Are we alone in the Universe?

Class 5.

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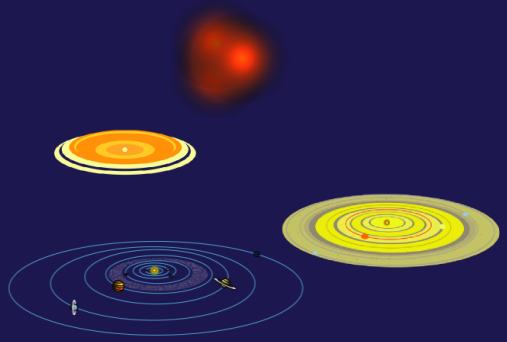
High School Summer Course, 2023

Our Map:

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

Our planet and Solar system

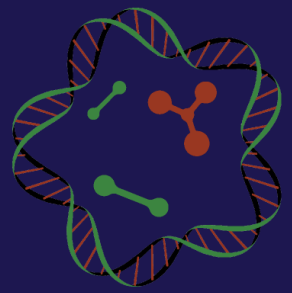


How did the Solar system form?
Is it unique?

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.

Today's goals… (learning objectives)

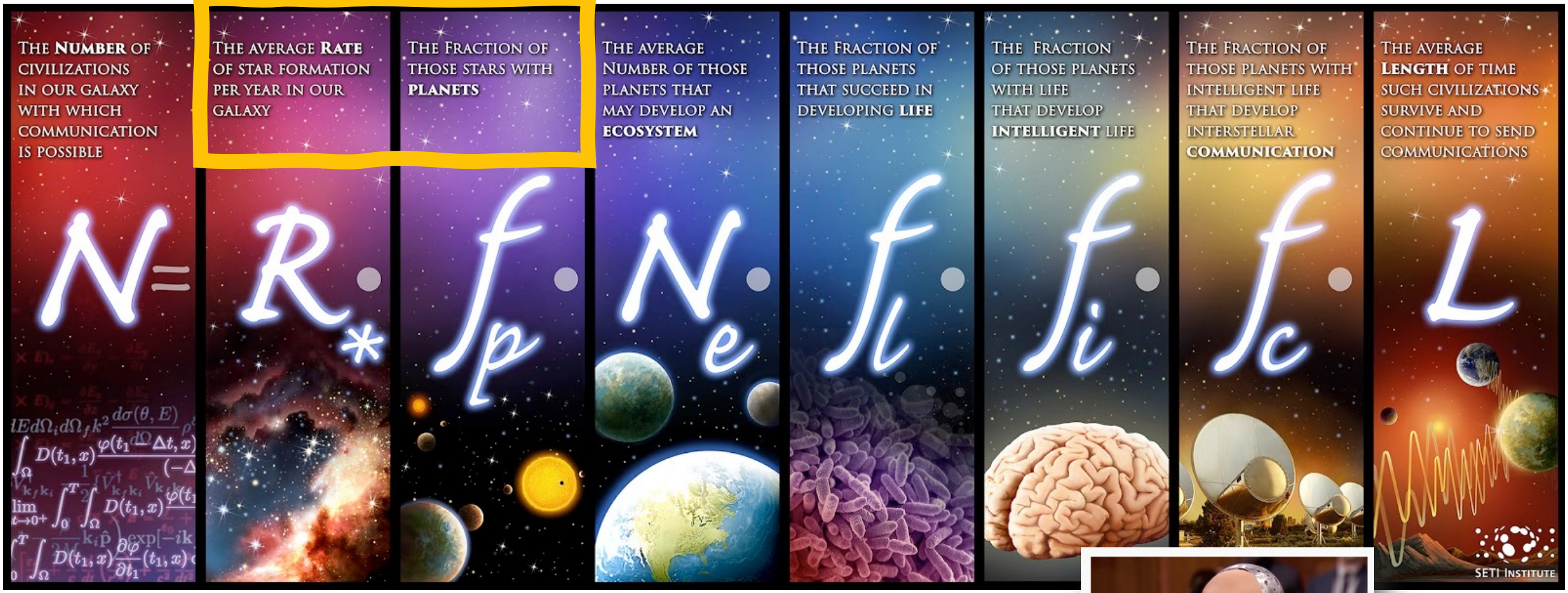
Class 5.

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

https://www.informationisbeautiful.net/visualizations/the-drake-equation/

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

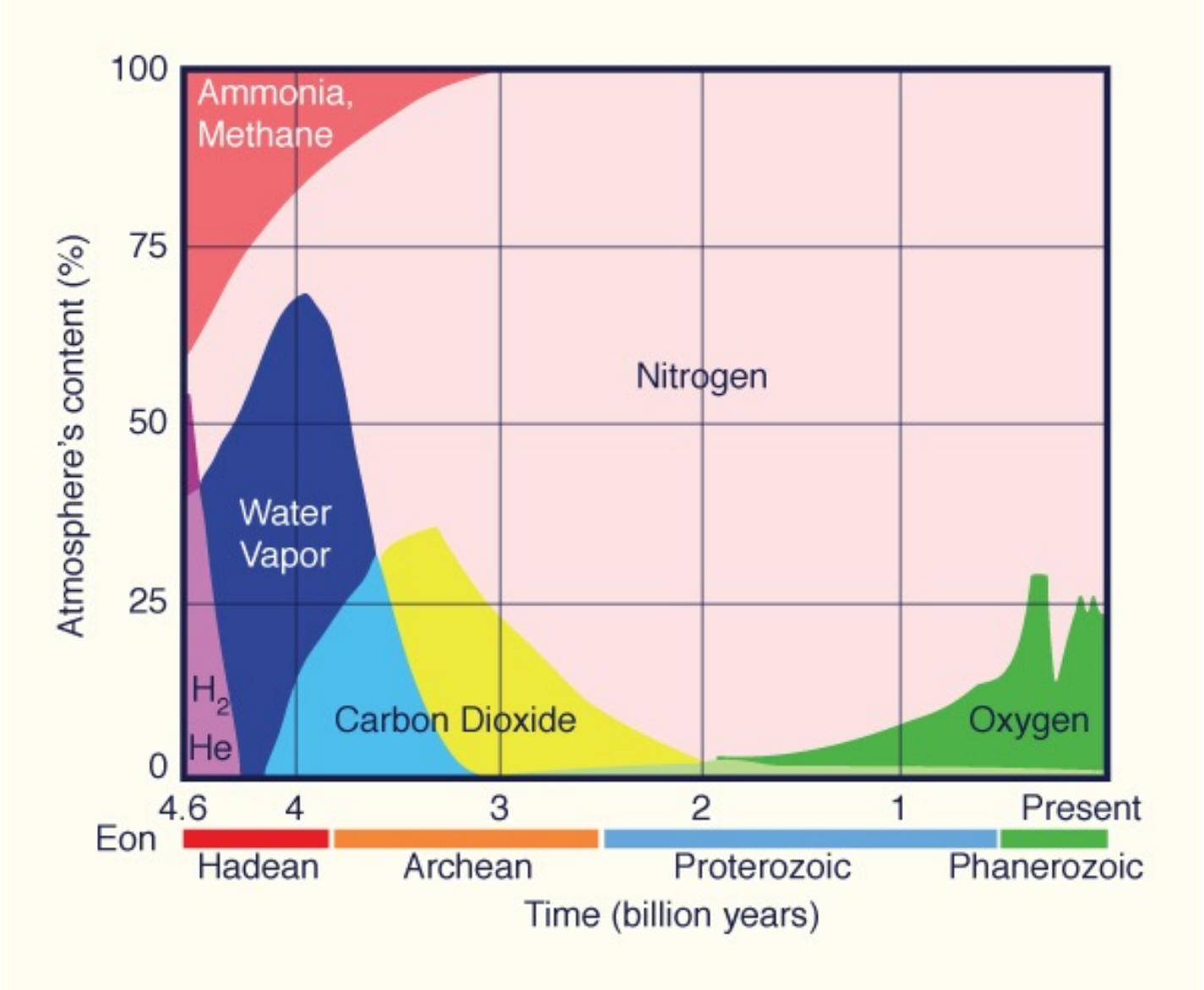
But also see: https://astrobiology.nasa.gov/research/life-detection/about/

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:

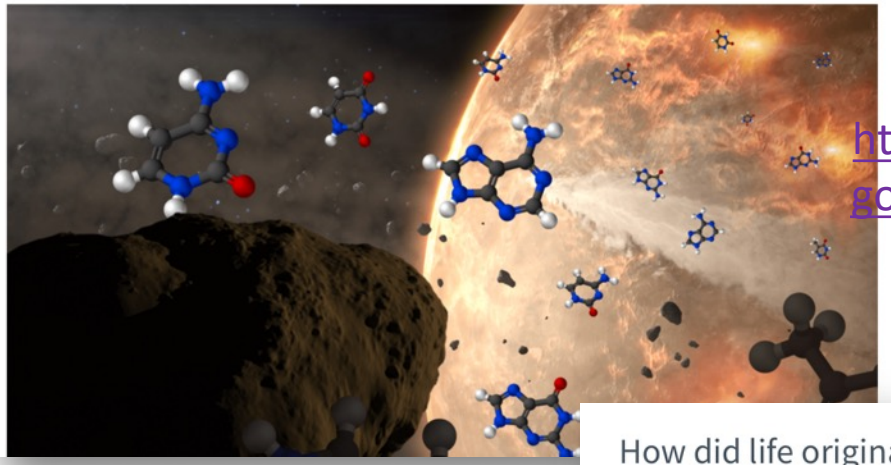
Read these two pages and write down what you think are the differences between these two theories of “origin of life”.

