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A Four-Stage Hypothesis for the Origin of Life

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- According to one hypothesis, the first organisms were products of chemical evolution in four stages.

**Stage 1: Abiotic Synthesis of Organic Monomers**

**Stage 2: Abiotic Synthesis of Polymers**

**Stage 3: Formation of Pre-Cells**

**Stage 4: Origin of Self-Replicating Molecules**

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**Stage 1: Abiotic Synthesis of Organic Monomers**

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- The first stage in the origin of life was the first to be extensively studied in the laboratory.

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**The Process of Science:**  
Can Biological Monomers Form Spontaneously?

– **Observation:** Modern biological macromolecules are all composed of elements that were present in abundance on early Earth.

– **Question:** Could biological molecules arise spontaneously under conditions like those on early Earth?

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**The Process of Science:**  
Can Biological Monomers Form Spontaneously?

– **Hypothesis:** A closed system designed to simulate early Earth conditions could produce biologically important organic molecules from inorganic ingredients.

– **Prediction:** Organic molecules would form and accumulate.

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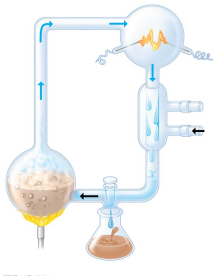
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**The Process of Science:**  
Can Biological Monomers Form Spontaneously?

– **Experiment:** An apparatus was built to mimic the early Earth atmosphere and included

- hydrogen gas (H<sub>2</sub>), methane (CH<sub>4</sub>), ammonia (NH<sub>3</sub>), and water vapor (H<sub>2</sub>O),
- sparks that were discharged into the chamber to mimic the prevalent lightning of early Earth, and
- a condenser that cooled the atmosphere, causing water and dissolved compounds to "rain" into the miniature "sea."



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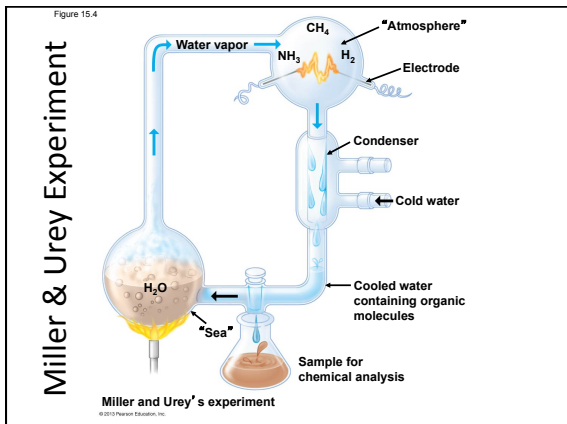
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**The Process of Science:  
Can Biological Monomers Form Spontaneously?**

- **Results:** After the apparatus had run for a week, an abundance of organic molecules essential for life had collected in the "sea," including amino acids, the monomers of proteins.
- These laboratory experiments
  - have been repeated and extended by other scientists and
  - support the idea that organic molecules could have arisen abiotically on early Earth.

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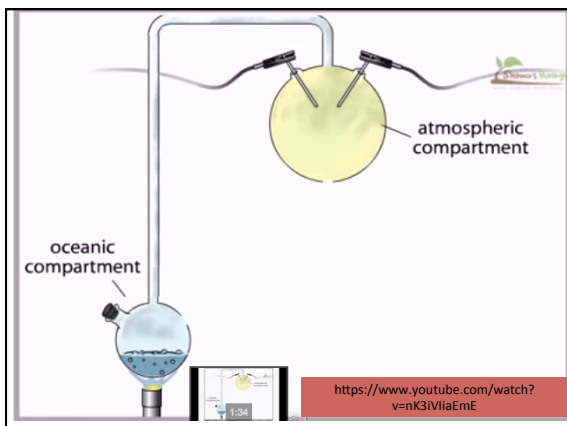
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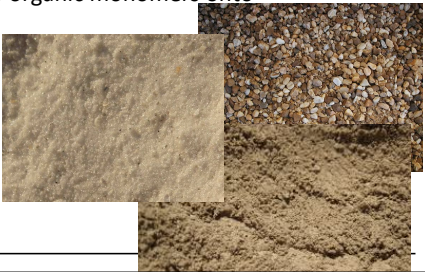
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*Stage 2: Abiotic Synthesis of Polymers*

- Researchers have brought about the polymerization of monomers to form polymers, such as proteins and nucleic acids, by dripping solutions of organic monomers onto
  - hot sand,
  - clay, or
  - rock.



