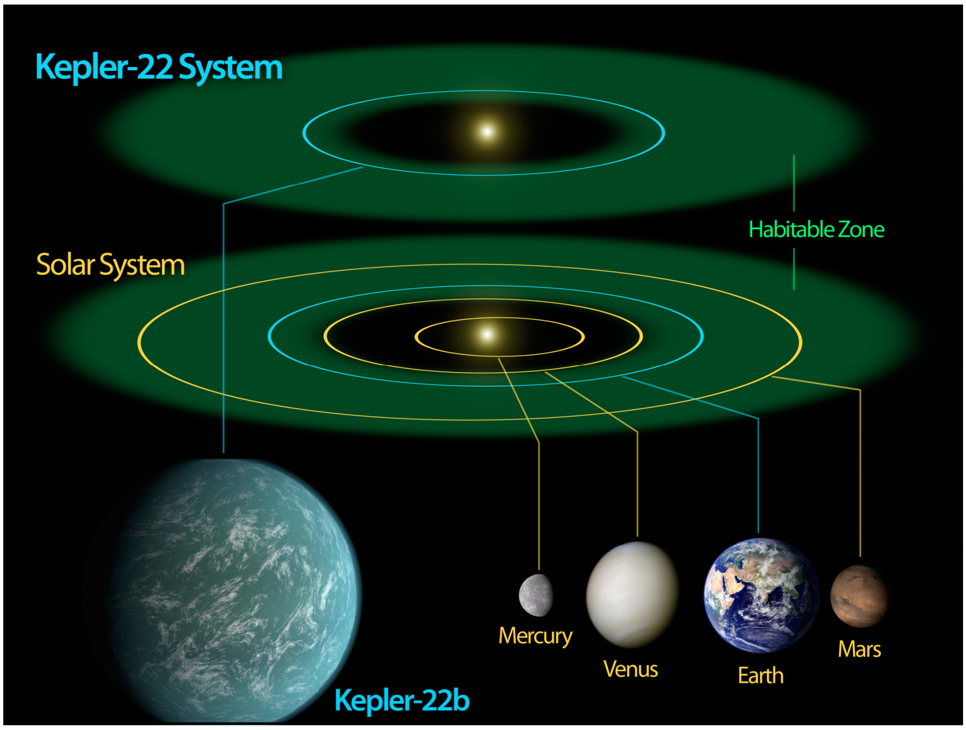
Evolutionary Biology and Biodiversity

Origin of life, speciation and evolution of environment- Physiochemical and biological factors in the environment.

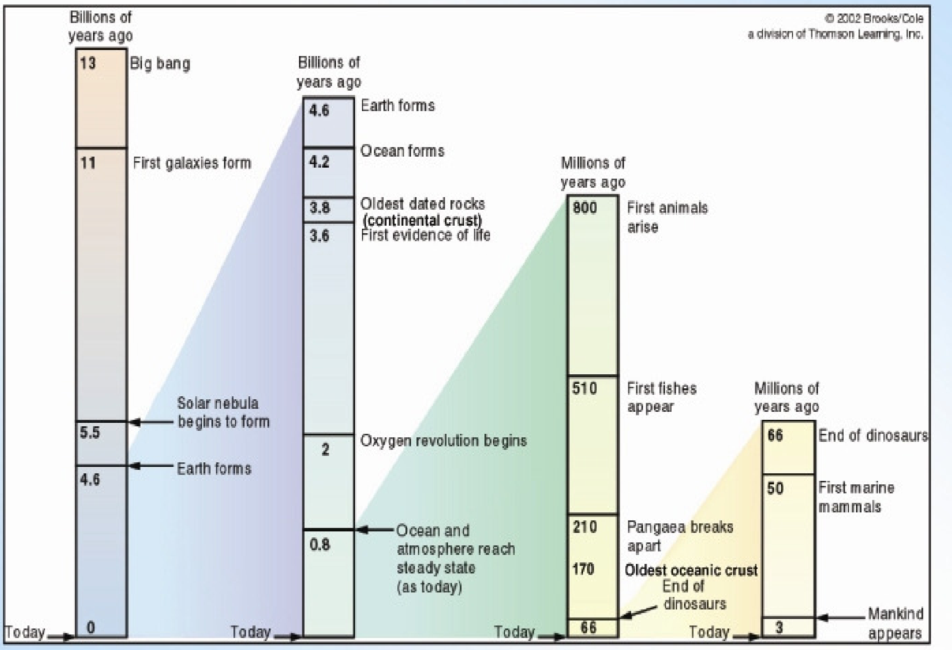
Where we are?

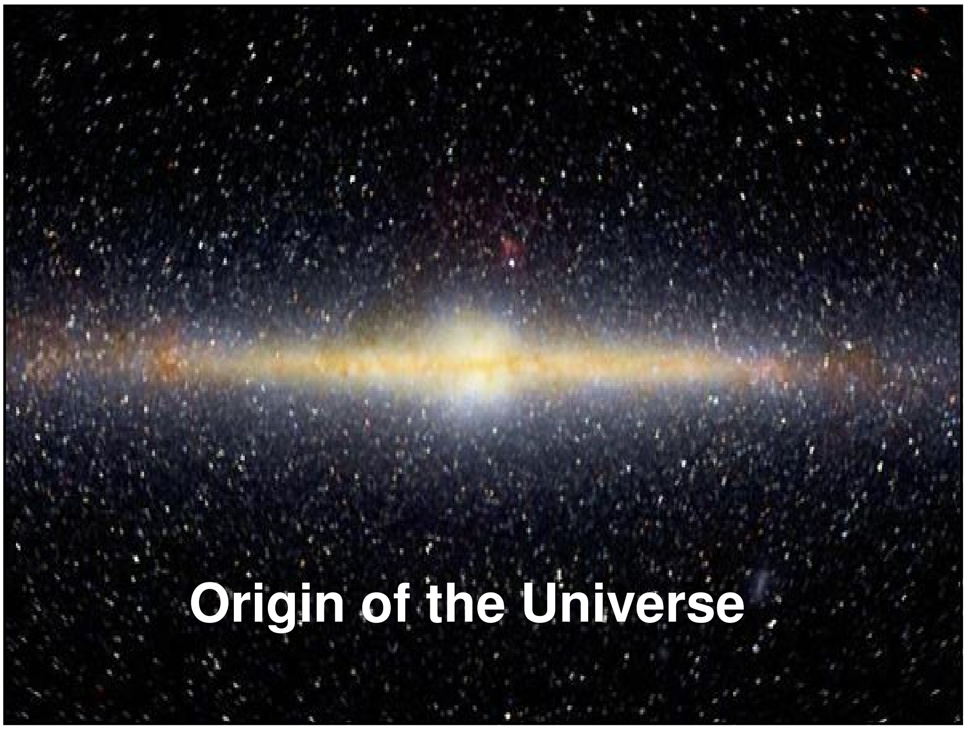
How we came here?



