MODULE: PRINCIPLES OF EVOLUTIONARY BIOLOGY

Part II – ORIGIN OF LIFE

BIO 111 Ecology and Evolution

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- Simplest life forms today have:

  nucleic acids (RNA/DNA) – store information

  proteins – capture energy, replicate nucleic acids

  membranes to protect

  can replicate

Spontaneous generation

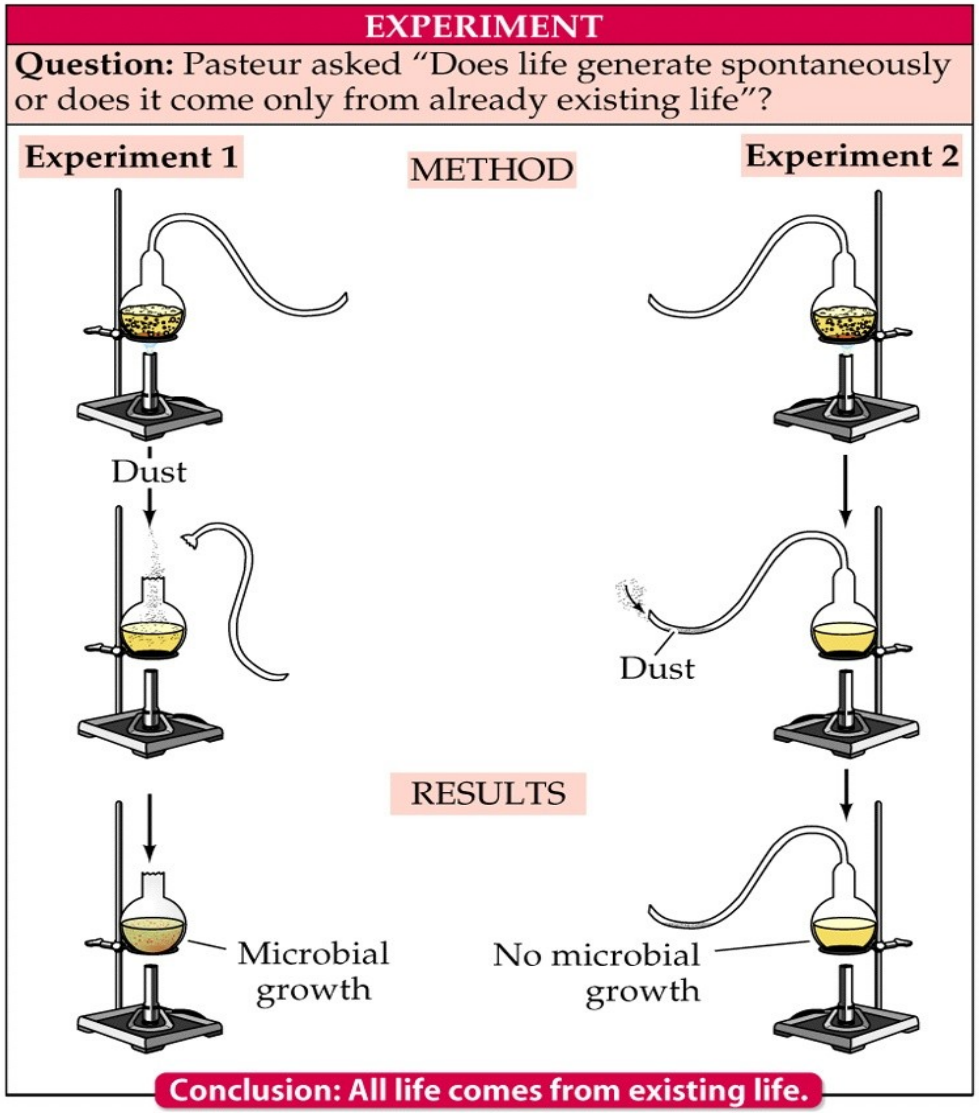
- Believed for a long time that life can arise out of non-living matter spontaneously

    maggots from rotting flesh

    'recipes' to grow mice, etc

- Pasteur's experiments disproved this theory

Swan neck flask expt



Panspermia hypothesis

Idea: Life could have originated elsewhere and travelled to earth. Meteors could have dislodged large pieces of debris which landed on earth