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.



1.

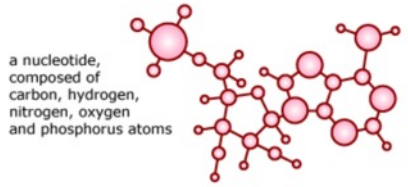
https://www.nasa.gov/feature/goddard/2022/life-blueprint-in-asteroids

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.

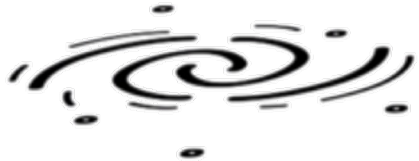


2.

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

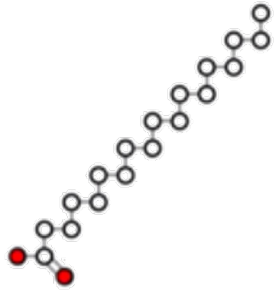
Origin of life: Theories

1. Panspermia
(= “seeds everywhere”)

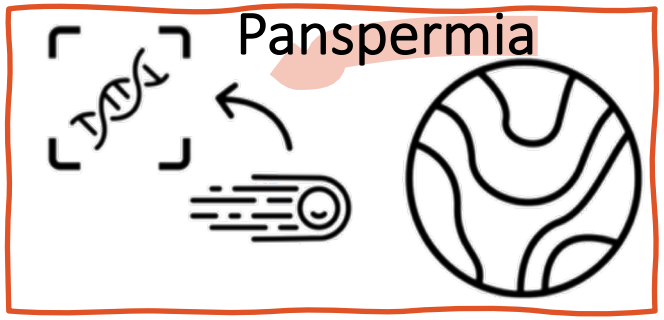


Life (or building blocks of life) **originated on another planet** and was delivered to Earth

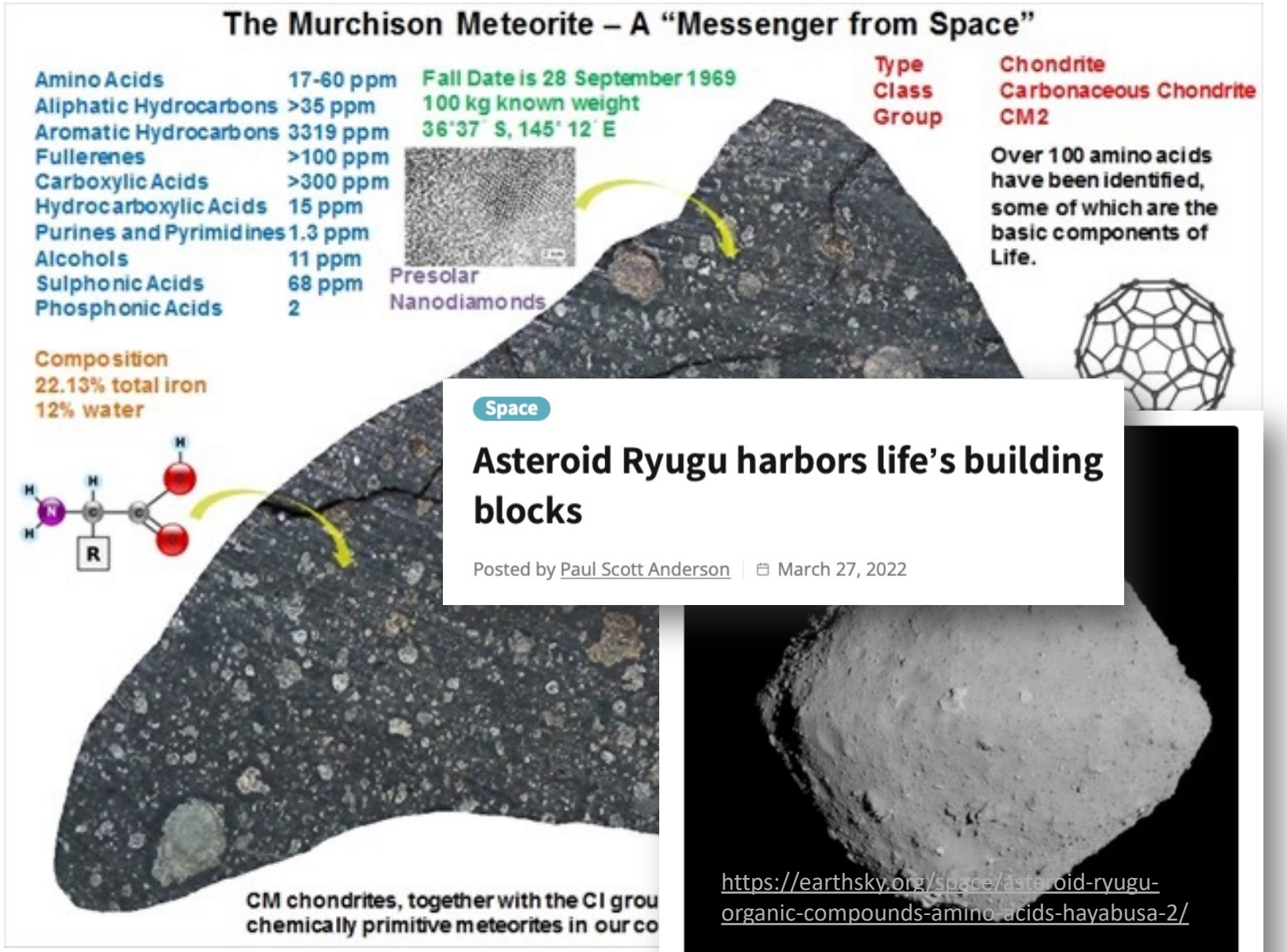
2. Chemical evolution



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

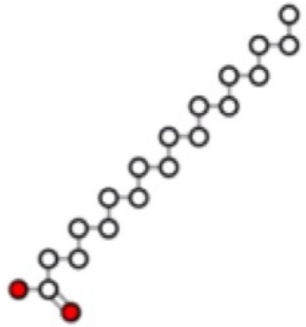


An observation:
The Murchison Meteorite



https://www.geocaching.com/geocache/GC6EK8H_murchison-meteorite-the-building-blocks-of-life

How about **Chemical Evolution**?



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

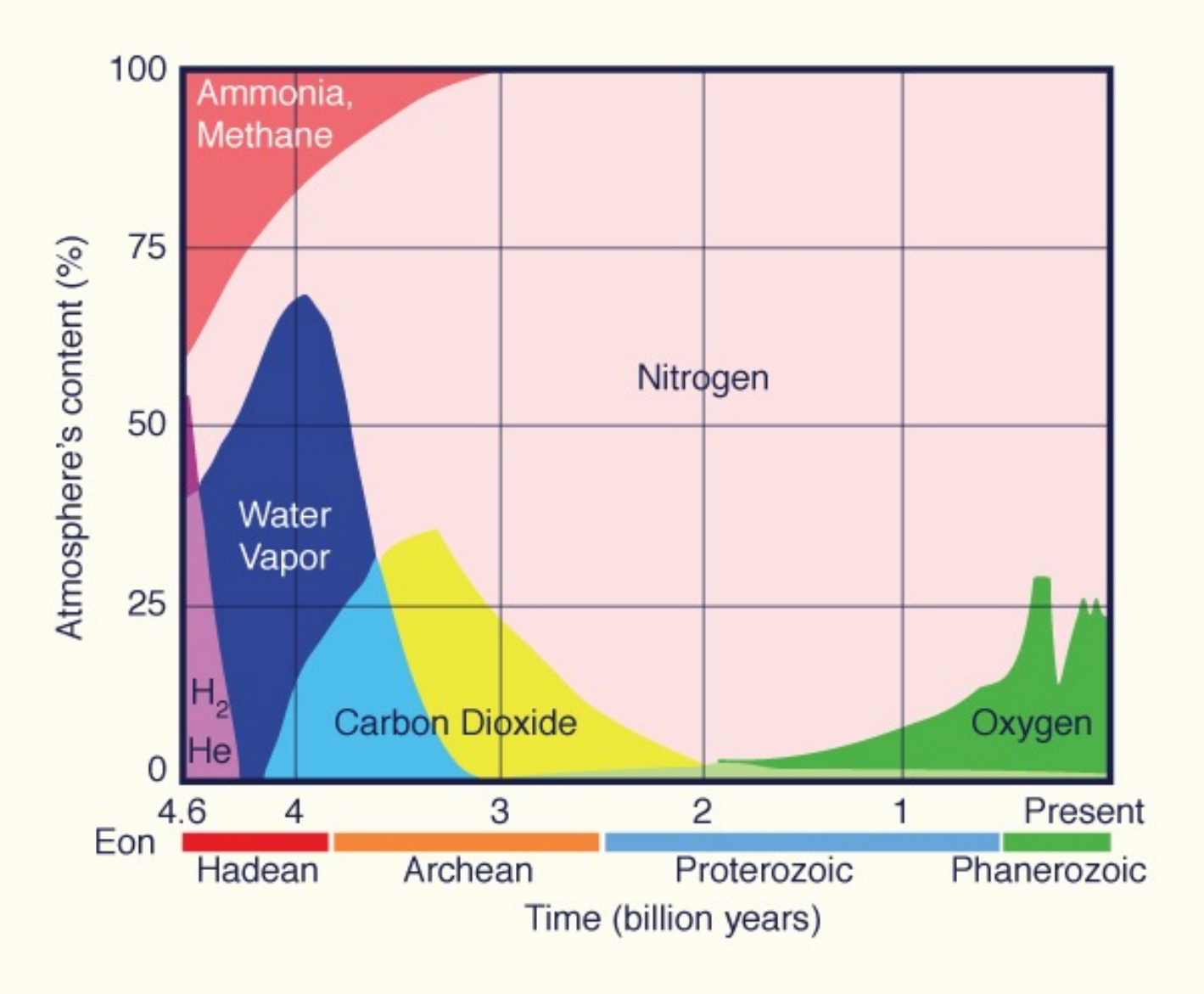
What do YOU think are needed for life to start on a planet?