Aspects of Pre-biotic Environment

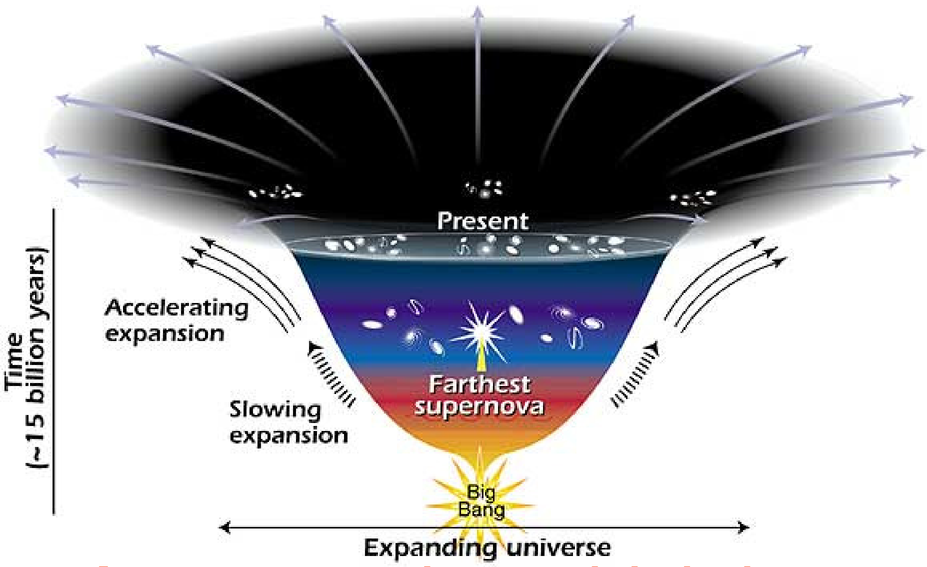
Brief History of Time



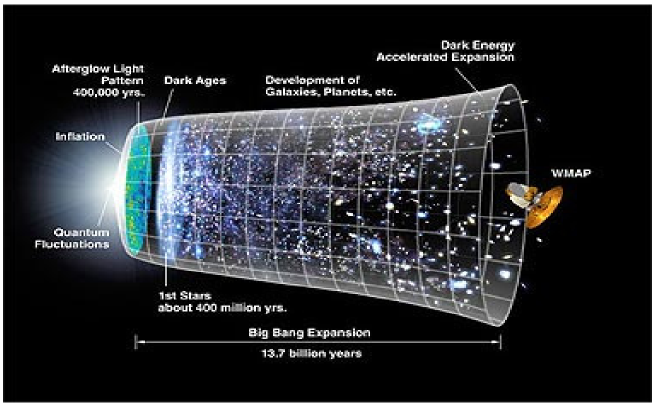


At the beginning of the Universe (ca. 13 billion years ago) all matter was in one place at a single instant. This event is known as a '**singularity**', a term which describes the inference that an infinitely large amount of matter is gathered at a single point

At the Big Bang there was a huge expansion of matter

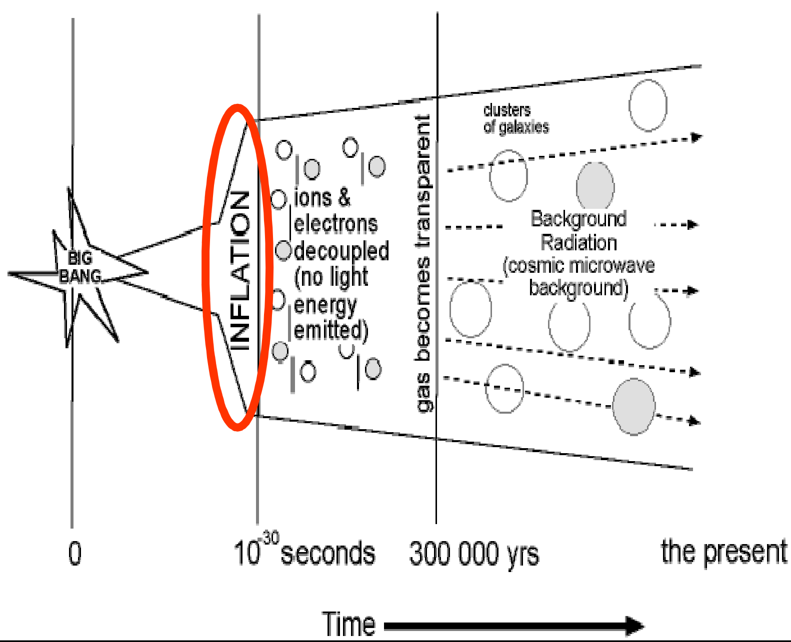


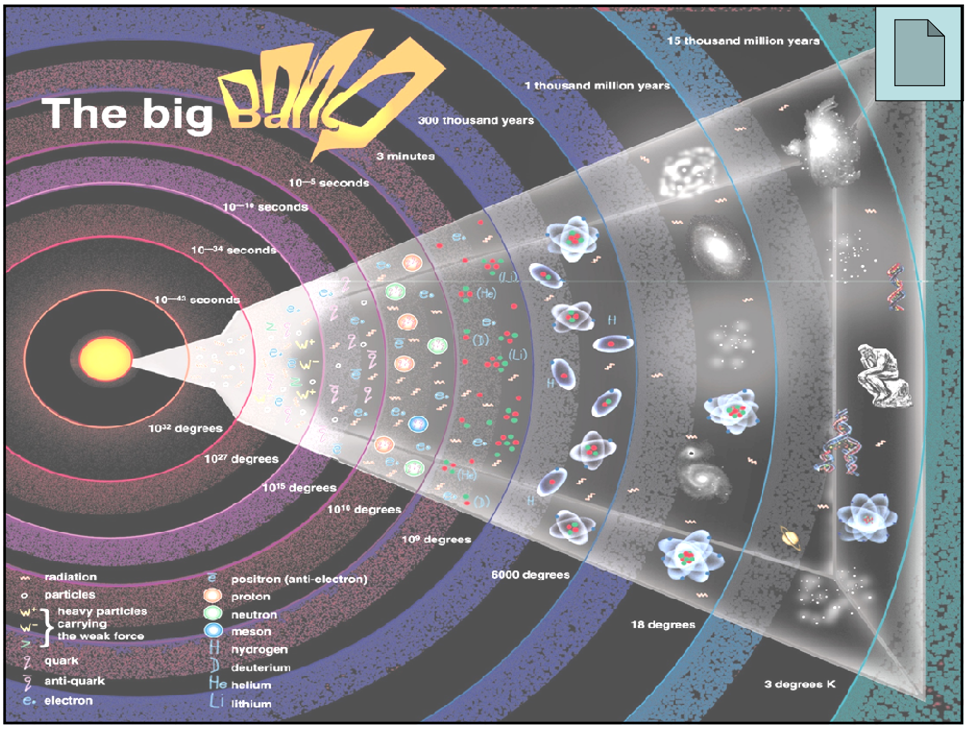
An expansion which has continued ever since



However, between 10^{-50} and 10^{-30} sec after the big bang there was a particularly rapid expansion of the Universe. This process is known as inflation. Later expansion slowed to a more normal rate

The origin, inflation and expansion of the Universe, from the Big Bang to the present





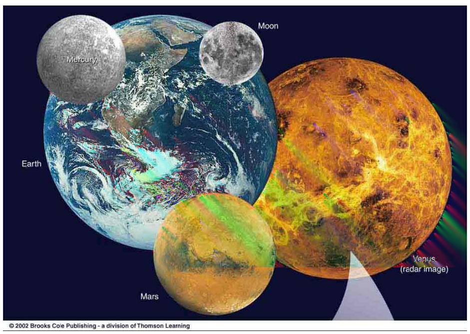
The big Bang
15 thousand million years
1 thousand million years
300 thousand years
3 minutes
10—5 seconds
10—10 seconds
10—34 seconds
10—43 seconds
10^32 degrees
10^27 degrees
10^15 degrees
10^10 degrees
10^9 degrees
6000 degrees
18 degrees
3 degrees K
radiation
particles
heavy particles carrying the weak force
quark
anti-quark
electron
positron (anti-electron)
proton
neutron
meson
hydrogen
deuterium
helium
lithium

