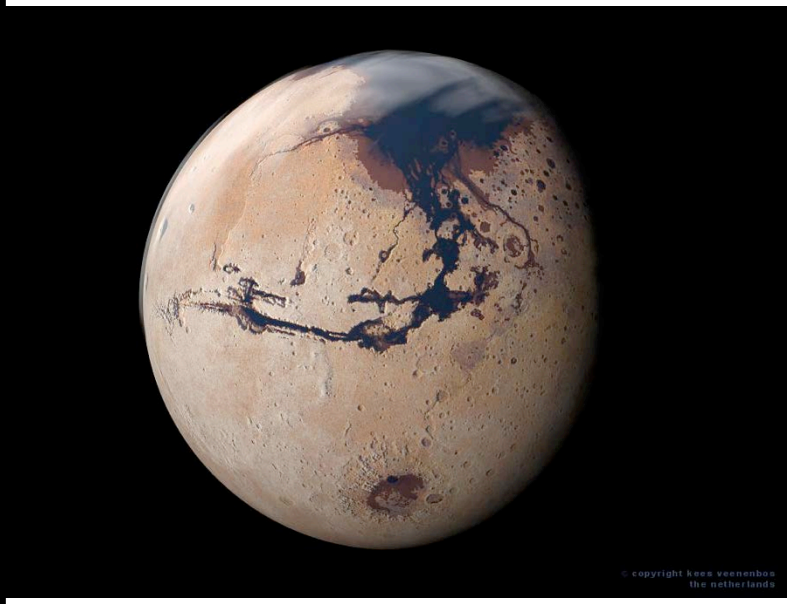
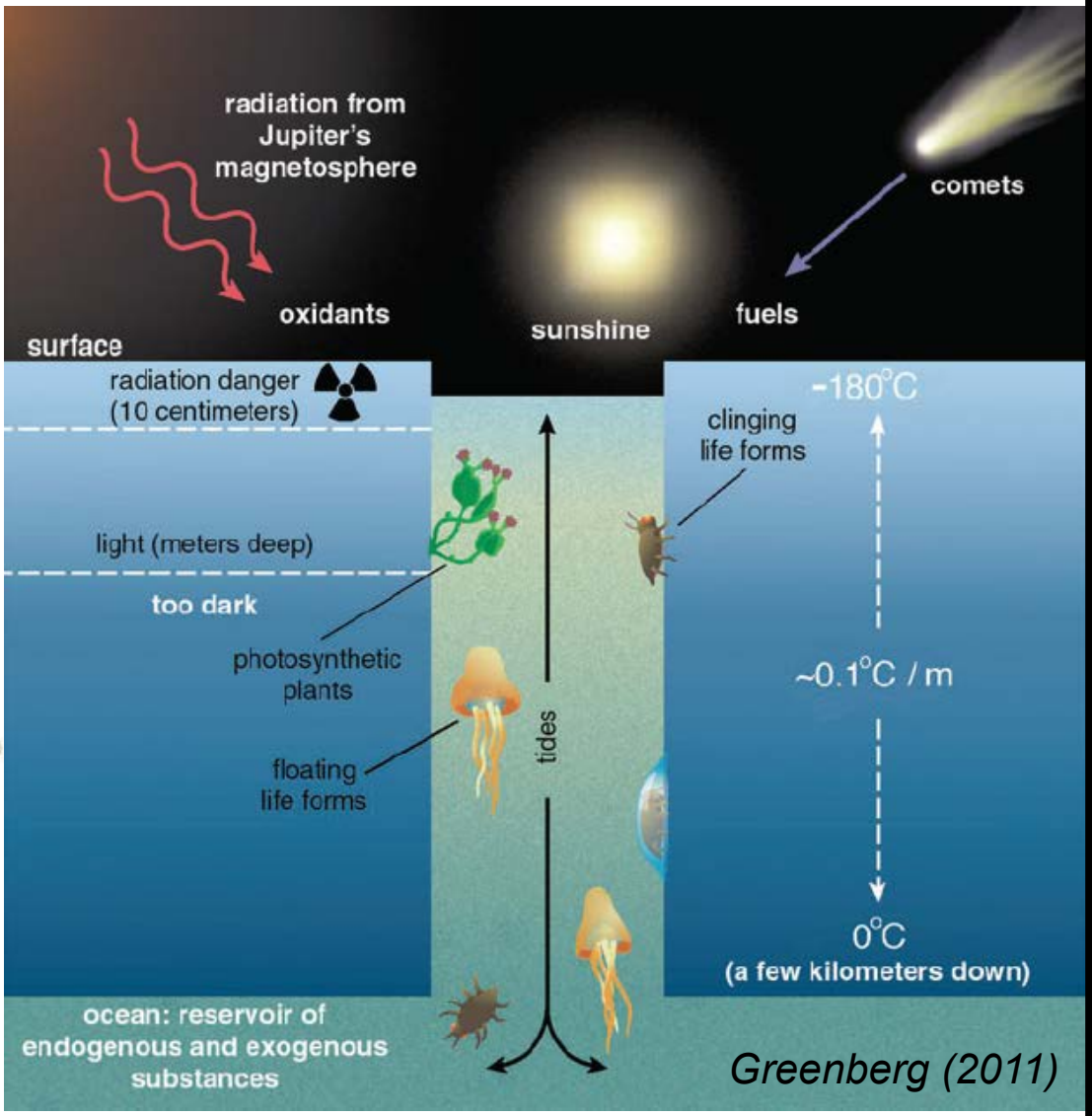
Astrobiology





Greenberg (2011)

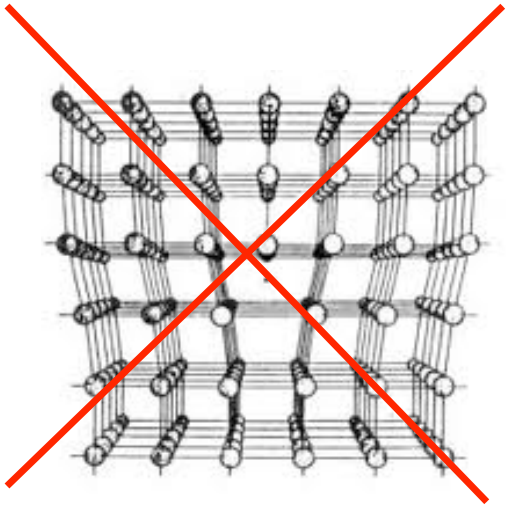
What is astrobiology?

"Astrobiology is the study of the origin, evolution, distribution, and future of life in the universe." —*astrobiology.nasa.gov*

What is life?

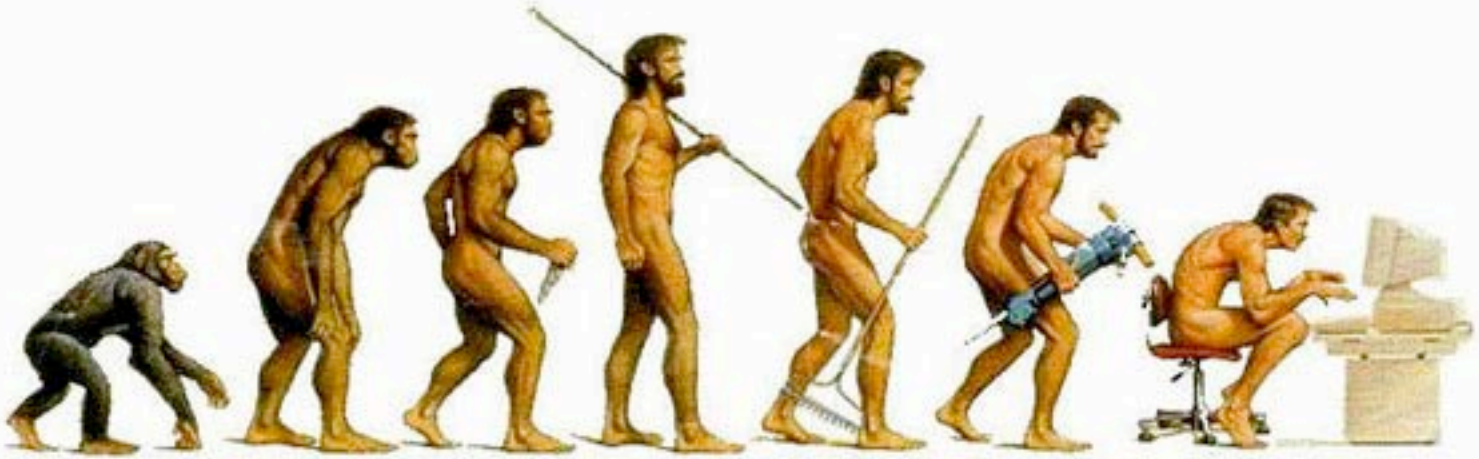
"We'll know it when we see it."