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

Atmospheric composition

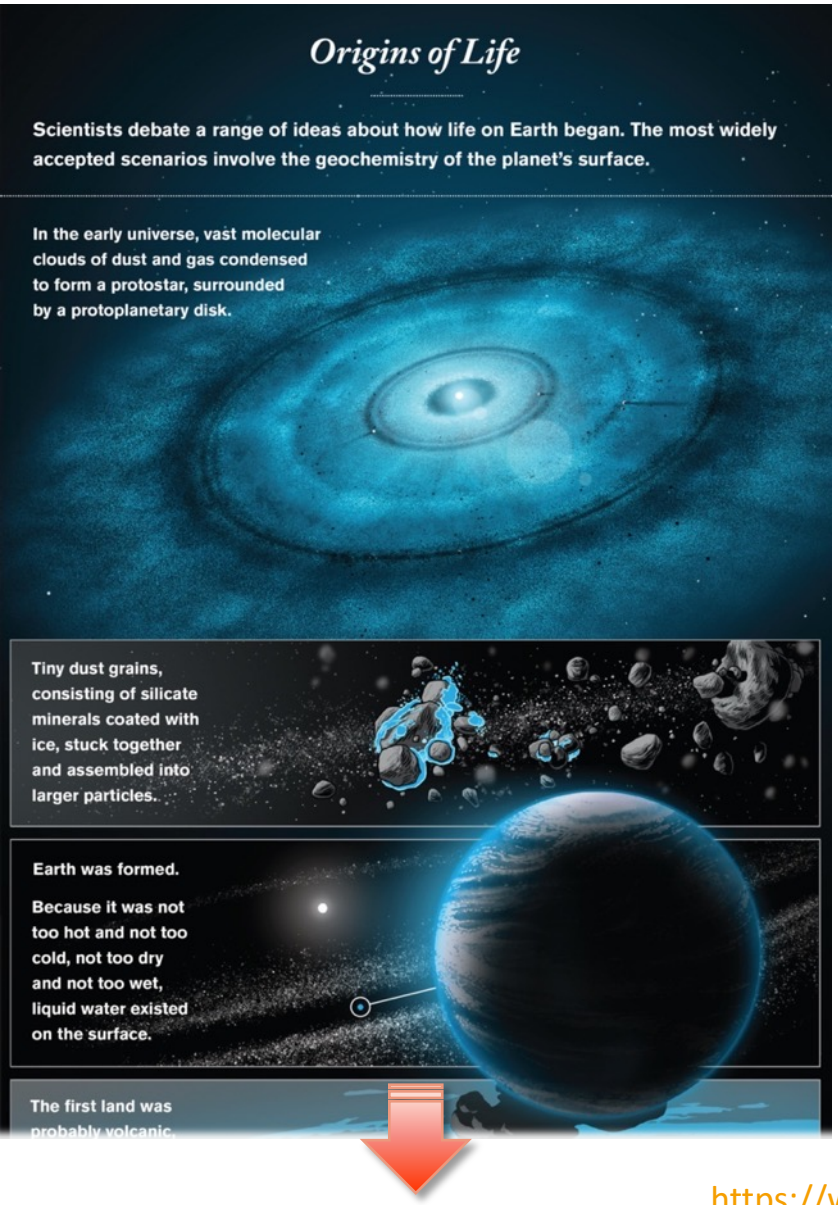
- When did the first life emerge?

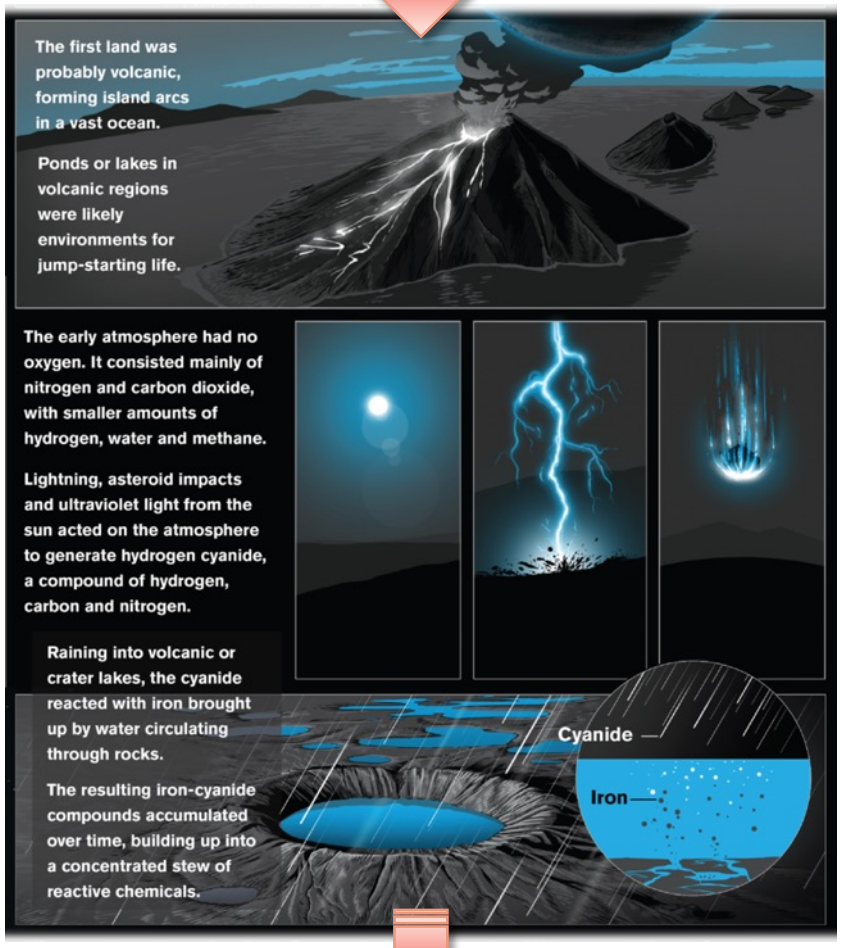
https://www.bbc.com/travel/article/20220126-is-the-pilbara-the-oldest-place-on-earth

