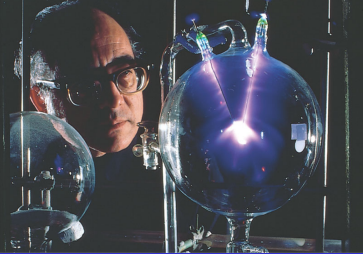


## “Origin of Life”

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Professor Peter O'DONOGHUE

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## Topic

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Origin of life (mixture of pseudo-science and science)

- creationism (life from God)
- spontaneous generation (life from non-life)
- biogenesis (life from life)
- abiogenesis/biopoiesis (life from inorganic matter)
  - extra-terrestrial (panspermia theories)
  - terrestrial (multiple theories)

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## Scientific extrapolation

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Work with extant/extinct physical forms

- comparative biology (greatest divide – Prokaryotes/Eukaryotes)
  - chemical basis (hydrocarbon macromolecules)
  - cellular basis (hereditary, metabolism)
- paleontology (microfossils – oldest 3.5 BYA)
- phylogenetic reconstruction (differential ‘molecular clocks’)
- environmental prerequisites (vary with time, ‘Goldilocks’ zone)

Speculation

- common ancestry (Last Universal Common Ancestor - LUCA)

Why study ‘origins’?

- Understand past - esp. evolution (competition/collaboration)
- Understand present - esp. interactions (eco-systems)
- Predict/manipulate future!

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## SET

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Posits symbioses of different life-forms

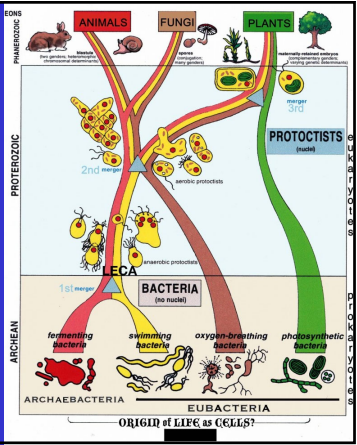
Two prokaryotic domains

- archaeobacteria
- eubacteria

Giving rise to four eukaryotic domains

- protocista
- fungi
- animalia
- plantae

Where did they come from?




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## Timeline

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<ul style="list-style-type: none"> <li>• 4.5 BYA Earth forms</li> <li>• 4.3 BYA water</li> <li>• 4.1 BYA massive bombardment</li> <li>• 4.0 BYA carbon</li> <li>• 3.5 BYA first archaea</li> <li>• 3.2 BYA first eubacteria</li> <li>• 1.9 BYA first eukaryotes</li> <li>• 0.5 BYA first animals</li> </ul>	<div style="display: flex; align-items: center;"> <div style="font-size: 3em; margin-right: 10px;">}</div> <div> <p>prebiotic</p> <hr style="width: 100%;"/> <p>biotic</p> </div> </div>
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## Conceptual basis

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**Matter**

- self-replicating molecules
- self-organization (polymers, membranes)

**Energy**

- proton motive forces
- steady supply of electrons
- thermodynamics

**‘Life’**

- proteinoids (cross-linked amino acids)
- protobionts/microspheres (with membranes)
- protocells (with nucleic acids)

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## Prebiotic Chemistry

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<p>fundamental biochemicals (monomers)</p> <ul style="list-style-type: none"> <li>• amino acids</li> <li>• saccharides</li> <li>• nucleotides</li> </ul>	<p>complex macromolecules (polymers)</p> <ul style="list-style-type: none"> <li>• proteins</li> <li>• polysaccharides</li> <li>• nucleic acids</li> </ul>
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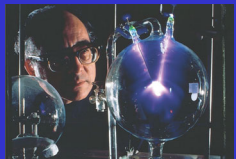
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## Prebiotic

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primordial soup

- 50 years ago, Miller & Urey simulated primordial environmental conditions in glass flasks
- ocean of water + atmosphere of methane, ammonia, hydrogen, carbon dioxide + volcanic heat + lightning sparks
- observed spontaneous synthesis of organic compounds, including simple amino acids and sugars

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## Origin of organic molecules

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**Primordial soup (components)**

- warm pond (oceanic/atmospheric)
- hydrothermal vents (upwellings)
- hot rock (nanobes)

**Structured models (templates)**

- pyrites (iron-sulfur world) (built-in E)
- sphalerite (zinc world) (retain radiant E)
- radioactive beach (actinides)
- community clay (mineral crystals)

**Stochastic models (unpredictable)**

- hypercycles (ribozymes)
- autocatalysis (chemical networks)

