

Are we alone in the Universe?

Class 5.

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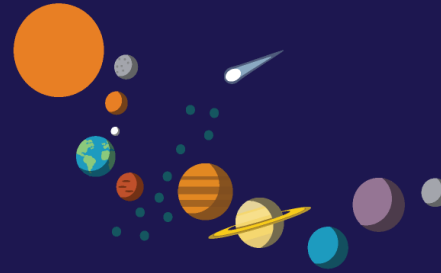
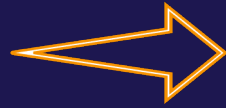


High School Summer Course, 2023

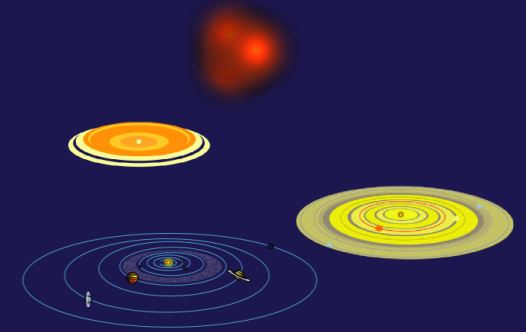
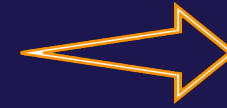
Our Map:



What are there in the Universe?
Scales involved in describing Universe



Our planet and Solar system



How did the Solar system form?
Is it unique?

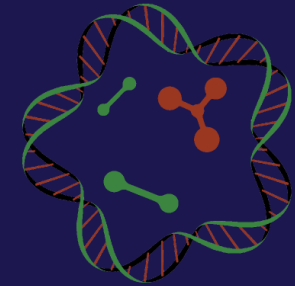
Are we alone in the universe?



What form of life would you look for and how? Possibility of life on other planets.



How can we look for ET life?
Atom and EM spectrum.



What is life?
How did life on Earth begin? Building blocks of life, first form of life on Earth.



A person is sitting on a dark rock in the foreground, looking up at a vast night sky filled with stars and the Milky Way galaxy. The galaxy's bright, colorful band stretches across the sky from the bottom left towards the top right. The background is a deep blue and black, with numerous individual stars visible.

Today's goals... (learning objectives)

Class 5.

By the end of this class, you should be able to:

1. List essential characteristics of **“life”**
2. State two theories of **origin of life** on Earth
3. Describe the main ideas of **chemical evolution** theories of origin of life on Earth

Drake Equation



Is an AI robot alive?

https://youtu.be/Bg_tJvCA8zw?t=245



OUR

Criteria of Life?

Living organisms have all of the following traits:

1. **Organization:** Exhibit complex but ordered organization (cells → tissues → organs)
2. **Regulation:** Regulate their internal environment to maintain the conditions needed for cell function (e.g., body temperature)
3. **Response to environment:** Change properties reacting to environment / stimulus (mimosa plant)
4. **Growth and Development:** Information carried by genes controls the pattern of growth and development
5. **Energy utilization:** Use energy to function (chemical reactions = “metabolism”)
6. **Reproduction:** Reproduce to carry on their own kind
7. **Evolution:** Capacity of populations to change (evolve) over time for the survival of the species



But also see: <https://astrobiology.nasa.gov/research/life-detection/about/>

Earth 4 billion years ago...

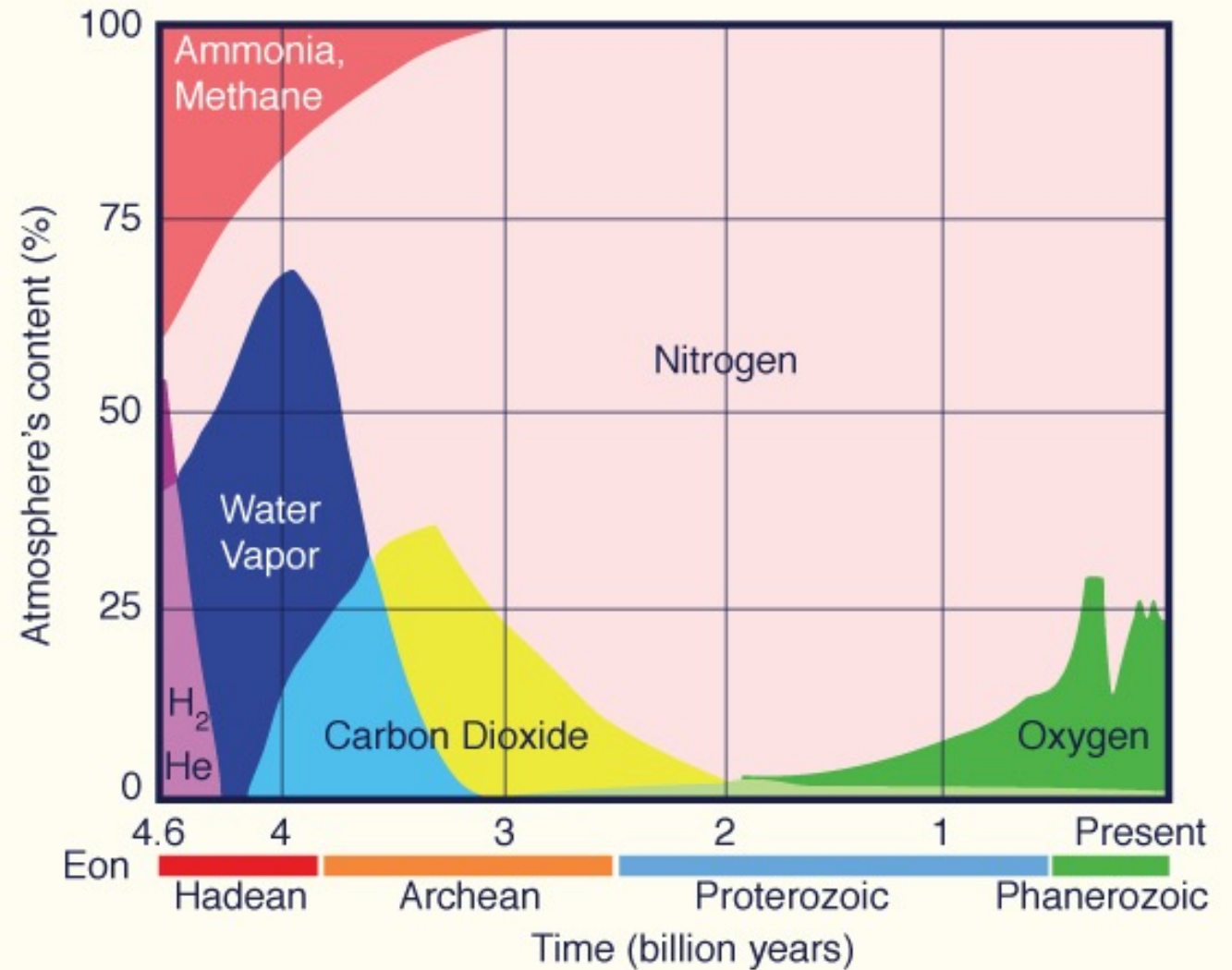
Going back to the planet formation....

- How did life start on Earth?
- What were the conditions of Earth?
- What observational evidences do we have for the “origin of life”?



Atmospheric composition

- When did the first life emerge?



For the weekend:

Read these two pages and write down what you think are the differences between these two theories of “origin of life”.



Asteroids

Apr 26, 2022

Could the Blueprint for Life Have Been Generated in Asteroids?

