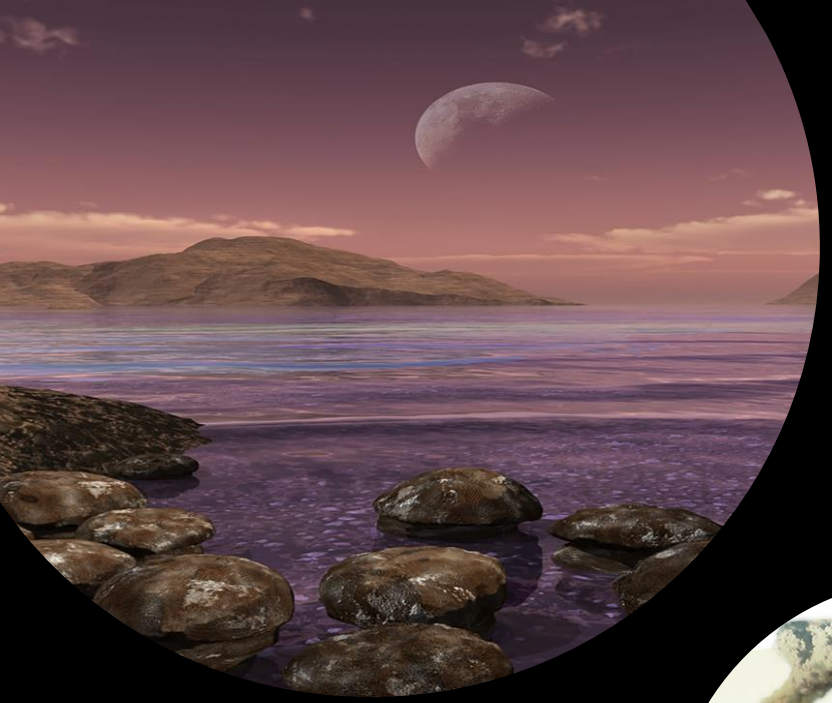


Understanding the origin and early evolution of Life on Earth, & Mars?

