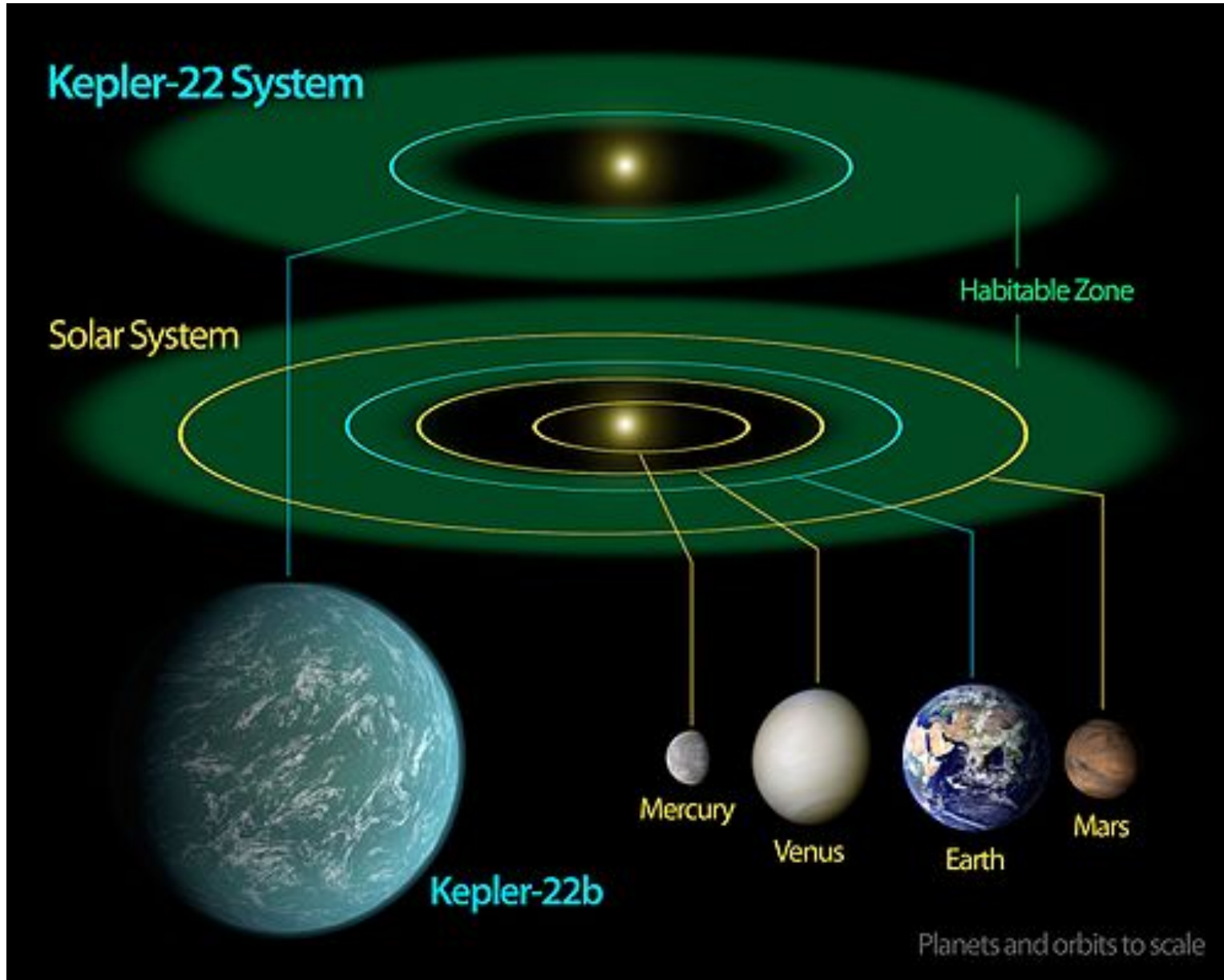


Astrobiology and ETs (Extraterrestrials)

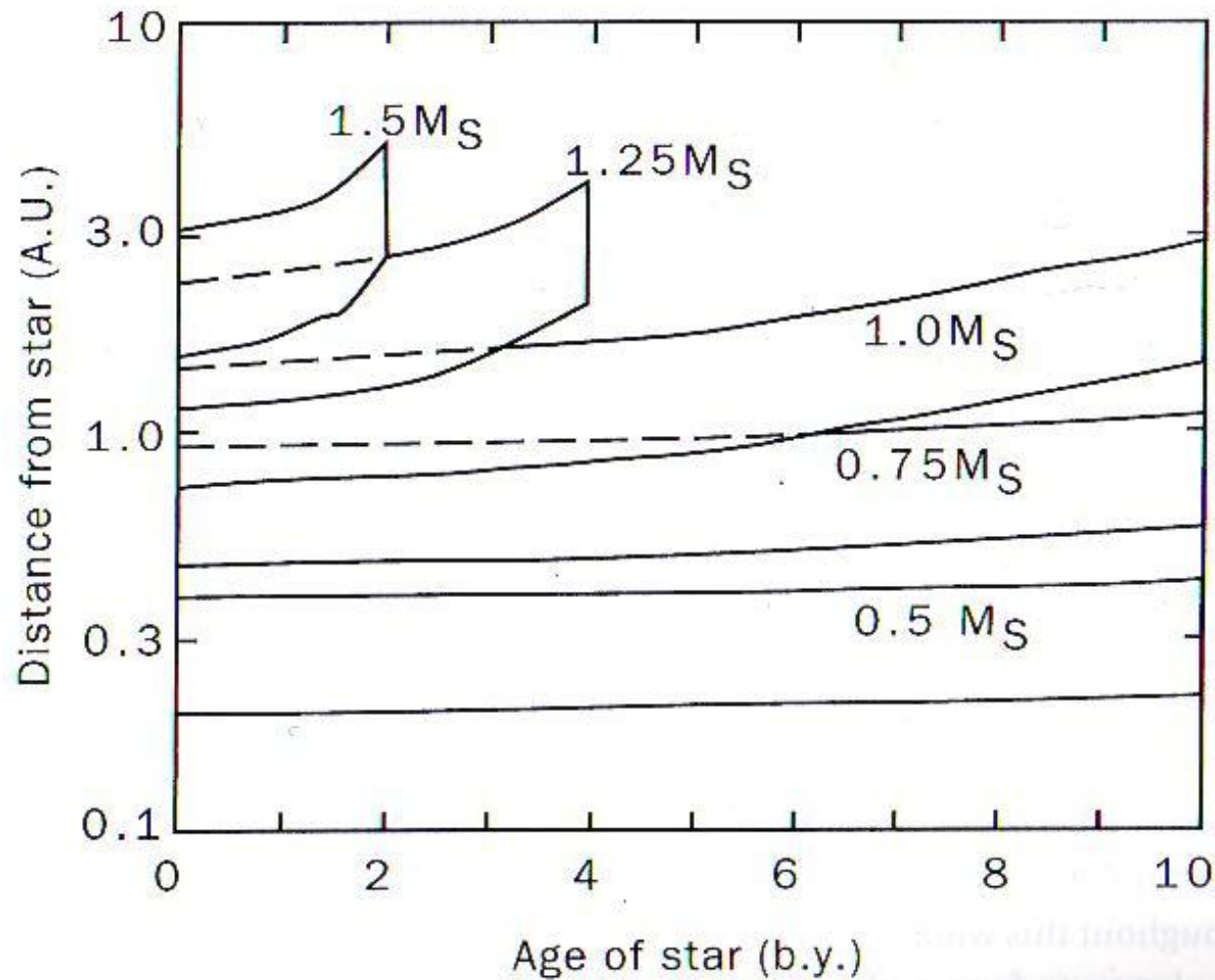
- One thing we did not know 30+ years ago:
there are exoplanetary systems in the Universe
- Another thing we did not know 20+ years ago:
There are as many planets as stars in our Universe,
 $\sim 10^{22}$. Or more!
- A new planet forms every X seconds. Compute X.
- Does that mean that chances are good... or not
necessarily good, that life exists out there?

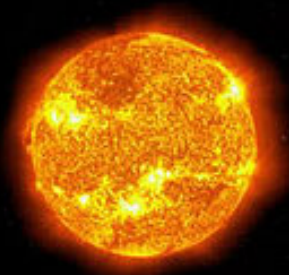
Habitable zone (HZ) by definition are such places where water can exist in liquid form



Habitable zones (HZ) for stars of different masses and ages suggest which stars have a higher chance to harbor life.

HZ: water in liquid form (assumption: on the surface)





