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Topic - Origin of life; basic concepts

For

Undergraduate Students (B.Sc. Zoology)

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ORIGIN OF LIFE

1. Introduction

The **origin of life** refers to the process by which **living organisms first arose from non-living matter** on the primitive Earth. This subject integrates **biology, chemistry, geology, and astronomy** and is fundamental to **evolutionary biology**.

Life originated about **3.8–4.0 billion years ago**, while Earth formed nearly **4.6 billion years ago**.

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2. Early Earth Conditions

- Primitive Earth atmosphere was **reducing** (no free oxygen).
- Major gases: **CH_4 (methane), NH_3 (ammonia), H_2, H_2O vapor**
- High energy sources:
  - UV radiation
  - Lightning
  - Volcanic activity
  - Cosmic radiation
- Oceans acted as a **chemical soup** (hot dilute broth).

3. Theories of Origin of Life

A. Special Creation Theory

- Life was created by a **supernatural power**.
- No scientific evidence.
- **Rejected by modern science**.

B. Spontaneous Generation (Abiogenesis – Old Concept)

- Proposed by **Aristotle**.
- Life arises spontaneously from non-living matter.
- Disproved by experiments of:

- **Francesco Redi**
- **Lazzaro Spallanzani**
- **Louis Pasteur**

C. Biogenesis

- Life arises only from **pre-existing life**.
- Supported by Pasteur's **swan-neck flask experiment**.
- Does not explain the **first origin of life**, only continuity.

D. Cosmozoic Theory (Panspermia)

- Proposed by **Richter**, supported by **Arrhenius**.
- Life came from outer space as spores or microbes.
- Variants:
  - Radiopanspermia
  - Lithopanspermia
- Lacks experimental proof.

E. Chemical Evolution Theory (Modern Theory)

Most accepted theory

Proposed by **A. I. Oparin (1924)** and **J. B. S. Haldane (1929)**.

Key Concept:

Life originated through a **gradual chemical evolution** from simple inorganic molecules to complex organic compounds.

4. Steps in Chemical Evolution

Step 1: Formation of Simple Organic Molecules

- Inorganic molecules → Organic molecules
- Examples:
  - Amino acids
  - Sugars
  - Nitrogenous bases

- Fatty acids

Experimental Evidence:

Miller–Urey Experiment (1953)

Setup:

- Simulated primitive atmosphere (CH_4, NH_3, H_2, H_2O)
- Electric sparks as lightning

Results:

- Amino acids (glycine, alanine)
- Organic acids

✔Provided first experimental support to chemical evolution.

Step 2: Formation of Macromolecules

- Monomers → Polymers
- Amino acids → Proteins
- Nucleotides → RNA/DNA
- Sugars → Polysaccharides

Role of:

- Clay minerals (montmorillonite)
- Heat and dehydration

Step 3: Formation of Protobionts (Protocells)

- Aggregates of organic molecules
- Show properties like:
  - Growth
  - Metabolism
  - Internal environment

Examples:

- **Coacervates** (Oparin)

- **Microspheres** (Sidney Fox)
- **Liposomes**

Step 4: Origin of First Living Cell

- First cells were:
    - Anaerobic
    - Prokaryotic
    - Heterotrophic
- Used organic molecules for energy.

5. RNA World Hypothesis

Proposed by **Walter Gilbert (1986)**

Key Points:

- RNA was the **first genetic material**.
- RNA acts as:
    - Genetic material
    - Catalyst (ribozymes)

Evidence:

- Ribozymes
- RNA primers in DNA replication
- Central role of RNA in ribosomes

6. Evolution of Metabolism

Heterotrophic Hypothesis

- First organisms consumed organic molecules.

Autotrophic Hypothesis

- First organisms synthesized their own food.

Photosynthesis:

- First photosynthesizers: **Cyanobacteria**
- Oxygen released → **Great Oxidation Event**

- Led to aerobic respiration.

7. Endosymbiotic Theory (Related Concept)

Proposed by **Lynn Margulis**

- Mitochondria from aerobic bacteria
- Chloroplasts from cyanobacteria

Evidence:

- Circular DNA
- 70S ribosomes
- Double membrane

8. Summary Timeline

- 4.6 bya – Earth formed
- 4.0 bya – Chemical evolution
- 3.8 bya – First life
- 2.5 bya – Oxygen atmosphere
- 1.5 bya – Eukaryotes

IMPORTANT MCQs

1. Who proposed the theory of chemical evolution?
A. Darwin
B. Lamarck
C. Oparin and Haldane
D. Miller
Answer: C

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2. Miller–Urey experiment provided evidence for:
A. Origin of eukaryotes
B. Abiotic synthesis of organic molecules
C. Panspermia
D. Spontaneous generation
Answer: B

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3. Primitive Earth atmosphere was:
A. Oxidizing
B. Neutral

C. Reducing
D. Oxygen-rich
Answer: C

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4. First living organisms were most likely:
A. Aerobic autotrophs
B. Anaerobic heterotrophs
C. Aerobic heterotrophs
D. Photosynthetic eukaryotes
Answer: B

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5. RNA World hypothesis suggests:
A. DNA preceded RNA
B. Proteins preceded nucleic acids
C. RNA was the first genetic material
D. Lipids were genetic material
Answer: C

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6. Ribozymes are:
A. Protein enzymes
B. DNA enzymes
C. RNA molecules with catalytic activity
D. Lipid enzymes
Answer: C

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7. Coacervates were proposed by:
A. Miller
B. Fox
C. Oparin
D. Margulis
Answer: C

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8. Microspheres were experimentally produced by:
A. Oparin
B. Haldane
C. Sidney Fox
D. Pasteur
Answer: C

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9. First photosynthetic organisms were:
A. Green algae
B. Diatoms
C. Cyanobacteria
D. Bryophytes
Answer: C

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10. Which gas was absent in primitive atmosphere?

A. Methane
B. Ammonia
C. Hydrogen
D. Oxygen

Answer: D

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