…or will we??



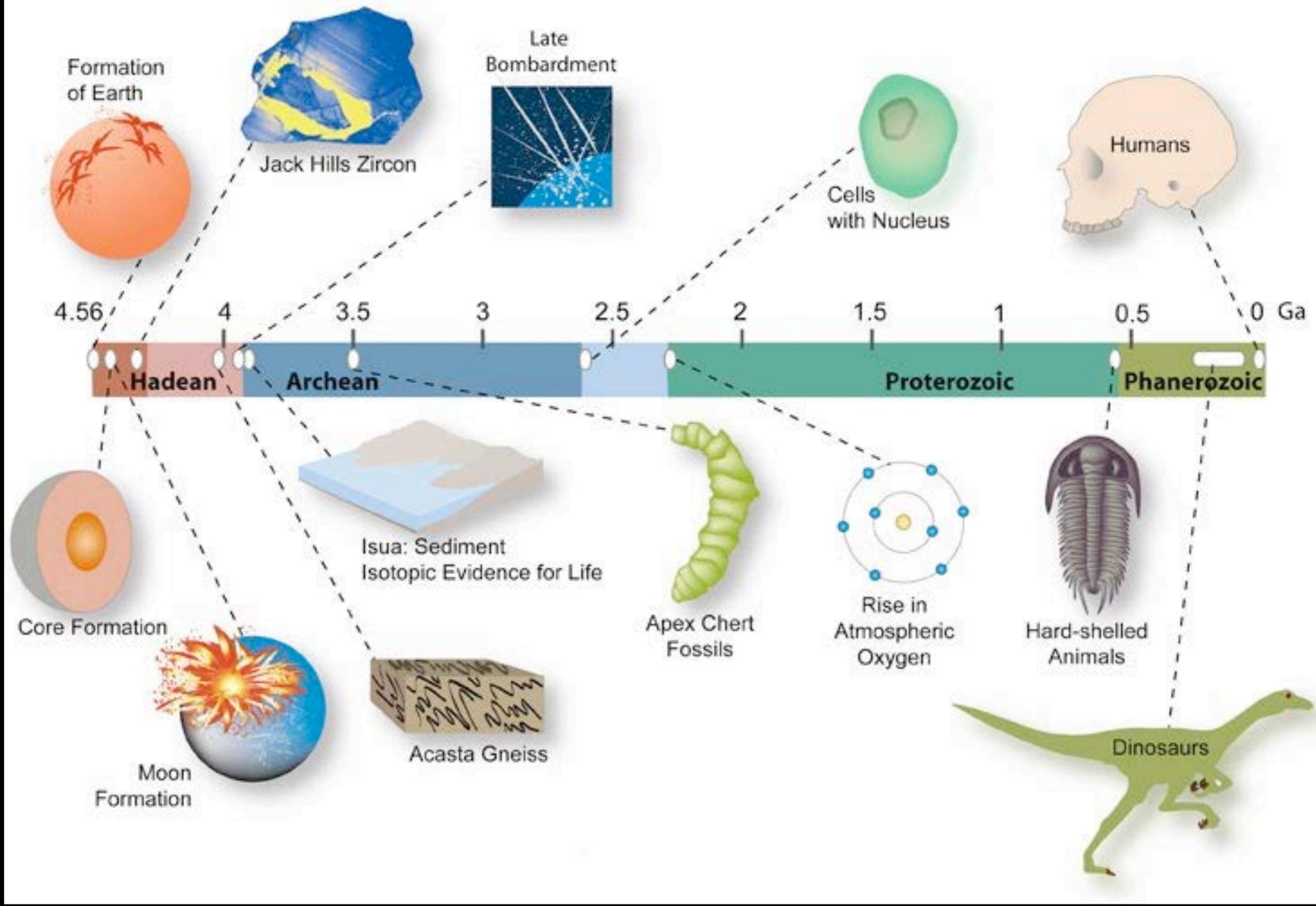
We generally accept that life must be able to reproduce, to mutate, and to reproduce its mutations.

