ET: Astronomy 230

HW 7 due on Friday!

Presentations Monday Nov 7th

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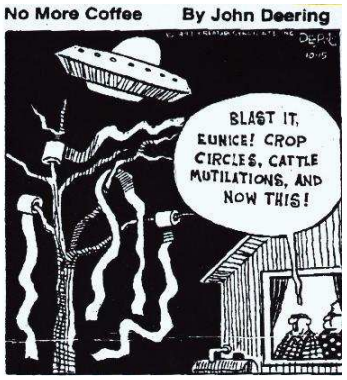
This Class (Lecture 28):

Biological Evolution

Next Class:

Origin of Intelligence

Music: *Space Oddity* – David Bowie



Outline

- Two types of cell life: Eukaryotes and Prokaryotes.
- All life can be divided into 3 types:
  - Bacteria
  - Archaea
  - Eukarya
- Variation in Life from evolution.
- And sex
- Radioactive decay
- Early Life– making the atmosphere.
- Summary of life on Earth.

Drake Equation

= 0.21

Life planets /year

Frank Drake

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

# of advanced civilizations we can contact in our Galaxy today	Rate of star formation	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
	10 stars/ yr	0.38 systems/ star	0.11 planets/ system	0.5 life/ planet	intel./ life	comm./ intel.	yrs/ comm.

Evolution of Intelligence

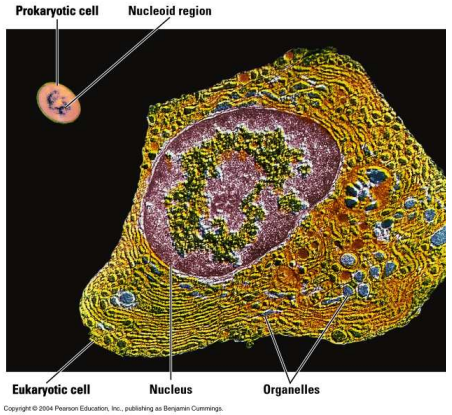
- First we will examine the diversity of life; the fossil record shows a huge diversity with time.
- Organisms range from bacteria to humans.
- 1.8 x 10^6 known species
  - Insects account for most (1.0 x 10^6)
  - Estimated that only 10% are known.
  - Bacteria are hard to classify– only 4000 species so far.
- 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?

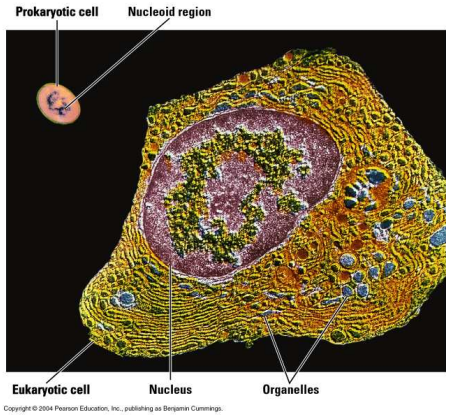
Classification of Life

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



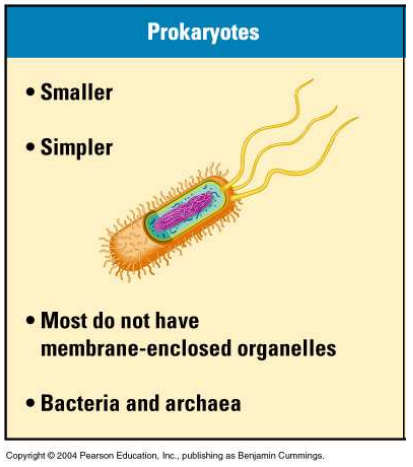
Classification of Life

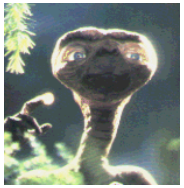
2. Eukaryotes
   - Have a cell nucleus, a membrane to protect the DNA
   - Basis of all multi-cell creatures
   - Also some single-cell creatures like amoebas.
   - DNA arranged into chromosomes in nucleus– 23 pairs for humans.



