

Are we alone in the Universe?

Class 4.

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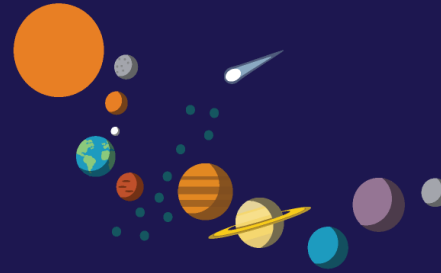


High School Summer Course, 2023

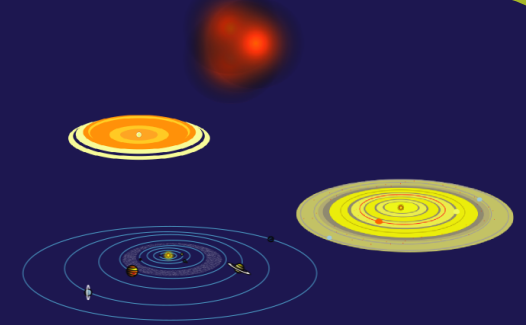
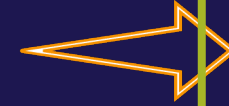
Our Map:



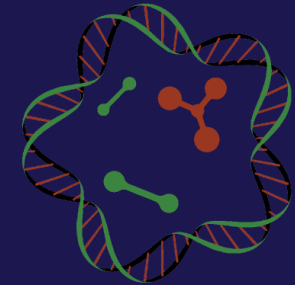
What are there in the Universe?
Scales involved in describing Universe



Our planet and Solar system



How did the Solar system form?
Is it unique?



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



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



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

Are we alone in the universe?

Today's goals... (learning objectives)

Class 4.

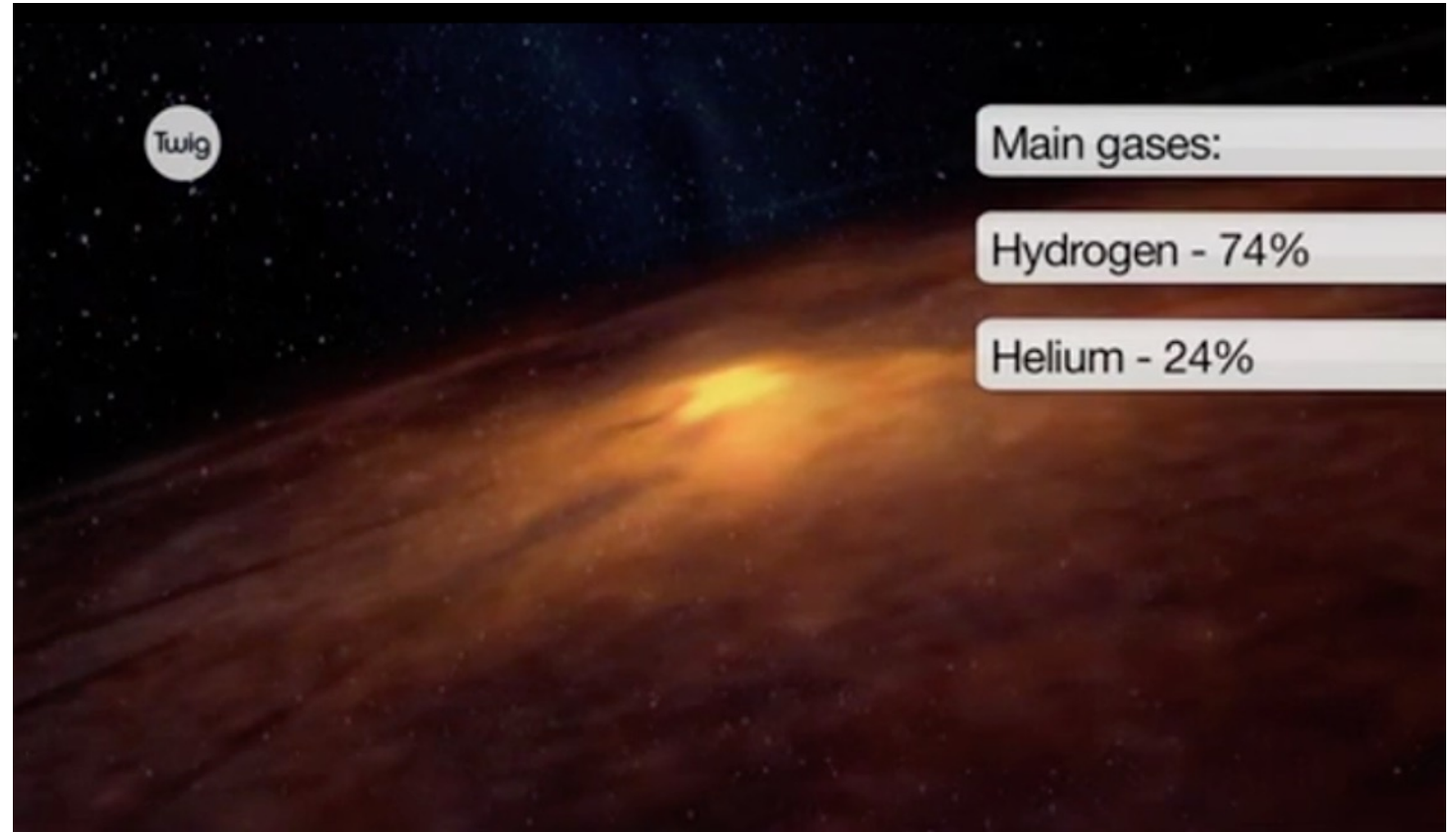
By the end of this class, you should be able to:

1. Describe how **planets** may form from a collapsing nebula
2. State how **Hot Jupiters** present a challenge in the planetary system formation theory
3. List characteristics of “**life**”

What is a planet?

