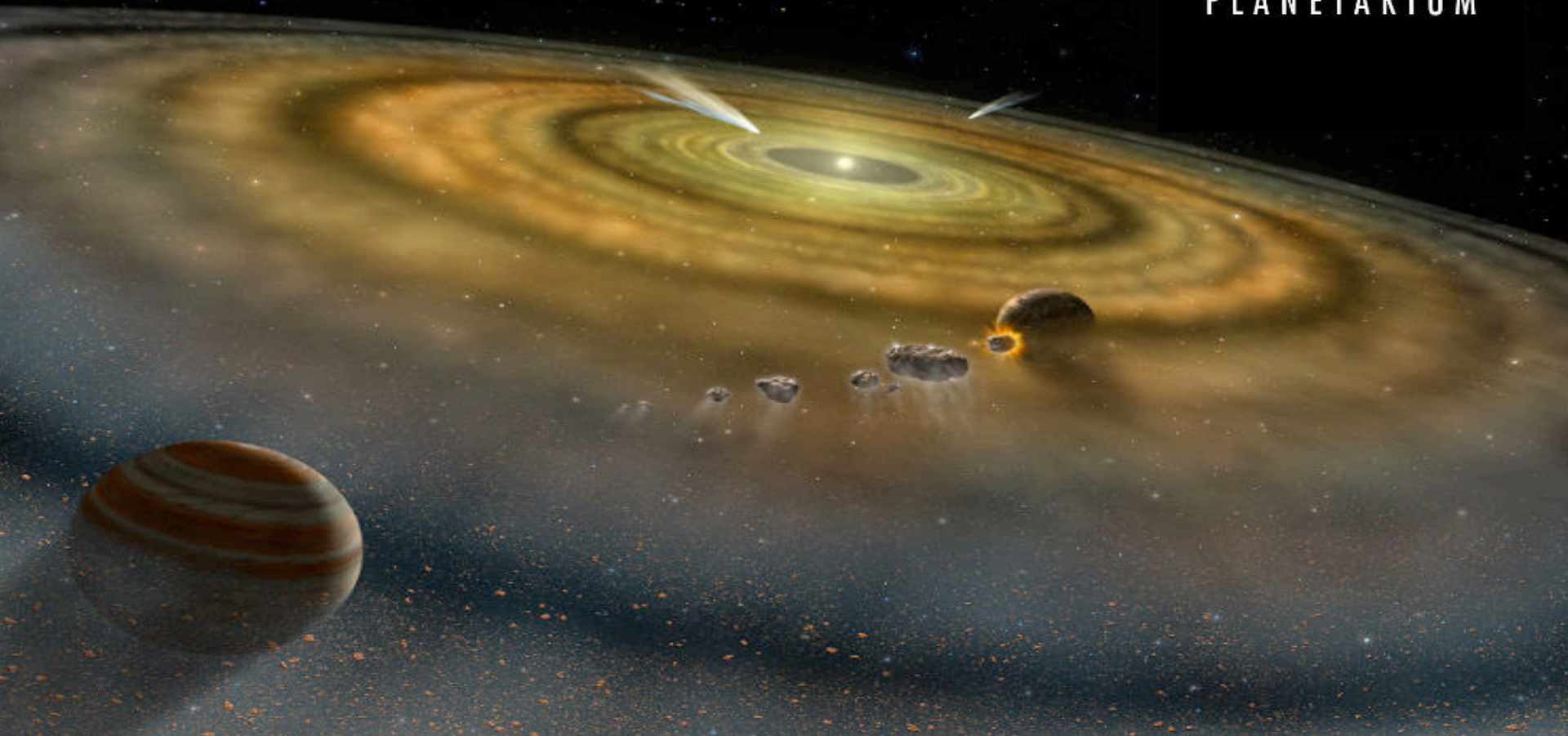


Astrobiology

Looking at life's connection to space

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PLANETARIUM



Astrobiology

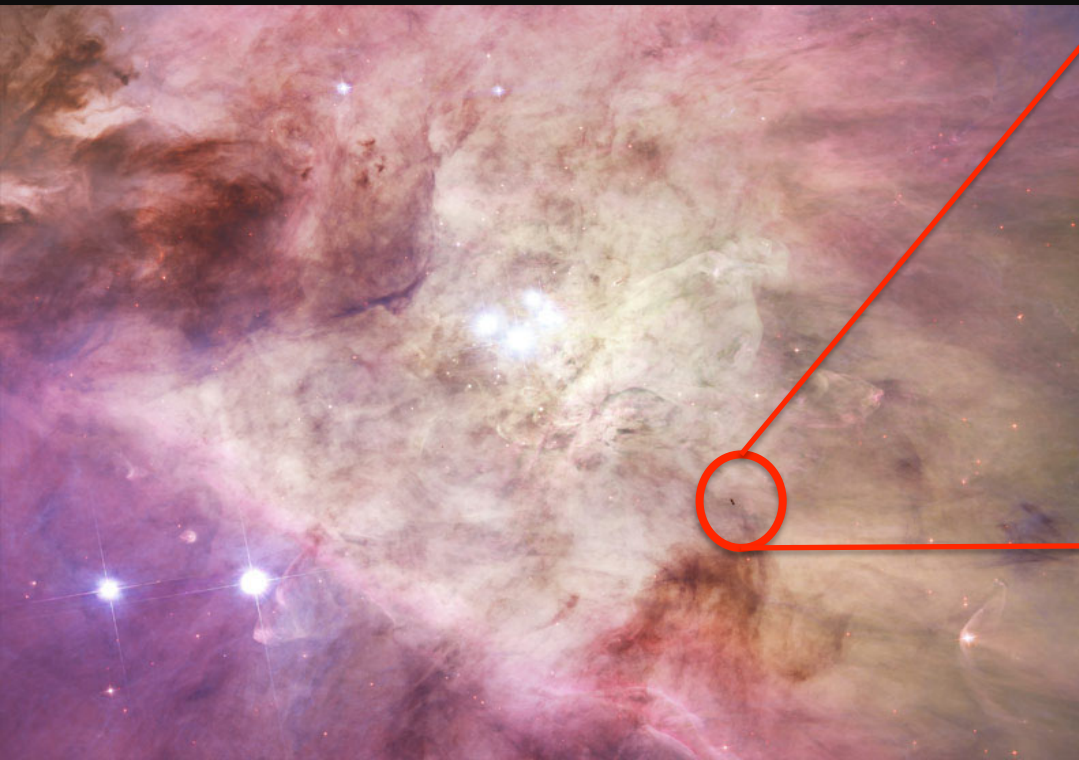
Astronomy + Biology



Study of **life** in the context of/the universe

takes energy, “makes waste”, reproduces

- Early work from 1957 to 1976 Viking landing