Using new analyses, scientists have just found the last two of the five informational units of DNA and RNA that had yet to be discovered in samples from meteorites. While it is unlikely that DNA could be formed in a meteorite, this discovery demonstrates that these genetic parts are available for delivery and could have contributed to the development of the instructional molecules on early Earth. The discovery, by an international team with NASA researchers, gives more evidence that chemical reactions in asteroids can make some of life's ingredients, which could have been delivered to ancient Earth by meteorite impacts or perhaps the infall of dust.

An illustration of a large, dark, rocky asteroid in space. In the foreground, several ball-and-stick molecular models are shown, representing various organic compounds. The background features a bright, glowing celestial body, possibly the sun or a planet, with a hazy atmosphere.

1.

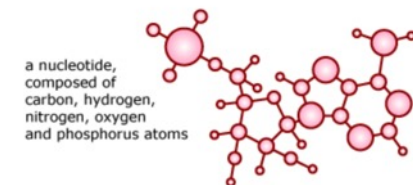
<https://www.nasa.gov/feature/goddard/2022/life-blueprint-in-asteroids>

How did life originate?

Living things (even ancient organisms like bacteria) are enormously complex. However, all this complexity did not leap fully-formed from the primordial soup. Instead life almost certainly originated in a series of small steps, each building upon the complexity that evolved previously:

1. Simple organic molecules were formed.

Simple organic molecules, similar to the nucleotide shown below, are the building blocks of life and must have been involved in its origin. Experiments suggest that organic molecules could have been synthesized in the atmosphere of early Earth and rained down into the oceans. [RNA](#) and [DNA](#) molecules — the genetic material for all life — are just long chains of simple nucleotides.



2.

<https://evolution.berkeley.edu/from-soup-to-cells-the-origin-of-life/how-did-life-originate/>

Origin of life: Theories

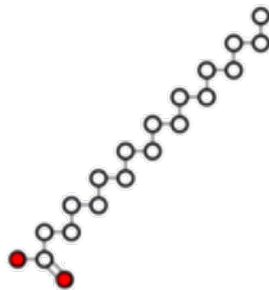
1. Panspermia

(= "seeds everywhere")

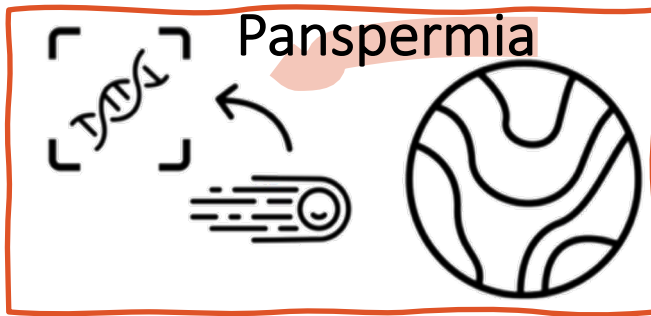


Life (or building blocks of life) **originated on another planet** and was delivered to Earth

2. Chemical evolution



Life (or building blocks of life) **developed on Earth** in early (primordial) Earth condition



An observation: The Murchison Meteorite

The Murchison Meteorite – A “Messenger from Space”

Amino Acids	17-60 ppm	Fall Date is 28 September 1969	Type	Chondrite
Aliphatic Hydrocarbons	>35 ppm	100 kg known weight	Class	Carbonaceous Chondrite
Aromatic Hydrocarbons	3319 ppm	36°37' S, 145° 12' E	Group	CM2
Fullerenes	>100 ppm			
Carboxylic Acids	>300 ppm			
Hydrocarboxylic Acids	15 ppm			
Purines and Pyrimidines	1.3 ppm			
Alcohols	11 ppm			
Sulphonic Acids	68 ppm			
Phosphonic Acids	2			

Composition
22.13% total iron
12% water

Presolar Nanodiamonds

Over 100 amino acids have been identified, some of which are the basic components of Life.

Space

Asteroid Ryugu harbors life’s building blocks

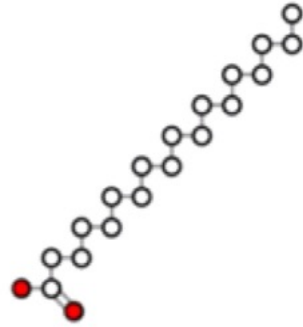
Posted by [Paul Scott Anderson](#) | March 27, 2022

<https://earthsky.org/space/asteroid-ryugu-organic-compounds-amino-acids-hayabusa-2/>

UTC 2018-06-30 10:21

CM chondrites, together with the CI group, are the most chemically primitive meteorites in our collection.

How about **Chemical Evolution**?



Life (or building blocks of life)
developed on Earth in early
(primordial) Earth condition

What do **YOU** think are needed for
life to **start** on a planet?

