Chapter 18: Life in the Universe

All EC & Dark Energy assignment
due December 5th

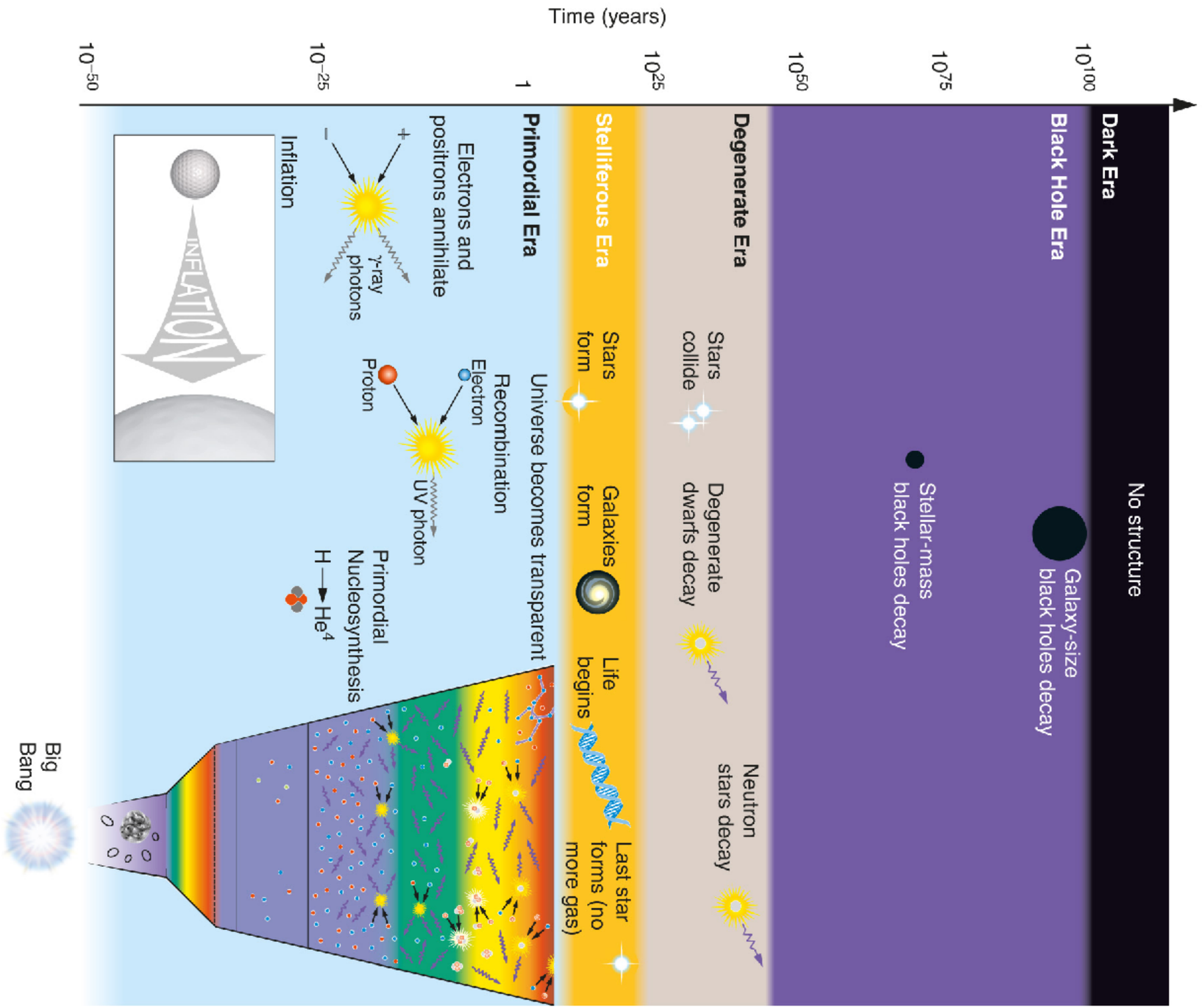
Check your grades in Canvas!

Complete feedback survey to get grade early!

Mirna: no office hours today, but will be around
longer tomorrow (3pm to 5 or 6pm)

Galaxy Quest (1999) still frame,
Goblin Valley State Park

The Deep Future (maybe?)



Primordial Era	10^5 yr
Stelliferous Era	10^{14} yr
Degenerate Era	10^{39} yr
Black Hole Era	10^{100} yr
Dark Era	infinity?

Why this universe? An anthropic perspective

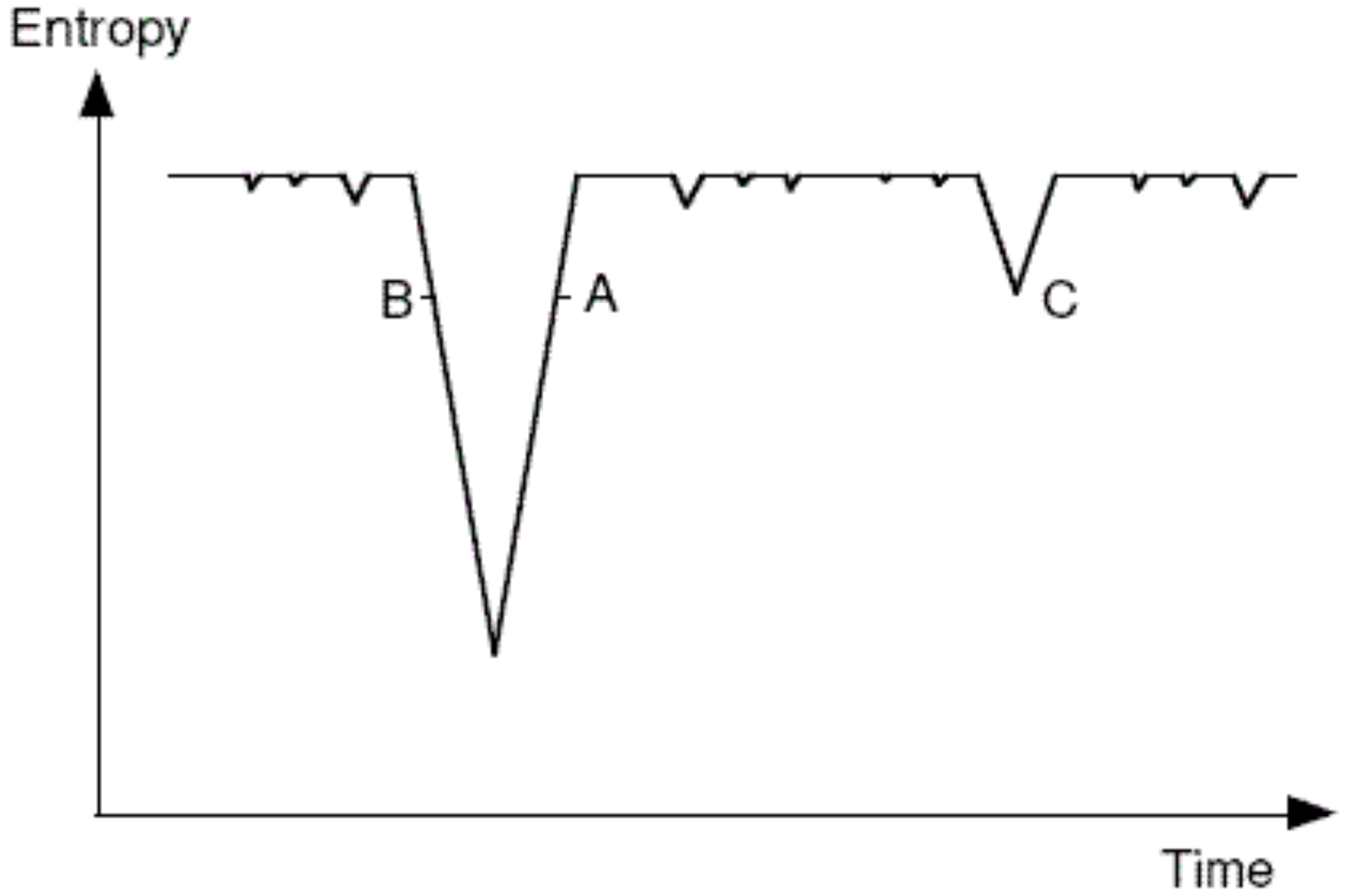


Figure 1. Boltzmann's entropy curve.

Life in the Stelliferous Era

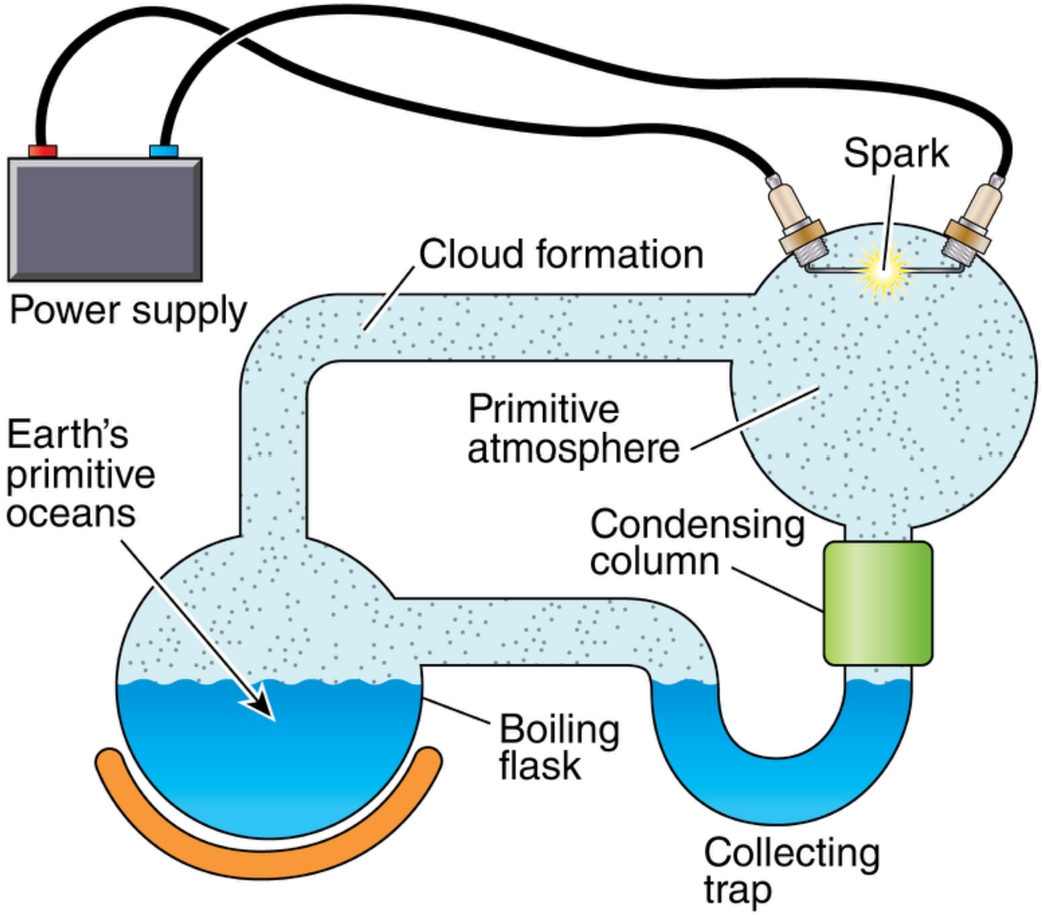
What is life?

What are the conditions necessary for life?