- Took off after first “exoplanet” discovery in 1995, and Hubble Space Telescope results



Credit: HST

Fundamental questions:

How does life begin and evolve?

Does life exist elsewhere? If so, how can we detect it?

What is the future of life here on Earth and in the universe?



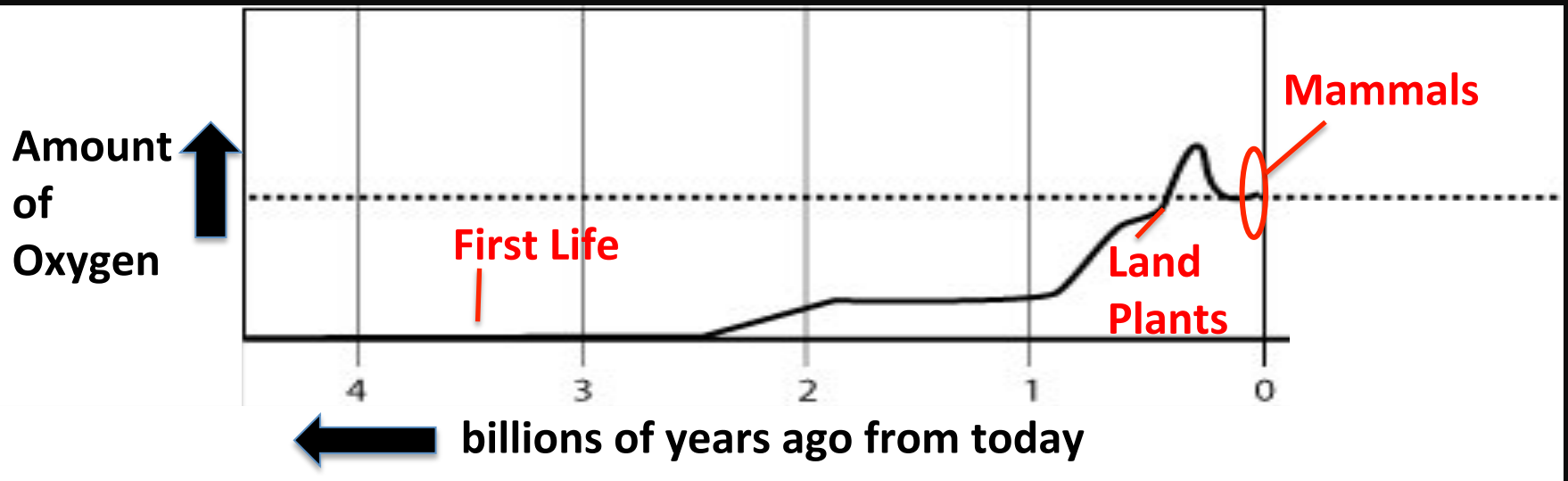
How does life begin and
evolve?