Prokaryotes

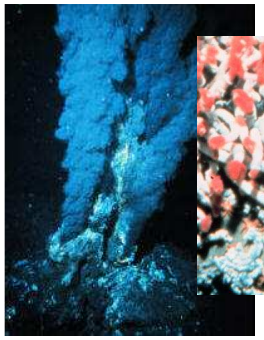
- Divided into 2 domains:
- Eubacteria or "true" bacteria
- Archaea
  - Thought to be oldest life forms.
  - Often found in harsh environments: hot springs, undersea vents, salty seashores, etc, which were probably more common on the early Earth.
  - Some live deep underground, and may represent a significant fraction of the Earth's biomass.
  - Some evidence that ancient organisms were heat-lovers (maybe)





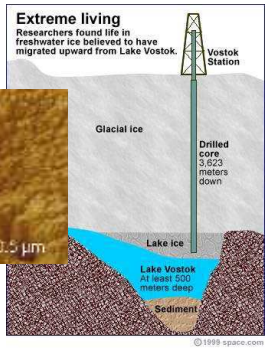
Not your Parent's ET-- Extremophiles

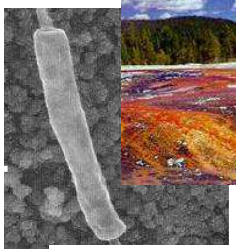
- These are microbes that live in the most extreme places on Earth.
- Temperature extremes
  - boiling or freezing, 100^0C to -1^0C (212F to 30F)
- Chemical extremes
  - vinegar or ammonia (<5 pH or >9 pH)
  - highly salty, up to ten times sea water
- They are exciting, as they are the most likely candidate for extraterrestrial life.
- Probably dominated life on early Earth until fairly recently.


Hydrothermal vent

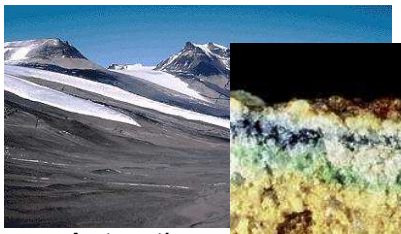

Tubeworms


Lake Vostok - Antarctica




Thermophilic bacteria

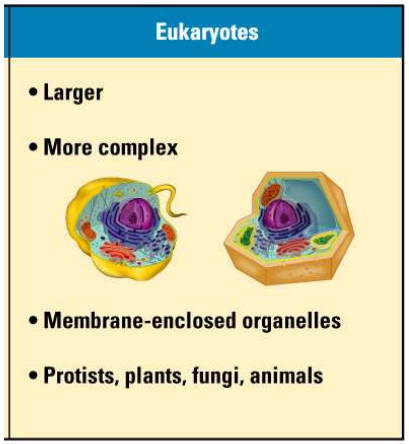

Hot springs


Antarctic dry valley

Cryptoendoliths

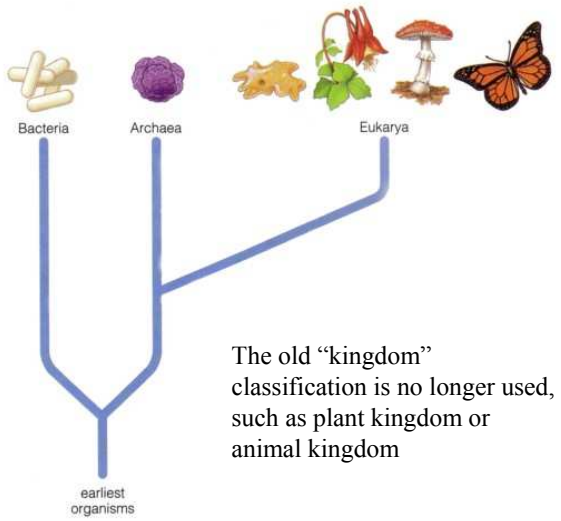
Eukaryotes

- All animals, plants, and fungi.



3 Domains of Life

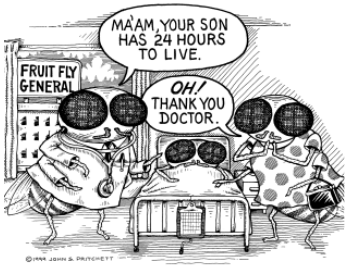
- Genetically speaking, Archaea and Eukarya are more similar to one another than are Bacteria and Archaea
- Implies that Archaea and Bacteria split and then all Eukarya split from Archaea
- A major implication for the evolution of life on Earth



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

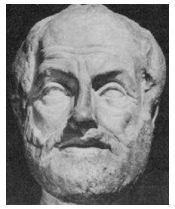
Genetic Relations

- 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.