Large Hadron Collider

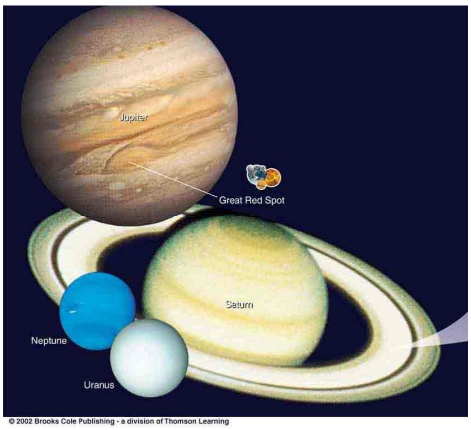
Origin of the Solar System & Earth

Two Kinds of Planets

Planets of our solar system can be divided
into two very different kinds:



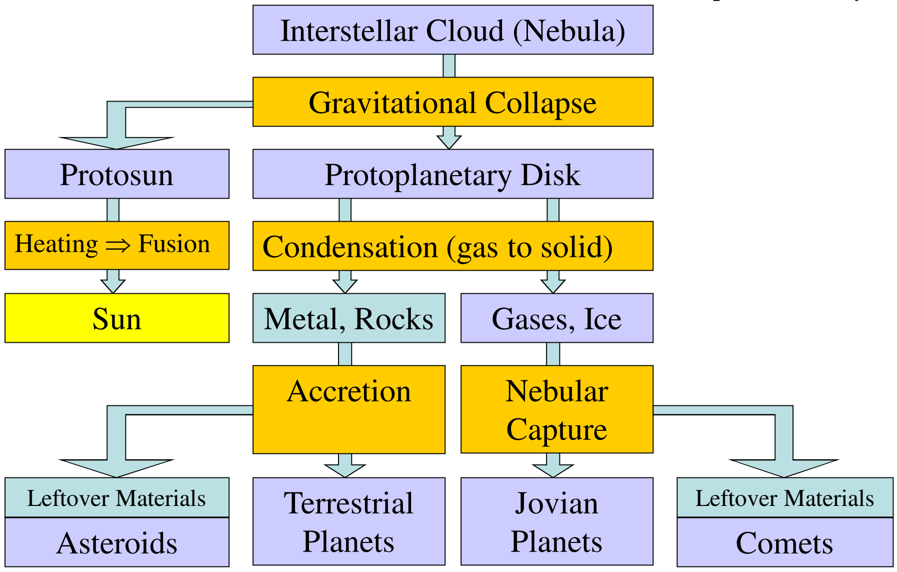
Terrestrial (earthlike) planets:
Mercury, Venus, Earth, Mars



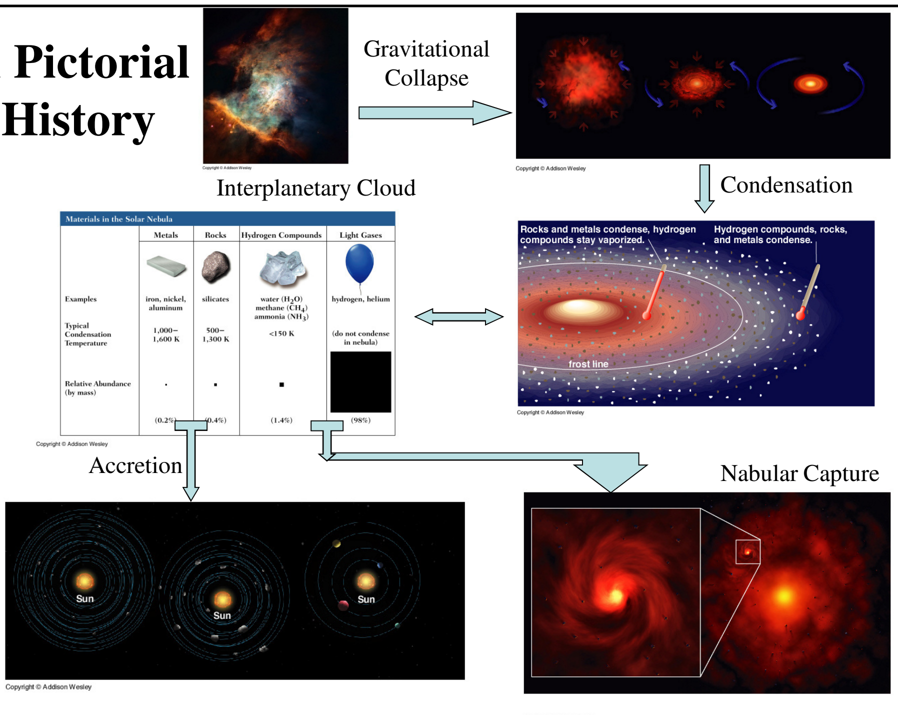
Jovian (Jupiter-like) planets:
Jupiter, Saturn, Uranus, Neptune

The Nebular Theory* of Solar System Formation

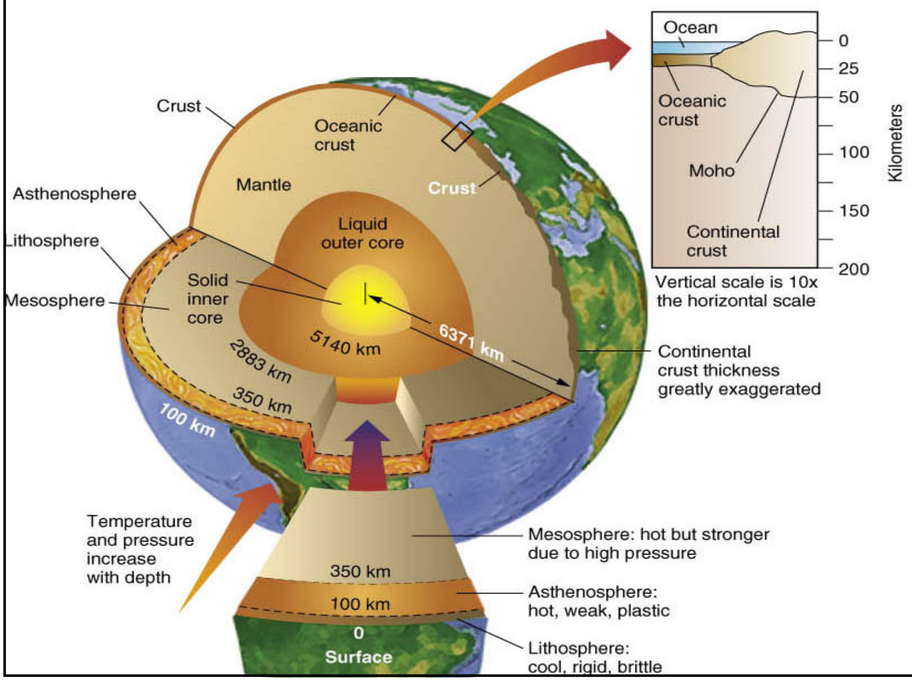
**It is also called the 'Protoplanet Theory'.*



A Pictorial History



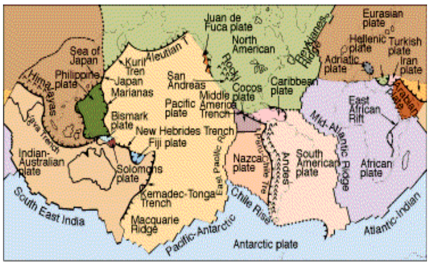
Prebiotic Environment of the planet earth



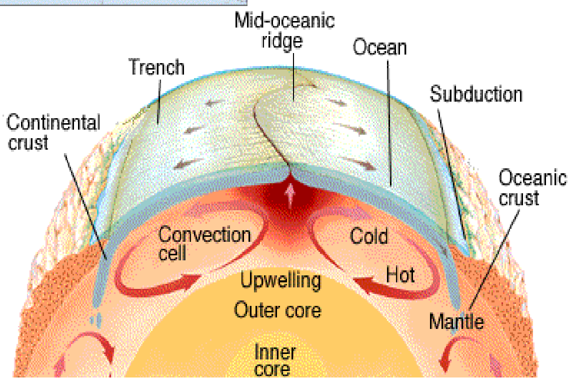
Formation of the oceans

- The earth is cool enough that H_2O condenses to form the oceans.
  - Estimates of the amount of H_2O outgassed is not enough to fill the oceans
  - It seems likely that a large volume of water was added by the impact of icy meteors