The Early Earth...



You developed a time machine but don't know how to set it... you randomly go back in time, which danger are you likely to face?

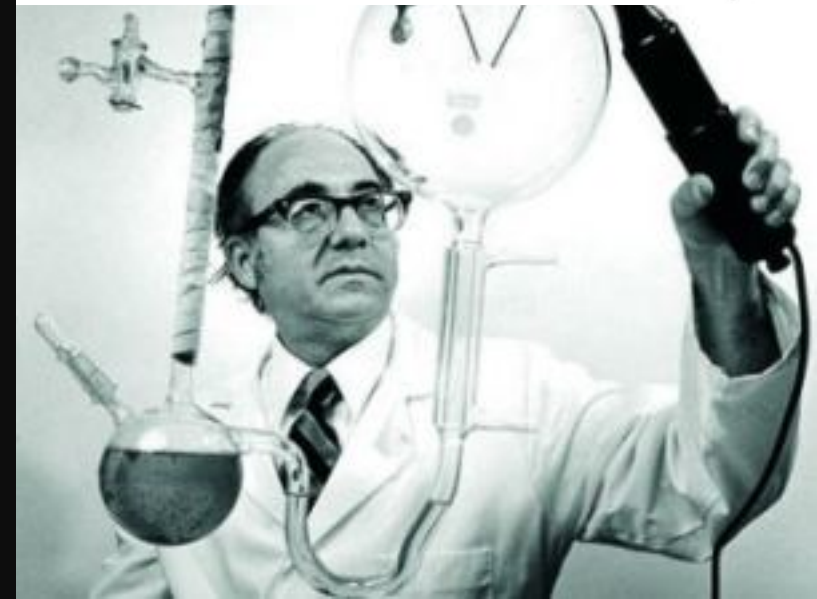
C) Won't be able to breathe



- Cyanobacteria made enough oxygen for plants and animals to evolve

- 1953 Miller-Urey Experiment showed that the building blocks of life could form under conditions of early Earth.

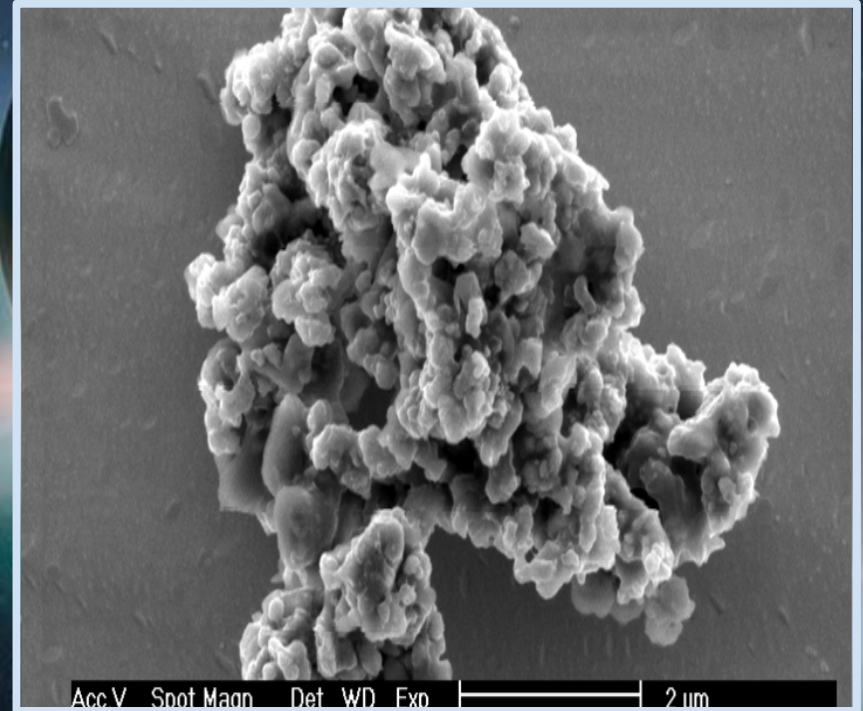
- But how organic material became self-replicating “life” is still very unclear