Birth of the Solar System

Why are the inner planets rocky and the outer planets gaseous?



<https://www.stem.org.uk/elibrary/resource/26893>

Nebular theory of Solar system formation

- **Hypothesis:** Our Solar system formed out of a nebula which collapsed under its own gravity (This is the basis of nebular theory of star formation)
- **Supporting Observation:** Newly forming stellar systems are observed to be inside dense interstellar gas clouds.

Nebula: a large cloud in space consisting of gas and dust

"Star-forming" nebulae

Trifid nebula



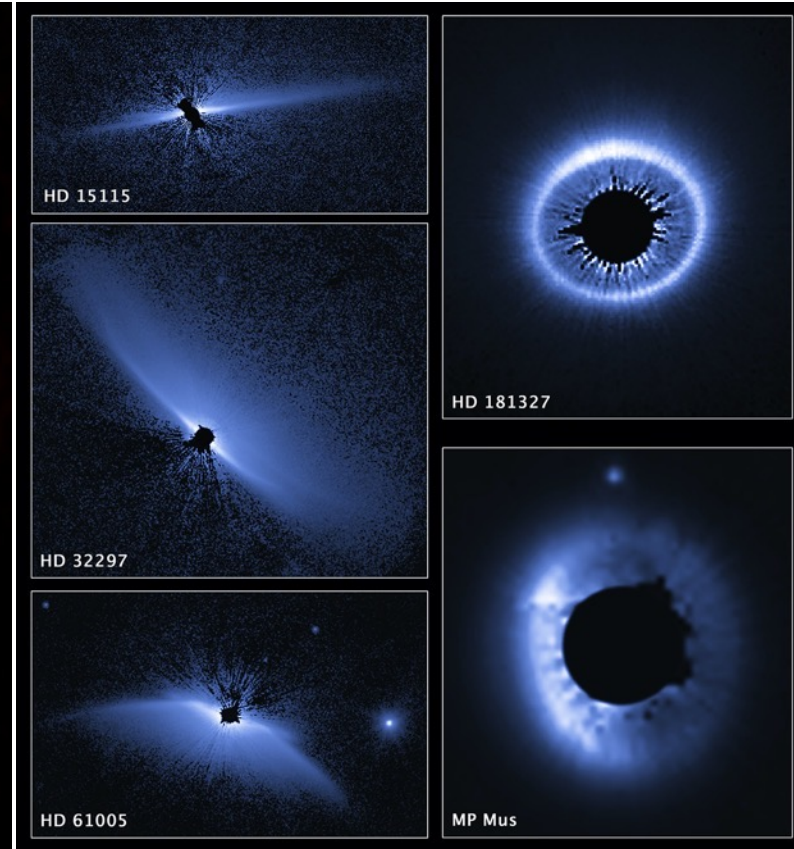
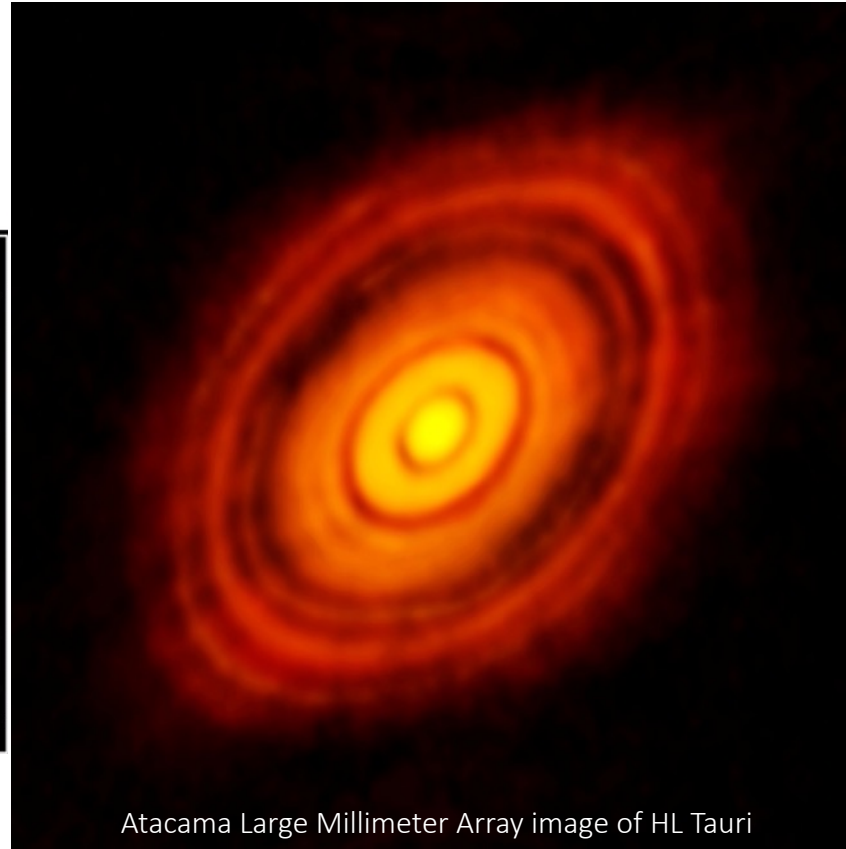
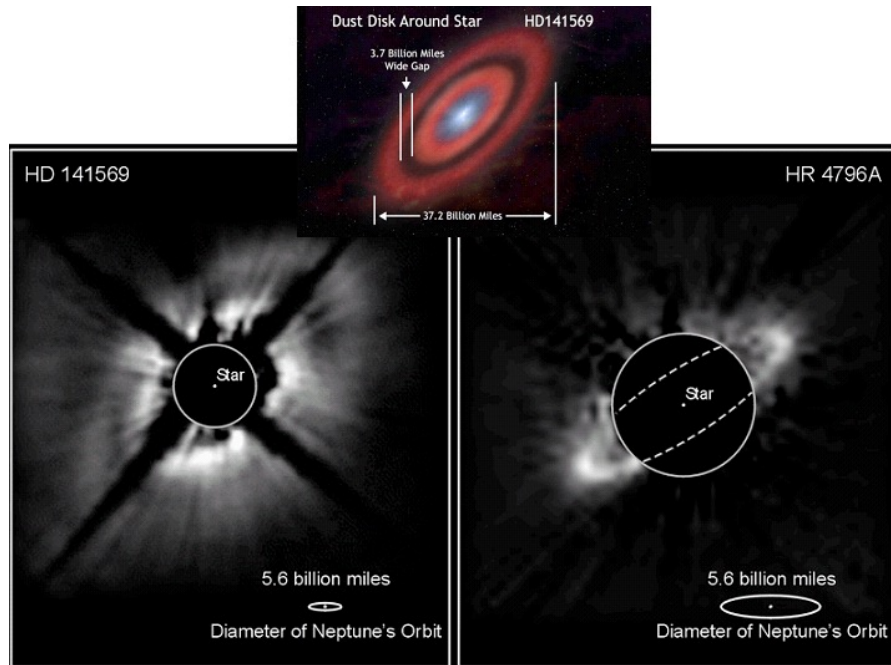
Orion nebula