Exobiology / Astrobiology: Searching for life forms in space

However, no evidence for this hypothesis

Earth formed about 4.5 bya (billion years ago)

- Big Bang

Remained inhospitable for a few million years

- Meteors, high temperature, No free Oxygen in the atmosphere, etc

No physical record of first biological events, must be reconstructed from indirect evidence

Several tools used by biologists to put together parts like fitting parts of a puzzle together

- physical, chemical, mathematical, biological

Oldest fossils – ca. 3.5 billion years

Chemical fossils – ca. 3.8 billion years

Best estimate for origin of life: **ca. 4 bya**

Probable sequence of events

Simple organic monomers (building blocks of life) - from inorganic molecules

Polymers

Self-replicating systems

At least one of them evolved to using DNA to store heritable information and proteins to express that information

Eventually this system gave rise to all the lineages of life

Oparin-Haldane Model for the Origin of Life
(Alexandr Oparin and JBS Haldane)

Inorganic molecules

↓

Simple organic compounds (*building blocks of life*: nucleotides, amino acid)

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Complex organic compounds (*biological polymers*: nucleic acids, polypeptides)

↓

Self replicating systems

↓

Cellular Life

Miller-Urey experiments

Stanley Miller and Harold Urey

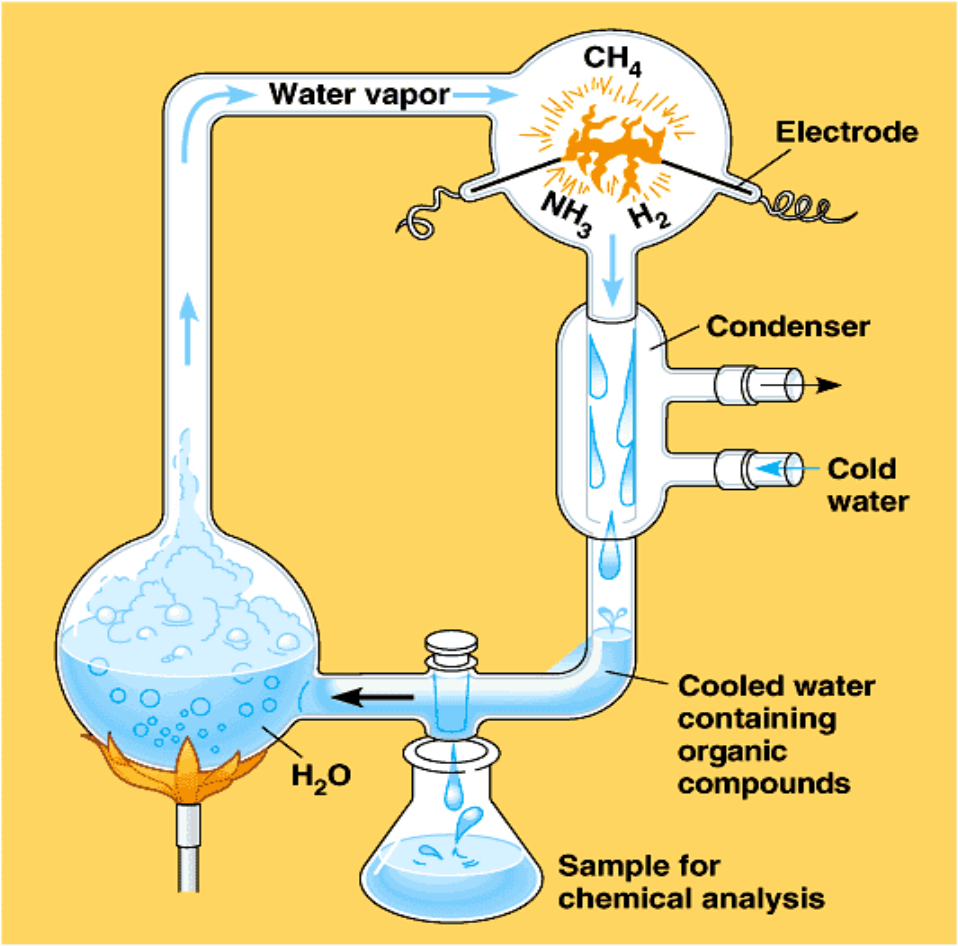
Simulated Oparin-Haldane's early earth & demonstrated how simple biological molecules could arise abiotically through non-biological processes