Origins could also be tied to space

- Comets and asteroids brought Earth water and possibly organic material too

- Space dust packed with organic materials, also see organics in far away clouds of gas and dust



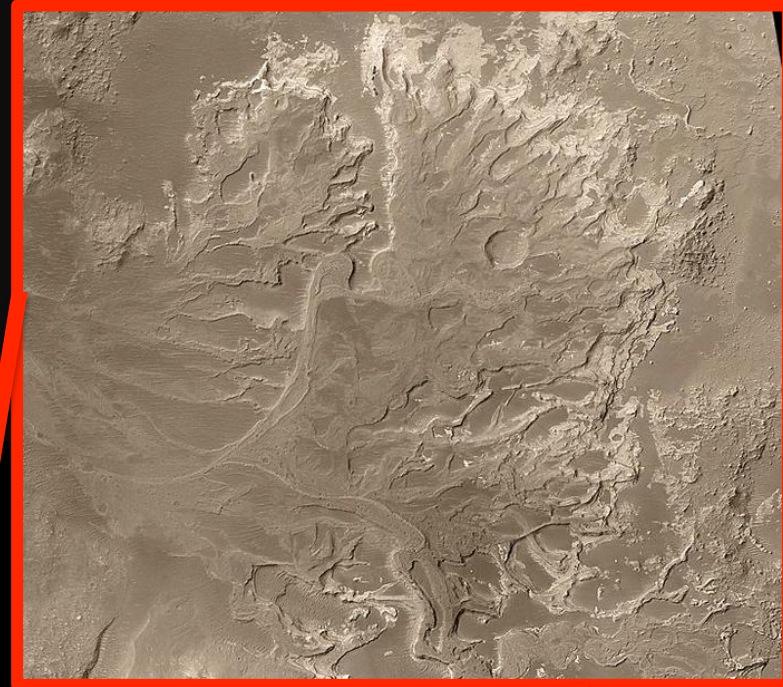
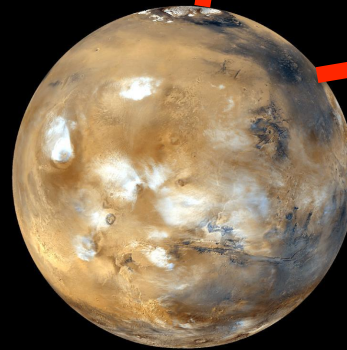
Credit: N. Spring

- Was first life on Earth actually extraterrestrial?

Does life exist elsewhere? If so, how can we detect it?

Candidate # 1: Mars

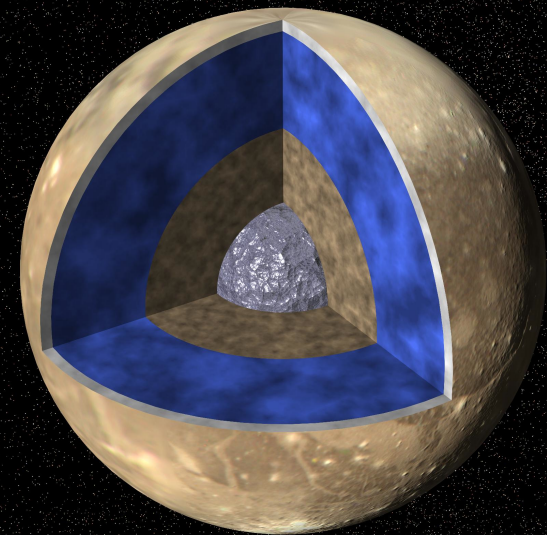
- Abundance of evidence from rovers and orbiters for past water
- Current water locked up in ice and permafrost
- Liquid water beneath surface???