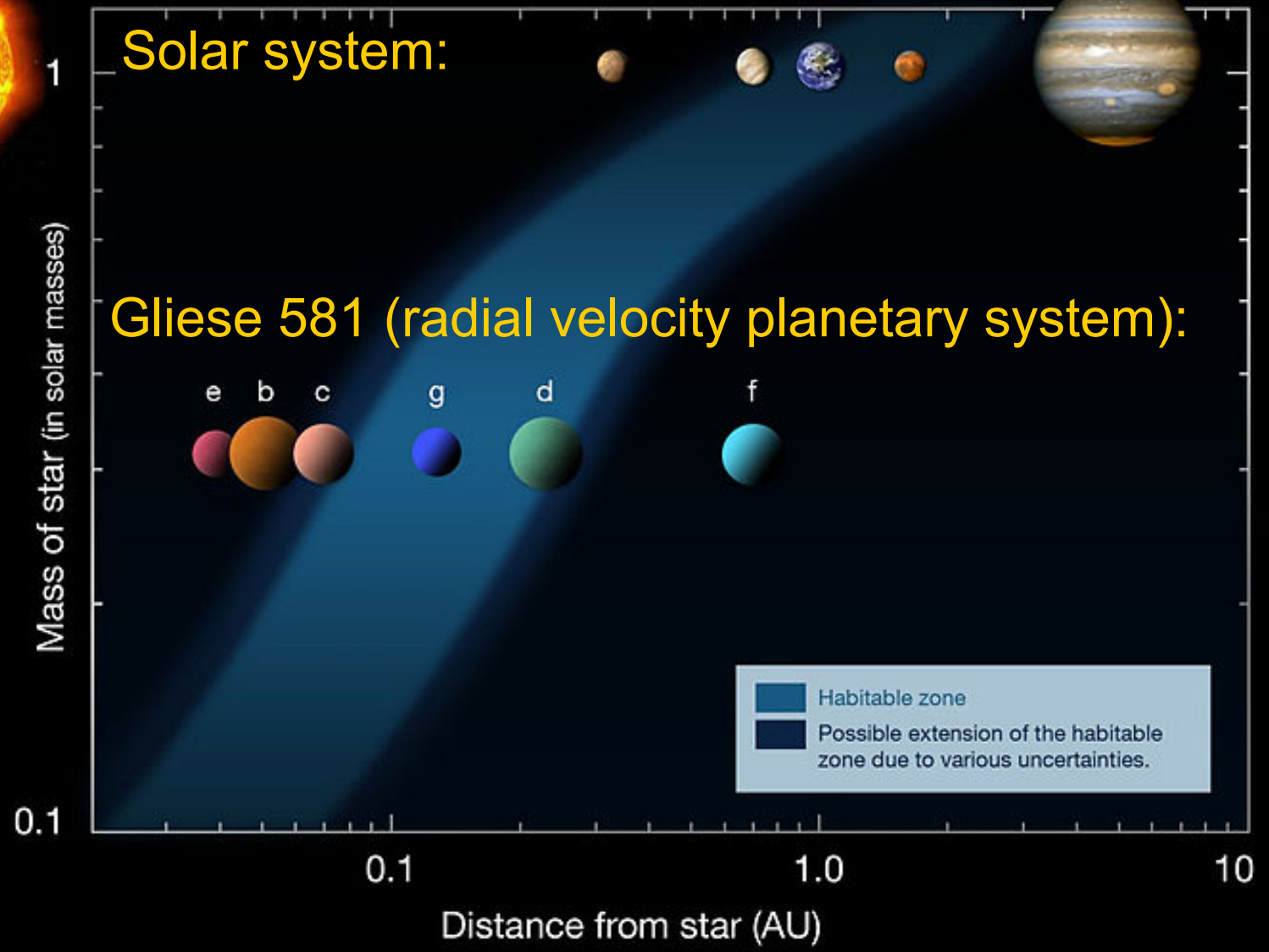
Sun

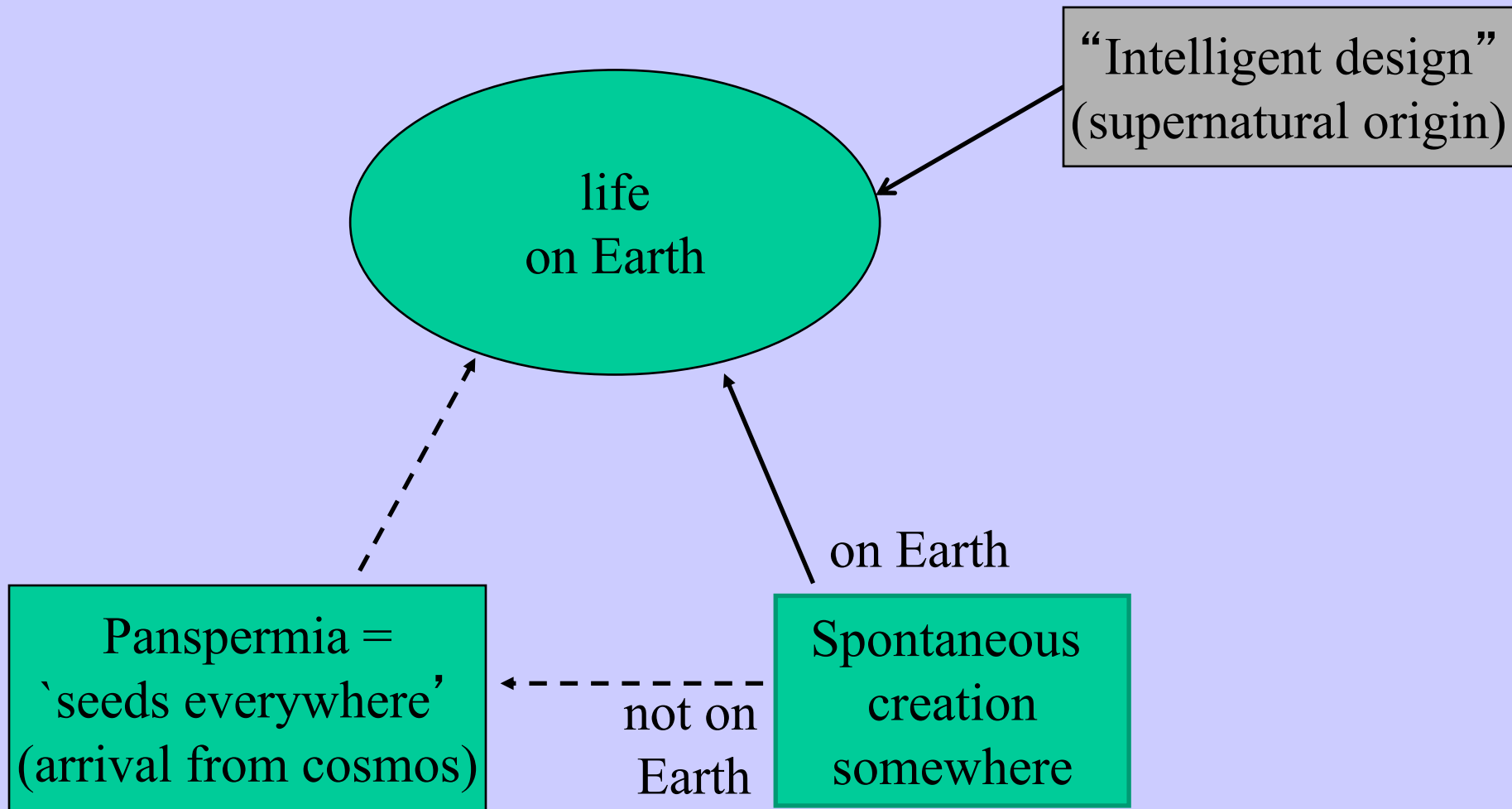


Gliese 581

Solar system:

Gliese 581 (radial velocity planetary system):





We do not know when, where and how life started in the Universe (or maybe on Earth). But we know some possibilities.

Panspermia (“seeds everywhere”):

life arrives, ready-made, on the surface of planets from space.

Anaxagoras is said to have spoken of the "seeds of life" from which all organisms derive.

Panspermia began to assume a more scientific form through the proposals of Berzelius (1834), Richter (1865), Kelvin (1871), and Helmholtz (1871).

It reached the level of a detailed, widely-discussed hypothesis through the efforts of the Swedish chemist Svante Arrhenius (1903).

He thought that life in the form of spores (cf. later) could survive in space and be spread from one planetary system to another. He did not exclude the possibility of living things generating from simpler substances somewhere in the universe. According to Arrhenius, spores escape by random movement from the atmosphere of a planet that has already been colonized and are then launched into interstellar space by the pressure of starlight.

About panspermia

Paul Becquerel tested in early 20th century whether spores and bacteria could survive in space. He thought that stellar UV would probably prove deadly to any organisms. For this reason, panspermia quietly faded from view-only to be revived some four decades later.

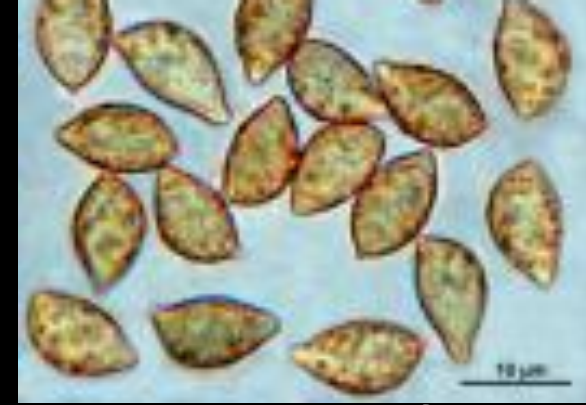
In 1960s, Carl Sagan analyzed in detail both the physical and biological aspects of Arrhenius scenario.

The dynamics of a microorganism in space depends on the ratio β (radiation pressure/gravity). If $\beta > \frac{1}{2}$, a microbe that has drifted into space will move away from the star. To escape from the vicinity of a sunlike star, the organism would have to be between 0.2 and 0.6 μm across. This is within the range of some terrestrial prokaryotes, bacterial spores and viruses.

Higher L/M will blow out larger spores.

Bacterial spores

A highly resistant, resting phase displayed by some types of bacteria. They form in adverse changes in the environment.



The original cell replicates its genetic material, and one copy of this becomes surrounded by a tough coating. The outer cell then disintegrates, releasing the spore which is now well protected against a variety of traumatic influences, including extremes of heat and cold, an absence of nutrients, water, or air.

In 1995, R.Cano and M.Borucki recovered and reanimated bacterial spores from the digestive tracts of bees that had been entombed in amber for between 25 and 40 million years.

Temperature resistance of spores: about one in 100,000 have been shown to survive brief exposure to the 3,000° C flame of a rocket exhaust, while other have emerged unscathed from a bath in liquid helium at -269° C. Life could travel as spores in interstellar space, sheltered inside meteoroids or comets.

Many variations on the panspermia have been put forward

- William Thomson (Lord Kelvin) proposed that spores might travel aboard meteorites ("lithopanspermia"), thus affording them better protection from high-energy radiation in space. Collisions violent enough to hurl rocks from the surface of a biologically active planet into *interstellar* space are necessary.
- There is strong evidence that ballistic transport occasionally operates between planets. 277 meteorites came to Earth almost certainly from the surface of Mars (so-called SNC meteorites) and more from the Moon.
- In the 1960s, biologist T. Gold pointed out another way for life to travel from world to world. He imagined the visitors having a picnic and not cleaning up afterward. (They'd have to arrive very early after Earth formation! Why then?)
- Astronomer Carl Sagan pointed out an additional possibility of *intentional*, directed panspermia. We do the opposite: everything we send into space, we try to clean of biomaterials.

Arguments supporting the theory of panspermia

Quite complicated animals like these mites are survival experts.



The remarkable case of *Surveyor 3* makes it clear that some terrestrial microbes can survive for significant periods in hostile conditions on other worlds.

An unmanned lunar probe *Surveyor 3*, which soft-landed on the Moon near Oceanus Procellarum in 1967. In 1969, 2.5 yrs later, Apollo 12 astronaut Pete Conrad and Alan Bean recovered the camera from *Surveyor 3* and brought it back to Earth.

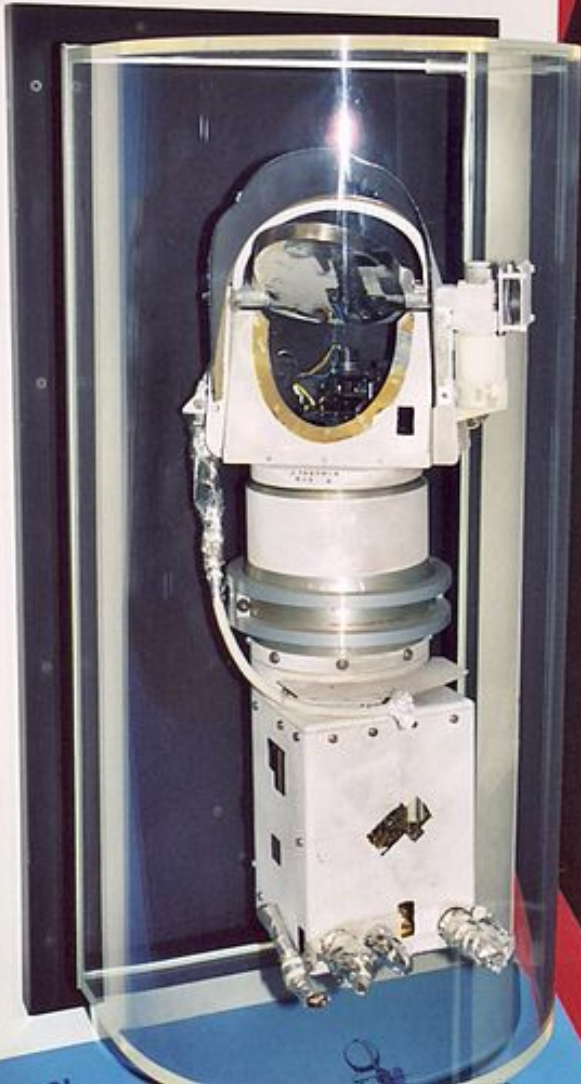
The polyurethane foam insulation covering its circuit boards contained 50 to 100 viable specimens of *Streptococcus mitis*, a harmless bacterium commonly found in the human nose, mouth, and throat.