Eagle nebula



Disks around stars (Observations)



Planets occupying same orbit in PDS 70b

A planet may be forming in the region where gravitational pulls of the planet and the star are similar (trojan planet)



<https://www.space.com/two-exoplanets-same-orbit-trojan-planet>

https://www.youtube.com/watch?v=T7-cp8Om_qU

The Nobel Prize in Physics 2019

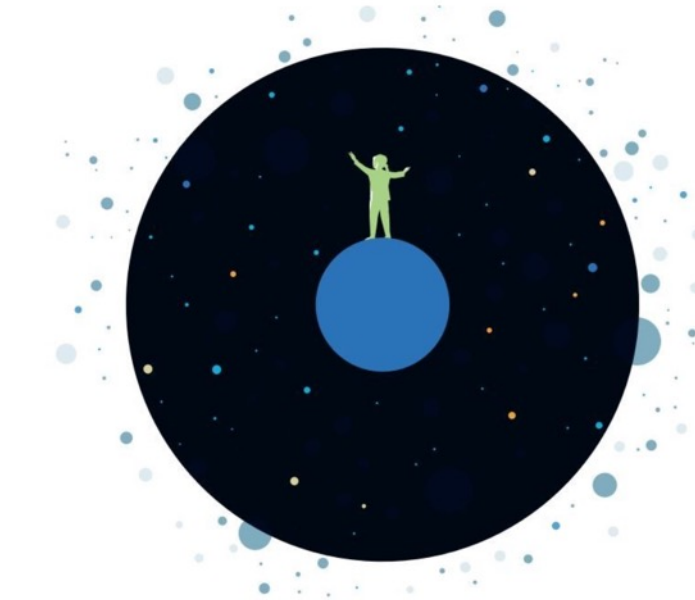
New perspectives on our place in the universe

The Nobel Prize in Physics 2019 rewards new understanding of the universe's structure and history, and the first discovery of a planet orbiting a solar-type star outside our solar system. This year's Laureates have contributed to answering fundamental questions about our existence. What happened in the early infancy of the universe and what happened next? Could there be other planets out there, orbiting other suns?

[Read the press release](#)

[Read the scientific background](#)

[Learn more in the popular information](#)



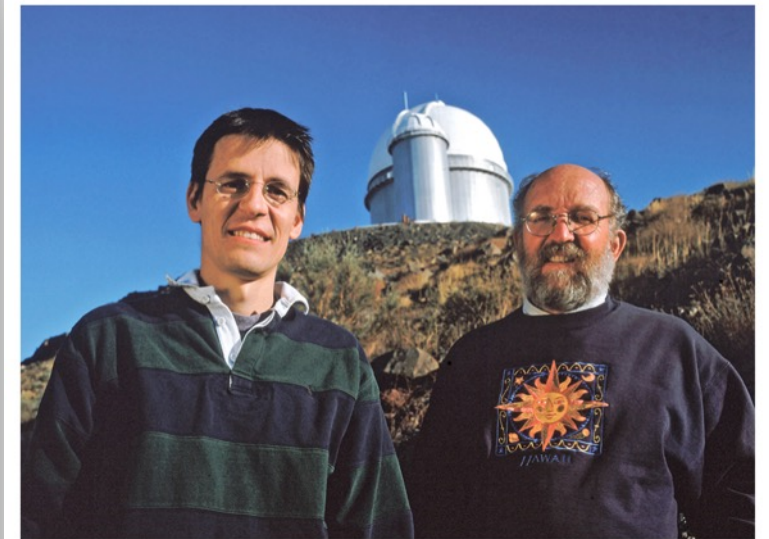
© Johan Jarnestad/The Royal Swedish Academy of Sciences

The 2019 Physics Laureates

The 2019 Nobel Prize in Physics are awarded "for contributions to our understanding of the evolution of the universe and Earth's place in the cosmos", with one half to [James Peebles](#) "for theoretical discoveries in physical cosmology" and the other half jointly to [Michel Mayor](#) and [Didier Queloz](#) "for the discovery of an exoplanet orbiting a solar-type star."

