianne Collins.

Haikouella lanceolata

Primitive Chordate???

Conodonts: Ancestral Chordates
DIVERSIFICATION DURING THE PRECAMBRIAN PERIOD RESULTED IN THE ORIGIN OF VIRTUALLY ALL THE EXTANT MAJOR ANIMAL PHYLA!

(AS WELL AS QUITE A FEW WE KNOW ALMOST NOTHING ABOUT)
Evolution of the Hox Gene Cluster

- Expansion of a gene family
- Acquisition of novel gene function
- Increasing complexity

Is morphological complexity correlated with genetic/genomic complexity?

The Enigmatic Placozoans

What precipitated the Cambrian Explosion?

- Diversification may have been promoted by increasing oxygen levels in the atmosphere.
- Vacant ecological niches may have fostered diversification.
- Key innovations related to multicellularity and the organization of developmental processes may have evolved (e.g., collagen, hierarchies of gene action).
- Nobody knows for sure.

Or maybe there was no such thing...
Molecular Evidence for Deep Precambrian Divergences Among Metazoan Phyla

FROM Wray et al. 1996 Science

Sufficient O2 for animal life?

First terrestrial plant and fungal life

- Oldest terrestrial plant fossils are 475 myo
- Large forest ecosystems within 100 million years
- Fungi appear ~ 400 myo
  - Associated with plants
First terrestrial animal life

- Invertebrate trackways date to 480 mya
  - Probably relatives of insects and spiders (Arthropods)
  - Not clear whether they lived on land permanently
- Oldest fossil of fully terrestrial animal dates to 428 mya

First terrestrial vertebrates

- Oldest trackways date to 390 mya
- Oldest fossils of tetrapods date to 370 mya
BIG PATTERNS IN THE HISTORY OF LIFE

- If life originated on earth, the main plan may have been set down in a “relatively” short period of time.

- In terms of the appearance of major evolutionary novelties, long periods of stasis appear in the fossil record.

- Explosive periods of diversification appear to follow the ‘invention’ of new genetic mechanisms or ecological changes precipitated by life itself.

- Periods of stasis in the complexity of life appear to be getting shorter – suggesting evolution has “autocatalytic” properties.