Astronomy 330

This class (Lecture 19):
Origin of Intelligence
Ryan Ruddell

Next Class:
Origin of Intelligence 2
Adam Flanders

HW8 is due Thursday

Music: *Intelligent Guy*– Butthole Surfers

Presentations

- Ryan Ruddell
  Panspermia

Outline

- Two types of cell life: Eukaryotes and Prokaryotes.
- All life can be divided into 3 types:
  - Bacteria
  - Archaea
  - Eukarya
- Genetic diversity of life… leads to intelligence

Drake Equation

That's 2.7 life systems/year

Frank Drake








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

N	R_*	f_p	n_e	f_l	f_i	f_c	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
	20 stars/ yr	0.8 systems/ star	2 x 0.11 = 0.22 planets/ system	0.775 life/ planet	intel./ life	comm./ intel.	yrs/ comm.

Evolution of Intelligence

What is intelligence?

Evolution of Intelligence

- What is intelligence?
- "The ability to model the world, including the organism's own self" is a workable definition.
  - A spectrum of ability
- Crucial development for the full spectrum of intelligence is the diversity of life on Earth.
- Intelligence <u>is not</u> a requirement of life.

http://www.amonline.net.au/insects/images/site/insect1.jpg

Evolution of Intelligence

- First, we will examine the diversity of life; the fossil record shows a huge diversity with time.
- Organisms range from bacteria to humans.
- 1.9 x 10^6 known species
  - Insects account for most (1.0 x 10^6)
  - Estimated that only 10% are known.
  - Bacteria are hard to classify– only 9000 species so far.

http://www.amonline.net.au/insects/images/site/insect1.jpg
http://en.wikipedia.org/wiki/Bacterium#Classification_and_identification

Evolution of Intelligence

- 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.

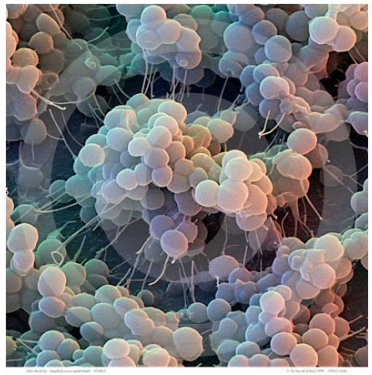
Life

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

Question

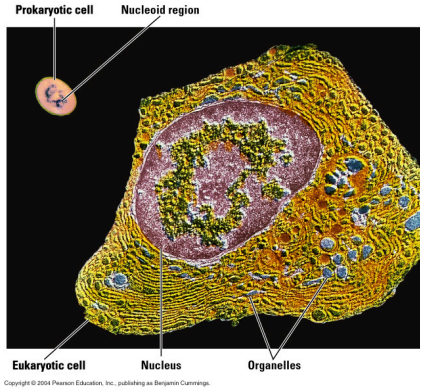
What is a fair definition of intelligence?

a) Able to get an A on the midterm.
b) Able to develop a new iphone application
c) Leslie
d) The ability to model the world, including the organism's own self
e) The ability to model the world into food or threat

Classification of Life

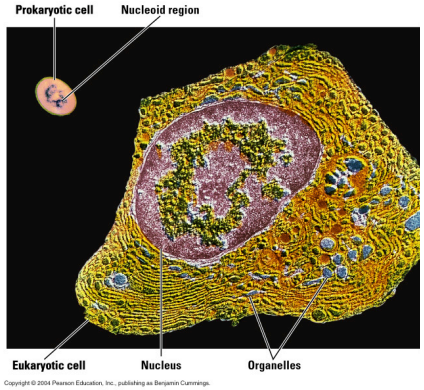
Two types

1. Prokaryotes
2. Eukaryotes



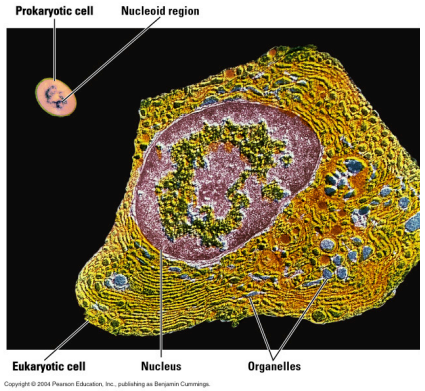
Classification of Life

1. Prokaryotes
   - No cell nucleus– DNA floating around
   - Always single-cell creatures like bacterium
   - Came first
   - Outnumber and outweigh the second class (eukaryotes)



Classification of Life

2. Eukaryotes
   - Have a cell nucleus, a membrane to protect the DNA
   - Basis of all multi-cell creatures
   - Also some single-cell creatures like amoebas.
   - DNA arranged into chromosomes in nucleus– 23 pairs for humans.

