Life in the Universe 11/06/2019

Revision of Monday's lecture:
When did life arise on Earth? —> most likely earlier than 3.5-3.8 billion years ago.

- *How do we know this? stromatolites/microfossils/isotope dating*
- *Why do we say probably earlier than the earliest found evidence?*

How do we determine what early life looked like? —> DNA sequencing
Where did early life originate? Why is it more likely that deep sea life survived?

Today's lecture: HOW early life originated?
Short answer: we still don't know for sure, but we have ideas and experiments

If we're sticking to hardcore science and abandon all magic, myths and religious interpretations, we're left with only one option: there needs to be a mechanism in nature that gives rise to living organisms from non-living matter. This process is called **abiogenesis.**

First step towards building life: making the basic ingredients

The chemical history of the Universe:
Big Bang, early beginnings of the Universe: H, He, Li
Stars (massive): atoms of elements up to Fe
Supernovae (stellar explosions): even heavier elements (U, Au)
Interstellar dust: cold enough for molecules to form, we have even found simple organic molecules
Living organisms: very complex organic molecules: carbohydrates, lipids, proteins, nucleic acids

Carbohydrates are typically used as sources of energy for living organisms, lipids are used as sources of energy and in membranes, while the building blocks of living "structures" are proteins. Proteins are large, complex organic molecules that perform a variety of functions in living organisms: catalysing metabolic reactions, DNA replication, responding to stimuli, providing structure to cells, and organisms, and transporting molecules from one location to another.
So how do we make proteins? —> we need to make amino acids first!

About 500 naturally occurring amino acids are known (though only 20 appear in the genetic code) and can be classified in many ways.
Which amino acids and how they're bound gives rise to all different proteins used in life. The 20 amino acids are combined in **different** ways to make up the 100,000 or so **different proteins** in the human body.
https://www.youtube.com/watch?v=yZ2aY5lxEGE

How did these complex organic molecules arise and why can't we observe similar processes happening on Earth today?

- Because life today is based on organic molecules, it is safe to believe that these molecules assembled through chemical reactions that took place in the physical conditions of early Earth. Today, they can't spontaneously happen because of the large amounts of oxygen in our atmosphere, which prevents complex organic molecules from forming outside of living cells. Oxygen is a highly reactive gas that destroys chemical bonds by removing electrons and thus destroying organic molecules. Therefore, it is safe to assume the Earth's early atmosphere was deprived of oxygen and all of the oxygen present today was made through photosynthetic processes in living organisms. So, if we want to observe organic molecules spontaneously emerging, we need to recreate the conditions of early Earth.

The Miller-Urey experiment

Hypothesis (1920s): Earth's early atmosphere was oxygen free and sunlight-driven chemical reactions gave spontaneous rise to organic molecules

1950s: Miller & Urey put it to the test.

Experiment: water heated up to produce water vapor, gaseous ammonia and methane, sparks to produce lightning, condense vapor to simulate rain and get it back in the water tank. Let it run for 1-2 weeks, water turns murky brown. Analysis: 5 amino acids produced, and some other organic compounds

https://www.ucsd.tv/miller-urey/

Problems: CH_4 and NH_3 were probably not present in high abundances in the early atmosphere. Hydrogen can play a major role in facilitating the creation of organic molecules but we don't know for sure if it was present or not in Earth's atmosphere. Therefore, we still don't have an experiment that shows EXACTLY how life came to be from non-life on Earth. The importance of Miller-Urey's experiment is in the fact that it first showed that under certain conditions, organic material, amino acids, can form from non-organic molecules. A second series of experiments that weren't analyzed until decades later showed 23 amino acids and other organic compounds.

Other sources of organic molecules

Deep sea vents:

Miller-Urey's experiment tried to demonstrate the production of organic material in conditions conducive of Earth's surface. However, as we saw on Monday, life most likely survived around deep sea vents, where it could also have originated. These underwater volcanic vents heat the water around them, which can give rise to a variety of chemical reactions between the water and minerals. These are also spontaneous reactions so another source of abiogenesis.

https://www.sciencedaily.com/releases/2019/11/191104112437.htm

Material from space:
Analysis of meteorites, asteroids and comets show the presence of organic material, in some cases even DNA bases. The impacts of these bodies could have brought the necessary particles for life on Earth. Interplanetary dust grains in the solar nebula, energized by the UV radiation from the young Sun could also have produced organic molecules. Finally, the heat and pressure from the impacts of bodies in the early days of Earth, could have catalyzed the formation of organic molecules. Experiment: laser to reproduce the heat and pressure over chemicals from early Earth: all 4 DNA bases were created.

Summary:
- Chemical reactions near the ocean surface
- Chemical reactions in deep sea vents
- Material from space
- Heat and pressure from impacts

Conclusion: all four mechanisms probably played a part in the origin of life on Earth.

What are the ingredients for life?
- Materials: water, organic compounds, phosphates
- Energy source: Solar energy (photosynthesis), chemical reactions (chemosynthesis)
- Metabolism - catalytic energy utilization (sustain life using compounds and energy from the environment via catalytic chemical reactions)
- Reproduction and heredity
- Membrane to separate life from the outside non-life