Conrad later commented:

"I always thought the most significant thing that we ever found on the whole Moon was that little bacteria who came back and living and nobody ever said anything"

SURVEYOR 3 TELEVISION CAMERA

This television camera landed on the Moon as part of Surveyor 3 on April 20, 1967. On Nov. 24, 1969, it was returned to earth by the crew of Apollo 12. Holes in the camera case are where material was removed for study. These studies showed that the hardware was very resistant to damage in the severe lunar environment. Analyses of the material also showed the nature of micro-meteoroids, cosmic rays, and the solar wind.



(NASA Johnson Space Center)

7 August 1996: NASA announced fossilized evidence of ancient life in a 2-kg meteorite Allan Hills ALH 84001 from Mars.



ALH 84001 formed originally from molten lava, about 4.5 billion years ago in a Martian volcano. About 4.0 billion years ago, it was heated again and deformed by a strong shock from the nearby impact of an asteroid. Some kind of liquid flowed through ALH 84001 and deposited rounded globules of carbonate minerals. The possible martian fossils are in these carbonate globules.

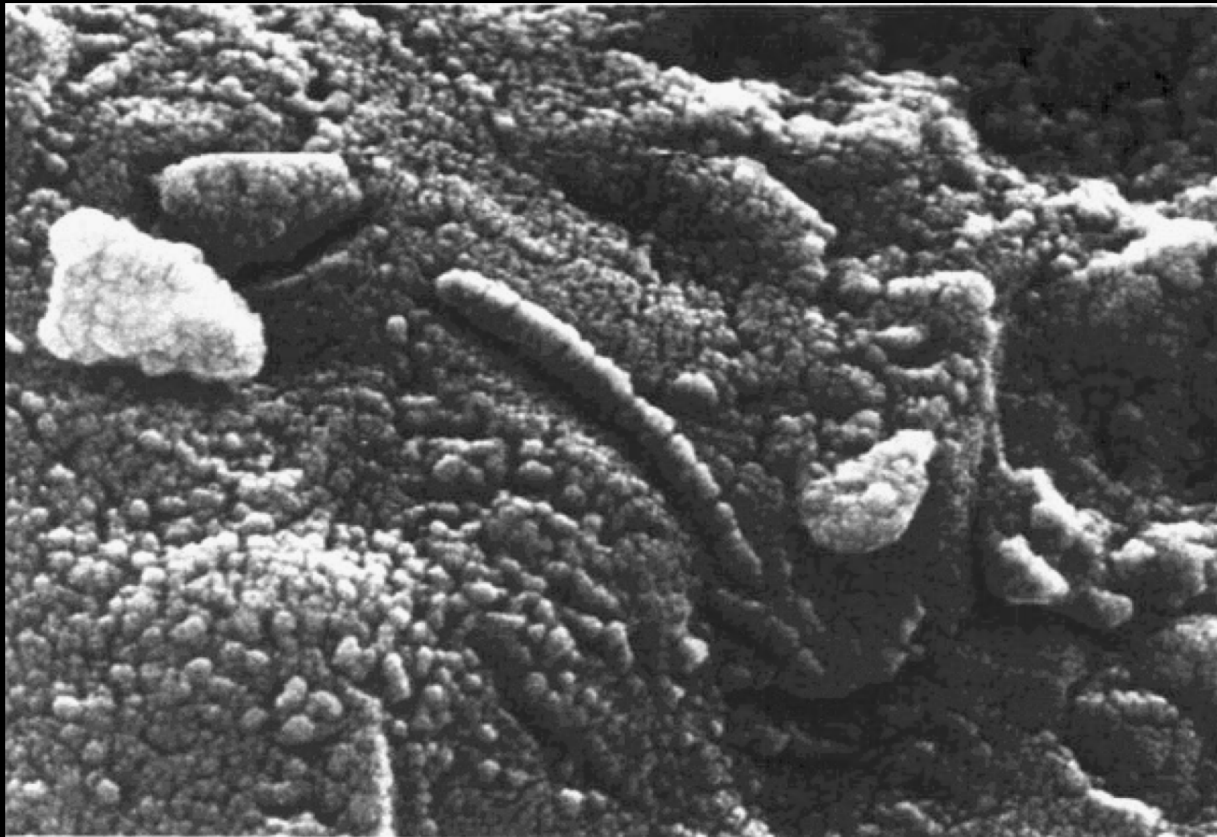
11 other meteorites, called the SNCs, that are also almost certain to be from Mars. They contain traces of gas that is just like the Martian atmosphere.

ALH 84001 was probably blasted off Mars about 16 million years ago, then ALH 84001 was in space, exposed to cosmic rays, as it traveled between Mars and the Earth. It landed in Antarctica about 13 kyr ago.

meteorite ALH 84001 from Mars,
found in 1984 in Antarctica.



But ALH 84001 does NOT have alien life...



20 nm diameter – too
small for cells

Interpretation of
morphology is
notoriously subjective,

there are geological
processes that can
create such structures

technology nowadays helped to estimate precise age of these pieces by ^{40}Ar - ^{39}Ar dating, especially with the use of secondary ionization mass spectrometry (SIMS also called an ion microprobe). Now we estimate Allende's CAIs age to be 4567.72 ± 0.93 Myr (see Fig. 3) (Connelly et al. 2008). To compare, CAIs of Efremovka CV3 chondrite are 4567.2 ± 0.6 Myr old (Amelin 2002).

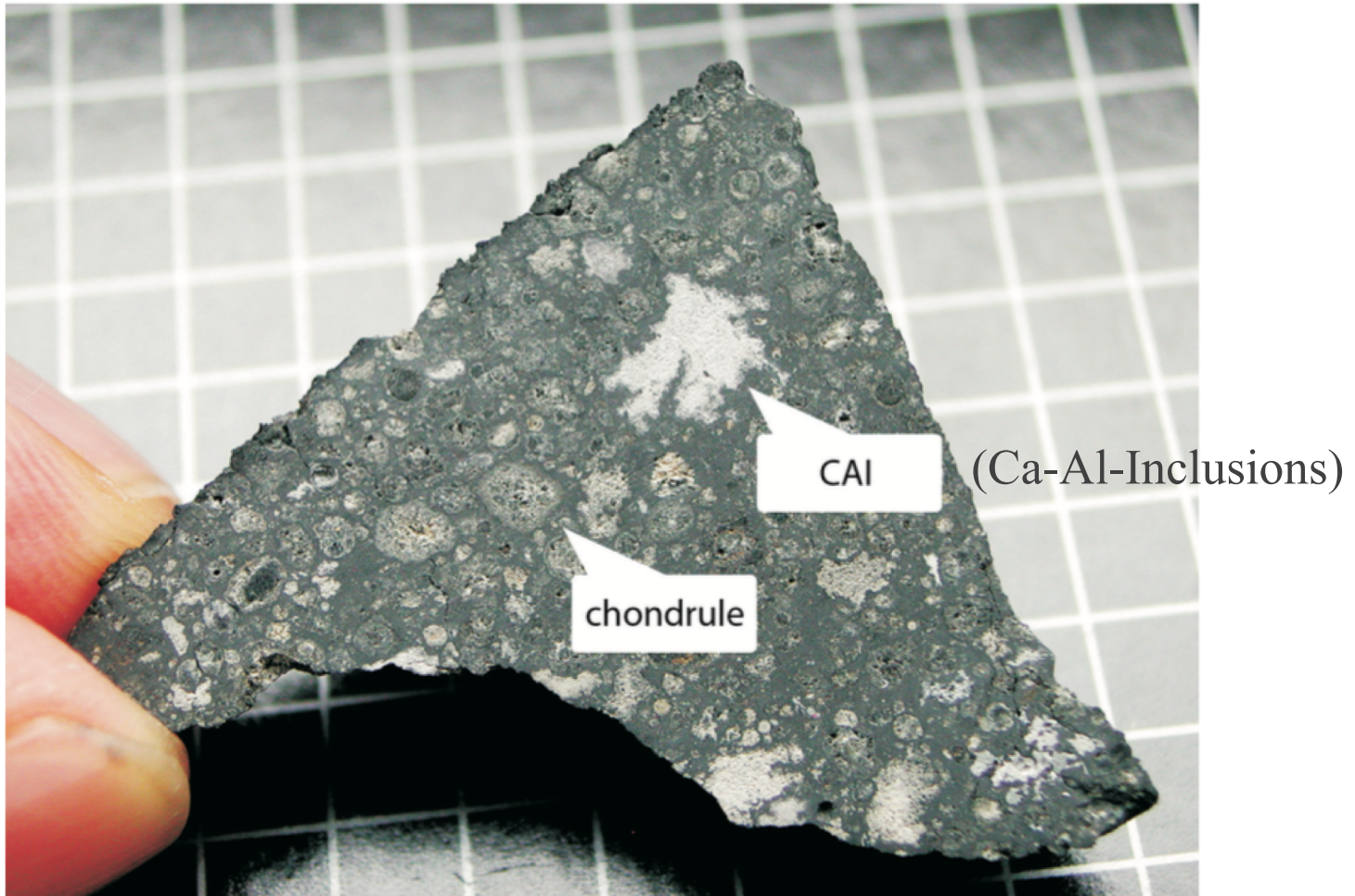


Fig. 2. Allende's CAIs and chondrules. The grid behind is 1×1 cm (courtesy of Jan Woreczko).

ORGANIC COMPOUNDS IN THE MURCHISON CHONDRITE

Class	Concentration (ppm)	Compounds Identified
Monocarboxylic Acids	>300	20
Polar Hydrocarbons	100-120	10+
Amino Acids	60	74
Amides	55-70	49+
Aliphatic Hydrocarbons	>35	140
Dicarboxylic Acids	>30	38
Aldehydes & Ketones	27	9
Aromatic Hydrocarbons	>15-28	87+
Hydroxy Acids	15	51
Alcohols	11	8
Amines	8	10
Basic N-Heterocycles	7	32
Purines and Pyrimidines	1	5
Sulfonic Acids	71	8
Phosphonic Acids	2	4

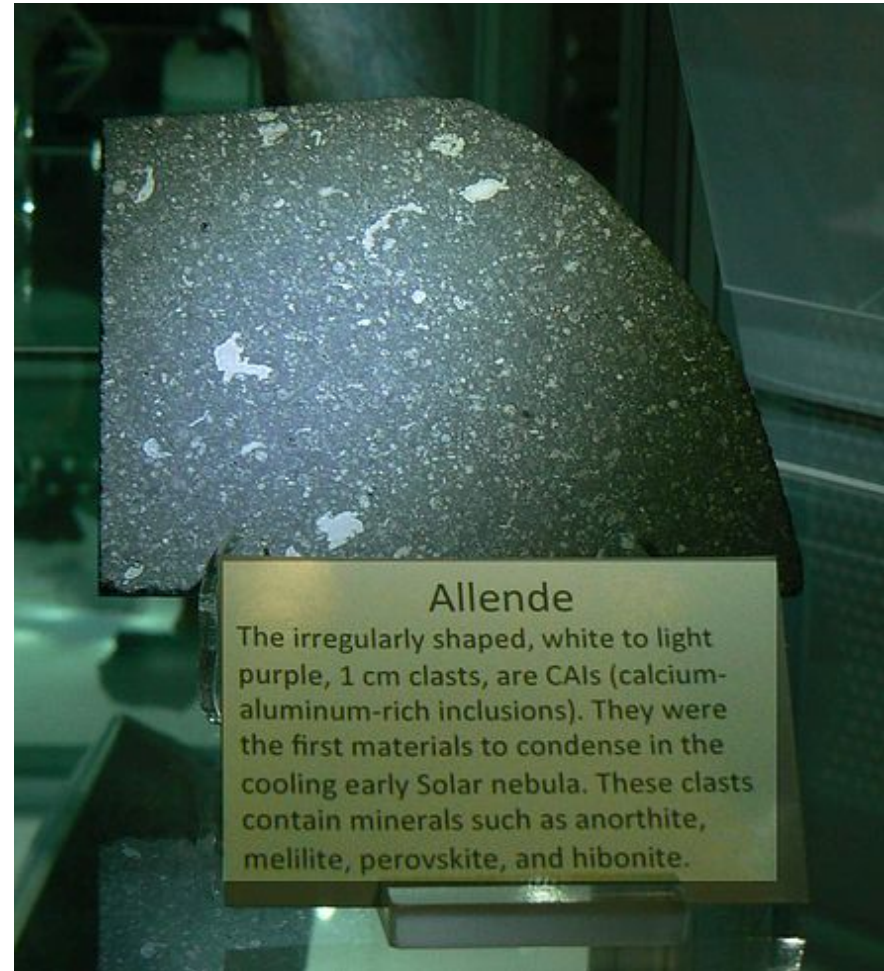
(-:

Hemolithin is a proposed protein containing iron and lithium, of extraterrestrial origin, described in a 2020 preprint.