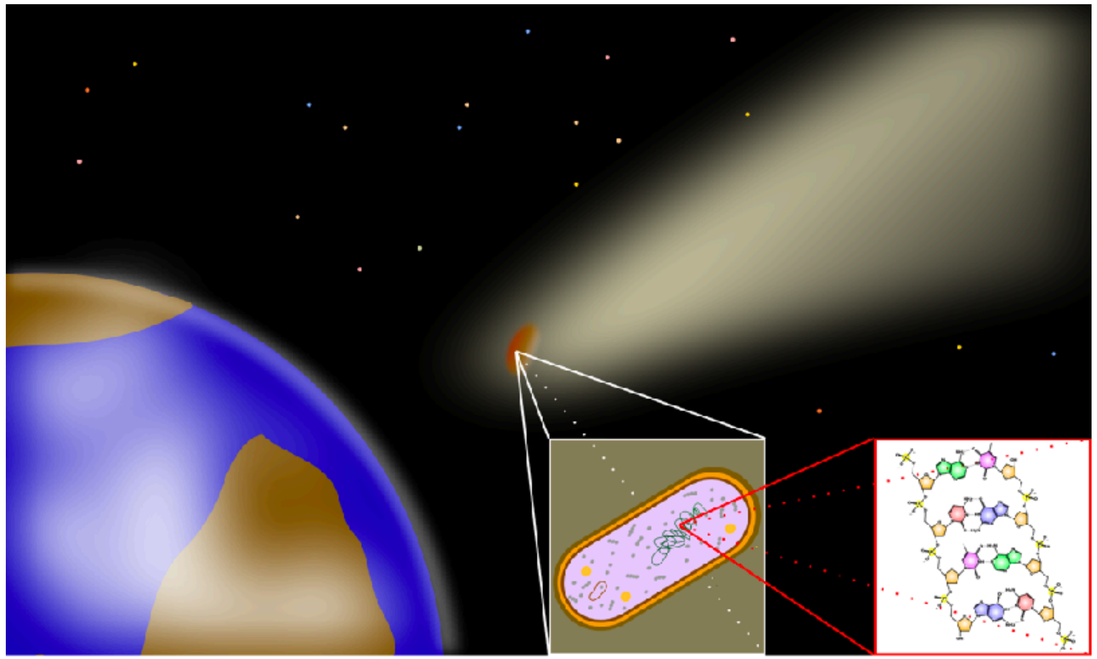
How does life become more complex?

Only have 1 example to work from (so far) — life on Earth

Origin of life unclear, but arises quickly

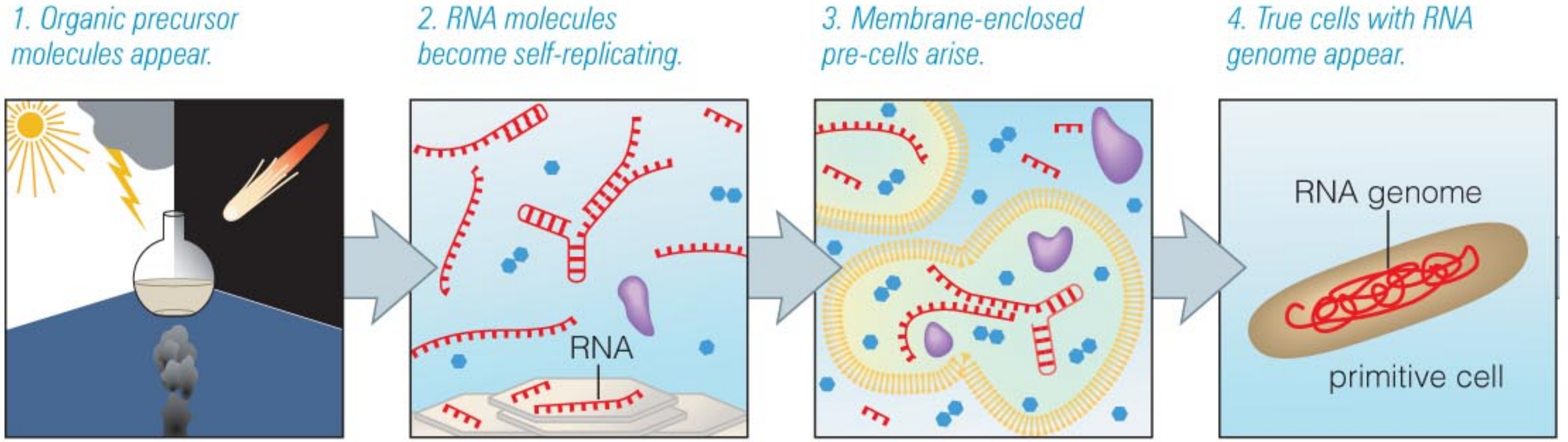


Panspermia: life delivered by comets, or ancient aliens?

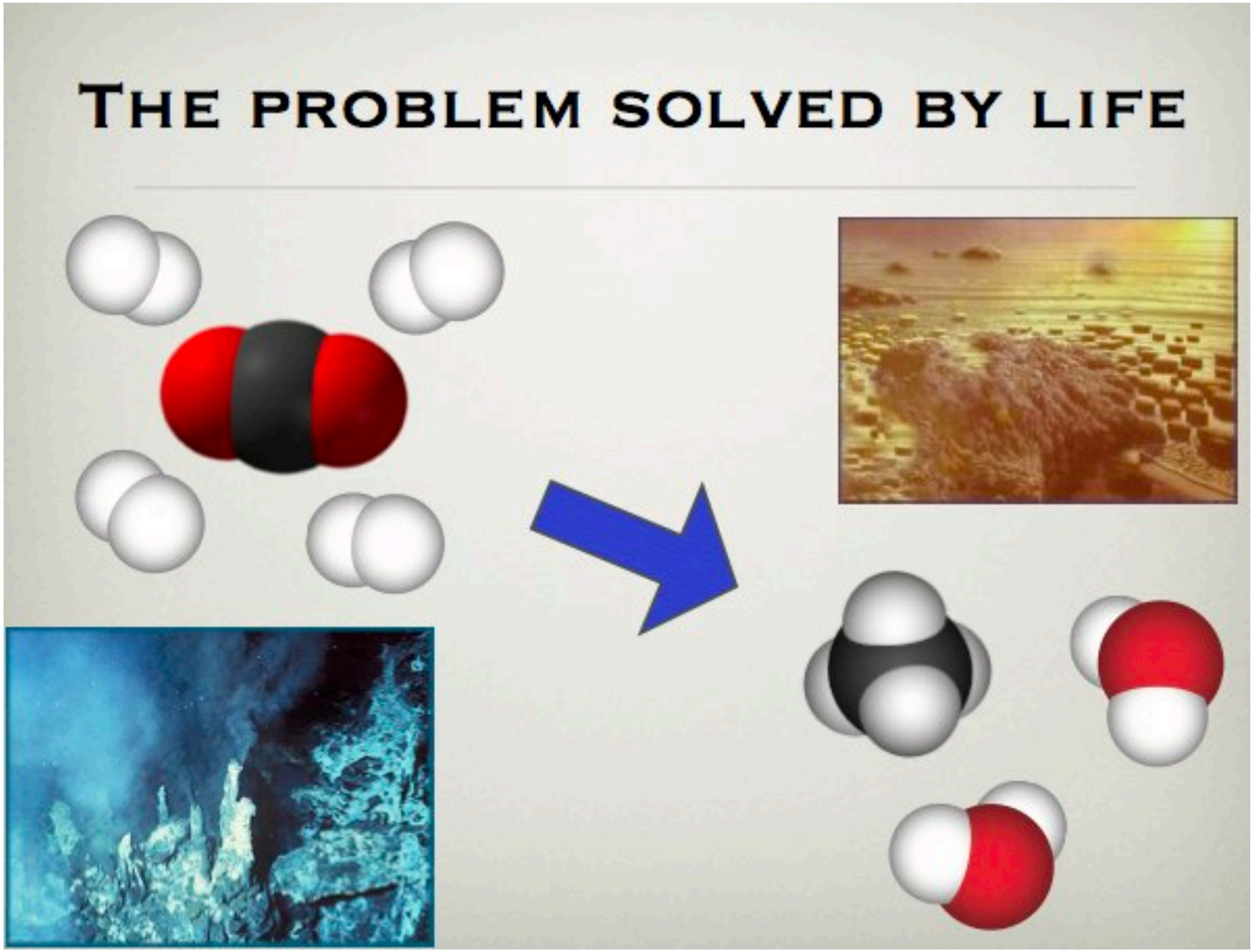


Miller-Urey Experiment: amino acids created from simple molecules (methane, ammonia, water) and simulated lightning strikes