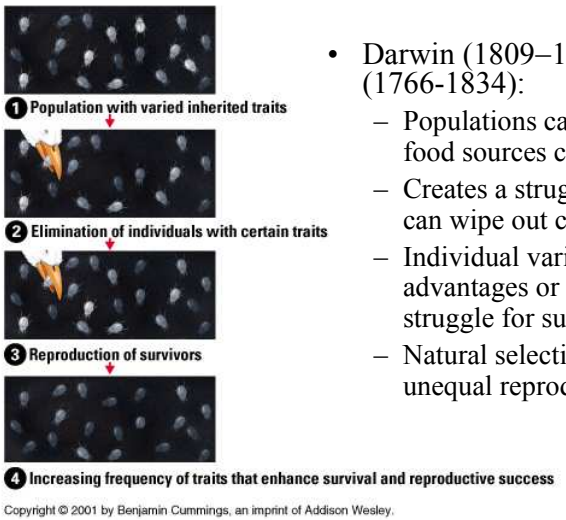
http://www.uglybug.org/index00.shtml
http://www.pritchettcartoons.com/fruitfly.htm

Changes?



- 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"* by 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

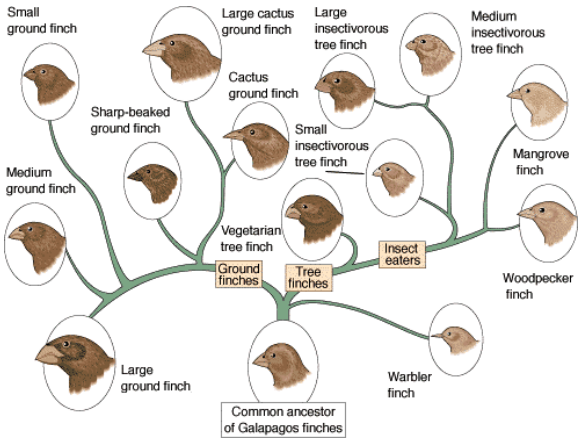
For the Species Survival



- 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 enviroment



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

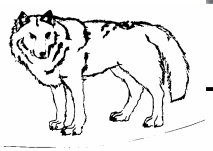
- Sexual reproduction leads to greater genetic diversity– a difference between prokaryotes and eukaryotes?
- Asexual reproduction does not allow 2 new and beneficial mutations to combine.
- Blackberries have not changed much in 10 millions years, but sexual plants have produced: raspberries, thimbleberries,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

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

Does it 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.

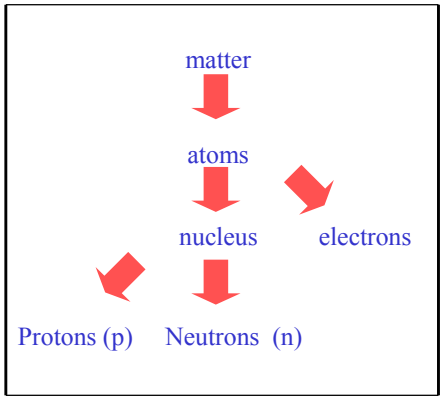
This is selective breeding, but still the potential is in the DNA.



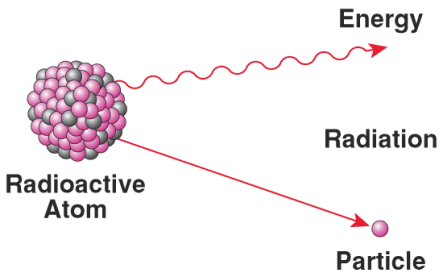
Or domestic lap dogs from wolves in about 5000 years.

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

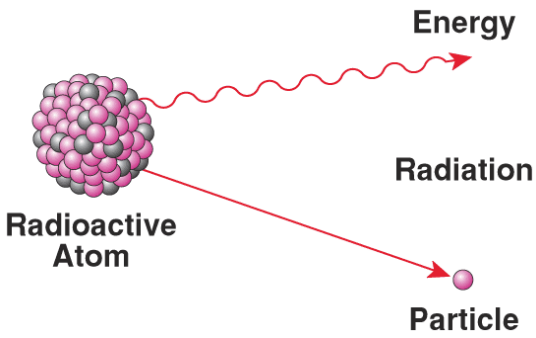
Decay Rule

Start out with N parents, 0 daughters

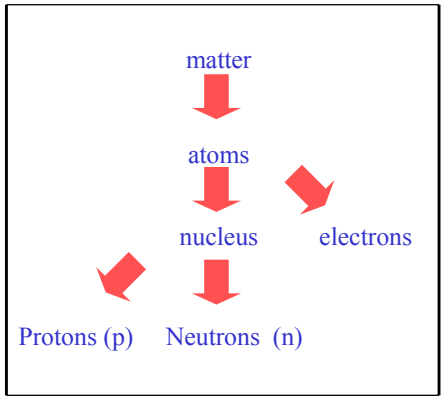
Time t since start	# parents	# daughters
0	N	0
$t_{1/2}$	½ N = half as much	½ N have appeared
$2t_{1/2}$	¼ N = half again as much	¾ N
$3t_{1/2}$	1/8 N	7/8 N
$30t_{1/2}$	About $N/10^9$	99.9999999% N