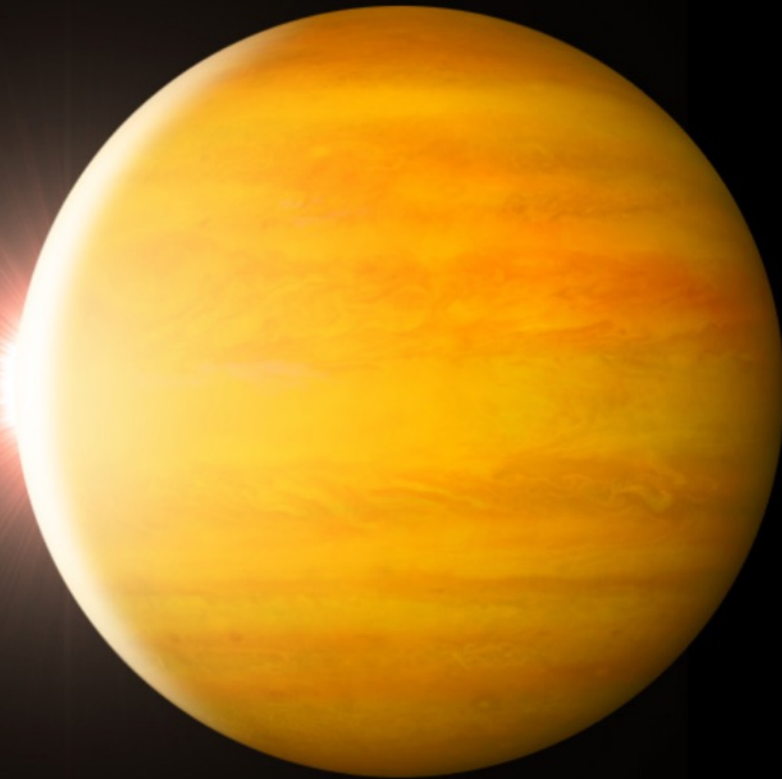


Ill. Niklas Elmehed. © Nobel Media



Swiss astronomers Didier Queloz and Michel Mayor in front of La Silla Observatory in Chile. The pair discovered 51 Pegasi b in 1995, the first planet found orbiting a star like our sun. Credit: L. Weinstein/Ciel et Espace Photos

THE **FIRST PLANET** DISCOVERED AROUND A **SUN-LIKE** STAR



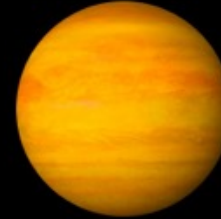
51 Pegasi b

Discovered October 6, 1995

This year we celebrate the discovery of 51 Pegasi b in October, 1995. This giant planet is about half the size of Jupiter and orbits its star in about 4 days. '51 Peg' helped launch a whole new field of exploration.

