Astronomy 330:

Extraterrestrial Life

This class (Lecture 21):

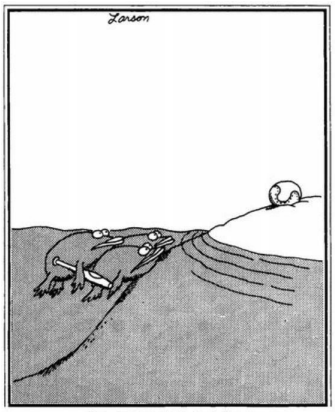
Biological Evolution

Next Class:

Evolution of Humans

Saaya Nath

Obinna Onyemepu



Great moments in evolution

Music: *Intelligent Guy*– Butthole Surfers

HW #2

Brian Campbell-Deem
http://www.alienresistance.org/stop-alien-abduction/
Alien abductions can be permanently stopped and don't need to be accepted. God is the answer to overcome, but is not a magic tool.

Itamar Allali
http://www.veteranstoday.com/2013/08/04/secret-space-war-vii-joint-usgalien-hybrid-program/
Unless folks have already spent some time learning about the claimed secret space wars of the USG and the SSG, they are probably wasting their time reading this article

Drake Equation


Frank Drake

That's 45.1 Life-liking systems/year





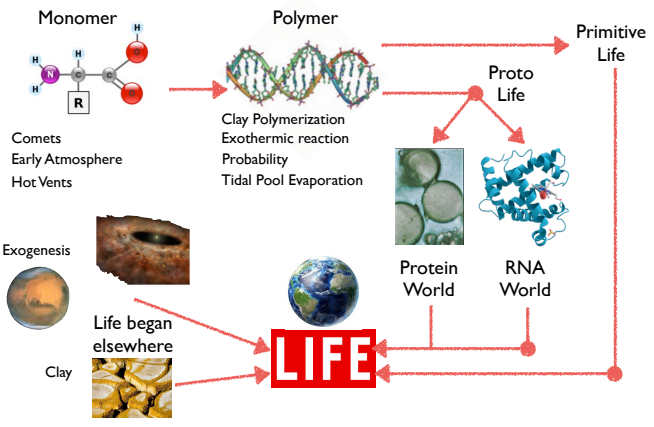



$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	30 stars/ yr	0.8 systems/ star	4 X 0.47 = 1.88 planets/ system	life/ planet	intel./ life	comm./ intel.	yrs/ comm.

The next term in the Drake equation is fl. Arguably the hardest term to estimate. We do not know much about the early Earth as we do not have the rock from that time period— too much processing by seismic activity. Nonetheless, we can develop likely pathways for life, then try to draw conclusions from those arguments. One of the difficult things here is that we will mostly be examining modern life— not early life. We are looking at the perfected machinery of life, but early life may have been very different. We skip ahead to the top of the line best designed (by evolution) car— sports car, and we do not see the first steps of develop of cars— the first car was slow, clunky, and less efficient, likely just like early life. So although modern life looks like it has too many fine-tuned parameters to have ever happened through the mechanisms we will discuss, remember we are skipping ahead to the Ferrari, by-passing the first Benz.

The Game of *Life*



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Life Fraction

Laws of nature → *Life*

Planet outgas?

Reducing Atmosphere?

Liquid Water?

Space?

Monomer production?

Atmosphere?

Polymerization?

Surface?

Tides?

Alternative Life?

Protolife or Life?

Earth *special* or *common*?

$f_l = 10^{-6}$

$f_l = 1$

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Existence of organic molecules in space implies that amino acid complexity is common. Fact: On Earth polymers arose and evolved to life and did it quickly. Life it seems evolves naturally through a number of intermediate steps if conditions are right and $f_l = 1$ But how often are the conditions right? Nonetheless, even with only a vague notion of how life on Earth evolved, it seems that there are possible pathways that take the mysterious polymerization to transition to life steps.

Still a number of questions: Is life a natural occurring consequence of the laws of nature? Will each planet from ne outgas and produce water or other liquid? Will it have a reducing atmosphere? Will it have the right energy sources to produce life's monomers? Monomers from space? Will polymerization occur? Are tides necessary to wash polymers back into liquid water? Will basic life occur? Protolife or life? Alternative life? Maybe the conditions that produced life on Earth are unusual or maybe common. That means f_l can range from small numbers 0.0001 to 1.

Think Pair/Share

In small groups develop an estimate for f_l

Monomer Assembly

Polymer Assembly

Transition to Life

Earth-Chauvinism

What is Life?

Unknowns

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Remember we are talking about basic life. Not advanced life. No idea on the absolute value here, but the fact that it occurred quickly on Earth suggest that it is not that hard— or we were lucky.

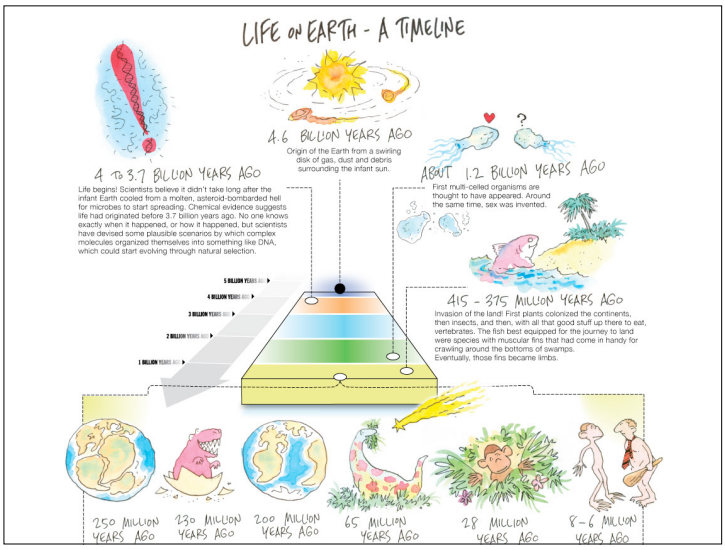
Drake Equation

Frank Drake

That's 9 life systems/year

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

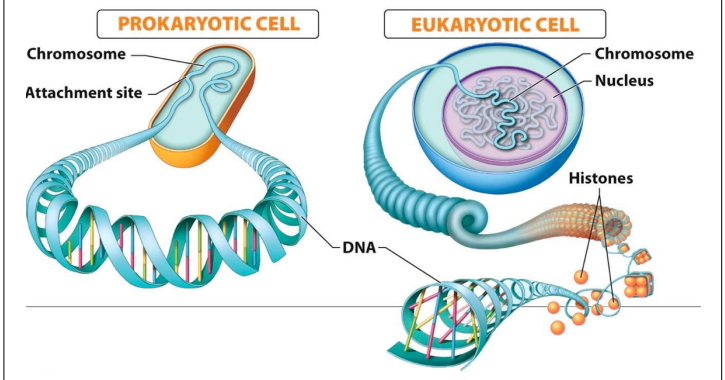
# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
	30 stars/ yr	0.8 systems/ star	4 x 0.47 = 1.88 planets/ system	0.2 life/ planet	intel./ life	comm./ intel.	yrs/ comm.