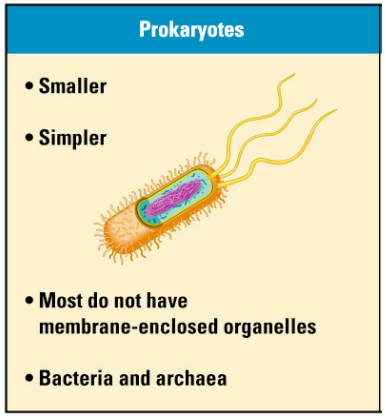


Prokaryotes

<u>Divided into 2 domains:</u>

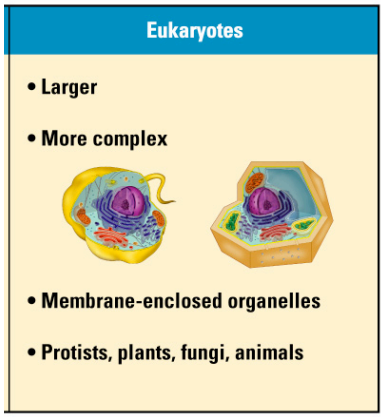
1. Eubacteria or "true" bacteria
2. Archaea
   - 20% of the world's biomass.
   - Thought to be the oldest surviving organisms.
   - Often found in harsh environments: hot springs, undersea vents, salty seashores, etc, which were probably more common on the early Earth.
   - Some evidence that ancient organisms were heat-lovers (maybe)

Carl Woese here at Illinois, discovered Archaea scheme.



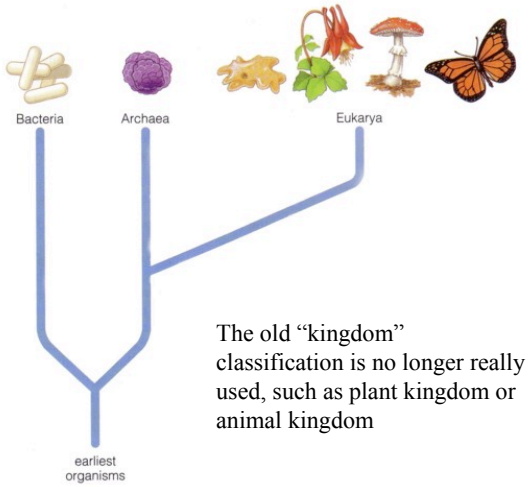
Eukaryotes

- All animals, plants, and fungi.



3 Domains of Life

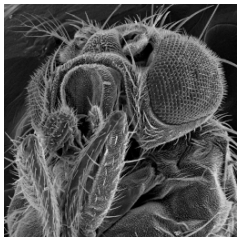
- Genetically speaking, Archaea and Eukarya are more similar to one another than are Bacteria and Archaea
- Implies that Archaea and Bacteria split and then all Eukarya split from Archaea
- A major implication for the evolution of life on Earth

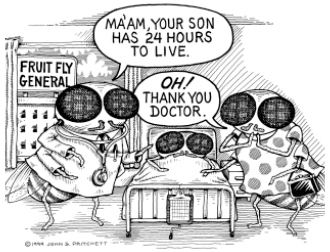


The old "kingdom" classification is no longer really used, such as plant kingdom or animal kingdom

Genetic Relations

- This is a major change from the old methods of assigning groups based on outward form and anatomy.
- Instead based on studies of the genetic code.
- Surprise: Human and chimpanzees share about 99% of the same DNA, and about 97% with mice.
- Surprise: 2 species of fruit fly look very much alike, but only share about 25%. Some of this differences is due to "*junk*" DNA.





http://www.nelybug.org/index00.shtml

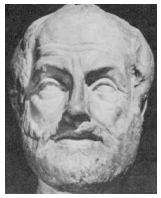
http://www.pritchettcartoons.com/fruitfly.htm

Question

What type of life is more closely related to us?