Self-replicating molecules spread, compete

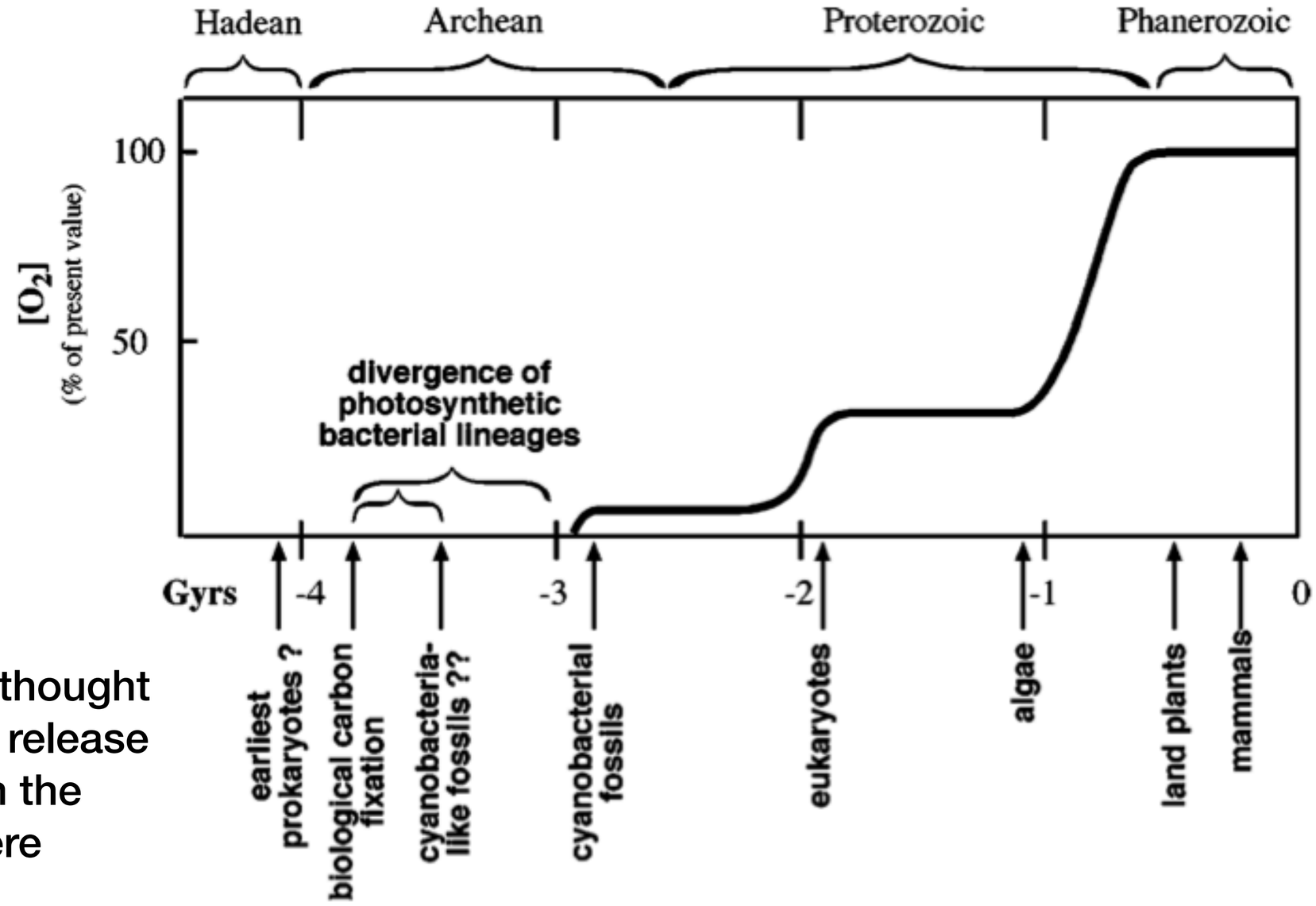


Alternative view: life is a catalyst to convert CO_2 to hydrocarbons



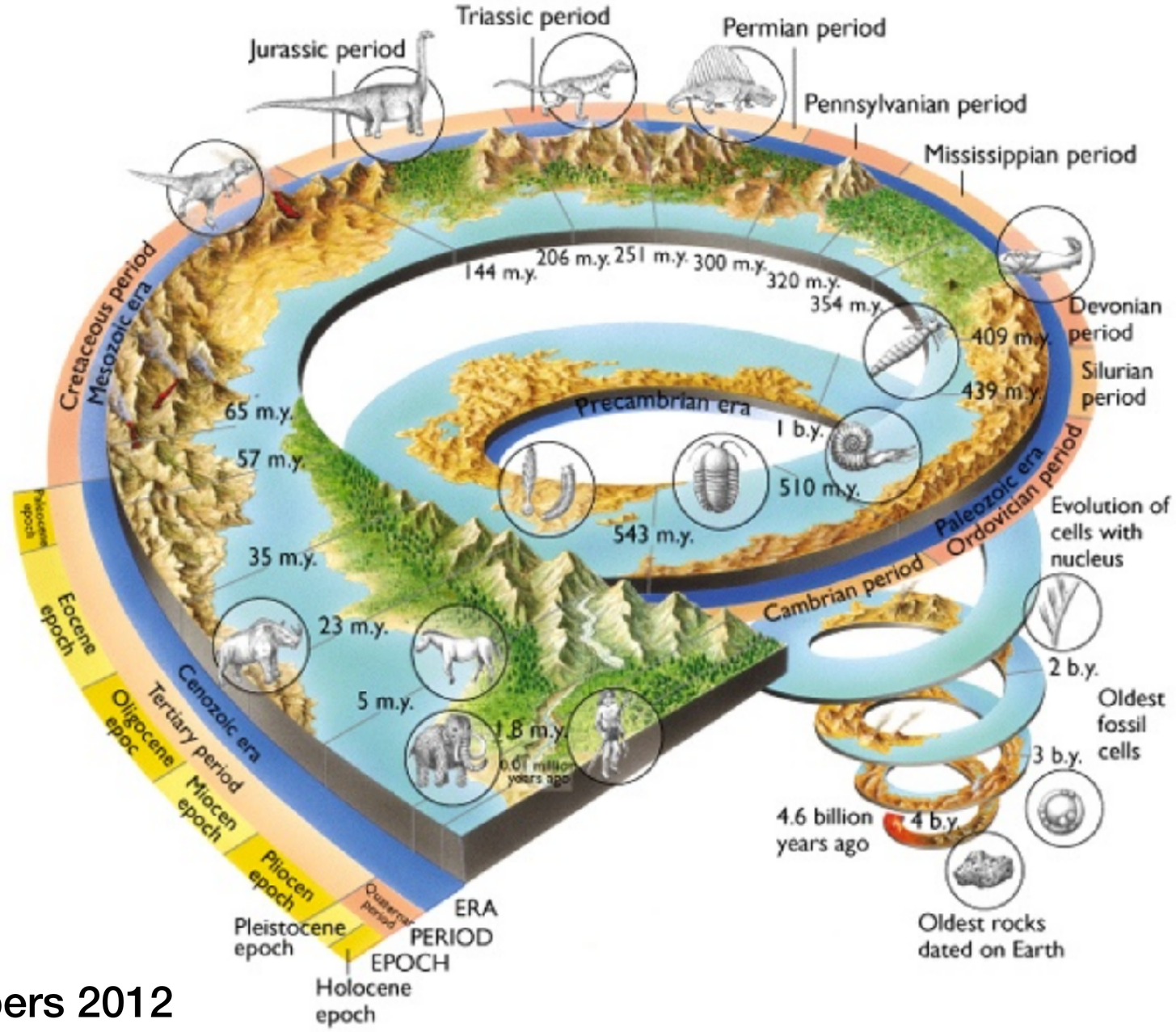
http://www.preposterousuniverse.com/blog/2010/03/10/free-energy-and-the-meaning-of-life/

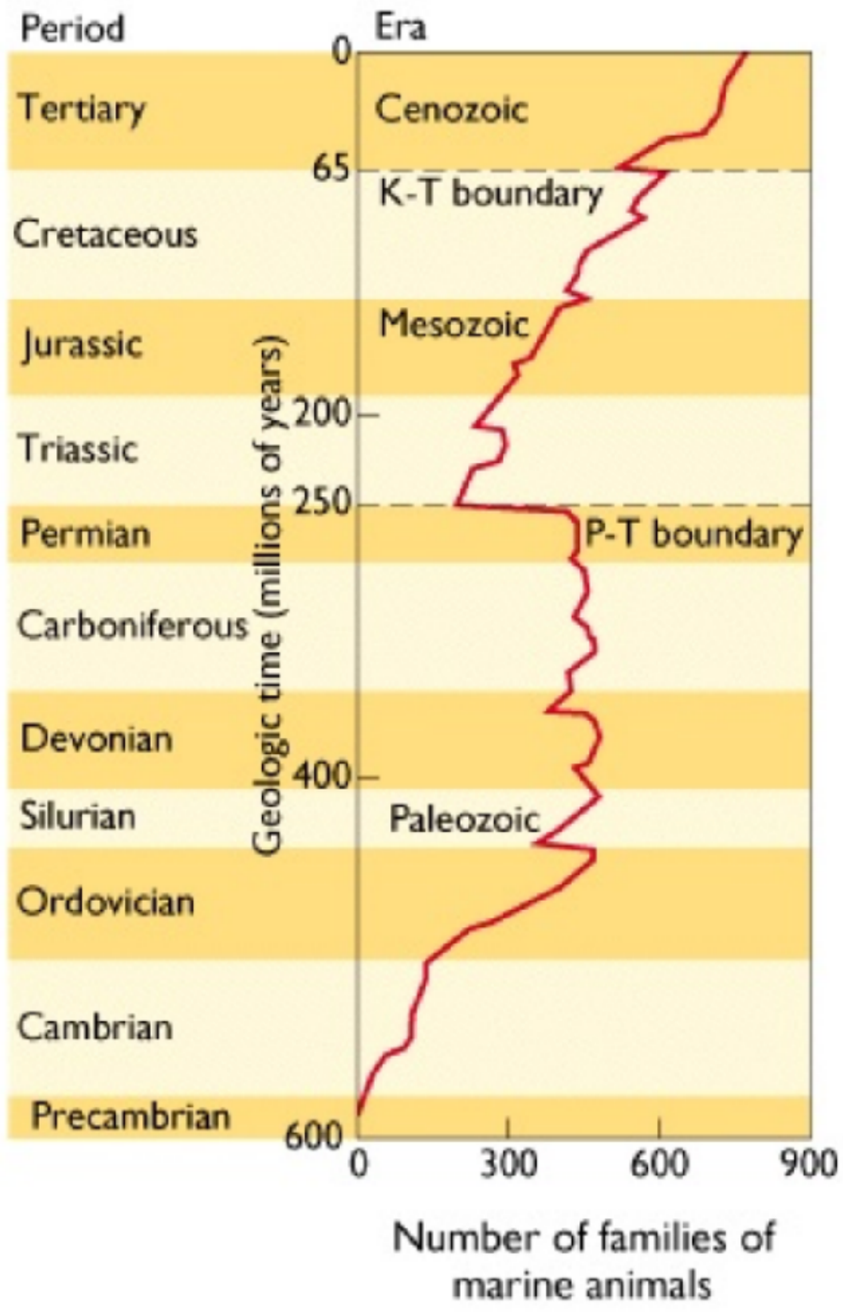
Early life pollutes the Earth with oxygen



Xiong & Bauer 2002

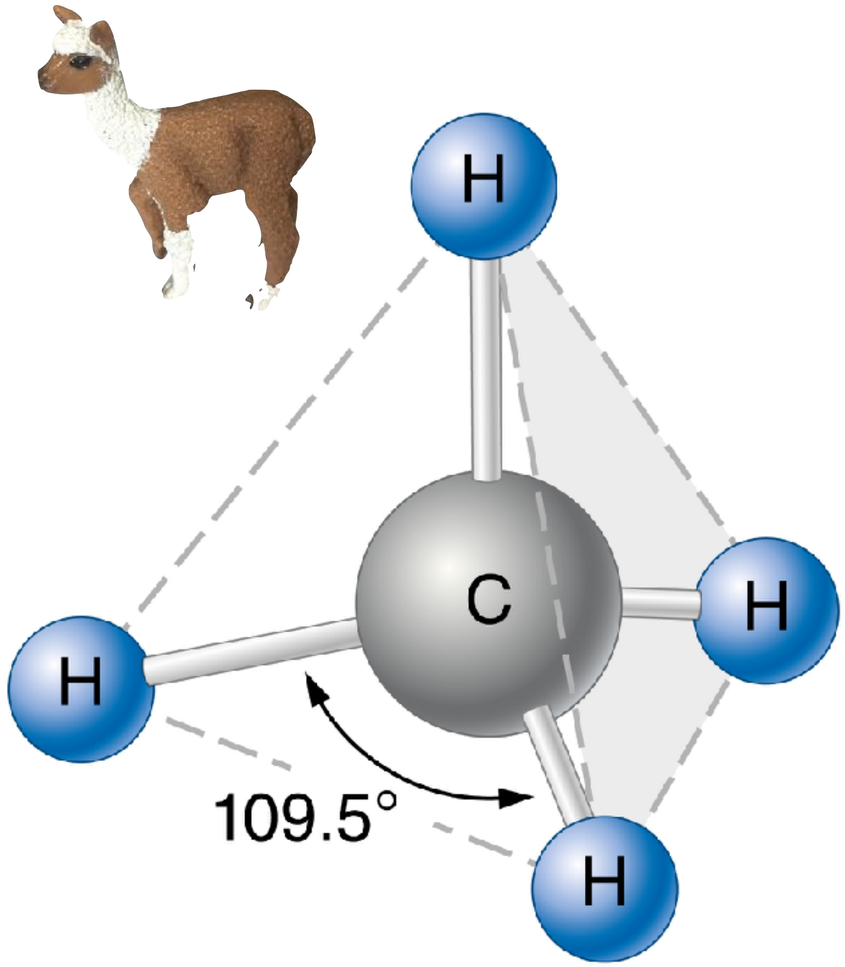
Cyanobacteria thought to have started release of oxygen in the atmosphere


Jurassic period
Triassic period
Permian period
Pennsylvanian period
Mississippian period
Devonian period
Silurian period
Cretaceous period
Mesozoic era
Precambrian era
Paleozoic era
Ordovician period
Cambrian period
Cenozoic era
Tertiary period
Eocene epoch
Oligocene epoch
Miocen epoch
Pliocen epoch
Pleistocene epoch
Holocene epoch
ERA
PERIOD
EPOCH
144 m.y.
206 m.y.
251 m.y.
300 m.y.
320 m.y.
354 m.y.
409 m.y.
439 m.y.
543 m.y.
510 m.y.
1 b.y.
65 m.y.
57 m.y.
35 m.y.
23 m.y.
5 m.y.
1.8 m.y.
0.01 million years ago
Evolution of cells with nucleus
2 b.y.
Oldest fossil cells
3 b.y.
4 b.y.
4.6 billion years ago
Oldest rocks dated on Earth