Evolution

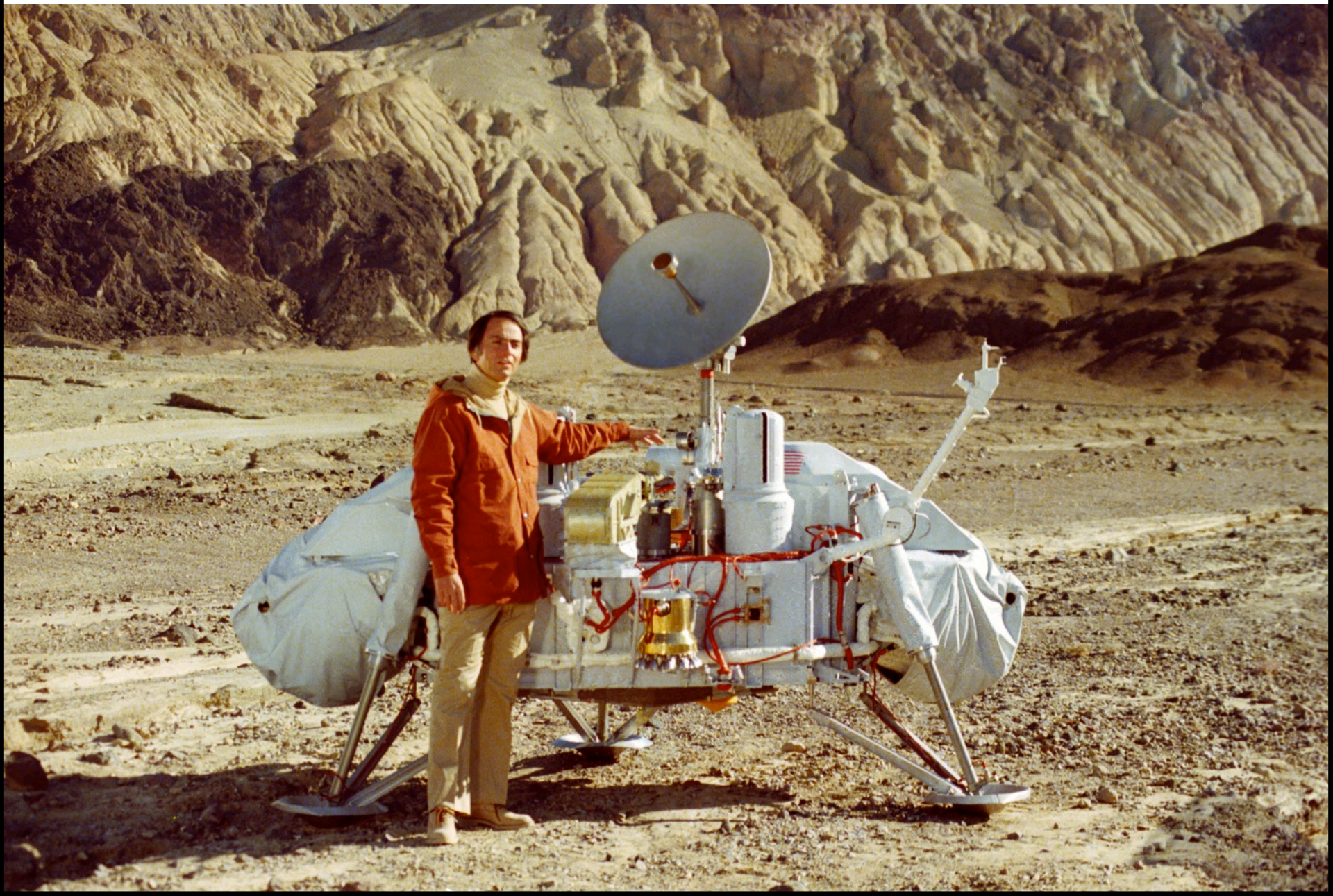


http://www.youtube.com/watch?v=gZpsVSVRsZk

Evolutionary Timeline

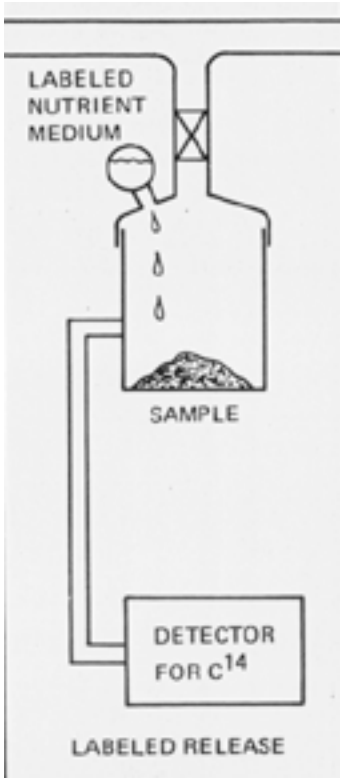


1976: Our one and only direct search for life

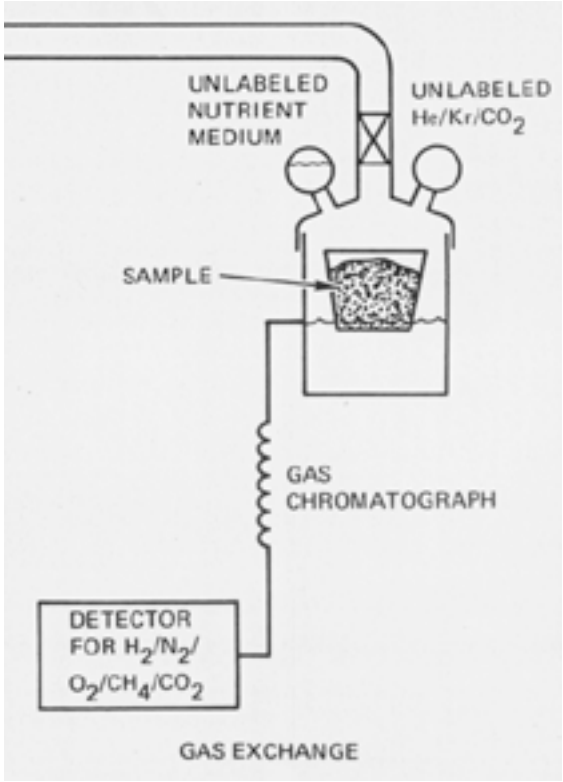


Viking Biology Experiment
(offer food, see what happens)

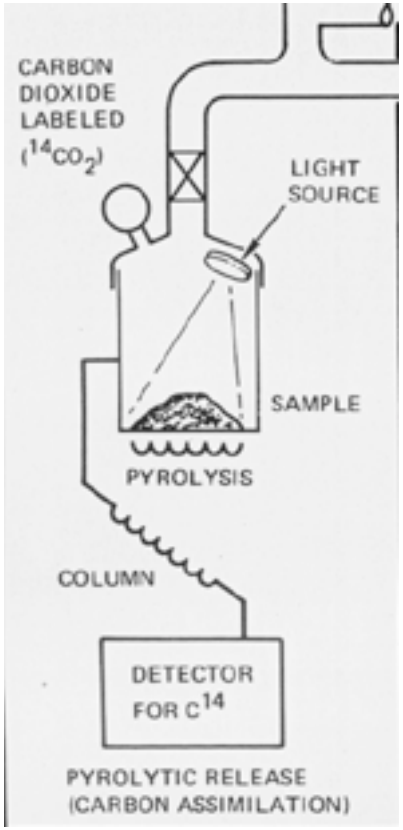
Labeled Release



Gas Exchange



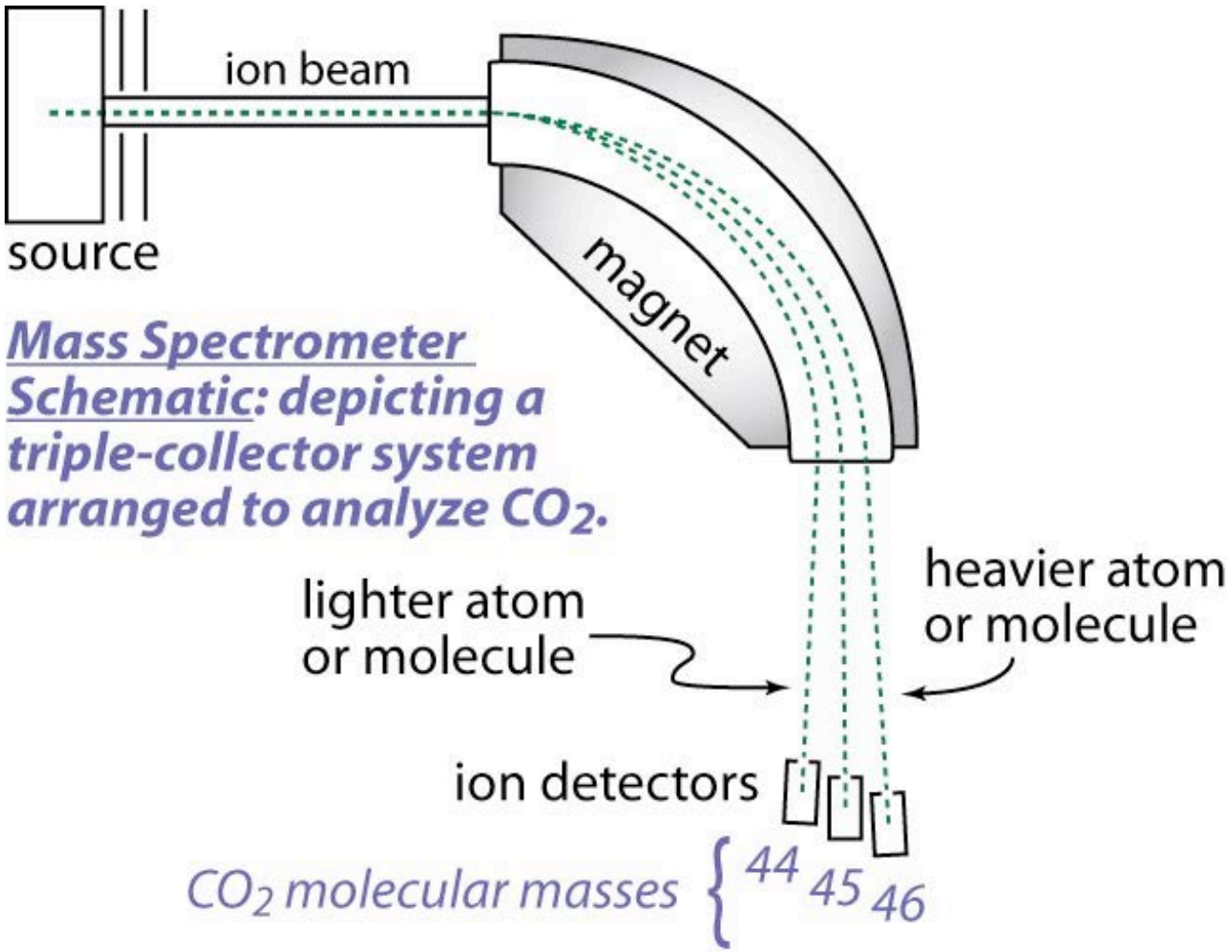
Pyrolytic Release



- All three experiments got positive results!