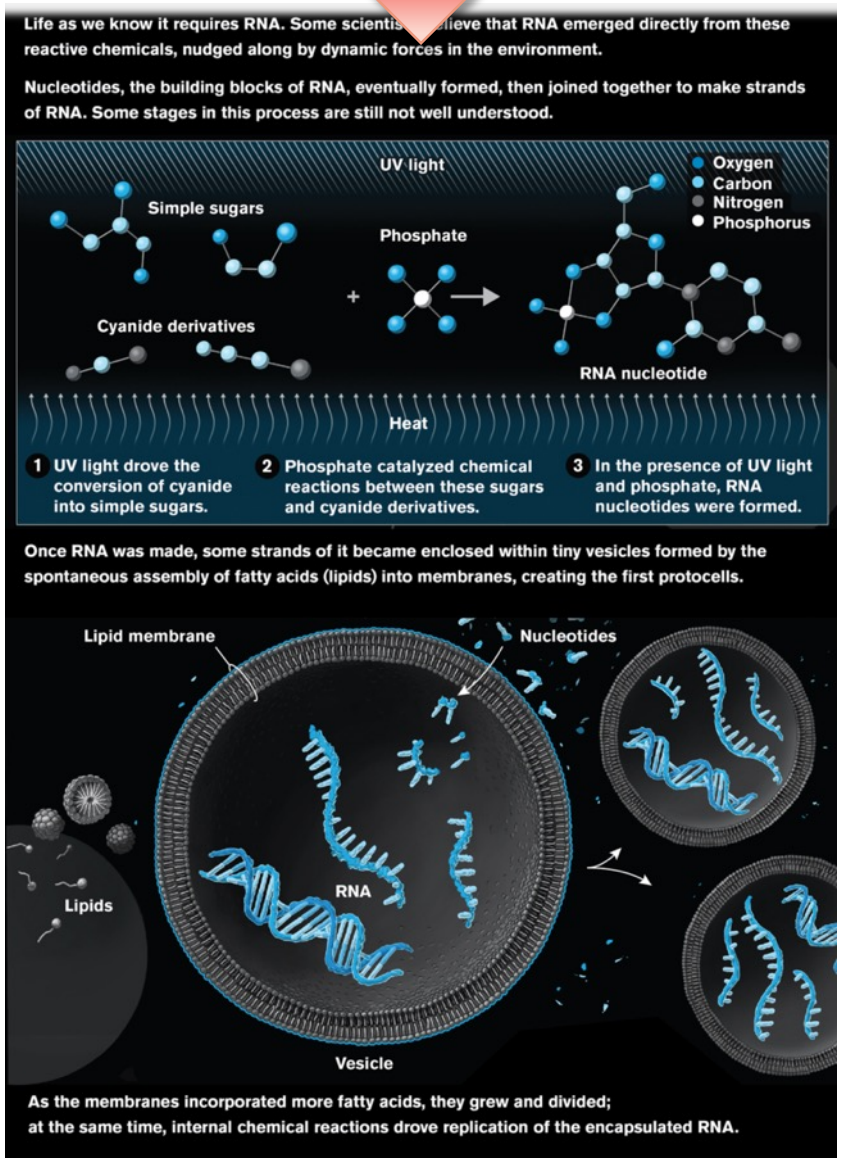


Stromatolites: The Earth's oldest living lifeforms

(Possible) Origin of Life in a Nutshell

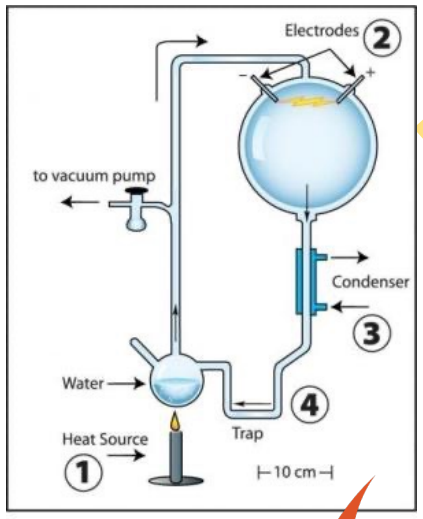






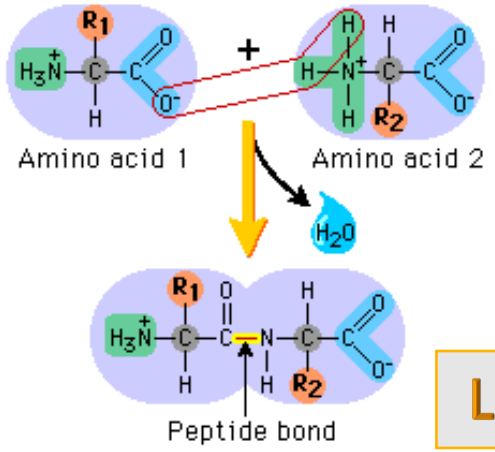
https://www.scientificamerican.com/article/how-did-life-begin1/

Chemical Evolution: 4 Phases



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

Small molecules



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

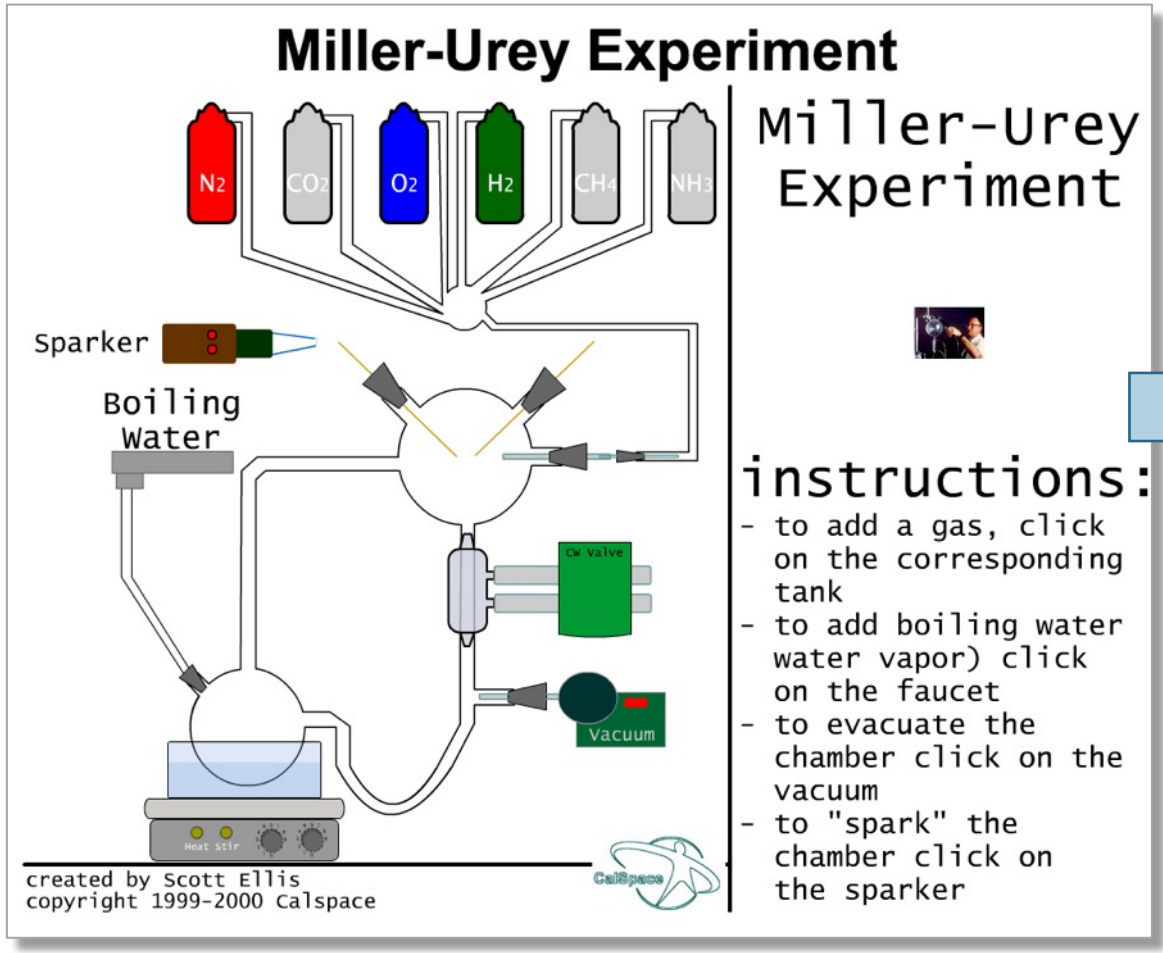
Large molecules

HOW?

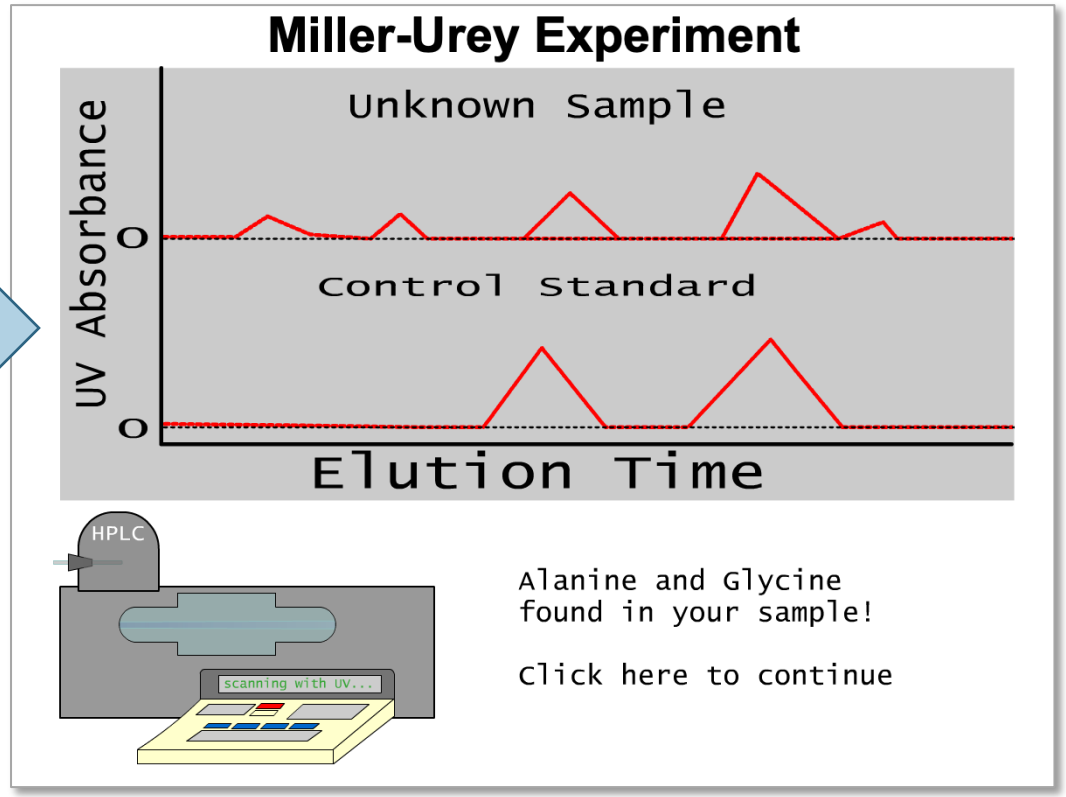
https://evolution.berkeley.edu/from-soup-to-cells-the-origin-of-life/how-did-life-originate/