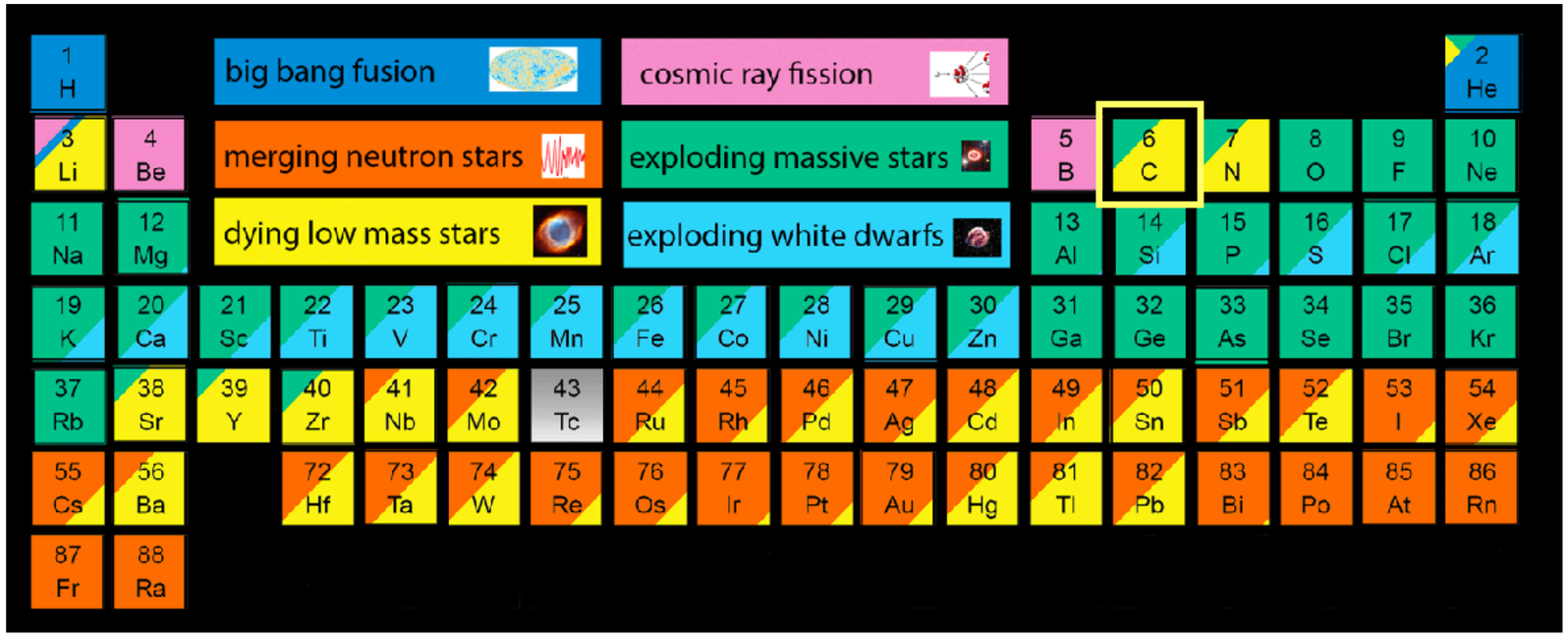

Period
Era
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Carboniferous
Devonian
Silurian
Ordovician
Cambrian
Precambrian
Cenozoic
K-T boundary
Mesozoic
P-T boundary
Paleozoic
0
65
200
250
400
600
Geologic time (millions of years)
0
300
600
900
Number of families of marine animals

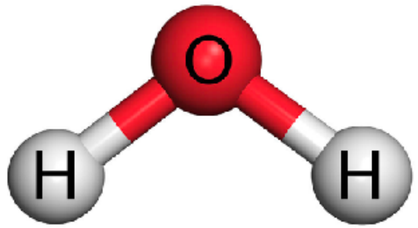
Olbers 2012

Complex life is likely to be carbon-based



Methane tetrahedron



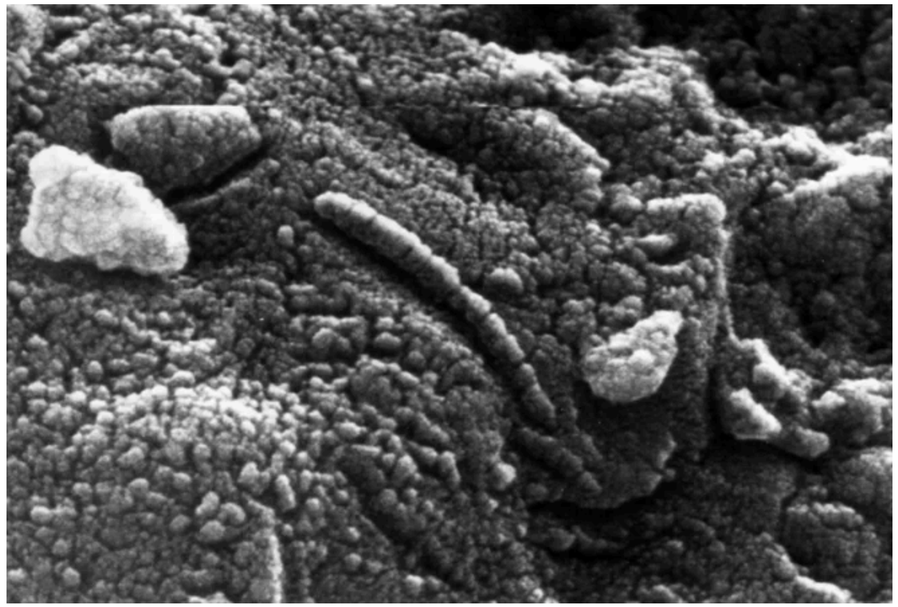


Water Solvent!

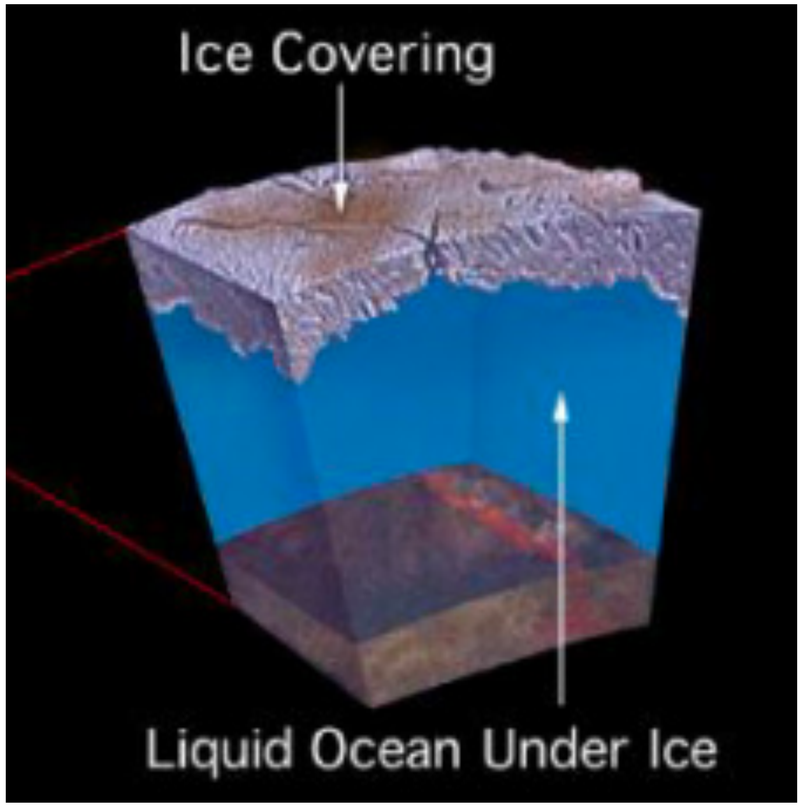
Life needs:
- organic molecules
- water
- energy