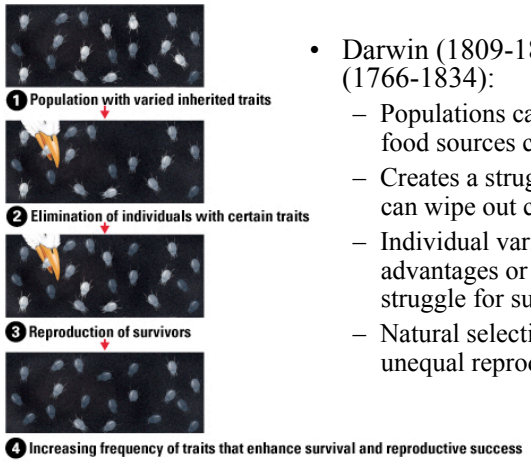
a) Archaea
b) Eubacteria
c) True Bacteria

Changes in Bio-Systems



- Today's view: evolution is the most important and unifying property of life.
- Anaximander (c. 610-547 BC): life arose in water and gradually became more complex
- Empedocles (c. 492-432 BC): survival of the fittest (but, "*a good idea stated within an insufficient theoretical frame loses its explanatory power and is forgotten",* Hans Reichenbach)
- Aristotle (384-322 BC): species are fixed and independent of each other → evolution discarded for 2000 years
- Fossil record: slowly broke down the Aristotelian theory

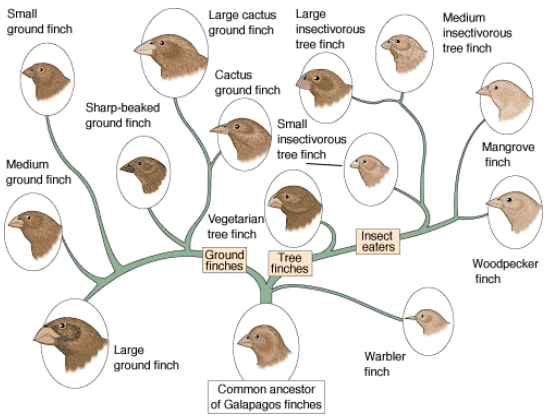
For the Species Survival



- Darwin (1809-1882) & Malthus (1766-1834):
  - Populations can grow faster than food sources can support them.
  - Creates a struggle for survival that can wipe out competitors.
  - Individual variations has advantages or disadvantages in the struggle for survival
  - Natural selection can create unequal reproductive success

Filling the Niche with Finch

- Other Evidence:
  - Adapted species in the Galápagos Islands, in particular finches
  - Artificial breeding of house/farm animals and vegetables
- DNA is really the mechanism of natural selection, but evolution requires both heredity and environment



Mutant Sex

- Mutations from changes in the bases of DNA.
- Usually copying errors, but also radiation– radioactivity, cosmic rays, chemical agents, or UV light.
- About 3 mutations per person per generation.
- Most mutations are neutral, changes in the *junk* DNA.
- Why is sex important to this class?

http://www.mutantx.net/features/press_vw_sexy.html

Mutant Sex

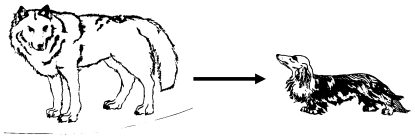
- Sexual reproduction leads to greater genetic diversity– a difference between prokaryotes and eukaryotes?
- Asexual reproduction does not allow 2 new and beneficial mutations to combine.
- Blackberries have not changed much in 10 millions years, but sexual plants have produced: raspberries, thimbleberries, cloudberries, dewberries, etc.
- Sex is useful in the process, but the mutations are still key.

http://www.alcasoft.com/arkansas/blackberry.html

Does Mutant Sex take a long time?

Cabbage, kale, kohlrabi, brussels sprouts, cauliflower and broccoli have same common ancestor– wild mustard. All bred by humans on a very short time scale.

This is selective breeding, but still the potential is in the DNA.



Or domestic lap dogs from wolves in about 5000 years.

Question

Sex in space, or on Earth, is important because

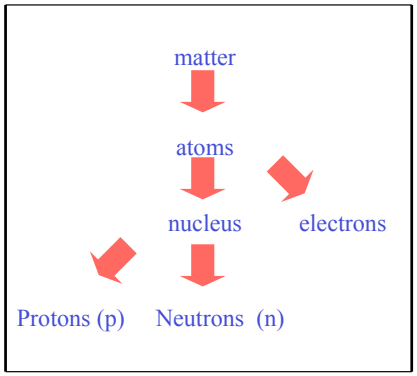
a) sex, although fun, also stimulates gene mutations.
b) it allows the genetic material of the better organisms to survive.
c) mutations can only occur in sexual reproduction.
d) it leads to greater genetic diversity and an increase of positive mutations in the offspring.

Comparing Ages

- Important to understand history of Earth life is the ability to age different components
- Can be difficult
- Radioactive dating….
  - ^{14}C for the last 60,000 years
  - ^{40}K and ^{235}U for 100's of millions of years

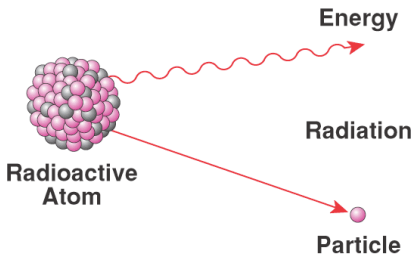
Radioactive Dating

Recall:



- Most atomic nuclei stable
- But some nuclei are *unstable*.