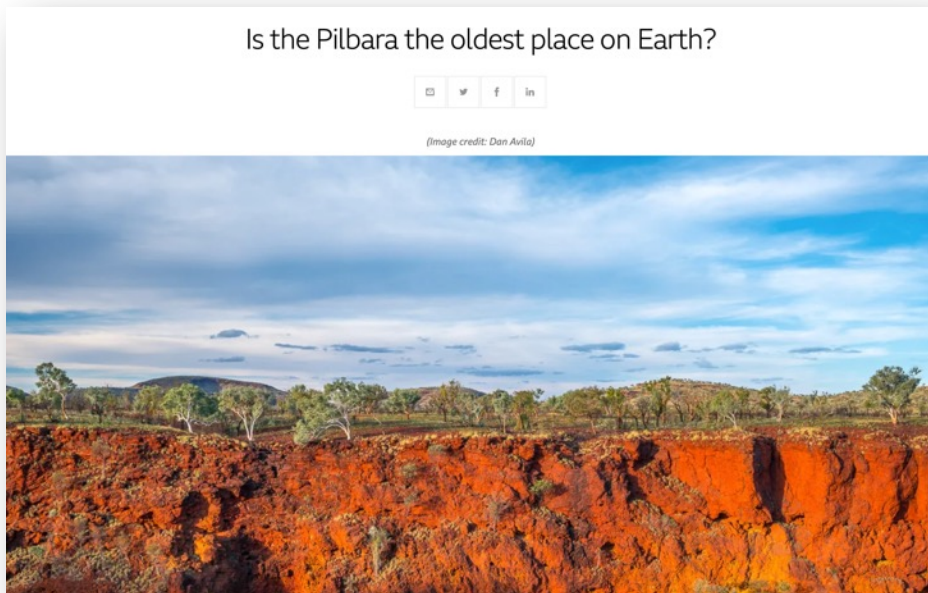


- Go to <https://www.menti.com/w9uijafuv8>

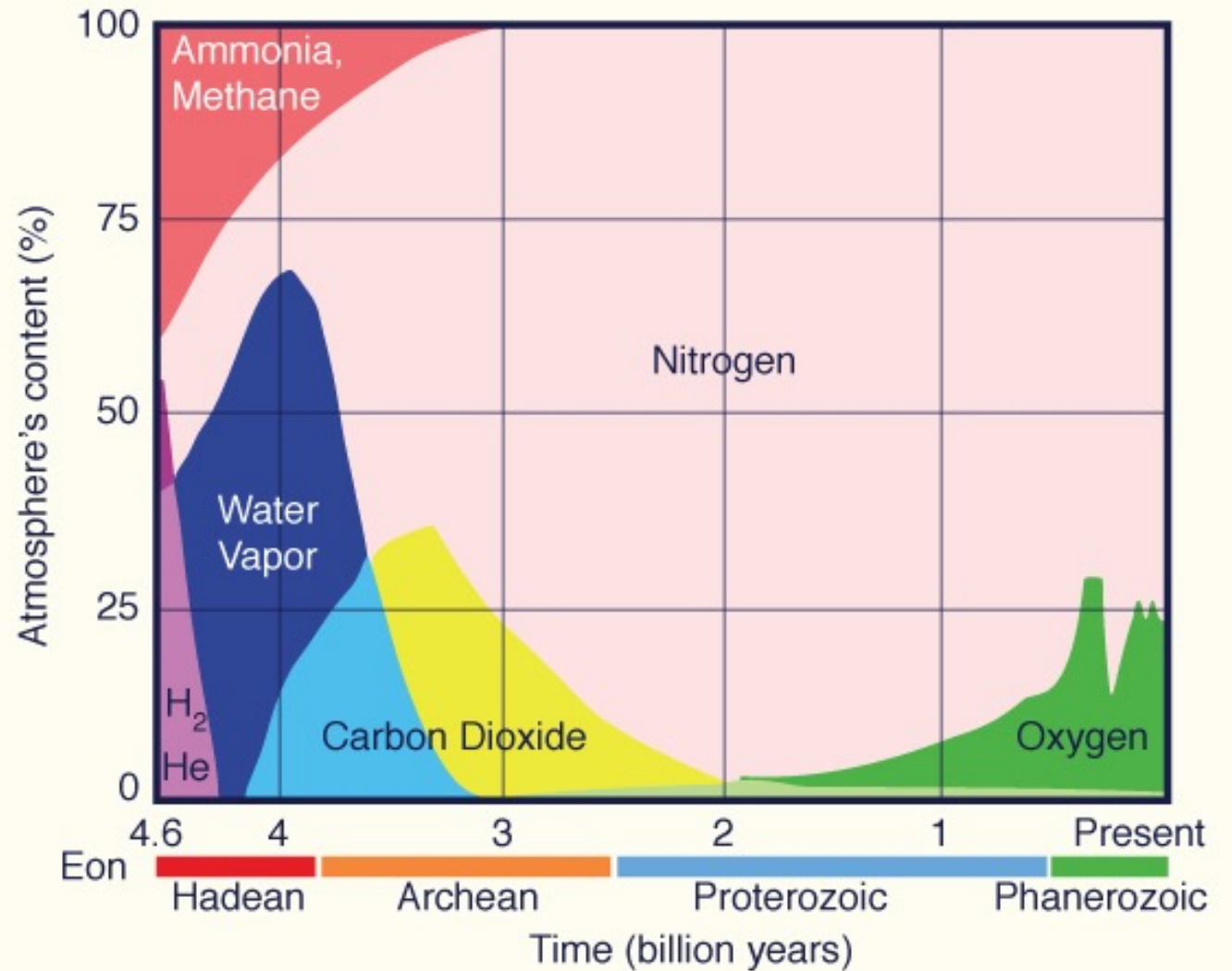


Atmospheric composition

- When did the first life emerge?



<https://www.bbc.com/travel/article/20220126-is-the-pilbara-the-oldest-place-on-earth>



[Stromatolites: The Earth's oldest living lifeforms](#)

(Possible) Origin of Life in a Nutshell


Origins of Life

Scientists debate a range of ideas about how life on Earth began. The most widely accepted scenarios involve the geochemistry of the planet's surface.

In the early universe, vast molecular clouds of dust and gas condensed to form a protostar, surrounded by a protoplanetary disk.



Tiny dust grains, consisting of silicate minerals coated with ice, stuck together and assembled into larger particles.



Earth was formed. Because it was not too hot and not too cold, not too dry and not too wet, liquid water existed on the surface.



The first land was probably volcanic.



The first land was probably volcanic, forming island arcs in a vast ocean.

Ponds or lakes in volcanic regions were likely environments for jump-starting life.


The early atmosphere had no oxygen. It consisted mainly of nitrogen and carbon dioxide, with smaller amounts of hydrogen, water and methane.

Lightning, asteroid impacts and ultraviolet light from the sun acted on the atmosphere to generate hydrogen cyanide, a compound of hydrogen, carbon and nitrogen.



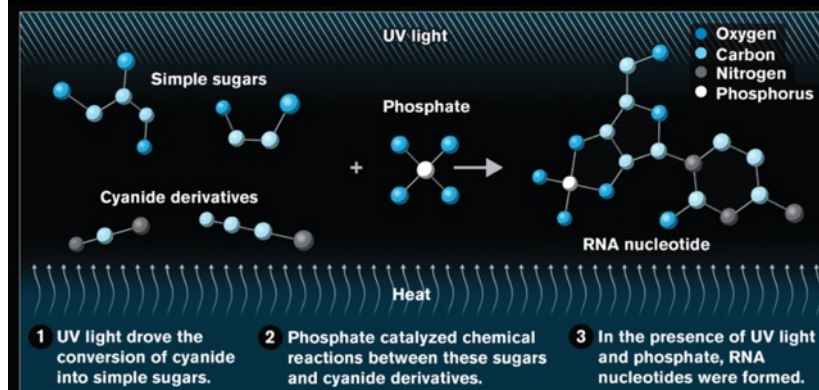
Raining into volcanic or crater lakes, the cyanide reacted with iron brought up by water circulating through rocks.

The resulting iron-cyanide compounds accumulated over time, building up into a concentrated stew of reactive chemicals.



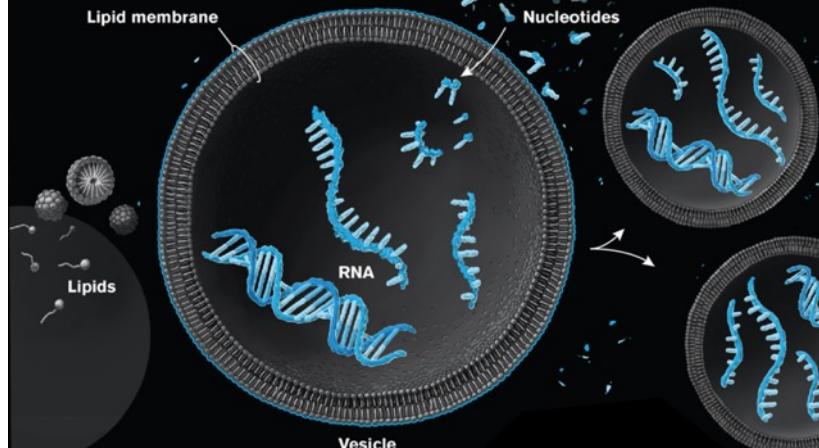
Life as we know it requires RNA. Some scientists believe that RNA emerged directly from these reactive chemicals, nudged along by dynamic forces in the environment.

Nucleotides, the building blocks of RNA, eventually formed, then joined together to make strands of RNA. Some stages in this process are still not well understood.



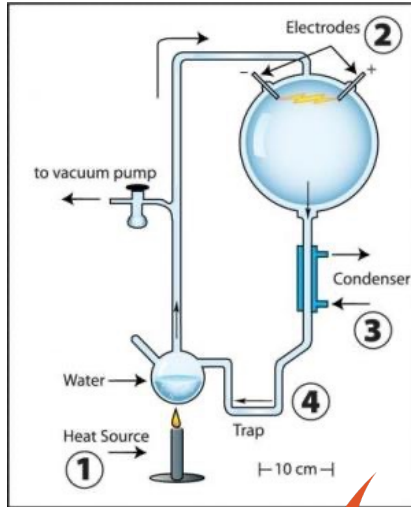
1 UV light drove the conversion of cyanide into simple sugars. 2 Phosphate catalyzed chemical reactions between these sugars and cyanide derivatives. 3 In the presence of UV light and phosphate, RNA nucleotides were formed.