Actively searching for life elsewhere in the solar system

Martian meteorite

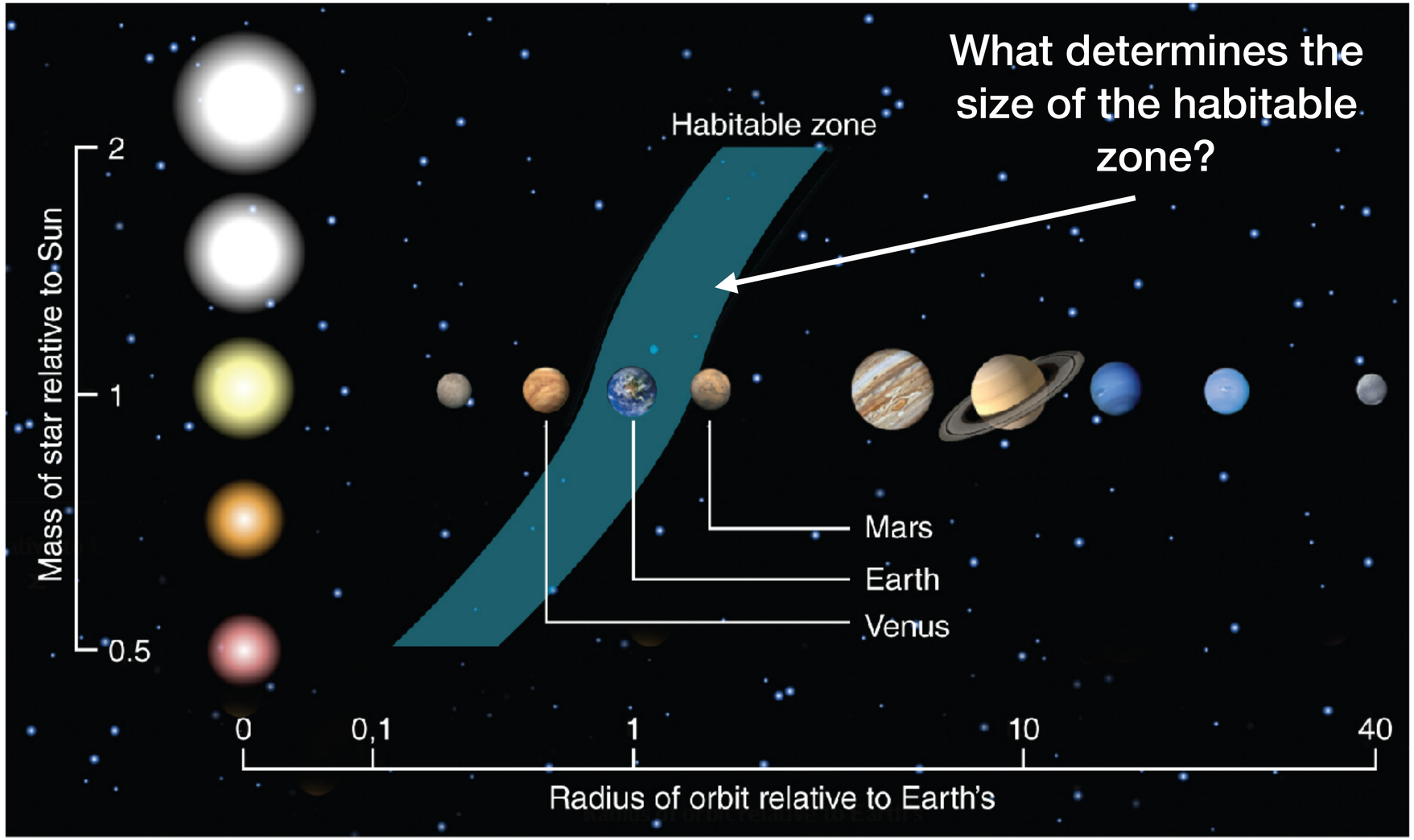


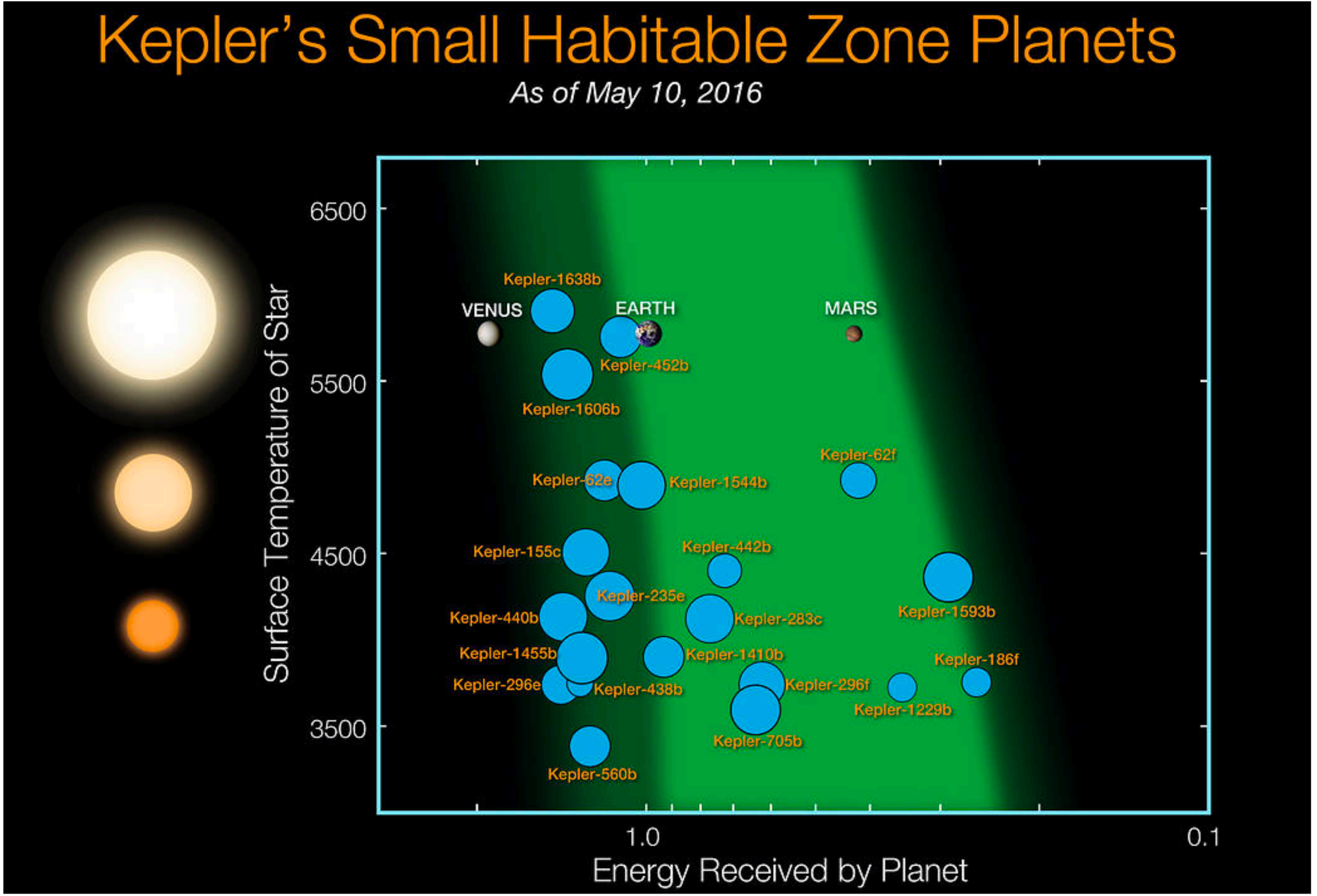
Oceans under ice of Jupiter's moons Europa and Enceladus



Beginning the search outside the solar system

Where should we look?

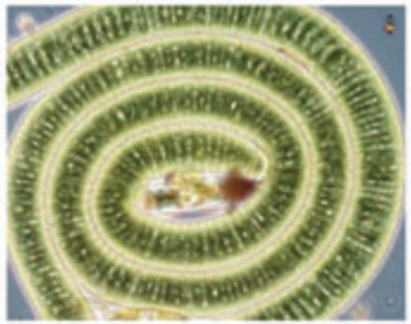


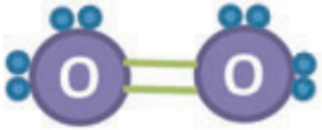

Kepler's Small Habitable Zone Planets
As of May 10, 2016
Surface Temperature of Star
6500
5500
4500
3500
VENUS
EARTH
MARS
Kepler-1638b
Kepler-452b
Kepler-1606b
Kepler-62f
Kepler-62e
Kepler-1544b
Kepler-155c
Kepler-442b
Kepler-235e
Kepler-1593b
Kepler-440b
Kepler-283c
Kepler-1455b
Kepler-1410b
Kepler-186f
Kepler-296e
Kepler-438b
Kepler-296f
Kepler-1229b
Kepler-705b
Kepler-560b
1.0
0.1
Energy Received by Planet

Biosignatures of Life in an Exoplanet Atmosphere

Gaseous

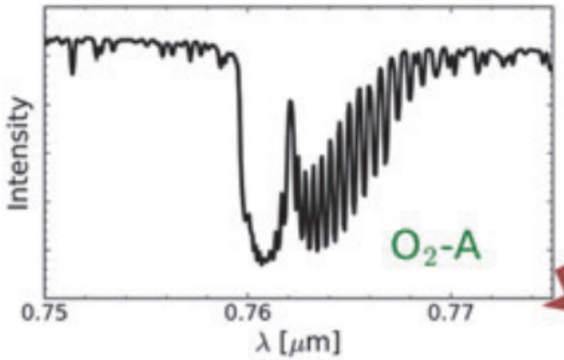
Ex: **Oxygenic Photosynthesis**





$H_2O + CO_2 + h\nu \rightarrow$

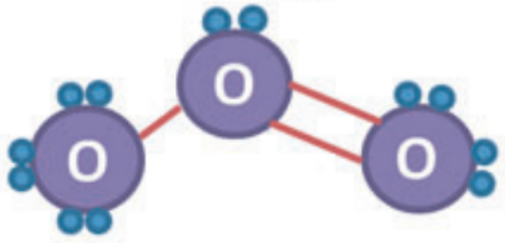
$O_2 + (CH_2O)_{org}$

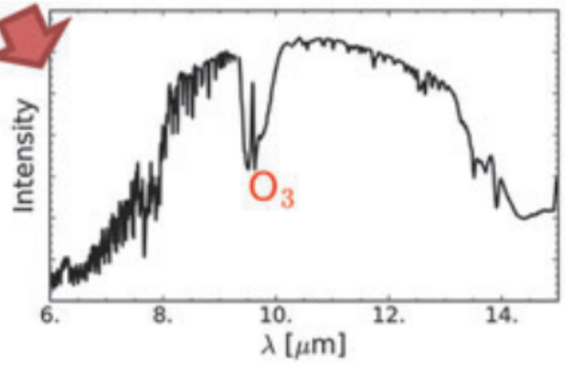


Photolytic Byproduct

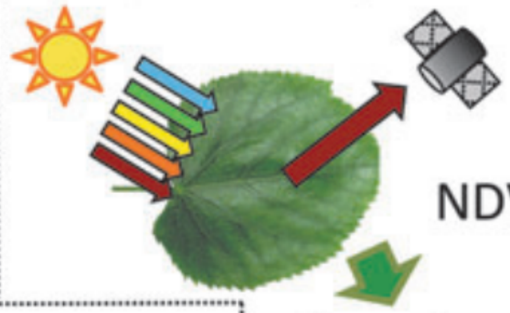
$O_2 + h\nu \rightarrow O + O$

$O_2 + O + M \rightarrow O_3 + M$

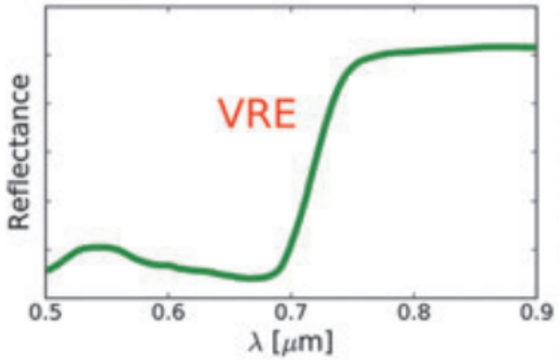


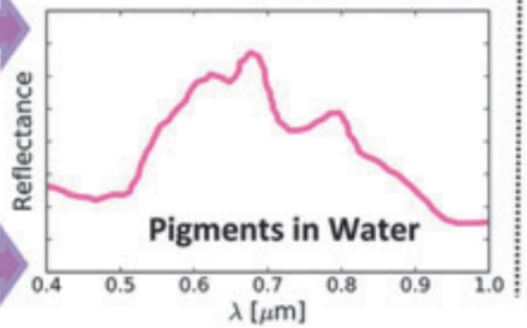


Surface

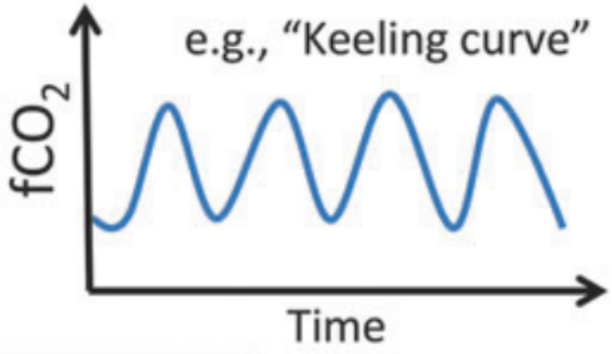


$$NDVI = \frac{IR - VIS}{IR + VIS}$$

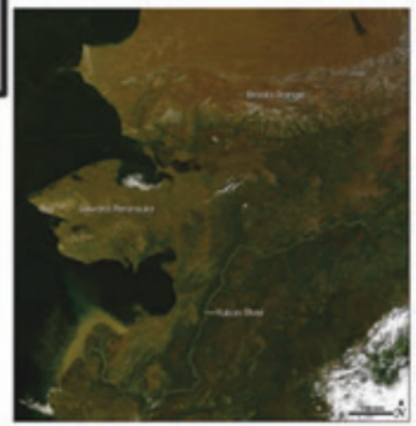




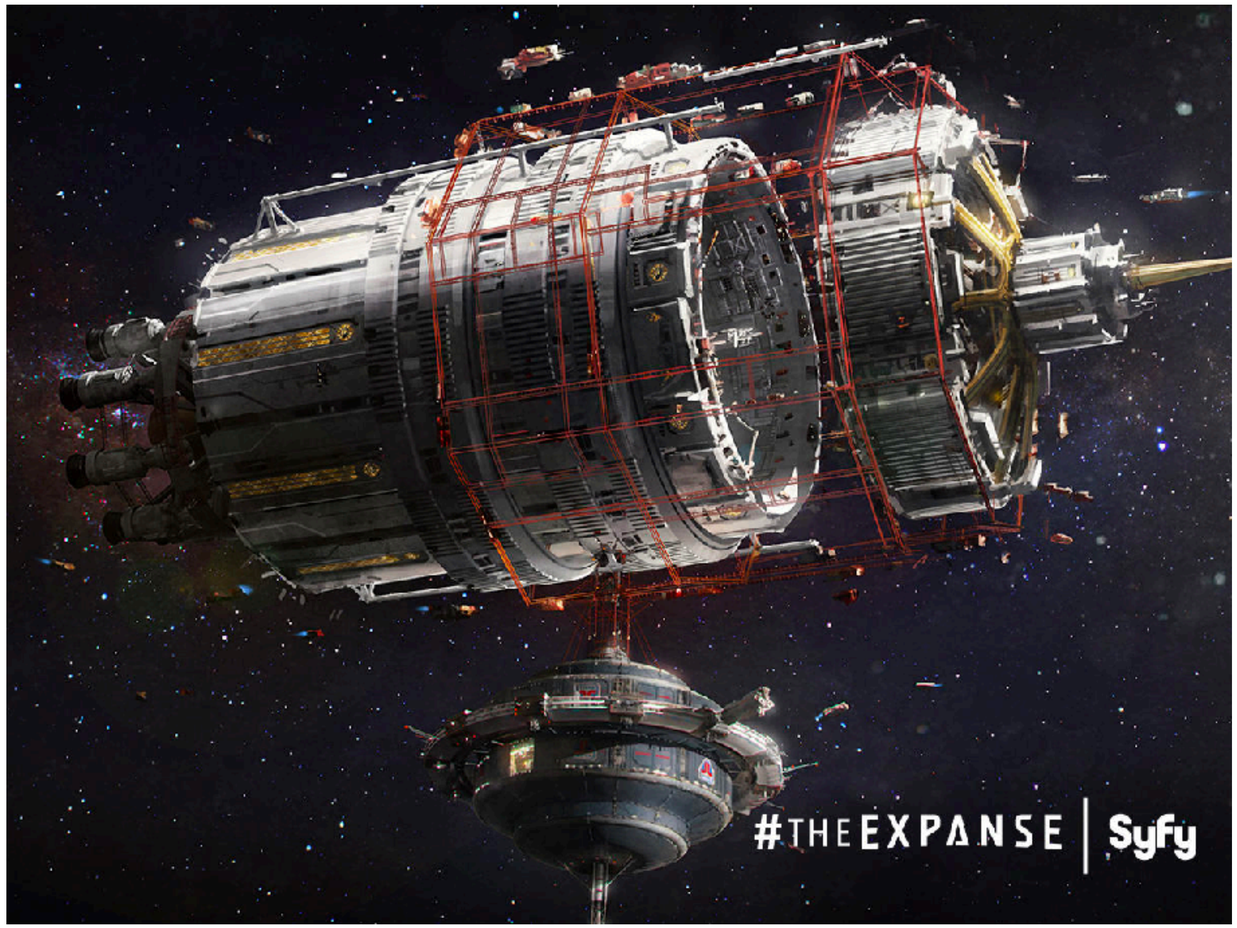
Temporal



Seasonal Changes in Gases or Surface



What if we find a nearby planet with life?

