A2.1 Origins of cells [HL]

Conditions on early Earth and the prebiotic formation of carbon compounds

Formation of the Earth: 4,500 million years ago

Atmospheric gases:

- Traces of Oxygen that probably reacted with iron to form iron oxides.
- Methane concentration was higher due to volcanic activity and meteorite bombardment.
- CO_2 concentrations were probably higher due to emissions from volcanoes.

Temperature:

- Likely higher due to higher concentration of greenhouse gases

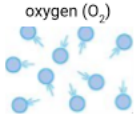
pH of oceans:

- Uncertain. Estimates range from pH 5 to pH 11

UV radiation:

- With less O_2, the ozone layer (O_3) probably did not exist. Therefore, more solar UV would have penetrated to the Earth's surface

→ The conditions of prebiotic Earth may have caused a variety of carbon compounds to form spontaneously.

Atmosphere	Temperature	UV Radiation	Volcanic Activity	Asteroid Bombardment
"Reducing atmosphere" with higher proportion of reactive gasses such as ammonia (NH_3) and hydrogen (H_2). Very little oxygen (O_2) 	Significantly warmer than today due to heat from asteroid collisions and accretion (coming together, formation) of the planet 	No ozone (O_3) layer to block radiation from the sun so intense UV radiation reached the surface 	Volcanic eruptions released gasses (H_2O and CO_2) into the atmosphere 	Constant bombardment by asteroids as the solar system was forming. 

Challenge of explaining the spontaneous origin of cells

- Cells can only be formed by division of pre-existing cells.

  A cell is a highly complex structure and no natural mechanism has been suggested for producing cells from simpler subunits

  No example is known of increases in the number of cells in a population, organism or tissue without cell division occurring

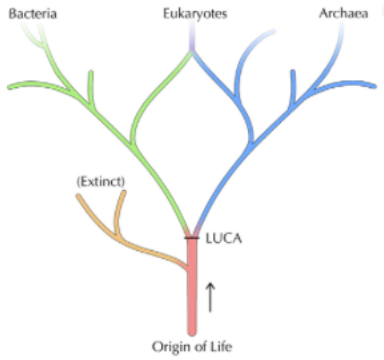
- The first cells must have arisen from non-living material.

  Unless cells arrived on Earth from somewhere else in the universe, they must have arisen from non-living material. But how is that possible???

HYPOTHESES			
Production of carbon compounds	**Assembly of carbon compounds into polymers**	**Formation of membranes**	**Development of a mechanism for inheritance**
Stanley Miller & Harold Urey passed steam through a mixture of methane, hydrogen, ammonia and water vapor (pre-biotic atmosphere!). Electrical discharges simulated lightning. → Amino acids and other carbon compounds needed for life were produced!	In deep sea vents, inorganic chemicals are present. These chemicals (eg iron sulphide) represent readily accessible supplies of energy, a source of energy for the assembly of these carbon compounds into polymers so LUCA must have lived in the vicinity of these vents.	If phospholipids occurred naturally, they would have formed bilayers if mixed with water. Therefore, small vesicles could have formed looking "cell-like". This would have allowed different internal chemistry from that of the surroundings to develop	Living organisms have genes made of DNA and use enzymes as catalysts. Prior to DNA, RNA might have existed that can store information and can replicate and act as a catalyst itself. It would act as a catalyst for their own replication without the use of enzymes. RNA that still acts as a catalyst is called **ribozyme**

It is also possible for striking similar structures to evolve in organisms that do not have a common ancestor (= convergent evolution).

- The most recent common ancestor (molecular evidence) to have existed is called **LUCA (last universal common ancestor)**.



- Other forms of life might have become extinct due to competition and natural selection that lead to evolution.

Approaches used to estimate dates of the first living cells and the last universal common ancestor

→ Paleontology has provided invaluable evidence about the pathways of evolution.

→ Well preserved rocks from billion years ago, contain fossil-like structures with isotope ratios suggesting they are the remains of living organisms (fossil evidence).

→ Stromatolites are formed when cyanobacteria trap sediments and secrete calcium carbonate, slowly building rocky mounds (chemical evidence).