Plate Tectonic Theory

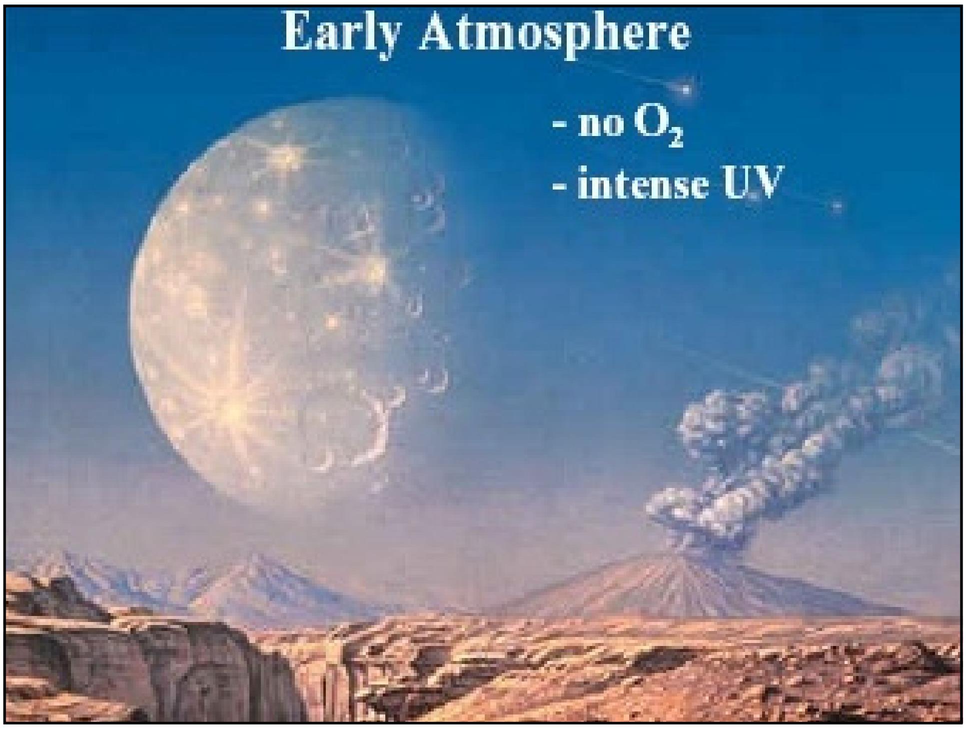


The Earth's lithosphere is divided into rigid plates of various sizes



Continental masses

- Pangea – all continents
- Gondwana – southern hemisphere continents
- Laurasia – northern hemisphere continents



Origin of the atmosphere

- The original atmosphere
  - Probably made up of **hydrogen and helium**.
  - These are fairly common in the universe.
  - The early earth was not protected by a magnetic field.

Thus the current atmosphere is secondary

The secondary atmosphere

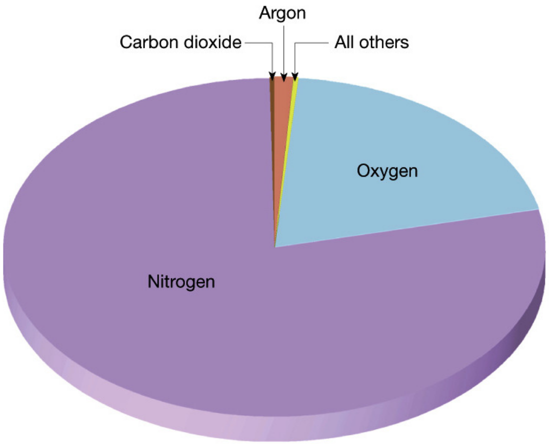
- Formed from degassing of volcanoes
- Gasses emitted probably similar to the gasses emitted by volcanoes today.
  - H_2O (water), 50-60%
  - CO_2 (carbon dioxide), 24%
  - SO_2 (sulfur dioxide), 13%
  - CO (carbon monoxide),
  - S_2 (sulfur),
  - Cl_2 (chlorine),
  - N_2 (nitrogen),
  - H_2 (hydrogen),
  - NH_3 (ammonia) and
  - CH_4 (methane)