The protein was found inside two CV3 meteorites: Allende and Acfer-086, by a team of scientists led by Harvard University biochemist Julie McGeoch.

Method: mass spectrometry, computer reconstruction.

The report of the discovery was met with some skepticism and suggestion that researchers had extrapolated too far from incomplete data.



Hemolithin – the 1st extraterrestrial protein (?)

Initially claimed in Allende & Acfer 086 (CV3 type chondritic meteorites). Paper was not accepted for publication in 2020. The claim about Allende meteorite is uncertain, manuscript was not published, but a paper about hemolithin in Acfer 086 was published).

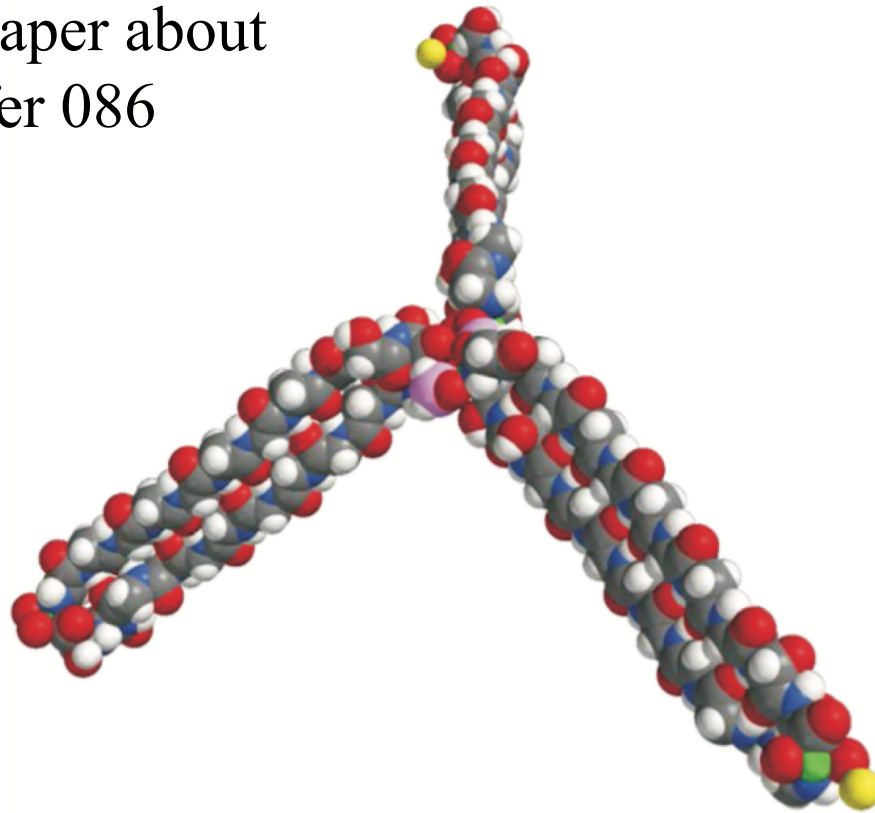


Fig. 4. Model of the hemoglycin molecule, a probable meteoritic protein. White = H; grey = C; blue = N; red = O; pink = Si; yellow = Na and green = Fe (McGeoch et al. 2020).

Looking for alien life forms?

So-called Cambrian Explosion
of life 0.53-0.50 Gyr ago on Earth.


Where do we find such fossils?



hallucigenia

Canadian Rockies, near Mount Burgess





*notice the strata of sedimentary
from ancient ocean shelf*

Burgess shale in Canadian Rockies, 1 km above trans-Canada rail station in the town of Field, B.C., near the border with Alberta. 508-530 Myr old, very well preserved fossils. Result of a mud-slide, preserving soft-bodied animals with a great diversity of body architecture.

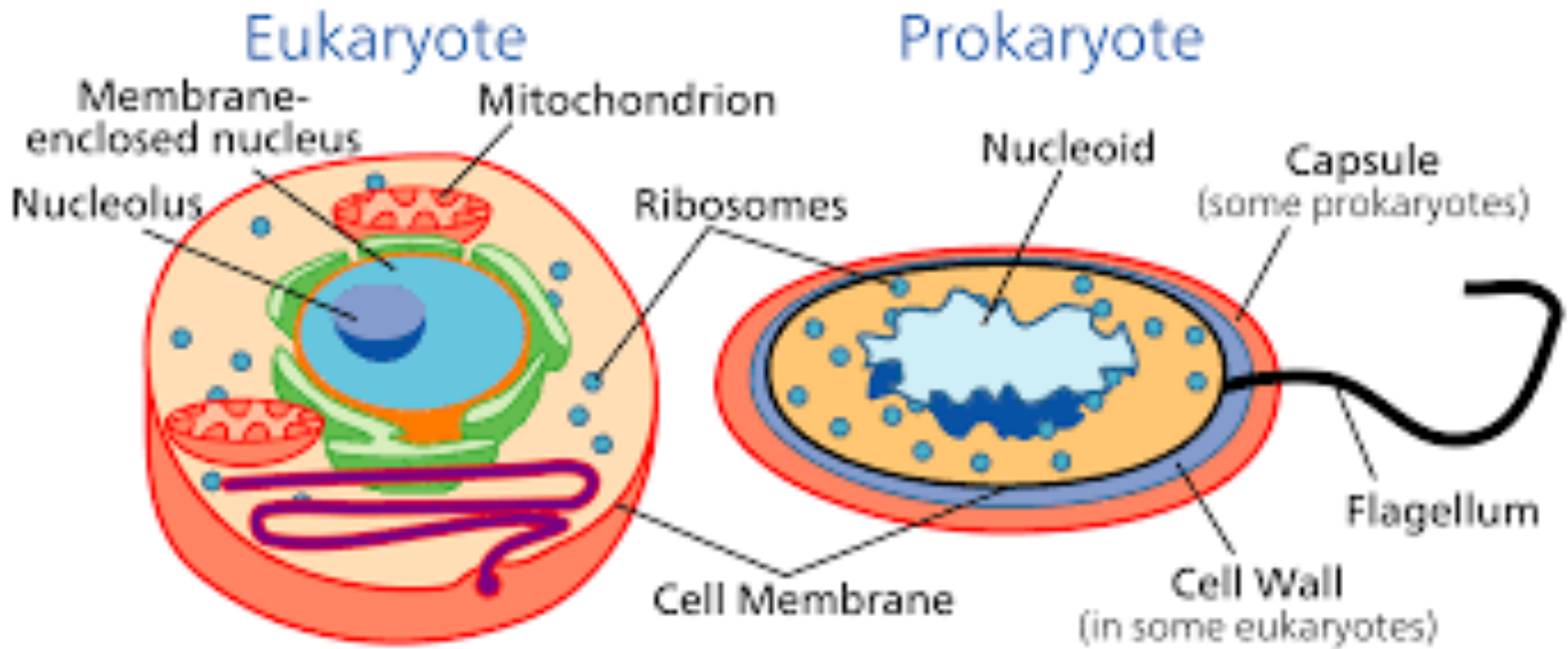
Steven J Gould "Wonderful Life: The Burgess Shale and the Nature of History"



Trilobites



Marrella



size ~1...10+ microns

0.1...5 microns

first appeared ~2.7 Gyr ago

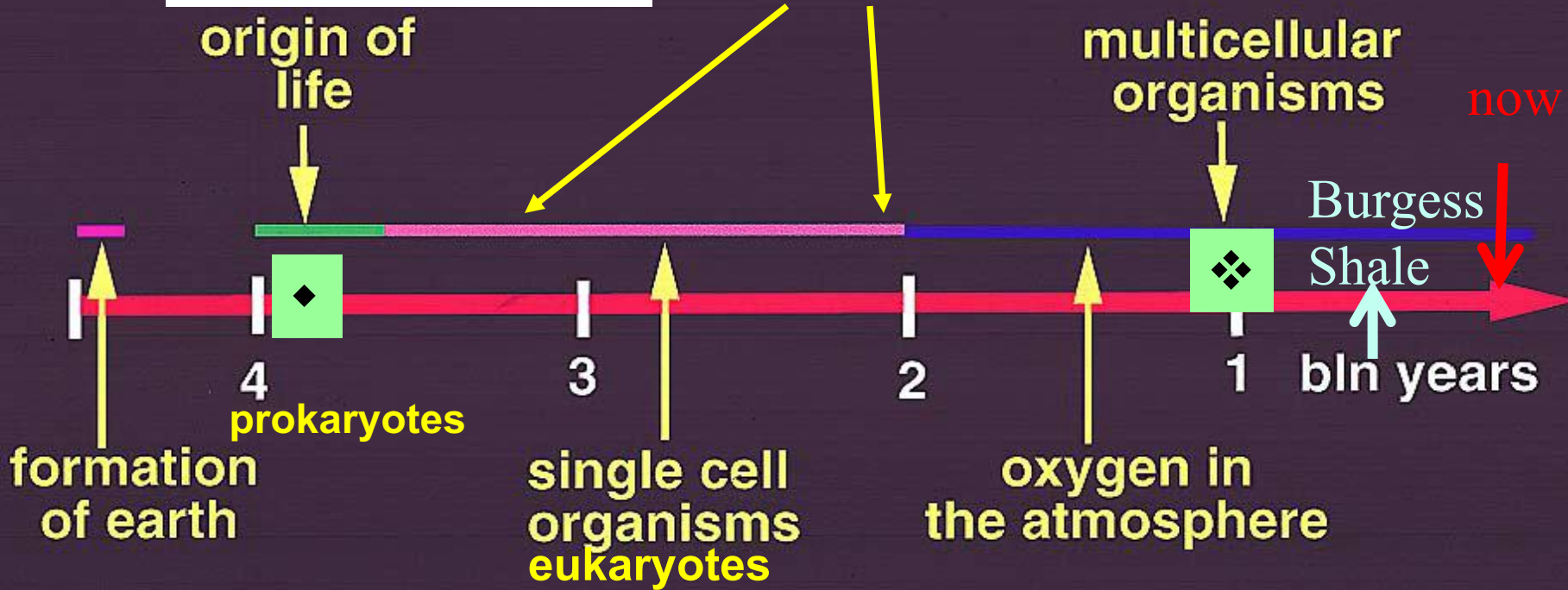
3.7-4.2 Gyr ago

One of the indications of non-local origin of life on Earth is from timing:

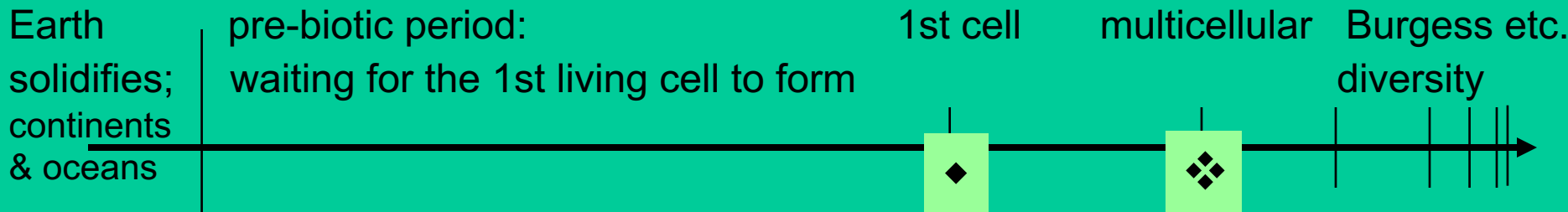
A BRIEF HISTORY OF EARTH

Immediately after Earth formation & heavy bombardment!!!

