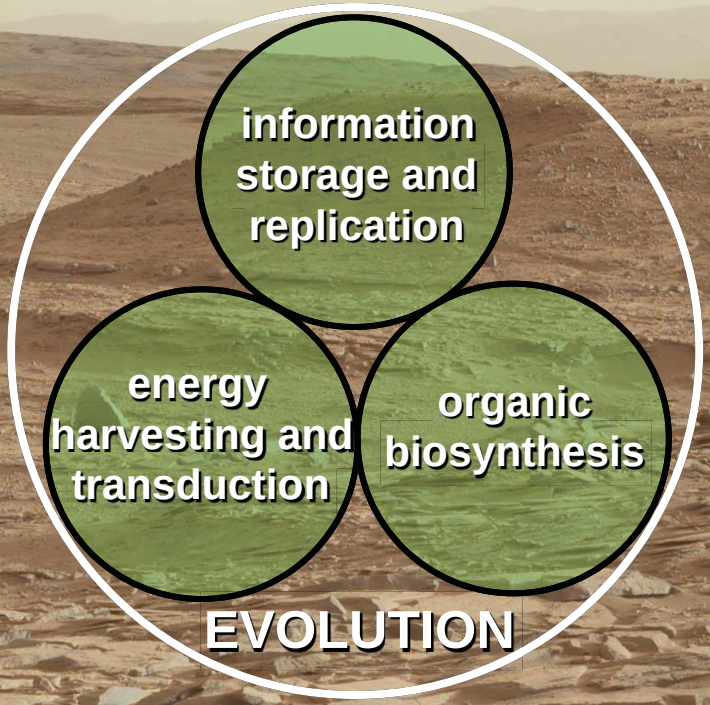
Concepts of Life and Biosignatures in the Contexts of Mars and Mars-analog Environments