- But GEx and PR also got these results for sterilized soils…

Viking GC / Mass Spectrometer



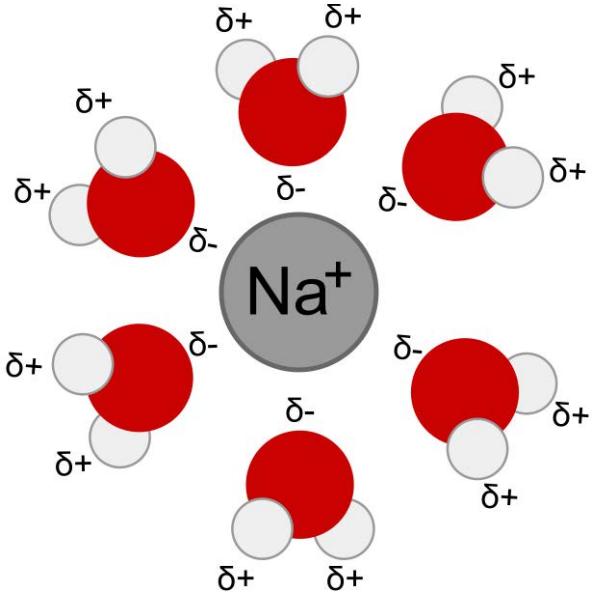
- Detected ***no organics****, not even from meteorites that hit Mars

but we are now trying again with Curiosity's SAM instrument

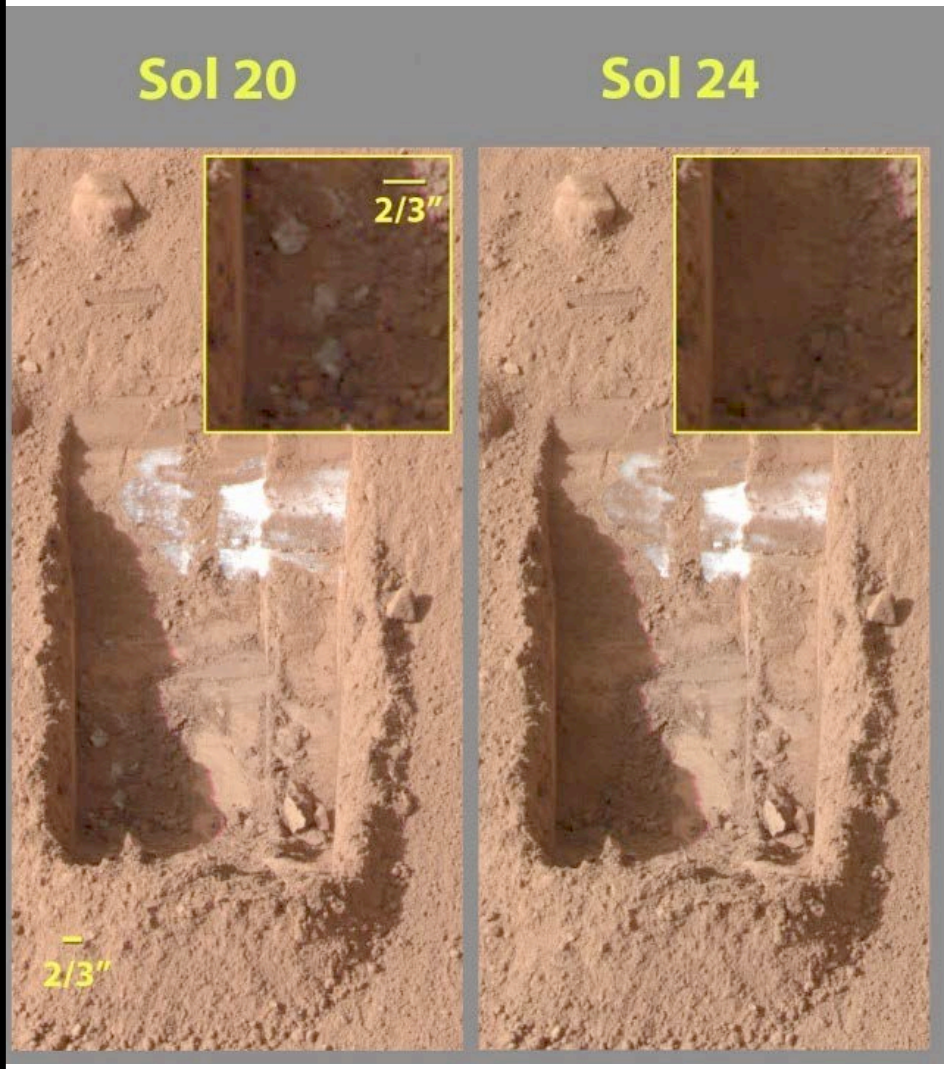
What does life require?

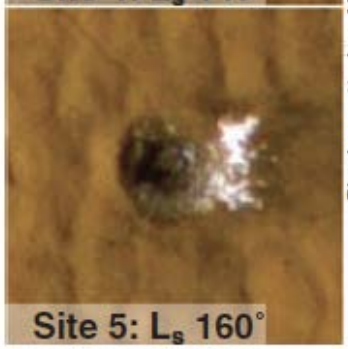
1) Liquid water

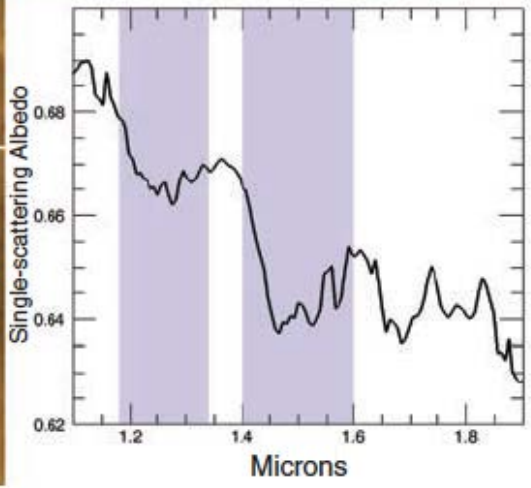
…or another polar solvent (e.g., methanol?), but H_2O is most effective and abundant



Modern Mars: Could life persist in the ice?