Note that most of life on Earth was microscopic.. and only made it to land recently.

Evolution is driving diversity of species.

Classification



Two main types of cells.. Prokaryote cells are about 10 times smaller than eukaryote cells.

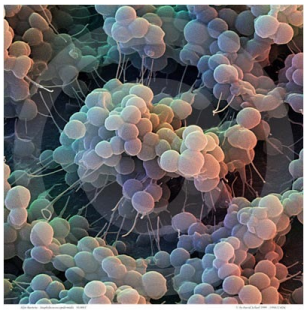
Life

If we took all the biomass of all the animals, and all the biomass of all the viruses, bacteria, protozoa, and fungi– who weighs more?

Around 90% of all biomass on the Earth is in the smallest and simplest lifeforms.

Bacteria

- 40 million bacterial cells in a gram of soil
- 1 million bacterial cells in a milliliter of fresh water
- Something like five nonillion (5×10^{30}) bacteria in the world.



Staph bacteria
http://www.scharfphoto.com/fine_art_prints/archives/000608.php

You or not you?

- This is more non-you cells in your body than you-cells in your body!
  - You are outnumbered 10 to 1!
  - Mostly on your skin and in your digestive track

Bacteria under a toe-nail

http://news.nationalgeographic.com/news/2007/02/070206-skin-microbes.html

Because they are smaller, more fit in your body.

Evolution of Intelligence

What is Intelligence?

Spectrum of ability

Wikipedia Definition?
Psychology Definition?

Our Definition:

The ability to model the world, including the organism's own self.

Frank Drake

Intelligence is ***NOT*** a requirement for life!

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Evolution of Intelligence

Diversity of life provides the foundation for the development of intelligence

Starting Point: *Fossil Record*

Bacteria to Humans

1.9×10^6 known species

~ 10% of all species are known

Most of these are insects
$> 1 \times 10^6$ species!

Bacteria are hard to classify
(9000 species known)

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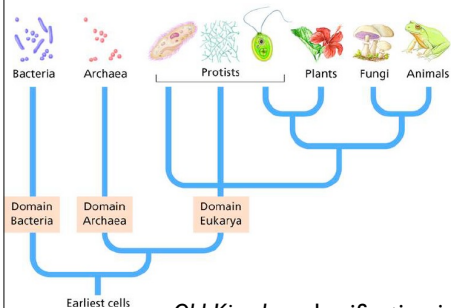
Tree of Life

Tree of life now organized by genetics



Archaea and Eukarya are genetically more similar.

Archaea and Bacteria split first.

Eukarya separated later from Archaea

Old Kingdom classification is no longer relevant:
Animal versus Plant kingdom.

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Genetically speaking, Archaea and Eukarya are more similar to one another than are Bacteria and Archaea. Implies that Archaea and Bacteria split and then all Eukarya split from Archaea. A major implication for the evolution of life on Earth

The old "kingdom" classification is no longer really used, such as plant kingdom or animal kingdom

Genetic Relations

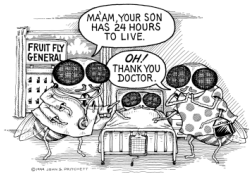
Major change in biological classification.

Humans & Chimpanzees
99% same DNA

Old: Anatomy and outward form.

New: Genetic Code

Humans & mice
97% same DNA



2 species of fruit fly appear the same, but only share 25% of the same DNA. Some difference due to junk DNA

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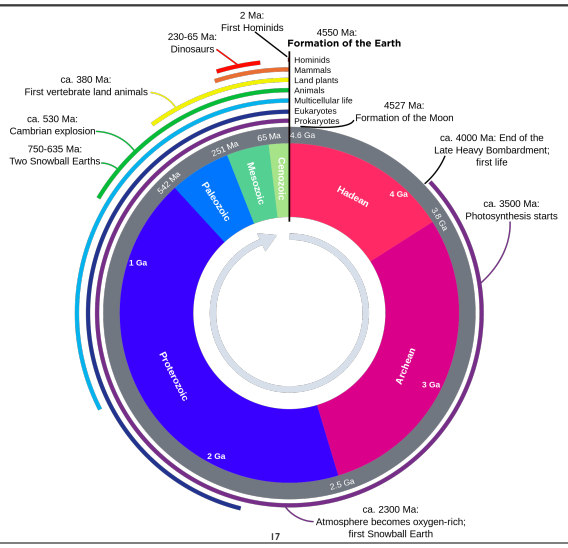
Remember that all of these organisms use nearly identical genetic codes, so life descended from a common ancestor. Primary challenge of biology is to explain how life from a single type of organism, diversified so much. Evolution is the primary concept.

Earth History



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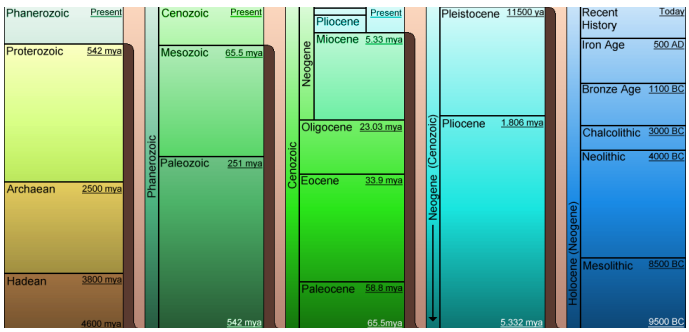
Earth History



SuperEon: Precambrian

Eons: Hadean, Archaean, Proterozoic, Phanerozoic

Eras: Paleozoic, Mesozoic, Cenozoic

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Hadean Eon

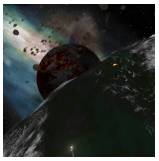
4.6–4.0 Gyrs

Originates from Greek Hades (Hell!)

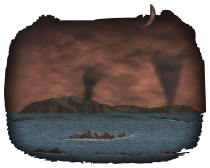
Formation of Earth!

Heavy Bombardment

Formation of Moon



Formation of Oceans



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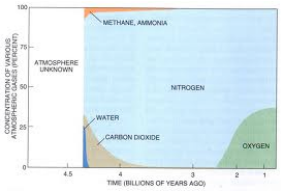
Early Earth

Early Atmosphere:

N & CO_2



First 3 Billion Years

Life was polluting the planet even then.

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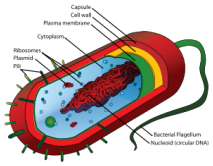
Archaean Eon

4.0–2.5 Gyrs

Αρχή: Greek for origin or beginning

Prokaryote Life

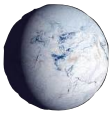


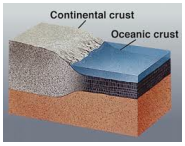
Bacteria Evolve

Archaea Evolve

Stromatolites

Snowball Earth?





