



ASTR/PHYS 1060: The Universe

Chapter 18: Life in the Universe

Midterms up front

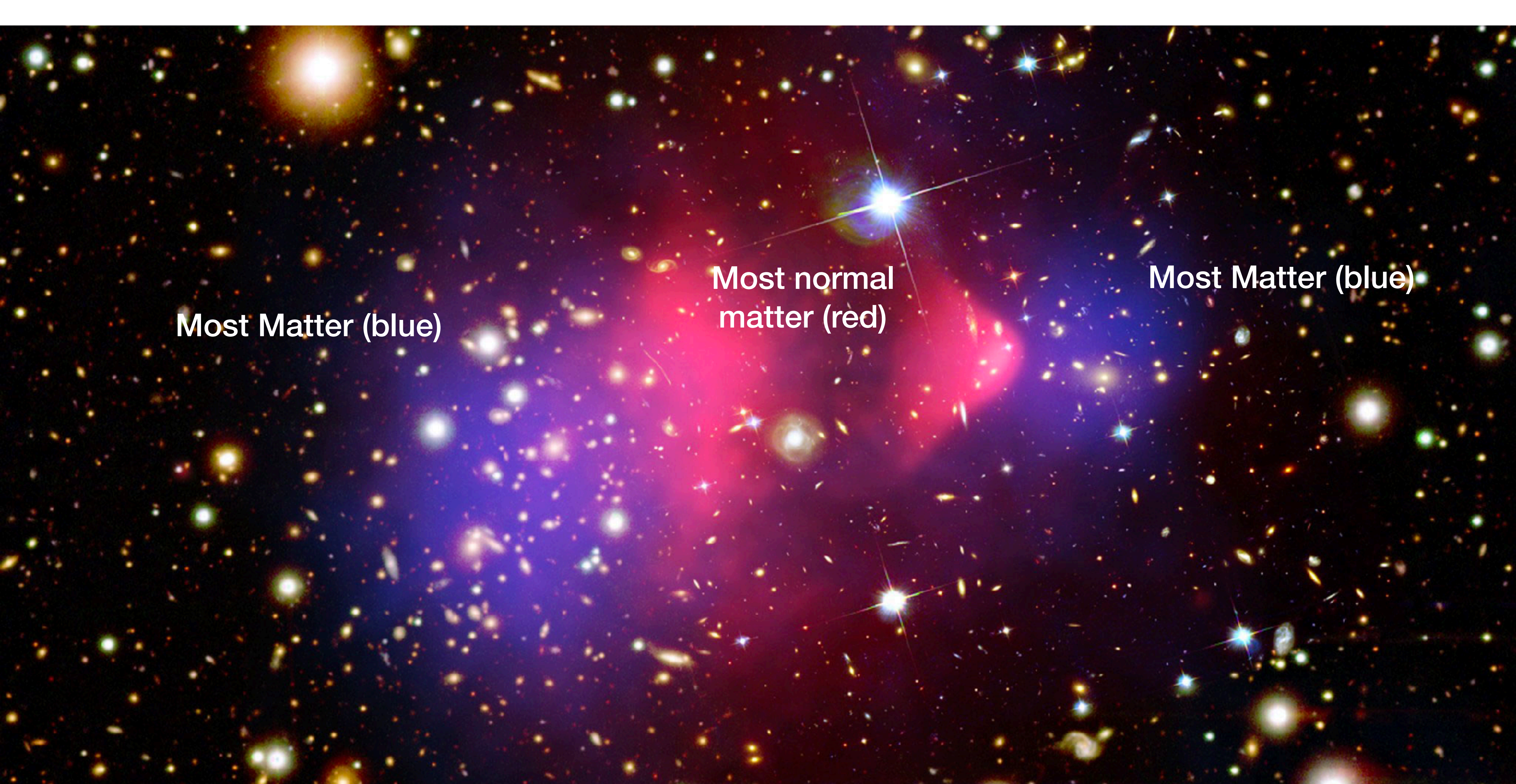
All EC due December 5th

Check your grades in Canvas!

Complete feedback survey to get grade early!



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

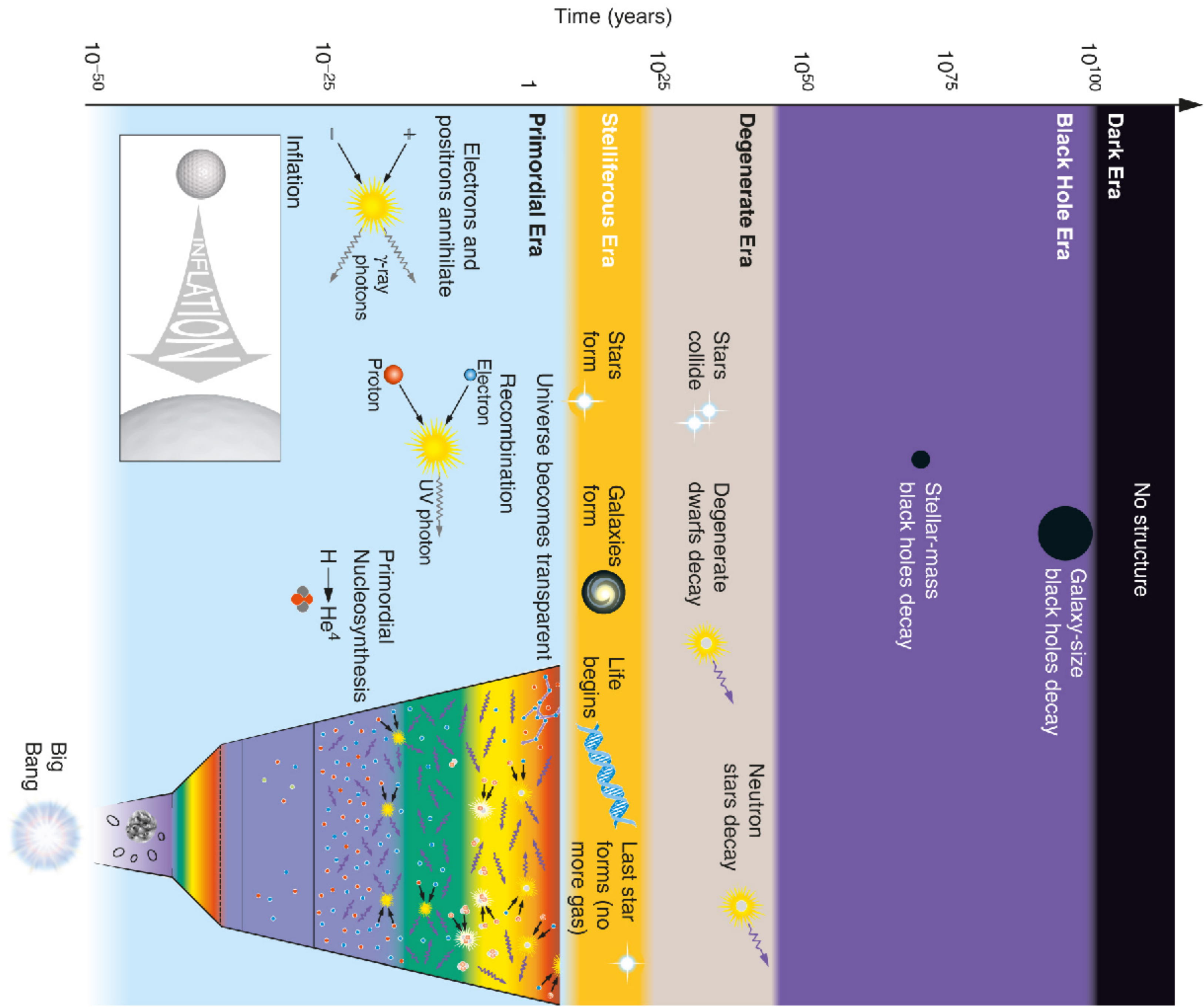


Most Matter (blue)

Most normal
matter (red)

Most Matter (blue)

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

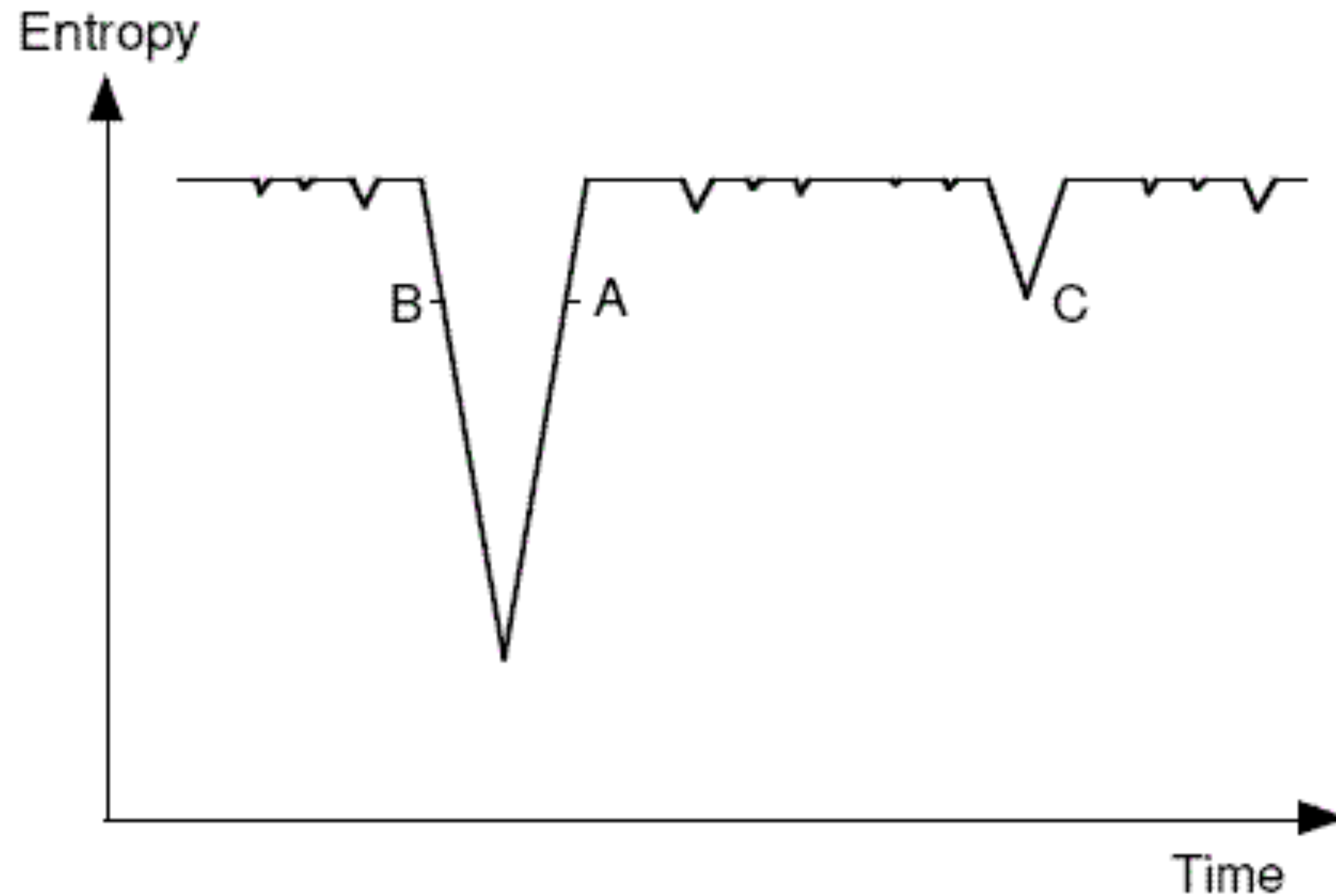


Figure 1. Boltzmann's entropy curve.