Once RNA was made, some strands of it became enclosed within tiny vesicles formed by the spontaneous assembly of fatty acids (lipids) into membranes, creating the first protocells.



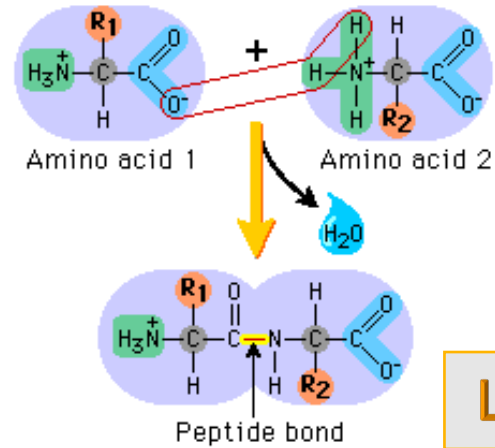
As the membranes incorporated more fatty acids, they grew and divided; at the same time, internal chemical reactions drove replication of the encapsulated RNA.

Chemical Evolution: 4 Phases



1. Synthesis of monomers (amino acids, nucleotides, ...)

Small molecules



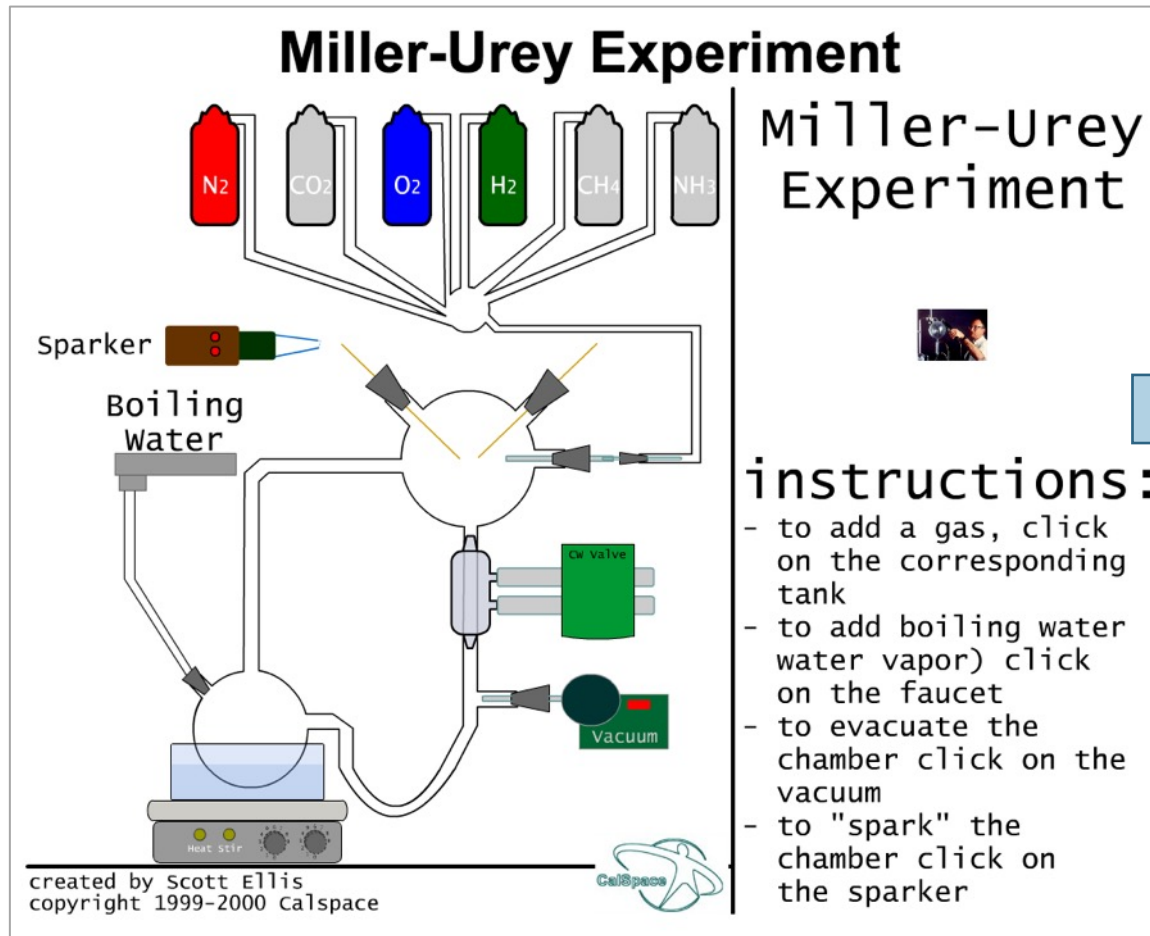
2. Polymer formation (e.g., RNA)

Large molecules

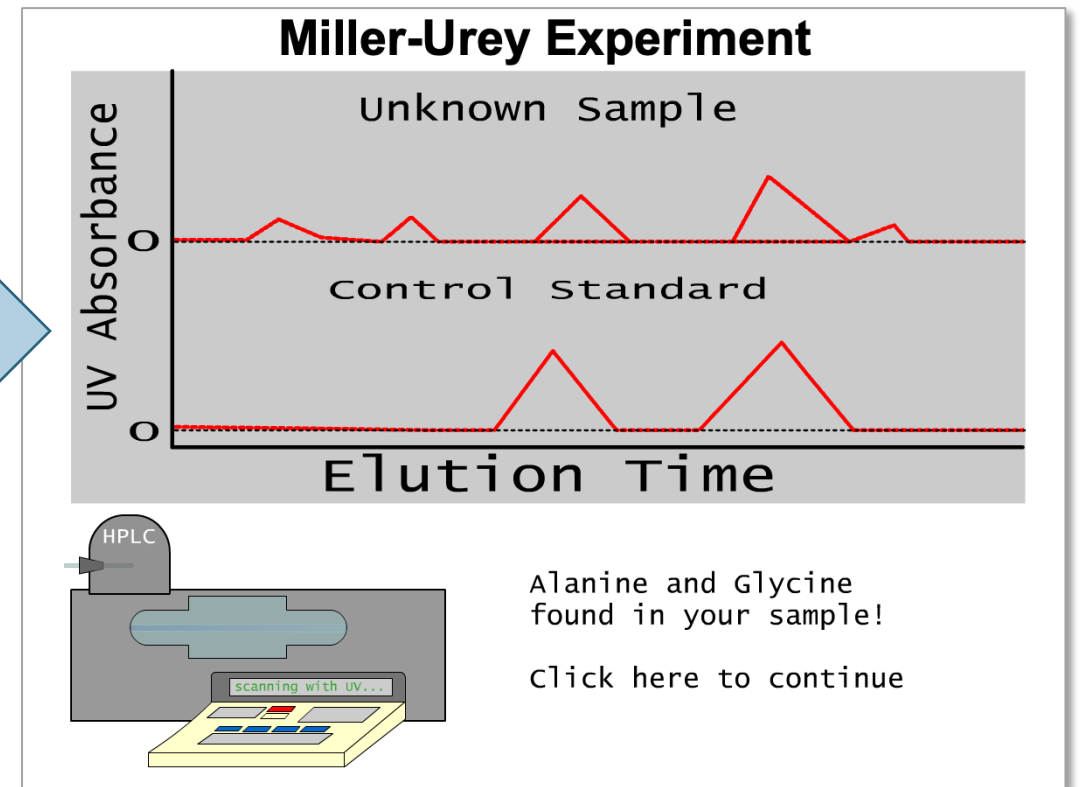
HOW?