Credit: NASA/JPL

Candidate # 2: Europa (a moon of Jupiter)

- Likely has a subsurface ocean
- Arguably the best place outside Earth to look for life in the solar system

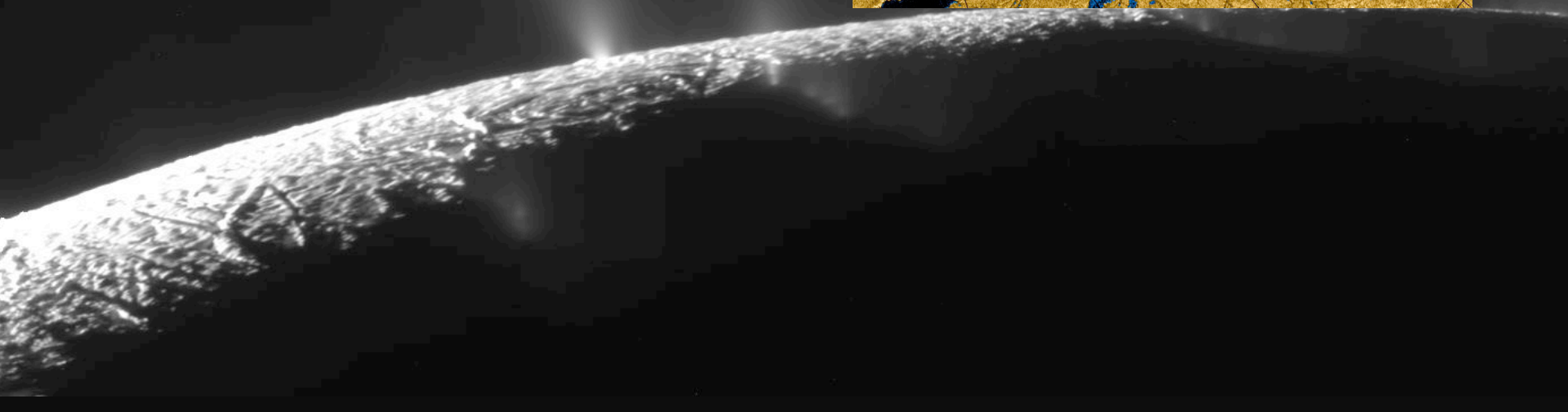
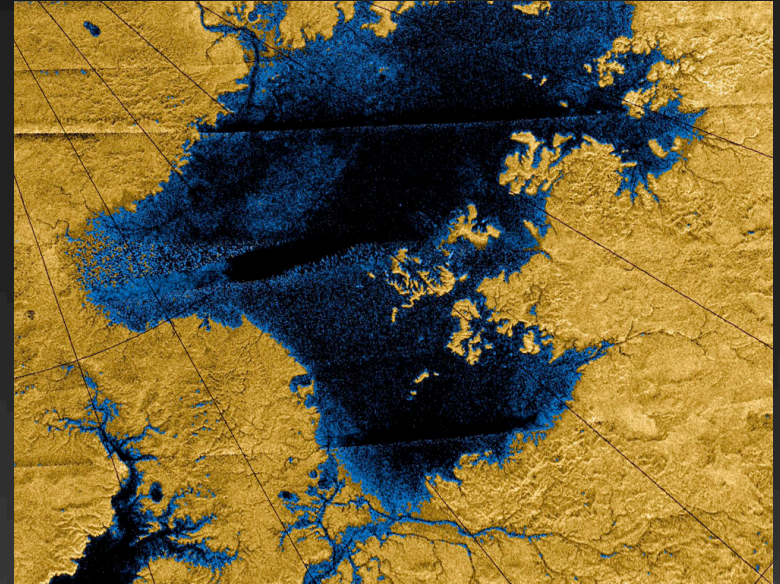