Life in the Stelliferous Era

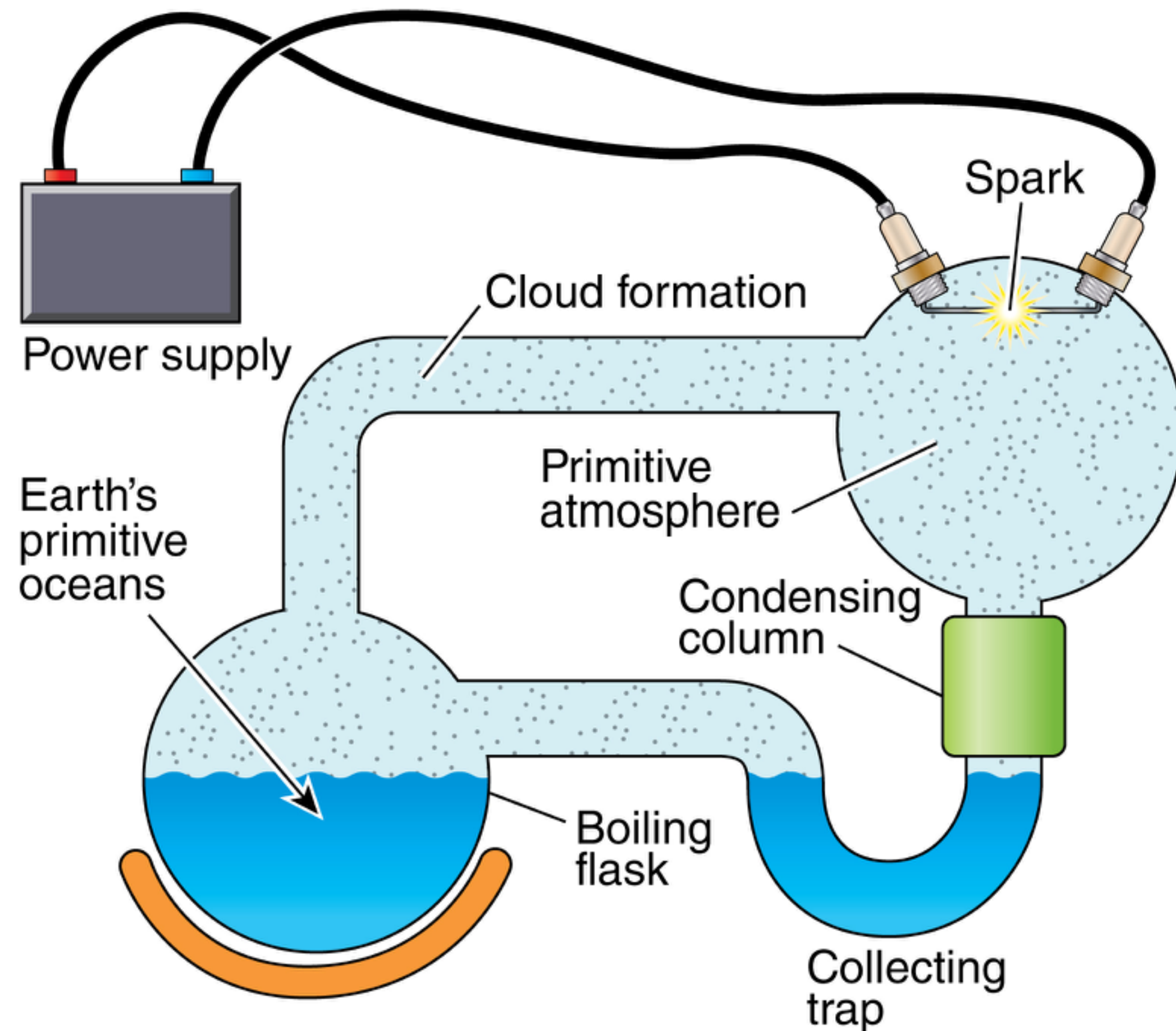
What is life?

What are the conditions necessary for life?

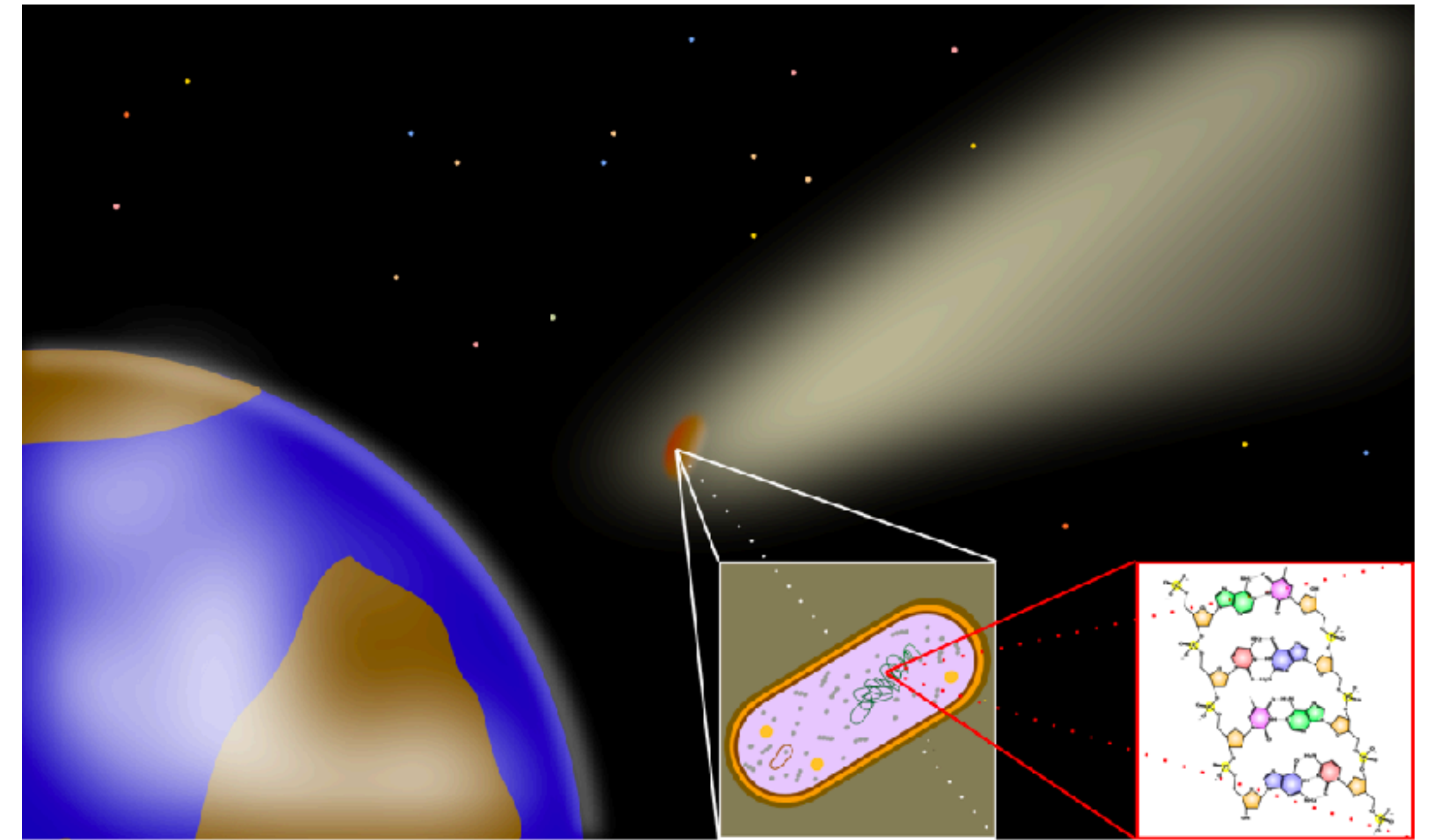
How does life become more complex?

Only have 1 example to work from — life on Earth

Origin of life unclear, but arises quickly



Panspermia: life delivered by comets, or ancient aliens?



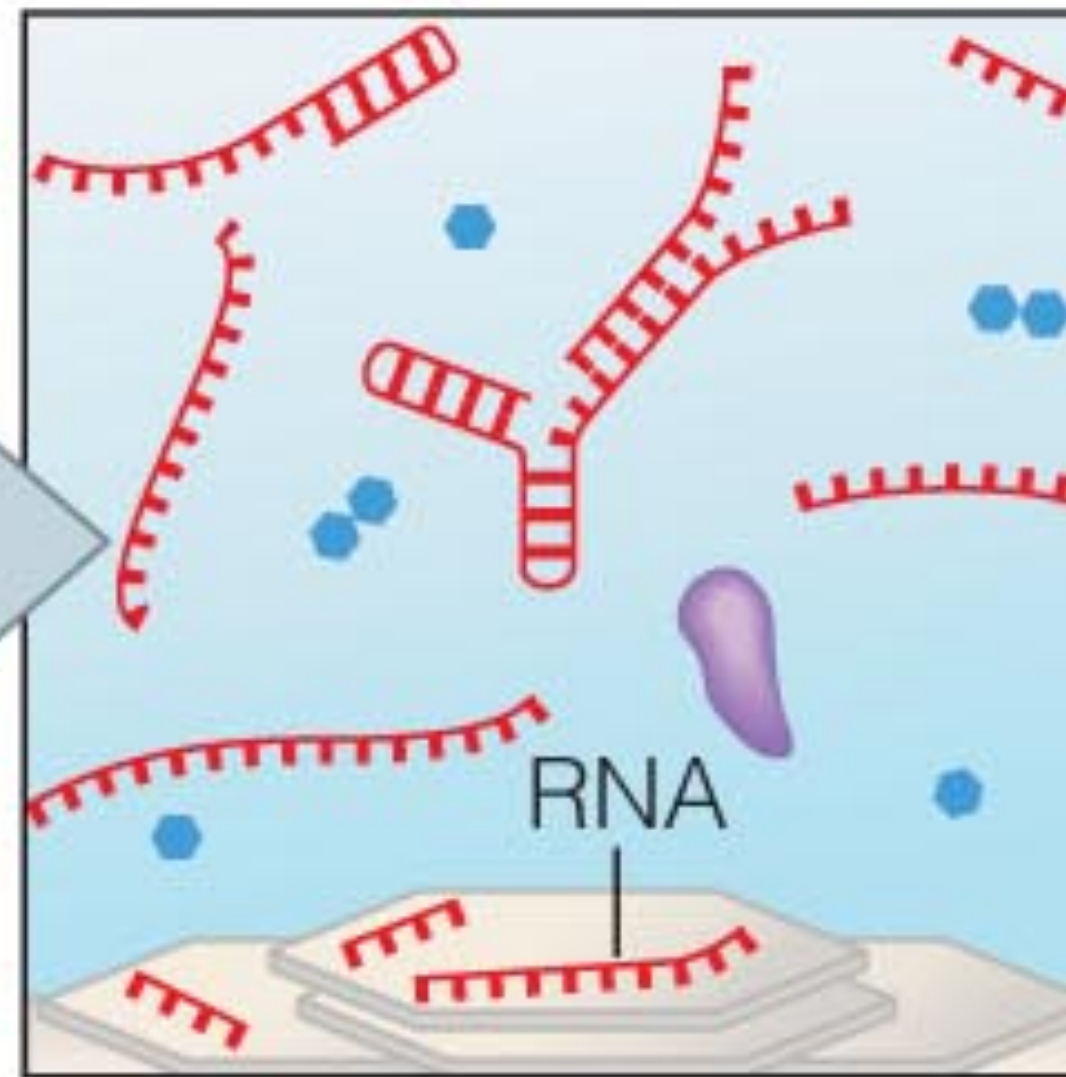
Miller-Urey Experiment: amino acids created from simple molecules (methane, ammonia, water) and simulated lightning strikes

Self-replicating molecules spread, compete

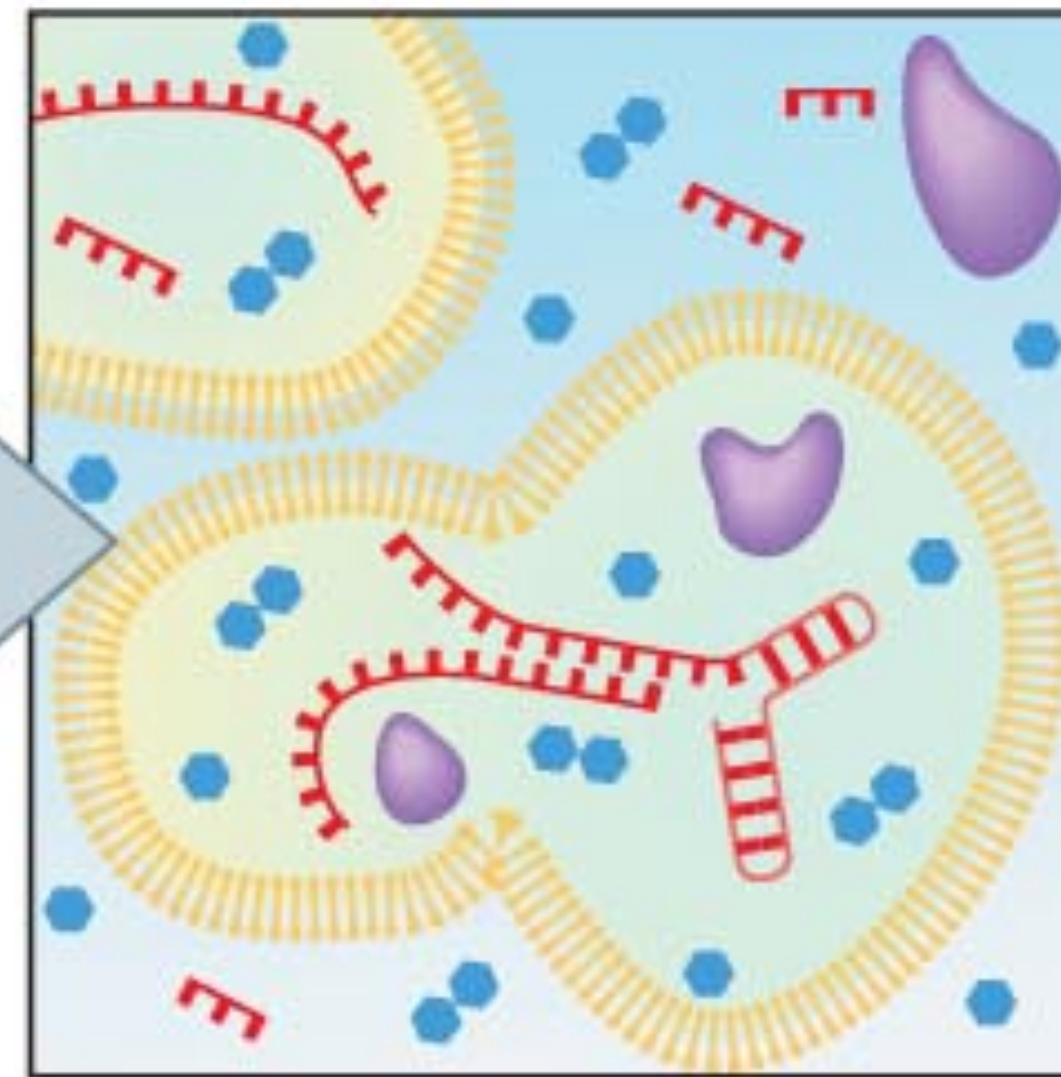
1. Organic precursor molecules appear.