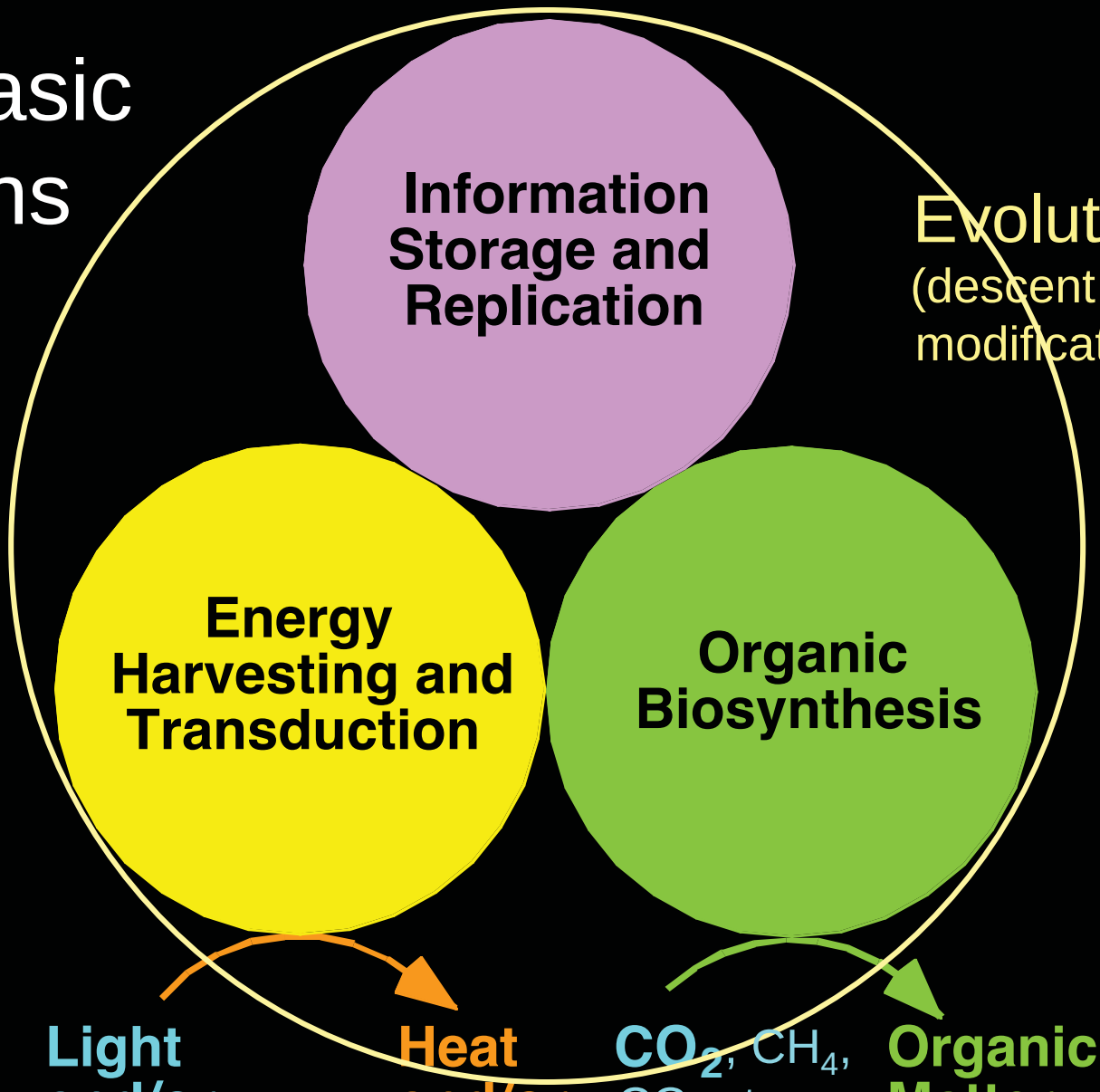


David J. Des Marais
NASA Ames Research Center

Research in Mars-Analog Environments
Examples of Key Challenges

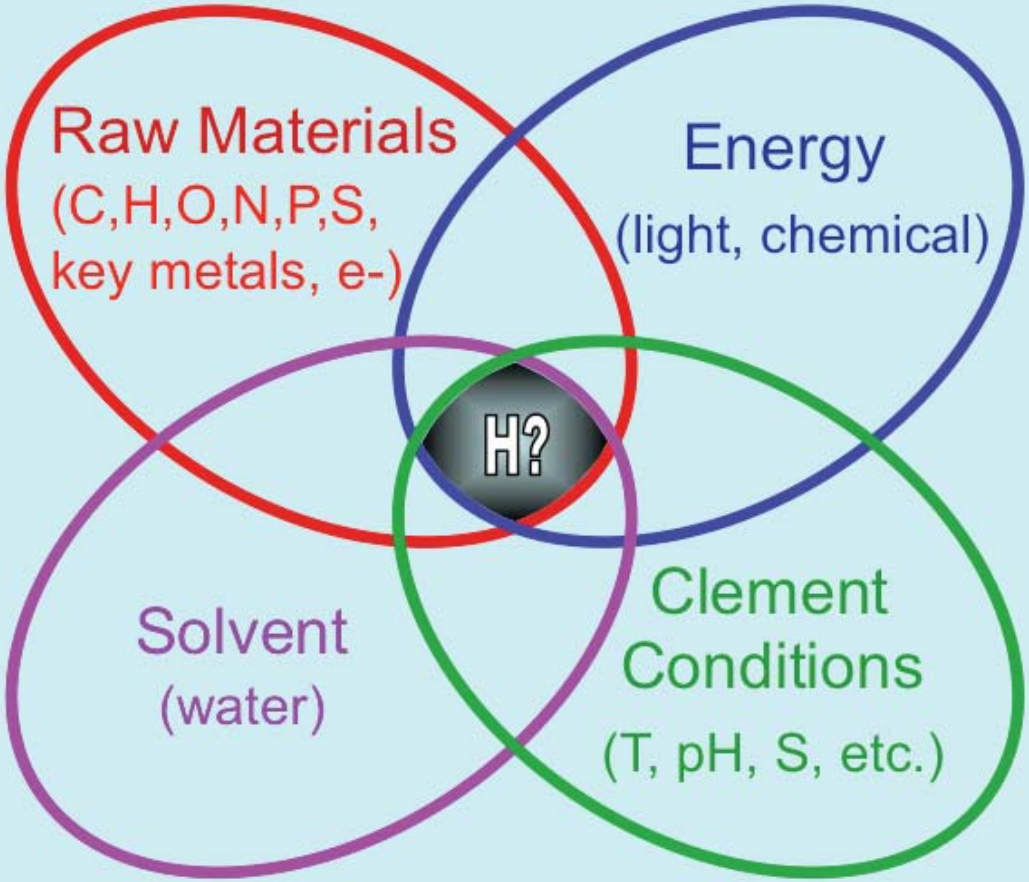
- Concepts of life: Earth-centric, Mars-relevant, truly universal
- Habitable environments: resources, conditions, duration, “envirosignatures”
- Biosignatures: biological “signals” vs environmental “noise,” potential vs definitive biosignatures
- Preservation: Biological primary production vs rates of destruction and preservation, preservation media, taphonomy
- Focus on processes that are directly relevant to environments on Mars (past or present)