  ⇒ *decay* to new nucleus
  "radioactive"



The Law of Radioactive Decay

As radioactive "parent" decays, the number of decay product or "daughters" increases

Decay is a good "clock"

- Each radioactive species has different "tick"
- Rate= "half-life"
- Exponential decay from original population of n_0

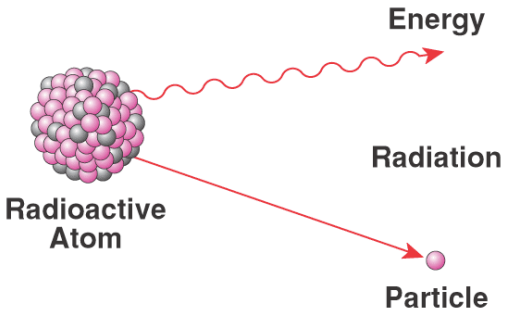
Decay Rule

Start out with N parents, 0 daughters

Time t since start	# parents	# daughters
0	N	0
$t_{1/2}$	½ N = half as much	½ N have appeared
$2t_{1/2}$	¼ N = half again as much	¾ N
$3t_{1/2}$	1/8 N	7/8 N
$30t_{1/2}$	About $N/10^9$	99.9999999% N

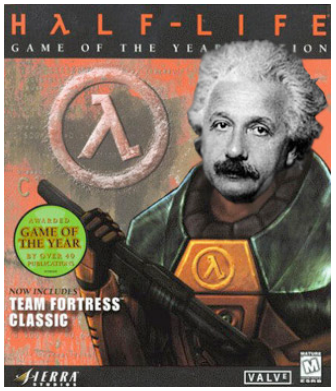
Radioactive Decay Examples

http://www.colorado.edu/physics/2000/isotopes/radioactive_decay3.html



Carbon-14

- Cosmic rays from space are constantly hitting the Earth.
- React with ^{14}N in atmosphere to create ^{14}C.
- Decays back to ^{14}N with half life of 5730 years.
- But, there is an equilibrium in abundance
- In atmosphere, the ^{14}C is mostly in $^{14}CO^2$.



http://bbspot.com/Images/News_Features/2003/12/half-life.jpg

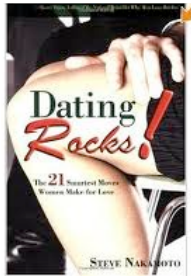
Carbon-14

- Plants take in $^{14}CO^2$ with the $^{12}CO^2$ and other animals eat the plants.
- So, every living creature has a equilibrium ratio of $^{14}CO^2/^{12}CO^2$.
- When the organism dies, the ^{14}C decays to ^{14}N. By measuring how much ^{14}C remains, you can date the fossil.
- This works well to about 60,000 years.
  - Viking remains in Newfoundland– 500 yrs before Columbus.
  - Shroud of Turin to 1330 AD

http://web.mit.edu/smcguire/www/newfoundland/newf16.html

Dating Rocks

- First you ask them out?
- No, you need a radioactive decay that has a longer half-life than ^{14}C.
- Potassium-argon
  - ^{40}K decays to ^{40}Ar with a 1200 Myr half-life.
- Uranium-lead
  - ^{235}U to ^{207}Pb with 700 Myr half-life.



Dating Rocks

- But these only work with volcanic layers.
- So, the ages of fossils are interpolated from ages of volcanic layers above and below them.

Era	*Period*	*Myr Ago*	*Life Forms*	*Events*
Cenozoic	Quaternary	2	H. Sapiens	Ice ages
	Tertiary	65	Primates	Extinction of Dinosaurs
Mesozoic	Cretaceous	136	Birds	S. Atlantic open to 1900 miles
	Jurassic	190		N. Atlantic open to 600 miles
	Triassic	225	Mammals	Continental drift
Paleozoic	Permian	280	Reptiles	Pangaea breaks up
	Carboniferous	345	Amphibians	Formation of coal
	Devonian	395	Insects	
	Silurian	430	Land Plants	
	Ordovician	500	Fish	
	Cambrian	543	Trilobites	
Precambrian		545	Small Shelly Fossils	
		580	Ediacarans	
		600-800	Multicellular life	Snowball Earth episodes

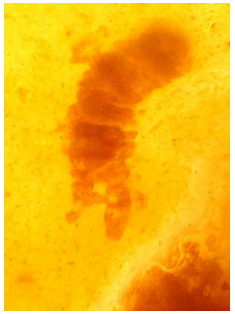
Increase of Complexity

- Last table showed only the last 800 Myrs.
- The more complex and intelligent organisms appeared towards the end.
- For many years it was thought that life originated in the Cambrian era, then Precambrian fossils were found.
- Then, it was realized that there were single-celled fossils that required microscopes.