Formation of Continents

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Lots of Volcanoes

Oxygen Catastrophe

Early Prokaryotes produced Oxygen through photosynthesis

Cyanobacteria (Blue-Green Algae)

Live in colonies
form mats or films
grow into large structures
called stromatolites

Still around, but were more common before ~700 Myrs

Oxygen Catastrophe

About 2 gyrs ago, the atmosphere became Oxygenated

Environmental catastrophe *Species destruction*

Oxygen atmosphere is new, and important step in development of intelligence.

Aerobic Metabolism: new energy extraction method

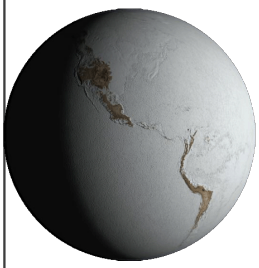
Allows more complex lifeforms

Created Ozone layer: Dry land is now an option for life on Earth.

Rate of O production exceeded O binding in rocks.

Snowball Earth

Global Glaciation



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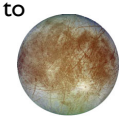
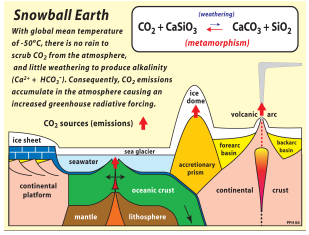


Oxygenation of Atmosphere:

CH_4 replaced by CO_2?

Reduction in Greenhouse?



Erosion increases Fe and P in Oceans?

Drives biodiversity explosion?

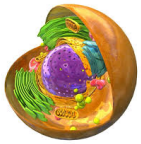
or Slushball Earth?

Proterozoic Eon

2500–542 Myrs

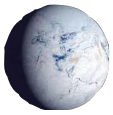
Greek for Early Life

Rodinia

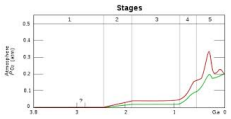


Eukaryotes

Snowball Earth (s)?



Oxygen rich atmosphere



Multi-cellular Life

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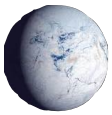
Phanerozoic Eon

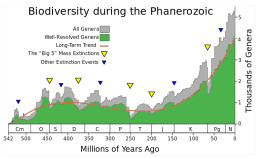
542 Myrs–present

Greek for Visible Life

Snowball Earth (s)?



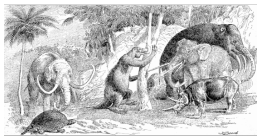
Evolution!



Pangea

Land Life

Dinosaurs



Mammals

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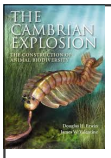
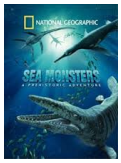


Paleozoic Era

542–252 Myrs

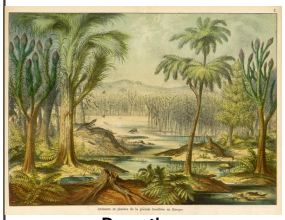
Greek for Ancient Life

6 Periods:
Cambrian,
Ordovician,
Silurian,
Devonian,
Carboniferous,
Permian



Fish

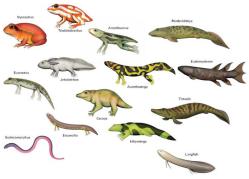
Life moves to the land!



Reptiles

Insects

Amphibians



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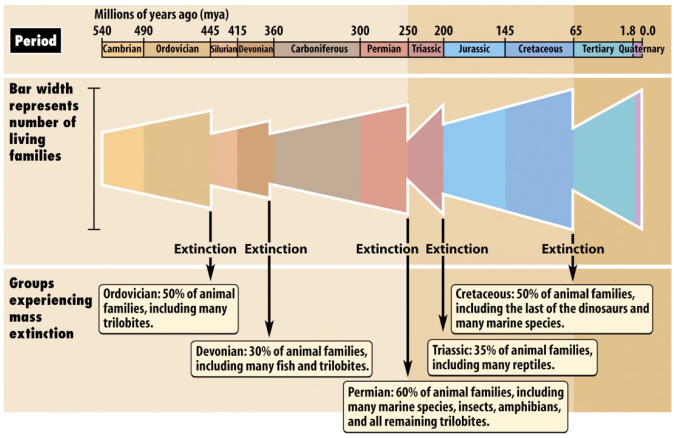
Evolution of Life: Extinctions



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Mesozoic Era

3 Periods:
Triassic,
Jurrasic,
Cretaceous

252–66 Myrs

Greek for Middle Life

Birds

Dinosaurs Ruled!

Mammals

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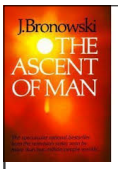
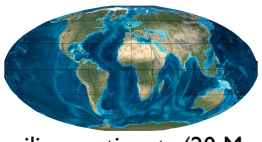


Cenozoic Era

3 Periods:
Paleogene,
Neogene,
Quaternary

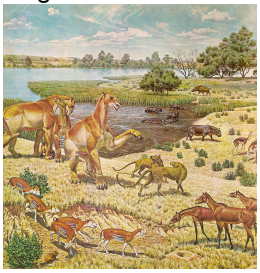
66 Myrs–present

Greek for New Life



Familiar continents (20 Myr)

Age of the Mammals



K-T impact Event

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ET Evolution

Does evolution proceed similarly in other locations?

Evolution is non-deterministic (stochastic)

Selection often based on random (luck) versus adaption.

Yet, many traits have developed independently in different lineages (e.g., warm blood or eyes)

Perhaps intelligence increases in many lineages. Thus, if life exists it is likely that intelligent life exists.

But plants never developed neurons.

Group Think

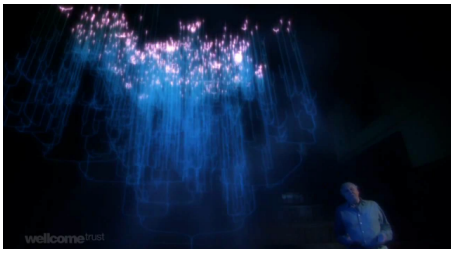
Alien Evolution

How unique is evolution to Earth?

What do you think?

Why?