Life's Basic Functions



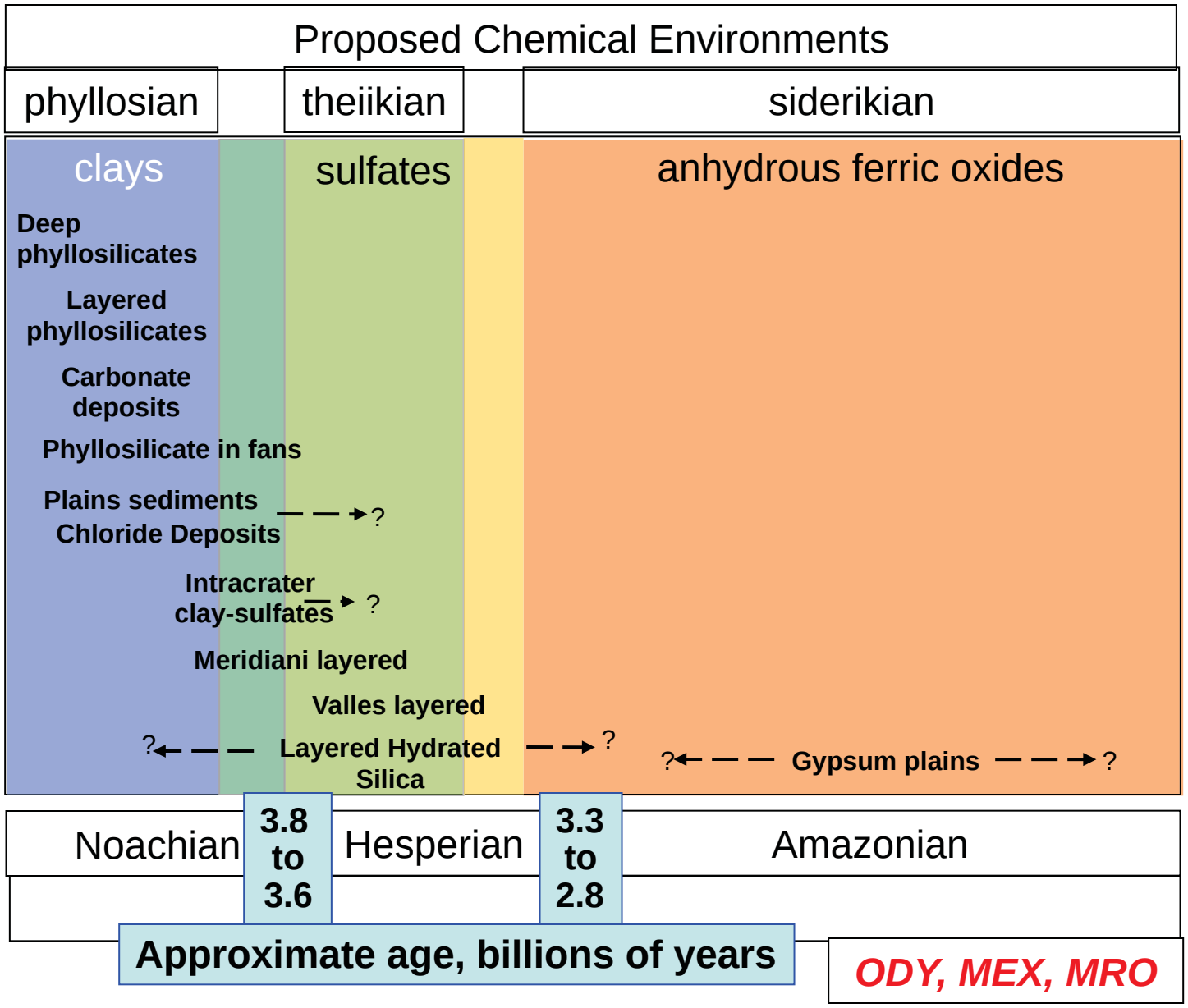
Habitable Environments

Requirements to Sustain Life



H = HABITABLE CONDITIONS

Martian Deposits Indicating the Former Presence of Aqueous Environments (Murchie et al., 2009)