PLANET COMPARISON

51 Pegasi b



Jupiter



51 Pegasi b is 47% less massive,
but 50% larger than Jupiter.

STAR COMPARISON

51 Pegasi



Our sun



51 Pegasi is 11% more massive
and 23% larger than our sun.



TEMPERATURE

51 Pegasi b has a temperature of **1000C°/1800F°**.



ORBITAL PERIOD

51 Pegasi b orbits its host star **every 4 days**.



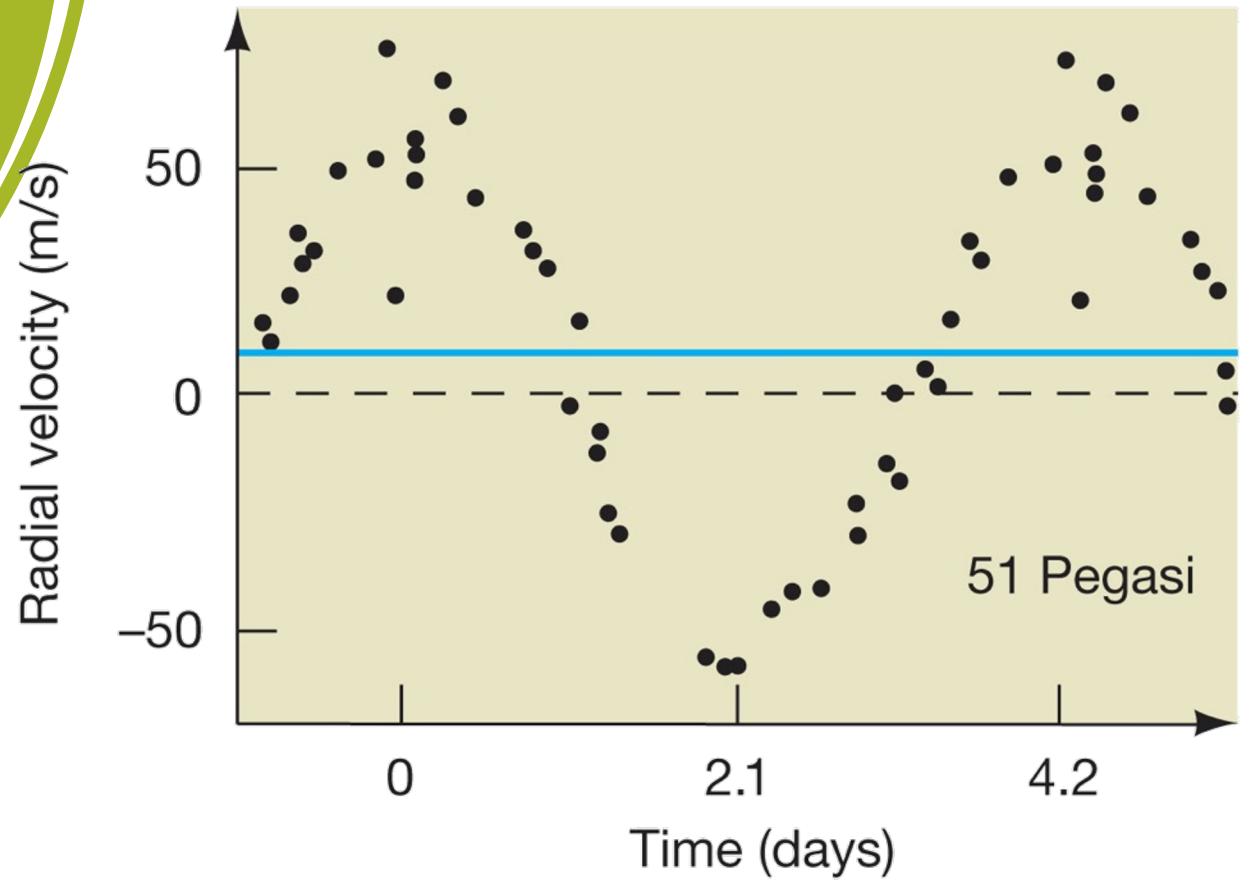
DISTANCE FROM EARTH

51 Pegasi b is **50 light-years** from Earth.

Full version:

<https://exoplanets.nasa.gov/resources/289/infographic-profile-of-planet-51-pegasi-b/>

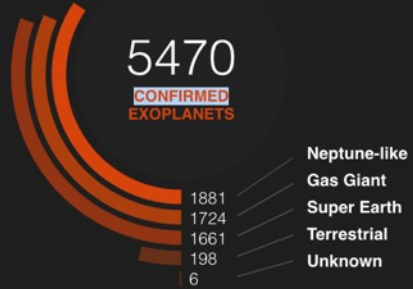
51 Pegasi: Planet Detection



The blue lines show the maximum possible signal produced by Jupiter orbiting the Sun.

“Doppler shift” measurements of the star 51 Pegasi with a planet mass of at least half the Jupiter mass

Planet Types



New Discovery



PLANET NAME

TOI-908 b

PLANET TYPE

Neptune-like

DISCOVERY DATE

2023

DETECTION METHOD

Transit

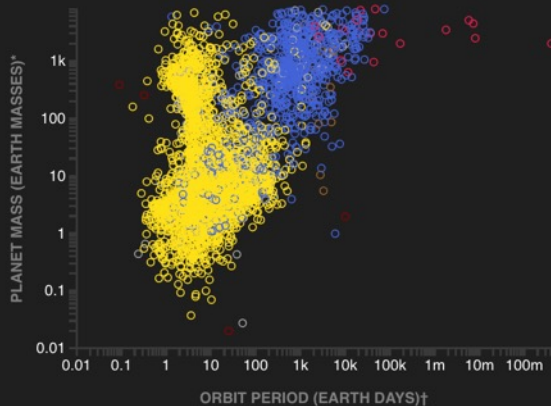
More about this planet

<https://exoplanets.nasa.gov/alien-worlds/ways-to-find-a-planet/>

Exoplanet Census

Display limited to planets with both measured or estimated orbital period and mass

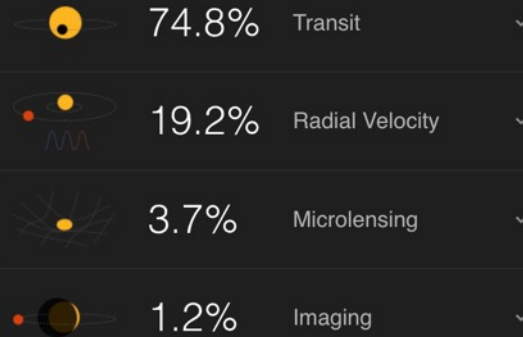
Transit (4063) Radial Velocity (1037) Microlensing (10)
Imaging (19) Pulsar Timing (6) Other (50)