Evolution

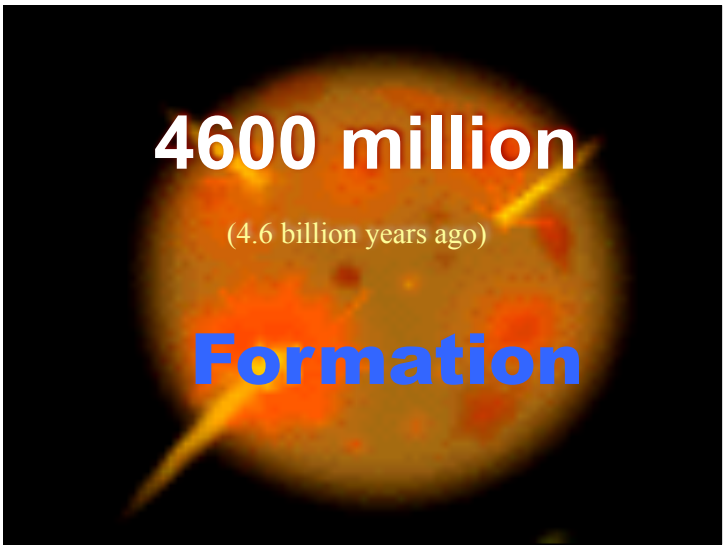


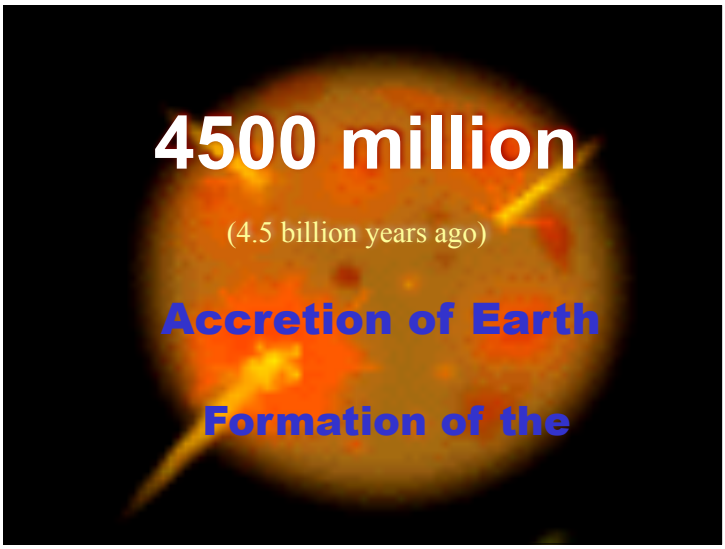
We can use the fossil record to reconstruct Earth's evolutionary history

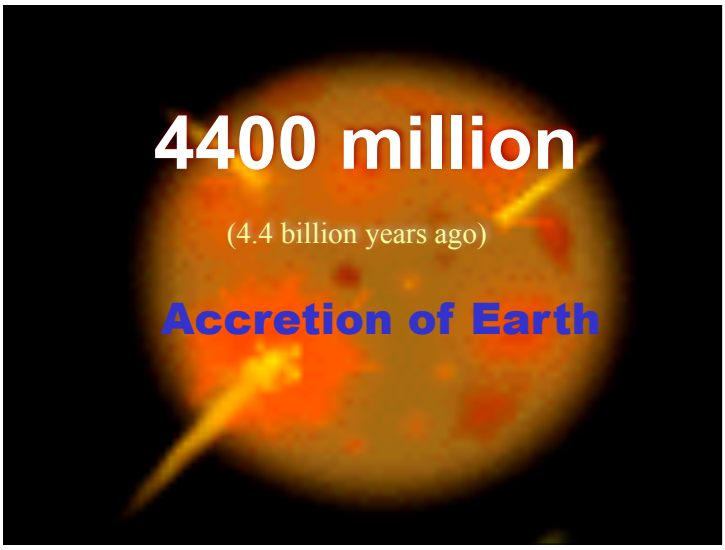
Earth History

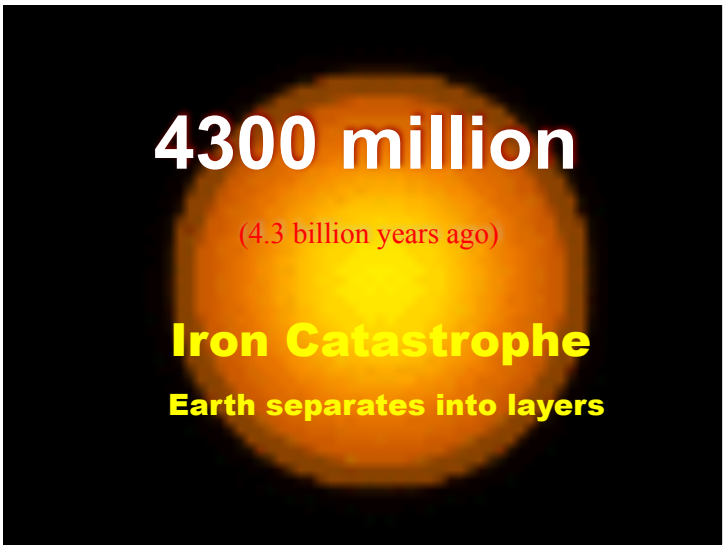
Following slides provide a nice timeline of life on Earth

http://www.udayton.edu/~INSS/






4400 million
(4.4 billion years ago)
Accretion of Earth


4300 million
(4.3 billion years ago)
Iron Catastrophe
Earth separates into layers

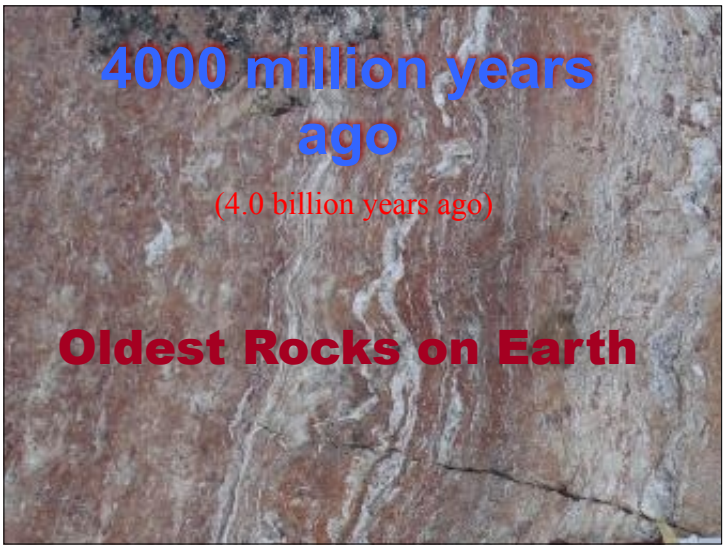

4200 million years ago
(4.2 billion years ago)
Early
No Life

4100 million years ago

(4.1 billion years ago)