Miller-Urey Experiment

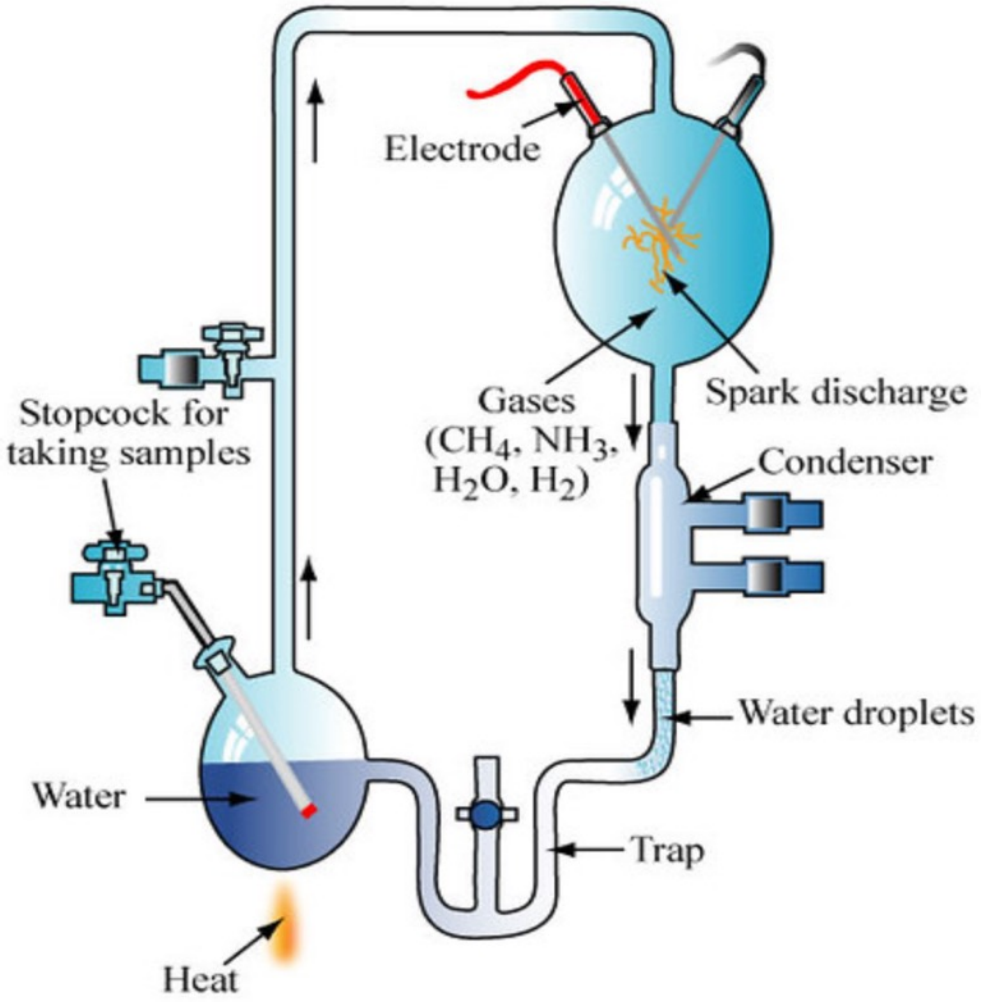
Idea: Let's simulate primitive Earth atmosphere and see if we could produce amino acids in the Early Earth condition.



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	●●●	●●●	X
Isovaline	●●	●●	X
Proline	●●●	●	
Pipecolic Acid	●	●	X
Aspartic Acid	●●●	●●●	
Glutamic Acid	●●●	●●	
β–Alanine	●●	●●	
β–Amino-*N*-Butyric Acid	●	●	X
β–Aminoisobutyric Acid	●	●	X
γ–Aminobutyric Acid	●	●●	X
Sarcosine	●●	●●●	X
N-Ethylglycine	●●	●●●	X

X Not used In life on Earth

https://www.flickr.com/photos/mitopencourseware/3589582386

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	genetic information	yes	yes
X	nitrogenous bases		yes	yes
	nucleic acids (polymerized sugars, phosphates and nitrogenous bases)		yes	no

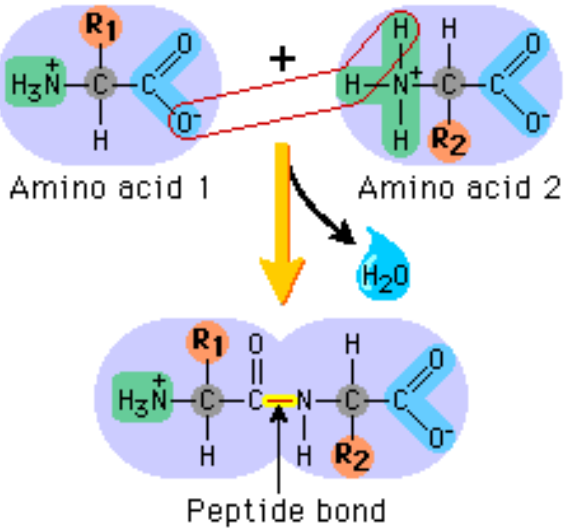
- Long polymers absent (single sugars, no proteins)
- No nucleotide nor nucleic acids

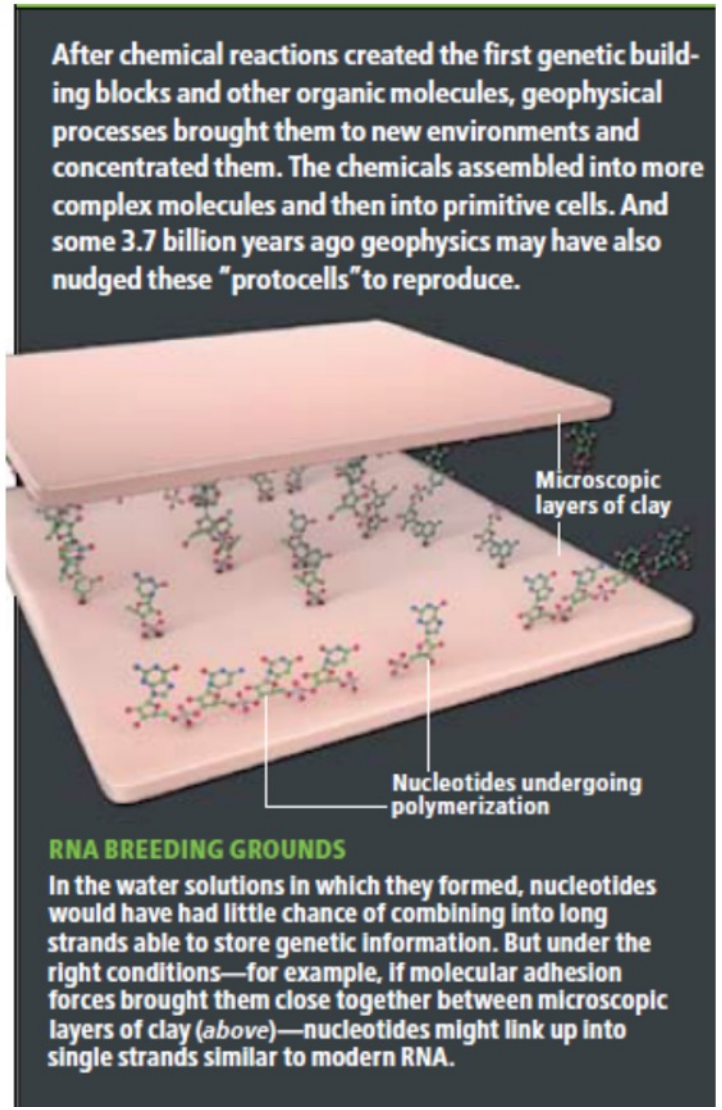
X: building block of life (→ all present in Muchison!)

http://lcd-www.colorado.edu/~axbr9098/teach/ASTR_2040/lectures/ASTR_2040_7.pdf

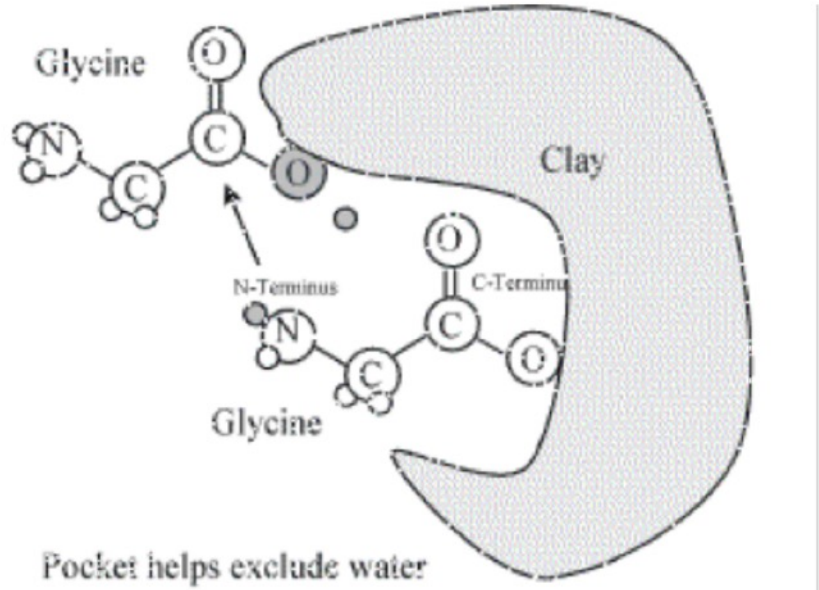
STAGE 2, how did first polymers form?