Emmanuelle Javaux

Switch to Space 3

Space Exploration: the Moon & Mars

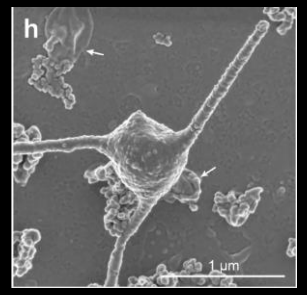
19 October 2022

LIÈGE université Early Life

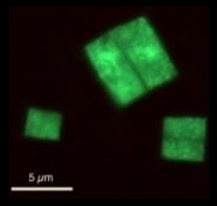
LIÈGE université ASTROBIOLOGY

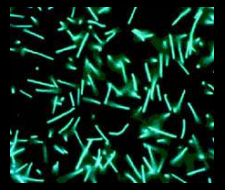
Life everywhere

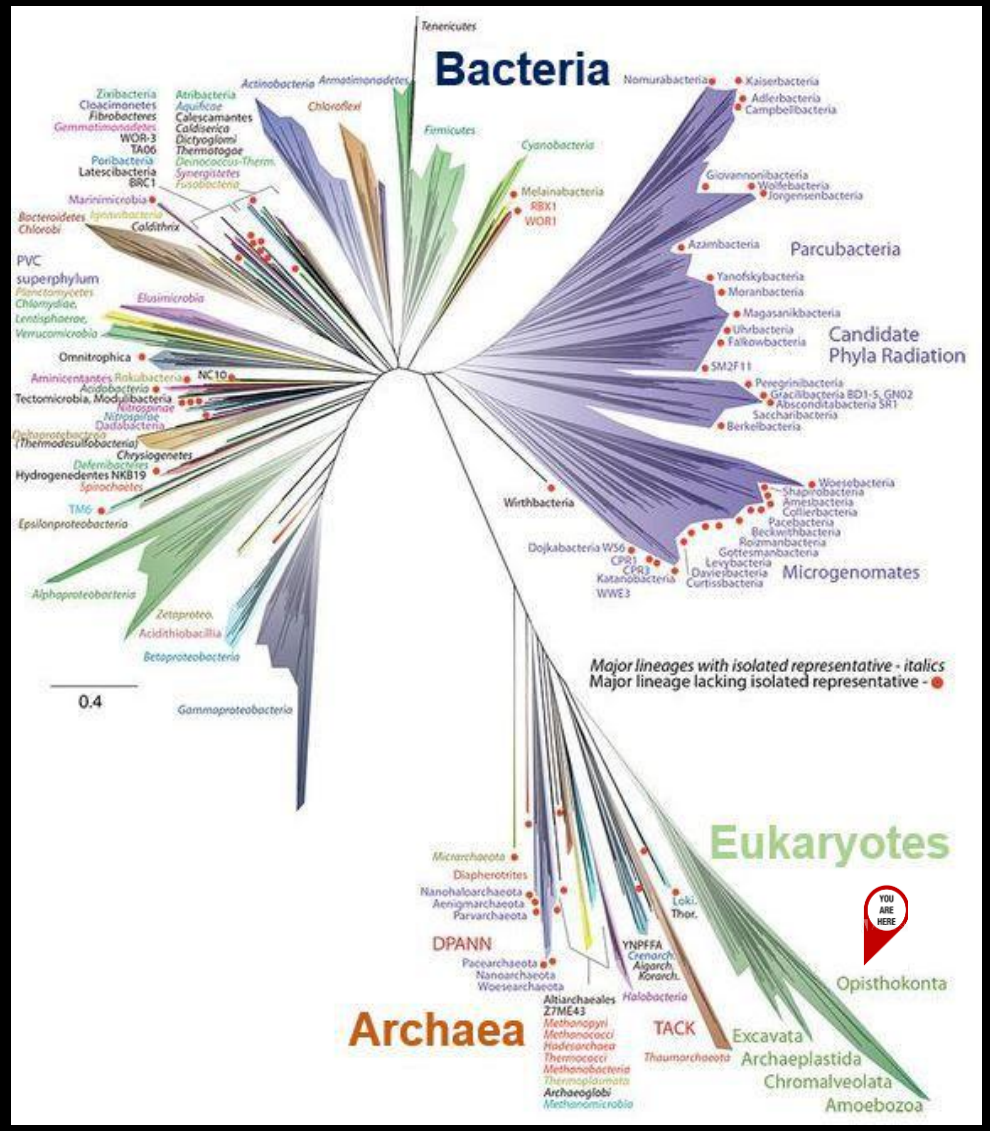
Beautiful Life today



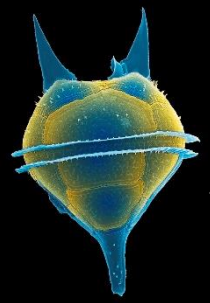
Imachi+, 2019





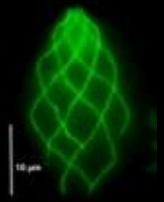


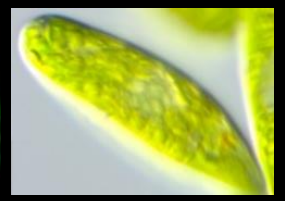
Hug +, Nature 2016

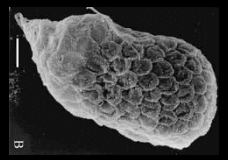


Steve Gschmeissner

Lax +, 2018





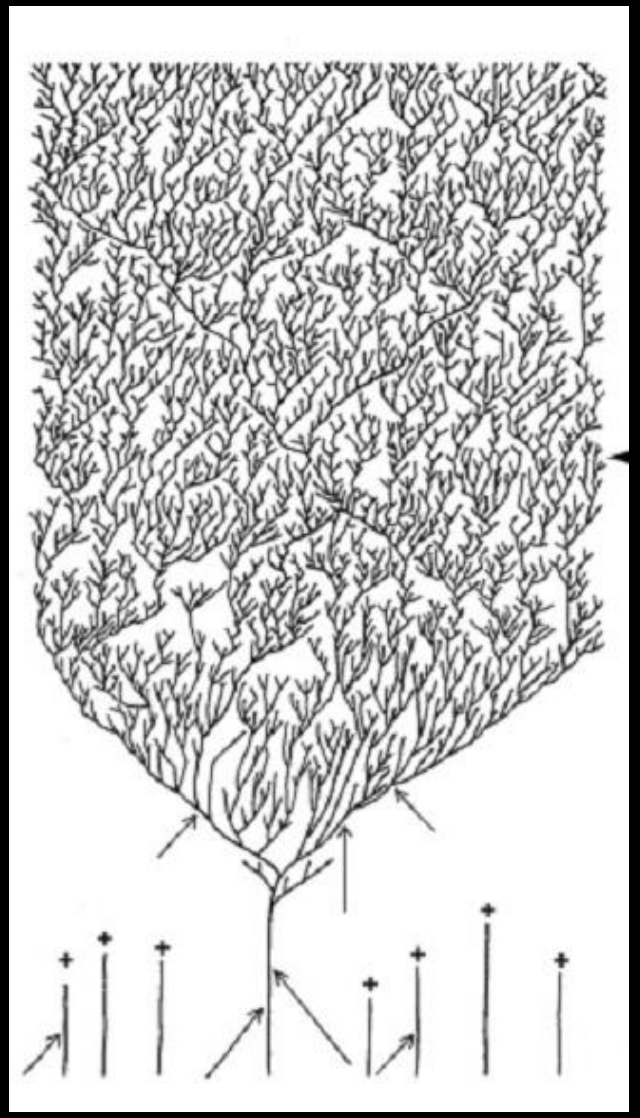


Time

Biology
Paleobiology
Geology
Geochemistry

+Philosophy &
History of sciences

Astrophysics
Chemistry
Biology



Mod from http://gogarten.uconn.edu/

Life today

LUCA

First cells

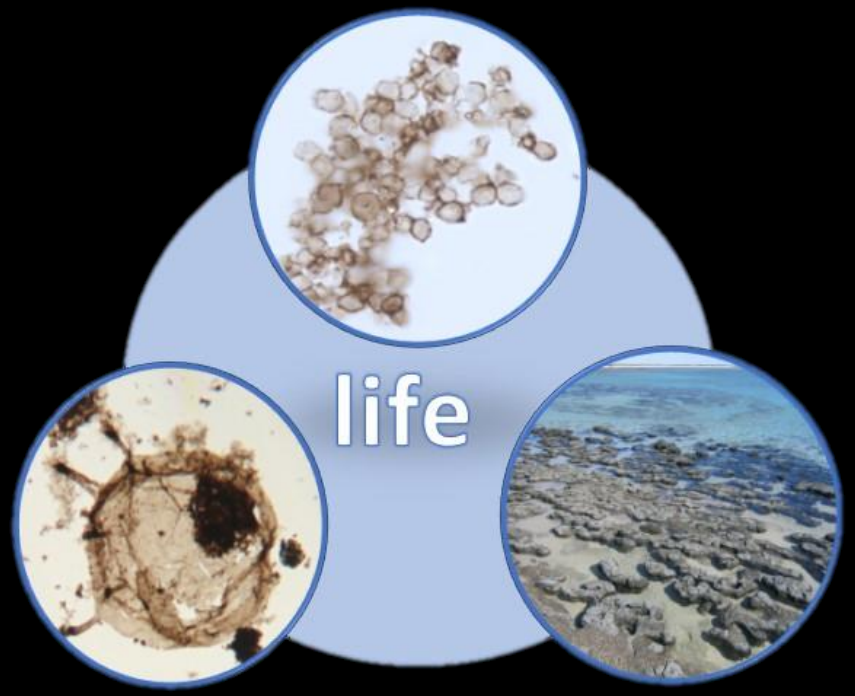
ORIGINS of LIFE

WHAT IS LIFE?

Life as we know it

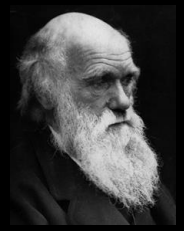
reproduction

compartmentalization



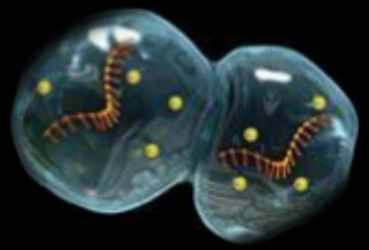
metabolism

Evolution by natural selection



OoL minimum conditions

- Organic chemistry CHONPS
- Liquid water
- Nutrients-minerals
- Energy

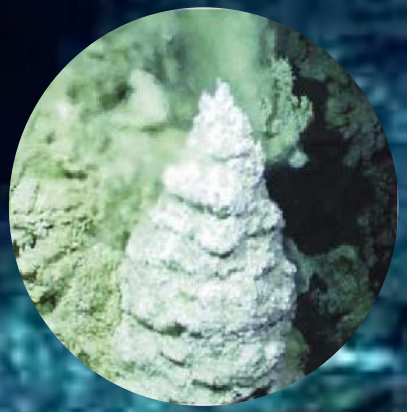


Oparin-Haldane 1920's
Miller 1965

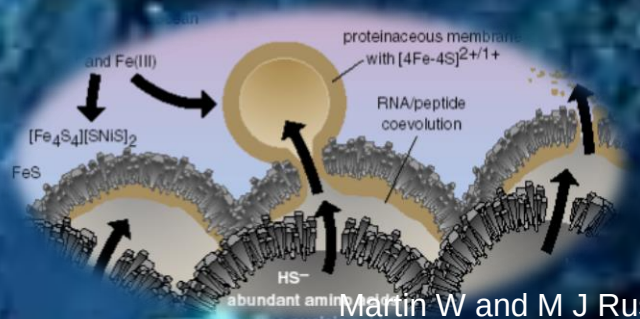
Darwin1871
« warm little pond »