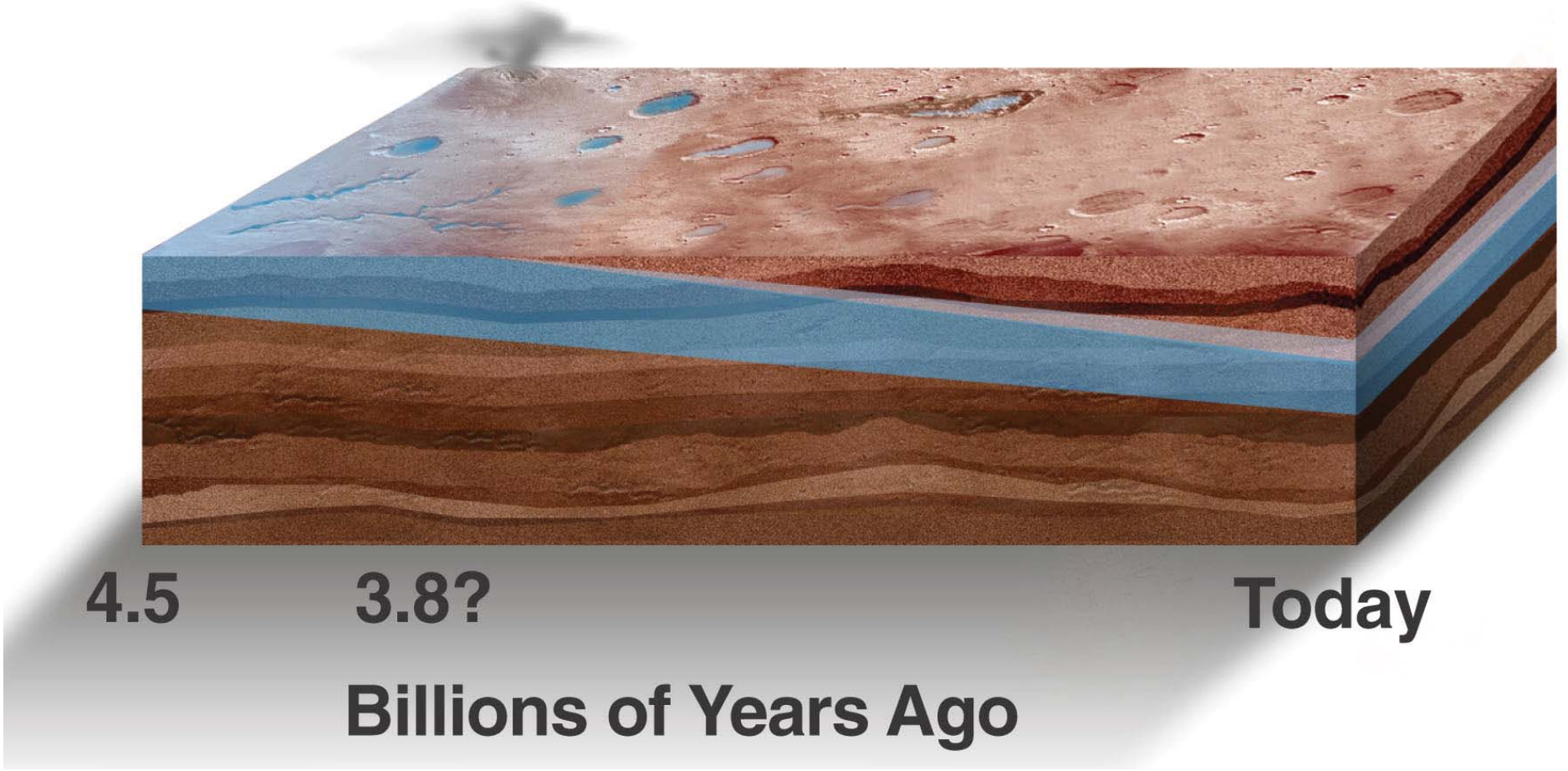
Coupled mineralogy and morphology define aqueous environments