Miller-Urey Experiment

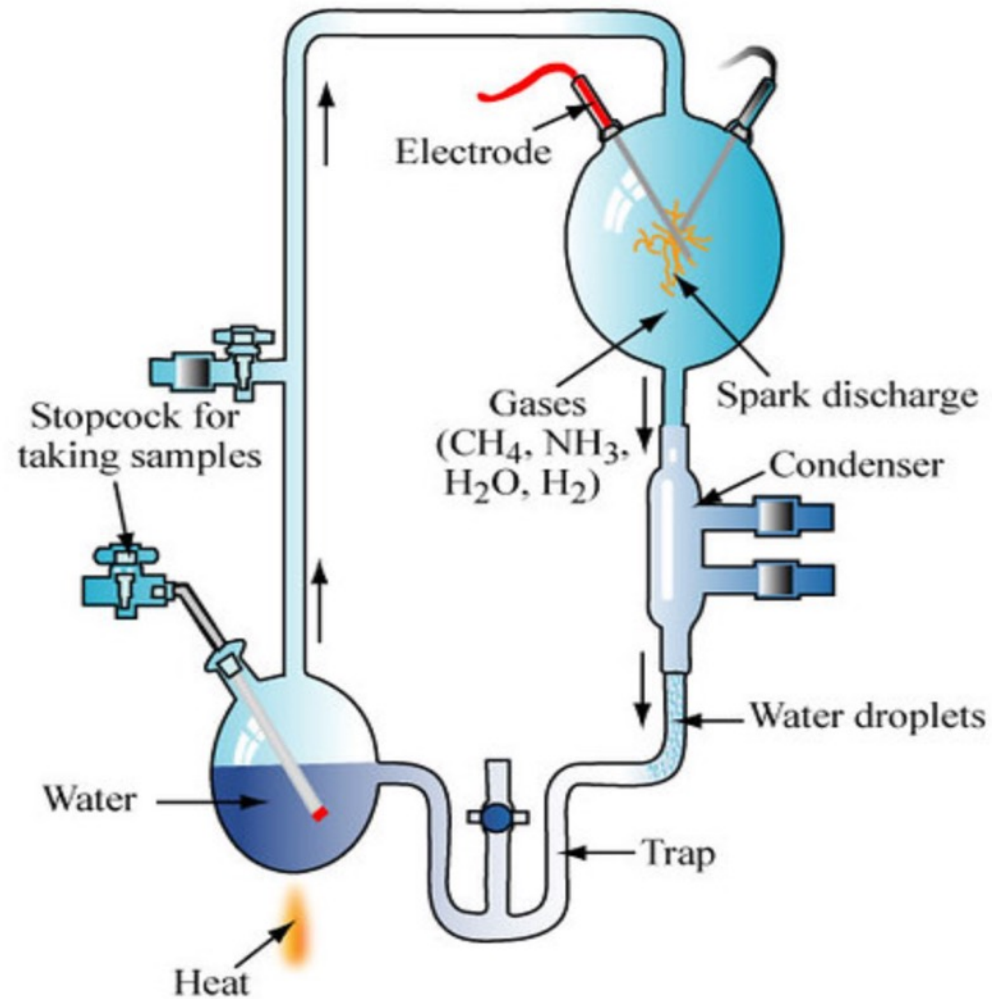
Idea: Let's simulate primitive Earth atmosphere and see if we could produce amino acids in the Early Earth condition.



Analysis Results:



Miller-Urey experiment vs. Murchison Meteorite



Amino Acid	Murchison Meteorite	Discharge Experiment
Glycine	●●●●●	●●●●●
Alanine	●●●●●	●●●●●
α-Amino-N-Butyric Acid	●●●	●●●●●
α-Aminoisobutyric Acid	●●●●●	●●
Valine	●●●	●●
Norvaline	●●●	●●●
Isovaline	●●	●●
Proline	●●●	●
Pipecolic Acid	●	●
Aspartic Acid	●●●	●●●
Glutamic Acid	●●●	●●
β-Alanine	●●	●●
β-Amino-N-Butyric Acid	●	●
β-Aminoisobutyric Acid	●	●
γ-Aminobutyric Acid	●	●●
Sarcosine	●●	●●●
N-Ethylglycine	●●	●●●

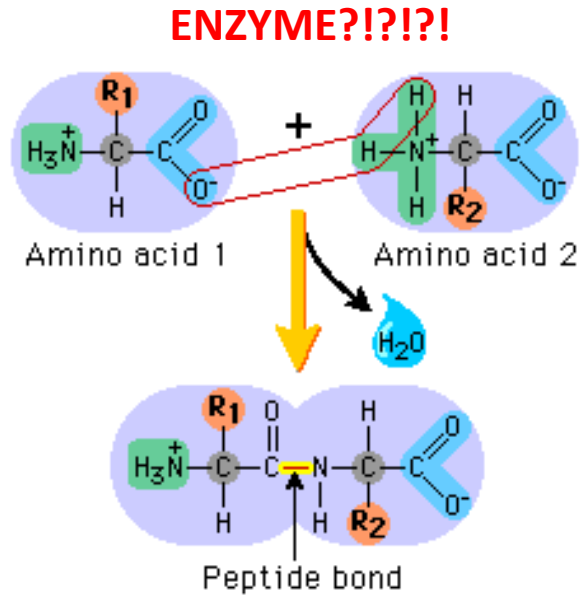
Not used
In life on
Earth

More on Murchison Meteorite/LIFE

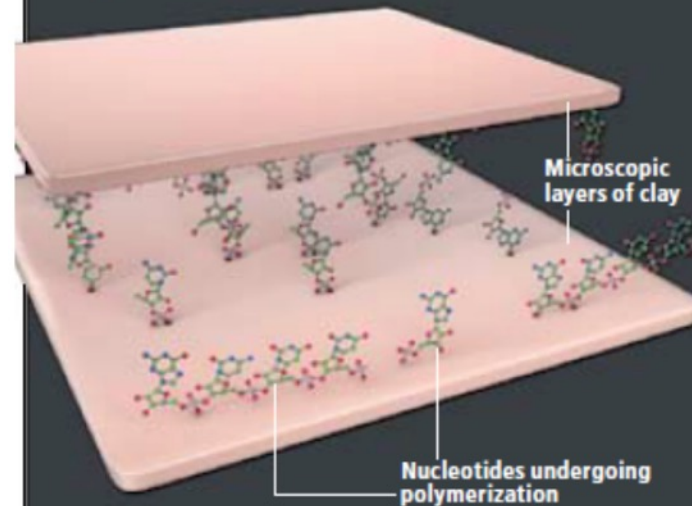
	Role	Life	Murchison meteorite
water	solvent	yes	yes
X lipids (hydrocarbons and acids)	membranes, energy storage	yes	yes
X sugars (monosaccharides)	} support, energy storage	yes	yes
polysaccharides (polymerized sugars)		yes	no
X amino acids	} many (support, enzymes, etc.)	yes	yes
proteins (polymerized amino acids)		yes	no
phosphate		yes	yes
nitrogenous bases	} genetic information	yes	yes
X nucleic acids (polymerized sugars, phosphates and nitrogenous bases)		yes	no

- Long polymers absent (single sugars, no proteins)
 - No nucleotide nor nucleic acids
- X: building block of life (→ all present in Murchison!)**

STAGE 2, how did first polymers form?