Cairns-Smith 1960;
Orgel & Ferris

Damer & Deamer 2020

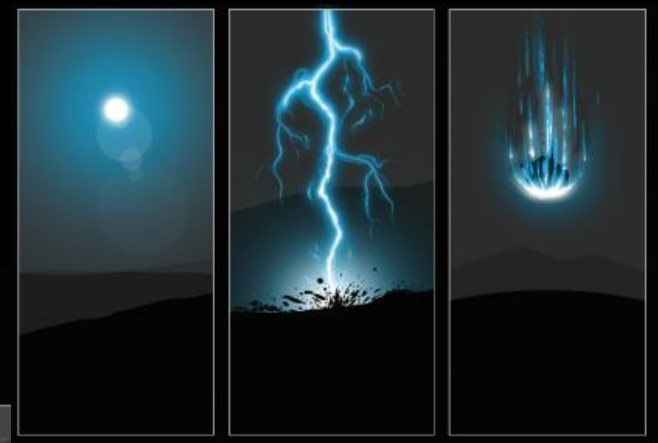


Wächterhäusser, 1988

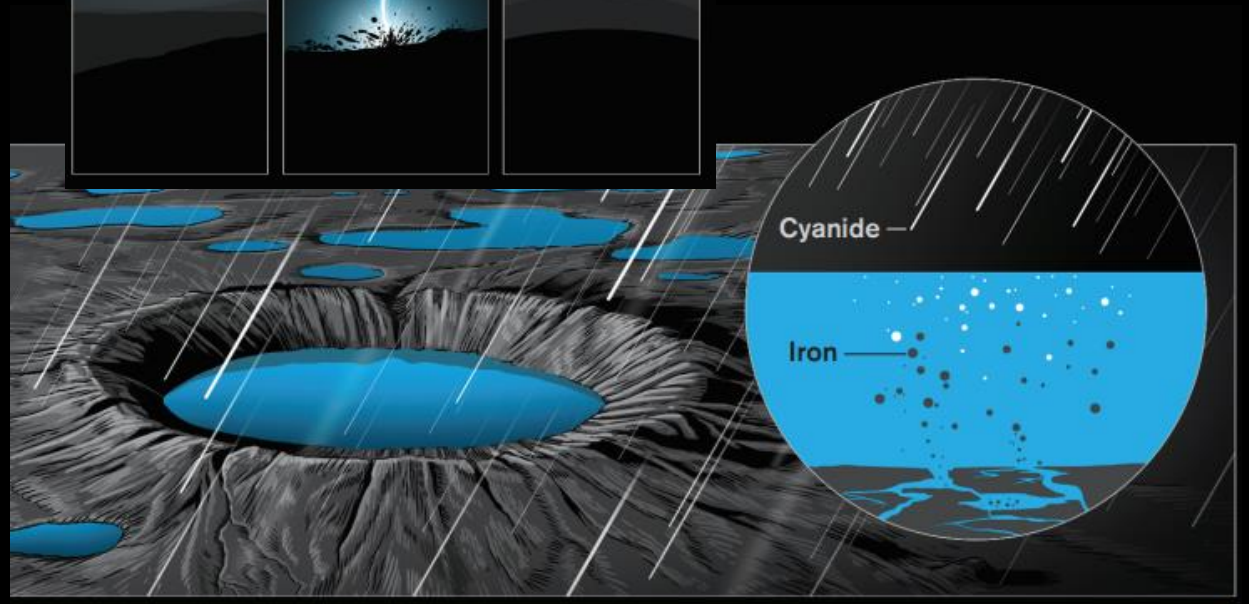


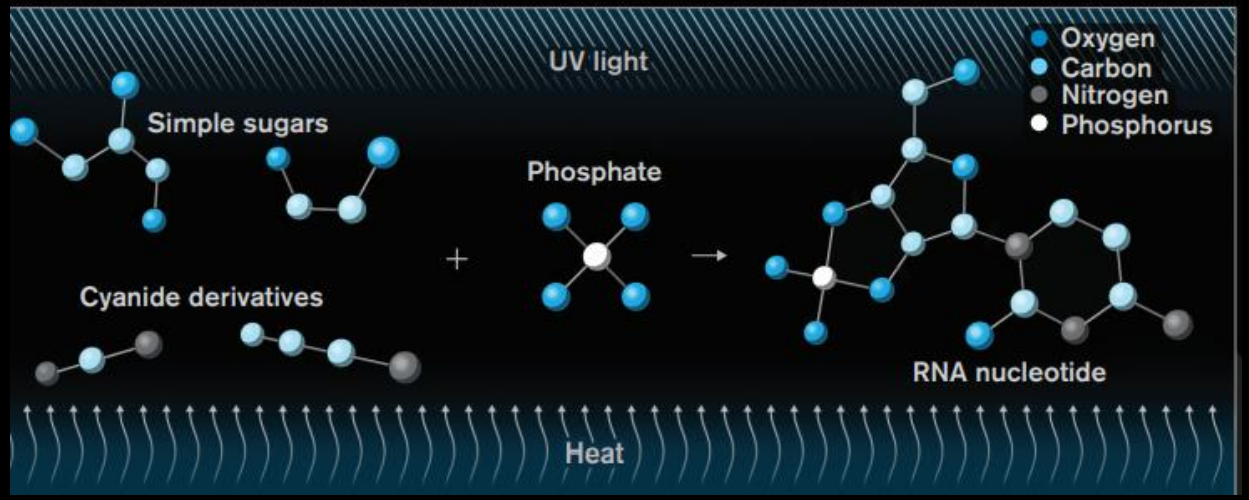
Martin W and M J Russell, 2003

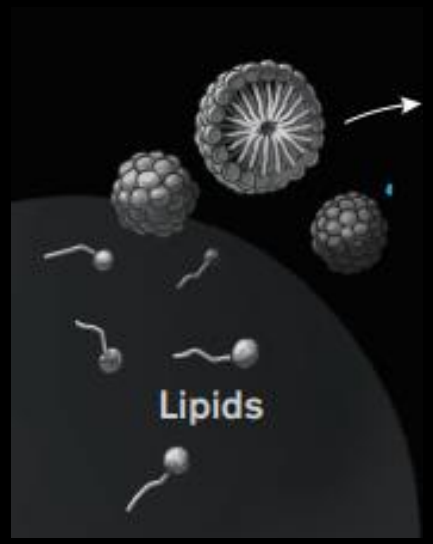
How did Life begin?

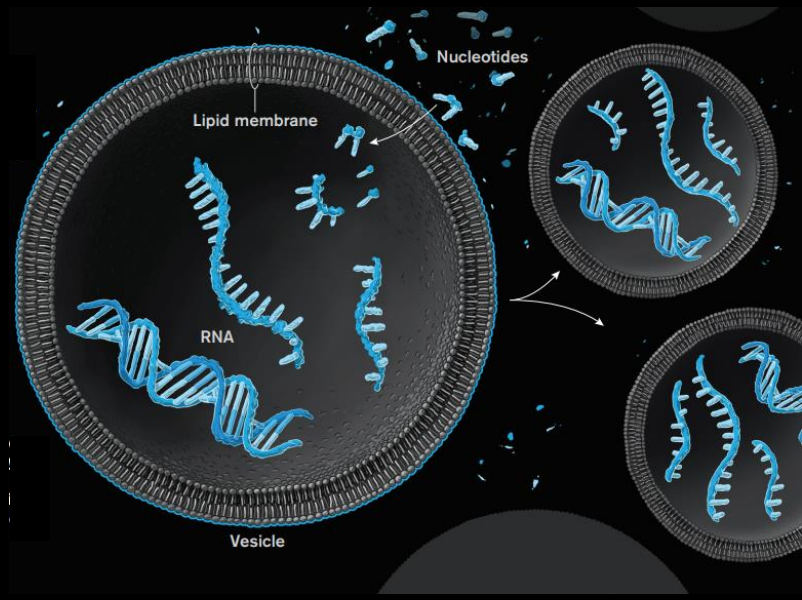


N_2,CO_2,
H_2, CH_4, H_20



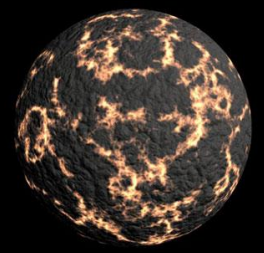




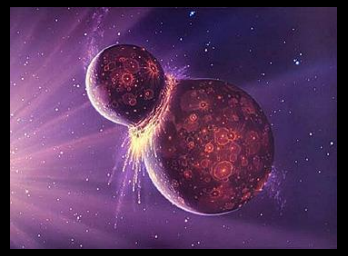


Szostak Nature 2018

When did Life begin?