Not much happening here! Why not, if the most difficult transition from non-life to life was accomplished so easily?




If life started on Earth, evolution would be accelerating like so:



Abiogenesis

or inorganic beginnings
(currently the most popular theory)

A black and white portrait of Charles Darwin, showing him from the chest up. He has a very full, white beard and mustache, and is wearing a dark coat over a white shirt and a dark cravat. He is looking slightly to the right of the camera with a serious expression.

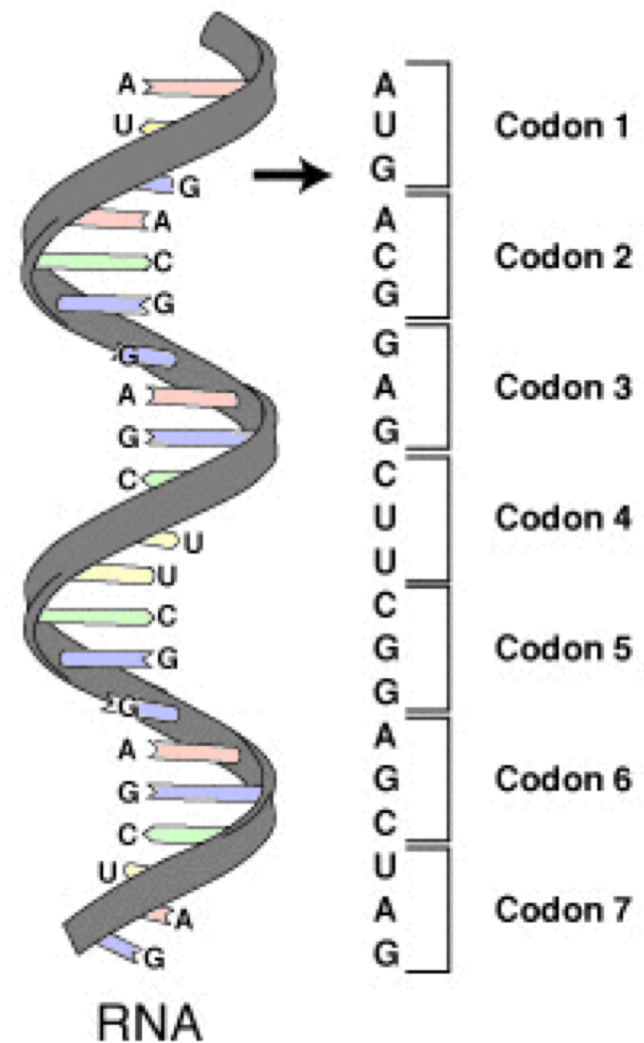
Charles Darwin suggested that the original spark of life may have begun in a *"warm little pond, with all sorts of ammonia and phosphoric salts, lights, heat, electricity, etc. present, so that a protein compound was chemically formed ready to undergo still more complex changes."*

He went on to explain that *"at the present day such matter would be instantly devoured or absorbed, which would not have been the case before living creatures were formed"*

Modern Organisms:



Essential reactions are catalyzed by protein enzymes. Nucleic acids are used to make proteins and to transfer information between generations.



Ribonucleic acid

Life has never been started in laboratory (as of 2022) despite all attempts at abiogenesis

All known life uses *digital* code based on “letters” :

ACG(T/U) N-containing bases adenine, guanine, cytosine, pyrimidines thymine (in DNA) or uracil (in RNA)



Russian biochemist Alexander Oparin (right) in 1924 wrote his book *The Origin of Life*

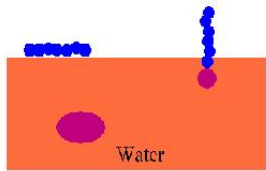
theory of *coacervate* droplets spontaneously growing and having primitive metabolism

There is still no "standard model" of the origin of life, but Oparin's ideas come close..

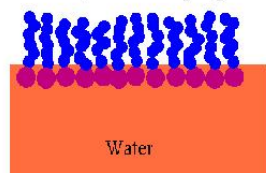
Some organic compounds assemble in membrane-like structures

Molecules

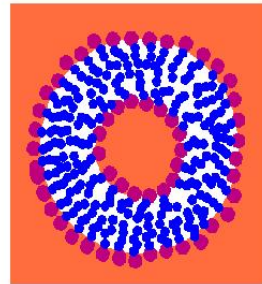
Polar (N, O, P) Nonpolar (C-H) Amphiphilic