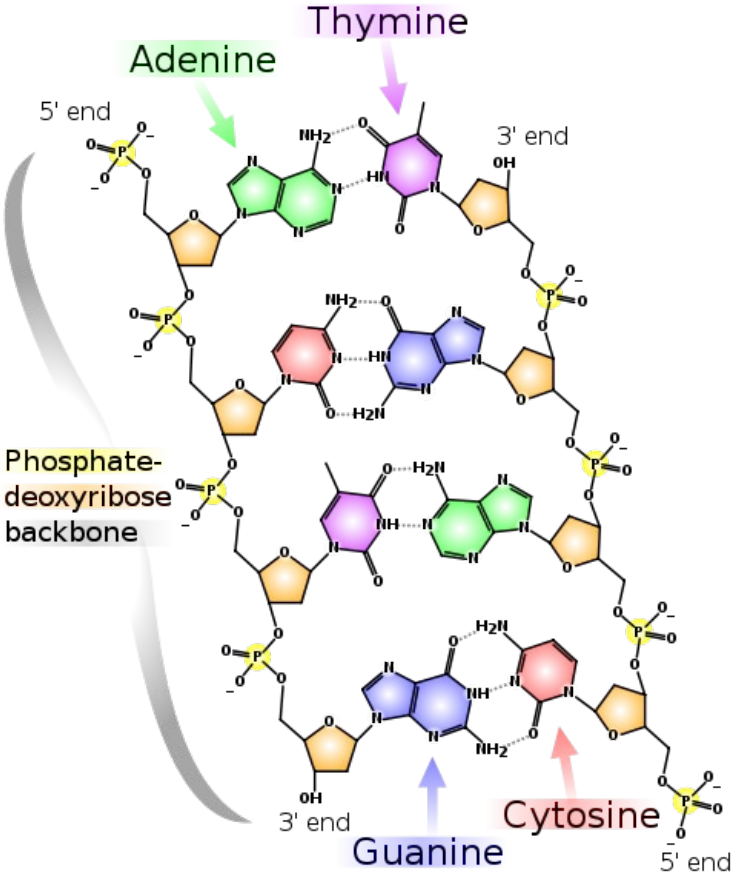


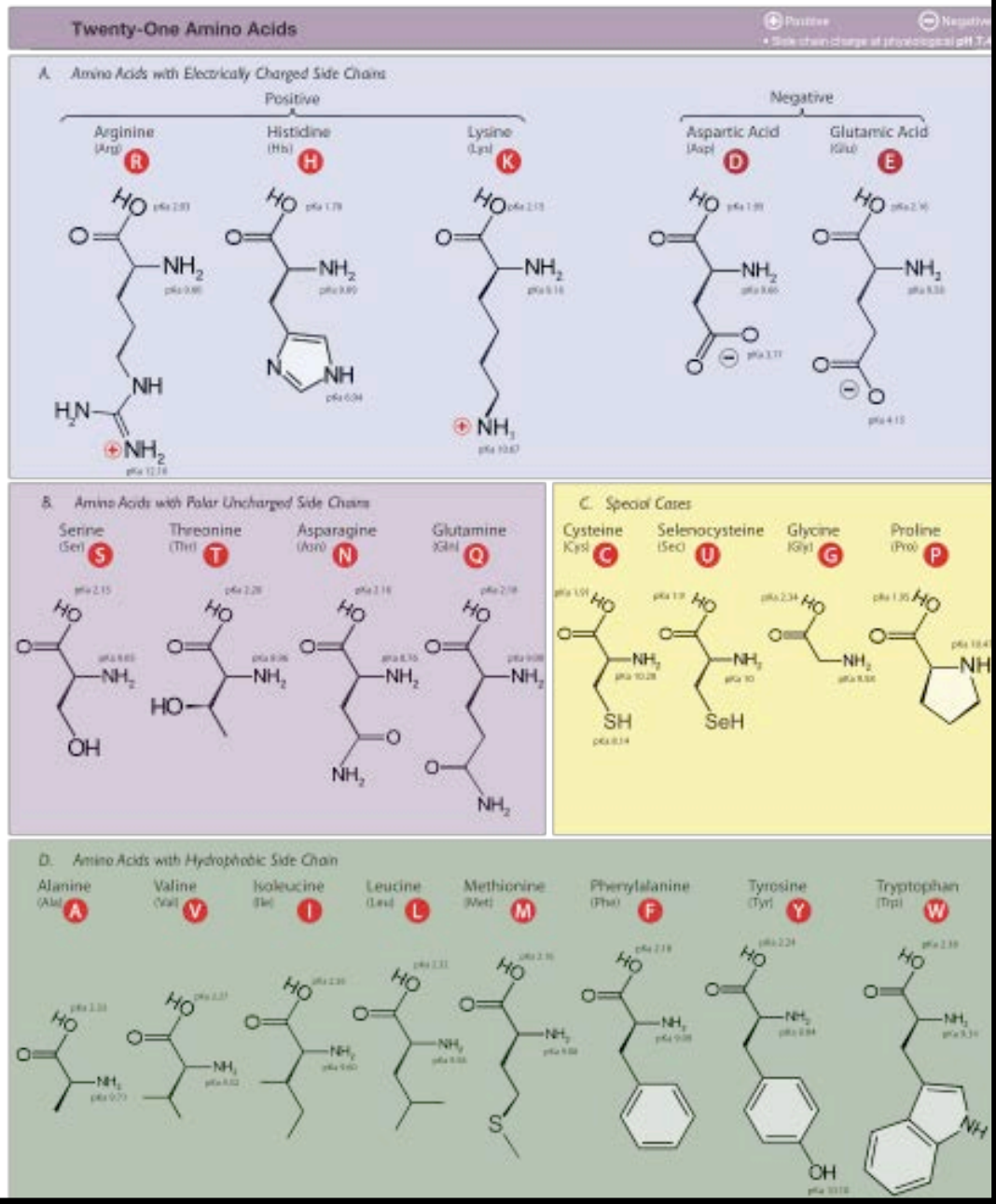


What does life require?

2) Chemical building blocks: C, H, N, O, P, S

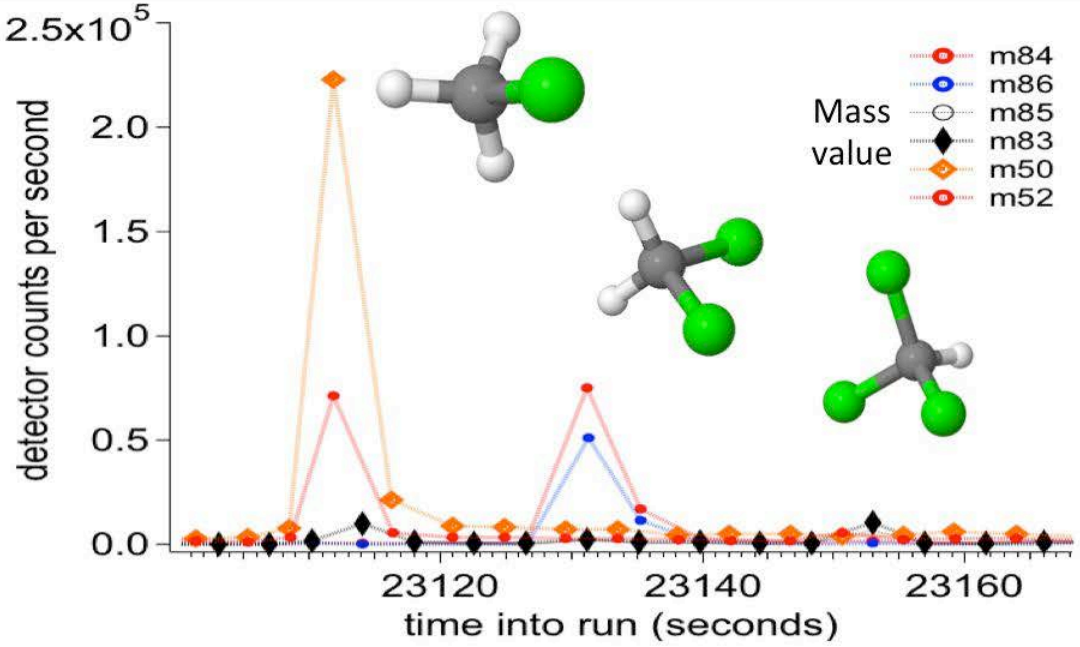
Si? As?





Chlorinated compounds CH_3Cl, CH_2Cl_2, $CHCl_3$, and a 4 carbon chlorine containing compound are detected by SAM

Chlorine compounds found in Rocknest



Although the Cl in these organic compounds is Martian, it is presently unclear whether the carbon is Martian or terrestrial. This remains to be established with ongoing analysis, future laboratory work, and experiments on Mars.