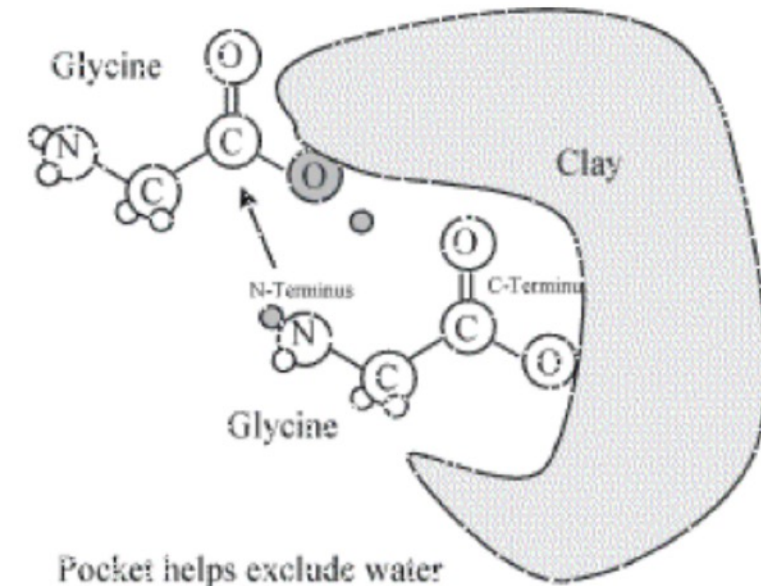
After chemical reactions created the first genetic building blocks and other organic molecules, geophysical processes brought them to new environments and concentrated them. The chemicals assembled into more complex molecules and then into primitive cells. And some 3.7 billion years ago geophysics may have also nudged these "protocells" to reproduce.



RNA BREEDING GROUNDS

In the water solutions in which they formed, nucleotides would have had little chance of combining into long strands able to store genetic information. But under the right conditions—for example, if molecular adhesion forces brought them close together between microscopic layers of clay (*above*)—nucleotides might link up into single strands similar to modern RNA.

- **Solid mineral surfaces** – silicates within **clay** may have been catalysts
- **Hydrothermal vents** – metals as catalysts
- **Hot pools at ocean edges** – concentrated monomers favored polymerization (the "primordial soup")



PROTOCELL FORMATION

Phospholipids are major components of cell membranes

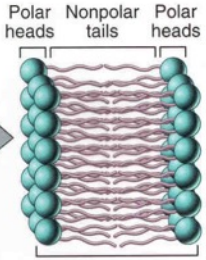
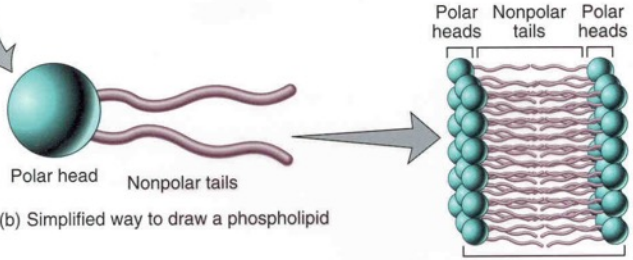
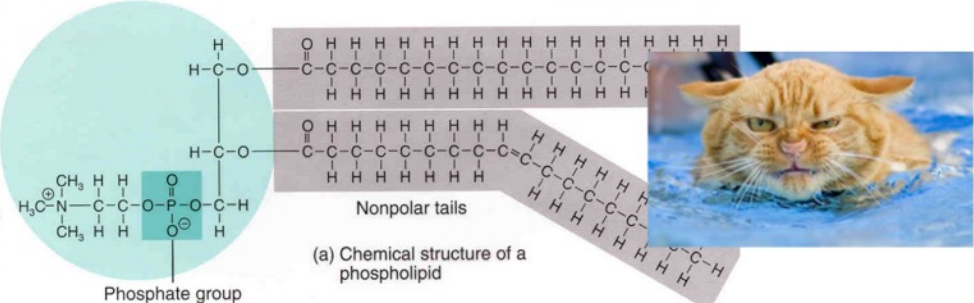
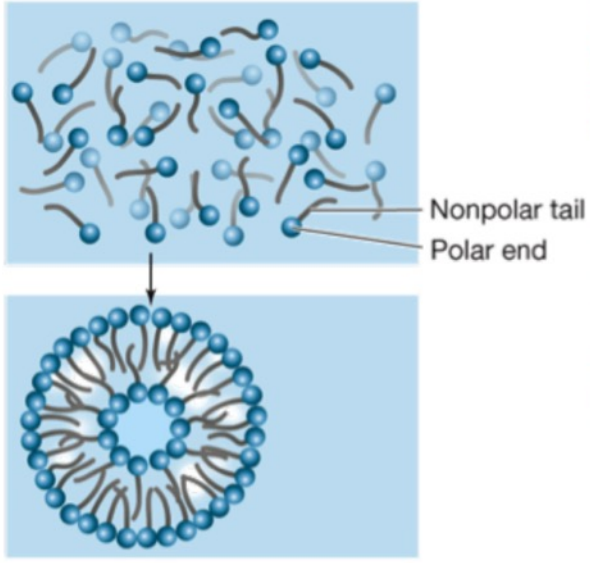
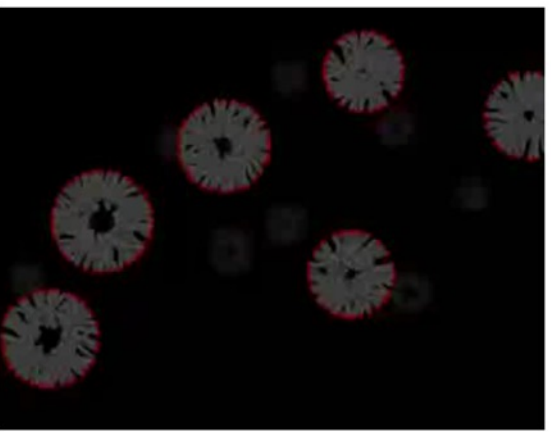
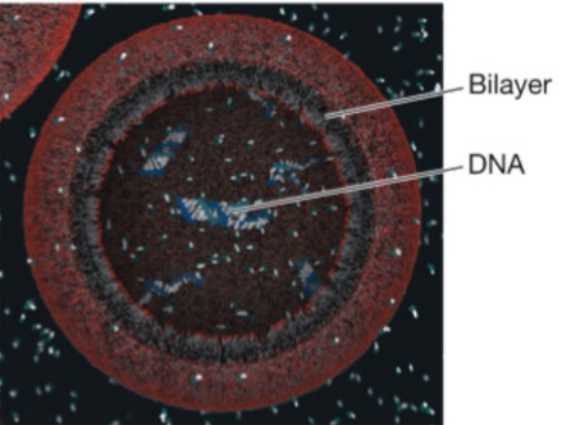