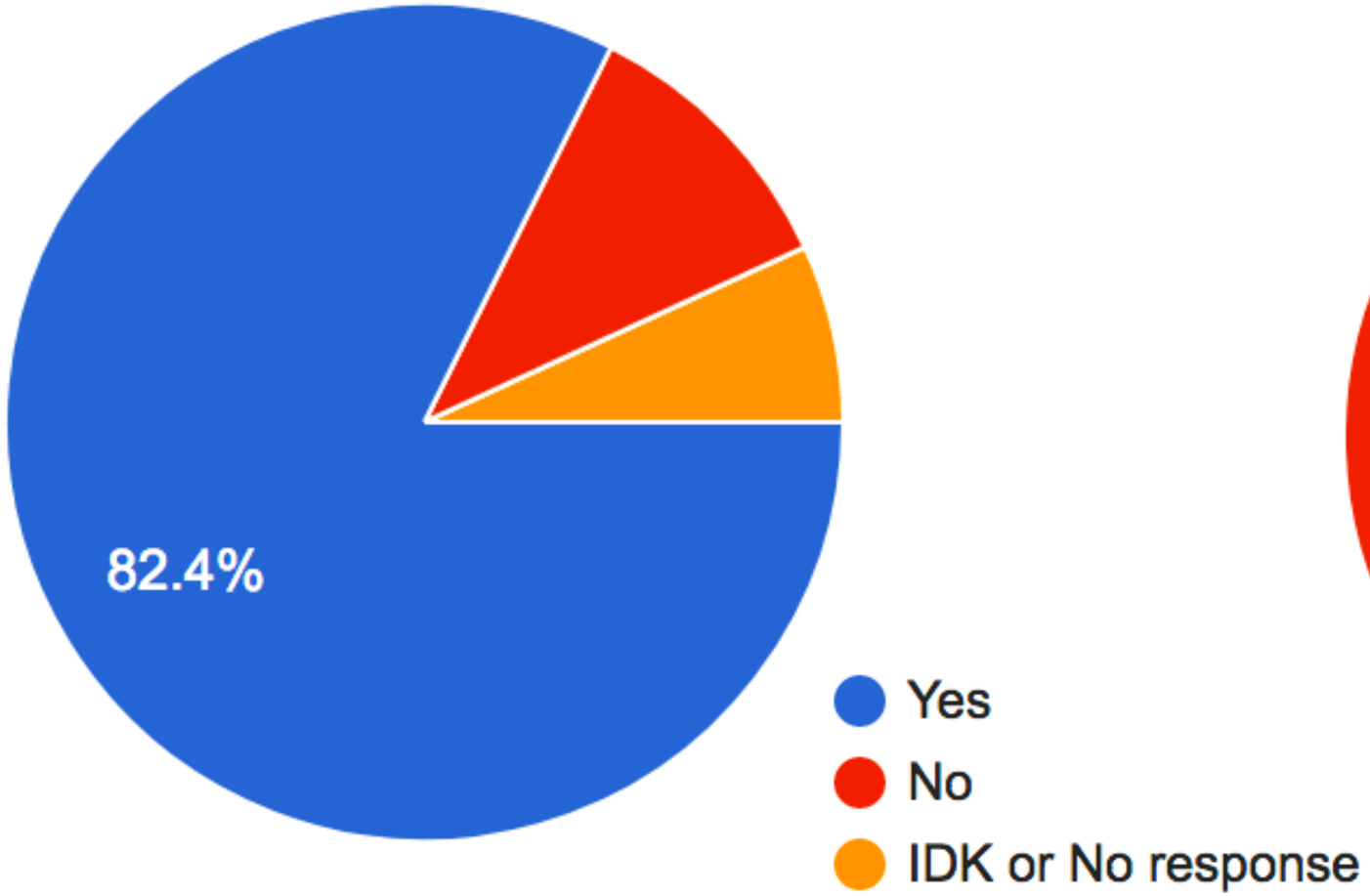


The Nauvoo: a generation ship

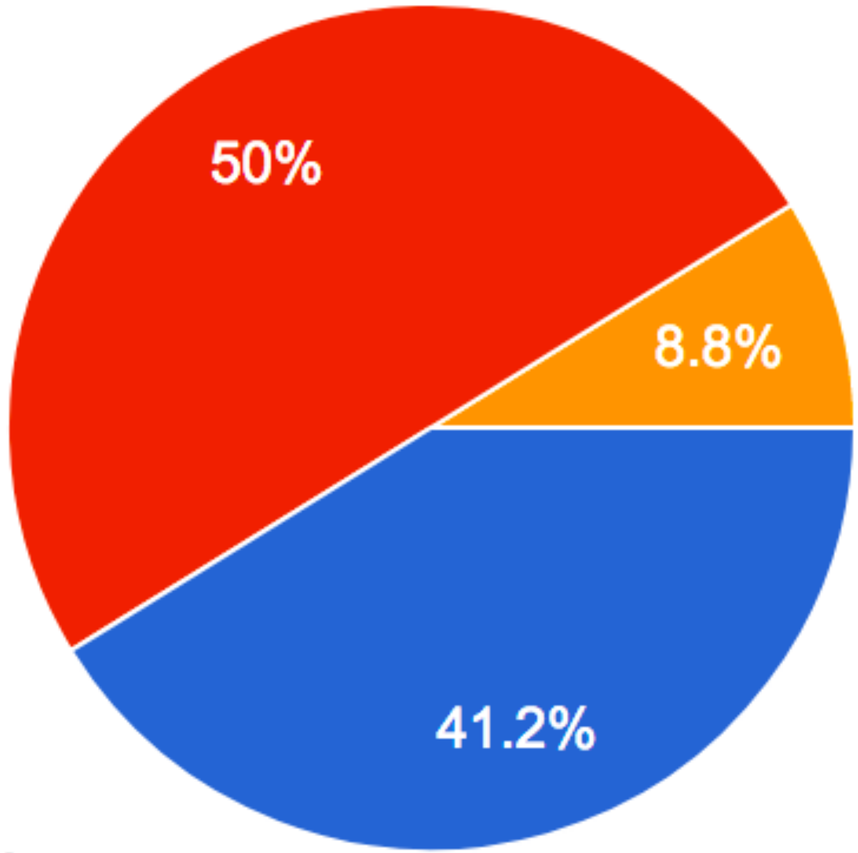
- Current world energy consumption: 4.7×10^{20} joules/year
- Energy = 1/2 * mass * velocity^2
- Energy to get a spaceship with 50 people moving at 10% the speed of light: 4.5×10^{20} joules.
- To transport a functioning civilization, however, requires many more people (all the specializations needed to keep the ship going and the people alive — think of an aircraft carrier crew, but bigger and with families)

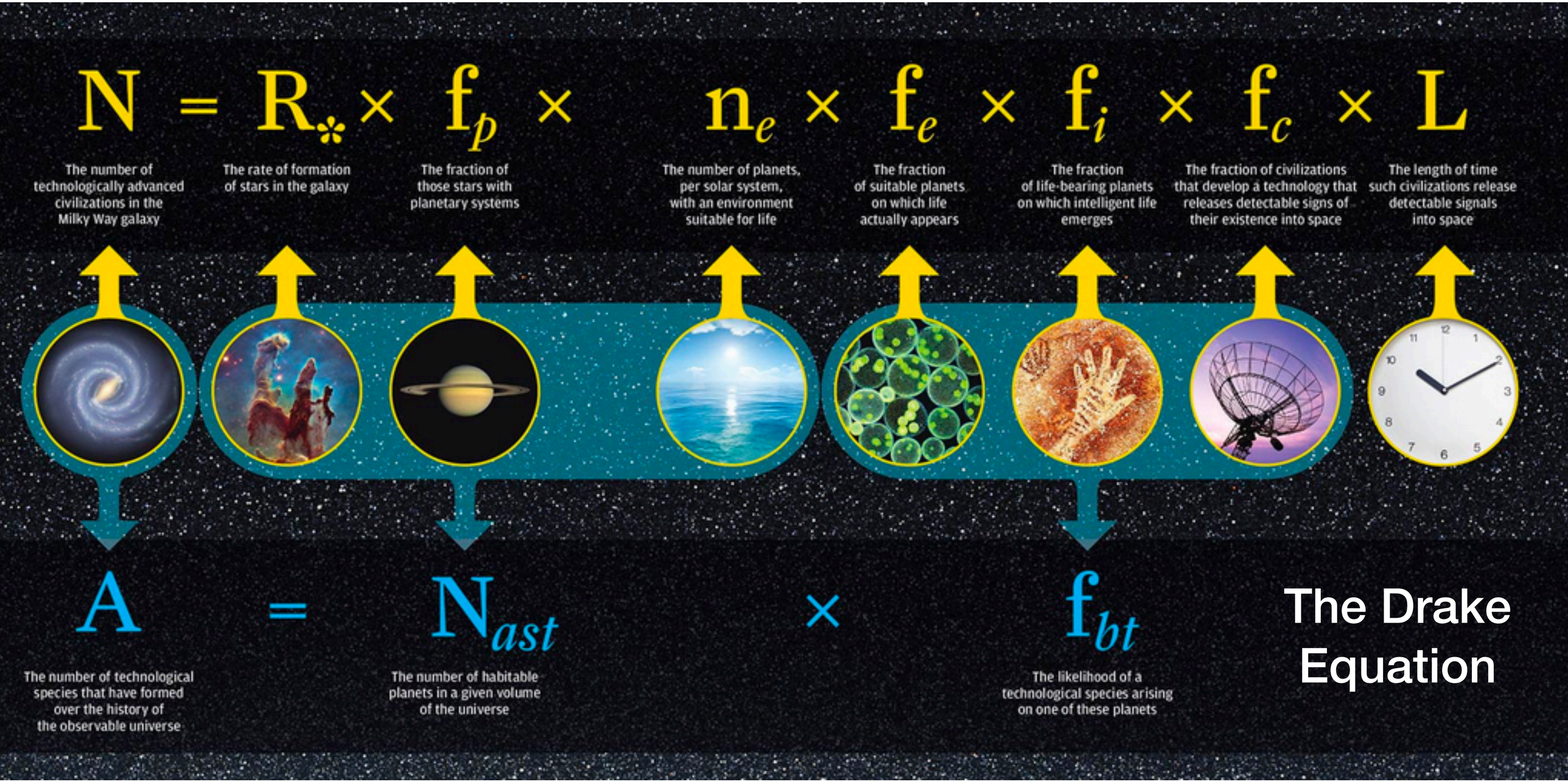
Why is it important to discover life beyond Earth?