Credit: NASA/JPL

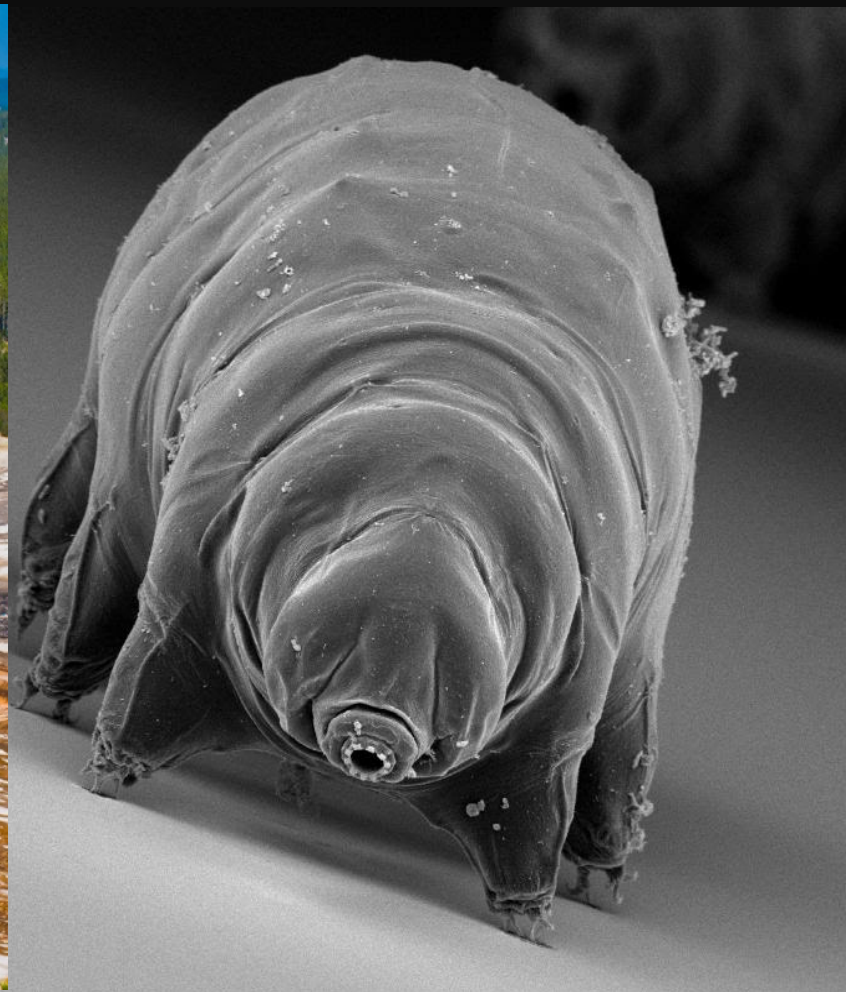
Candidate # 3: Titan (a moon of Saturn)



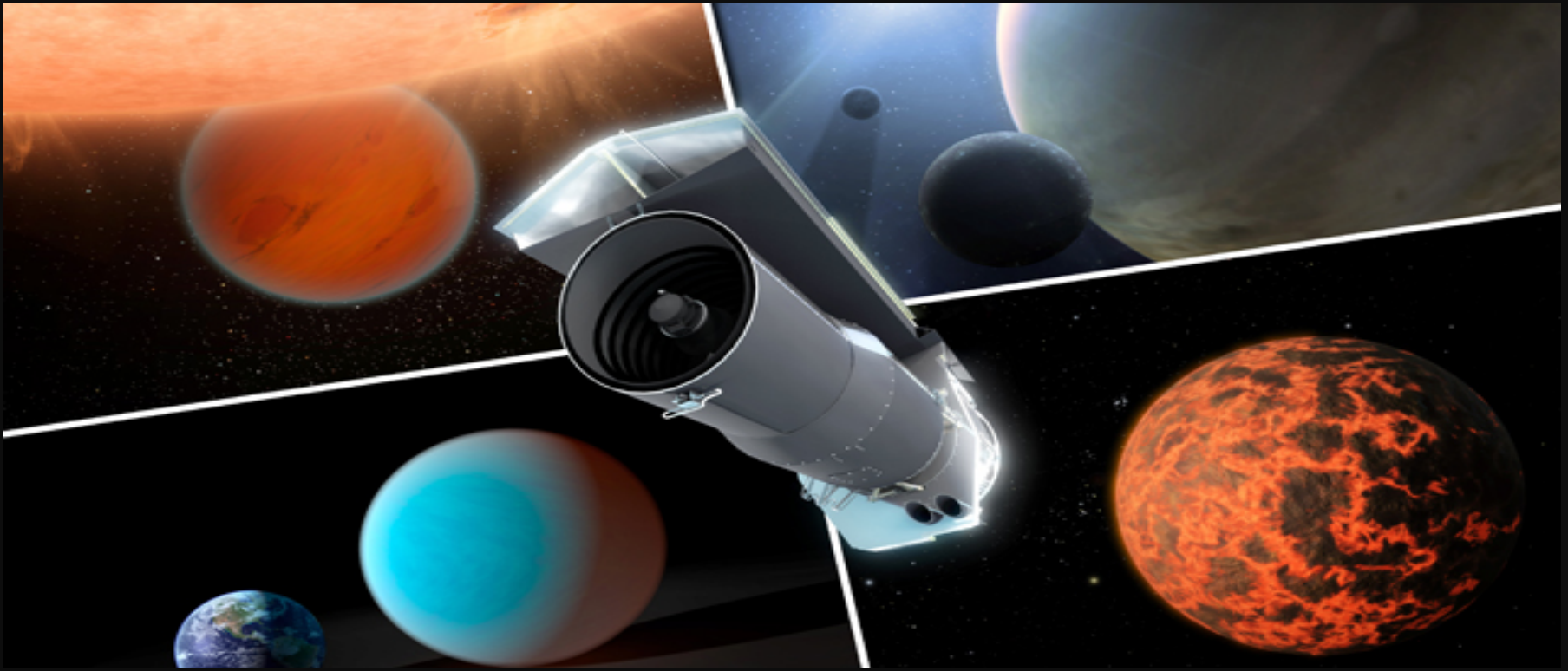
Enceladus is also candidate!