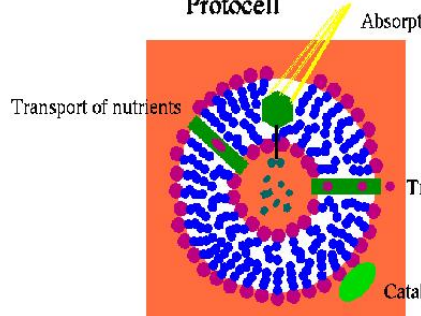
Monolayer of amphiphiles



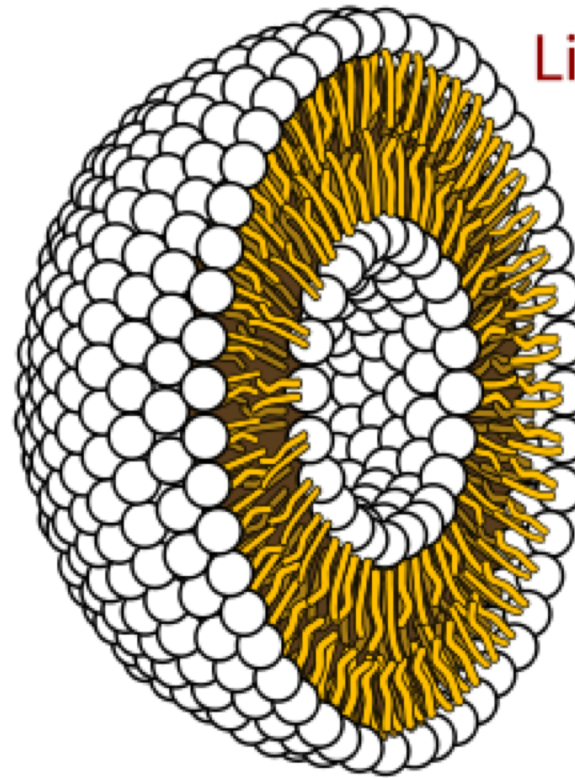
Bilayer Vesicle



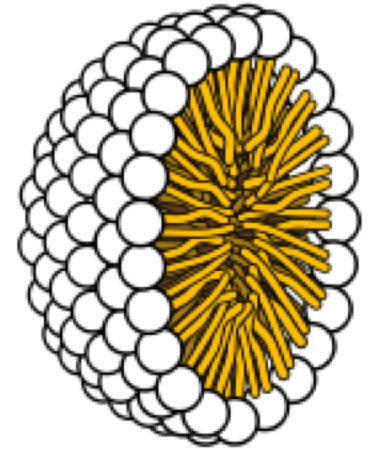
Proto-cell



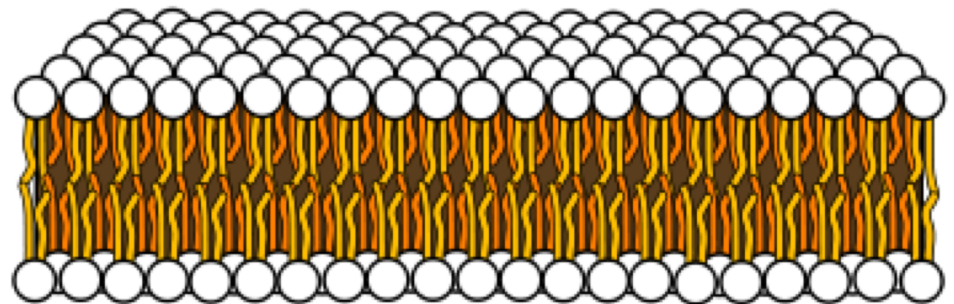
Liposome

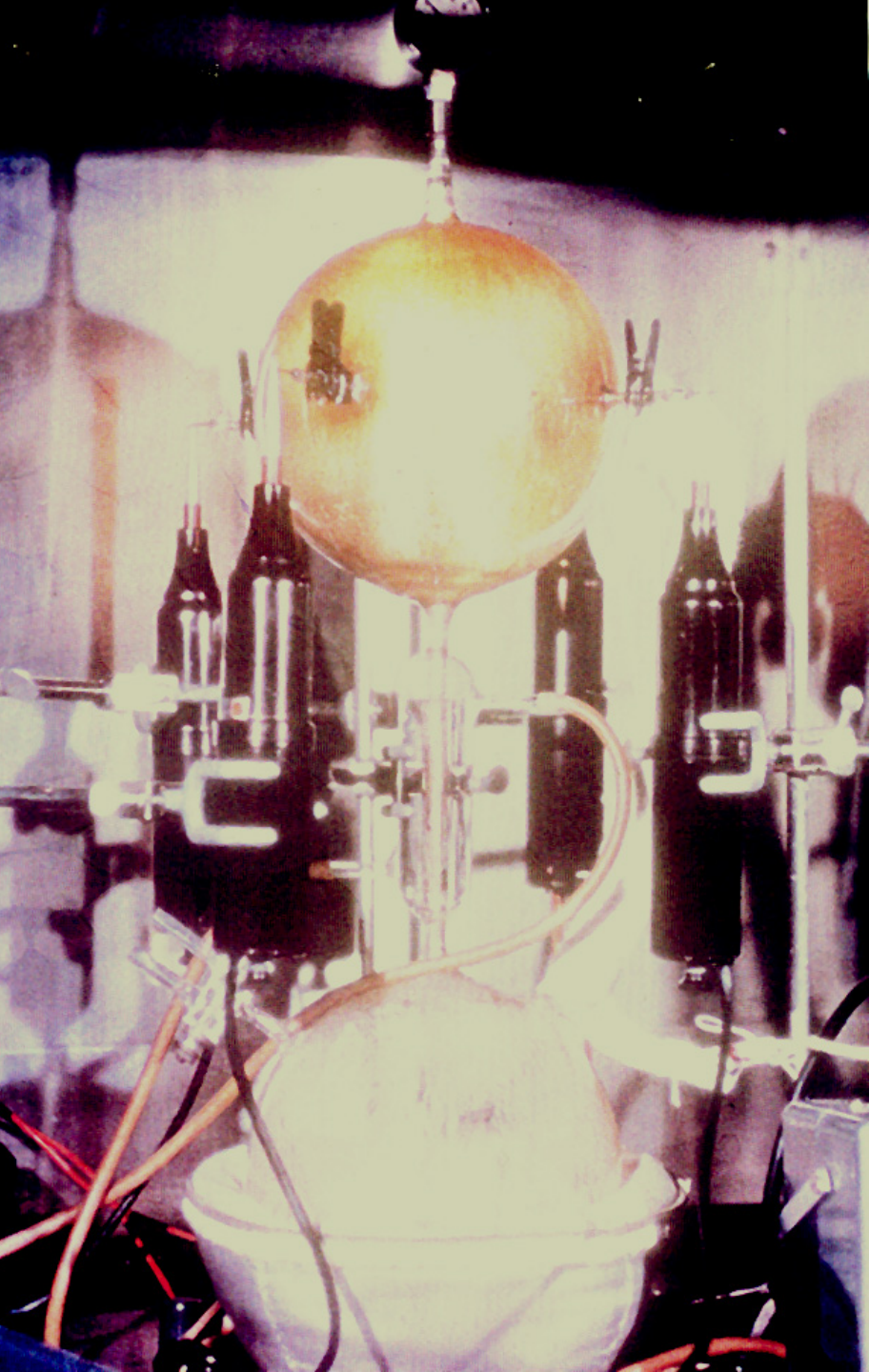


Micelle



Bilayer sheet





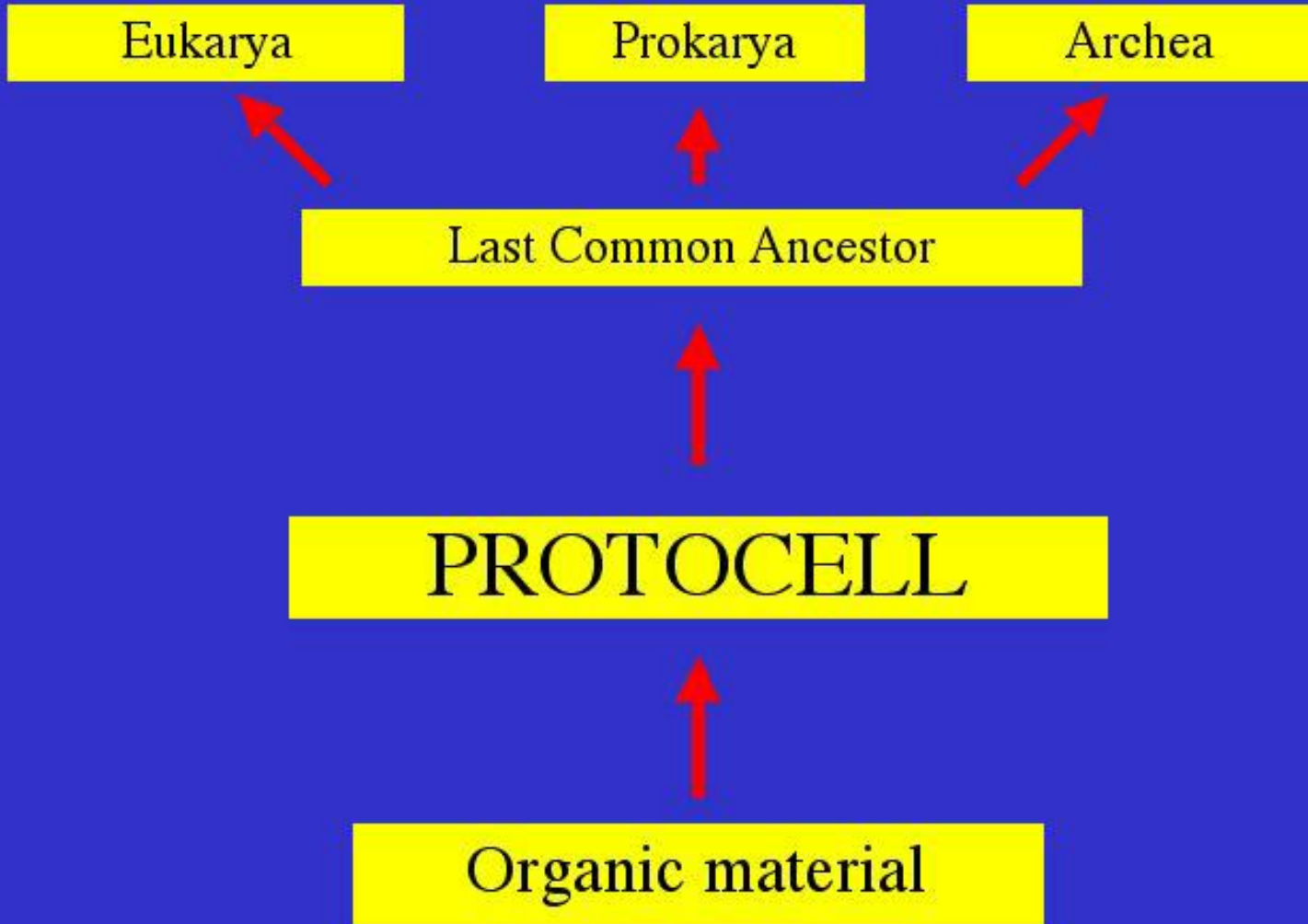
In the 1920s **Alexander Oparin** and English geneticist **J.B.S. Haldane** independently revived the doctrine of spontaneous generation in a more sophisticated form.

Supporting this theory, in 1953, American chemists **Stanley Miller and Harold Urey** showed that 5 amino acids can be chemically produced from ammonia (NH_3) and methane (CH_4). Today – not 5 but 23!

That experiment is now famous, and the Oparin - Haldane paradigm still prevails today, even though the atmosphere they had assumed never existed on Earth. They took too much methane and ammonia, & too little CO_2 .

have nucleus and organelles

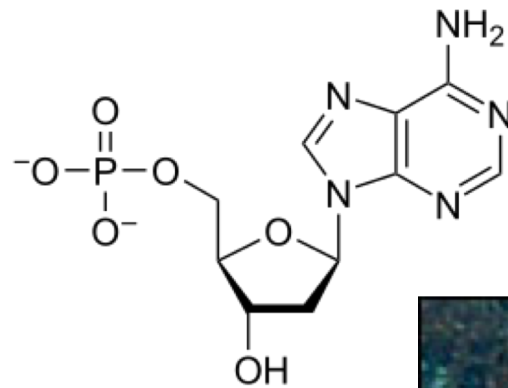
don't have (...)



Using the DNA sequences of modern organisms, biologists have tentatively traced the most recent common ancestor of all life to an aquatic organism that lived in extremely high temperatures: a hydrothermal vent archeobacteria. Such vents must exist on other Solar system bodies (Europa, Callisto, Enceladus) too. Thus the search for life in our Solar System continues.



A 3.465 Gyr old rock with a microbe



5-C
sugars
(deoxy-)ribose

adenine (A)

[G,A,C,T/U nucleotides
are building blocks of
nucleic acids DNA/RNA]



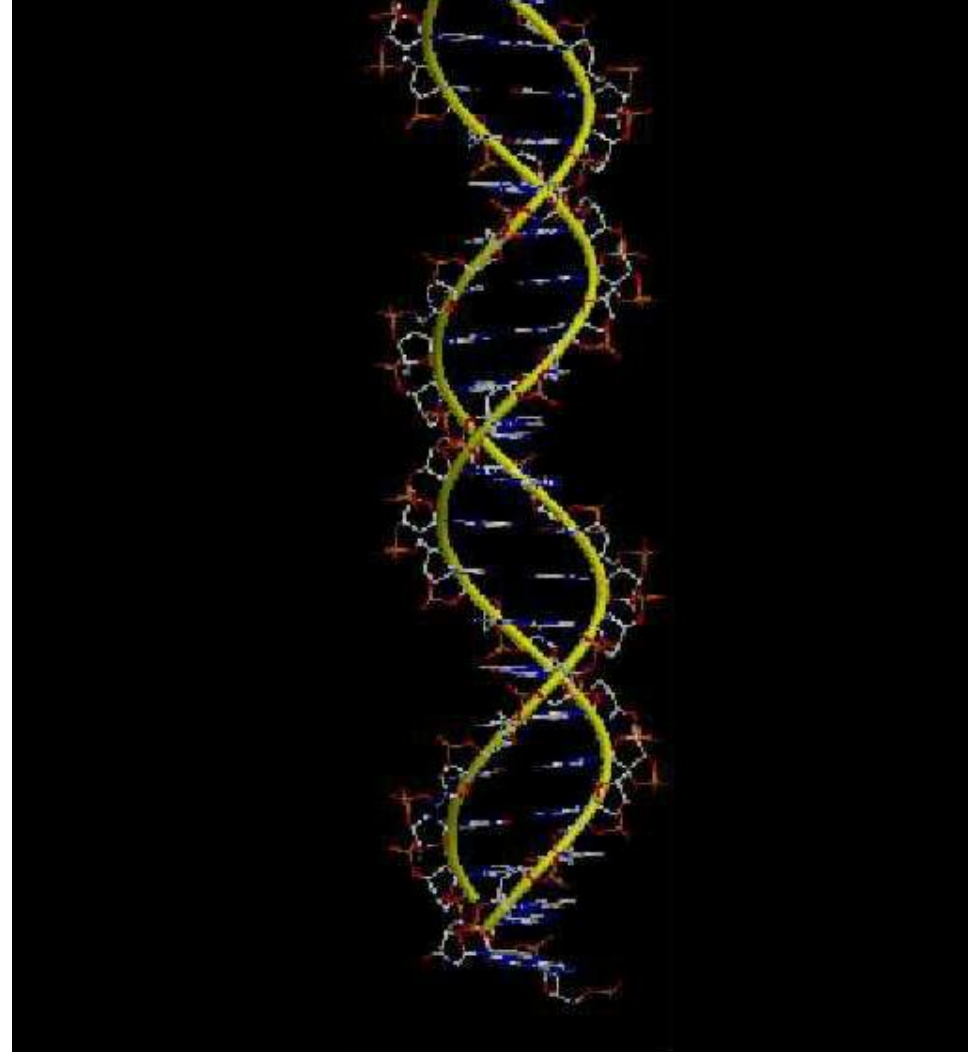
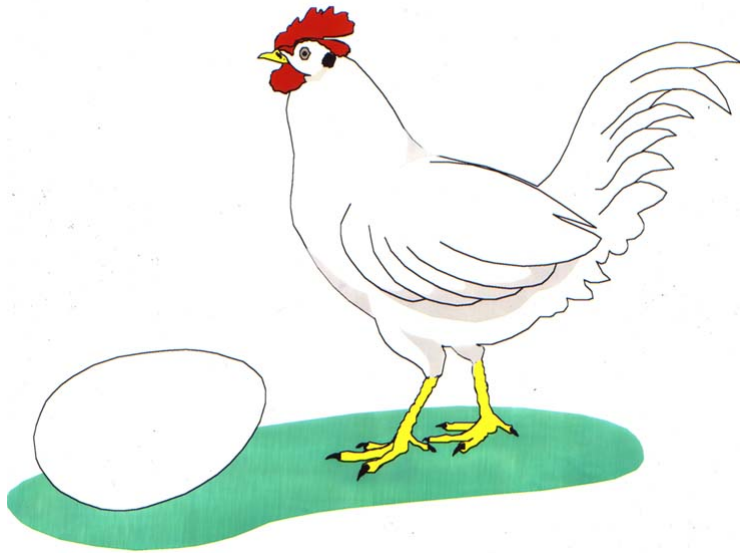
3.5 Gyr old stromatolites, bacterial mats may contain fossilized cyanobacteria.



abiogenesis



4.404 Gyr old zircon crystals from Australia show that oceans and continental crust existed 150 Myr after Earth formation (Hadean epoch).
4.1-3.8 Gyr ago Late Heavy bombardment → extinctions(?)