Boiled water

Circulated hot vapour, atmosphere of methane, ammonia and hydrogen

Passed electric current

Condensed the vapour and directed it into a boiling flask



Simple organic compounds (amino acids, sugars, lipids, etc)

Formation of nucleotides

- Nucleotides are generally difficult to produce abiotically using Miller-Urey style experiments
- Nucleotide adenine was formed in a reaction involving HCN and ammonia
- C, U, T are more difficult to construct abiotically
- Ribose sugars that form nucleotides can also be formed via condensation reactions with formaldehyde

Simple organic molecules to biological polymers

- e.g. polynucleotides & polypeptides have been synthesized on a mixture of two minerals

Protobionts: aggregates of abiotically produced molecules surrounded by membrane

Maintain internal chemical environment separate from surroundings

Some properties associated with life

What was the first self-replicating system?

Artificial cells and membranes have been synthesised from non-living sources.

But they require protein or DNA. What came first? Protein or DNA?

Proteins can perform complicated biological tasks but cannot REPLICATE.

DNA can store and transmit genetic information by complementary base pairing but cannot perform complex cellular tasks

The Enigma of the Origin of Life

"The largest stumbling block in bridging the gap between nonliving and living still remains. All living cells are controlled by information stored in DNA, which is transcribed in RNA (*transcription*) and then made into protein (*translation*).

This is a complicated system, and each of these three molecules requires the other two - either to put it together or to help it work. DNA, for example, carries information but cannot put that information to use, or even copy itself without the help of RNA and protein."

Kenneth R. Miller and Joseph Levine, *Biology: The Living Science* (Upper Saddle River, New Jersey: Prentice Hall), 1998, p.406-407. (Slide by Chris Macosko)

Central Dogma of Molecular Biology

- Francis Crick

- DNA is **TRANSCRIBED** to RNA

- RNA is **TRANSLATED** to an amino acid chain, which makes up proteins

Information cannot be transferred from protein back to nucleic acids

Discovery of **ribozymes** (RNA enzymes) by Altman and Cech in 1982 (shared the 1989 Nobel Prize)

Ribozymes - made of nucleic acid
- can catalyze chemical reactions, like protein enzymes

Till then RNA was considered to have the task of transferring genetic information from the DNA to proteins, which in turn carry out all the actual ‘work’ in the cell

RNA World Hypothesis

RNA preceded protein and DNA in the origin of life.

There was a time when life entirely was RNA based.

Walter Gilbert in 1986, Nobel Prize in Chemistry

Support for RNA World Hypothesis

RNA

- **can store & transmit genetic information**: e.g HIV
- is a **universal component** of information processing and transfer of genetic information
- **replicate**: build a complementary sequence with base pairing
- **mutate** and **evolve** (shown in test-tube experiments in 1967)

Short RNA-like molecules called **Pre-RNA** (or Pro-RNA) are thought to be the earliest self-replicating molecules.