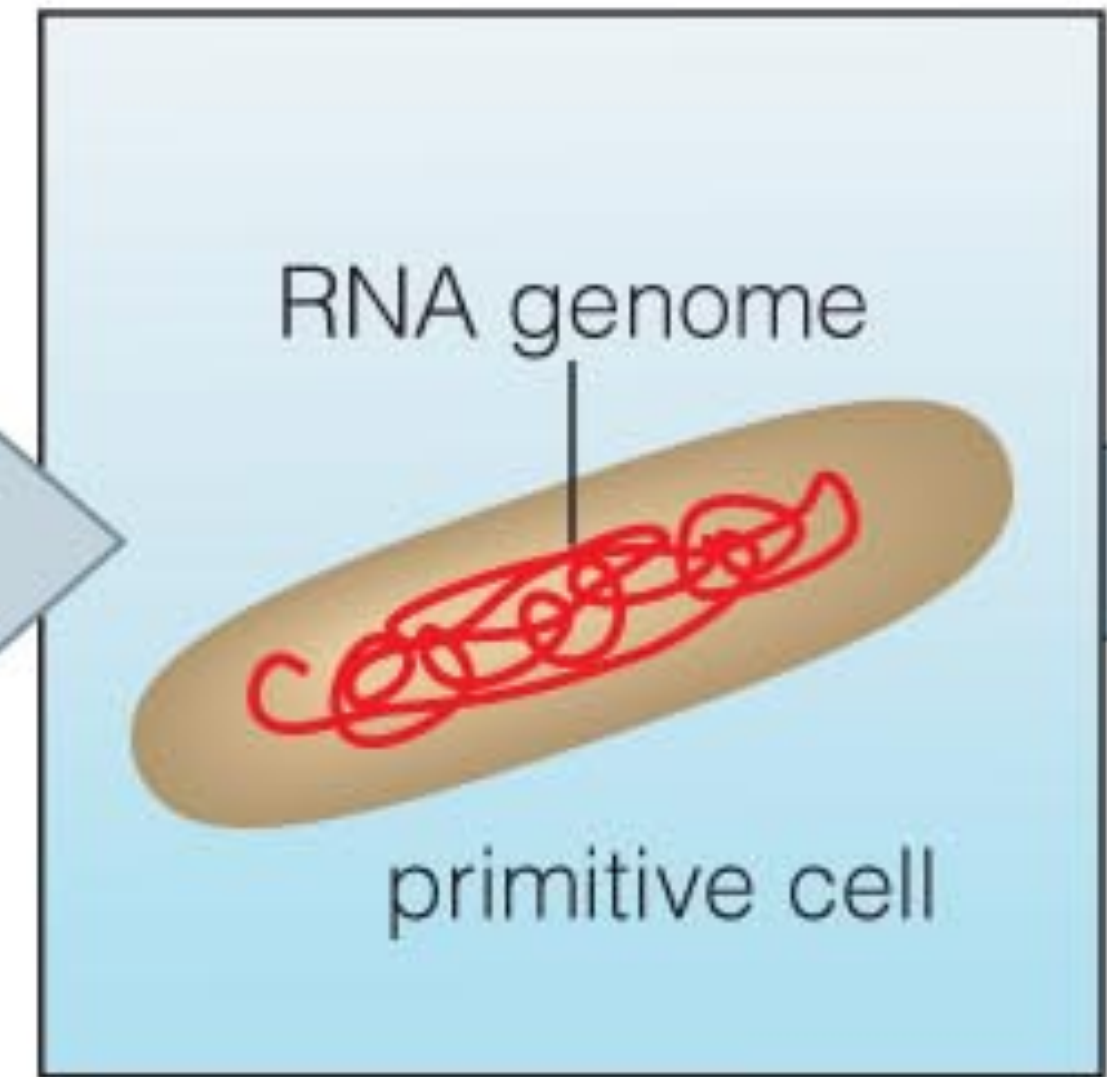
2. RNA molecules become self-replicating.



3. Membrane-enclosed pre-cells arise.

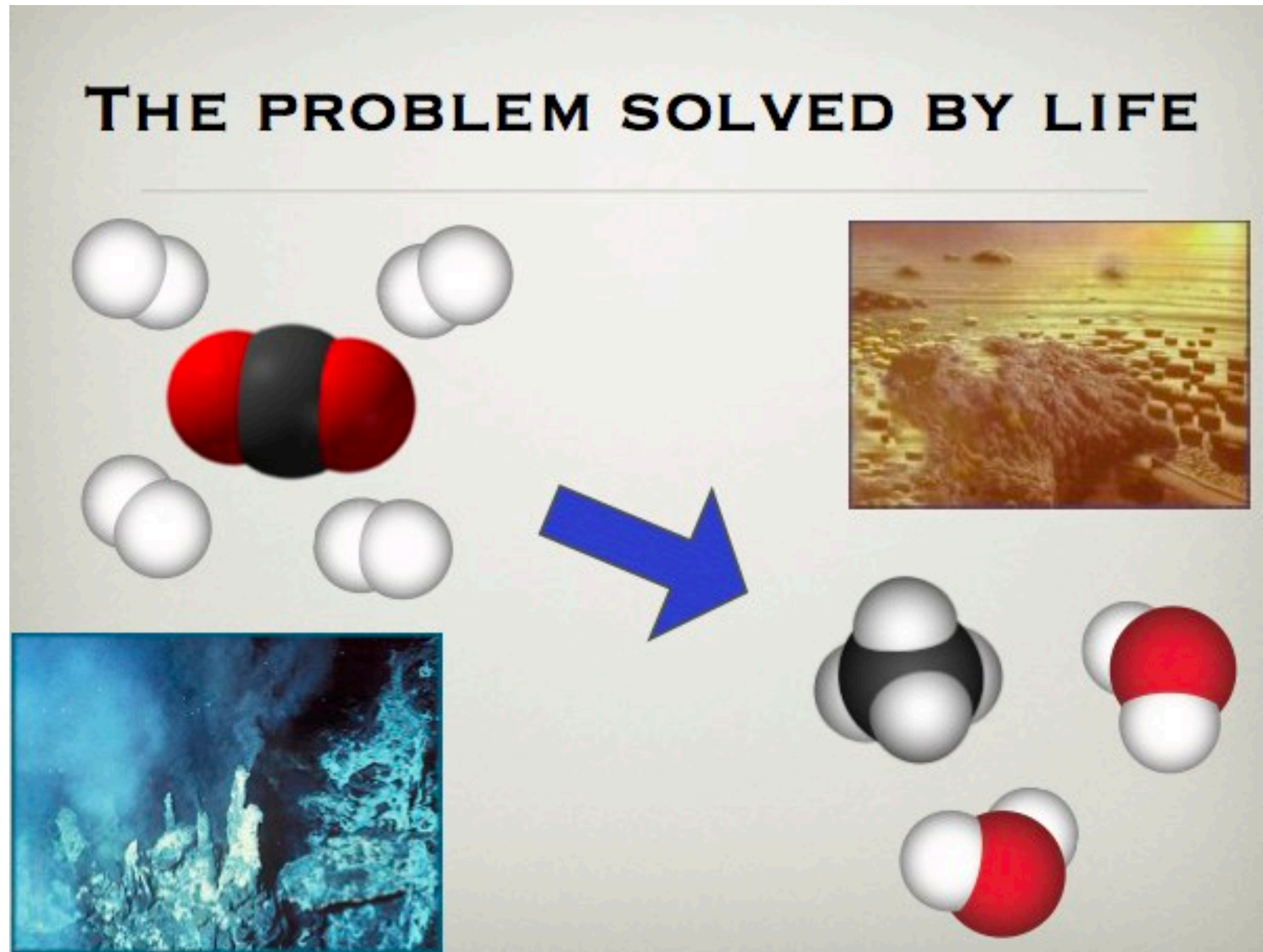


4. True cells with RNA genome appear.



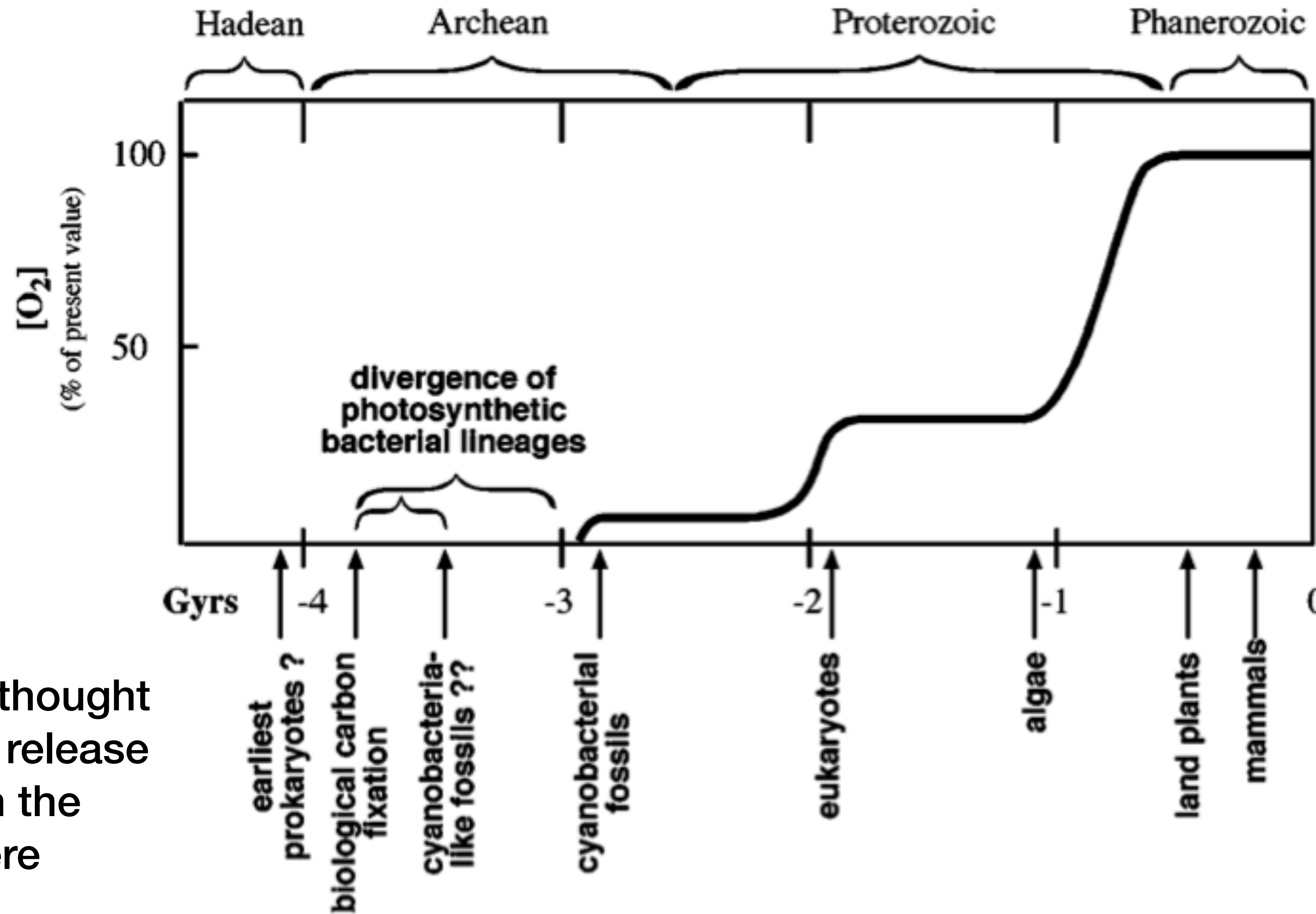
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**Alternative
view: life is a
catalyst to
convert CO₂
to
hydrocarbons**