Myr Ago	*Era*	*Event*
Now	Cenozoic	
	Mesozoic	
	Paleozoic	Macroscopic life/Snowball Earth
	Precambrian	
1000		Worm tracks
		Multicellular algae
		Eukaryotes certain
		Sexual reproduction
2000		Eukaryotes possible
	Protozoic	Oxygen-rich atmosphere
		Snowball Earth
		Formation of continents
3000	Archean	Life begins?
4000		Formation of Oceans
		Bombardment decreases
		Frequent impacts
	Hadean	Earth formed

Concepts

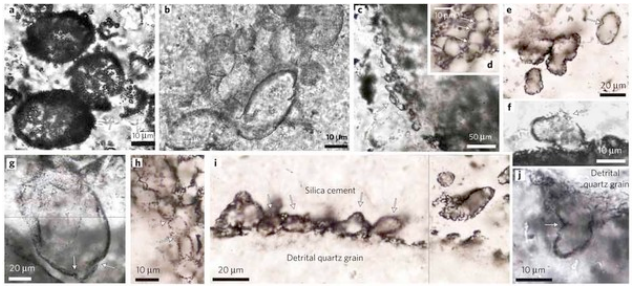
- As prokaryotes are simpler than eukaryotes, we expect them to exist first.
- Identifying fossil prokaryotes is difficult: they're tiny!
- All of the macroscopic life only arose in the last 600 Myrs– 1/6th of the history of life on Earth.



http://www.earth.ox.ac.uk/research/geobiology/geobiology.htm

Oldest Fossils

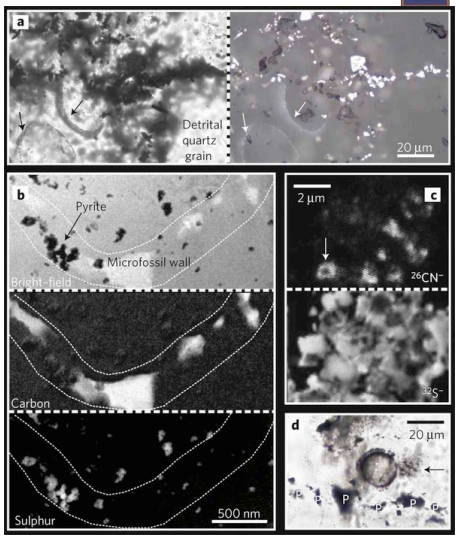
- Best examples of early fossil life are from microfossils of sulphur-metabolizing cells in 3.4-billion-year-old rocks of Western Australia!
- Feb 2011



http://www.nature.com/ngeo/journal/v4/n10/full/ngeo1238.htmlhttp://www.nature.com/ngeo/journal/v4/n10/full/ngeo1238.html

Oldest Fossils

- Best examples of early fossil life are from microfossils of sulphur-metabolizing cells in 3.4-billion-year-old rocks of Western Australia!



http://www.nature.com/ngeo/journal/v4/n10/full/ngeo1238.htmlhttp://www.nature.com/ngeo/journal/v4/n10/full/ngeo1238.html

Early Earth

- We've talked about the Early Earth's atmosphere– mostly N and CO_2, which dominated the atmosphere for the first 3 billion years!
- But life was polluting the planet even then.

Making Oxygen!

- The early prokaryotes played a crucial role for life on Earth by producing oxygen through photosynthesis.
- Cyanobacteria (also called blue-green algae) changed the world!
- Lived in colonies that formed mats or films, growing into large structures called stromatolites.
- Still around, but much more common before 700 Myrs ago.

Making Oxygen!

- About 2 billion years ago atmosphere became oxygenated!
- Probably killed off many species.
- But, oxygen was new and important step in intelligence
- It allowed a new energy extraction method
  - Aerobic (using oxygen) metabolism
  - More complex life
  - Created ozone layer (dry land now an option for life on Earth!)

Relationship to ETs

- Would evolution on other planets have a similar time-scale?
- Evolution is not a deterministic process.
- Selection seems to be mostly luck, rather than adaptation.
- On the other hand, many traits have developed in several lineages– warm blood and eyes.
- Some say that intelligence seems to increase in many lineages, so it is likely that if life exists then intelligent life exists.
- On the other hand, the plant kingdom never developed neurons.

