

Lecture 20 - The History of Life on Earth

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Astronomy 141 – Autumn 2012

This lecture reviews the history of life on Earth.

Rapid diversification of anaerobic prokaryotes during the Proterozoic Eon

Emergence of Photosynthesis and the rise of O₂ in the Earth's atmosphere.

Rise of Eukaryotes and the Cambrian Explosion in biodiversity at the start of the Phanerozoic Eon

Colonization of land first by plants, then by animals

Emergence of primates, then hominids, then humans.

A brief digression on notation: "ya" = "years ago"

Introduce a simple compact notation for writing the length of time before the present day. For example:

"3.5 Billion years ago"

"454 Million years ago"

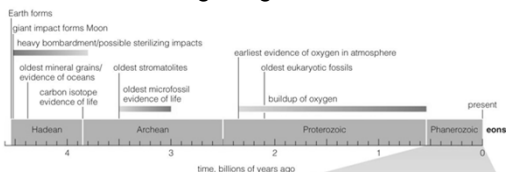
Gya = "giga-years ago", hence
3.5 Gya = 3.5 Billion years ago

Mya = "mega-years ago", hence
454 Mya = 454 Million years ago

[Note: some sources use Ga and Ma]

Lecture 20 - The History of Life on Earth

The four Eons of geological time.



- Hadean:** 4.5 – 3.8 Gya: Formation, oceans & atmosphere
- Archaean:** 3.8 – 2.5 Gya: Stromatolites & fossil bacteria
- Proterozoic:** 2.5 Gya – 454 Mya: Eukarya and Oxygen
- Phanerozoic:** since 454 Mya: Rise of plant and animal life

The Archaean Eon began with the end of heavy bombardment ~3.8 Gya.

Conditions stabilized. Oceans, but no O₂ in the atmosphere.

Stromatolites appear in the geological record ~3.5 Gya and thrived for >1 Billion years

Rise of anaerobic microbes in the deep ocean & shores using Chemosynthesis.

Time of rapid diversification of life driven by Natural Selection.



The Proterozoic Eon (2.5Gya – 454Mya) was the time of single-celled life and the rise of Oxygen.

Find microfossils of prokaryotes.

Emergence of Photosynthesis:

First using H₂S instead of H₂O, so no Oxygen produced.

Then using CO₂+H₂O to make O₂ starting ~2.4 Gya.



The first O₂ is quickly soaked up by mineral oxidation, and very little makes it into the atmosphere.

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Most of the initial Oxygen made by photosynthesis was soaked up by mineral oxidation.

Banded Iron Formations

Iron oxide layers in sedimentary rocks.

Total O₂ locked up in BIFs is about 20x current atmospheric O₂ content!

Source of much modern iron ore for industry.



2.1Gy old banded iron formation

Major sink for early oxygen production until ~1.8 Gya.

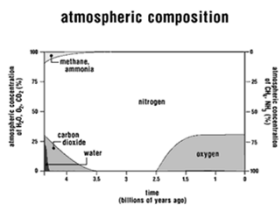
Rapid rise in atmospheric Oxygen once the mineral sinks became saturated ~1.8 Gya

Crisis for anaerobic life:
O₂ attacks chemical bonds

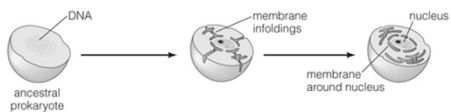
Mass extinction of anaerobic prokaryotes except in the deep oceans and Deep underground

Bad for anaerobic prokaryotes, but...

Good for photosynthetic prokaryotes and emerging Eukaryotes



The first Eukaryotes arose ~2.1Gya during the early Proterozoic Eon from large prokaryotes.



Accompanied the rise of Oxygen allowing larger organisms.

First Eukaryotes were a symbiosis of prokaryotes:

Mitochondria in animal cells } preserves this symbiosis to the present.
Chloroplasts in plant cells }

These symbiotic "organelles" still have their own DNA.

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First multi-celled Eukaryotes arose about 1.2Gya

Fossil red algae recognizable in modern-day descendants.

Probably started as colonies of single-celled Eukaryotes.

Developed specialized cell functions.