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*Stage 3: Formation of Pre-Cells*

- A key step in the origin of life was the isolation of a collection of abiotically created molecules within a membrane.
- Laboratory experiments demonstrate that pre-cells could have formed spontaneously from abiotically produced organic compounds.

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*Stage 3: Formation of Pre-Cells*

- Such pre-cells produced in the laboratory display some lifelike properties. They
  - have a selectively permeable surface,
  - can grow by absorbing molecules from their surroundings, and
  - swell or shrink when placed in solutions of different salt concentrations.

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*Stage 4: Origin of Self-Replicating Molecules*

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- Life is defined partly by the process of inheritance, which is based on self-replicating molecules.
- One hypothesis is that the first genes were short strands of RNA that replicated themselves
  - without the assistance of proteins,
  - perhaps using RNAs that can act as enzymes, called **ribozymes**.

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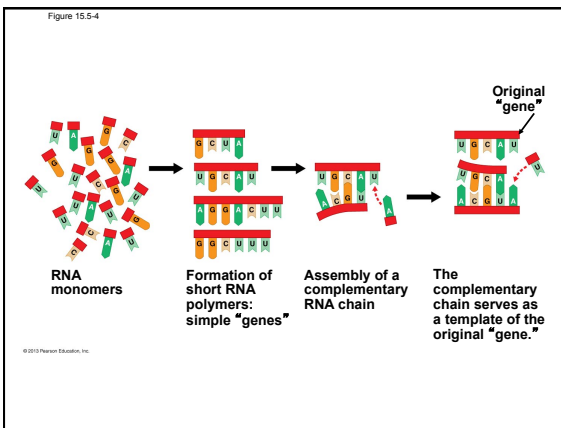
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From Chemical Evolution to Darwinian Evolution

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- Over millions of years
  - natural selection favored the most efficient pre-cells and
  - the first prokaryotic cells evolved.

**A Typical Prokaryote Cell**

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### PROKARYOTES

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– Prokaryotes lived and evolved all alone on Earth for about 2 billion years.



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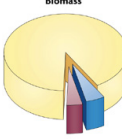
### They're Everywhere!

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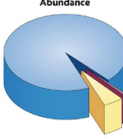
– Prokaryotes

- are found wherever there is life,
- have a collective biomass that is at least ten times that of all eukaryotes,
- thrive in habitats too cold, too hot, too salty, too acidic, or too alkaline for any eukaryote,
- cause about half of all human diseases, and
- are more commonly benign or beneficial.

**Biomass**



**Abundance**



■ Prokaryotes  
■ Protists  
■ Viruses

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Figure 15.6



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**They're Everywhere!**

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– Compared to eukaryotes, prokaryotes are

- much more abundant and
- typically much smaller.

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**The Origin of Multicellular Life**

**Synergy** – Together they do more than the sum of their parts

Many cells working together allows **SPECIALIZATION**

- Feeding
- Waste disposal
- Gas exchange
- Protection

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### The Origin of Multicellular Life

**Unicellular → Multicellular** • *Multi cellularity Evolved many times and plays a role in the diversity of life*

Colonial forms:

- Cells became increasingly independent

† actual true mult- the cells erdependent

† Figure 15.27 A model for the evolution of multicellular organisms from unicellular protists.

1 An ancestral colony may have formed, as colonial protists do today, when a cell divided and its offspring remained attached to one another.

2 Cells in the colony may have become specialized and interdependent, with different cell types becoming more efficient at performing specific tasks. Flagellated cells may have become specialized for locomotion, while others could have assumed functions such as ingesting or synthesizing food.

3 Additional specialization among the cells in the colony may have led to distinctions between sex cells (gametes) and nonreproductive cells (somatic cells).

Unicellular protist

Colony

Locomotor cells

Food-synthesizing cells

Gamete

Somatic cells

Early multicellular organism with specialized, interdependent cells

Later organism with gametes and somatic cells

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### The Origin of Multicellular Life

**Unicellular → Multicellular**

Colonial forms:

- Cells became increasingly independent

† actual true mult- the cells erdependent

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