Accretion
4,568 Ga



Moon formation
4,51 Ga

Liquid water
4,3 Ga

4 Ga

3.4 Ga

Time

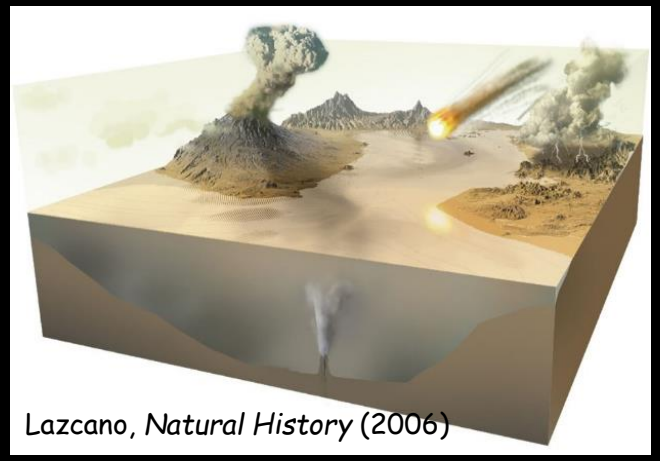
Habitable Earth (?OoL)

Earth Rock record

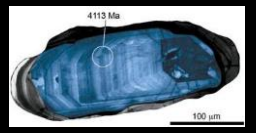
Uninhabitable Earth
>4.3 Ga

Magma ocean

habitable Earth
~4.3-4 Ga

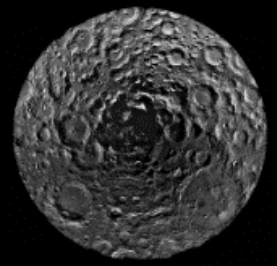


Lazcano, *Natural History* (2006)



@John Valley

@H.Martin



Moon Impacts
4.3-3.4-…Ga

Life diversification
>3.4 Ga

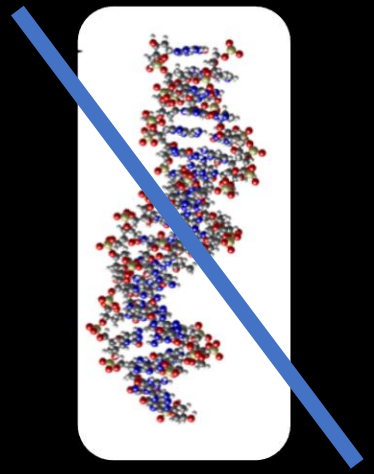
Current Biology 2020 30R451-R453DOI

Early traces of life (biosignatures)

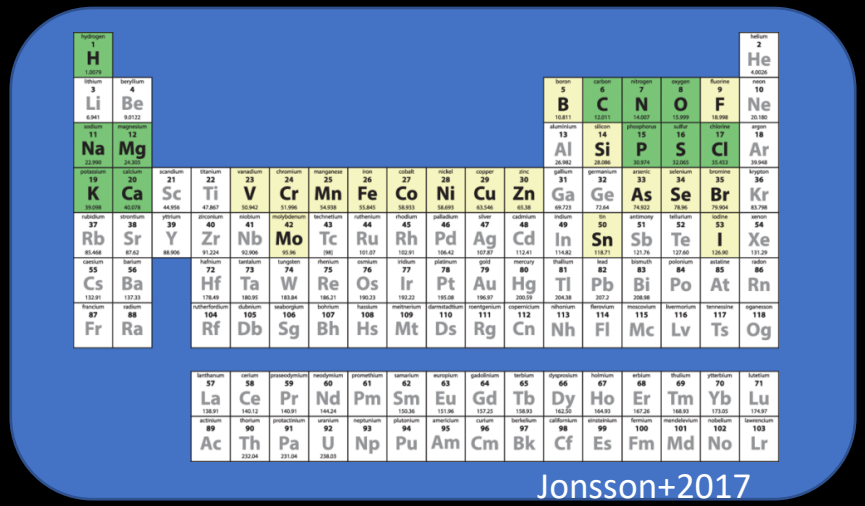
Biosedimentary structures

Microfossils

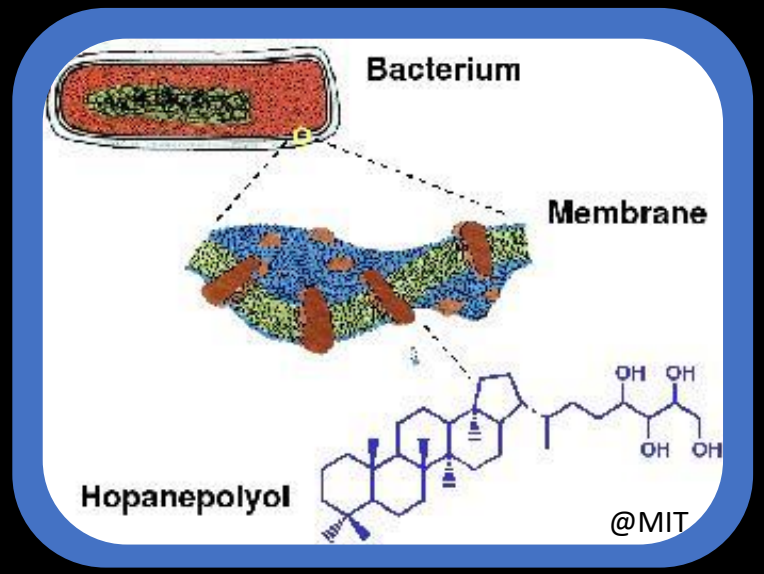
morphological



Isotopic and metal composition



Molecular fossils

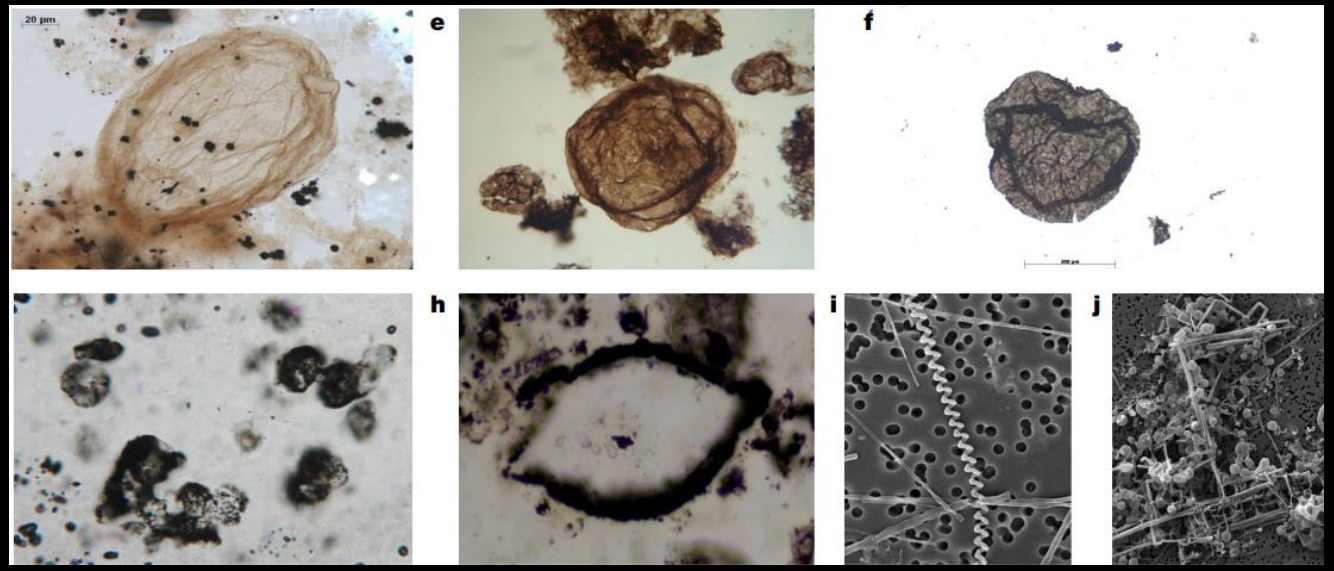


chemical

Rocks are archives of both Earth and life evolution

Life

Not Life

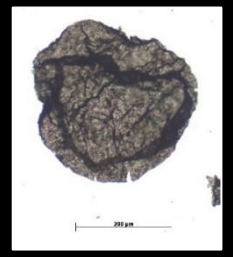


Javaux, Nature 2019

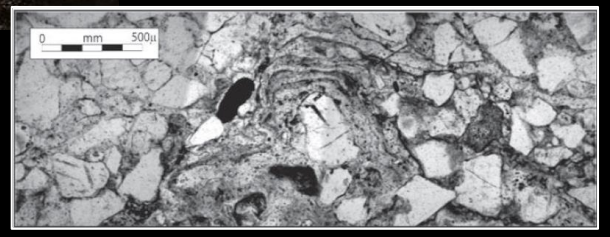
THE OLDEST UNDISPUTED (CHEMICAL & MORPHOLOGICAL) TRACES OF LIFE >3,4-3.2 GA

early cells and microbial mats used light, CH_4, S, Fe, N, C, and other elements from minerals