YEAR 2023 | DISCOVERIES: 5470

1989 2023

By Method

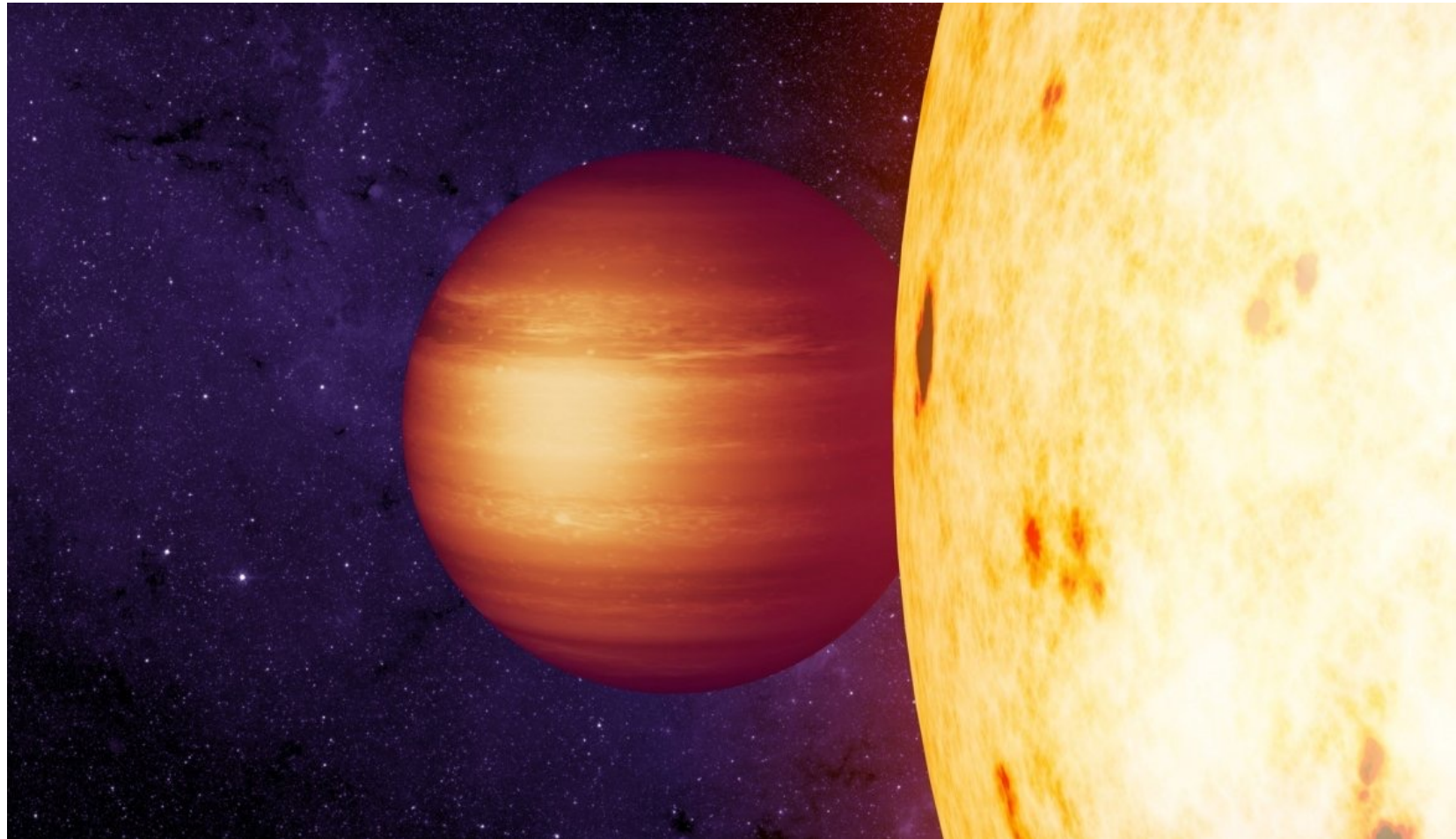
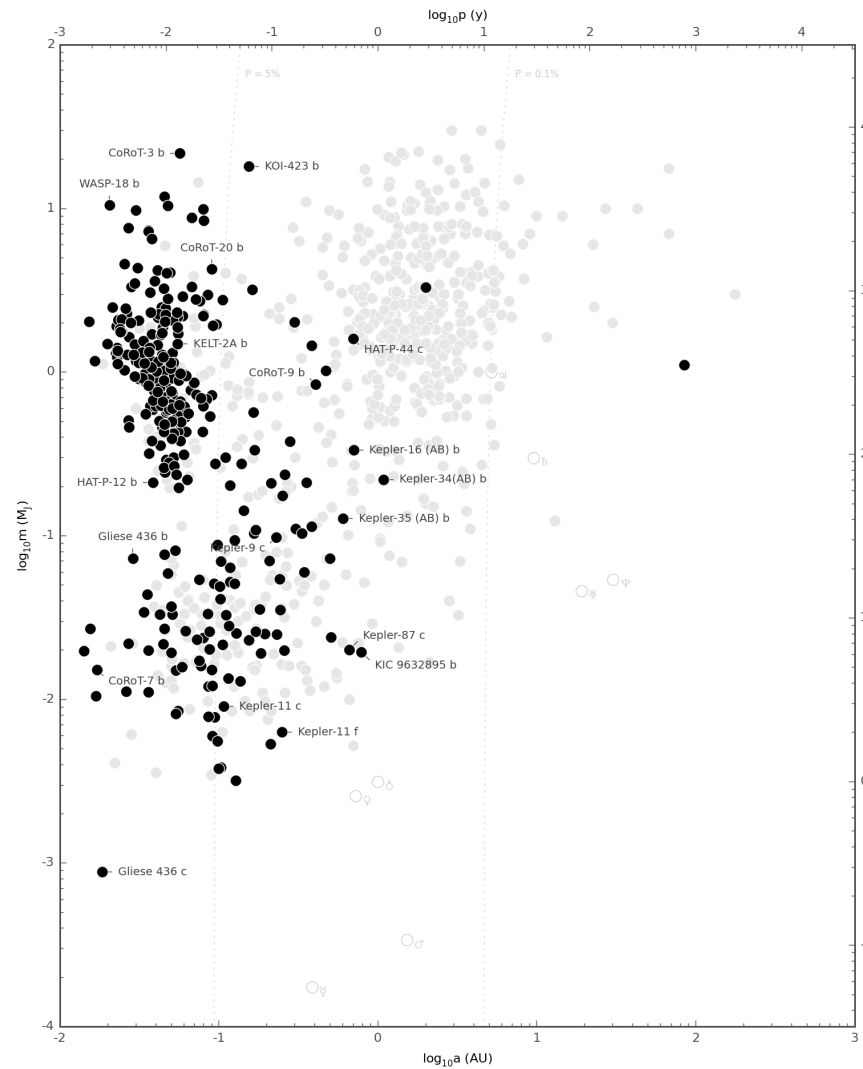