Clay particles with RNA adsorbed onto their surface could have catalyzed the formation of a lipid envelope - **membrane**

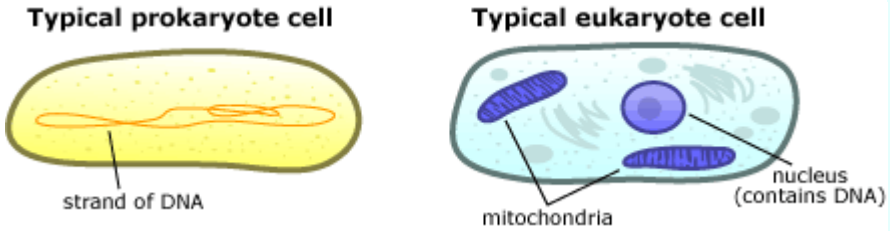
- **DNA** more stable than RNA
- DNA based replication systems evolved eventually and took over from RNA-based systems
- The first **prokaryotic cells** were thus assembled
- Diversified in metabolism and phenotypes
- Photosynthetic bacteria – ca 2 bya

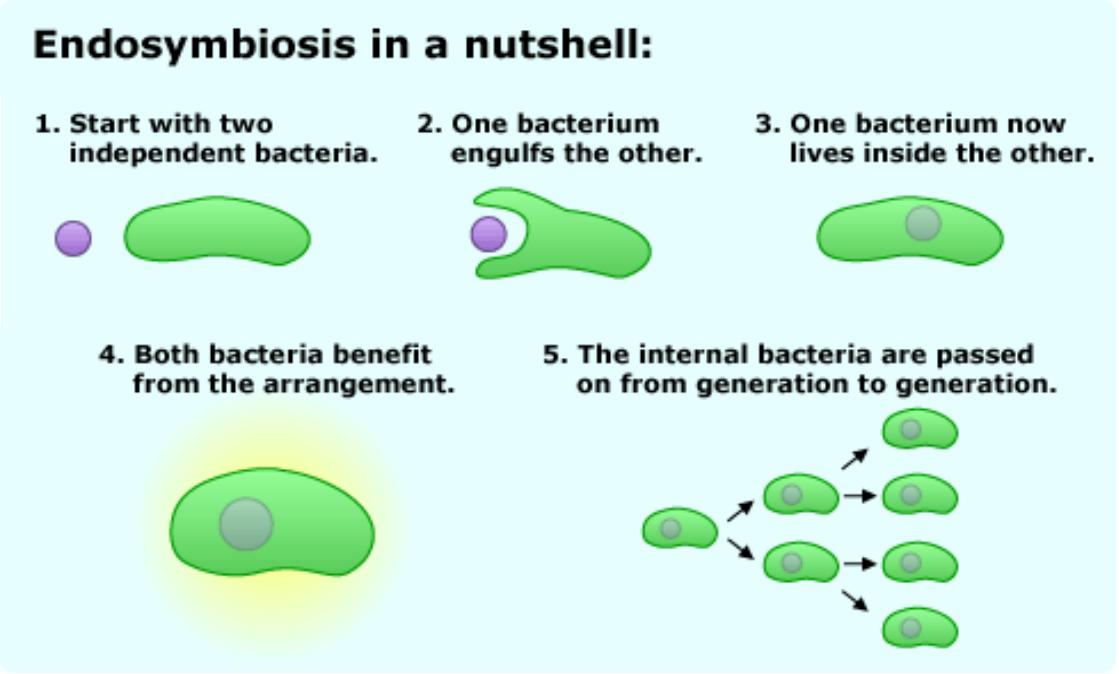
Aerobic respiration

How did eukayotes evolve?

- One of the main differences between prokaryotes and eukaryotes is that eukaryotes have membrane enclosed organelles.
- The endosymbitic theory tries to explain the origin of organelles such as mitochondria and plastics

Evolution of eukaryotes (ca. 2.1 bya) - Endosymbiont theory





evolution.berkeley.edu/evolibrary/article/0_0_0/endosymbiosis_03

Evolution of multicellularity (1.2 bya)

- related to size advantage (*surface area: volume ratio*)