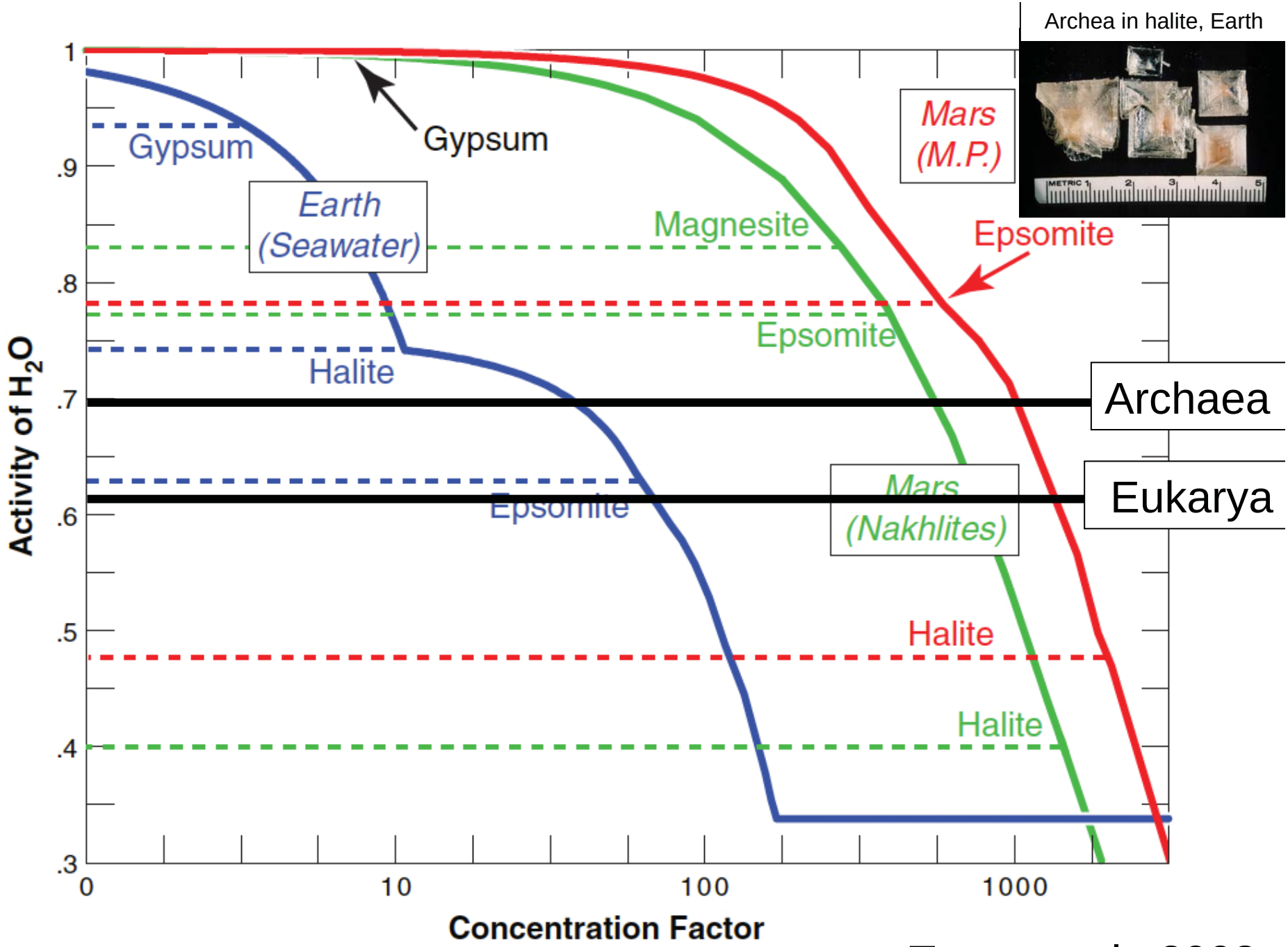
Their character has evolved, indicating changing environments

How should we prioritize these environments during landing site selection?

"So many places, so few landed science missions!"