Early

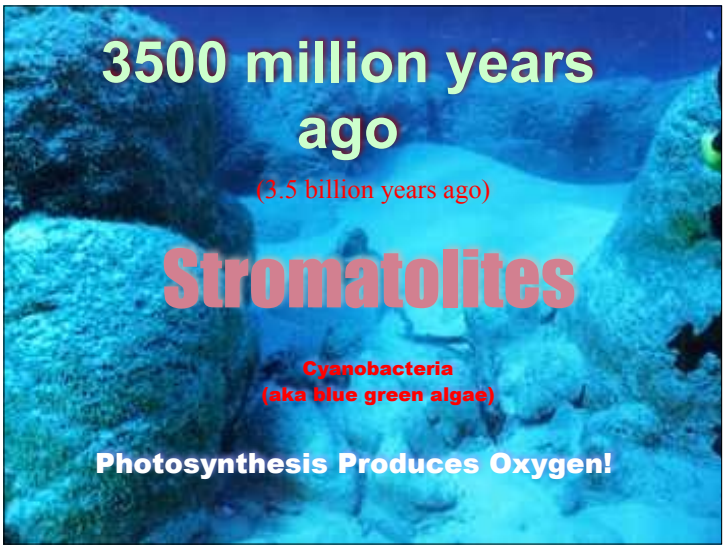
No Life

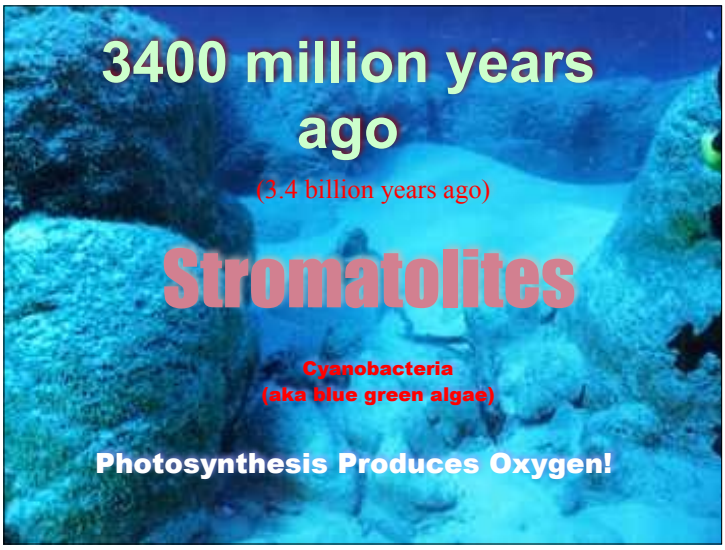


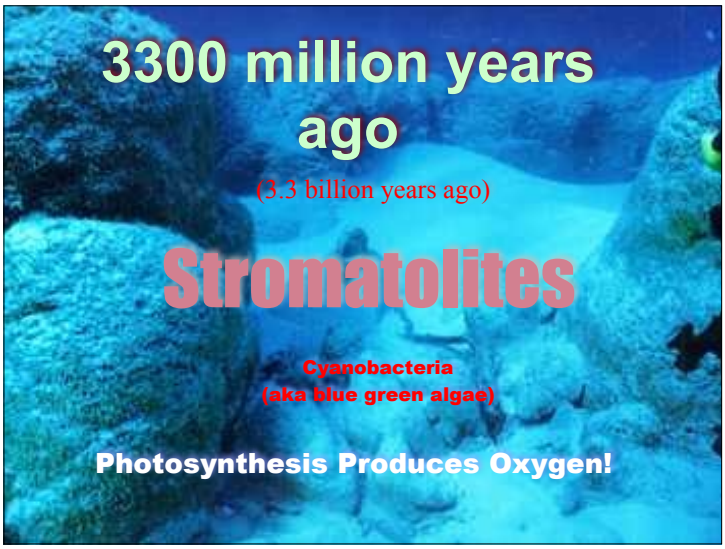

3800 million years ago
(3.8 billion years ago)
First Bacteria (Prokaryotic)

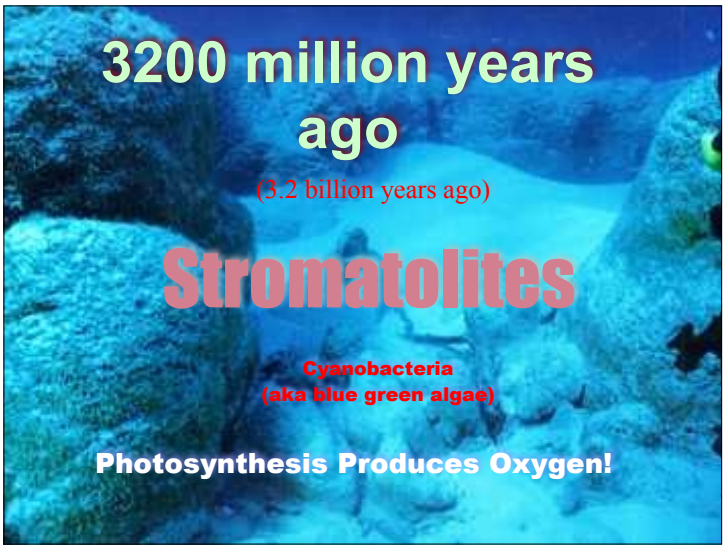

3700 million years ago
(3.7 billion years ago)
Bacteria

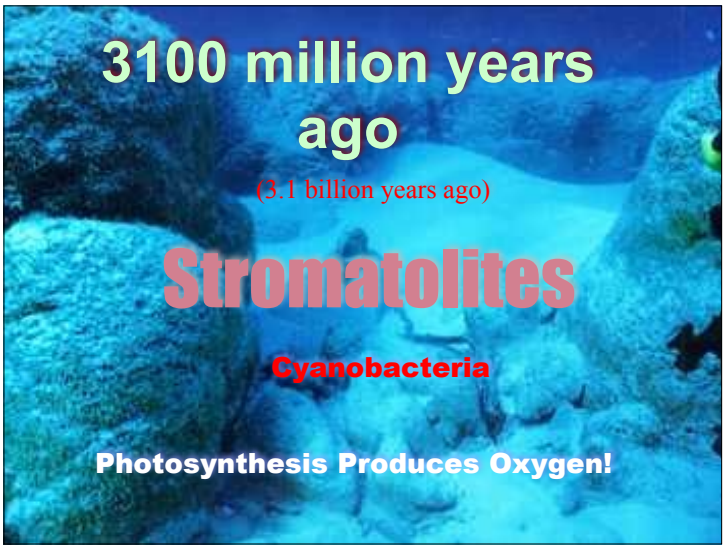

3600 million years ago
(3.6 billion years ago)
Bacteria

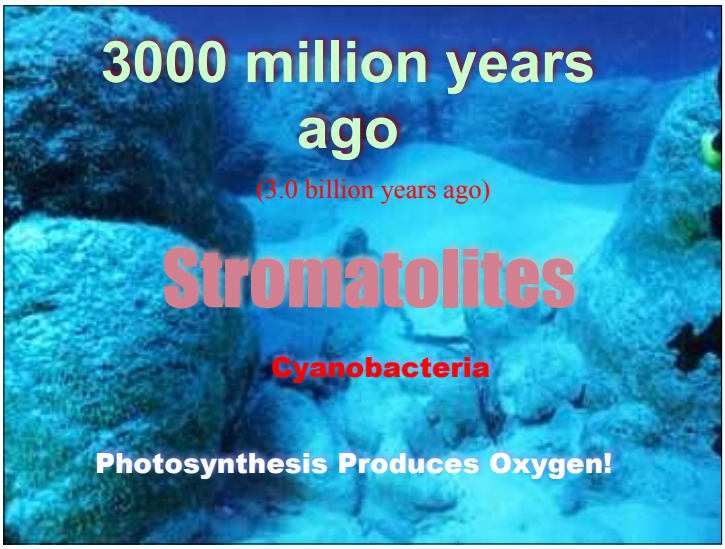

3500 million years ago
(3.5 billion years ago)
Stromatolites
Cyanobacteria
(aka blue green algae)
Photosynthesis Produces Oxygen!