ENZYME?!?!?!





- ***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

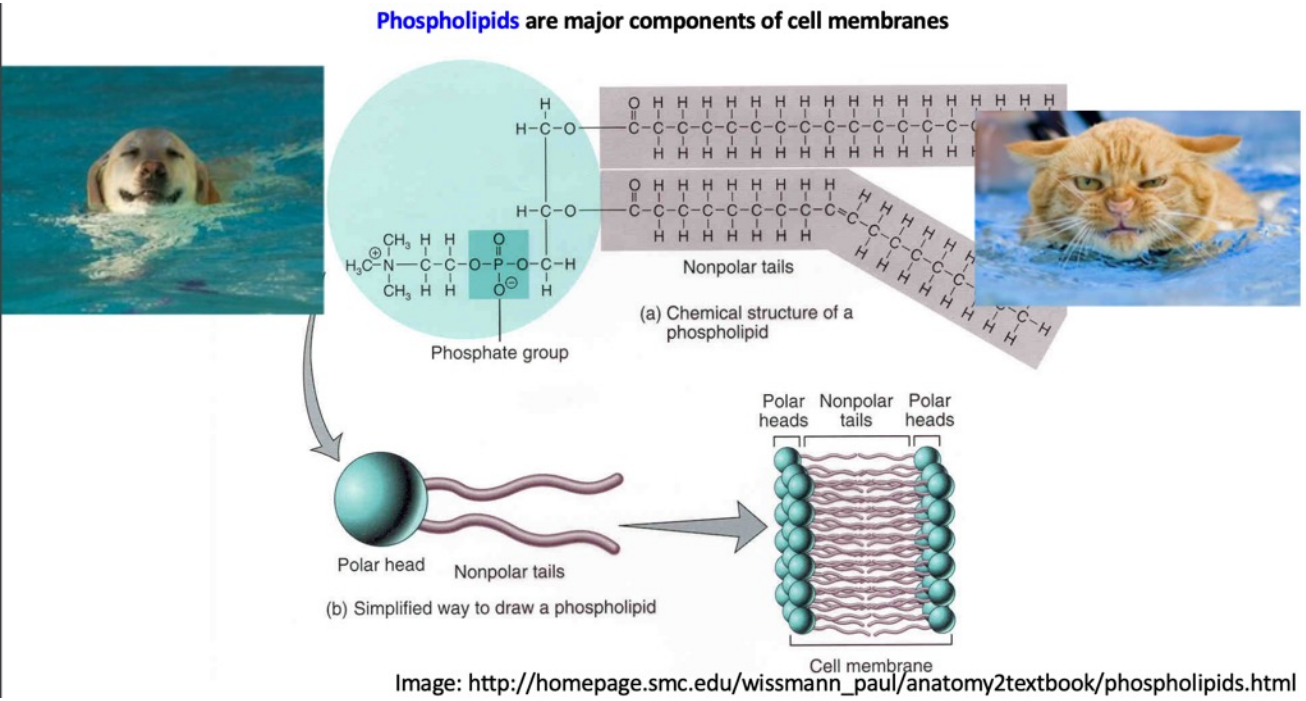
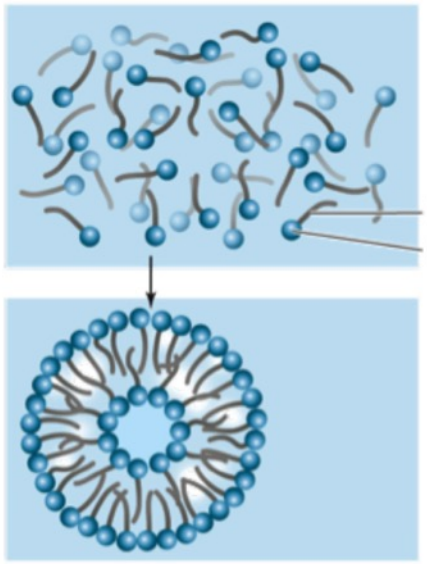
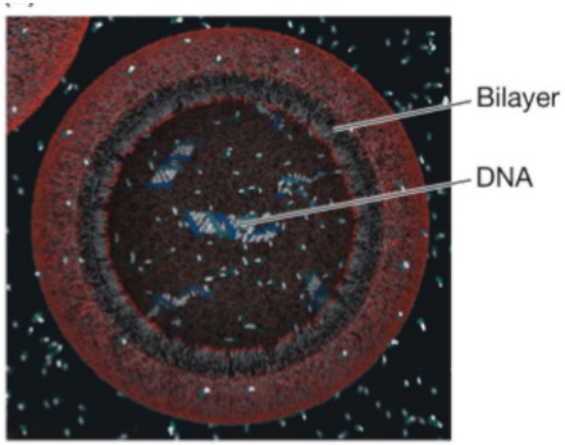
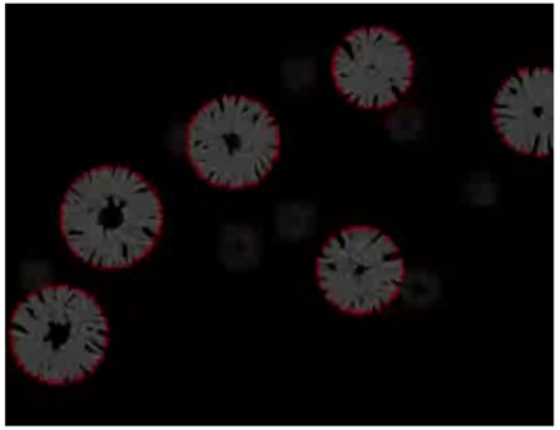


Image: http://homepage.smc.edu/wissmann_paul/anatomy2textbook/phospholipids.html



LIFE 9e, Figure 4.13

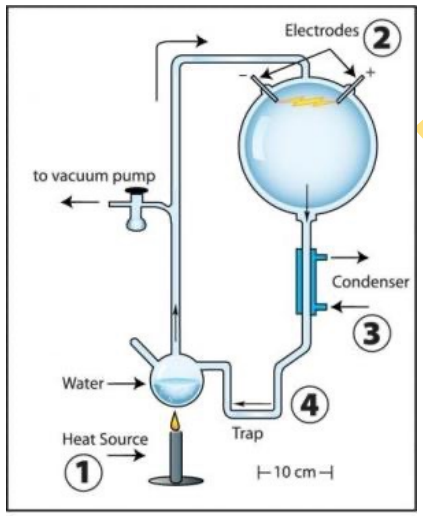




More on fatty acids at
http://exploringorigins.org/fattyacids.html

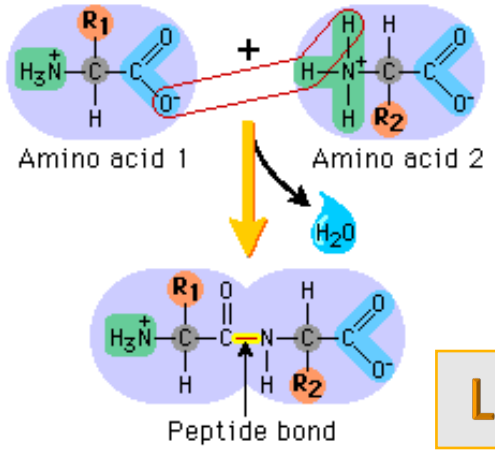
https://molbio.mgh.harvard.edu/szostakweb/movies.html

Chemical Evolution: 4 Phases



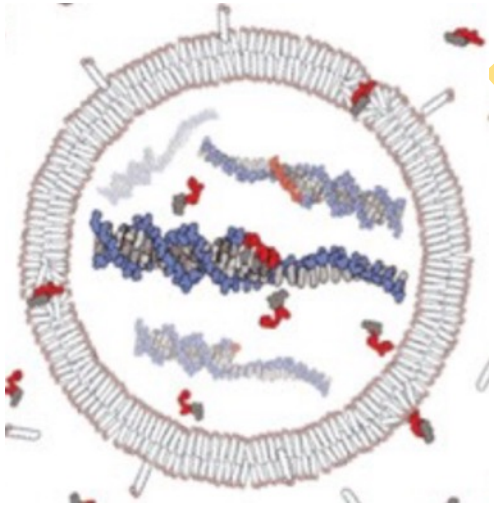
1. Synthesis of monomers (amino acids, nucleotides, …)