Conditions That Could Sustain Life on Mars: Changes Over the Eons

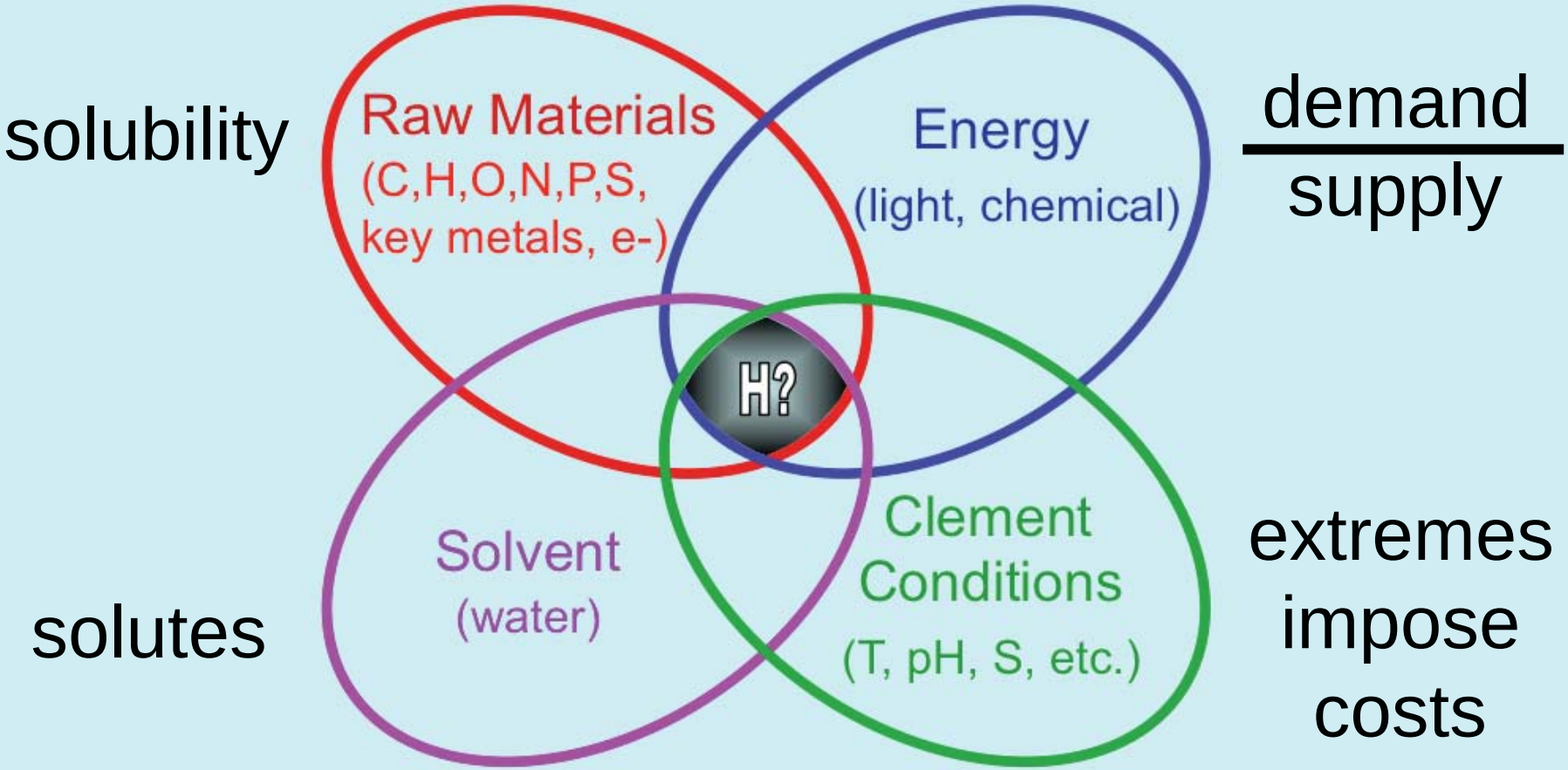




Tosca et al., 2008

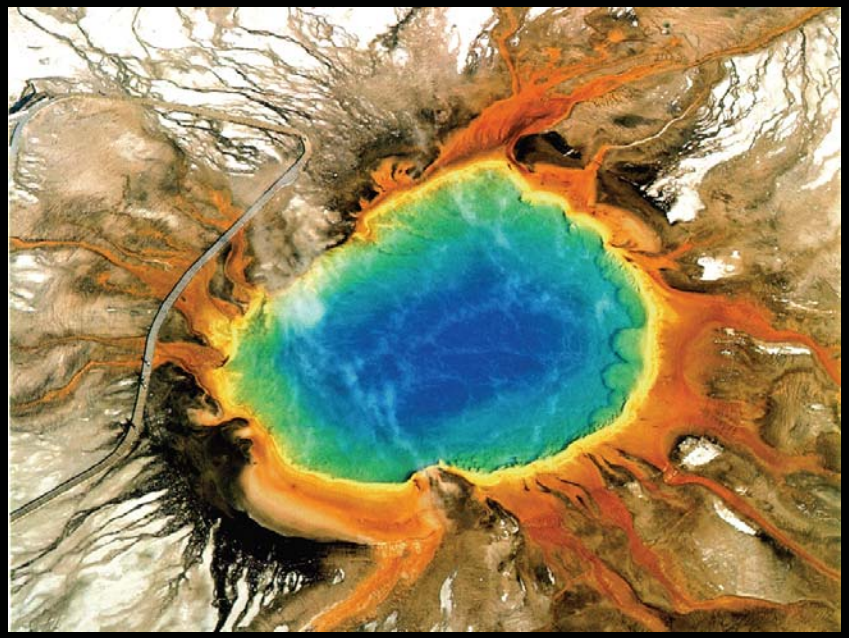
Habitable Environments

Requirements to Sustain Life



H = HABITABLE CONDITIONS

Note: Several examples of “classic” extreme environments tend to have ‘only’ one or two extreme parameters….