Modern atmosphere

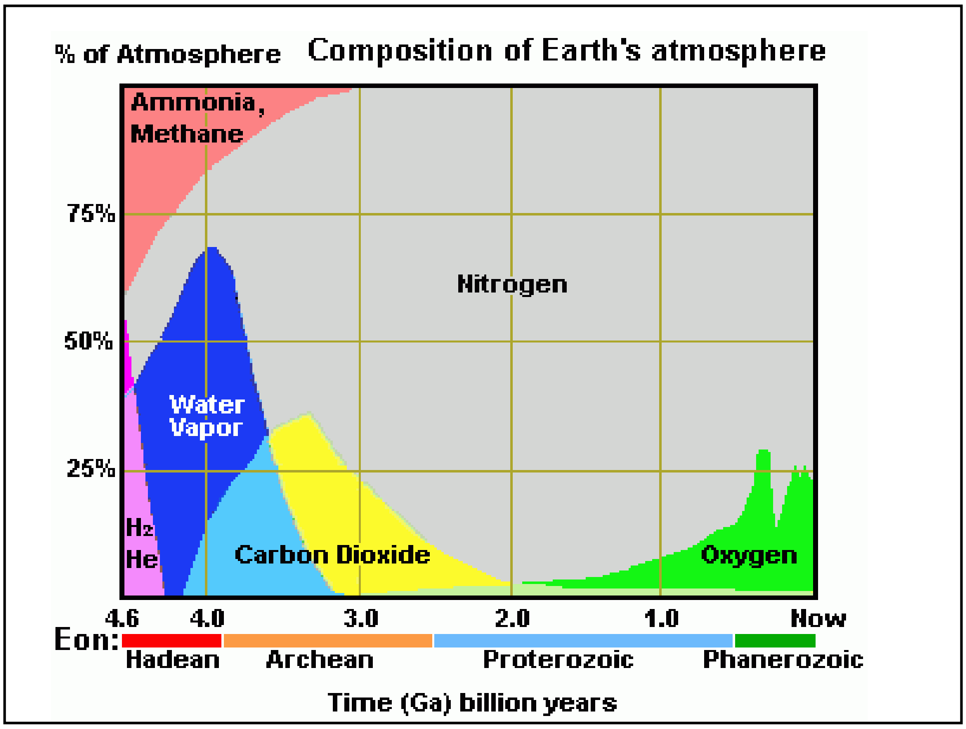
Nitrogen (N_2)- 78%,

Oxygen (O_2)- 21%,

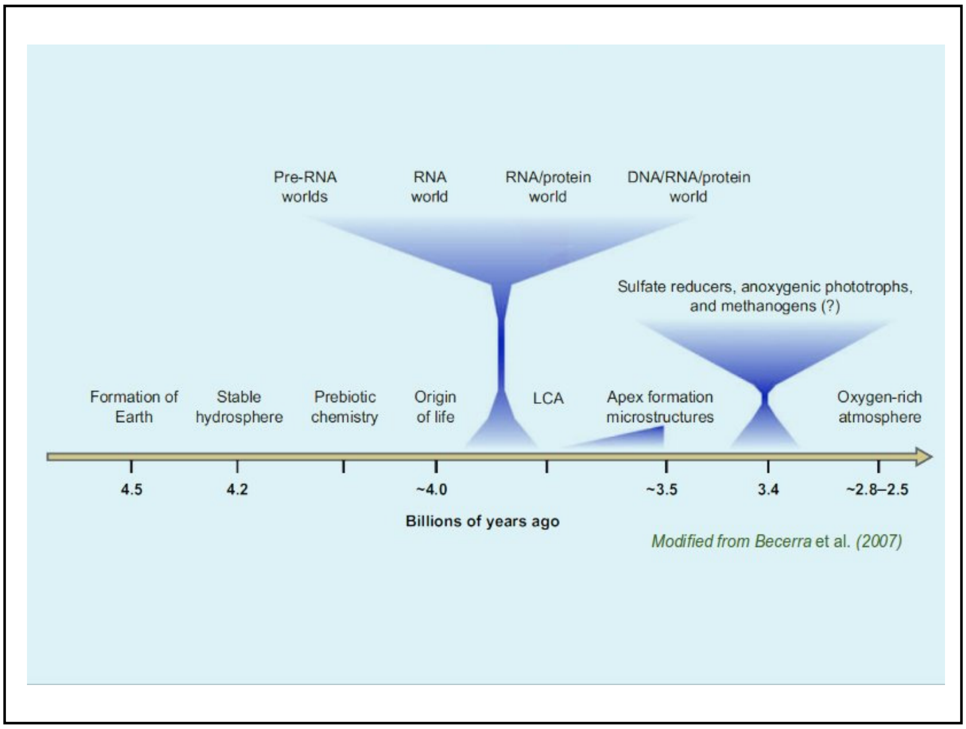
Carbon Dioxide (CO_2) 0.03 %,



1st atmosphere	H and He from solar nebula	Lost to solar wind
2nd atmosphere	H_20, CO_2,SO_2 and other gases from volcanic degassing	Transformed by photosynthesis
Current atmosphere	N_2, O_2 & CO_2	



% of Atmosphere
Composition of Earth's atmosphere
Ammonia, Methane
75%
Nitrogen
50%
Water Vapor
25%
H2
He
Carbon Dioxide
Oxygen
4.6
4.0
3.0
2.0
1.0
Now
Eon:
Hadean
Archean
Proterozoic
Phanerozoic
Time (Ga) billion years

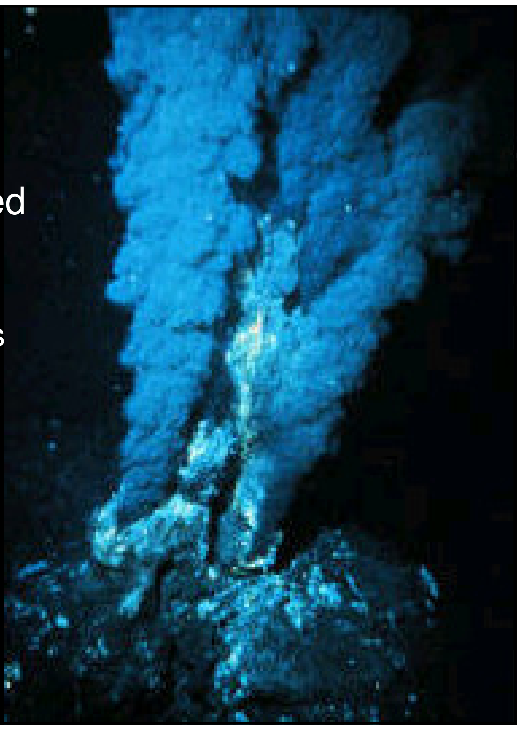


Pre-RNA worlds
RNA world
RNA/protein world
DNA/RNA/protein world
Sulfate reducers, anoxygenic phototrophs, and methanogens (?)
Formation of Earth
Stable hydrosphere
Prebiotic chemistry
Origin of life
LCA
Apex formation microstructures
Oxygen-rich atmosphere
4.5
4.2
~4.0
~3.5
3.4
~2.8–2.5
Billions of years ago
Modified from Becerra et al. (2007)

Cosmic Abundances

Element	Symbol	Atomic Number	Number of Atoms per Million Hydrogen Atoms
Hydrogen	H	1	1,000,000
Helium	He	2	68,000
Carbon	C	6	420
Nitrogen	N	7	87
Oxygen	O	8	690
Neon	Ne	10	98
Sodium	Na	11	2
Magnesium	Mg	12	40
Aluminum	Al	13	3
Silicon	Si	14	38
Sulfur	S	16	19
Argon	Ar	18	4
Calcium	Ca	20	2
Iron	Fe	26	34
Nickel	Ni	28	2

- Life may have originated
  - under the primitive atmosphere
  - or at hydrothermal vents deep in the oceans
  - or deep in the earth’s crust



Life changes the atmosphere

- With the evolution of life the first cellular organisms (cyanobacteria) began to use the gasses in the early atmosphere (NH_3 – ammonia, CH_4 – methane, H_2O – water) for energy.

Photosynthetic organisms evolved latter.

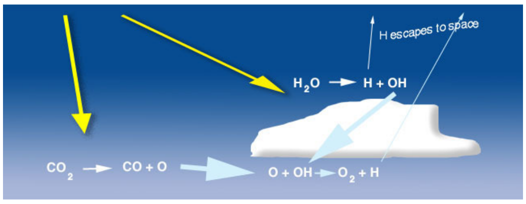
These organisms use CO_2 and produce oxygen (O_2) as a waste product.

The Biological Era -The Formation of Atmospheric Oxygen

The biological era was marked by the simultaneous decrease in atmospheric carbon dioxide (CO_2) and the increase in oxygen (O_2) due to life processes.

The build up of oxygen had three major consequences that we should note here.

Firstly, Eukaryotic metabolism could only have begun once the level of oxygen had built up to about 0.2%, or ~1% of its present abundance. This must have occurred by ~2 billion years ago, according to the fossil record. Thus, the eukaryotes came about as a consequence of the long, steady, but less efficient earlier photosynthesis carried out by Prokaryotes.



Photolysis of water vapor and carbon dioxide produce hydroxyl and atomic oxygen, respectively, that, in turn, produce oxygen in small concentrations. This process produced oxygen for the early atmosphere before photosynthesis became dominant

Oxygen increased in stages, first through photolysis of water vapor and carbon dioxide by ultraviolet energy and, possibly, lightning:

$$H_2O \rightarrow H + OH$$

produces a hydroxyl radiacal (OH) and

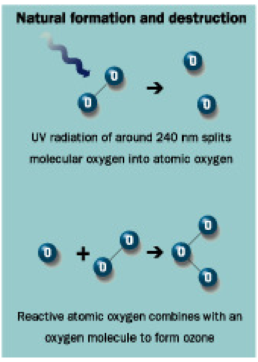
$$CO_2 \rightarrow CO + O$$

produces an atomic oxygen (O). The OH is very reactive and combines with the O

$$O + OH \rightarrow O_2 + H$$

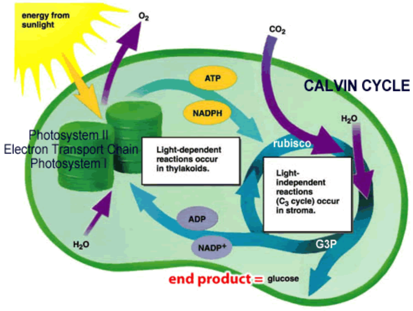
The hydrogen atoms formed in these reactions are light and some small fraction escaped to the space allowing the O2 to build to a very low concentration, probably yielded only about 1% of the oxygen available today.

Secondly, once sufficient oxygen had accumulated in the atmosphere, it was acted on by sunlight to form ozone,.