in ocean and on land

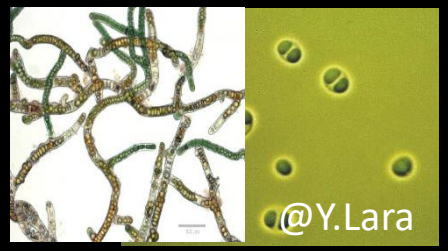


Javaux+ Nature 2010

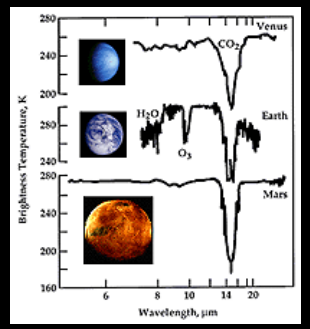


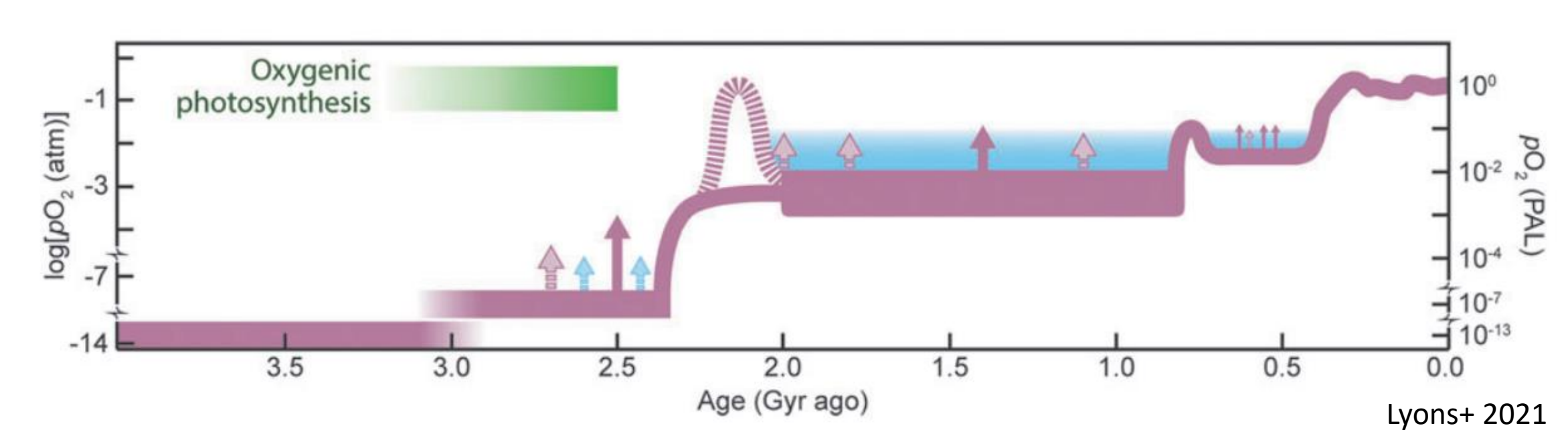
Homann+ Nature 2018

Allwood+2006; 2009; Botognali +2012; Flannery+2018; reviews in Javaux, Nature 2019; Lepot, ESR 2020; Cavalazzi-Westall 2019

