

Genetics and Evolution IB 201 06- Lecture 5

How Did Life Begin?

The origin of life begins with chemistry, which ultimately led to self-replicating molecules. Not much of these earliest stages of life on earth are likely to be preserved in the fossil record. Until very recently, there was no record of life before 550 Ma, which was a big dilemma for Darwin's views of evolution because all life was predicted to have evolved from even simpler forms than those represented in the fossils available in his day. Even today, as they discover more fossils, pushing back in time the age of many phyla, there are very few fossils to help scientists recover the origin of the first single-celled organisms.

The difficulties of estimating the origin of life:

- vast age of the origin of life-- ~ 4 Billion years ago
- no direct physical record of events, no rocks dating from earliest formation of Earth, so we are left with only indirect evidence.

Answers to three questions should help scientists reconstruct the earliest biological events.

I. What was the Earth's environment like when life arose?

II. How is life defined

III. How did life arise from inorganic forms?

I. Early Environment of Earth

Using radioisotopic dating of meteorites gives **Earth's age as about 4.5 billion years**. Initially, the Earth was too hot for life. It took several hundred million years to cool enough for an outer crust to form. Then as water vapor was released from the Earth's interior it cooled, condensed and formed the planet's oceans.

II. What is Life?

Basic Definition:

- ability to
- ability to
- ability to

Non-living systems do not have these fundamental capabilities.

III. How did life arise from inorganic forms?

A. The RNA World

1. Ribozymes--

They contain both **genotypic** and **phenotypic** properties:

- its **genotype** is the nucleotide sequence of the ribozyme molecule, which has the ability to store and transmit information.
- its **phenotype** is its single-stranded 3-dimensional structure with an active site for **catalyzing a chemical rxn to** form and break phosphoester bonds in RNA or DNA—a process required for **self-replication** (as with nucleic acids)

Example: *Tetrahymena thermophila* bacterium containing a ribozyme intron (catalytic RNA)

2. Is RNA old enough to be the precursor of complex life?

Evidence:

- Discovery of **ribozymes—catalytic RNA**
- RNA is in all cell machinery— i.e., **ribosomes** contain RNA that appears to be catalytic in protein synthesis
- Ribonucleoside triphosphates (ATP and GTP) are required for energy-transfer in all cells

3. Can RNA evolve?

- RNA molecules can store heritable information through complementary base pairing —i.e. they can replicate. Example: RNA virus, HIV, uses reverse transcriptase to copy itself into DNA
- RNA can evolve by natural selection in a test tube—examples:
 1. bacterial RNA virus Q_β
 2. evolution of catalytic ability of ribozyme *Tetrahymena*

B. Before RNA

1. Precursors need to be **simple inorganic** compounds
2. Need source of **energy** to make larger molecules from simple precursors
3. Building blocks need to **self-assemble into polymers** of RNA and polypeptides
4. Large molecules need **protection** from harsh environment--How occur in early Earth?

1. Precursors

Panspermia Hypothesis:

Carbonaceous Chondrites (organic carbon containing meteorites):

Murchison Meteorite contained traces of 18 amino acids—most of which have been made in laboratory experiments. First such experiment was that of **Stanley Miller**, as grad student at Univ. of Chicago, 1953.

Suggests that early-Earth conditions simulated in Miller's experiments were present on the asteroid that generated the meteorite (a small planet-like body)—and gave rise to the same kinds of monomeric compounds.

2. - 3. Energy Source and Polymer Assembly

All living systems are basically composed of:

CHON (Carbon, Hydrogen, Oxygen and Nitrogen) plus (SP: Sulphur, Phosphorous) – 99% of all living systems

These simple elements combine with one another to form the simple sturdy molecules of **CH₄, NH₃, H₂, H₂O, CO₂, NH₂**

All of life's basic building-block molecules are composed of CHON (SP), including

monomers of sugars, amino acids, DNA and RNA purines and pyrimidines

polymers of proteins, carbohydrates and nucleic acids are formed by linking together these monomers

These compounds have been found in the Hydrogen-rich clouds around Jupiter and Saturn, one of Saturn's moons (Titan) and in various comets (e.g., Hale-Bopp), even beyond the Solar System. Organic compounds are widespread in the Cosmos—in the dust clouds of interstellar space.

Oparin-Haldane Model (first half 20th century): Describes the hypothetical steps leading to the first self-replicating organisms on Earth

- An inorganic soup of simple inorganic compounds (Hydrogen cyanide, methane,) gave rise to *monomeric building blocks* (amino acids and nucleotides)—rxns took place in water
- building blocks assembled into biological *polymers* (proteins and nucleic acids). The reactions took place in water of the early Earth.
- biological polymers assembled into self-replicating cells, feeding off the simpler organic building blocks.

Criticisms of the hypothesis:

1. Did liquid water actually exist on Earth when life first formed?
2. Earth's atmosphere appears not to have been as Hydrogen-rich as originally thought, thus reactions were much less efficient

Controversial whether RNA was the first stage in the evolution of a replicating molecular world
Possibly other polymers were self-replicating earlier, including polymers of inorganic substances, such as clay.

4. Protective Enough Environment 3-4 billion years ago?

Apatite crystals produced by living organisms 1.3 billion years ago

- Evidence from rock formations on Akilia Island, Greenland

History of many large meteoritic impacts hitting Earth billions of years ago

One major one 4.5-3.8 billion years ago probably generated enough heat to vaporize the entire ocean.

We are left with many exciting and unanswered questions about origins.

Ref: F&H pp. 615-636