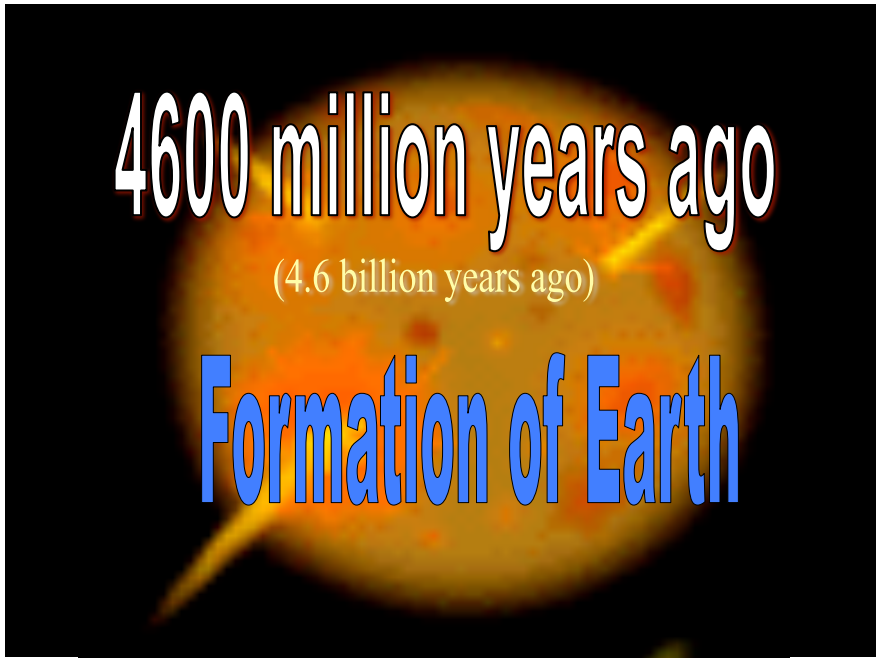
Question

The Early Earth's oxygen in our atmosphere came from

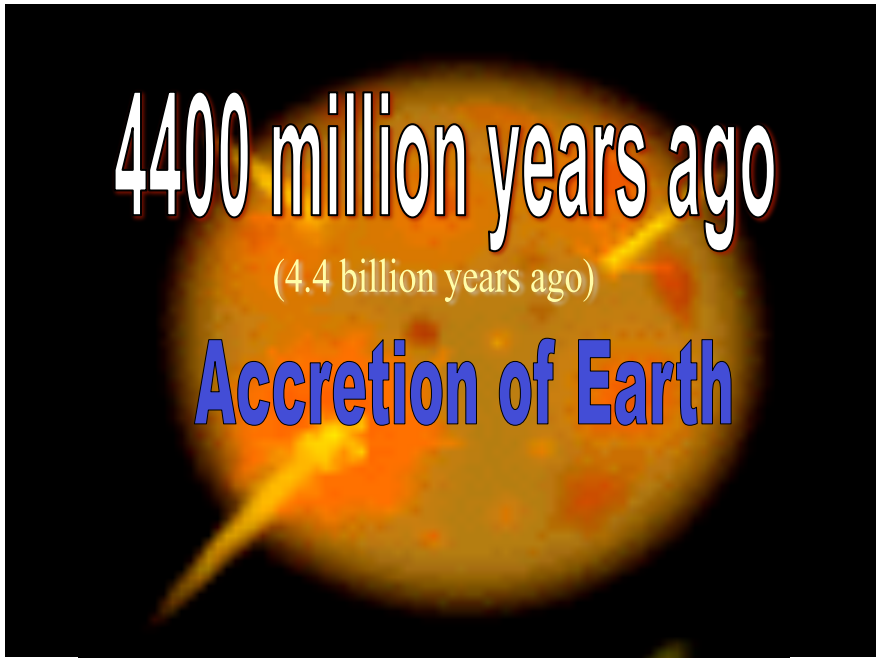
a) trees.
b) colonies of cyanobacteria.
c) comets.
d) colonies of plankton.
e) outer space.

Summary

- This following slides are from: http://www.udayton.edu/~INSS/
- Nice timeline of life on Earth.