<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



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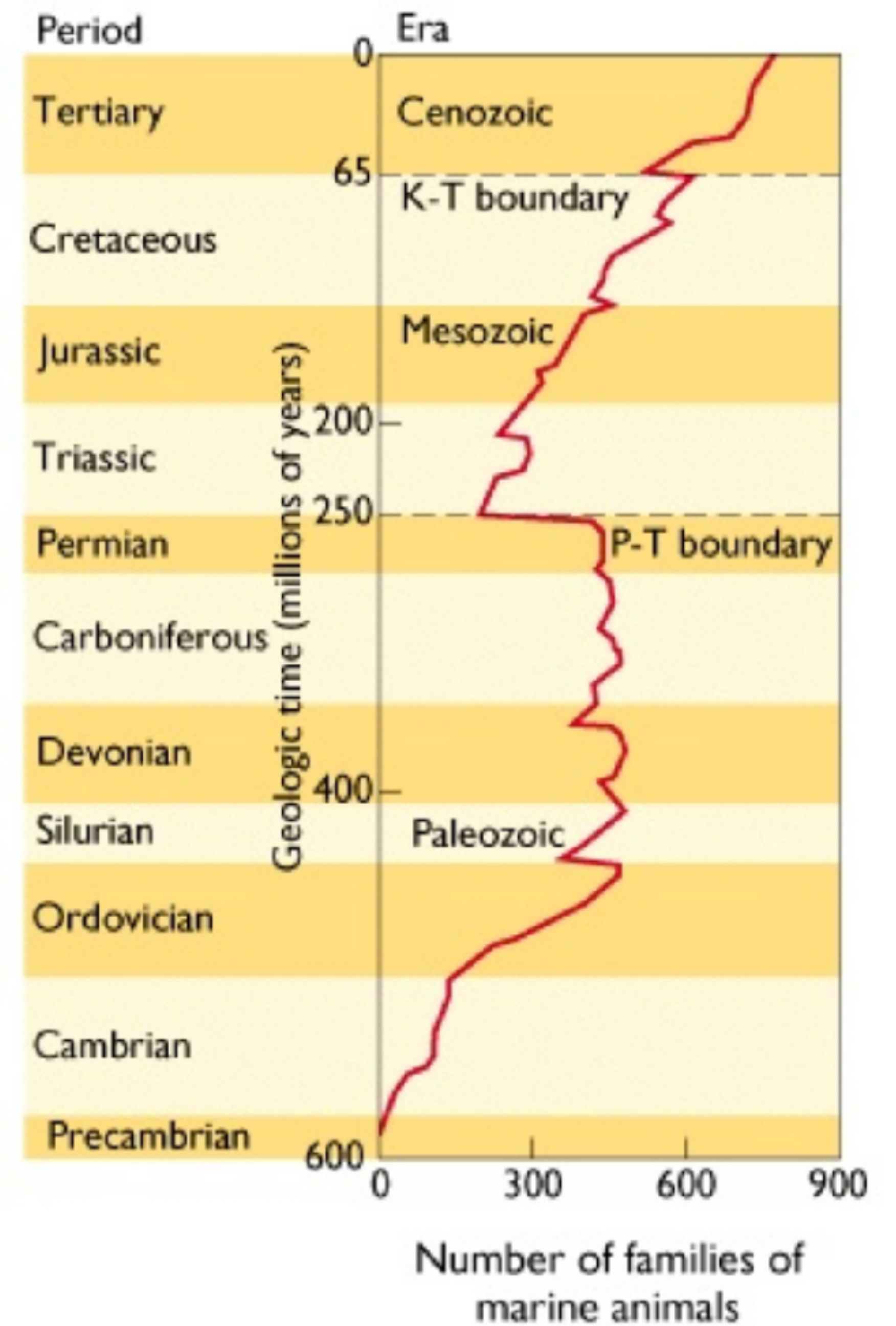
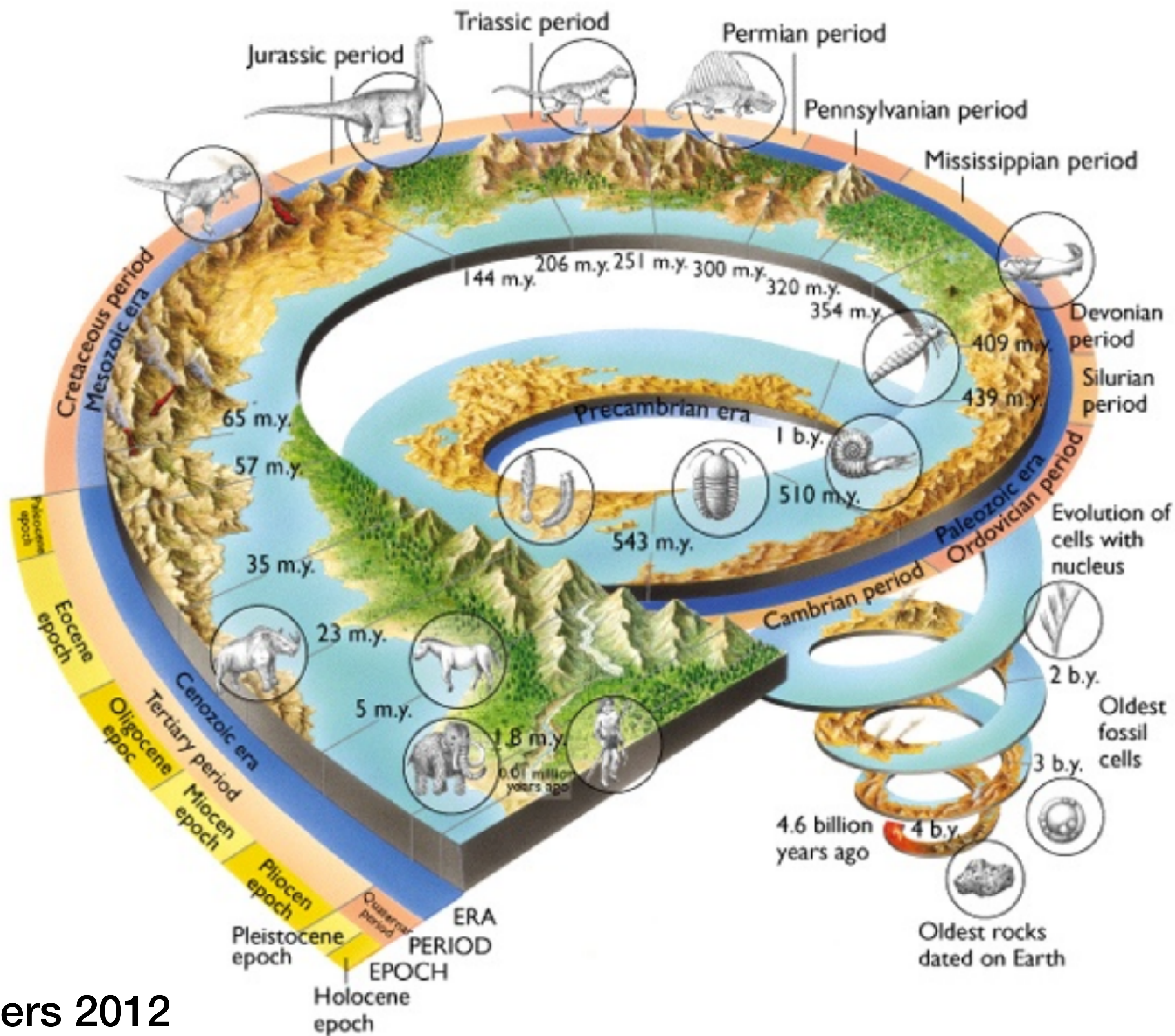
All EC due Wednesday

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

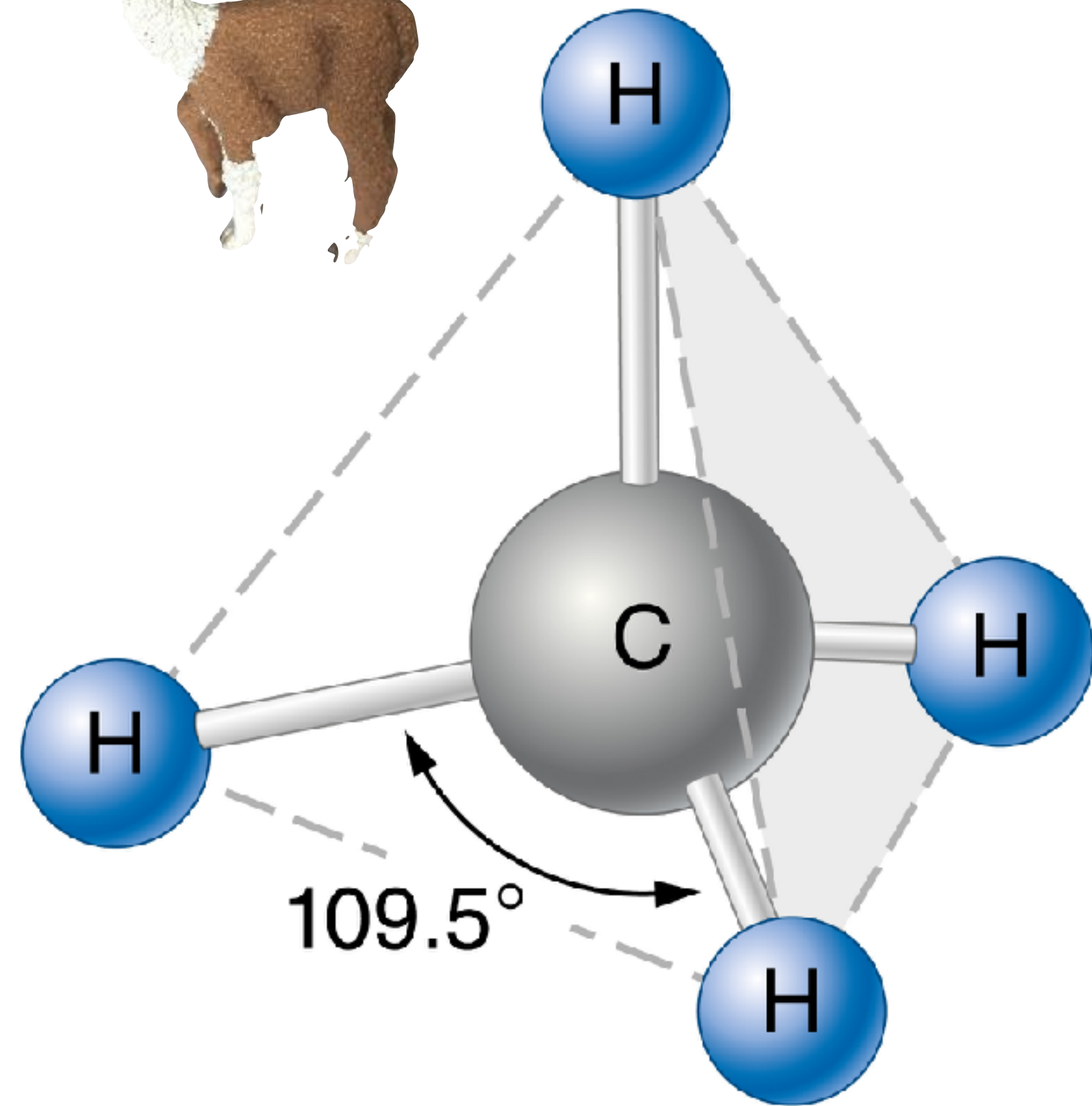


Olbers 2012

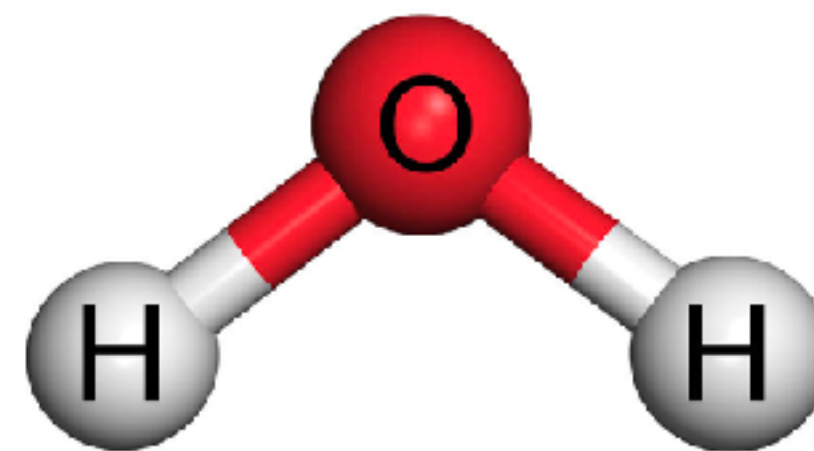
Complex life is likely to be carbon-based



1 H	big bang fusion										cosmic ray fission					2 He		
3 Li	4 Be	merging neutron stars					exploding massive stars					5 B	6 C	7 N	8 O	9 F	10 Ne	
11 Na	12 Mg	dying low mass stars					exploding white dwarfs					13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
55 Cs	56 Ba	72 Hf			73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra																	



Methane tetrahedron

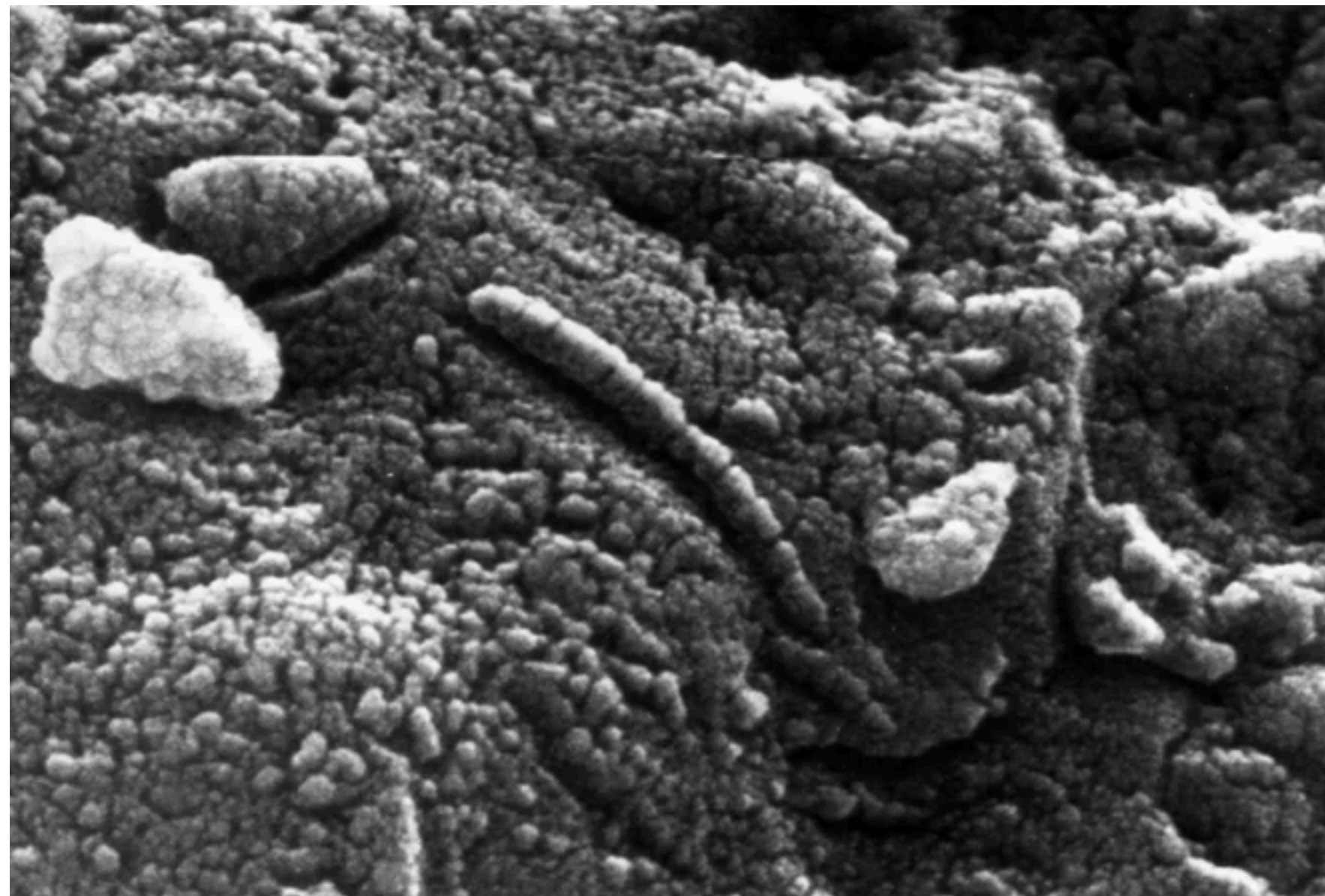


Water Solvent!