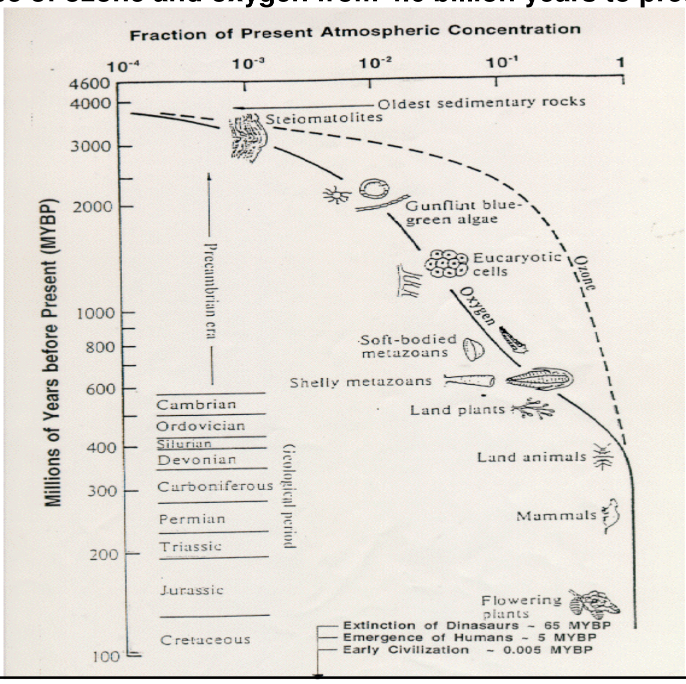


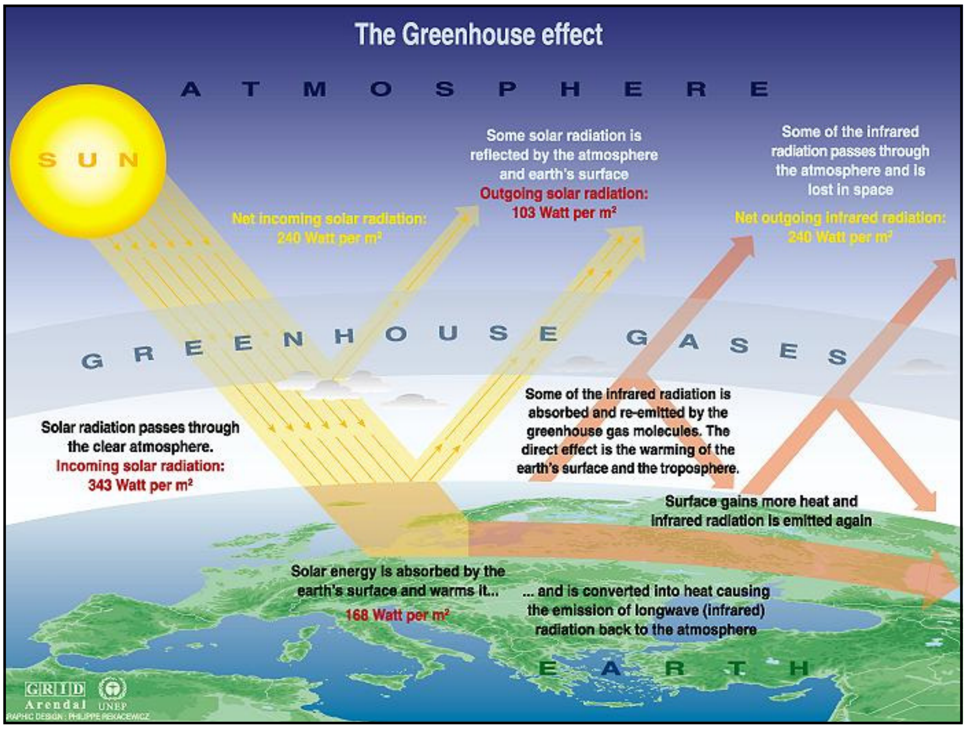
Thirdly, the availability of oxygen enabled a diversification of metabolic pathways, leading to a great increase in efficiency. The bulk of the oxygen formed once life began on the planet, principally through the process of photosynthesis:

$6CO_2 + 6H_2O <--> C_6H_{12}O_6 + 6O_2$

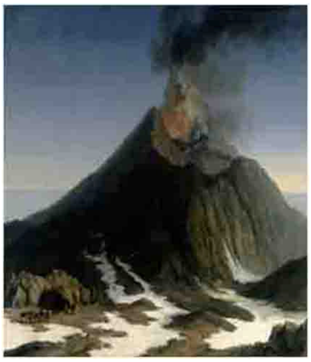


Abundance of ozone and oxygen from 4.6 billion years to present





Natural sources


Greenhouse Effect

Surface temperature without greenhouse effect

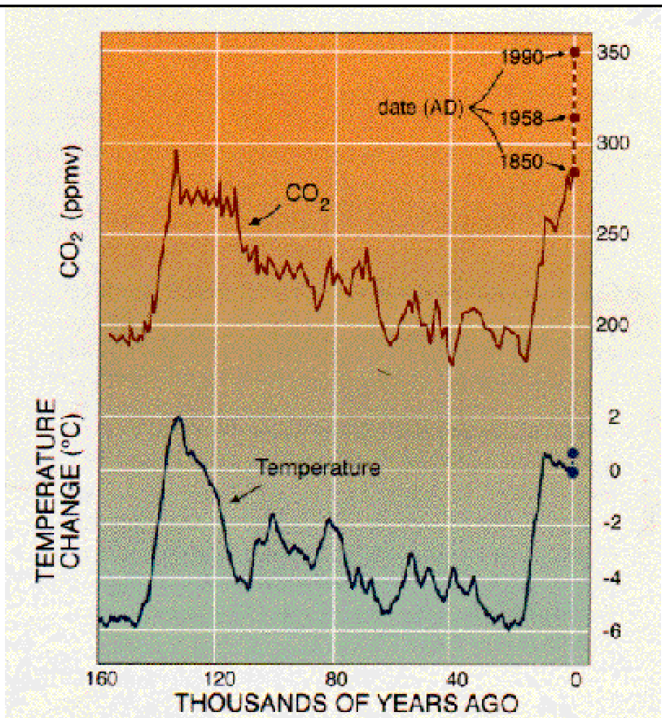
-18^0C

Observed global temperature with natural greenhouse effect

$+15^0C$

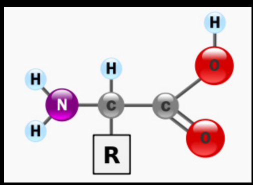
Predicted Surface temperature with anthropogenic greenhouse warming

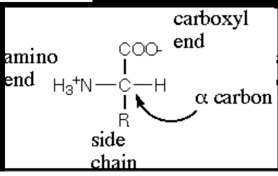
Without natural greenhouse there would have been no life

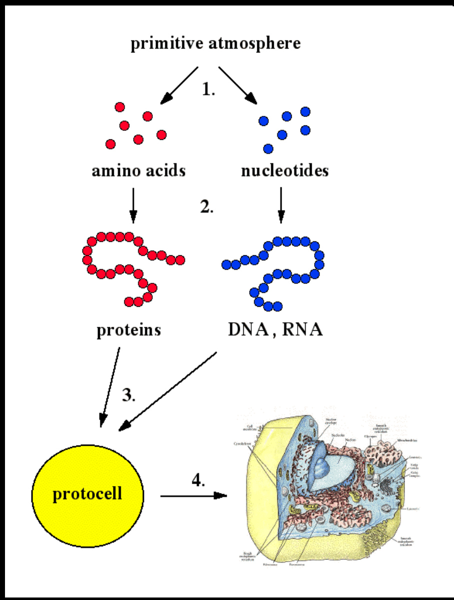


Changes in global atmospheric CO_2 and global surface temperature over the last 160,000 years