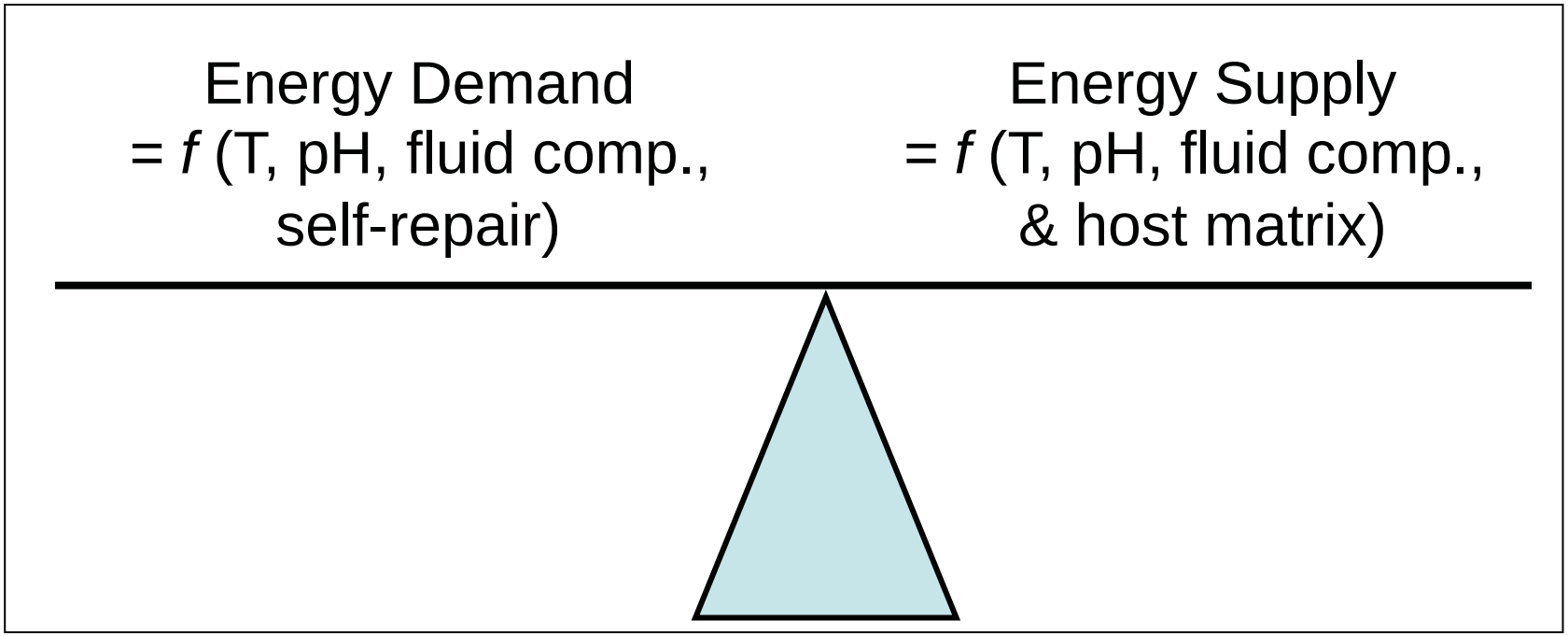
(T. Hoehler, 2011)

Water (availability, activity, composition), Energy (level, flux), Temp., pH, Salinity

(these factors combine to determine *how* habitable a system may be)