What was first: chicken or egg?

That is: **DNA or proteins?**

Surprising answer emerged recently: *none of the above.*

It was probably **RNA!** Whole life could have started with RNA (and proteins), DNA appearing later.

This idea is called an “RNA world” hypothesis.

[SARS-cov2 is an RNA molecule too...](#) ☹️

The Extraterrestrials (ETs)

ETI = Extraterrestrial Intelligence

SETI = Search for ETI

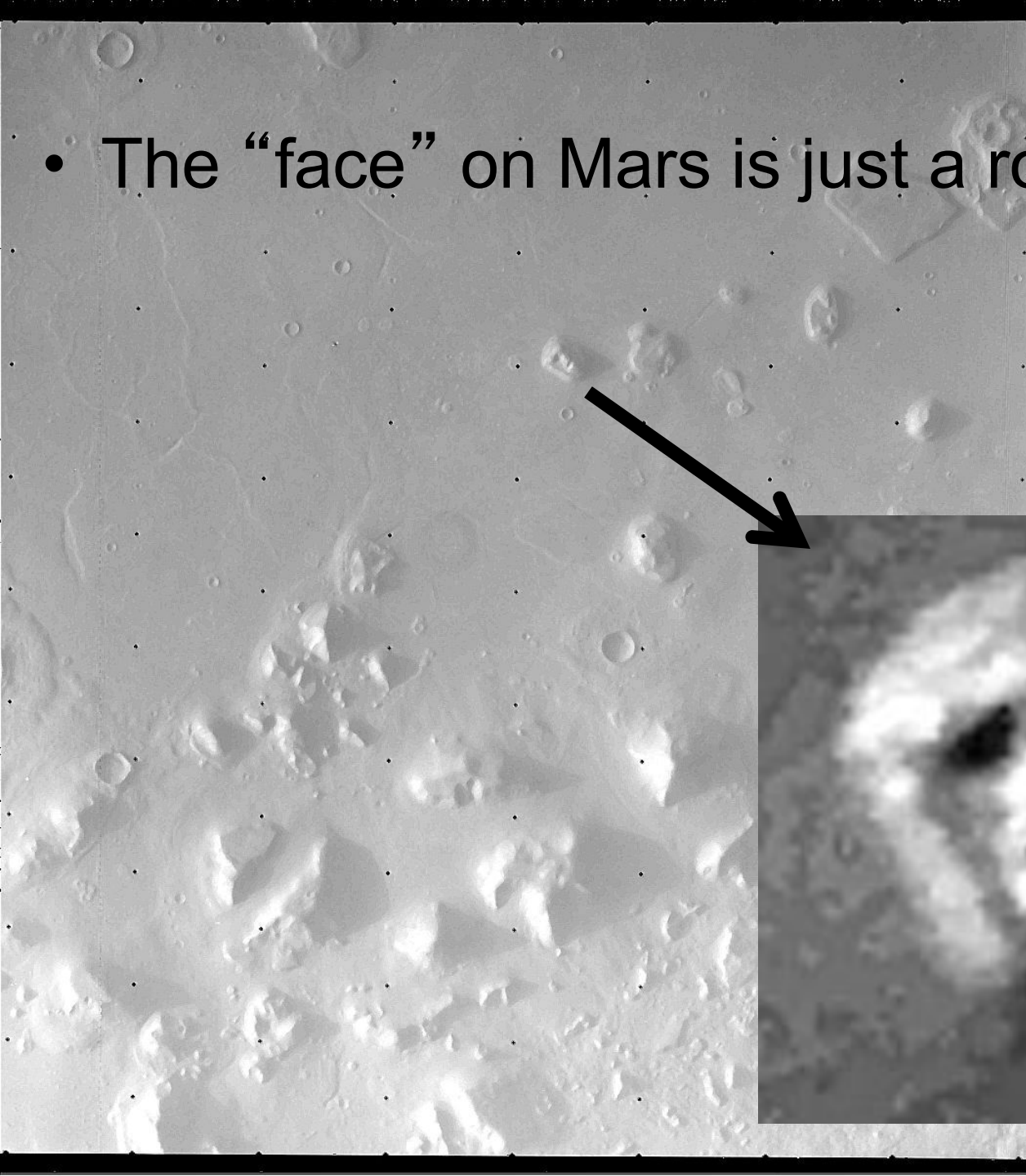
(a) active – we did it once & don't do that any more

(b) passive -- U.S. Congress paid for it a while back

but does not do it any more. Privately funded SETI projects exist.

If planets abound and life is easy(?) to start on a planet in a habitable zone (and thus must be abundant in the Galaxy) then there is one big question...

- The “face” on Mars is just a rock formation



Extraterrestrials

ETI = Extraterrestrial
Intelligence

They may be out there but
as Carl Sagan used to say:
an extraordinary claim requires extraordinary
evidence

UFOs = ETs ?

Wikicommons

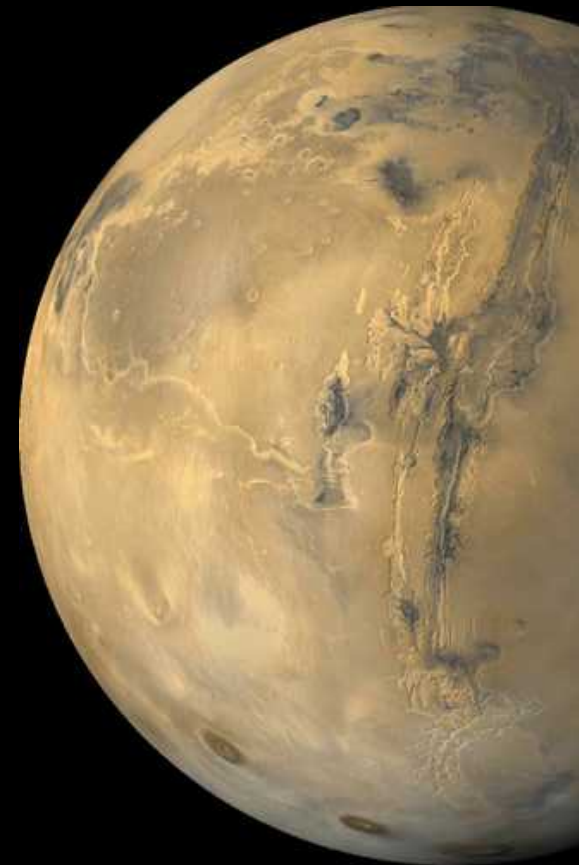
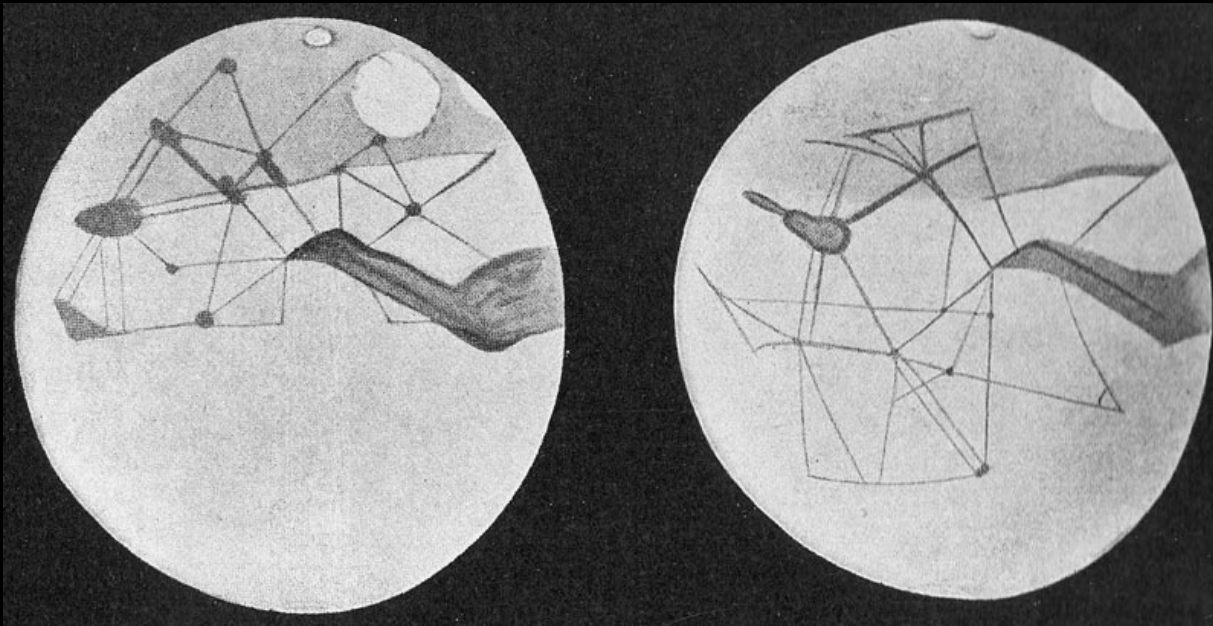
...which is still missing. And no, it's not
hidden by the U.S. Government in Area 51



Though a flying object, it's not a UFO. Military rocket launch
from Vandenberg Space Force Base in California.

Martians from Mars

- Mars was suspected to have Martian Canals (built by a civilization to transport water) by Schiaparelli in 1877, and by Percival Lowell later.



in the 20th century Canals turned out to be an optical illusion

- In 1900 one French society funded a 100,000 Franks prize for the person who discovers an intelligent life in the universe. Mars was excluded from the competition. It was considered too easy of a prediction – everybody was already sure Mars is inhabited by Martians
- H. G. Wells wrote in 1898 *The War of the Worlds* - a book about Martian invasion



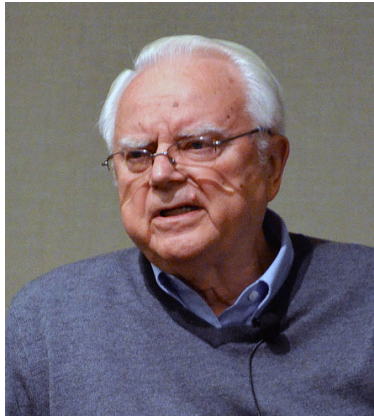
1938 WOTW

Orson Welles produced a very realistic radio broadcast of the WOTW, which has panicked many people in US and Canada and caused them to leave homes and flee from the Martians.



A reenactment in Quito, Ecuador, in 1949, ended with panic, then rioting and 6 deaths.

Frank Drake (prof. at UC Santa Cruz)



https://en.wikipedia.org/wiki/Drake_equation

Drake in 1961 tried to write an equation containing all the factors that go into the probability of existence of ETI *in our Galaxy* (not universe!).