Small molecules



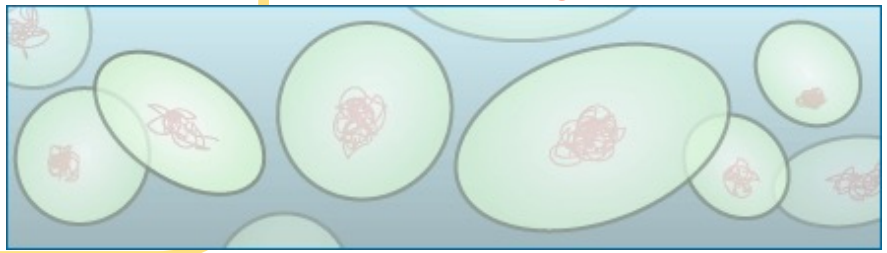
2. Polymer formation (e.g., RNA)

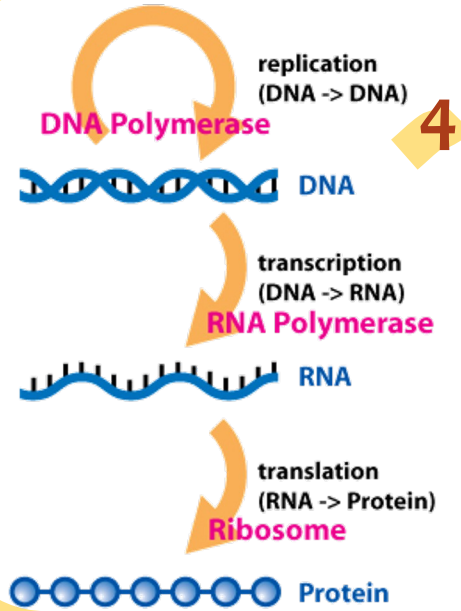
Large molecules



3. Protocell formation

Cell membranes enclose the genetic material

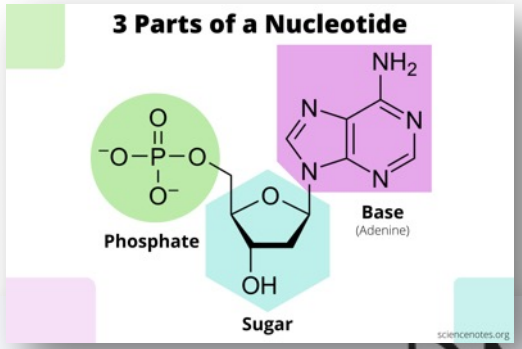


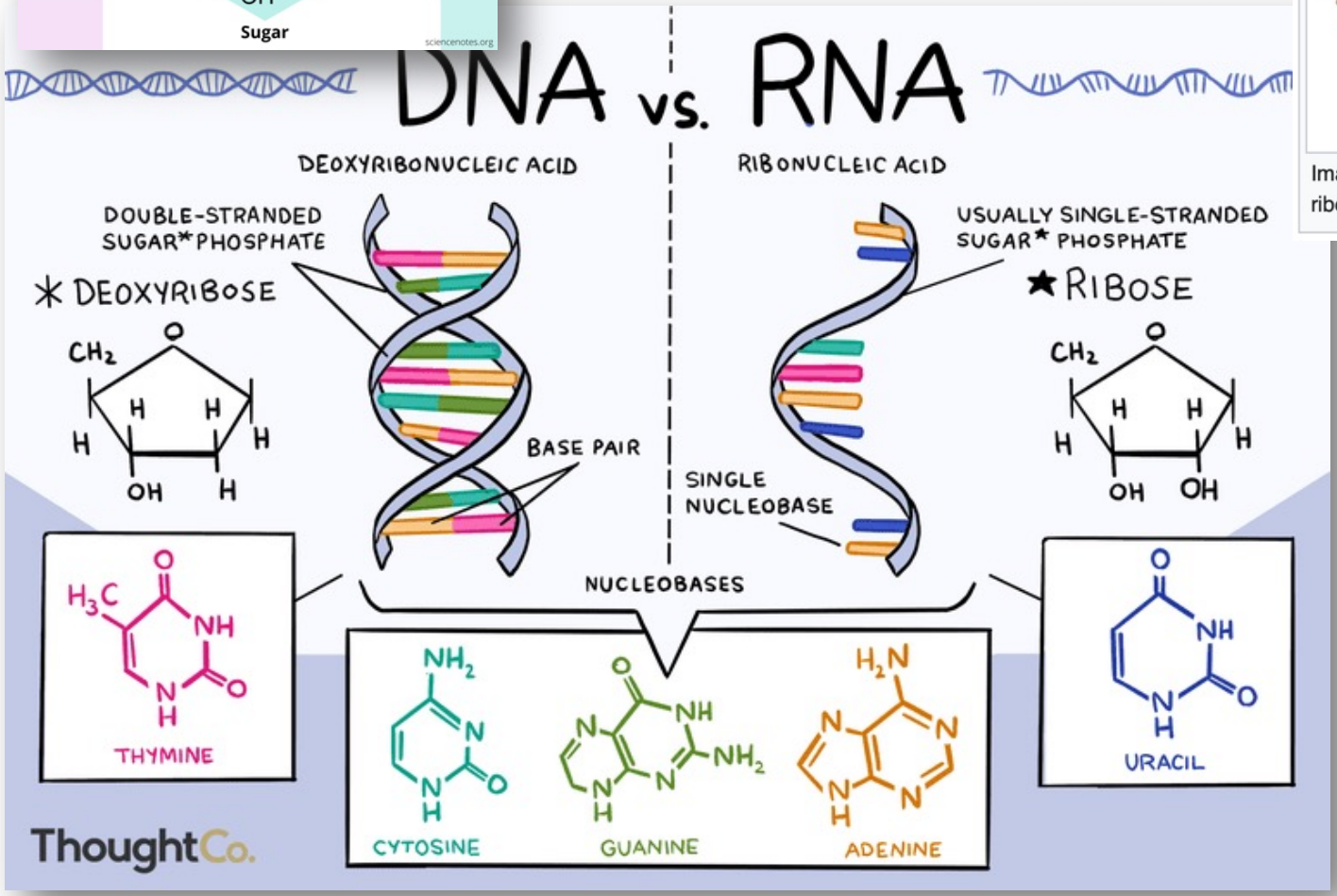


4. Self-replication (The origin of RNA and DNA)

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

“RNA world” hypothesis





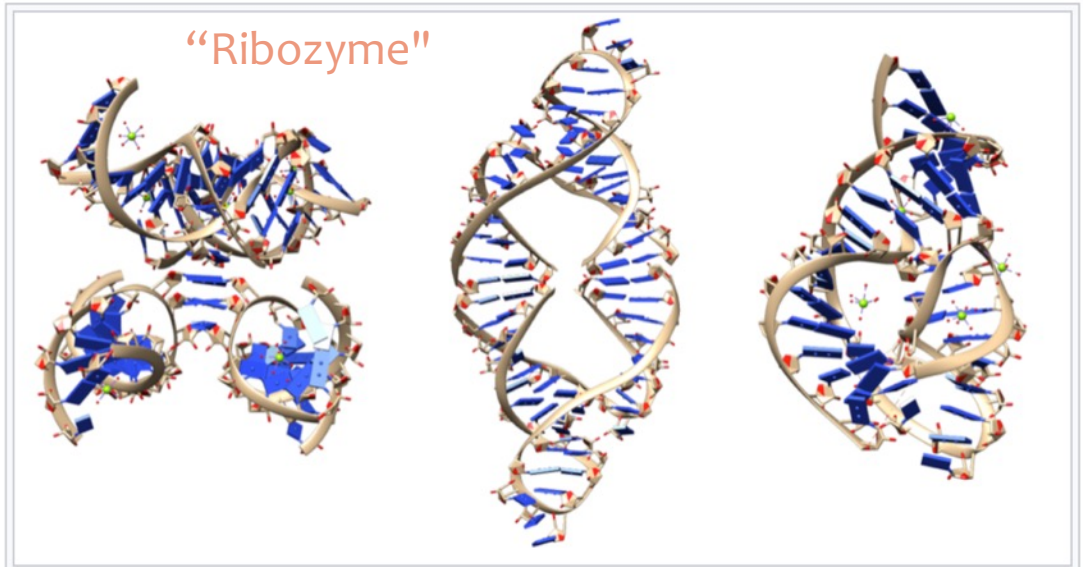


Image showing the diversity of ribozyme structures. From left to right: leadzyme, hammerhead ribozyme, twister ribozyme

