

MODULE: PRINCIPLES OF EVOLUTIONARY BIOLOGY

Part II – ORIGIN OF LIFE

BIO 111 Biological Diversity and Evolution
Varsha 2018

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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

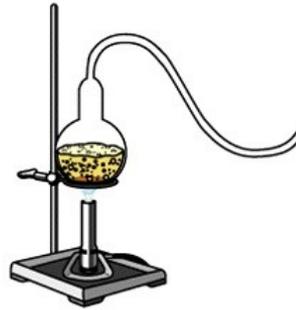
EXPERIMENT

Question: Pasteur asked “Does life generate spontaneously or does it come only from already existing life”?

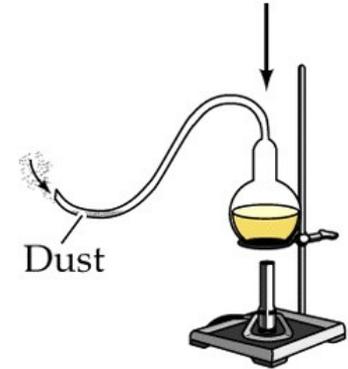
Experiment 1

METHOD

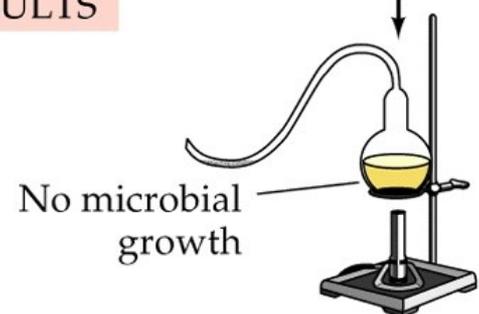
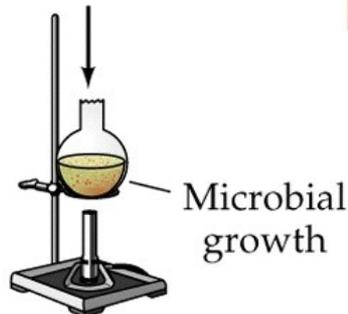
Experiment 2



Dust



RESULTS



Conclusion: All life comes from existing life.

Swan neck flask
expt

Panspermia hypothesis

Premise: 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

No real evidence

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 several 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

Self-replicating systems evolved on earth

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

Proposed a theoretical model for pre-biotic chemical evolution

Premise: Under strong reducing conditions present in the atmosphere of the early earth (4- 3.5 bya), inorganic molecules would spontaneously form organic molecules (simple sugars and amino acids)

Oparin-Haldane Model for the Origin of Life (A.I. Oparin and JBS Haldane)

Inorganic molecules



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



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



Self replicating systems



Cellular Life

Oparin-Haldane model

Simple inorganics to building blocks

Miller – Urey experiments

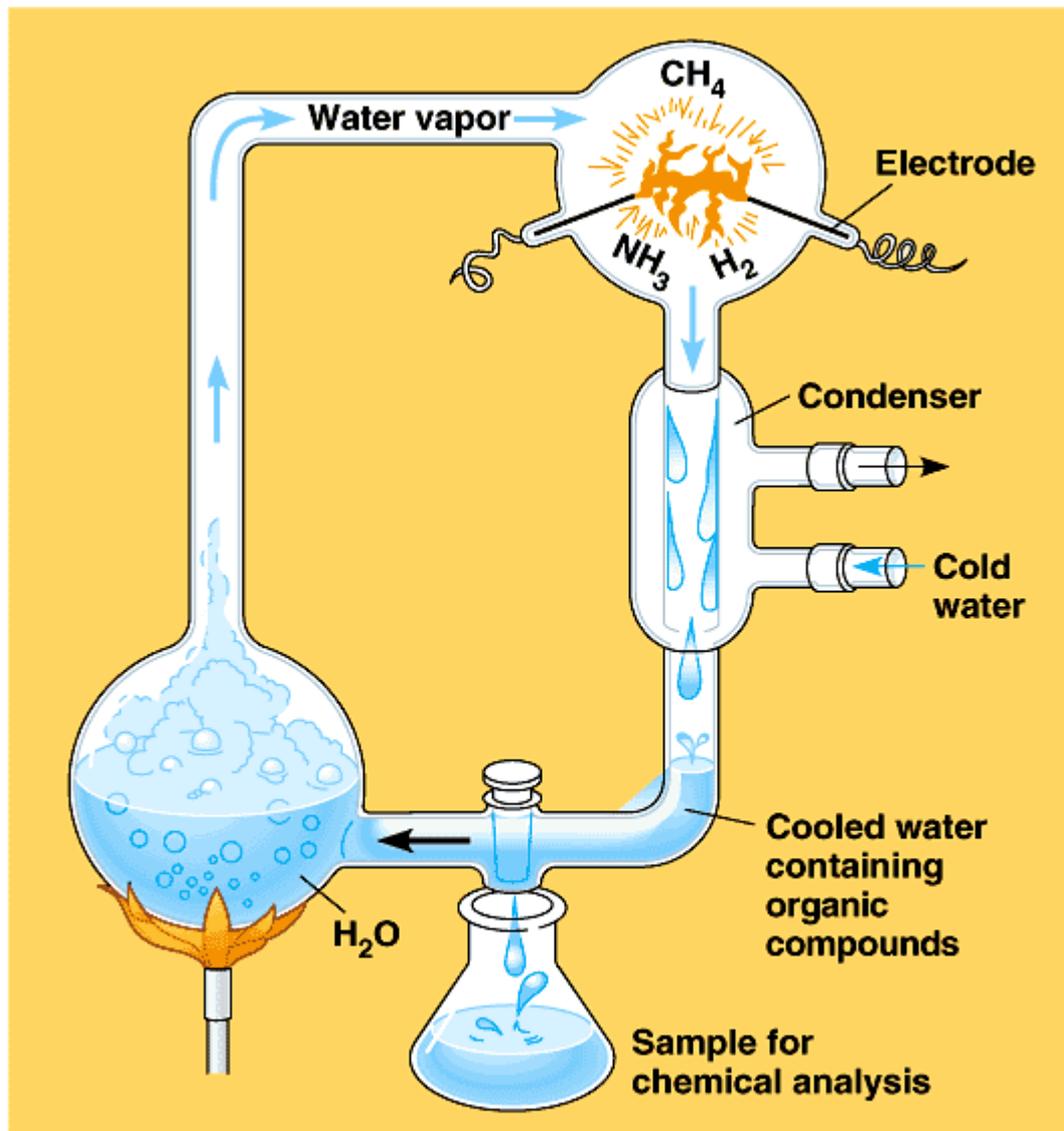
Simulated Oparin-Haldane's early earth & demonstrated how simple biological molecules could arise abiotically through non-biological processes