- Ingredients necessary for life
  - NH_3 – ammonia
  - CH_4 – Methane
  - H_2O – Water
- These can produce **amino acids**, the building blocks of life







Origin of Life on Earth

inanimate matter → animate matter

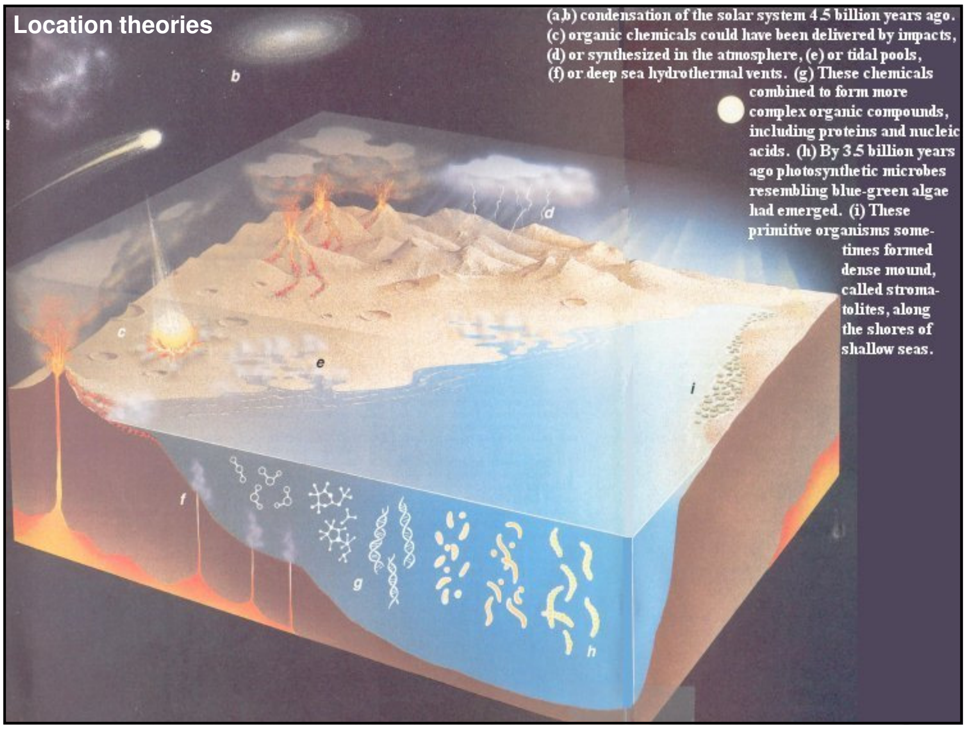
- Important steps in creation of life:
  - Nonbiological synthesis of organic compounds in nonoxidizing atmosphere.
  - Polymerization by removal of water from chemical joints of monomers.
  - Natural selection for objects that have genetic apparatus (nucleic acids)

Theories of the Origin of Life

Location theories
- •Primordial broth
- •Evaporative intertidal lagoons
- •Life in the deep sea vents
- •Life in clouds
- •Life in the subsurface
- •Life from Extraterrestrial material
- • Others

Mechanismal theories
- •The Bubble Theory
- • "Genes first" Theory : the RNA world
- •"Metabolism first" Theory

- • **And Others**

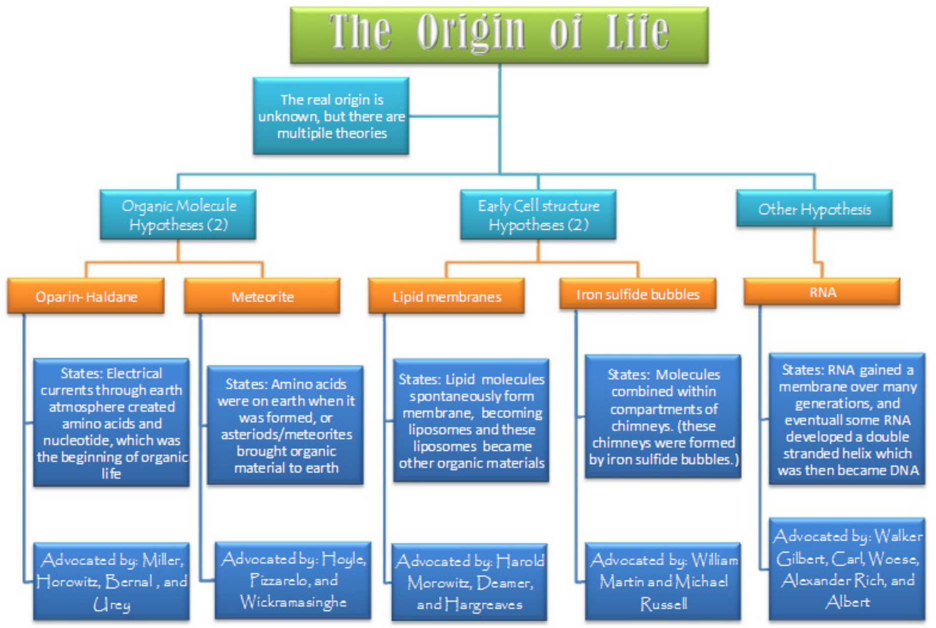


Mechanismal theories: The Bubble Theory

- Waves breaking on the shore create a delicate foam composed of bubbles.
- While bubbles comprised of mostly water burst quickly, oily bubbles happen to be much more stable.
- The phospholipid is a good example of an oily compound believed to have been prevalent in the prebiotic seas.
- Phospholipids contain a hydrophilic head on one end, and a hydrophobic tail on the other, they have the tendency to spontaneously form lipid membranes in water.
- a lipid bilayer bubble can contain water, and was a likely precursor to the modern cell membrane.

"Genes first" Theory: the RNA world

- **suggests that relatively short RNA molecules could have spontaneously formed that were capable of catalyzing their own continuing replication.**
- **Early cell membranes could have formed spontaneously from proteinoids, protein-like molecules that are produced when amino acid solutions are heated.**

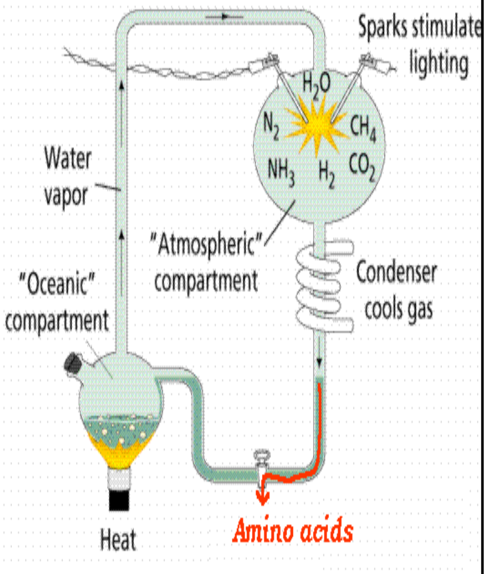


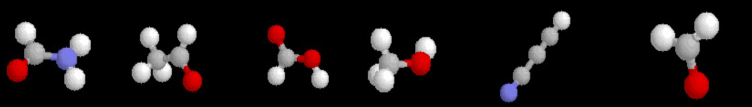
Stages in the Origin and Evolution of Biological Life

- Synthesis of elements
- Inorganic chemistry
- Liquid water
- Carbon- based organic chemistry (Monomers => Oligomers => Polymers)
- Primitive vesicles including catalysts
- First metabolic cycles and the Replication of genetic information
- Prokaryotes
- Eukaryotes
- Multicellular organisms

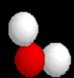
In 1953, Stanley L. Miller and Harold C. Urey, working at the University of Chicago, conducted an experiment which would change the approach of scientific investigation into the origin of life.