I believe that intelligent extraterrestrials exist



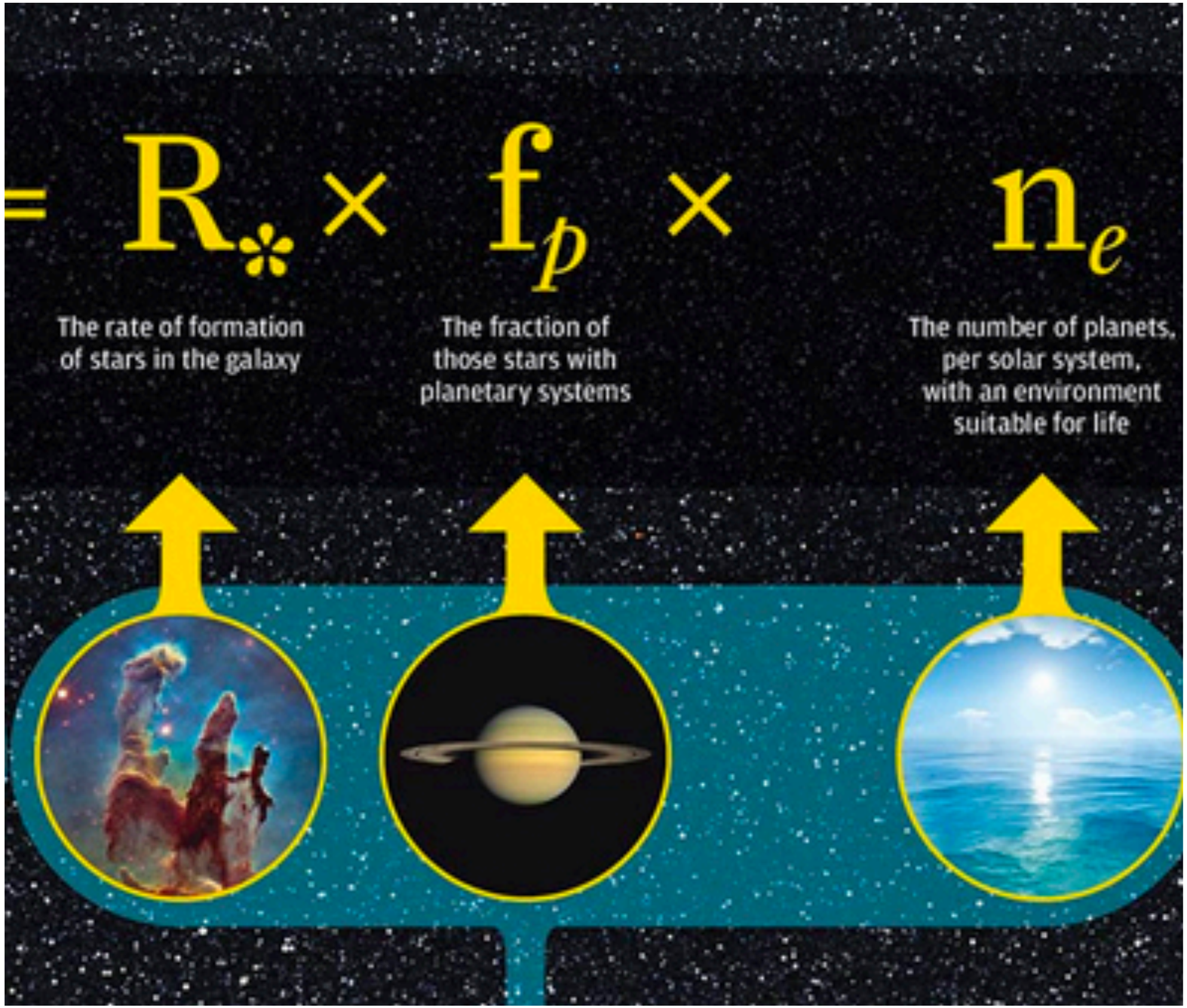
I believe Earth has been visited by aliens





The Drake Equation

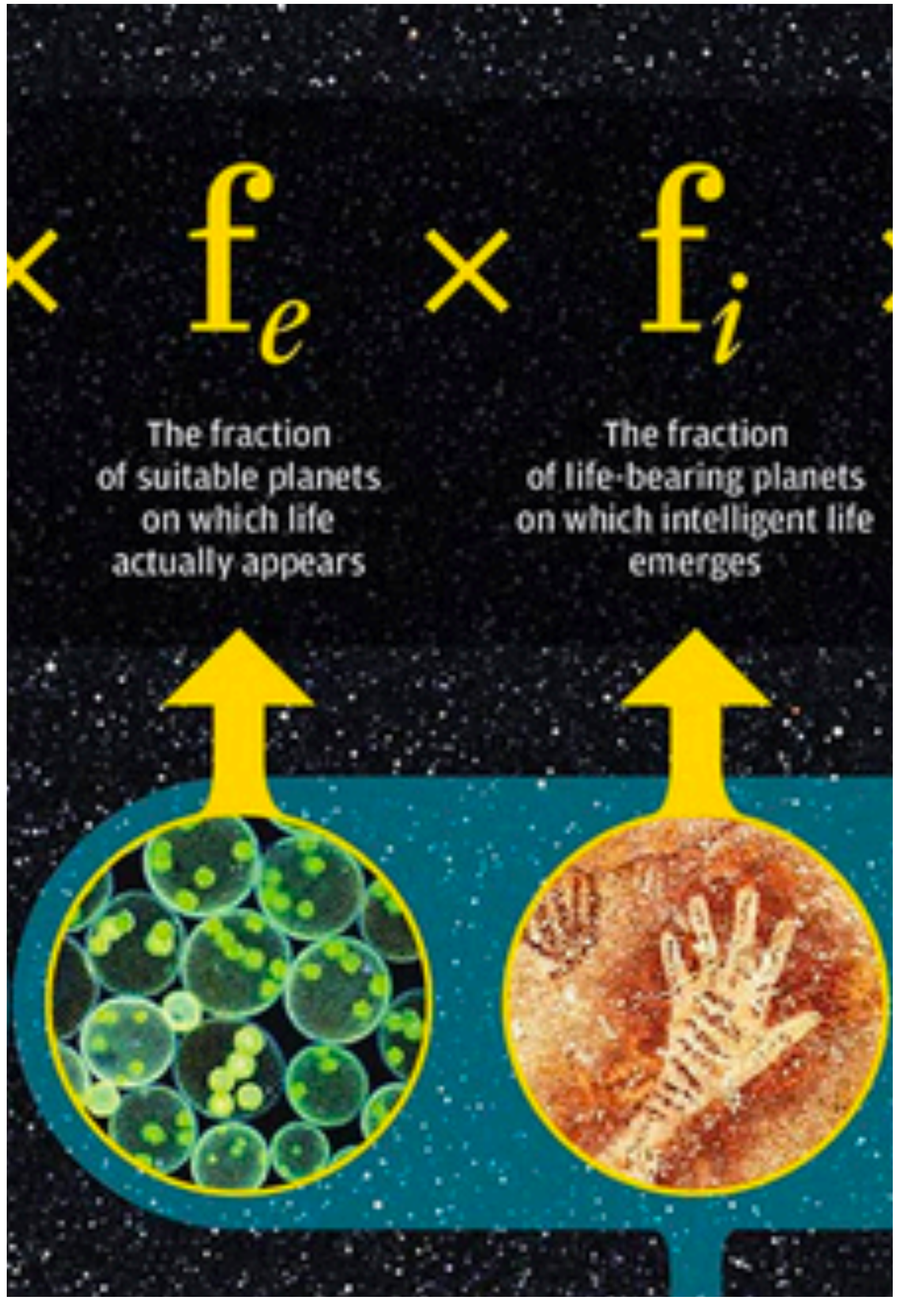
Credit: U. Rochester



R* —> rate of formation of long-lived stars (F, G, K, M types) in the galaxy:
~ 7 per year

f_p —> fraction of those stars with planets:
less than, but close to, 1

n_e —> number of planets, per solar system, with an environment suitable for life (habitable zone, right mass, right composition):
a few? 1-10?



f_e —> fraction of suitable planets on which life actually appears

f_i —> fraction of life-bearing planets on which intelligent life emerges

What do you think is the fraction of planets is that host any kind of life?

A) 1: all planets that can host life form life

B) 0.1: it happens about 10% of the time

C) 0.01: it happens about 1% of the time

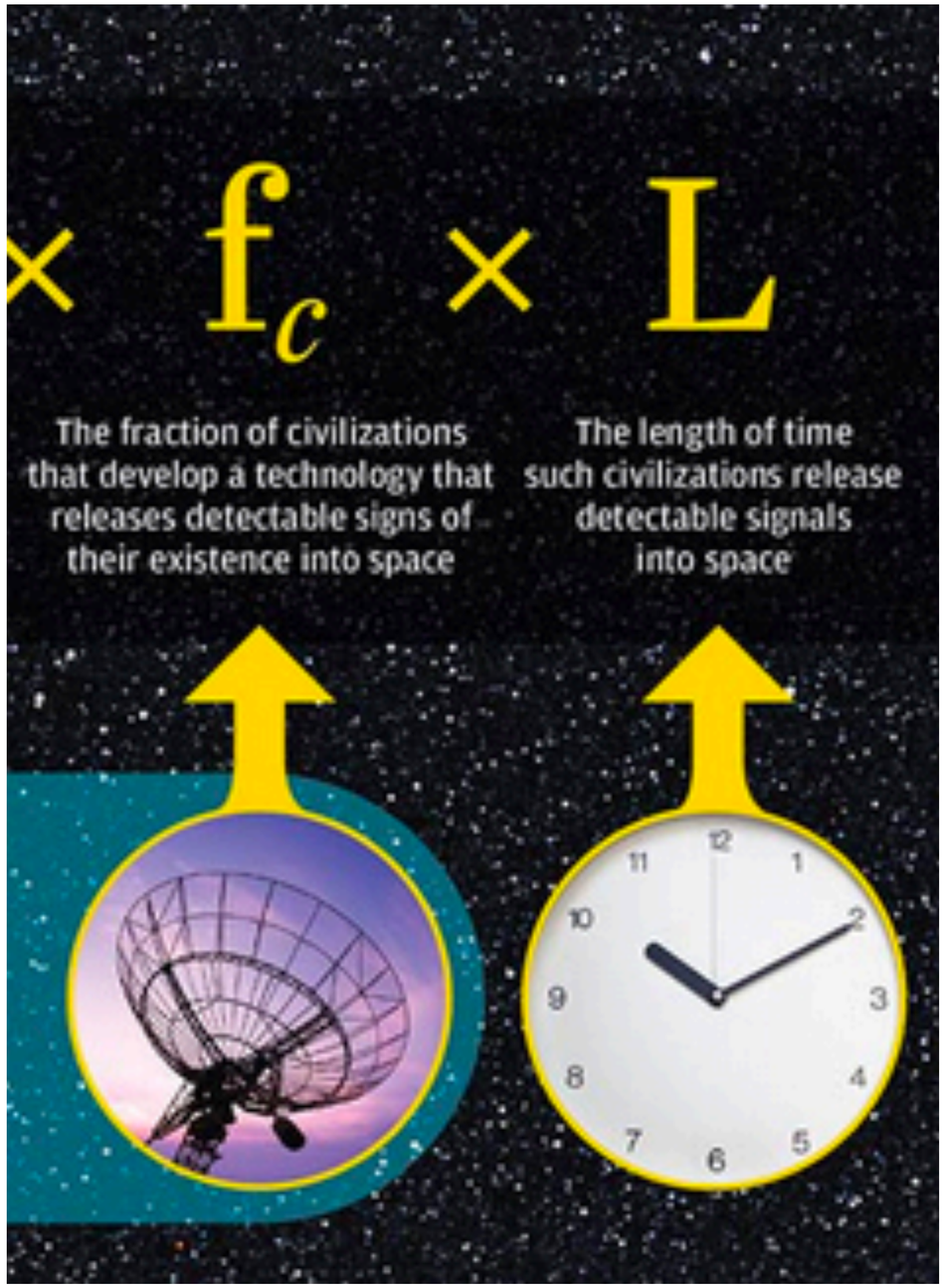
D) 0.001: it happens 1/1000 times

What do you think is the fraction of life-bearing planets on which intelligent life emerges?

A) 1: all planets form intelligent life

B) 0.01: it happens about 1% of the time

C) 0.0001: it happens 1/10,000 times.



f_c —> fraction of civilizations that develop a technology that releases detectable signs of their existence into space

L —> length of time such civilizations release those signals (their lifetime)

What do you think is the fraction of civilizations that develop a technology that releases detectable signs of their existence into space?

A) 1: all civilizations develop this technology

B) 0.01: it happens about 1% of the time

C) 0.0001: it happens 1/10,000 times.