Radioactive Decay Examples

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



Radioactive Dating



Example 1: Carbon C=6p

- Carbon-12: 6p+6n, stable
- Carbon-14: 6p + 8n, unstable (1/2 life of 5730 years)
- **$^{14}C \rightarrow {}^{14}N$ (nitrogen)**
- Nitrogen-14: 7p + 7n, stable

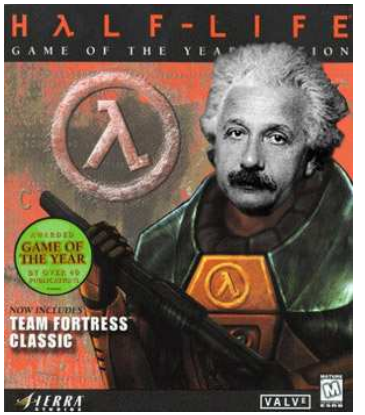
Example 2: Uranium U=92p

- Uranium-238: 92 p + 146 n (1/2 life of 4.5 billion years)

$^{238}U \rightarrow$ chain of decays $\rightarrow {}^{206}Pb$ (lead)

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.
- 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

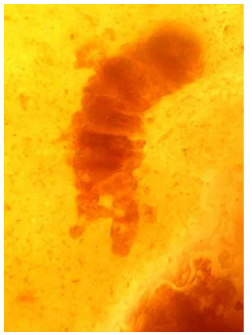
Increase of Complexity

- Last table showed only the last 800 Myrs.
- More complex and intelligent organisms appeared later on.
- 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

L.W. Looney

Concepts



- As prokaryotes are simpler than eukaryotes, we expect them to exist first.
- Identifying fossil prokaryotes is difficult: they're tiny!
- But there is enough evidence that before 1500-2000 Myrs ago there are only prokaryotes fossils.
- Note: the oldest fossils (3800 Myrs ago) are under dispute, but the 2800 Myr old fossils are universally accepted.
- 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

Making Oxygen!

- The early prokaryotes played a crucial role for life on Earth by producing oxygen through photosynthesis.
- Cyanobacteria (was 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!

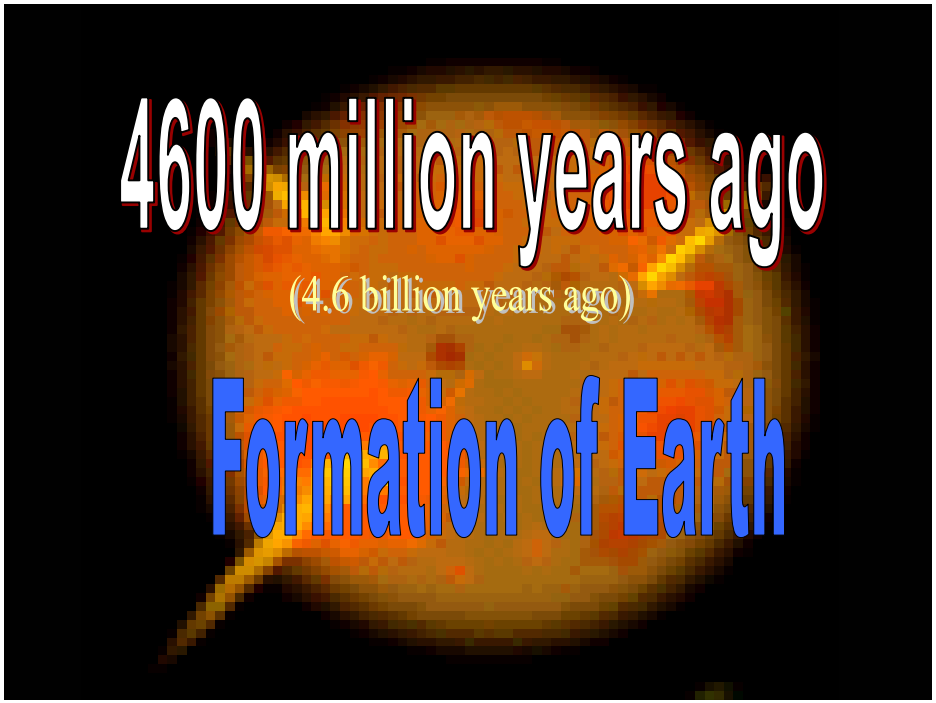
- Oxygen was new and important step in intelligence
- It allowed a new energy extraction method
  - Aerobic (using oxygen) metabolism
  - More complex life.
  - Created ozone layer (dry land now an option for life on Earth).