0.46% Transit Timing Variations, 0.31% Eclipse Timing Variations, 0.16% Orbital Brightness Modulation, 0.13% Pulsar Timing, 0.04% Astrometry, 0.04% Pulsation Timing Variations, 0.02% Disk Kinematics

More about planet-hunting methods

<https://exoplanets.nasa.gov>

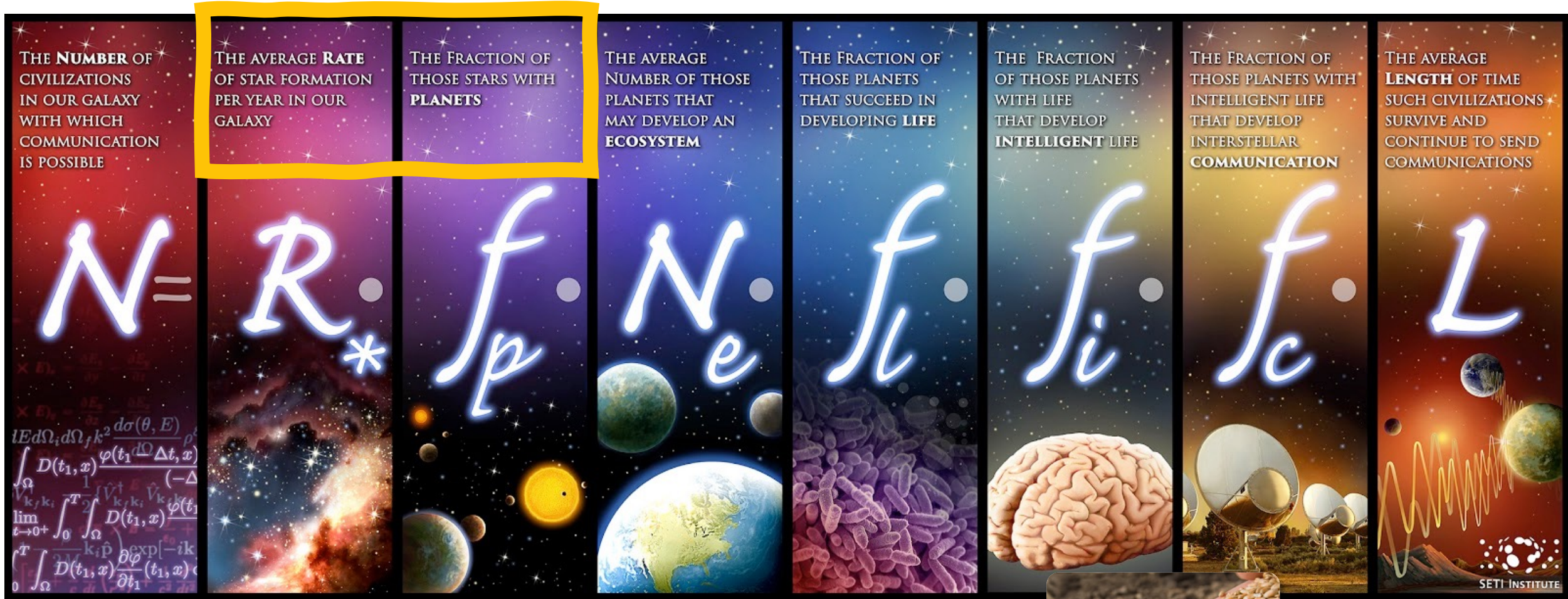
HOT JUPITERS?



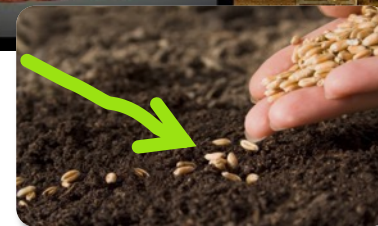
Drake Equation



Drake Equation



Question: Is a seed of a plant alive?



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/>

Assignment

- Based on the criteria of life presented in class, would you call a CYBORG operated by artificial intelligence as a living organism?



Earth 4 billion years ago...