- Life on Earth diverse, and is found in the most **extreme** places
- These extremophiles may hold the key to understanding alien life as well as the origin of life on Earth



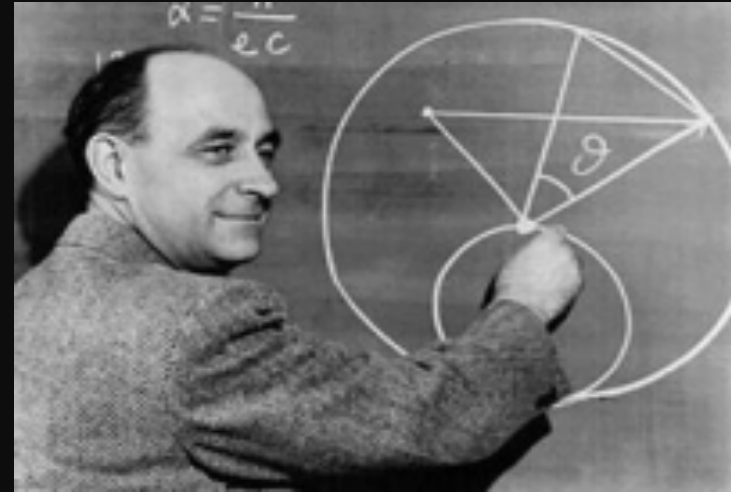
Estimated 10 billion Earth-like planets in our galaxy at a temperature where water could exist!



- We are just beginning to probe the atmospheres of some of the many known planets outside the solar system

What is the future of life here on
Earth and in the universe?

“If it seems so likely the universe may host other life forms, how come we haven’t seen any signs?”



-THE FERMI PARADOX

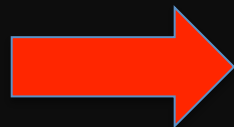
➔ Possible Answer: The Drake Equation

Drake thought that the number of intelligent transmitting civilizations in our galaxy could be estimated from a number of factors...

1. number of stars formed per year
2. fraction of stars that have planets
3. number of planets per system that can support life
4. fraction of those planets that develop life
5. fraction whose life that becomes "intelligent" enough to communicate
6. number of years they try to communicate