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 live exists then intelligent life exists.
- On the other hand, the plant kingdom never developed neurons.

Summary

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



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

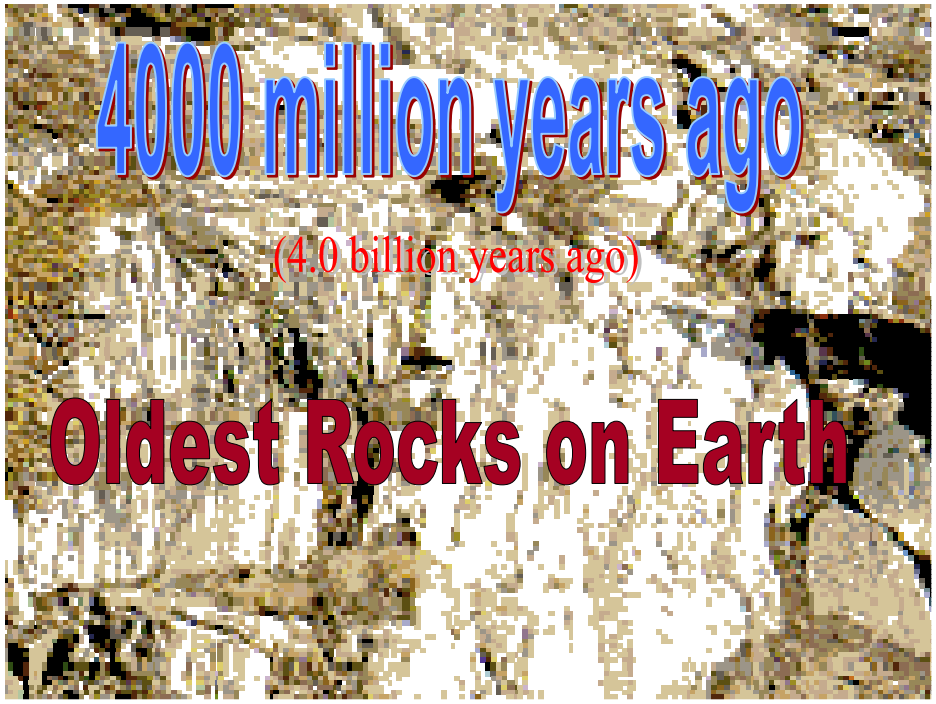
No Life

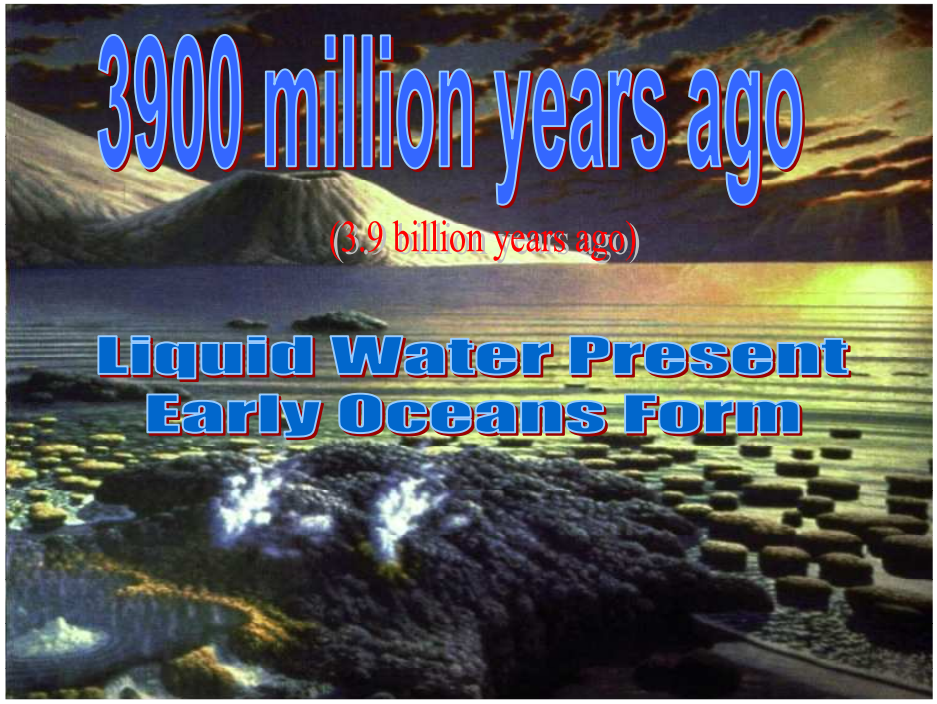
4100 million years ago

(4.1 billion years ago)

Early Atmosphere

No Life


4000 million years ago
(4.0 billion years ago)
Oldest Rocks on Earth


3900 million years ago
(3.9 billion years ago)
Liquid Water Present
Early Oceans Form


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!

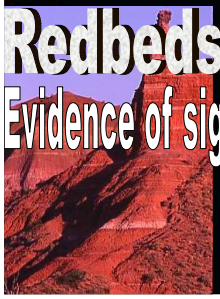

2100 million years ago
(2.1 billion years ago)
Stromatolites
Photosynthesis Produces Oxygen!

2000 million years ago

(2.0 billion years ago)

Beginning of 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)

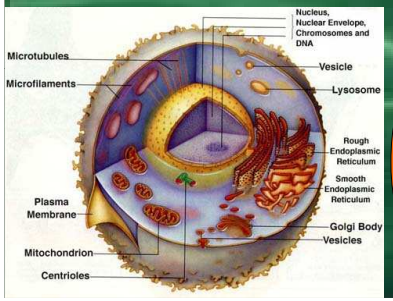
Oxygenated Atmosphere

Cyanobacteria still producing oxygen!

1700 million years ago

(1.7 billion years ago)

Single-celled Eukaryotes Appear



Cells get a nucleus!

Still Present:


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

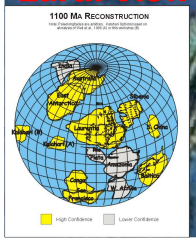
Still Present:

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

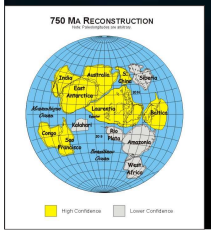
Marine Invertebrates Flourish

Still Present:

800 million years ago

Marine Invertebrates Flourish