Image: http://homepage.smc.edu/wissmann_paul/anatomy2textbook/phospholipids.html



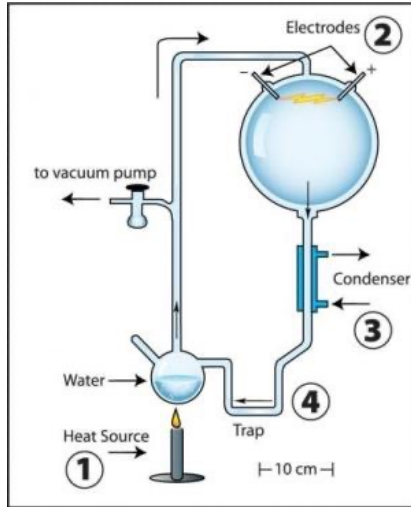
LIFE 9e, Figure 4.13

More on fatty acids at <http://exploringorigins.org/fattyacids.html>



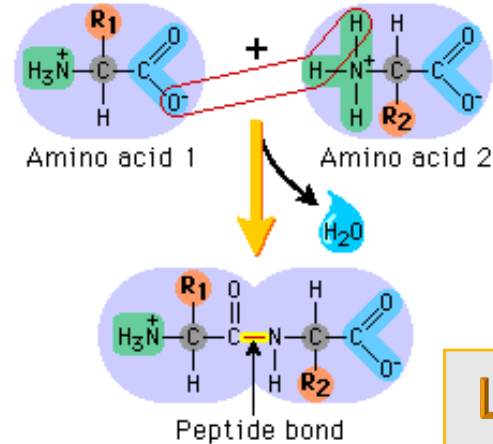
<https://molbio.mgh.harvard.edu/szostakweb/movies.html>

Chemical Evolution: 4 Phases



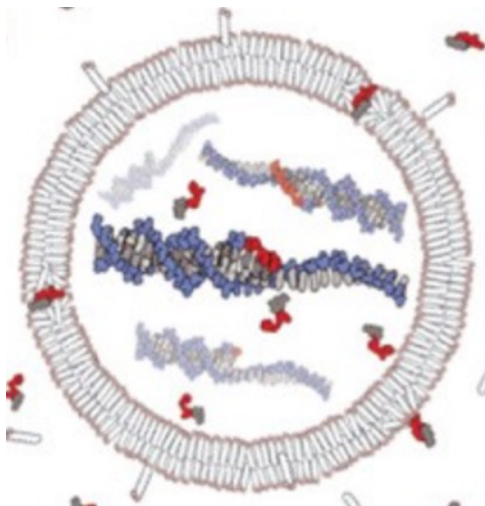
1. Synthesis of monomers (amino acids, nucleotides, ...)

Small molecules



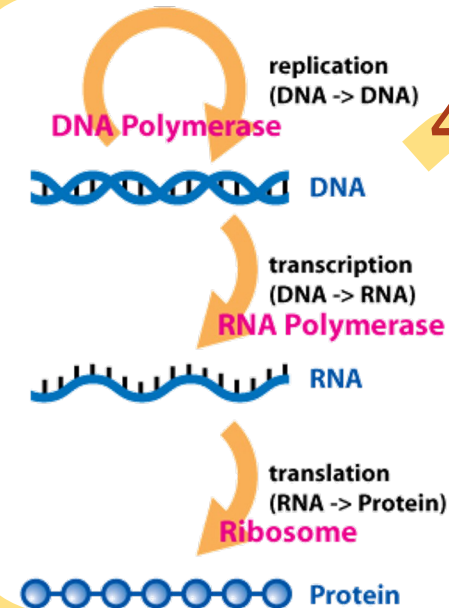
2. Polymer formation (e.g., RNA)

Large molecules



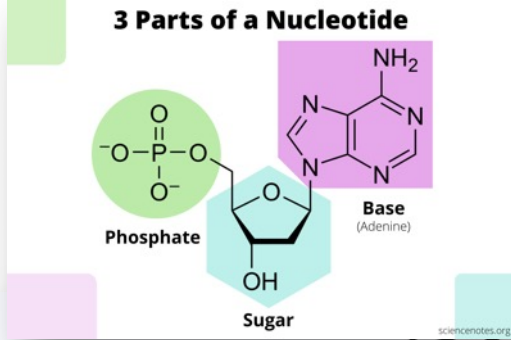
3. Protocell formation

Cell membranes enclose the genetic material



4. Self-replication (The origin of RNA and DNA)

“RNA world” hypothesis



DNA vs. RNA

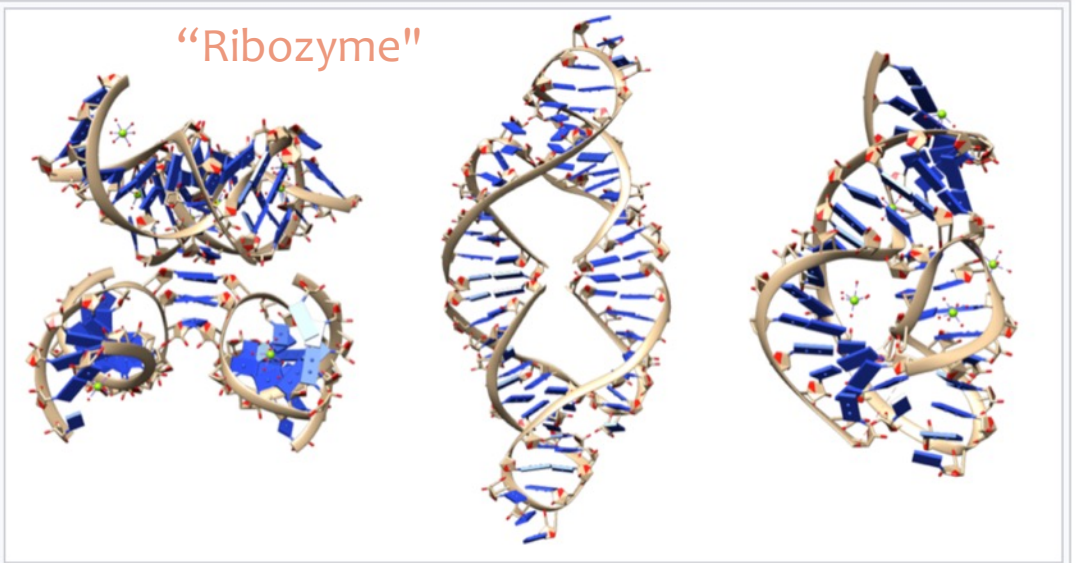
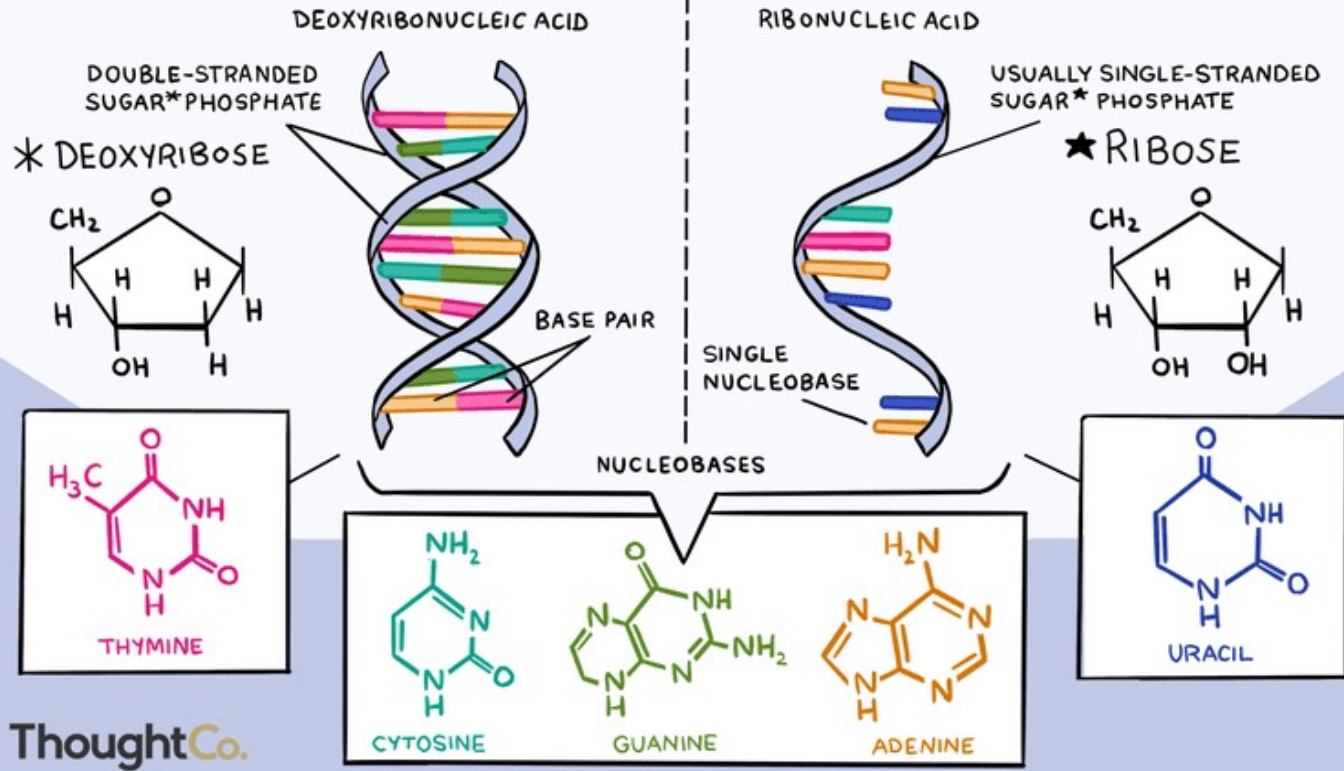