✓They took molecules which were believed to represent the major components of the early Earth's atmosphere and put them into a closed system
✓The gases they used were methane (CH_4), ammonia (NH_3), hydrogen (H_2), and water (H_2O).
✓ Next they ran a continuous electric current through the system, to simulate lightning storms believed to be common on the early earth.
✓Analysis of the experiment was done by chromotography.
✓At the end of one week, Miller observed that as much as 10-15% of the carbon was now in the form of organic compounds.
✓ Two percent of the carbon had formed some of the amino acids which are used to make proteins





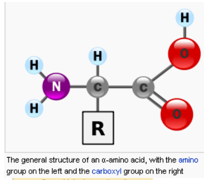
FORMAMIDE ACETALDEHYDE FORMIC ACID METHANOL CYANOACETYLENE FORMALDEHYDE
These organic molecules (above) were first discovered in interstellar space with the National Radio Astronomy Observatory (NRAO) 140ft telescope in Green Bank, West Virginia.

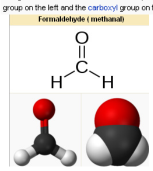


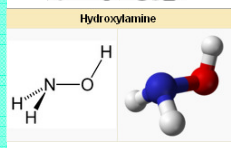
AMONNIA NRAO 140' WATER

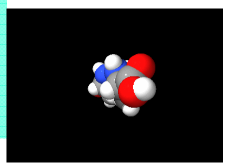
The nonenzymatic synthesis of biological monomers in an atmosphere of methane, nitrogen, ammonia, and water

- Gaseous mixtures, for example, methane, nitrogen, ammonia, and water, if supplied energy such as spark discharges, produce amino acids including those found regularly in proteins.
- In addition, most amino acids may be produced nonenzymatically starting with simple organic compounds such as formaldehyde(H_2CO) and hydroxylamine (NH_2OH).
- Furthermore, the abiotic routes of formation of all the components of DNA and RNA are known.
- Sugars easily form spontaneously from formaldehyde.
- polymerization occurs under alkaline conditions.
- The condensation of hydrogen cyanide in the presence of ammonia produces amino acids as well as the purine nucleotide bases, adenine and guanine, components of all nucleic acids.

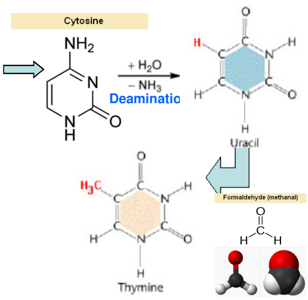


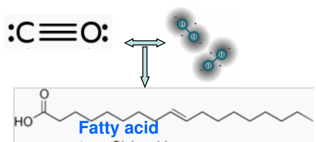


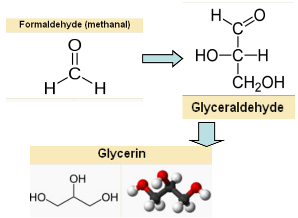




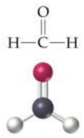
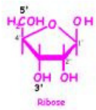
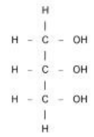
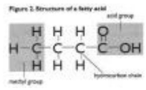
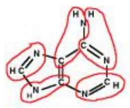
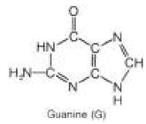
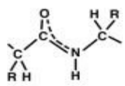
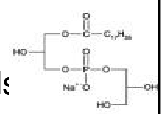
- Cytosine, a base found in nucleic acids, can be readily synthesized from cyanoacetylene (C_3HN) H—C≡C—C≡N
- By deamination, cytosine yields another major base of RNA, uracil.
- Thymine, a major base of DNA can be formed from the condensation of uracil with formaldehyde.
- In the presence of phosphate the phosphorylated forms of the nucleotides of these bases can be produced nonenzymatically.
- Fatty acids may be formed from carbon monoxide and hydrogen in the presence of nickel-iron catalysts, catalysts that might have been brought in by meteorites.
- Glycerol is a component of fats that has also been obtained nonenzymatically in the laboratory by reduction of glyceraldehyde.
- Glyceraldehyde may be formed by condensation of formaldehyde under alkaline conditions

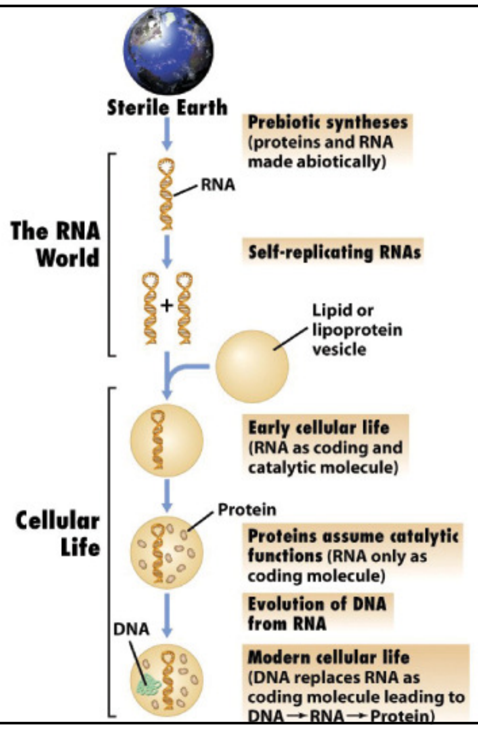






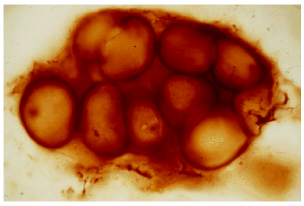
To create macromolecules of life

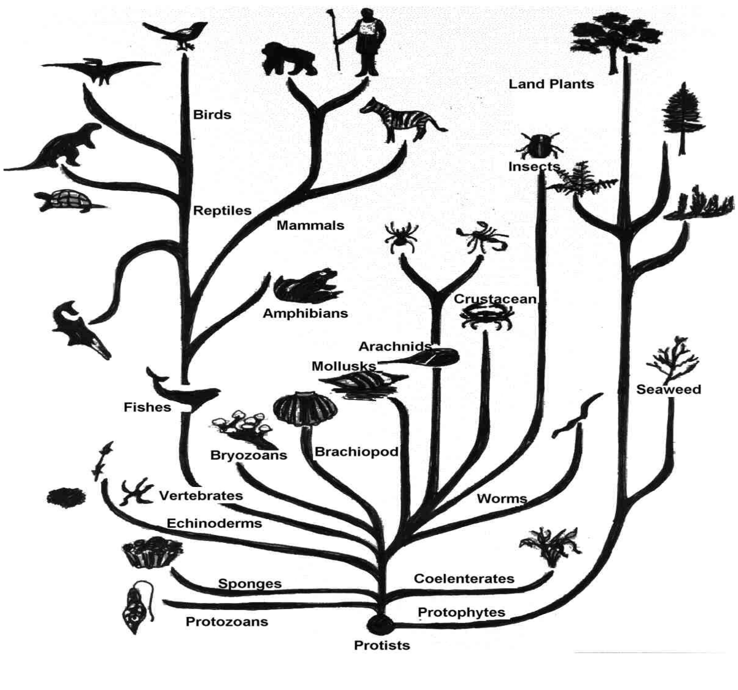
Precursor molecule			*Macromolecule of life*	
Formaldehyde CH_2O			Ribose, glycerol	
Carbon monoxide + hydrogen $CO + H_2$			Fatty acids	
Hydrogen cyanide	H−C≡N:		Adenine, guanine	
Cyanamide H_2NCN			Peptides and Phospholipids	



Oldest Record of Life

Stromatolite





Concepts of Evolution

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