The Curiosity search for organics in other environments and samples will continue

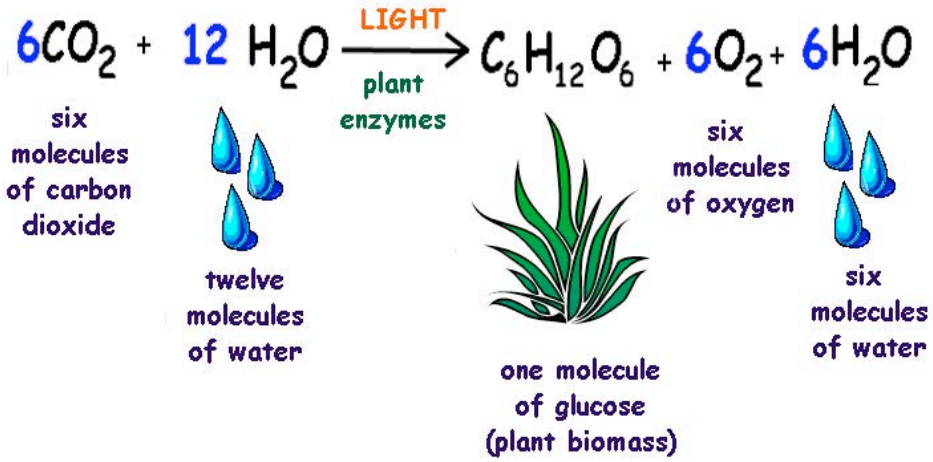
SAM results show that the Rocknest sand drift does NOT contain abundant organics

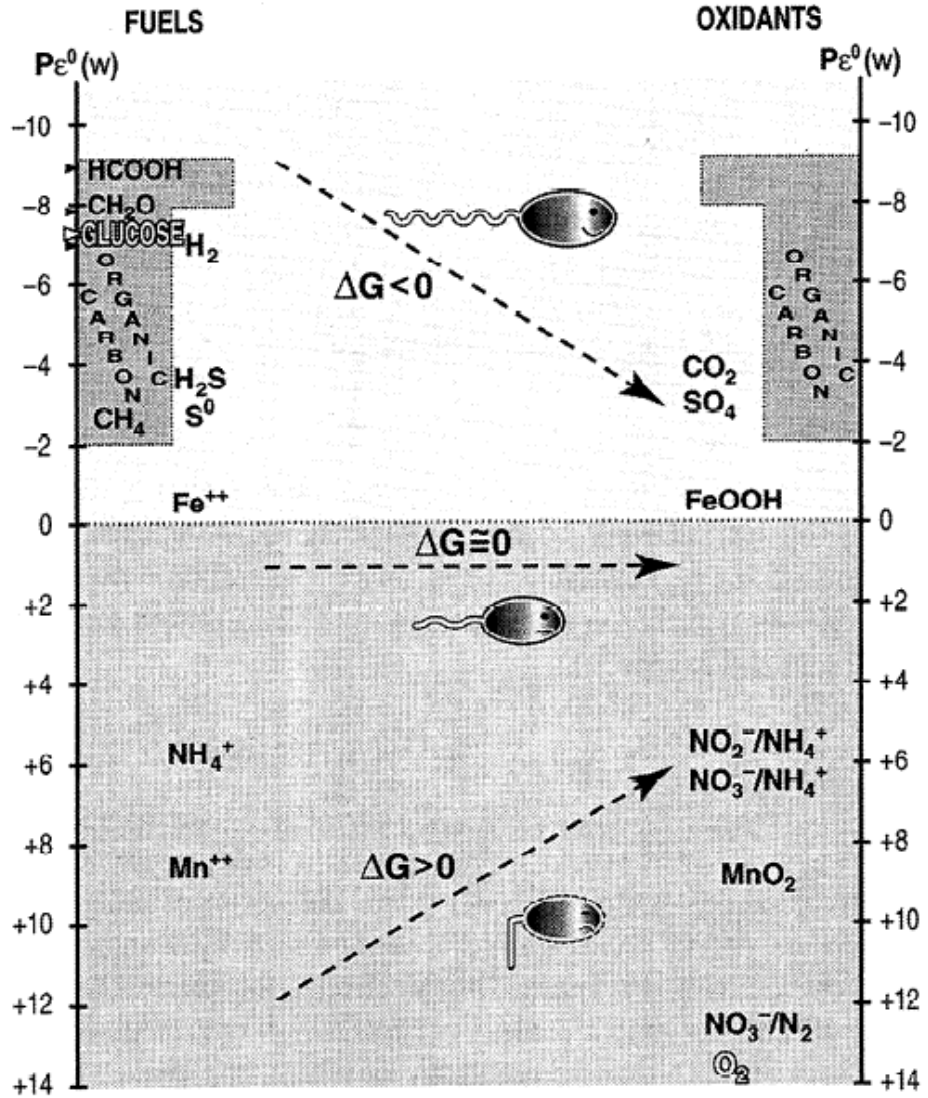
Organic compounds that arrive from space in the form of micrometeorites may be transformed by a variety of mechanisms

- **Cosmic radiation**
- **Ultraviolet radiation**
- **Hydrogen peroxide**
- **Dust induced electrical discharges**
- **Other oxidants in soil/dust**

What does life require?

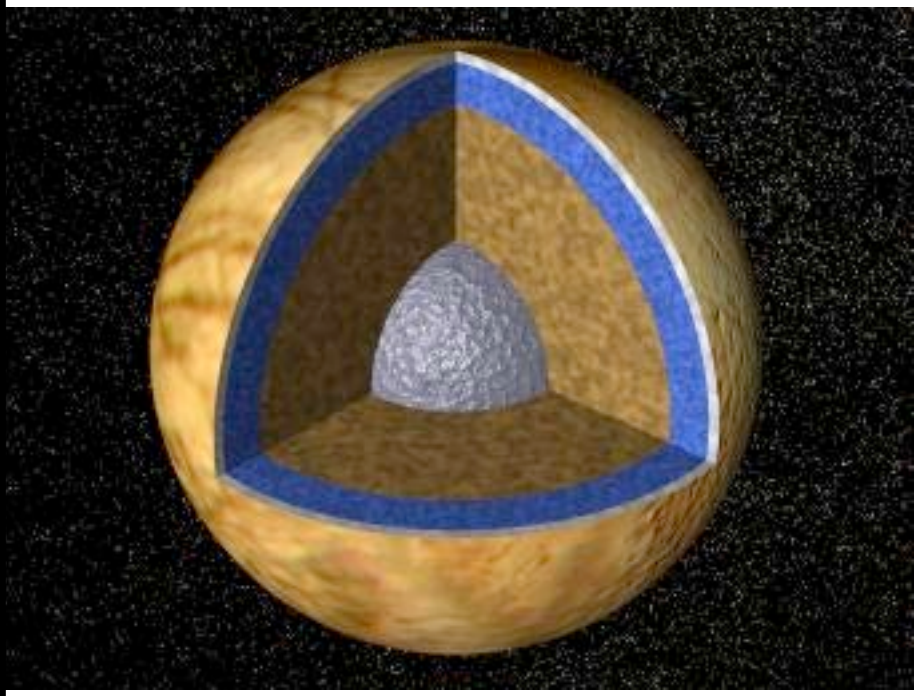
3) Energy source
(solar, chemical, thermal, electrical?)



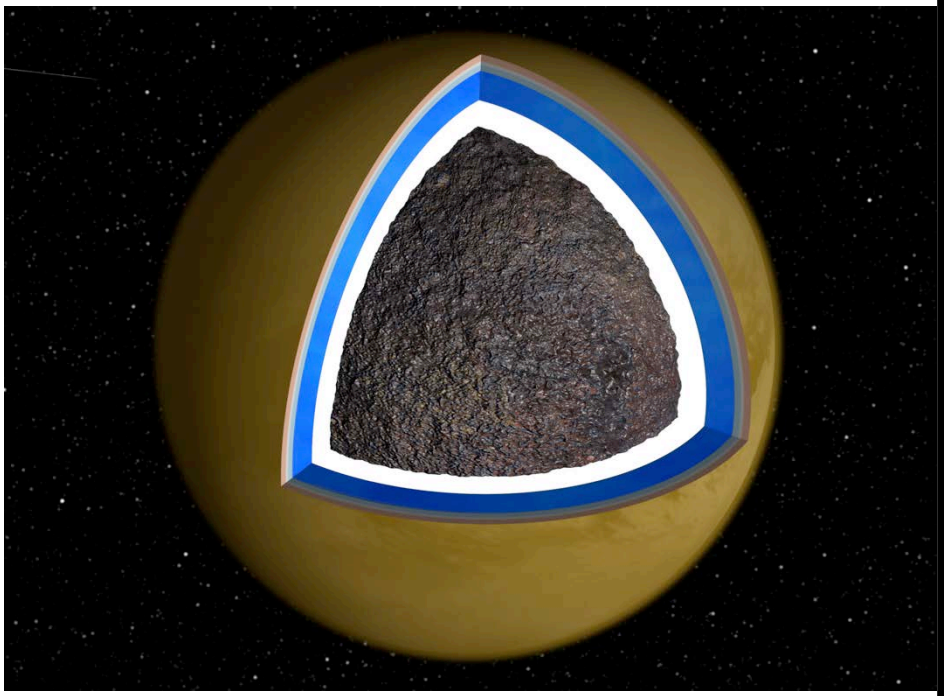


Nealson (1997)