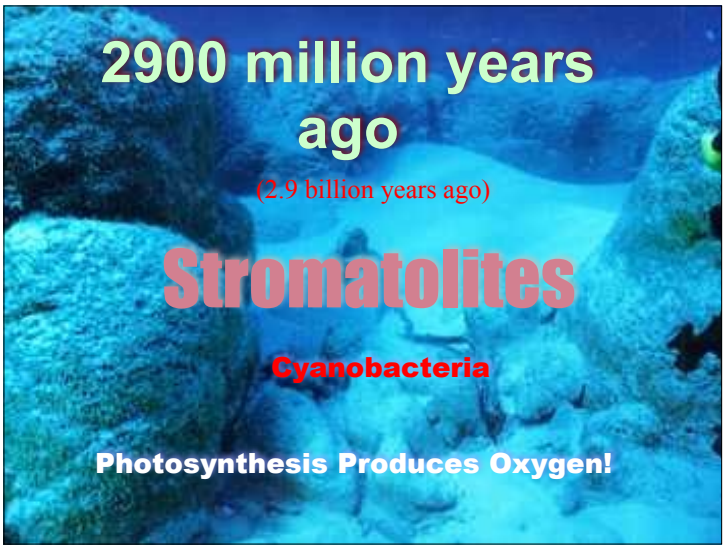

3400 million years ago
(3.4 billion years ago)
Stromatolites
Cyanobacteria
(aka blue green algae)
Photosynthesis Produces Oxygen!

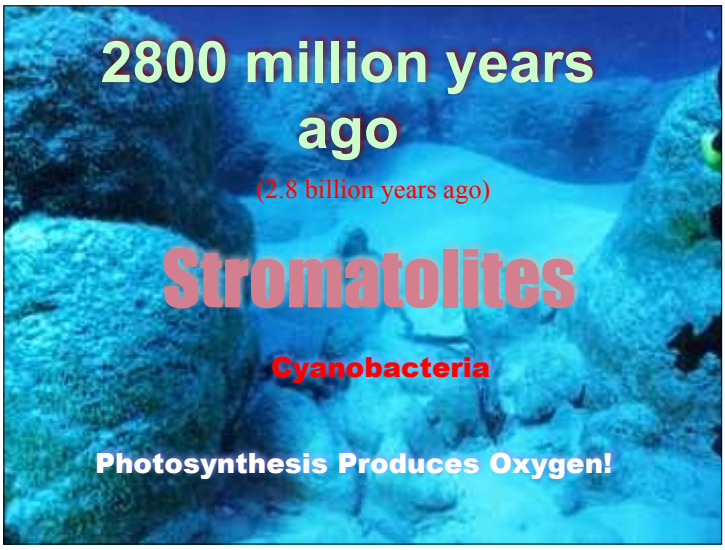

3300 million years ago
(3.3 billion years ago)
Stromatolites
Cyanobacteria
(aka blue green algae)
Photosynthesis Produces Oxygen!

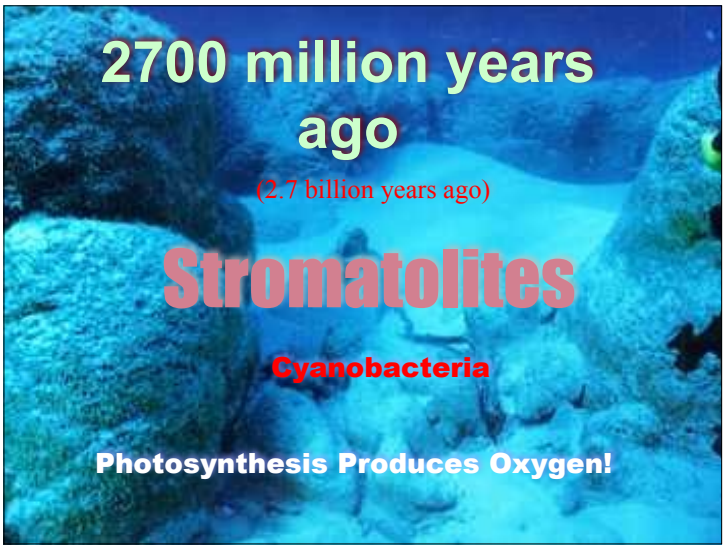

3200 million years ago
(3.2 billion years ago)
Stromatolites
Cyanobacteria
(aka blue green algae)
Photosynthesis Produces Oxygen!

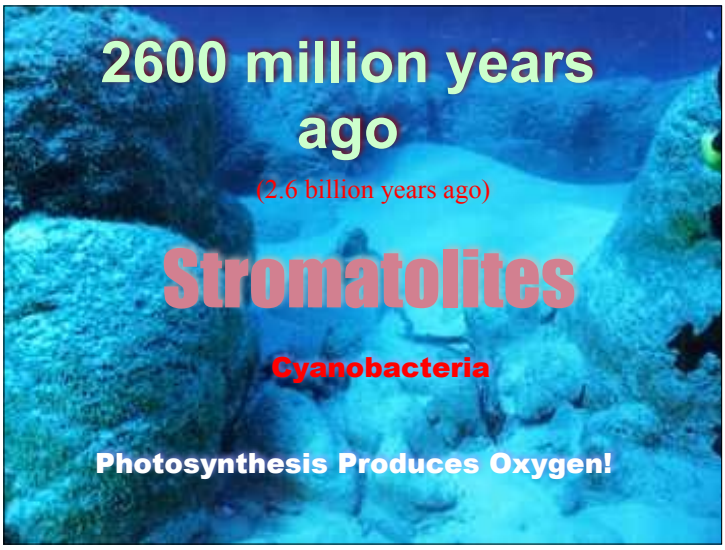

3100 million years ago
(3.1 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!

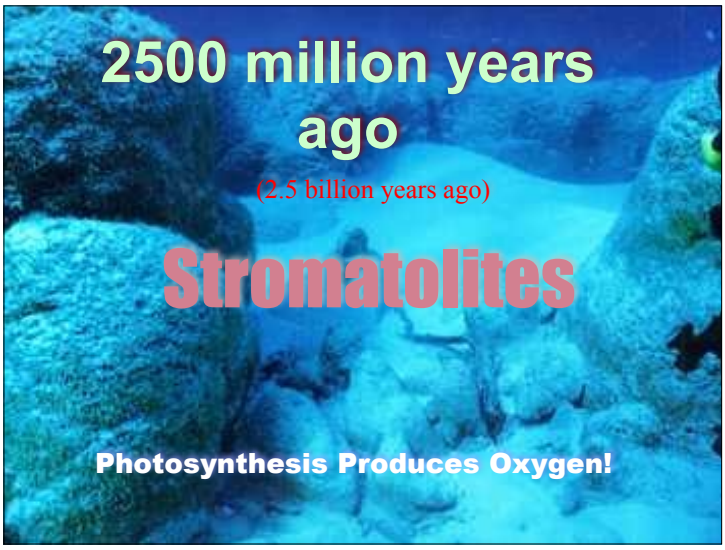

3000 million years ago
(3.0 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!