How long do these civilizations live?

fraction of technological civilizations
around: lifetime of civilization/10^{10} years

A) 100 years —> 10^{-8}

B) 1,000 years —> 10^{-7}

C) 100,000 years —> 10^{-5}

D) 10,000,000 years —> 10^{-3}

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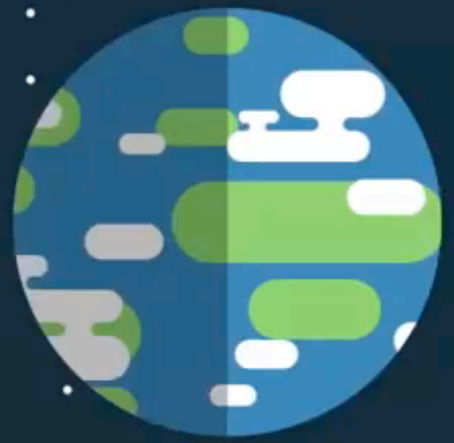
Complete feedback survey to get grade early!

Mirna review session: tomorrow from 3-6pm in AEB 320

Galaxy Quest (1999) still frame, Goblin Valley State Park

So, where are they?
The Fermi Paradox

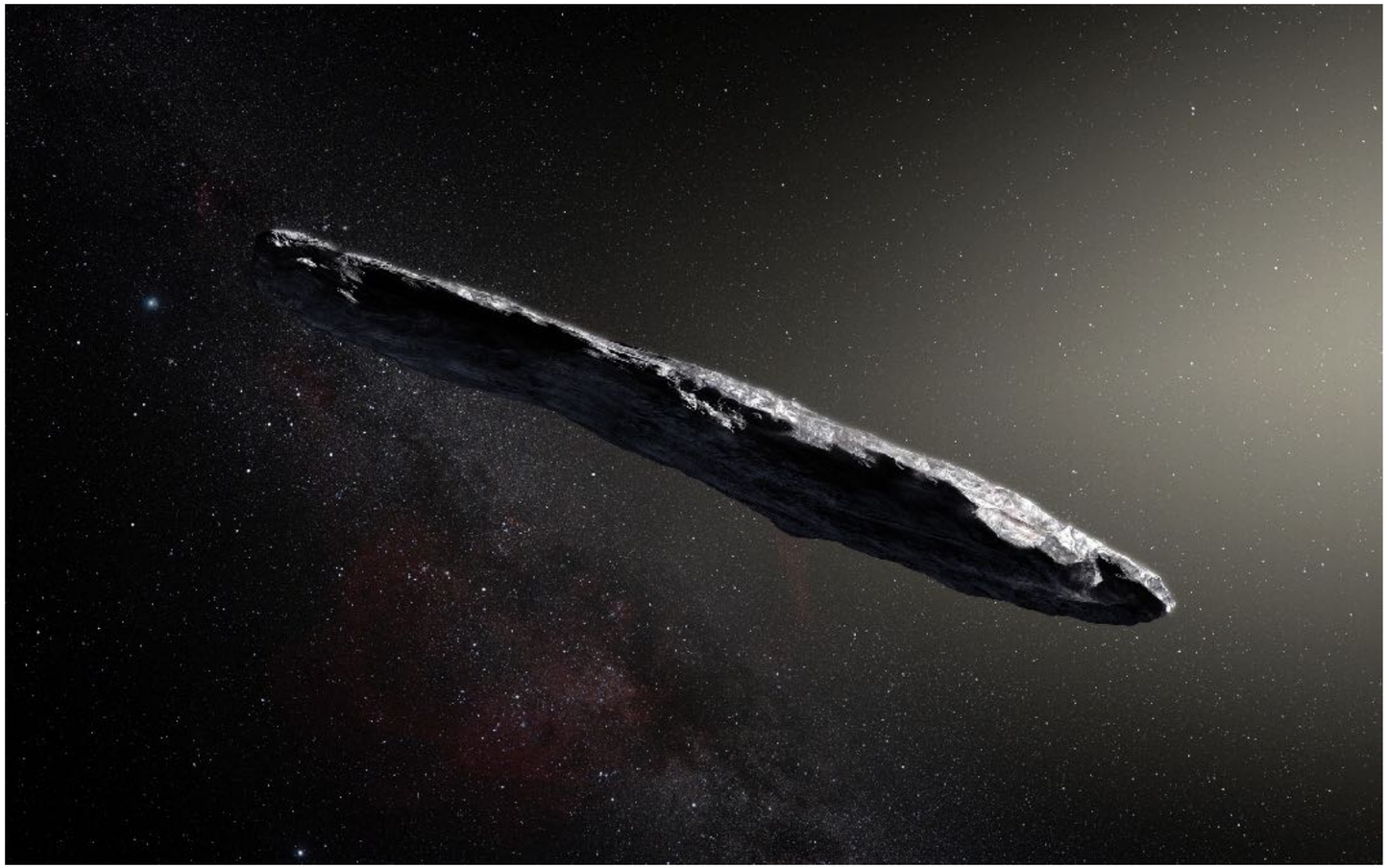
https://www.youtube.com/watch?v=sNhhvQGsMEc



What are some solutions to the Fermi Paradox?

https://www.youtube.com/watch?v=1fQkVqno-uI

‘Oumuamua: alien comet or space probe?!?



Artist’s impression of the object: ESO/M. Kornmesser

On an unbound orbit, about the speed stars move relative to each other

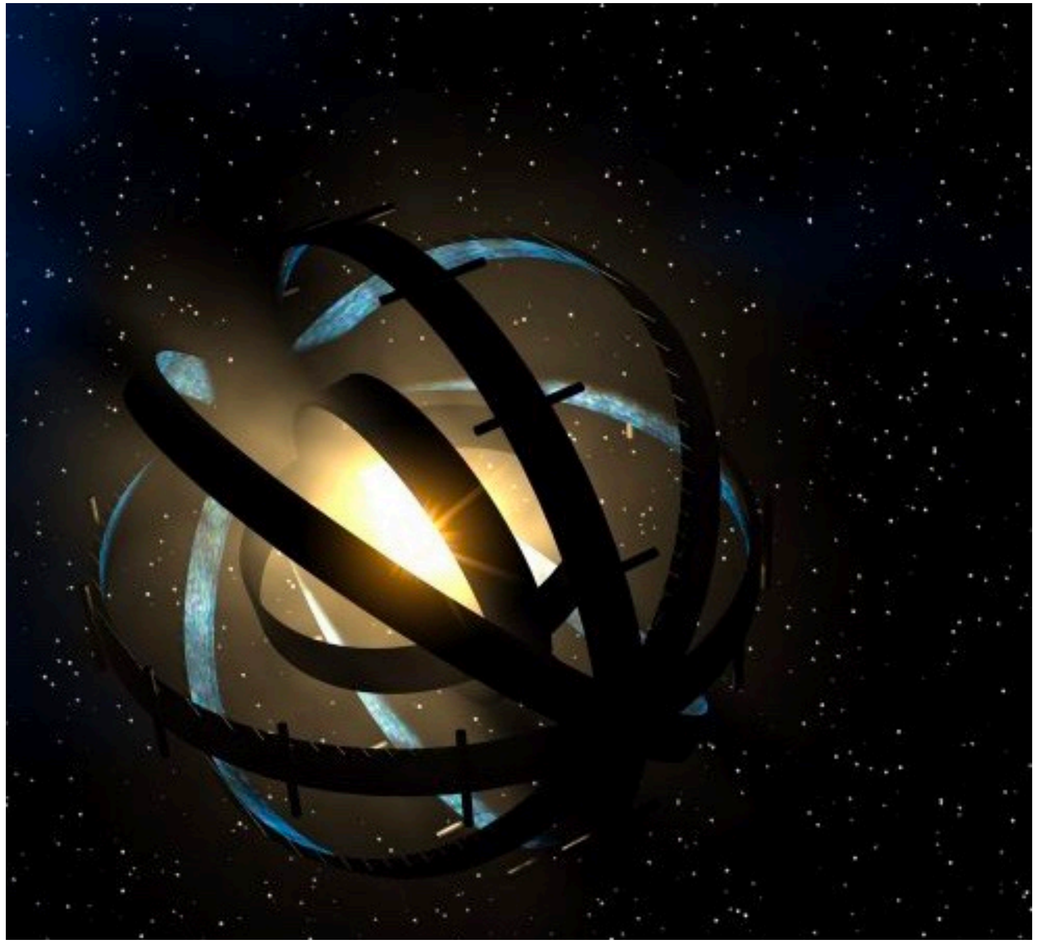
Size uncertain, but likely more cigar shaped spheroidal

Found to be accelerating away from the Sun as it left the solar system

Could it be an alien probe checking us out? Using a solar sail as propulsion?

Or is it just a rock from another star system (possibly carrying microscopic life)?

Dyson Spheres



Artist's conception of a Dyson Sphere (CapnHack)
https://earthsky.org/space/what-is-a-dyson-sphere

More correctly called a Stapleton Sphere, after Olaf Stapleton whose 1937 novel Star Maker inspired Freeman Dyson to propose the search for such objects

Kardeshev Type II civilization: harnesses all the power of its star

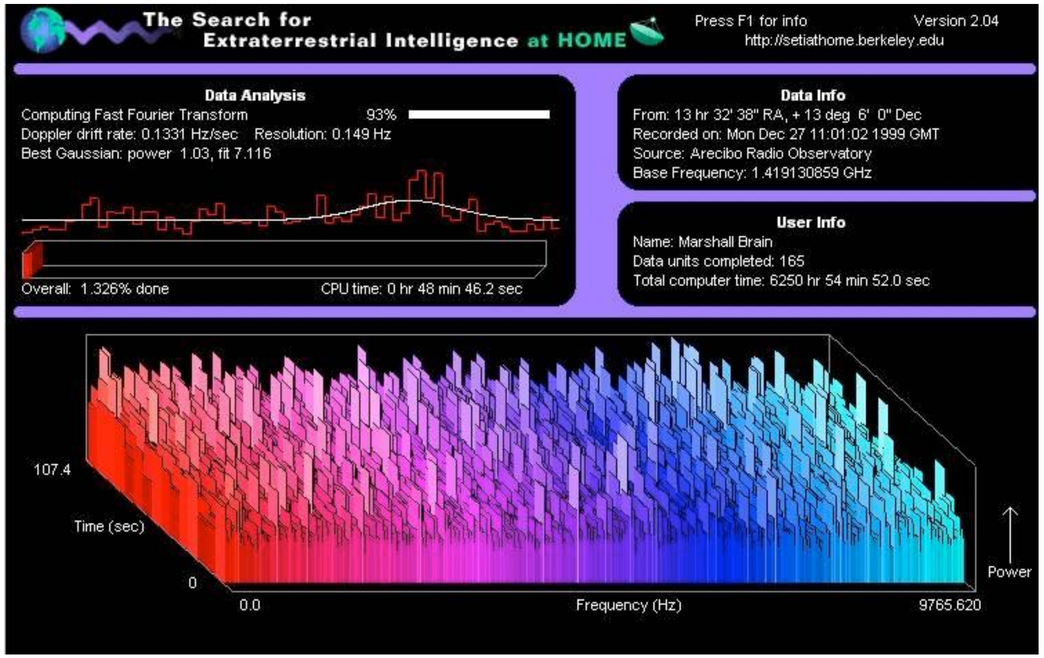
Can search for galaxies with "too much" IR light: sphere would emit waste heat —
no evidence of substantial structures yet found

Tabby's star (discovered with Kepler) — alien megastructures or dust? (spoiler, dust)

Kardeshev Type III+ civilization could capture stars with these spheres, out to a distance of 10s of millions of light years away, in an attempt to forestall lack of resources due to dark energy

SETI: Search for Extraterrestrial Intelligence

Contact (1997) movie still frame



Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every "superstar", every "supreme leader", every saint and sinner in the history of our species lived there - on a mote of dust suspended in a sunbeam.

The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors so that, in glory and triumph, they could become the momentary masters of a fraction of a dot. Think of the endless cruelties visited by the inhabitants of one corner of this pixel on the scarcely distinguishable inhabitants of some other corner, how frequent their misunderstandings, how eager they are to kill one another, how fervent their hatreds.

Our posturings, our imagined self-importance, the delusion that we have some privileged position in the Universe:, are challenged by this point of pale light. Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity, in all this vastness, there is no hint that help will come from elsewhere to save us from ourselves.

The Earth is the only world known so far to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit, yes. Settle, not yet. Like it or not, for the moment the Earth is where we make our stand.

It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known.

-Carl Sagan (1934-1996)