Europa's (unique?) rocky seafloor



Europa

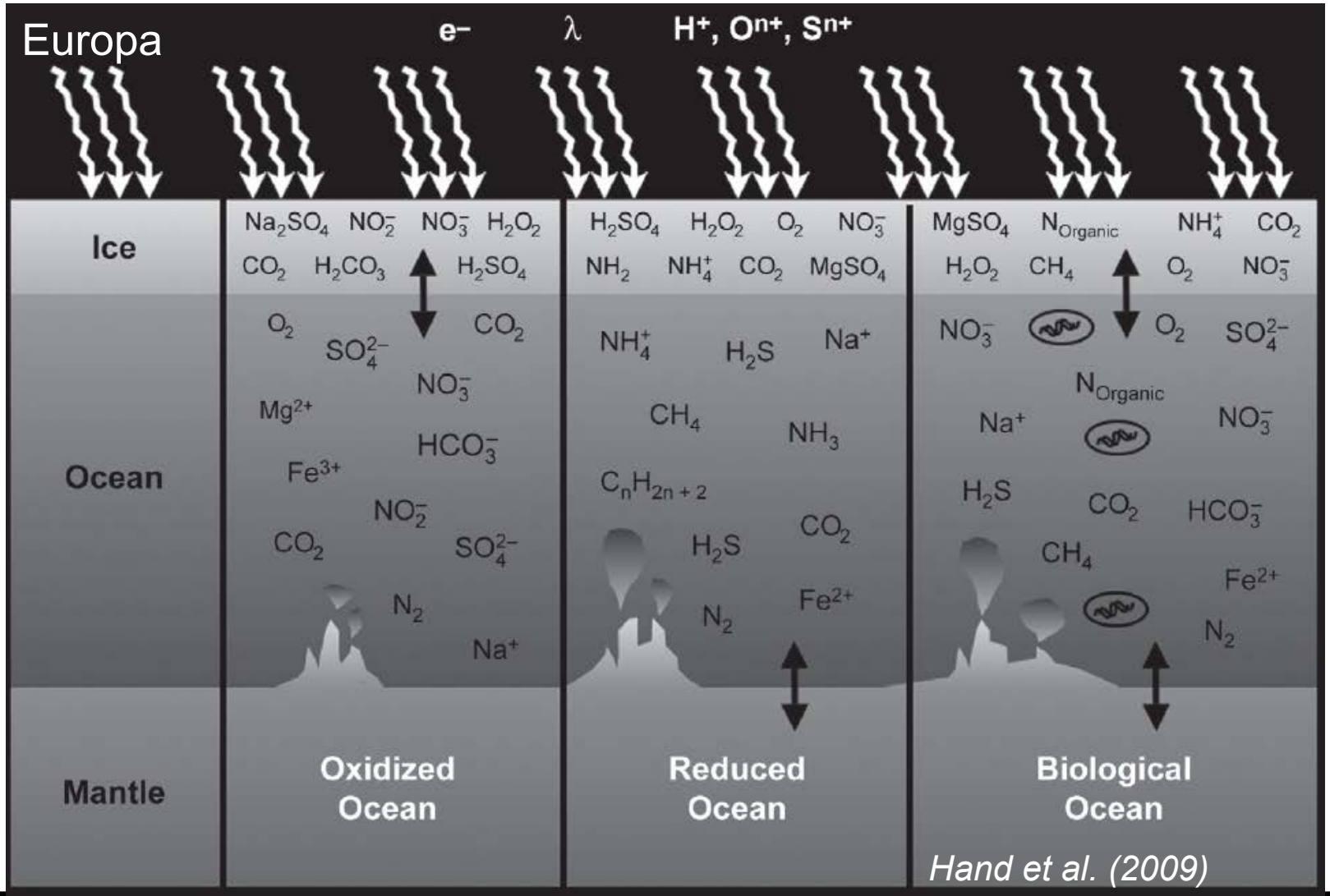


Titan

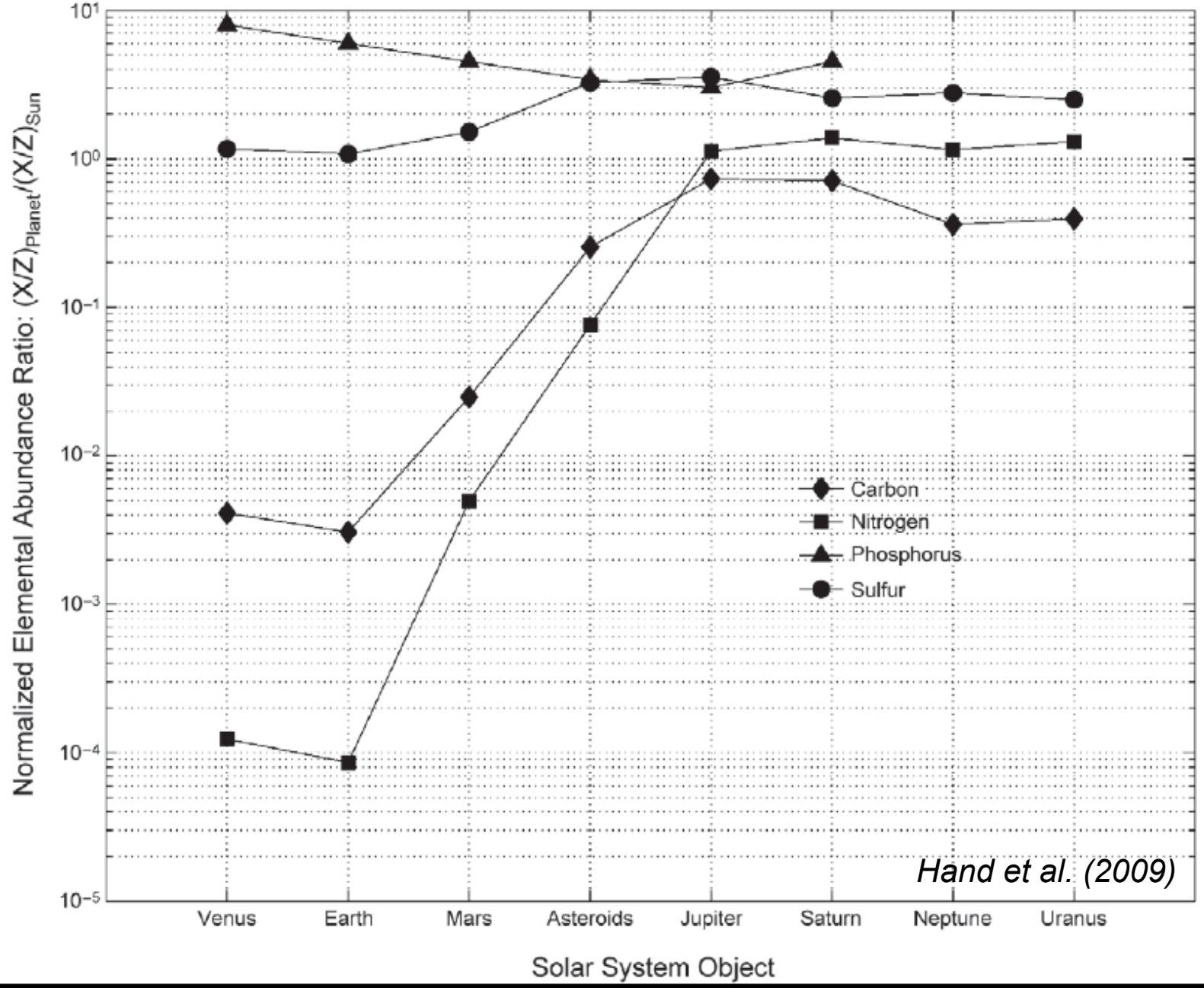
Many outer solar system bodies may have subsurface oceans (Ganymede, Callisto, Titan, Pluto, …) but most of these likely sandwiched between ice layers → ***no clear energy source***