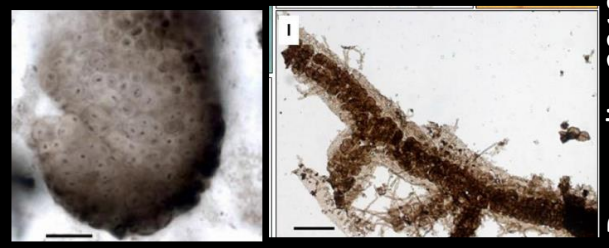


The rise of cyanobacteria > 2.4 Ga
Earth oxygenation
Emergence of complex life



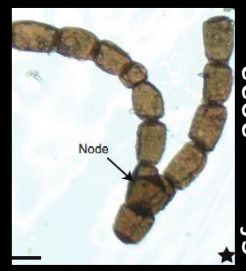


Lyons+ 2021

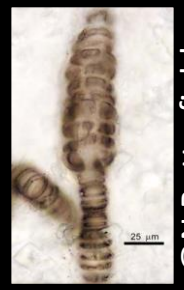


Demoulin+2019

Fossil cyanobacteria>2 Ga



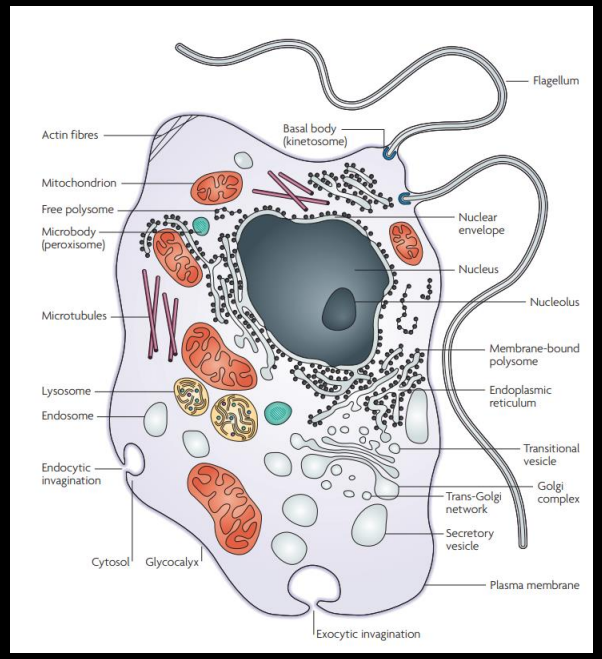
Sforna+2022



@N Butterfield

Multicellular algae >1 Ga

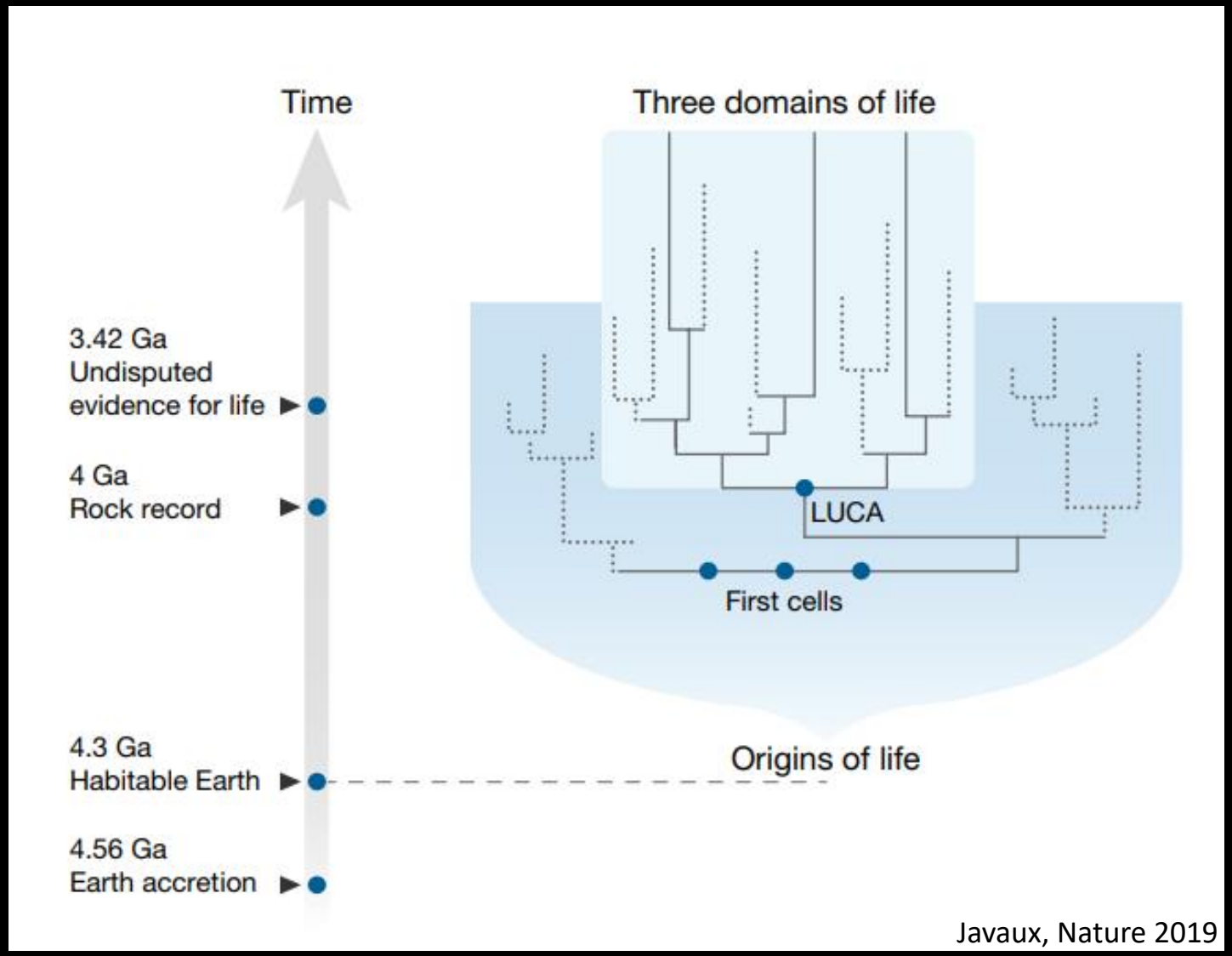
The oldest fossil eukaryotic cells (1.75-1.65 Ga)