4500 million years ago
(4.5 billion years ago)
Accretion of Earth
Formation of the Moon


4400 million years ago
(4.4 billion years ago)
Accretion of Earth


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

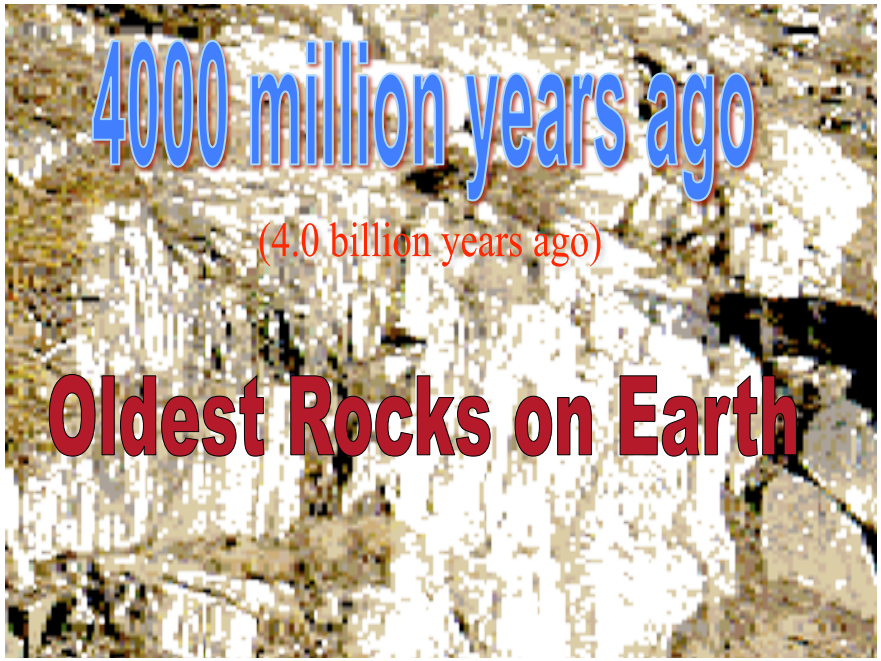

4200 million years ago
(4.2 billion years ago)
Early Atmosphere
No Life

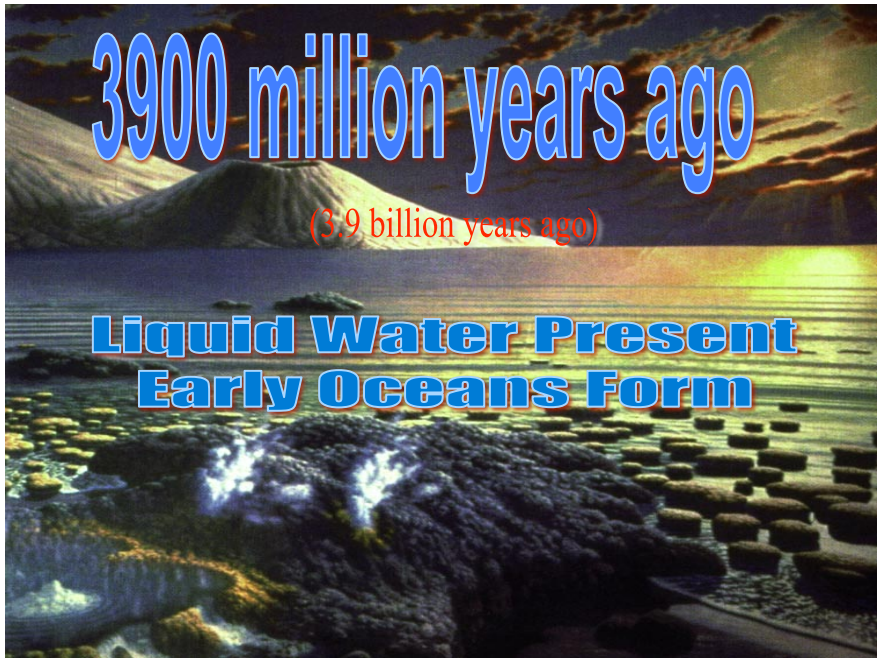
4100 million years ago

(4.1 billion years ago)

Early Atmosphere

No Life






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

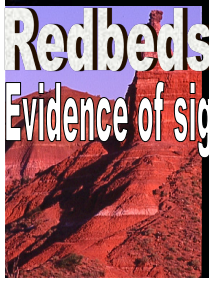
Photosynthesis Produces Oxygen!

2000 million years ago

(2.0 billion years ago)

Beginning of Oxygenated Atmosphere

First Pollution Crisis!



Redbeds

Evidence of significant free oxygen

1900 million years ago

(1.9 billion years ago)

Oxygenated Atmosphere

Cyanobacteria still producing oxygen!

1800 million years ago

(1.8 billion years ago)

Oxygenated Atmosphere

Cyanobacteria still producing oxygen!