Chemical energy in Europa's ocean

Seafloor can provide reduced compounds; what about oxidants?
On Earth, dissolved atmospheric O_2 descends from the surface

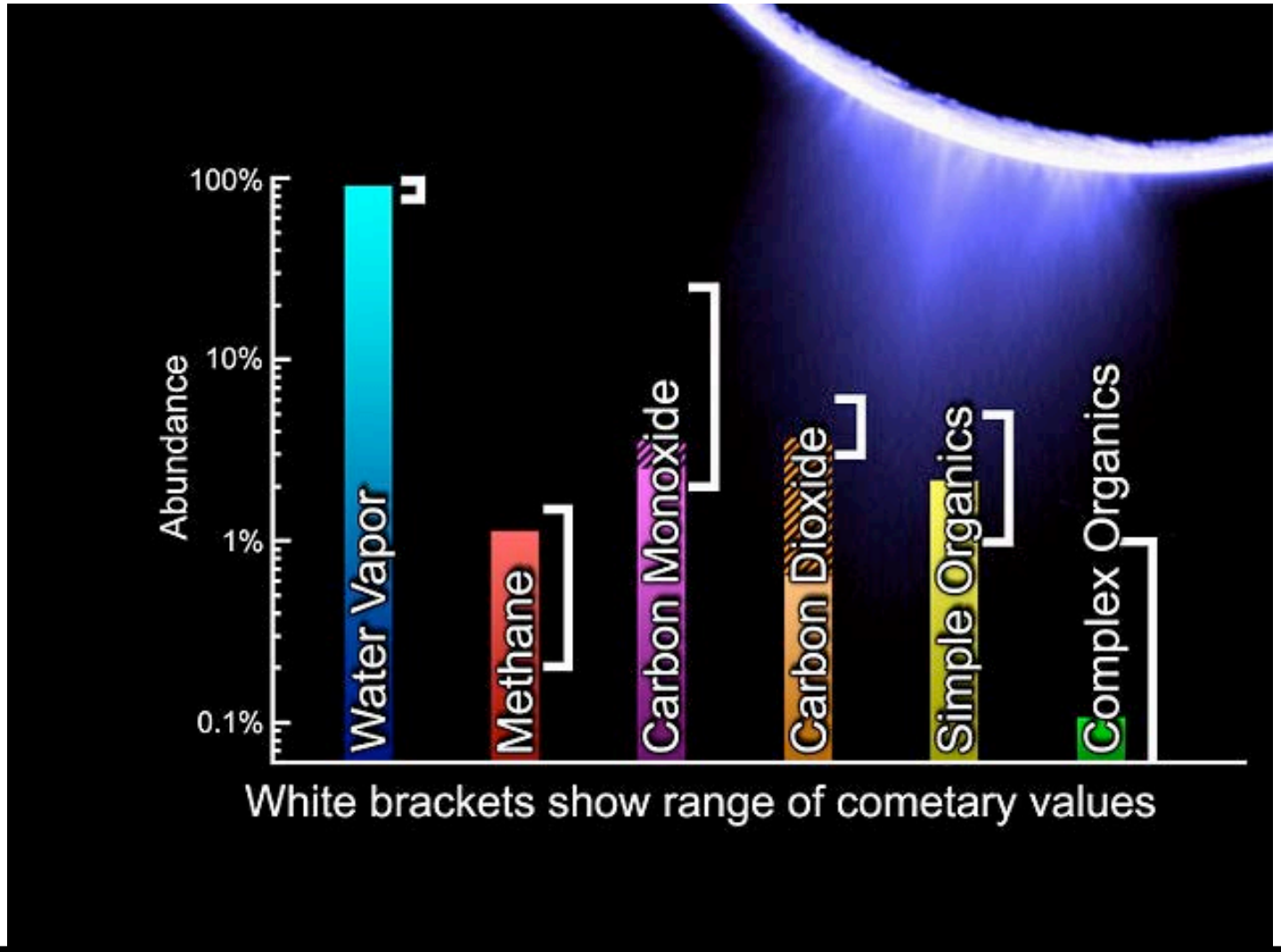


Chemical building blocks? No problem

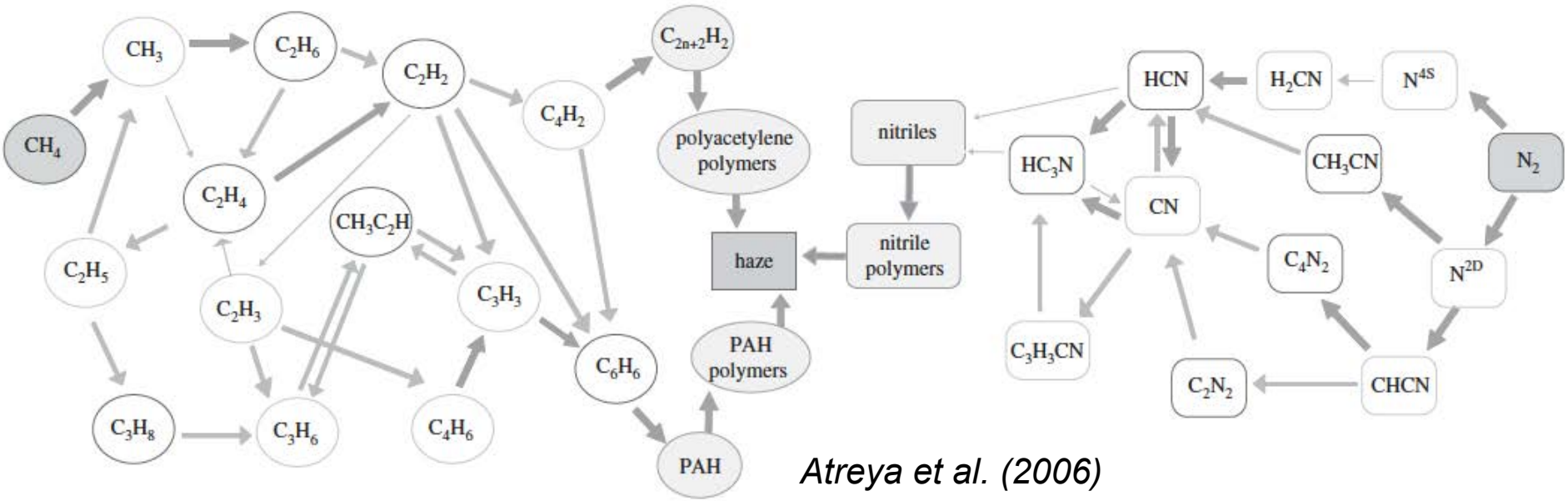


Enceladus

- Organic molecules bursting out into space
- Temperatures > Water-ammonia eutectic (but is NH_3 there?)
- Na-salts in icy plume particles *consistent with* rocky seafloor



Titan



Atreya et al. (2006)

Fig. 1. A simplified photochemical scheme for the formation of hazes in Titan's atmosphere is shown. The photolysis of methane leads to the formation of

- A natural laboratory for complex organic chemistry
- Meltwater, oxidants provided by impacts or cryovolcanism?
- Or can alternative biology occur in Titan's organic lakes?