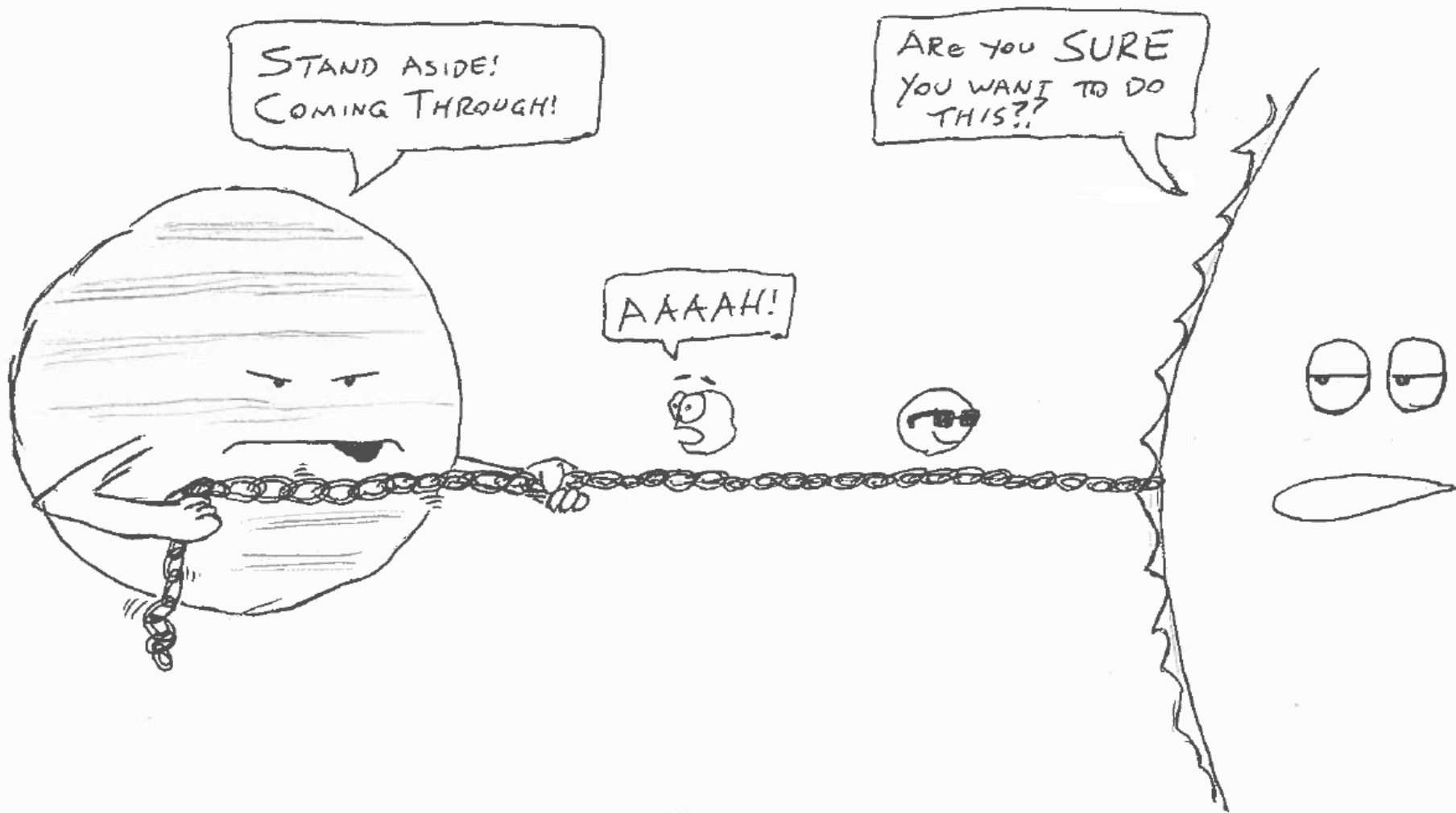
Well known!

?



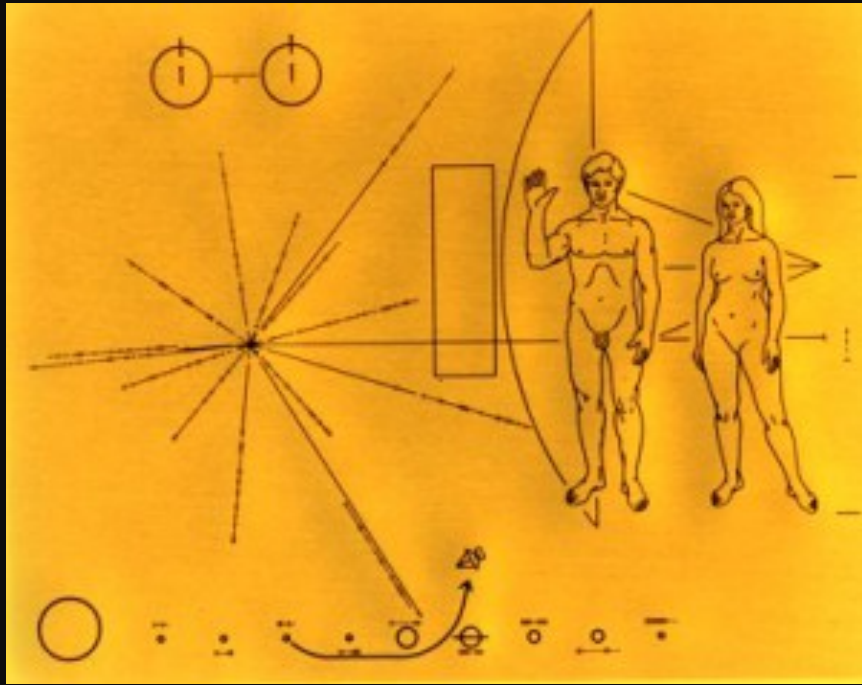
Estimates from 1 to 100,000!

What needs to happen for a planet to be able to support and develop life?



PLANETARY MIGRATION FOR DUMMIES

We are looking... and waiting to be found





Some part of our being knows this is where we came from. We long to return, and we can, because the cosmos is also within us. We're made of star stuff. We are a way for the cosmos to know itself.”

— [Carl Sagan, *Cosmos*](#)