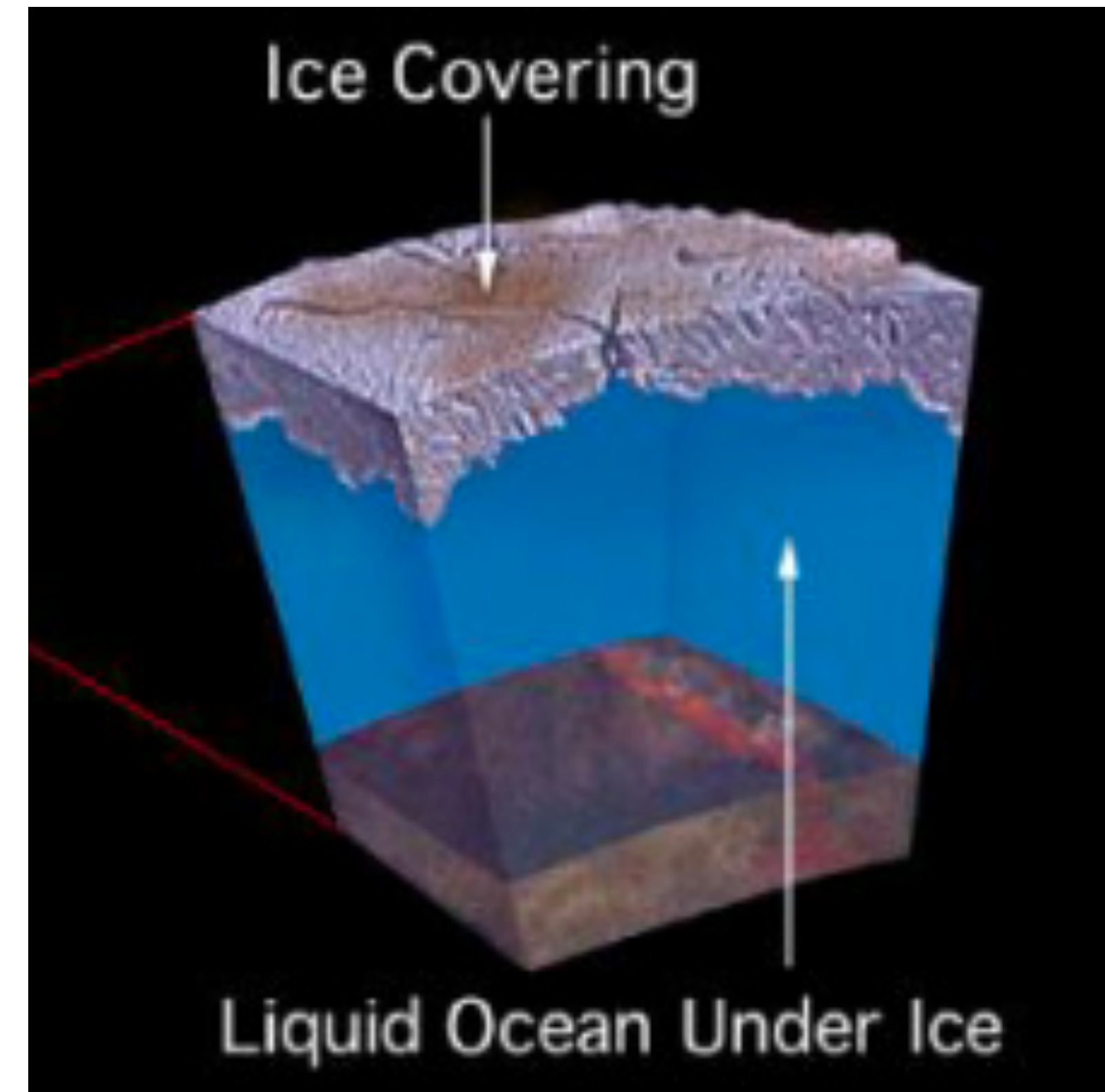
- Life needs:
- organic molecules
 - water
 - energy

Actively searching for life elsewhere in the solar system

Martian meteorite

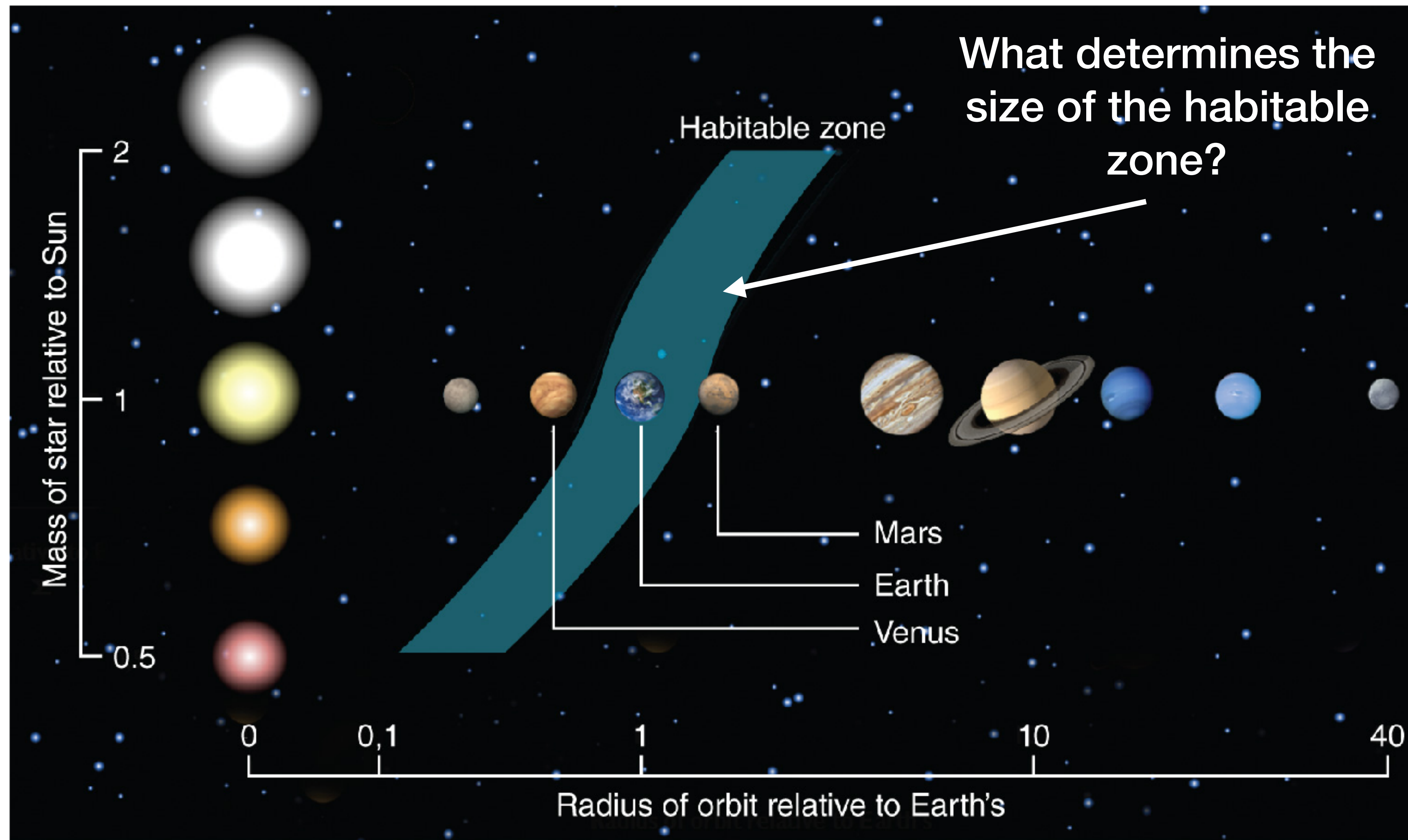


Oceans under ice of Jupiter's moons
Europa and Enceladus



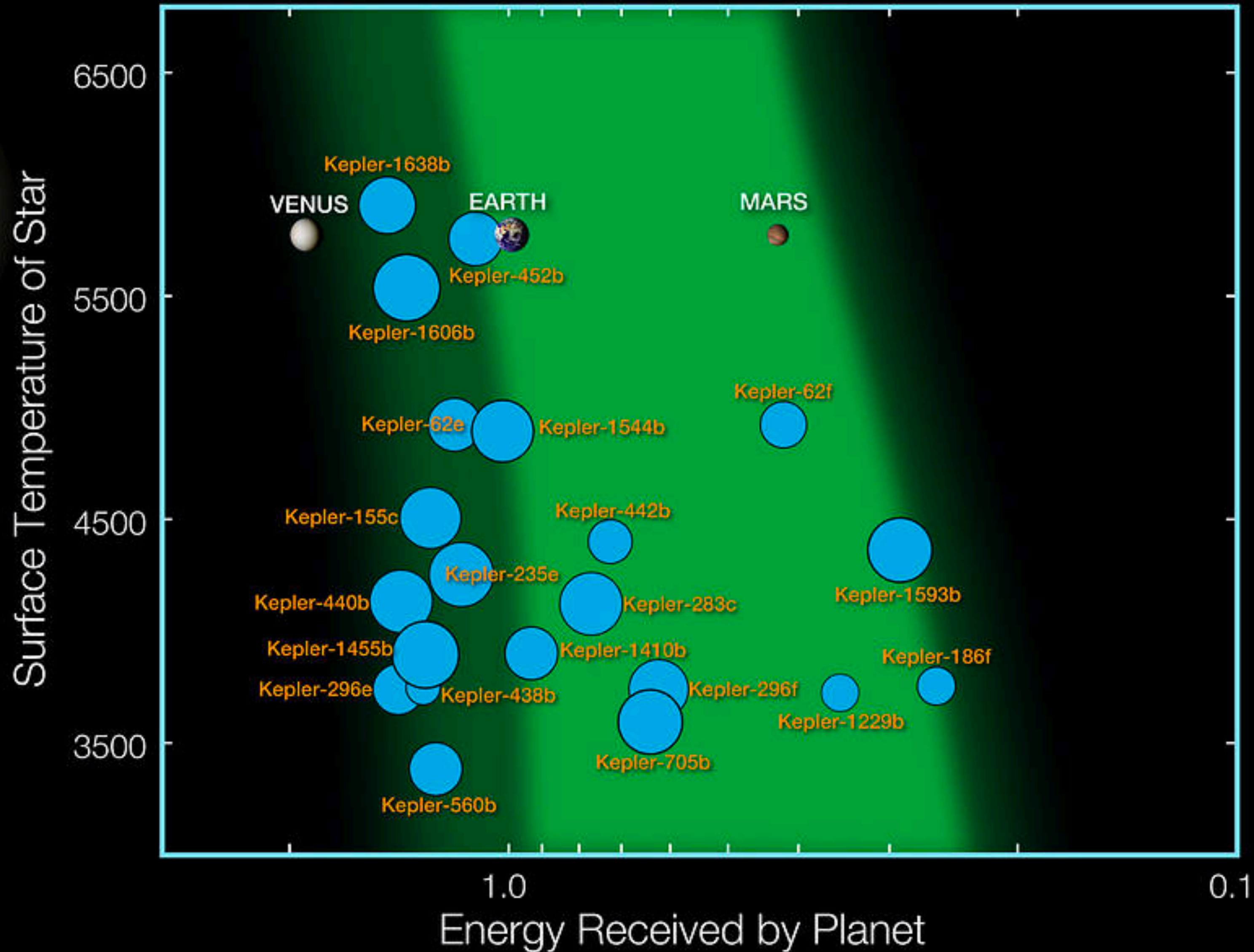
Beginning the search outside the solar system

Where should we look?