de Duve, Nat Rev Genetics 2007

Javaux Encyclopedia Astrobiology 2021
Javaux Nature 2019

Early Evolution of Life on Earth



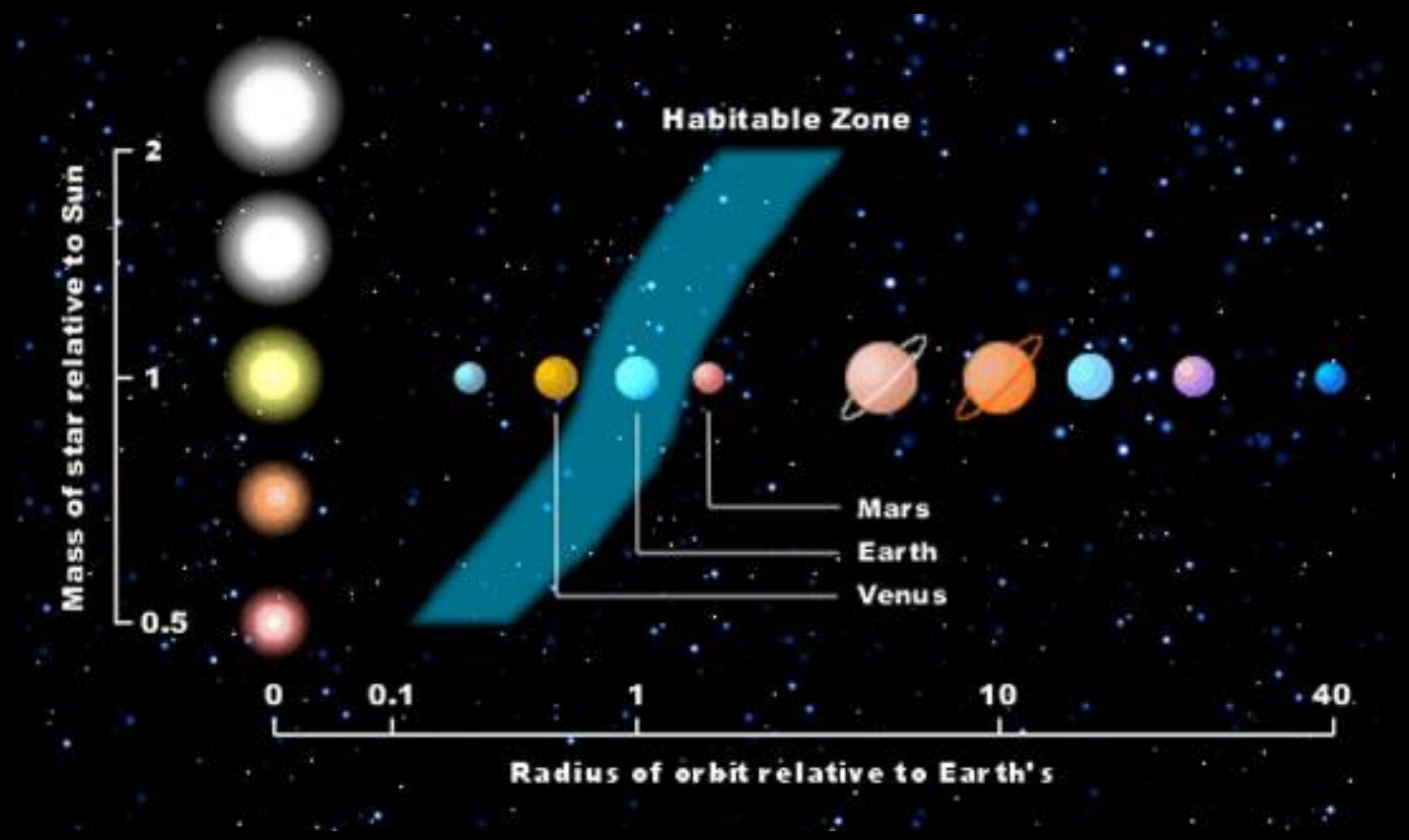
Javaux, Nature 2019

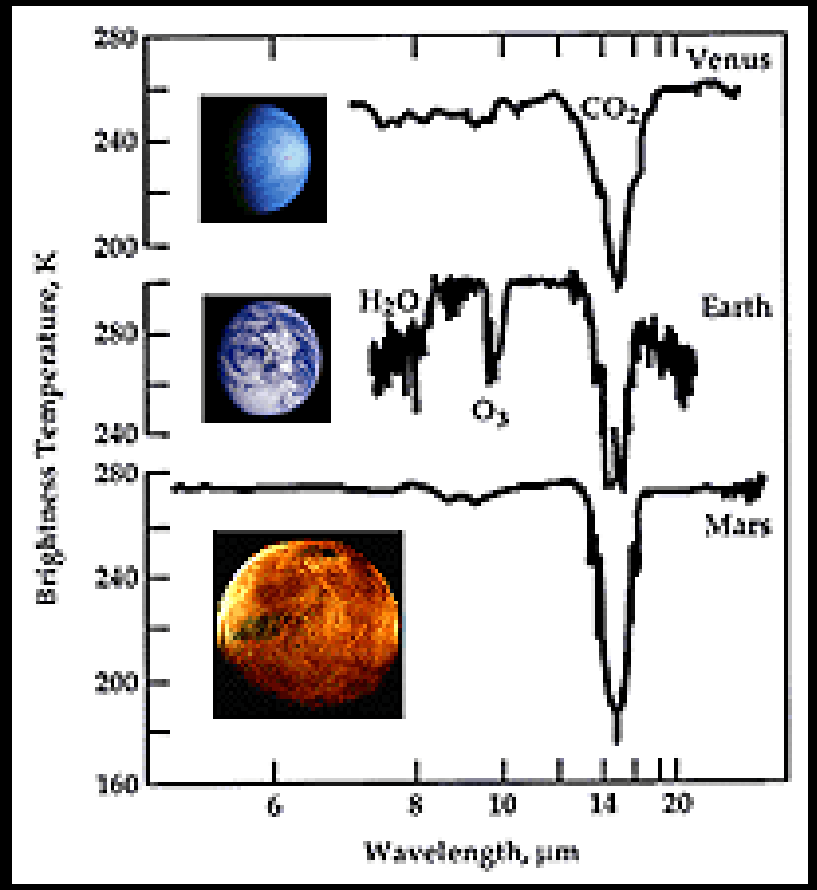
HABITABILITY

The possibility for a (exo)planet or moon to harbor life

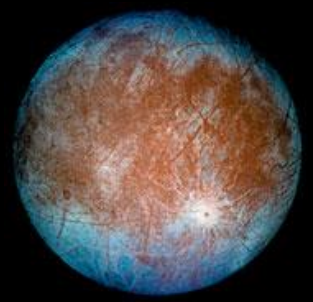
- Organic chemistry
- Liquid water (atmosphere)
- Nutrients (minerals)
- Energy

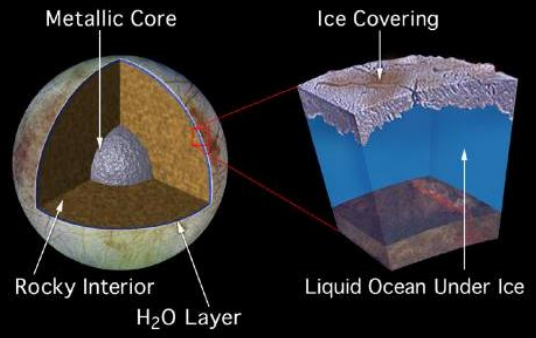
Habitable zone

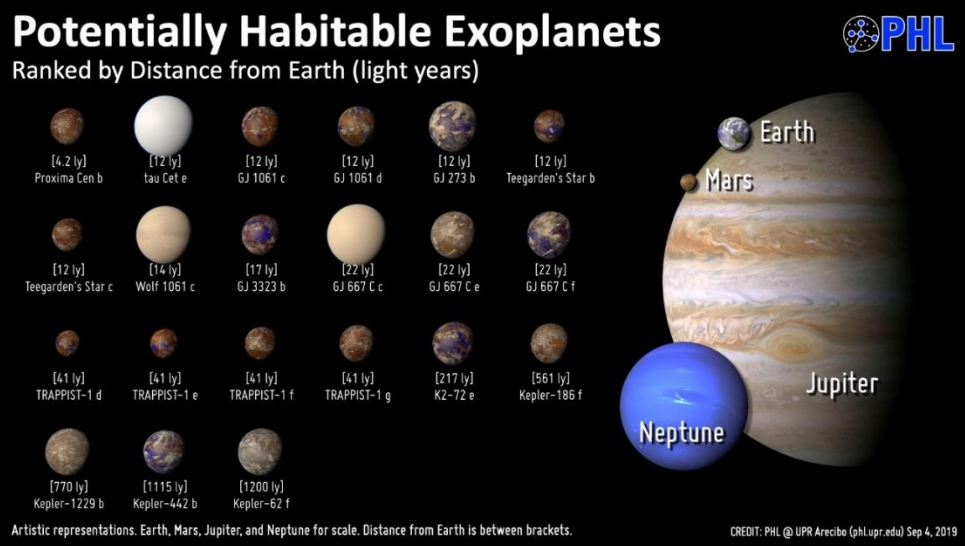


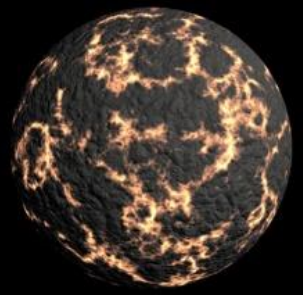


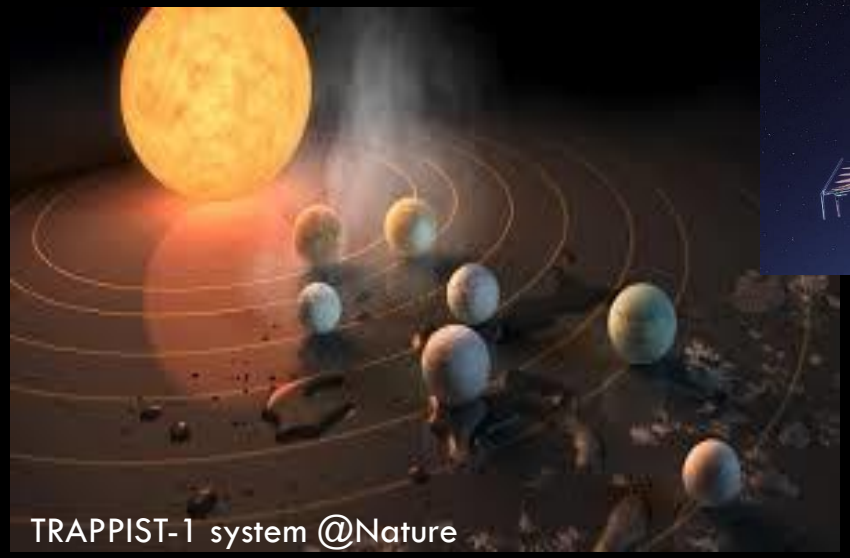
HABITABILITY CHANGES IN TIME AND SPACE

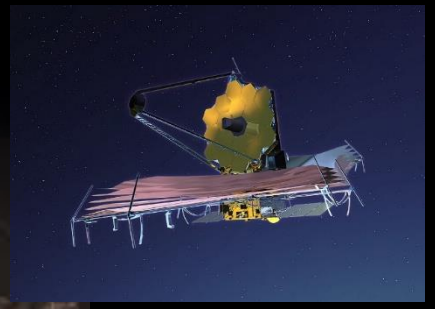










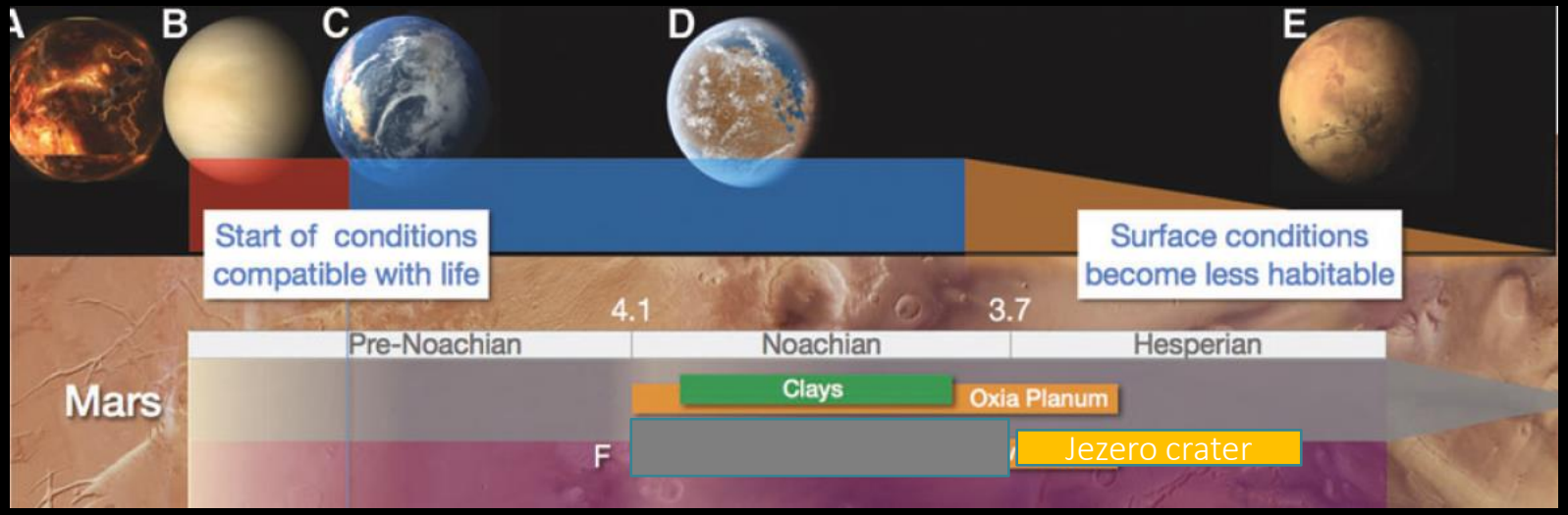


JWST

BELSPO BRAIN 2.0 project PORTAL

Life on Early habitable Mars?

