First biological systems

Prebiotic Earth

- A Young Sun:
  - Low energy input on Earth, but mainly UV and X-rays
  - => Highly energetical photons => Possible photochemical reactions
- A high electric and seismic activity on Earth
- A liquid ocean (evidence found in zircons dated as being 4.3 billion years old)
- Initial composition of the Atmosphere: **EDUCATED GUESSES**
  - H_2:
    - H most abundant element in the Universe
    - Has not escaped the atmosphere yet (Earth is not old enough)
  - CO_2:
    - Greenhouse gas => Allows surface temperature to be sufficient for liquid water
    - Dissolves in water Equilibrium $CO_{2(g)} \leftrightarrows CO_{2(aq)}$ => Temperature not too high
  - N_2:
    - High seismic activity of the young Earth => Emission of nitrogen
  - Chemical reactions lead to the formation of methane (CH_4) and ammonia (NH_3)
    - $CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$
    - $N_2 + 3H_2 \longrightarrow 2NH_3$
  - Photochemical reactions lead to the formation of aldehydes (R-CHO) and hydrogen cyanide (HCN)

- $H_2O \xrightarrow{h\upsilon} H^{\cdot} + HO^{\cdot}$
  $HO^{\cdot} + CH_4 \longrightarrow H_2O + H_3C^{\cdot}$
  $H_3C^{\cdot} + HO^{\cdot} \longrightarrow H_3COH$
  $H_3COH \xrightarrow{h\upsilon} H_2CO + H_2$

- $NH_3 \xrightarrow{h\upsilon} H_2N^{\cdot} + H^{\cdot}$
  $H_2N^{\cdot} + CH_4 \longrightarrow NH_3 + H_3C^{\cdot}$
  $H_2N^{\cdot} + H_3C^{\cdot} \longrightarrow H_3CNH_2$
  $H_3CNH_2 \xrightarrow{h\upsilon} HCN + 2H_2$

$H_3C^{\cdot} + H_3C^{\cdot} \longrightarrow H_3C - CH_3$
$HO^{\cdot} + H_3C - CH_3 \longrightarrow H_2O + H_3C - CH_2^{\cdot}$
$H_3C - CH_2^{\cdot} + HO^{\cdot} \longrightarrow H_3C - CH_2OH$
$H_3C - CH_2OH \xrightarrow{h\upsilon} H_3C - CHO + H_2$
...

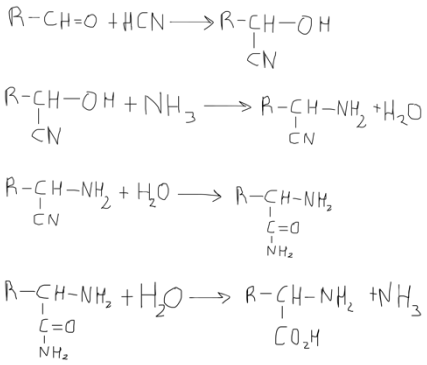
From small molecules to building blocks of life

From aldehydes and hydrogen cyanide, more complicated molecules can be derived. Amongst these, aminoacids and carbohydrates play an essential role in the metabolism and the inheritance.

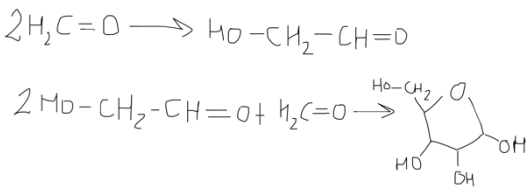
Formation of aminoacids: Miller-Urey experiment

The conditions stated above could lead to the formation of the building blocks of proteins, amino acids.

The Experiment lead by Stanley Miller (and supervised by Harold Urey) in 1952 simulated these conditions and confirmed the hypothesis through the identification of 5 different ones.



Note: Later, with an increase of the precision of measurement devices, more were found, but also other molecules like carbohydrates, lipids…



Formation of carbohydrates: Butlerov reaction (AKA formose reaction) (1861)

This reaction leads to the formation of hexoses, like ribose and desoxyribose, respectively building blocks of RNA (RiboNucleic Acid) and DNA (DesoxyriboNucleic Acid)

From there, several hypothesis are possible and still in discussion about the start of life:

- Replication before reproduction? Or the other way around
- An RNA world formed by self-replicating RNA molecules, followed by a DNA world? Or Both RNA and DNA at the same time?
- A membrane defining a cell before these molecules? Or RNA and/or DNA trapped in a vesicle of phospholipids?
- …

There is still a lot to discover