Number of ETI that can communicate with us = product of

- # of stars in our Galaxy ($1e12$)
 - average number of planets per star (~ 1)
 - fraction of planet that are habitable
 - fraction of habitable planet that have life
 - fraction of such planets that host civilizations
 - fraction of civilizations that can & want to communicate
- average longevity of a civilization (L) / age of Galaxy



https://en.wikipedia.org/wiki/Drake_equation

Only some factors were known or at least tightly constrained to within an order of magnitude in 1961. Back then participants of a small conference on SETI = Search for Extraterrestrial Intelligence, thought that numerically N (number of ETI in our Galaxy) is roughly of order L = lifetime of a technical civilization (before it dies out) -- a very uncertain number!

Frank Drake on his car in Santa Cruz had a customized license number plate stating $N = L$ to warn that this is the deciding factor.

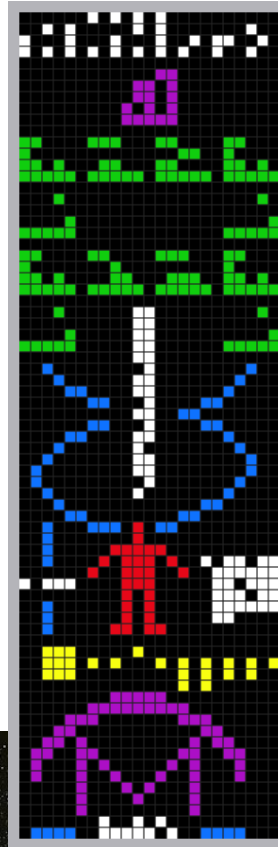
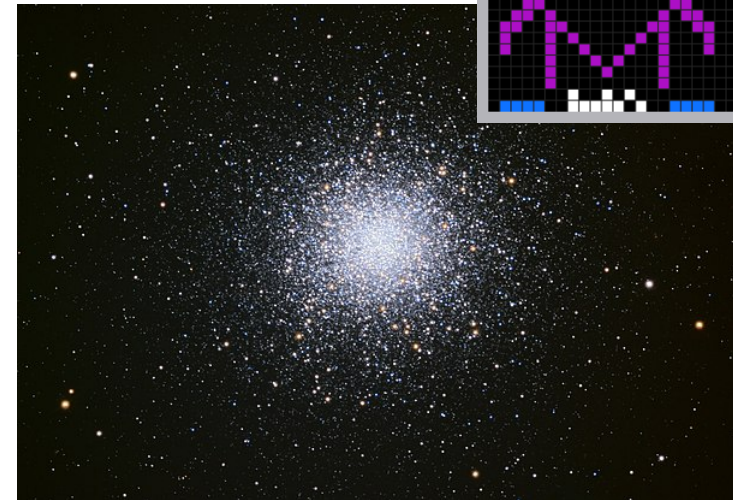
We cannot compute the ‘correct’ value of N because of various uncertainties. We can only place pessimistic ($N=0.00001$), and optimistic estimates on N ($N=1000000$).

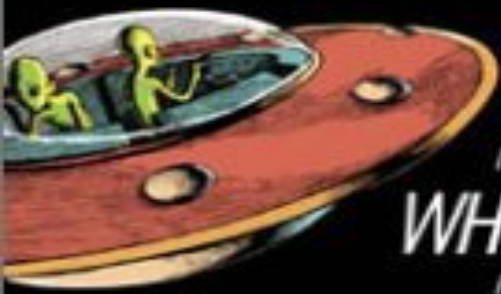


Drake participated in attempts to scan radio-frequencies near the 21 cm line of hydrogen. The result of his project Ozark was negative. He also sent Arecibo Message in Nov. 1974 from the Arecibo antenna space (in the direction of globular cluster M13 shown below).

50 years of sporadic and systematic SETI searches gave a null result so far.

*But if planets are so common, and
IF life is easy to start on a habitable
planet, then it must be abundant in the Galaxy
But then there is one big question...*



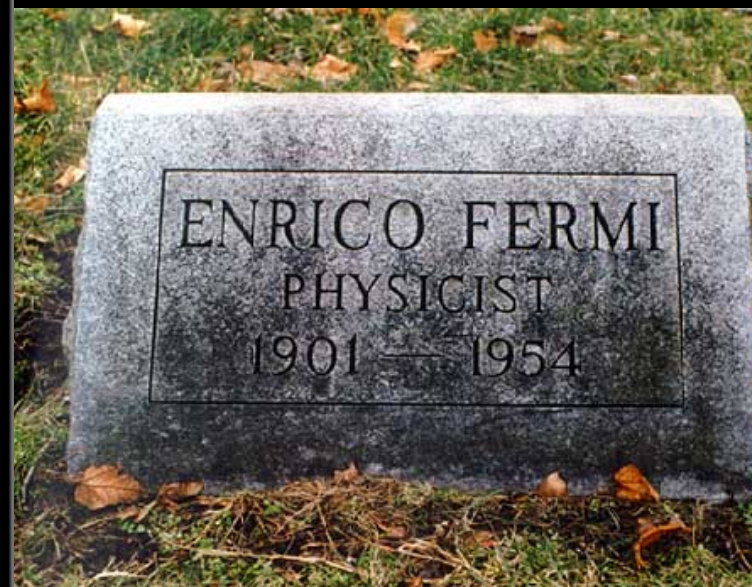
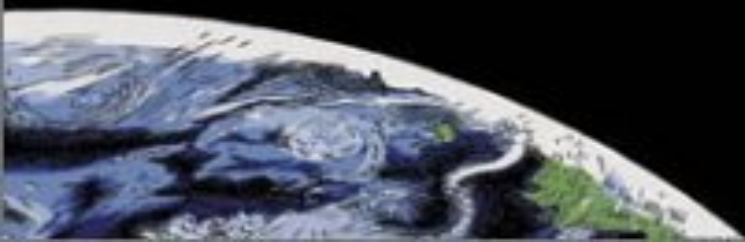


IF THE UNIVERSE IS TEEMING WITH ALIENS ...
WHERE IS EVERYBODY?

FIFTY SOLUTIONS TO THE FERMI PARADOX
AND THE PROBLEM OF EXTRATERRESTRIAL LIFE

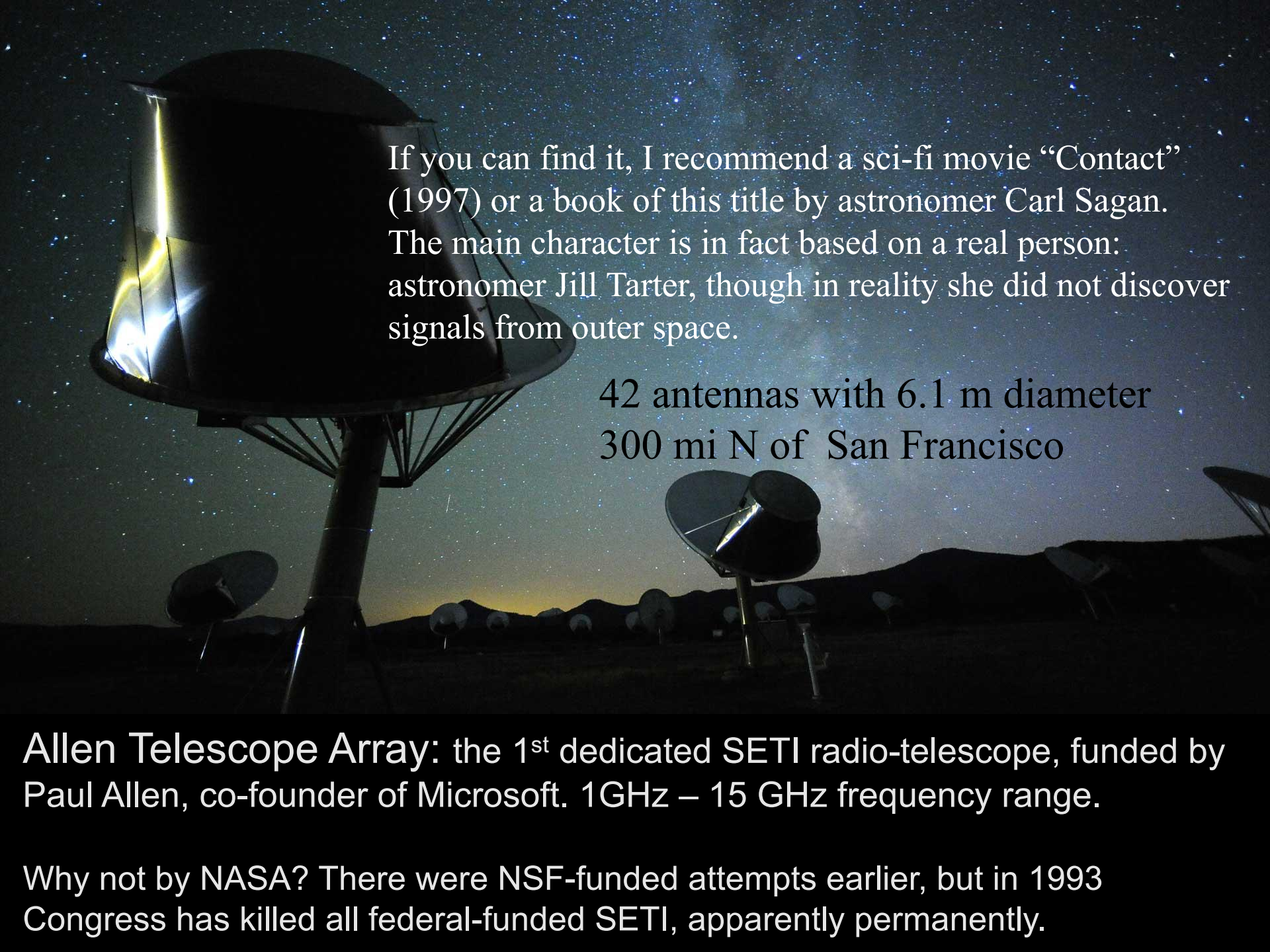
Stephen Webb

(Fermi's paradox)



Fermi Paradox "Why Aren't They Here Already?" Top 10 answers

1. We are truly alone in the universe: rare Earth hypothesis [unlikely!]
2. ETI is out there, but can't get here (too far, too long a travel) [not true! A solar sail vehicle starting from the vicinity of our sun could achieve speed ~100 km/s & cross our Galaxy in just 200 mln yrs]
3. We're not looking in the right place [still doesn't explain the question]
4. We're extraterrestrials [that doesn't explain the origins]
5. ETI is out there, but they are so energy-efficient we can't hear them [but why don't they come here?]
6. Self-destruction theory (e.g., humans very close to that in 1961)
7. We *could* hear them if we tried harder (==> motivation for SETI, including project SETI@home; see next slide)
8. They have landed (UFOs) but it's all covered up by the government
9. They are peaceful agrarians who lack the drive to contact anybody
10. We are a ZOO of lowly creatures to E.T.s, we are being watched ("the proof that E.T.s exist is that nobody wants to contact us")



If you can find it, I recommend a sci-fi movie “Contact” (1997) or a book of this title by astronomer Carl Sagan. The main character is in fact based on a real person: astronomer Jill Tarter, though in reality she did not discover signals from outer space.

42 antennas with 6.1 m diameter
300 mi N of San Francisco

Allen Telescope Array: the 1st dedicated SETI radio-telescope, funded by Paul Allen, co-founder of Microsoft. 1GHz – 15 GHz frequency range.

Why not by NASA? There were NSF-funded attempts earlier, but in 1993 Congress has killed all federal-funded SETI, apparently permanently.