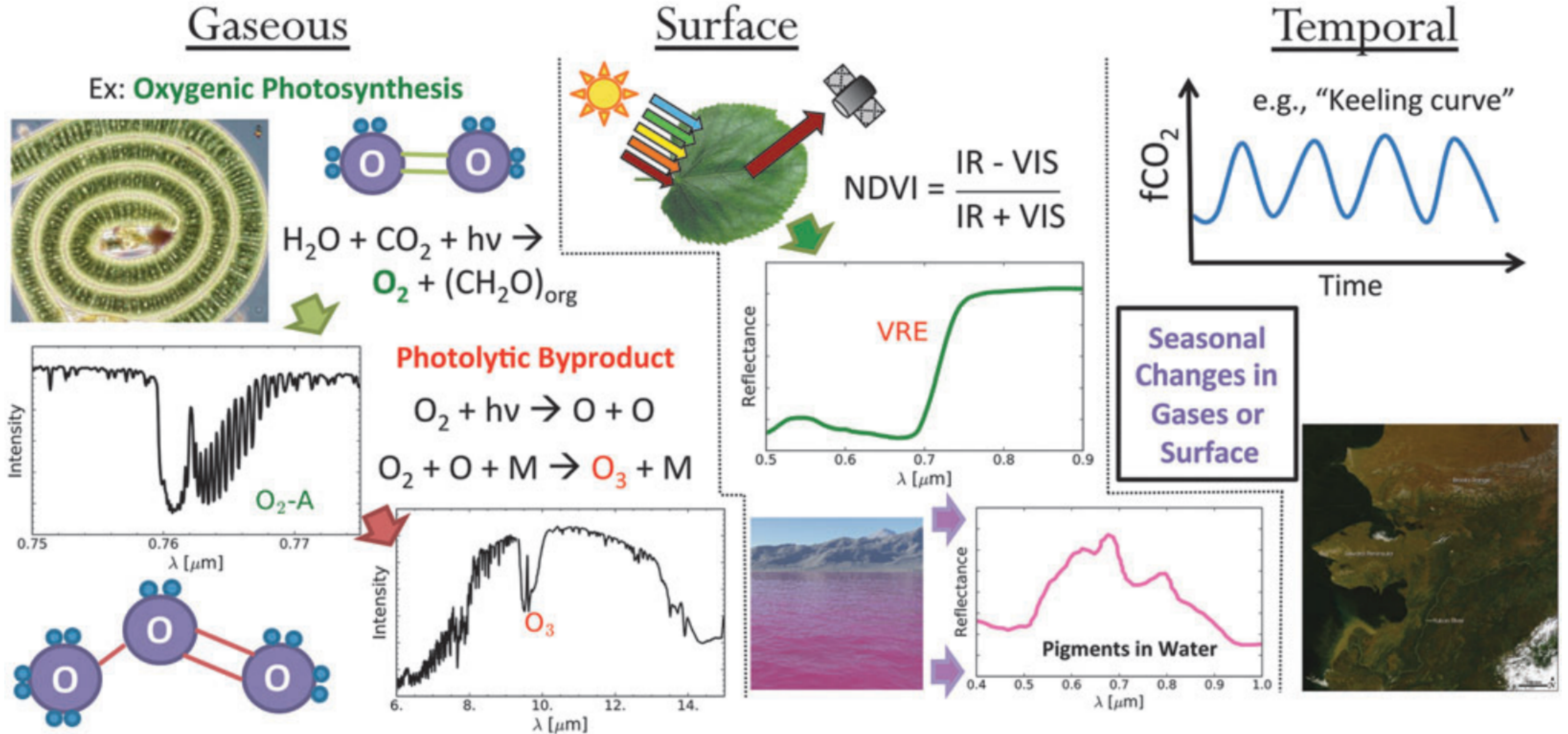


Kepler's Small Habitable Zone Planets

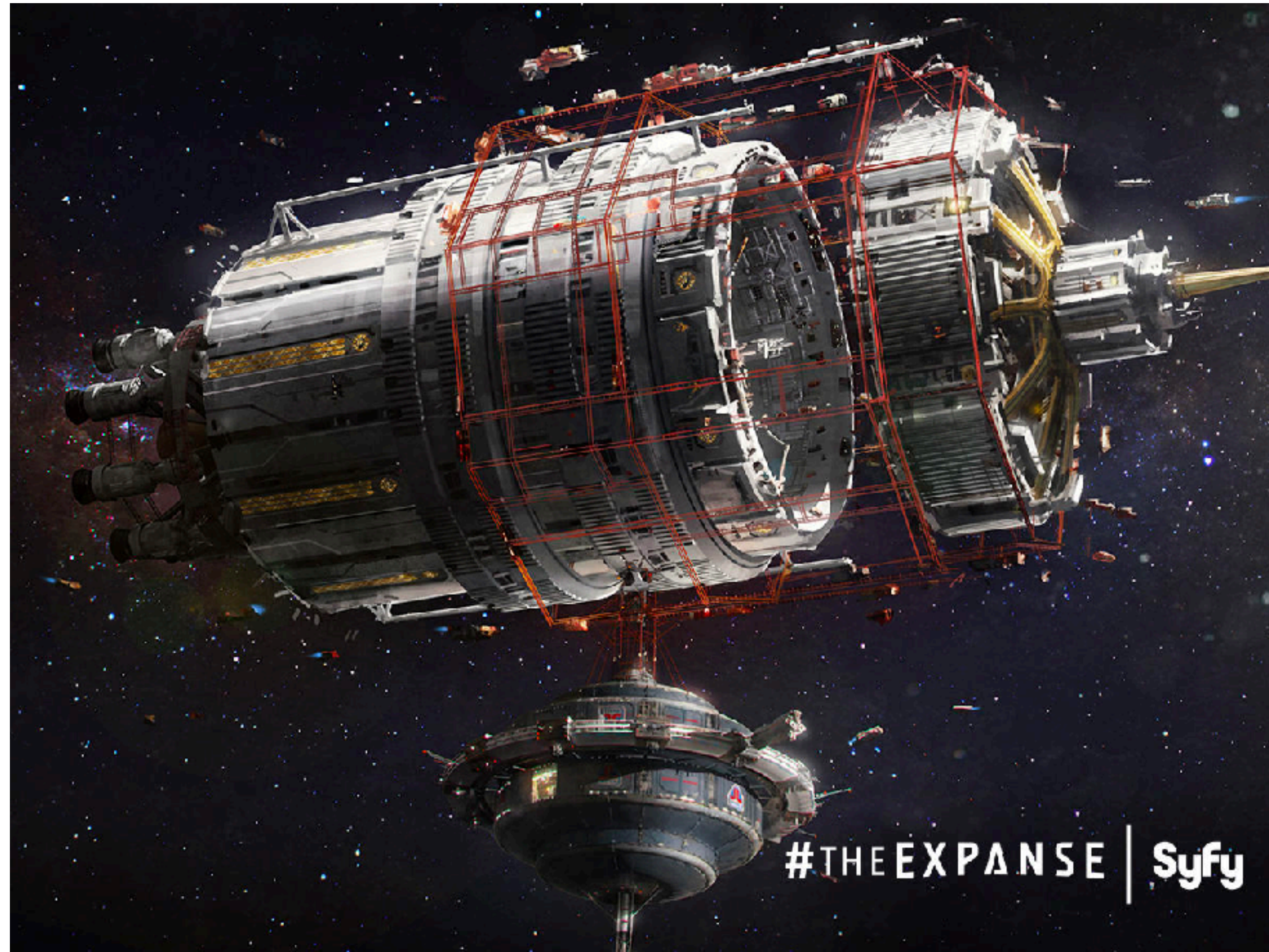
As of May 10, 2016



Biosignatures of Life in an Exoplanet Atmosphere



What if we find a nearby planet with life?

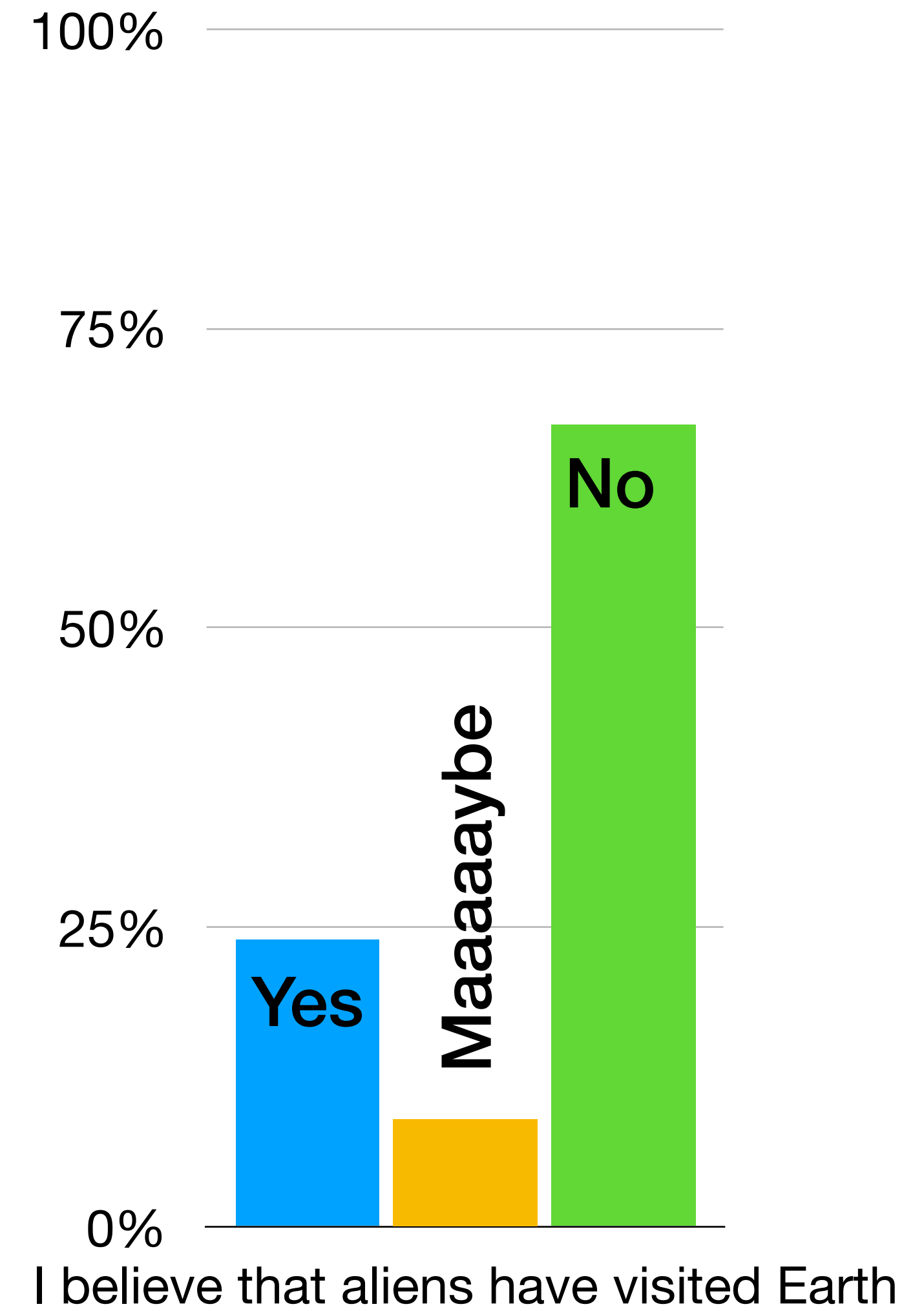
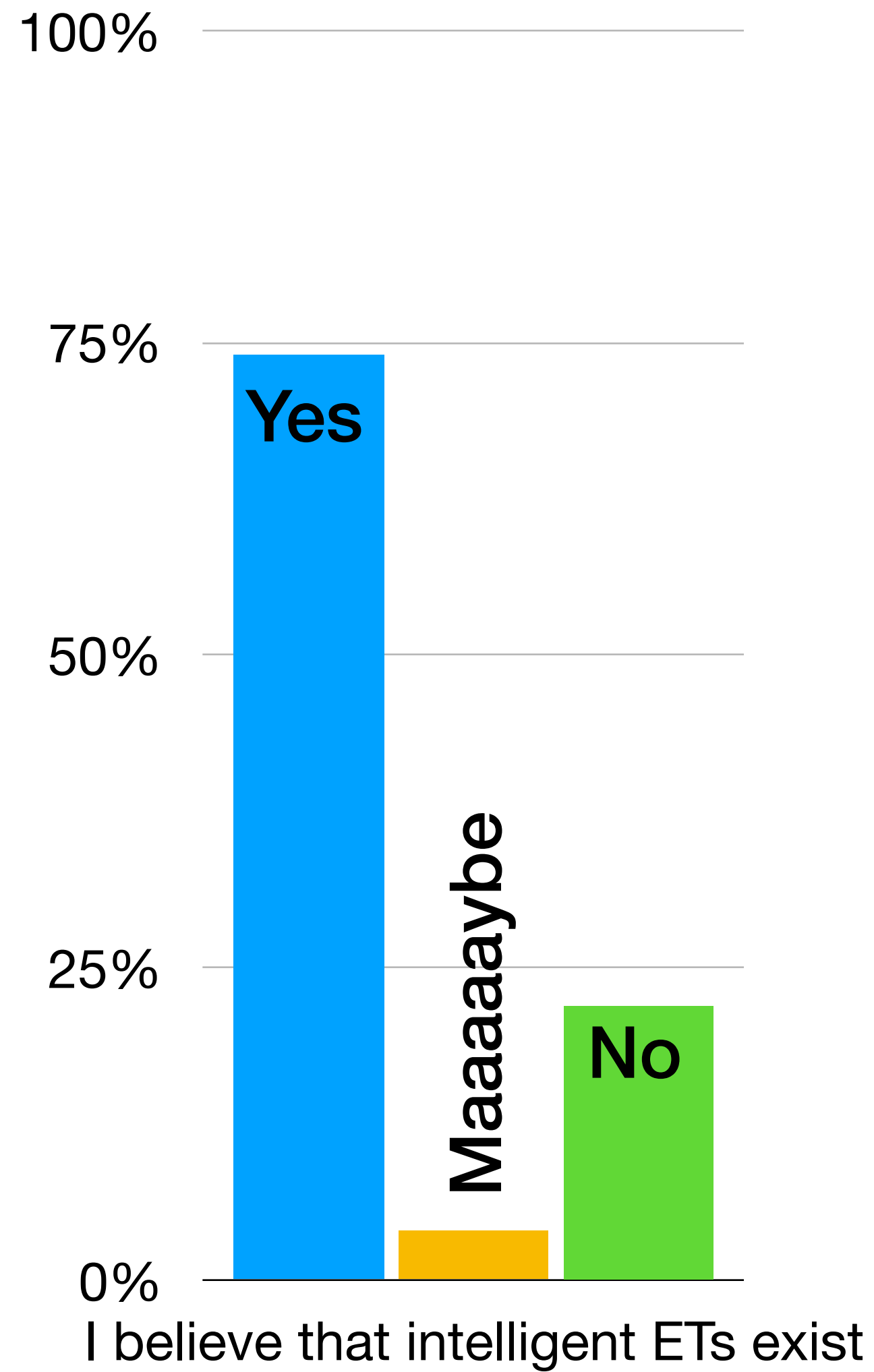