Image showing the diversity of ribozyme structures. From left to right: leadzyme, hammerhead ribozyme, twister ribozyme
<https://en.wikipedia.org/wiki/Ribozyme>

The Nobel Prize in Chemistry 1989



Photo from the Nobel Foundation archive.
 Sidney Altman
 Prize share: 1/2

Photo from the Nobel Foundation archive.
 Thomas R. Cech
 Prize share: 1/2

<https://www.nobelprize.org/prizes/chemistry/1989/summary/>

The Nobel Prize in Chemistry 1989 was awarded jointly to Sidney Altman and Thomas R. Cech "for their discovery of catalytic properties of RNA."

“RNA world” hypothesis

...and life starts

But the recent discovery indicates...

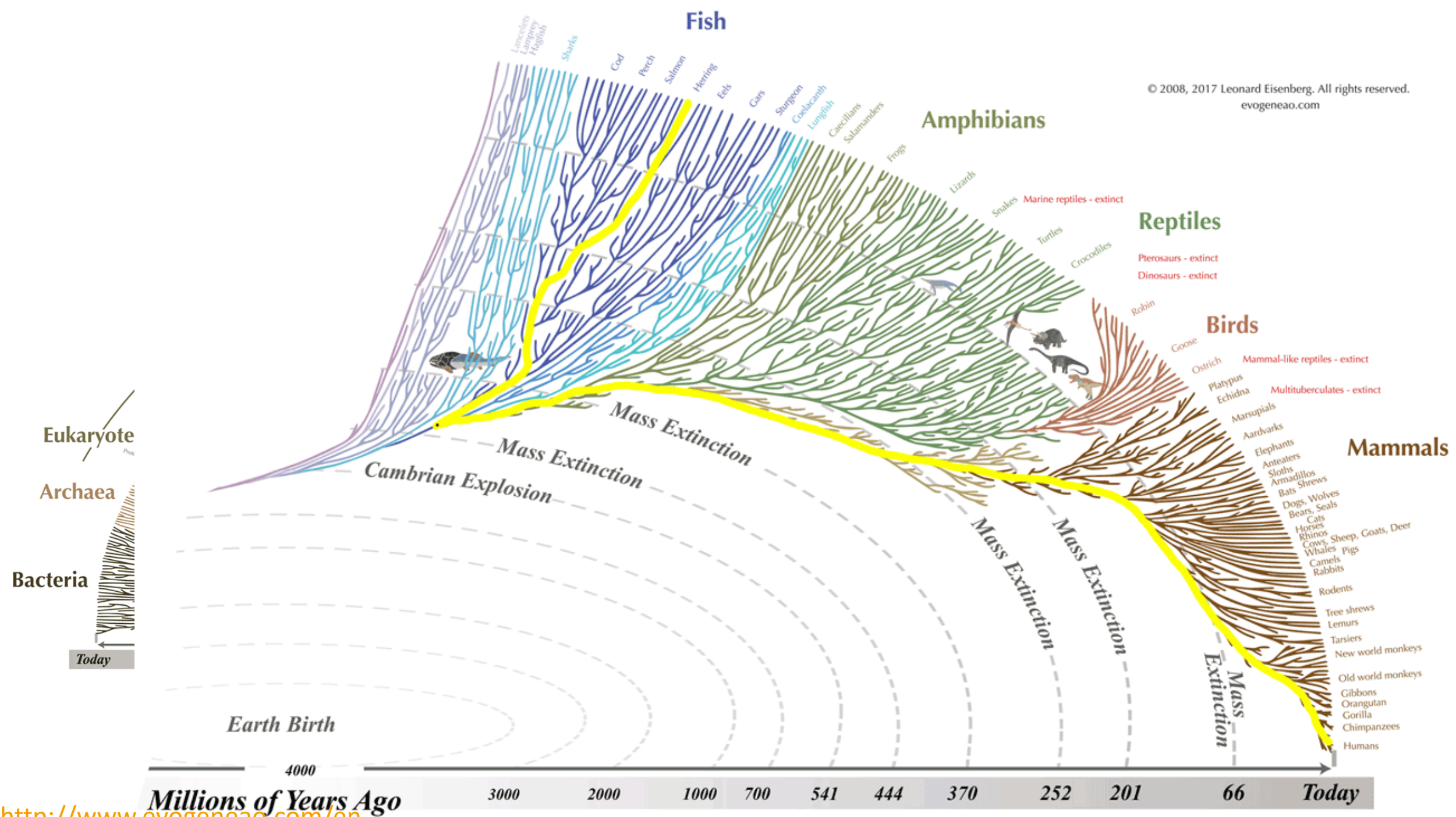


<https://phys.org/news/2020-12-discovery-boosts-theory-life-earth.html>



<https://link.springer.com/article/10.1007/s10531-015-0888-6>

What is the main idea of the **chemical evolution** theory of origin of life?



Question!

Which one is the main idea of the **chemical evolution** theory?

- A. Living cells in a complete working form appeared spontaneously at one point
- B. DNA must have acted as an enzyme to start the self-replication process
- C. Building blocks of life could arise naturally from non-organic molecules under the early Earth condition
- D. Building blocks of life were brought to the Earth from space