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

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

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

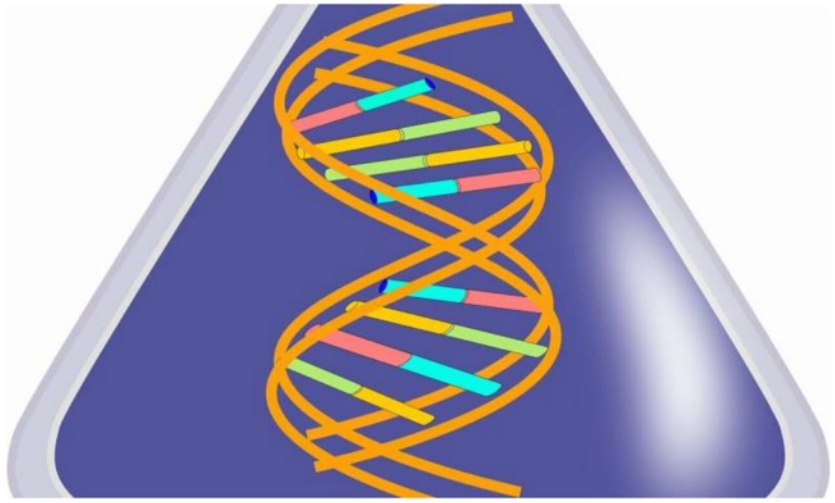
“RNA world” hypothesis

But the recent discovery indicates…

DECEMBER 28, 2020

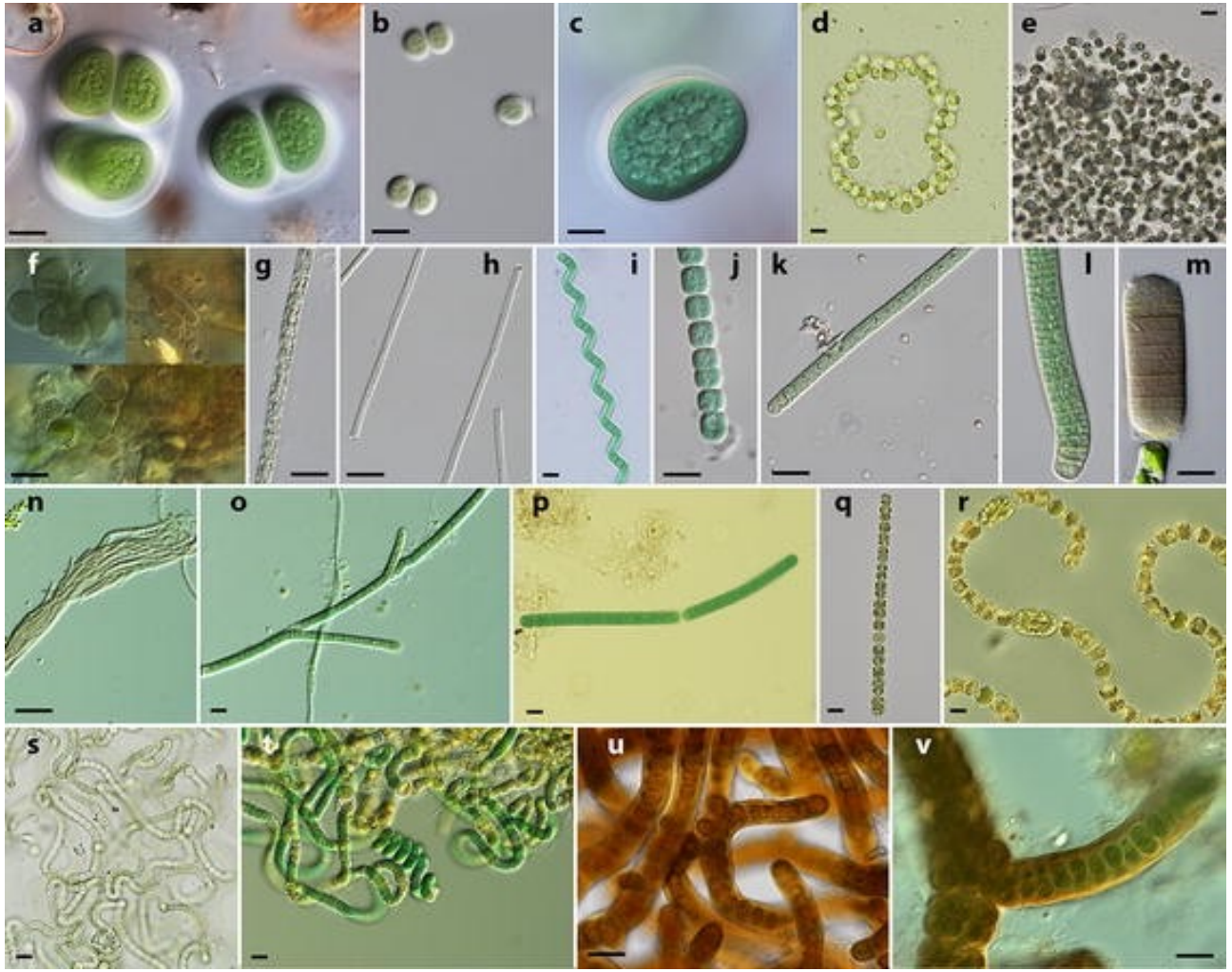
Discovery boosts theory that life on Earth arose from RNA-DNA mix

by The Scripps Research Institute



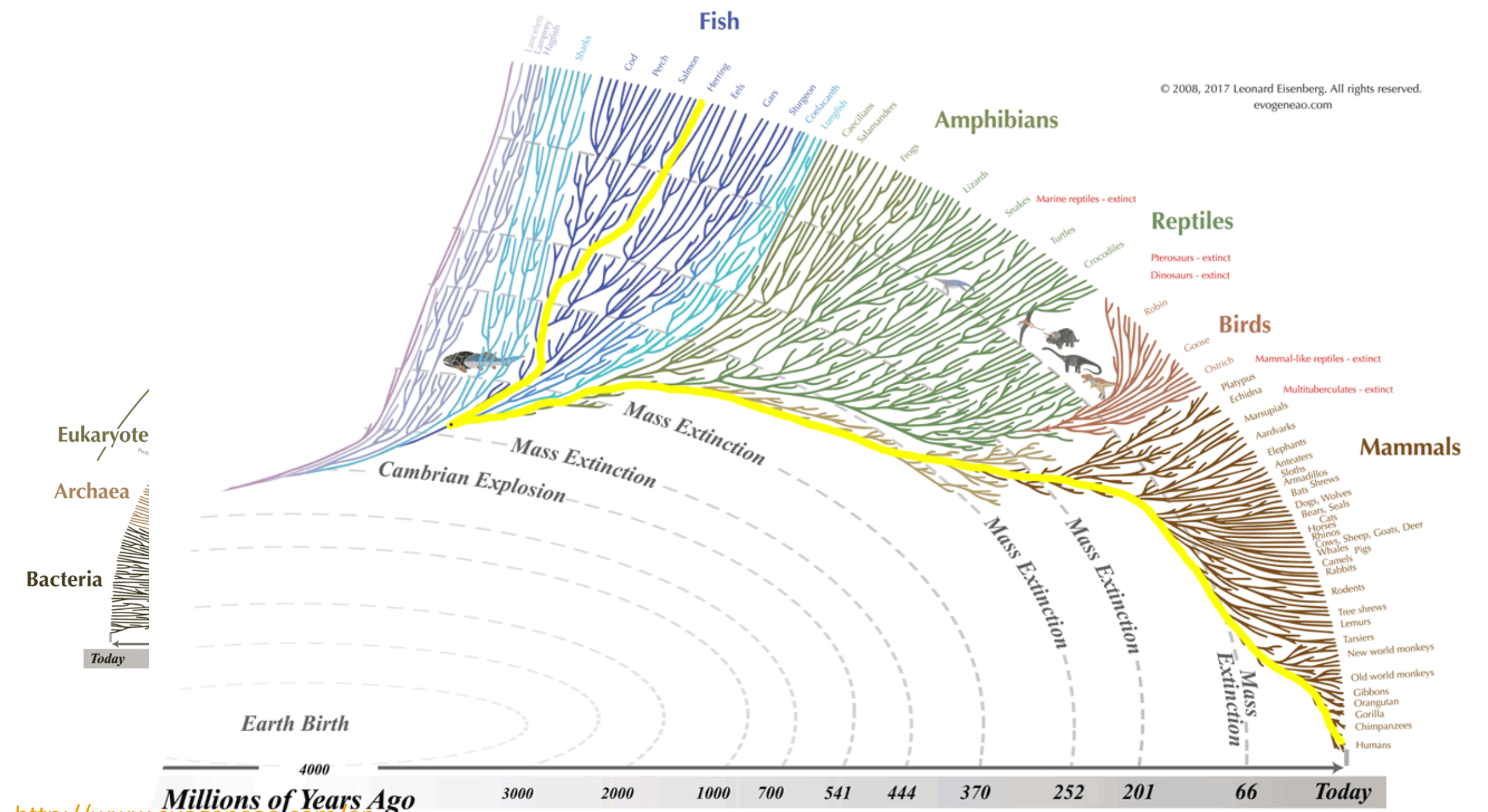
https://phys.org/news/2020-12-discovery-boosts-theory-life-earth.html

…and life starts



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?



http://www.evogeneao.com/en

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