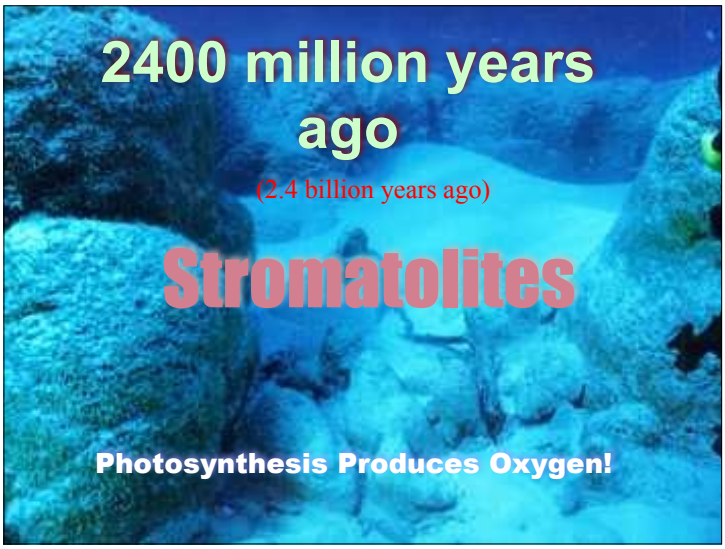

2900 million years ago
(2.9 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!

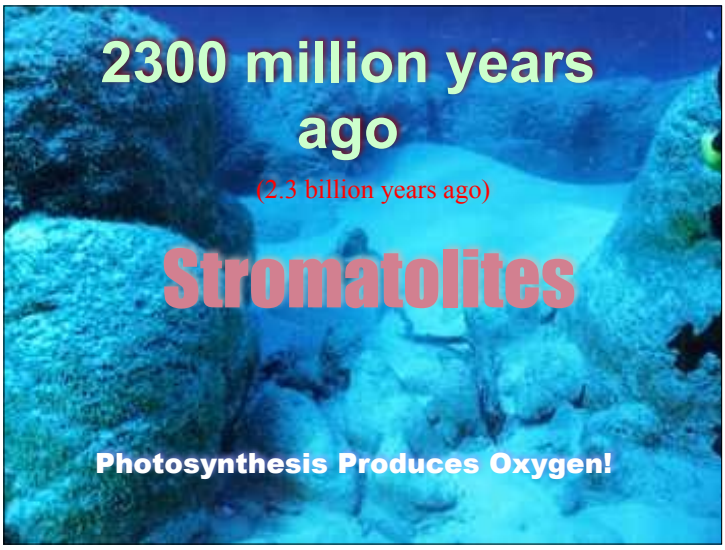

2800 million years ago
(2.8 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!

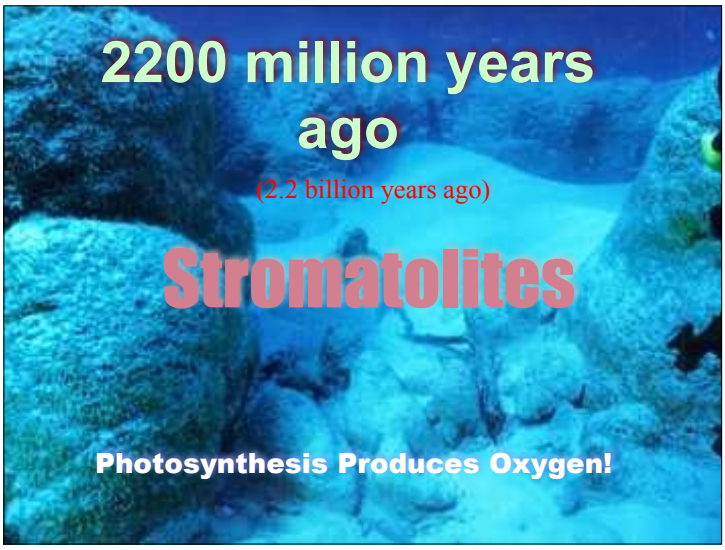

2700 million years ago
(2.7 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!

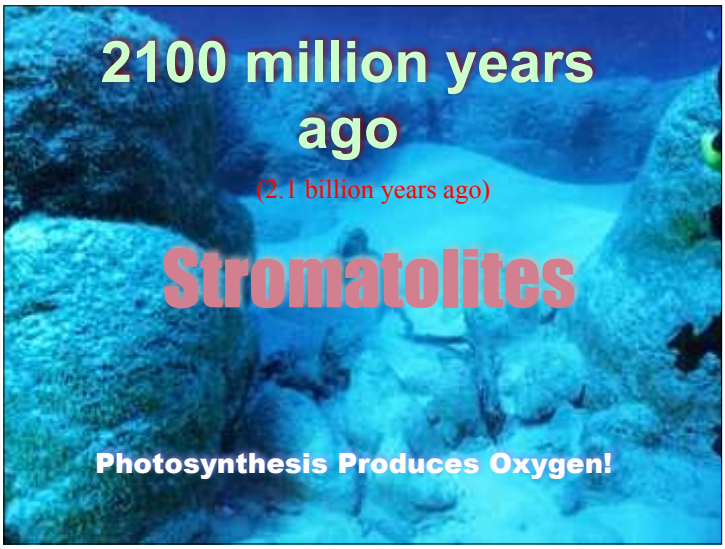

2600 million years ago
(2.6 billion years ago)
Stromatolites
Cyanobacteria
Photosynthesis Produces Oxygen!


2500 million years ago
(2.5 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!


2400 million years ago
(2.4 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!


2300 million years ago
(2.3 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!


2200 million years ago
(2.2 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!

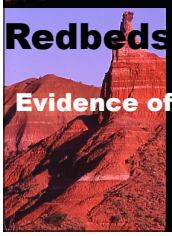

2100 million years ago
(2.1 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!

2000 million years ago

(2.0 billion years ago)

Beginning of

First Pollution Crisis!