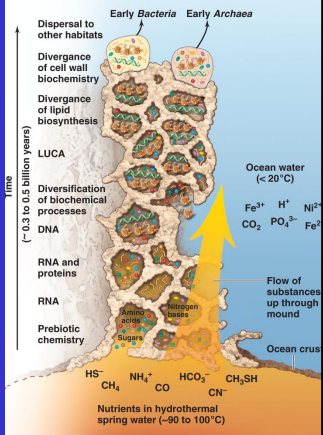
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## LIFE

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subsurface origin

- hydrothermal vents
- minerals + nutrients
- organics
- *Taq* polymerase



The diagram illustrates the subsurface origin of life. At the bottom, hydrothermal spring water (~90 to 100°C) contains nutrients like HS<sup>-</sup>, CH<sub>4</sub>, NH<sub>4</sub><sup>+</sup>, CO, HCO<sub>3</sub><sup>-</sup>, and CH<sub>3</sub>SH. These substances flow up through a mound. In the middle, prebiotic chemistry leads to RNA and proteins, then DNA. LUCA (Last Universal Common Ancestor) is shown at the top of this mound. Above LUCA, there is diversification of biochemical processes, divergence of lipid biosynthesis, and divergence of cell wall biochemistry, leading to Early Bacteria and Early Archaea. The top of the mound is labeled 'Ocean water (< 20°C)' and contains Fe<sup>3+</sup>, H<sup>+</sup>, Ni<sup>2+</sup>, CO<sub>2</sub>, PO<sub>4</sub><sup>3-</sup>, and Fe<sup>2+</sup>. A vertical axis on the left indicates time from 0.3 to 0.5 billion years.

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## CELLS

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Cellular life (containment, metabolism, replication)

transcription                      translation

DNA → RNA → Protein

↓ replication                      ↻ metabolism

DNA                      hereditiy

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## From organic molecules to protocells

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**Gene-first**

- RNA world hypothesis (good replicator, good catalyst)

**Metabolism-first**

- iron-sulfur world hypothesis (membrane-like surfaces)
- thermosynthesis (chemiosmosis)
- bubbles (amphiphilic foam)
- pumice rafts (percolation pores)

**Multiple origins**

- SET (merger of different forms)
- LUCA

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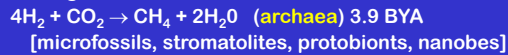
## CELLS

first cells (LUCA) – anaerobic autotrophs

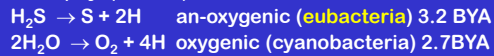


metabolic diversification

- methanogenesis

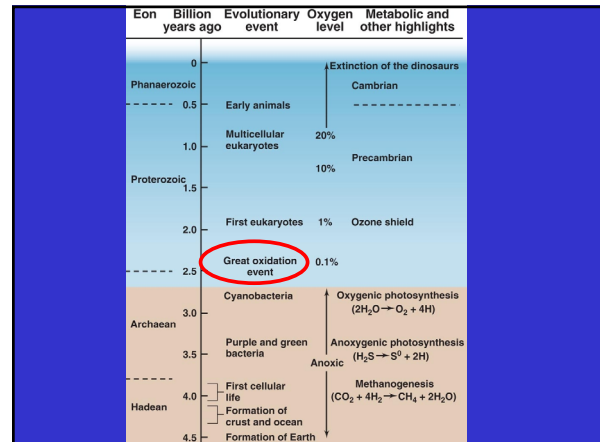


- phototrophy (solar E)



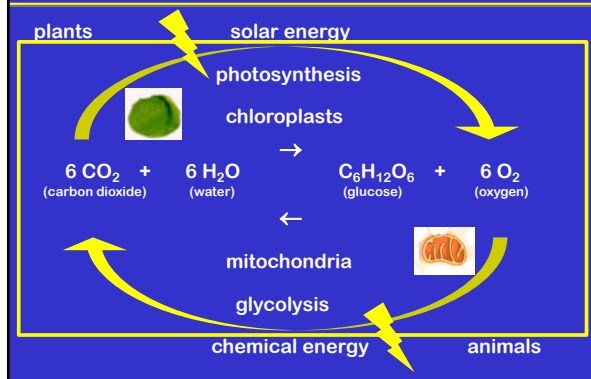
⇒ Great Oxidation Event 2.6 BYA  
(ozone shield, surface colonization)

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## Oxygen



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## Symbiosis

“Life did not take over the globe by combat,  
but by networking!”

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## Extraterrestrial

Explore solar system

Explore neighboring systems

Astrobiology, ‘Goldilocks’ zone

Instrumentation to detect matter, energy

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