Boiled water

Circulated hot vapour, atmosphere of methane, ammonia and hydrogen

Passed electric current

Condensed the vapour and directed it into a boiling flask



Formation of nucleotides

- 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

- 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

Did it precede protein and DNA in the origin of life? Was there a time when life entirely was RNA based?

RNA World Hypothesis

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.

The first steps in the origin of life are thought to have occurred in an **RNA World**

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

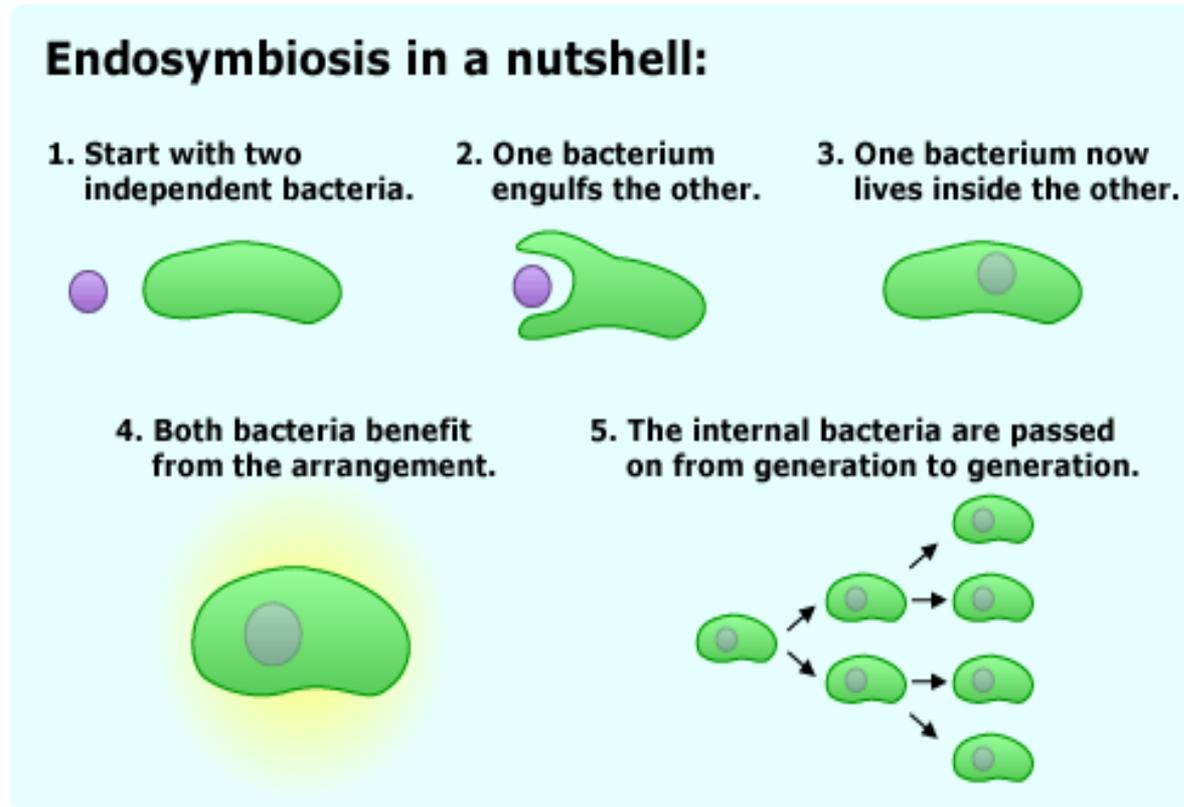
The first **prokaryotic cells** were thus assembled

Diversified in metabolism and phenotypes

Photosynthetic bacteria – ca 2 bya

Aerobic respiration

Evolution of eukaryotes (2.1 bya) - Endosymbiont theory



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

Evolution of multicellularity (1.2 mya) (*surface area: volume ratio*)