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

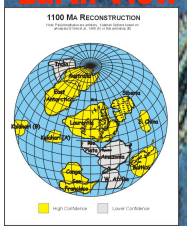
Still Present:

1100 million years ago

(1.1 billion years ago)

Single-celled Eukaryotes

Earth View



Still Present:

1000 million years ago

(1.0 billion years ago)

Multicellular Organisms Appear

Marine Invertebrates

Soft Bodies

900 million years ago

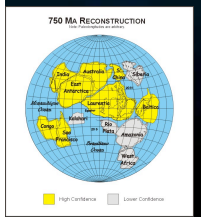
Marine Invertebrates Flourish

Still Present:

800 million years ago

Marine Invertebrates Flourish

Earth View

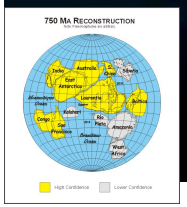


Still Present:

700 million years ago

Marine Invertebrates Flourish

Earth View



Still Present:

600 million years ago

Ediacara Fauna

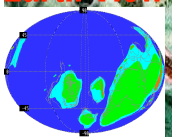
Earth View

Still Present:

500 million years ago

543 mya
First Hard Parts
(Shells & Bones)
First Primitive Fish

Earth View



Life Migrates to Land
470 mya

438 million years ago

Mass Extinction

400 million years ago

Most life still underwater

First Seed Plants

First Amphibians

Still Present:

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

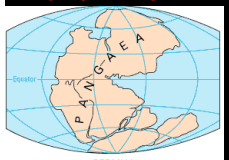
Pangea: "All lands". The face of the Earth has changed through time. 200 million years ago most of the world's landmasses was united into one 'supercontinent' called Pangea. USU's Paleomagnetics lab studies the past movement of continents.

245 million years ago

Mass Extinction

90 % of all species perish

Earth View



PERMIAN
225 million years ago

200 million years ago

Age of the Dinosaurs and Reptiles

Plant Life: Ferns & Gymnosperms

First mammals

Earth View

TRIASSIC
200 million years ago

Still Present:

100 million years ago

First birds

First Placental Mammals

First Flowering Plants

Still Present:

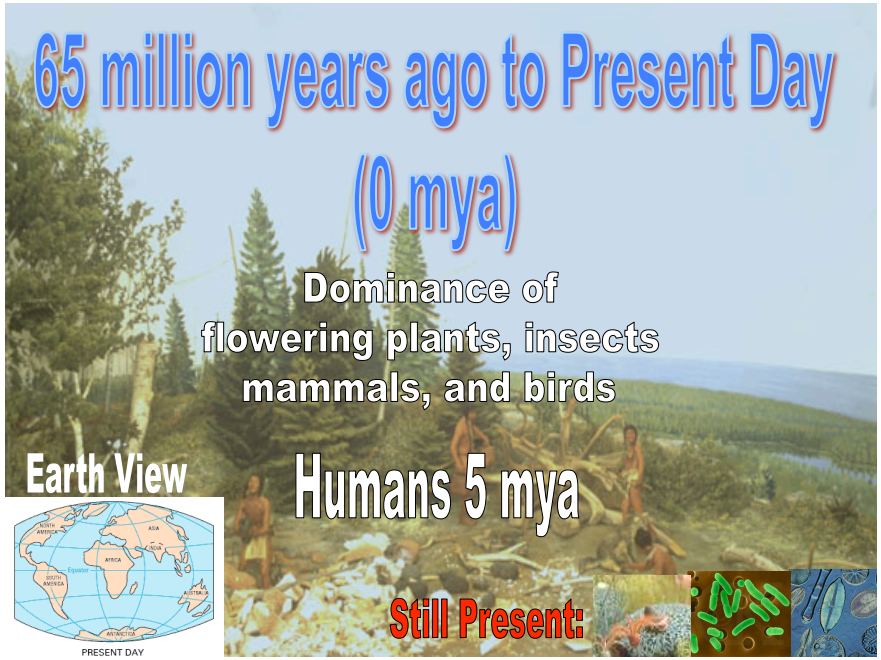
65 million years ago

Mass Extinction

Extinction of the dinosaurs and others

Earth View

CRETACEOUS
65 million years ago



Picture Credits

Smithsonian Institute
Field Museum
NASA
University of California, Berkeley Museum
http://rainbow.ldeo.columbia.edu/courses/v1001/7.html
http://www.geol.umd.edu/~kaufman/ppt/chapter3/sld019.htm
http://www.uta.edu/geology/geol1425earth_system/images/gaia_chapter_11/ArcheanLandscape.jpg
http://www.uta.edu/geology/geol1425earth_system/1425chap11.html
http://www.geol.umd.edu/~kaufman/ppt/chapter3/sld019.htm
http://www.exhibits.lsa.umich.edu/Exhibits/Anthropology/Diaramas/Nat.Am./Copper/Copper.html