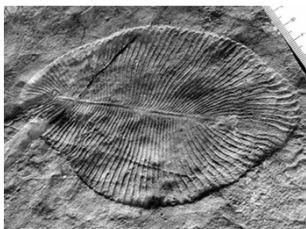
Bangiomorpha pubescens
Hunting Formation, Canada

Sexual reproduction emerged soon thereafter, providing greater genetic diversity to drive rapid evolution.

The whole became greater than the sum of the parts...

While diversity evolved quickly, body plans did not evolve much between 1.2 Gya and 550 Mya.

Biggest change in the late Proterozoic Eon ~580 Mya was the emergence of the Ediacara biota after the last Snowball Earth episode.

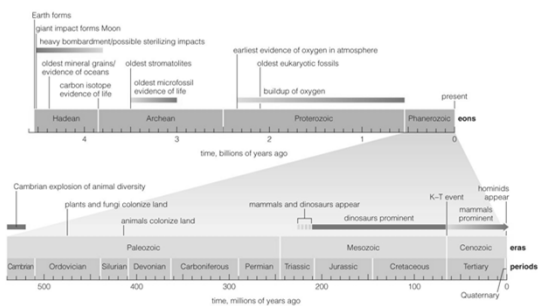


Dickinsonia costata (Ediacara, S. Australia)

First complex multicellular organisms.

Apparently soft-bodied and abundant until the start of the Cambrian.

The Phanerozoic Eon marks the rise of plant and animal life on the Earth.



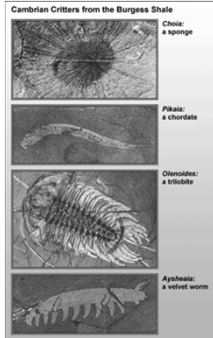
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The Cambrian Explosion in multicellular organisms marks the start of the Phanerozoic Eon.

Most major groups of animals and their body plans appeared rapidly during a 40Myr period at the start of the Cambrian Period 450Mya.

Only major diversification in basic body plans in the geological record.

Complex animal and plant life quickly filled most available ecological niches.



Why the sudden explosion in biodiversity at the start of the Phanerozoic?

Abundant atmospheric O₂ allows larger creatures by providing for their higher metabolism.

Snowball Earth at the end of the Proterozoic caused mass extinctions:

Opened up ecological niches

Provided strong selection pressure.



Chengjiang fauna

Sexual reproduction led to greater genetic complexity driving rapid evolution to quickly adapt to the new niches.

Animal and plant life only slowly colonized land after the Cambrian Period

Land represents many challenges to complex life:

UV radiation before the ozone layer formed was a fatal hazard.

How to extract minerals and water from the ground (no soil yet)?

Plants and fungi first colonized land ~475Mya.

Animals followed plants ~75Myr later.



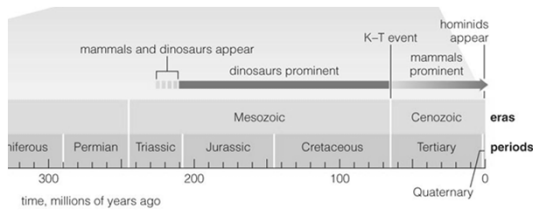
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By the Carboniferous Period 360Mya, the land was covered in vast forest with numerous insect species.



Carbon deposits from this period is our main source of coal...

The last 250 Myr has seen two major groups of land animals emerge on the Earth.



Dinosaurs and mammals first appear ~220Mya
 Dinosaurs rule the Earth for 155Myr until ~65Mya
 when they were wiped out by an asteroid impact
 Mammals radiated into the vacated niches, and are prominent
 to the present day.

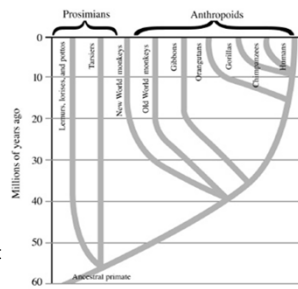
Primates arose shortly after the dinosaur mass extinction, but hominids are recent geologically.

First ancestral primates emerged ~58 Mya

Lineages of monkeys split off ~40 Mya

Lineages of apes split off between 35 and 7 Mya

First hominids arose about 6-7 Mya.



First ancient homo sapiens don't appear until 400 – 200 kya.