Earth View



Still Present:

700 million years ago

Marine Invertebrates Flourish

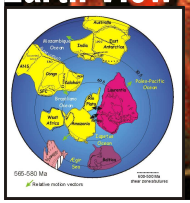
Earth View

Still Present:

600 million years ago

Ediacara Fauna

Earth View

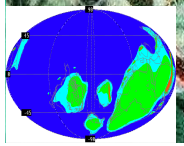


Still Present:

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

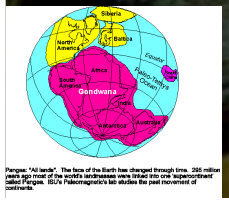
300 million years ago

Vast Coal Swamps on Land

Origin of Many Animals

amphibians, sharks, reptiles, insects

Earth View



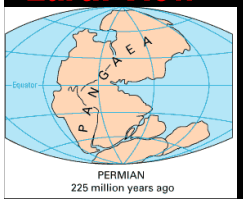
Pangaea: "All lands". The face of the Earth has changed through time. 286 million years ago most of the world's landmasses were united into one supercontinent called Pangaea. ISU's Paleomagnetic's lab studies the past movement of continents.

245 million years ago

Mass Extinction

90 % of all species perish

Earth View



200 million years ago

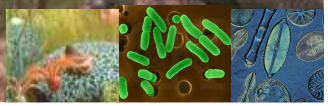
Age of the Dinosaurs and Reptiles

Plant Life: Ferns & Gymnosperms

First mammals

Earth View

Still Present:



100 million years ago

First birds

First Placental Mammals

First Flowering Plants

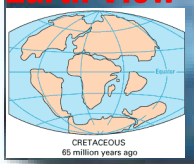
Still Present:

65 million years ago

Mass Extinction

Extinction of the dinosaurs and others

Earth View



65 million years ago to Present Day (0 mya)

Dominance of flowering plants, insects mammals, and birds

Earth View

Humans 5 mya

Still Present:

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