The Nauvoo: a generation ship

- Current world energy consumption: 4.7×10^{20} joules/year
- Energy = $\frac{1}{2} * \text{mass} * \text{velocity}^2$
- 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?

Are there intelligent aliens out there?



$$N = R_{*} \times f_p \times n_e \times f_e \times f_i \times f_c \times L$$

The number of technologically advanced civilizations in the Milky Way galaxy

The rate of formation of stars in the galaxy

The fraction of those stars with planetary systems

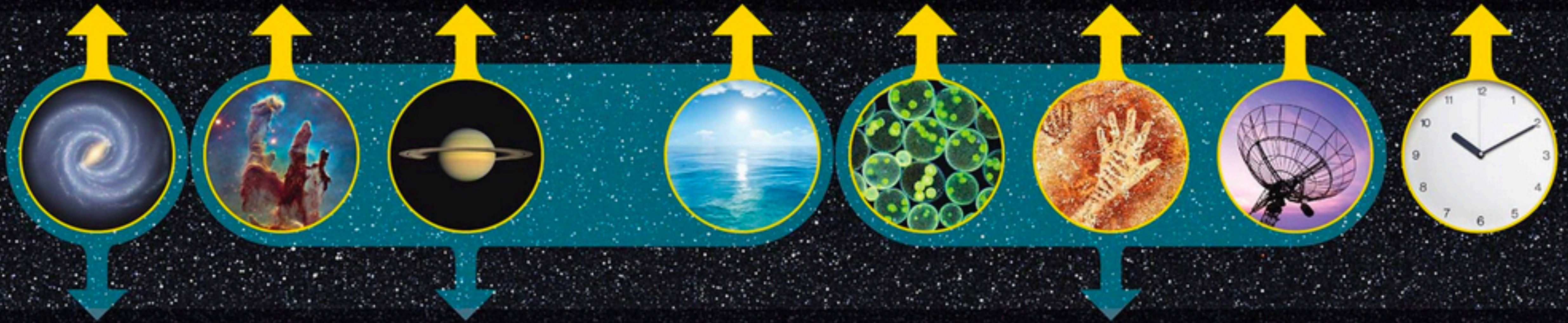
The number of planets, per solar system, with an environment suitable for life

The fraction of suitable planets on which life actually appears

The fraction of life-bearing planets on which intelligent life emerges

The fraction of civilizations that develop a technology that releases detectable signs of their existence into space

The length of time such civilizations release detectable signals into space



$$A = N_{ast} \times f_{bt}$$

The number of technological species that have formed over the history of the observable universe

The number of habitable planets in a given volume of the universe

The likelihood of a technological species arising on one of these planets

The Drake Equation

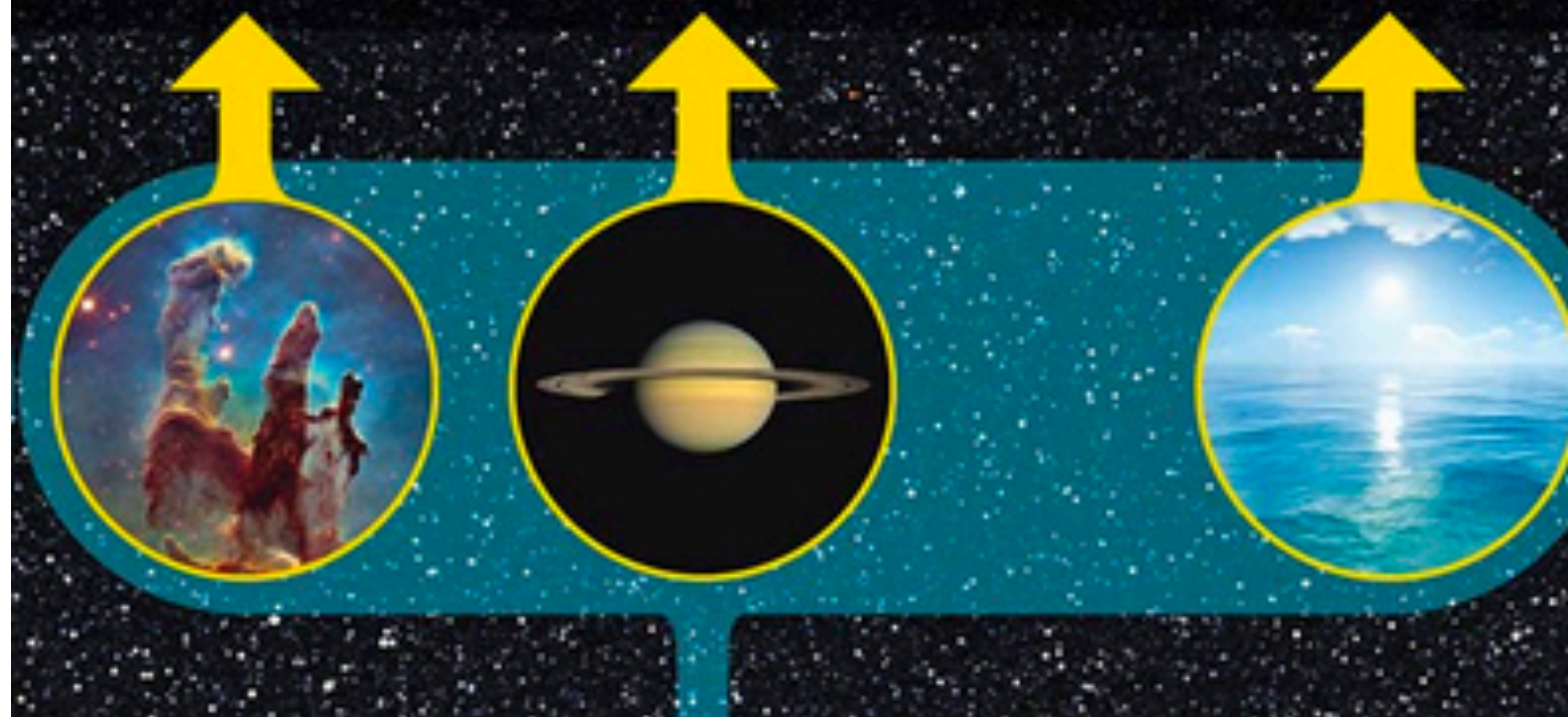
Credit: U. Rochester

$$= R_* \times f_p \times n_e$$

The rate of formation of stars in the galaxy

The fraction of those stars with planetary systems

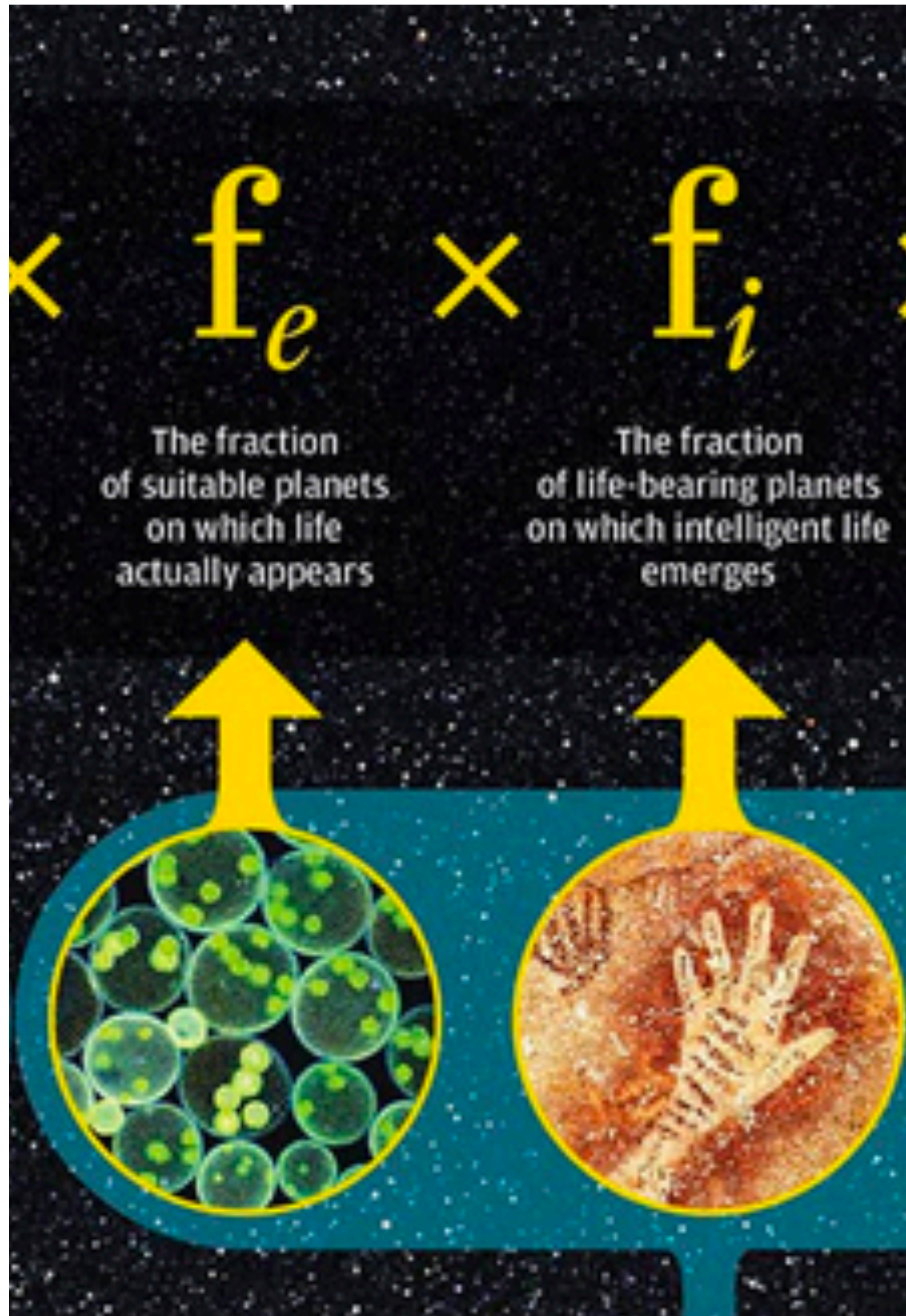
The number of planets, per solar system, with an environment suitable for life