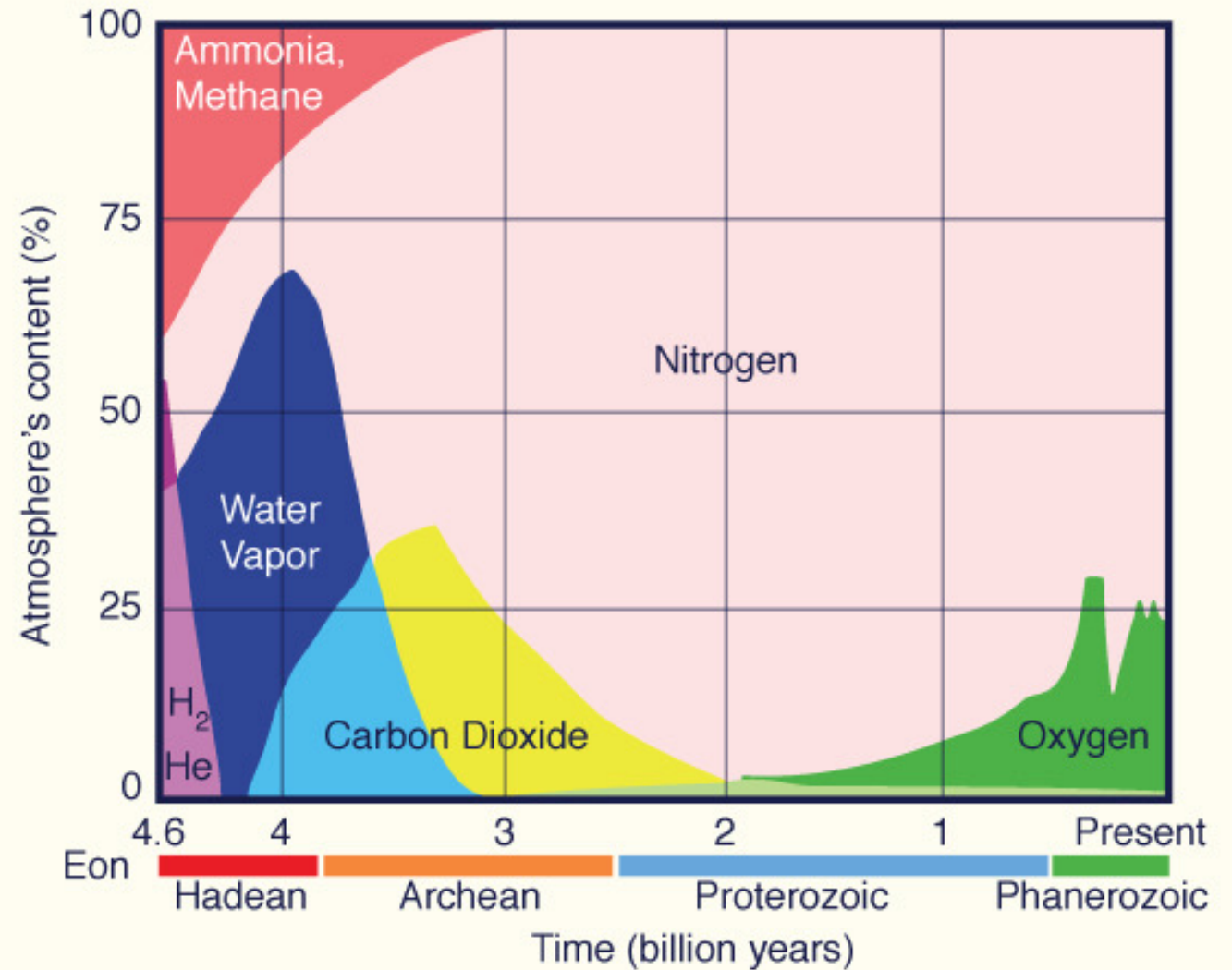
Going back to the planet formation....

- 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?



(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.



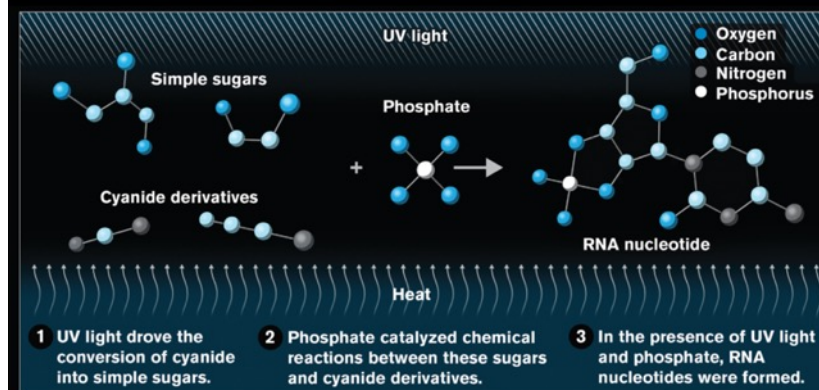
Cyanide

Iron



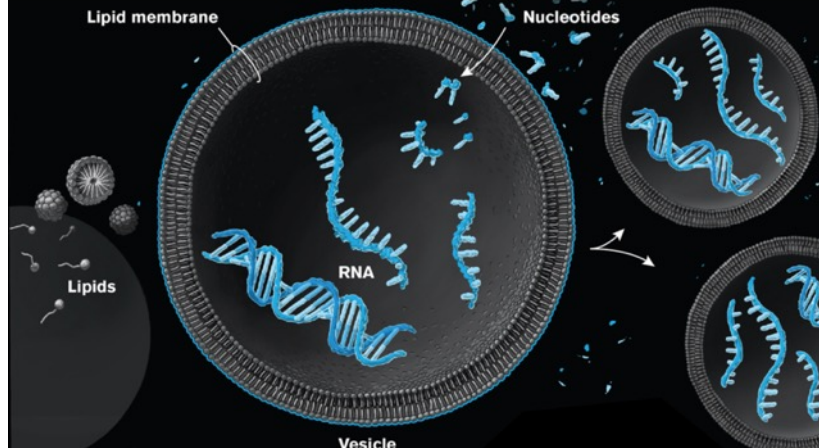
Life as we know it requires RNA. Some scientists believe that RNA emerged directly from these reactive chemicals, nudged along by dynamic forces in the environment.

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.



Lipid membrane

Nucleotides

RNA

Vesicle

Lipids

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