Exomars 2028



accretion

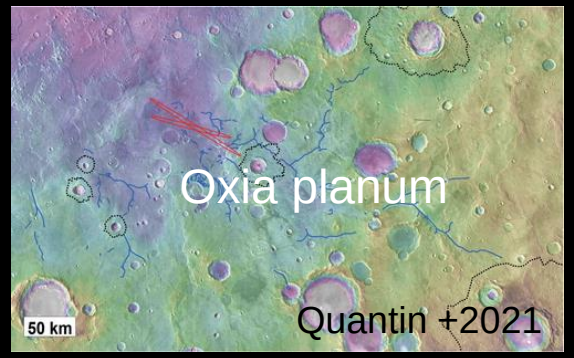
rocks preserved

accretion

no rocks preserved
Time of OoL

Earliest traces of Life

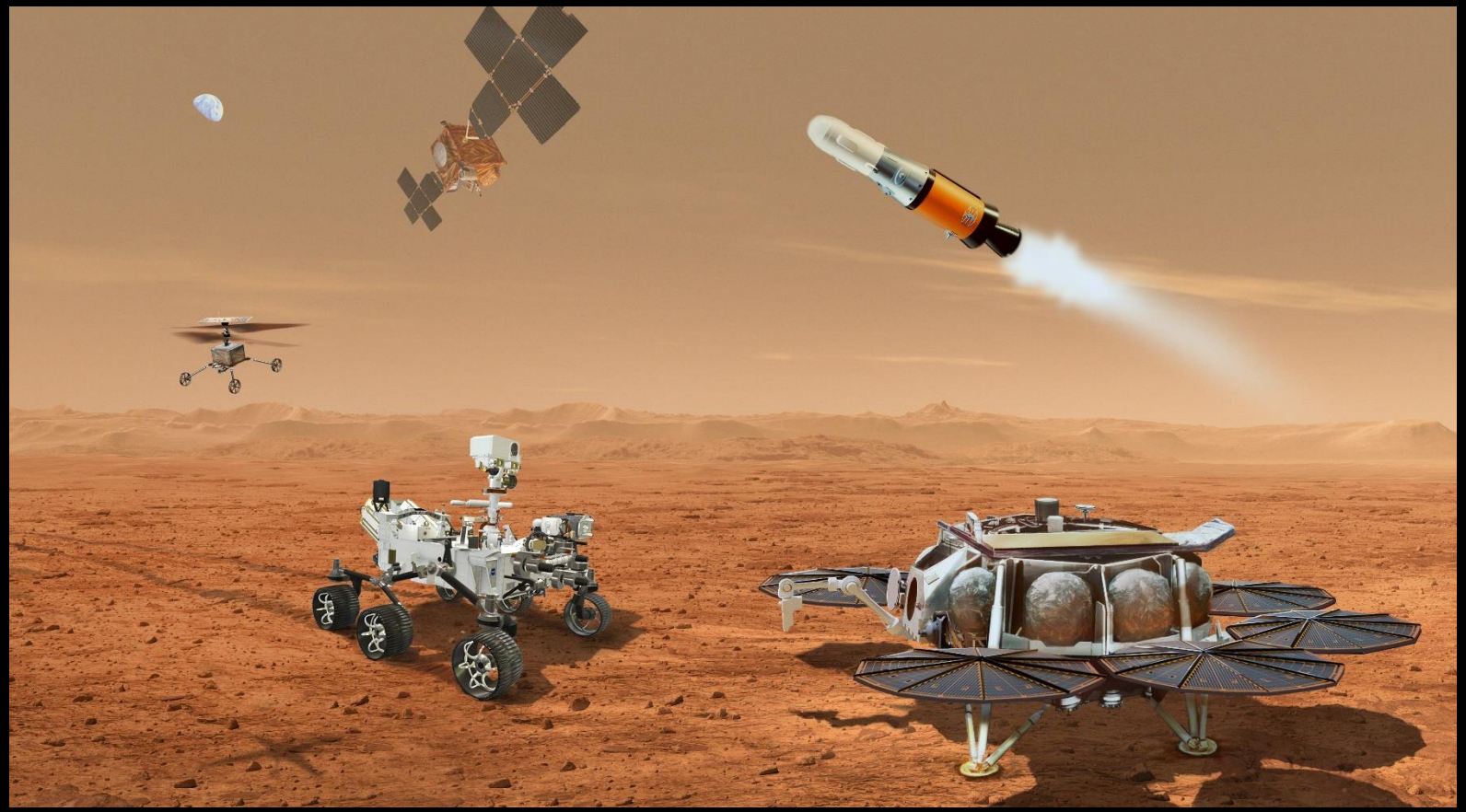
Perseverance 2020



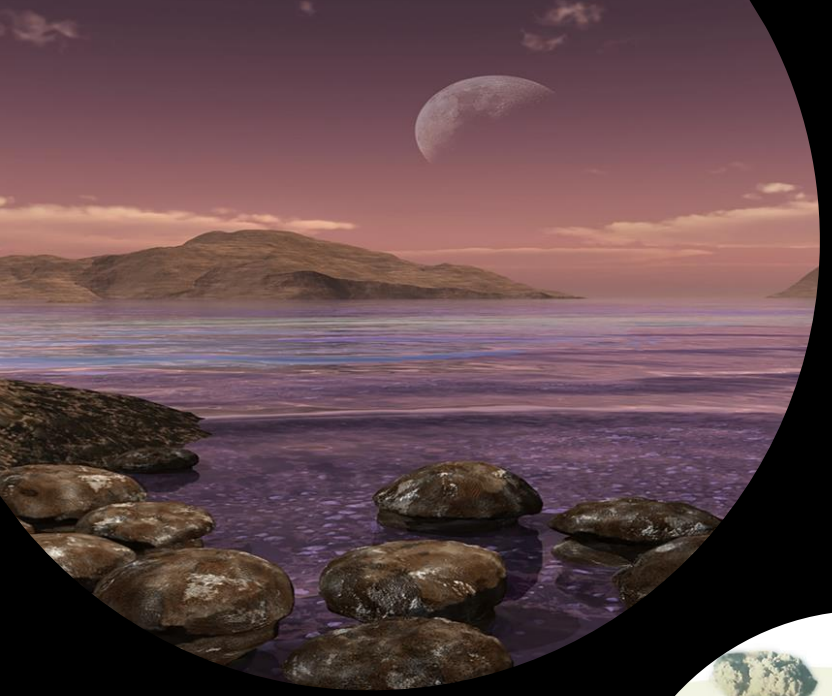
Quantin +2021

Modified from Vago+2017

Mars Sample Return 2033



NASA/JPL-Caltech



From early Earth to Mars!

Understanding the conditions for the origin & early evolution of Life in the Universe

LIÈGE université Early Life

LIÈGE université ASTROBIOLOGY

Switch to Space 3

www.earlylife.uliege.be; www.astrobiology.uliege.be