Redbeds

Evidence of significant free

1900 million years ago

(1.9 billion years ago)

Oxygenated Atmosphere

Cyanobacteria still producing

1800 million years ago

(1.8 billion years ago)

Oxygenated Atmosphere

Cyanobacteria still producing

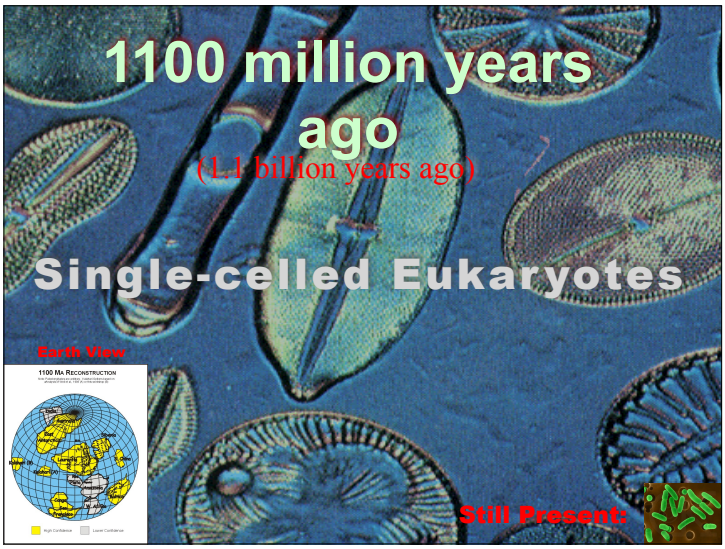

1600 million years ago
(1.6 billion years ago)
Single-celled Eukaryotes
Still Present:


1500 million years ago
(1.5 billion years ago)
Single-celled Eukaryotes
Still Present:


1400 million years ago
(1.4 billion years ago)
Single-celled Eukaryotes
Still Present:


1300 million years ago
(1.3 billion years ago)
Single-celled Eukaryotes
Still Present:


1200 million years ago
(1.2 billion years ago)
Single-celled Eukaryotes
Still Present:


1100 million years ago
(1.1 billion years ago)
Single-celled Eukaryotes
Earth View
1100 Ma Reconstruction
Still Present:


1000 million years ago
(1.0 billion years ago)
Multicellular Organisms Appear
Marine Invertebrates
Soft Bodies


900 million years ago
Marine Invertebrates
Still Present:


800 million years ago
Marine Invertebrates
Earth View
760 Ma Reconstruction
Still Present:

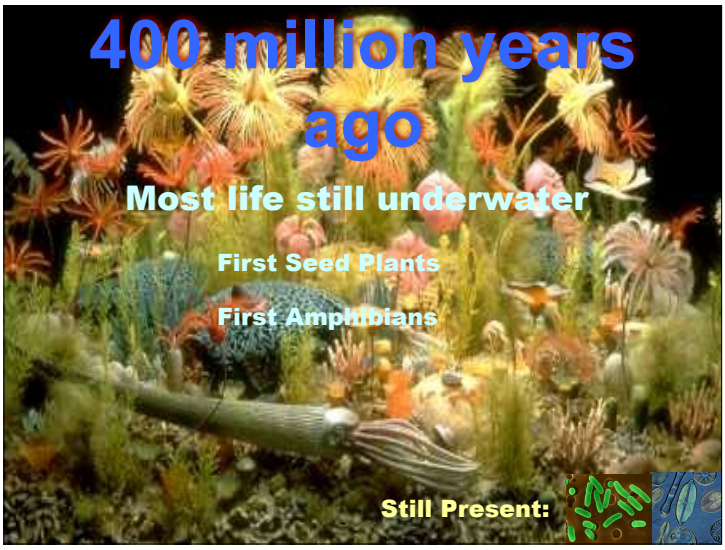

700 million years ago
Marine Invertebrates
Earth View
Still Present:


600 million years ago
Ediacara Fauna
Earth View
Still Present:


500 million years ago
543 mya
First Hard Parts
(Shells & Bones)
First Primitive Fish
Life Migrates to Land
470 mya
Earth View

438 million years ago

Mass Extinction



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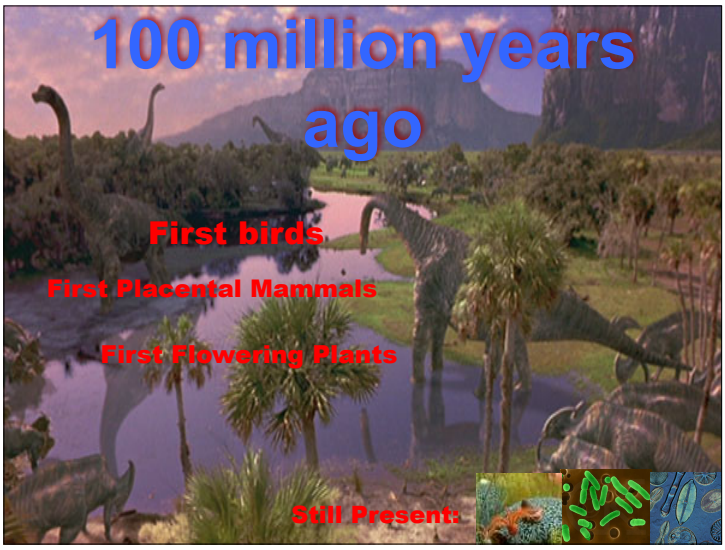
367 million years ago

Mass Extinction

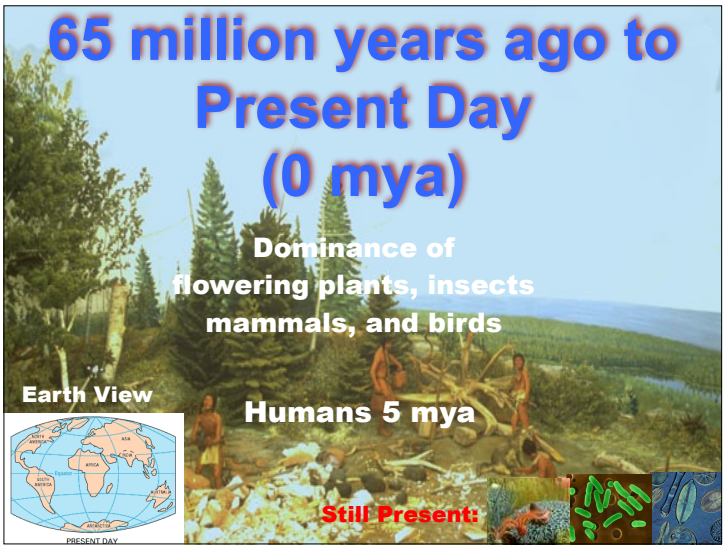

300 million years ago
Vast Coal Swamps on Land
Origin of Many Animals
amphibians, sharks, reptiles, insects
Earth View


245 million years ago
Mass Extinction
90 % of all species perish
Earth View
PANGAEA
PERMIAN
225 million years ago


200 million years ago
Age of the Dinosaurs
Plant Life: Ferns & Gymnosperms
First mammals
Earth View
LAURASIA
TETHYS SEA
GONDWANALAND
TRIASSIC
200 million years ago
Still Present:


100 million years ago
First birds
First Placental Mammals
First Flowering Plants
Still Present:


65 million years ago
Mass Extinction
Extinction of the dinosaurs and others
Earth View
CRETACEOUS
65 million years ago


65 million years ago to Present Day (0 mya)
Dominance of flowering plants, insects mammals, and birds
Earth View
Humans 5 mya
Still Present:
PRESENT DAY

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Evolution of Intelligence

Evolution has produced a diversity of life on Earth.

Evolution has also increased the complexity of organisms

Can complexity be associated with intelligence?

If intelligence is an advantageous trait, it seems plausible that intelligence would increase over time.

But how would we recognize intelligence?