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

f_p \rightarrow fraction of those stars with planets:
 less than, but close to, 1

n_e \rightarrow 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

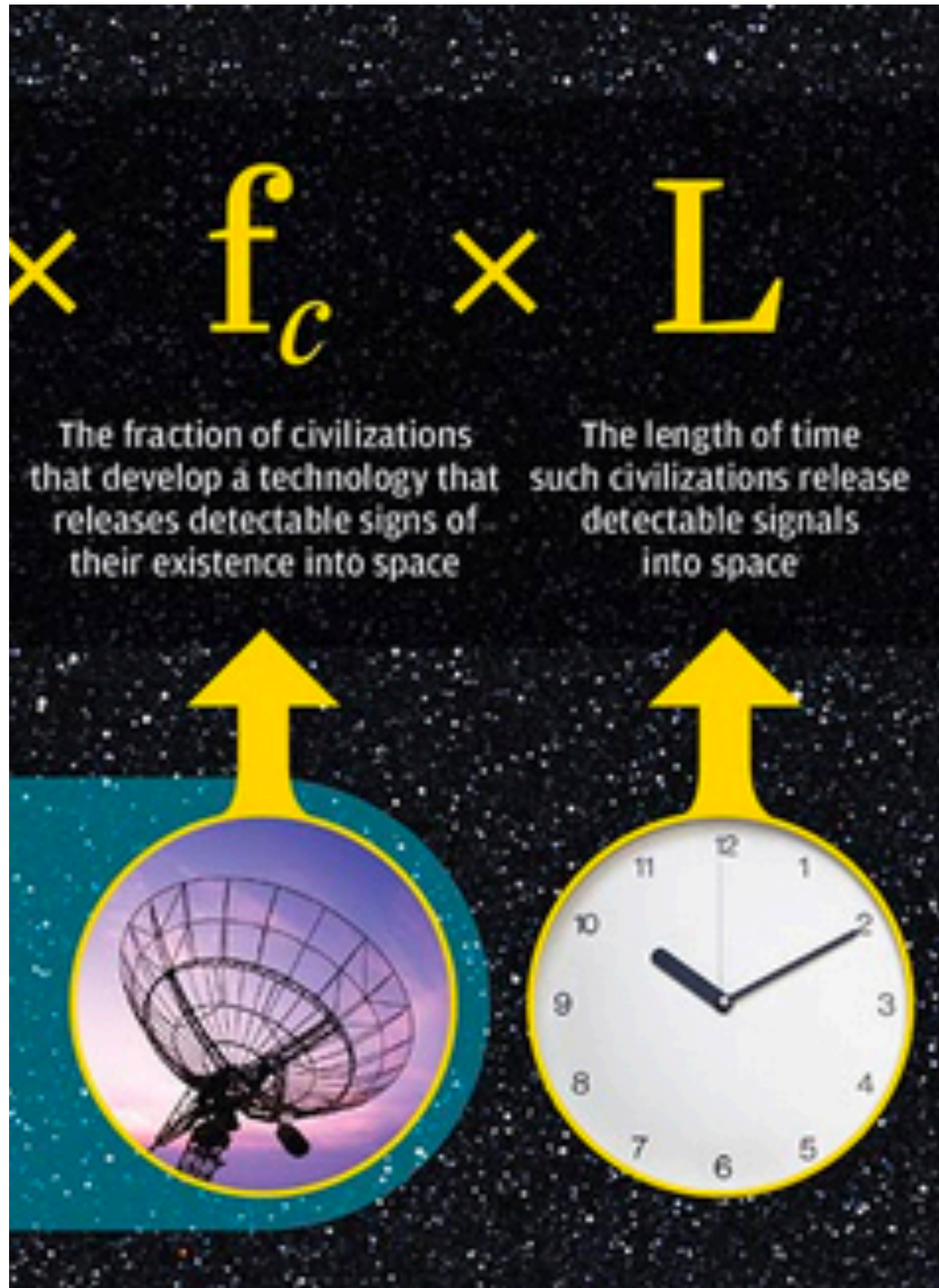
f_i → fraction of life-bearing planets on which intelligent life emerges

What do you think is the fraction of planets 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.**

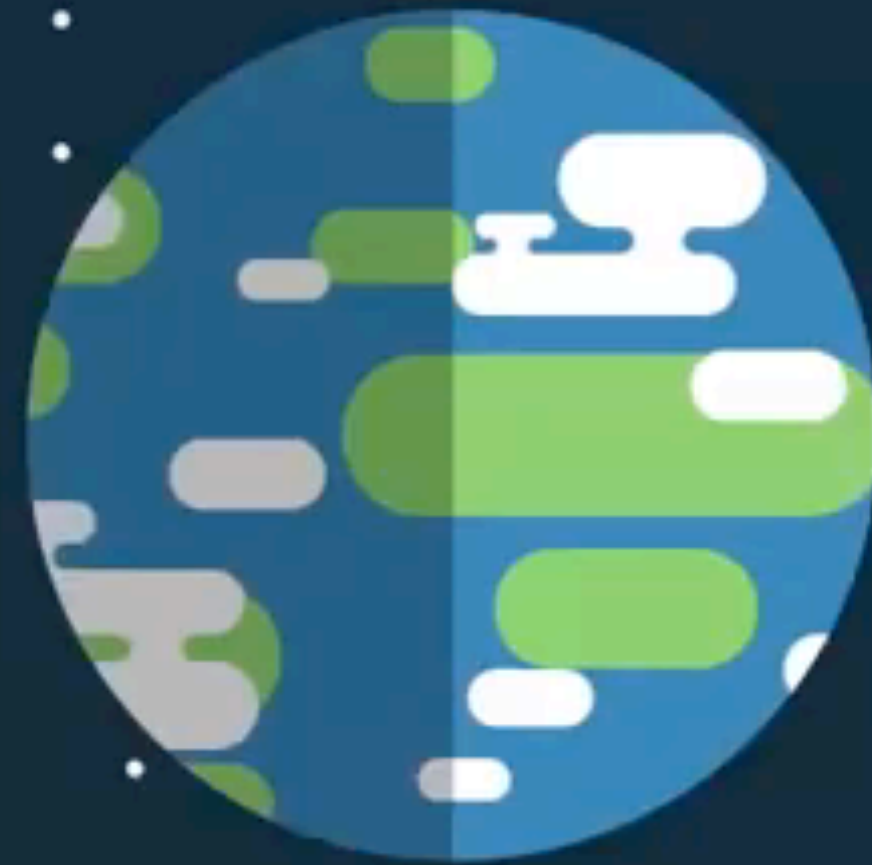
How long do these civilizations live?

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

- A) 100 years $\rightarrow 10^{-8}$
- B) 1,000 years $\rightarrow 10^{-7}$
- C) 100,000 years $\rightarrow 10^{-5}$
- D) 10,000,000 years $\rightarrow 10^{-3}$

So, where are they? The Fermi Paradox

<https://www.youtube.com/watch?v=sNhhvQGSEc>



What are some solutions to the Fermi Paradox?

<https://www.youtube.com/watch?v=1fQkVqno-ul>



'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

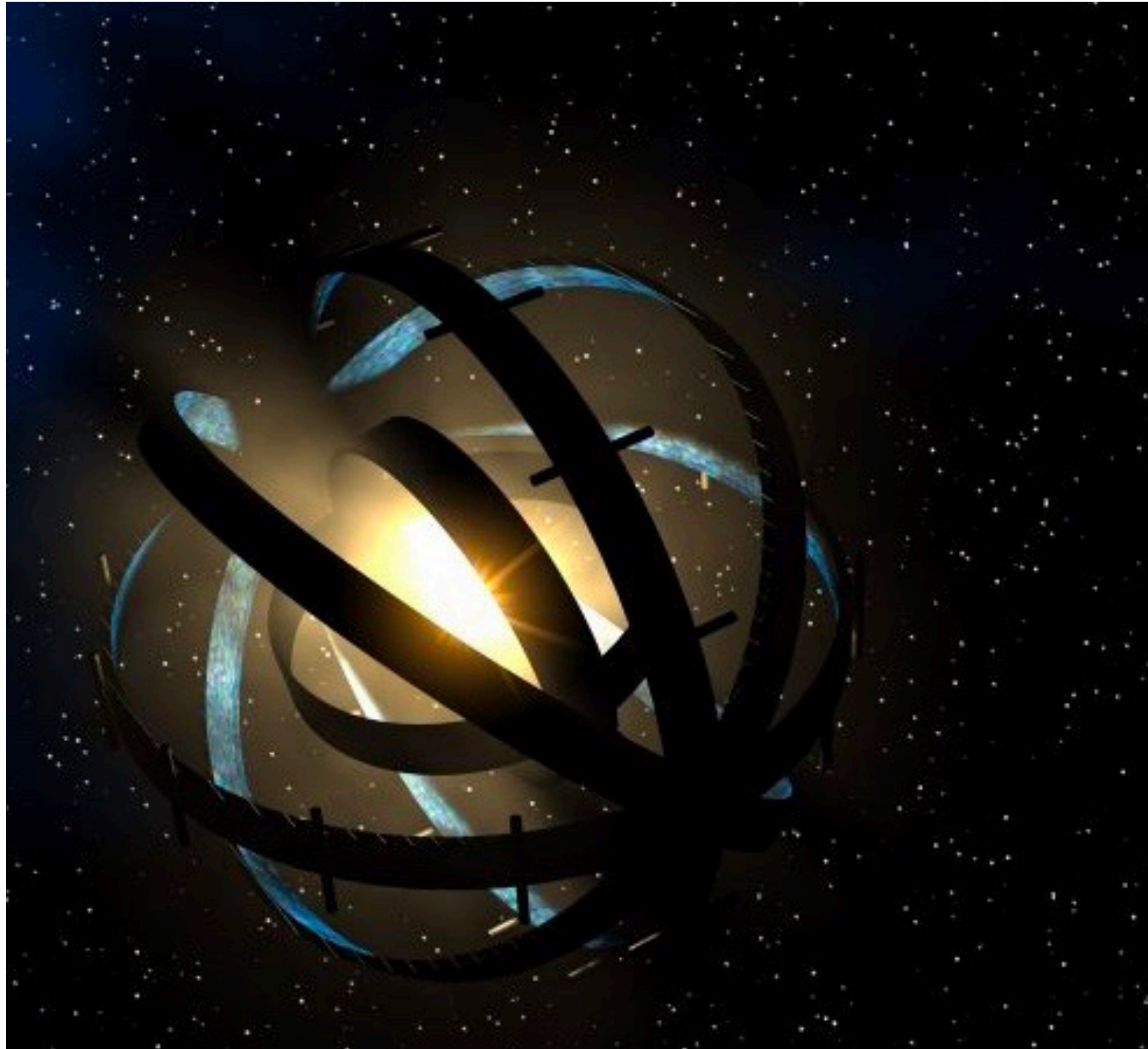
Size uncertain, but likely more cigar shaped spheroidal

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

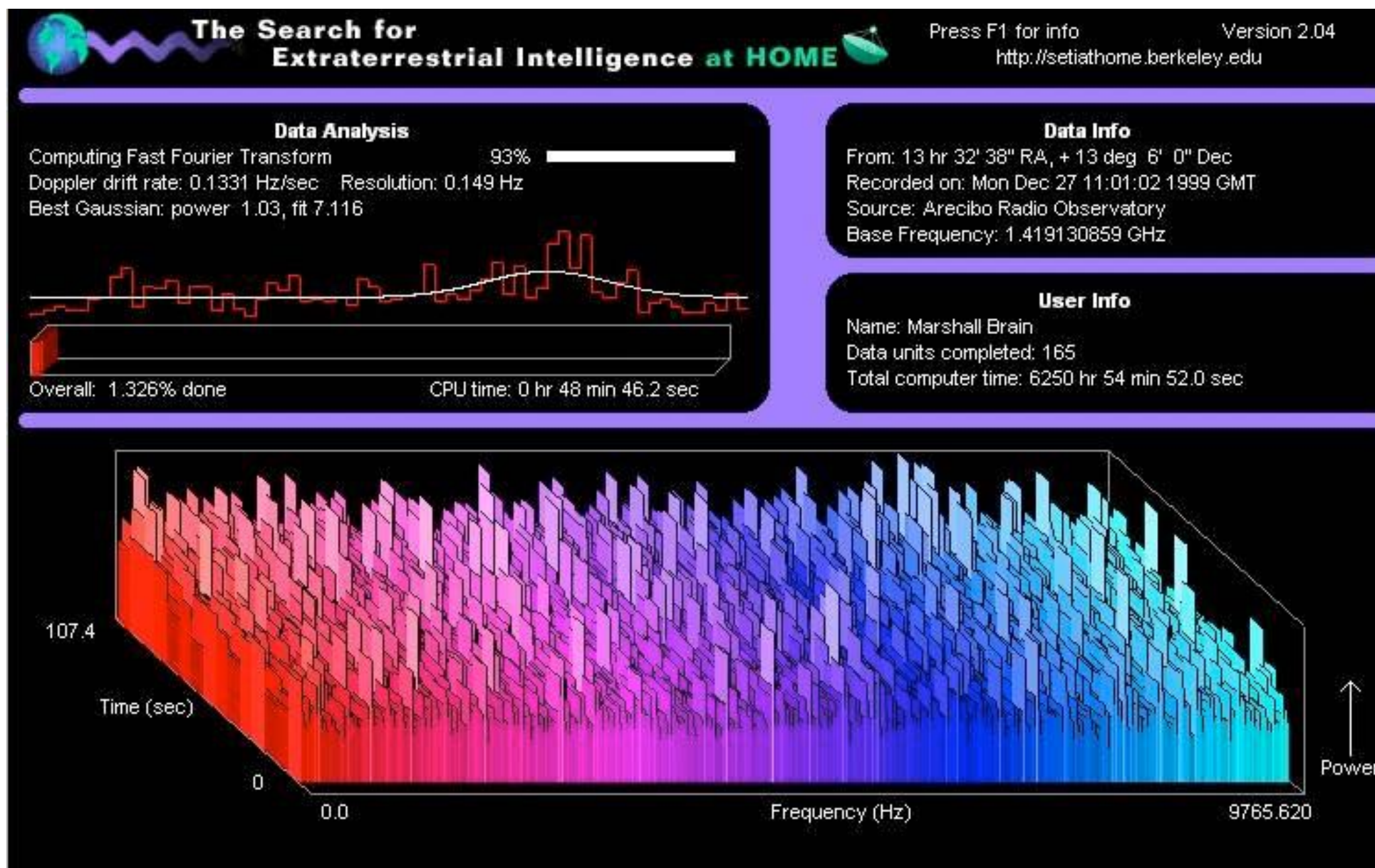
Tabby's star (discovered with Kepler) — alien megastructures or dust? (spoiler, dust)

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)