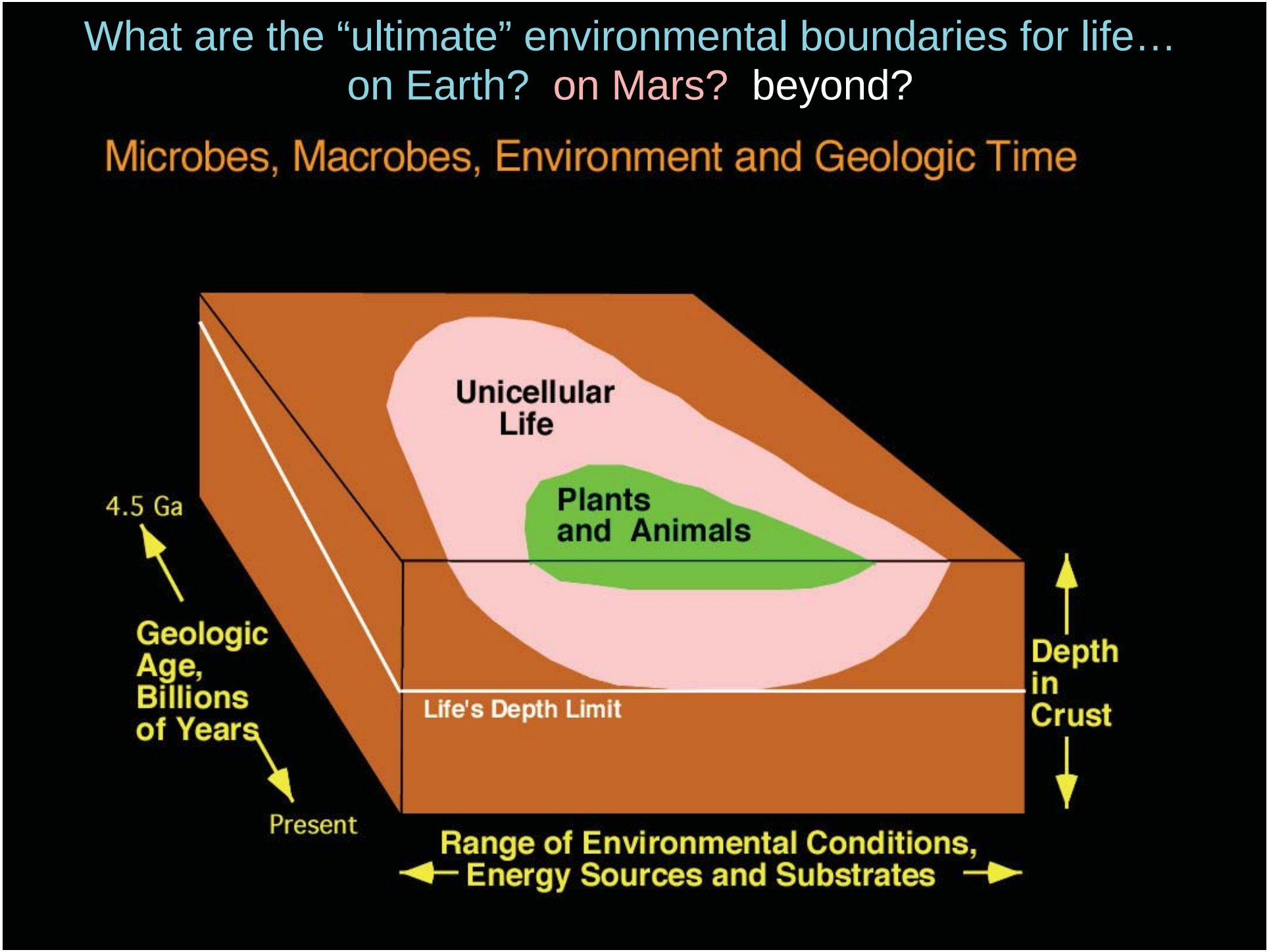
Biomass Abundance Estimate

Energy balance analysis

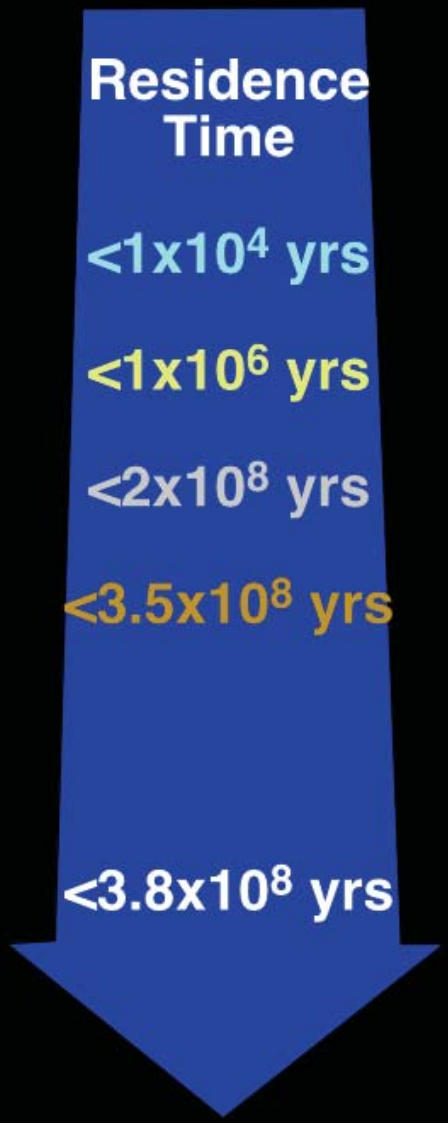


Extremes in T, pH, salinity, radiation, etc. impose substantial energy demands

What are the “ultimate” environmental boundaries for life…
on Earth? on Mars? beyond?

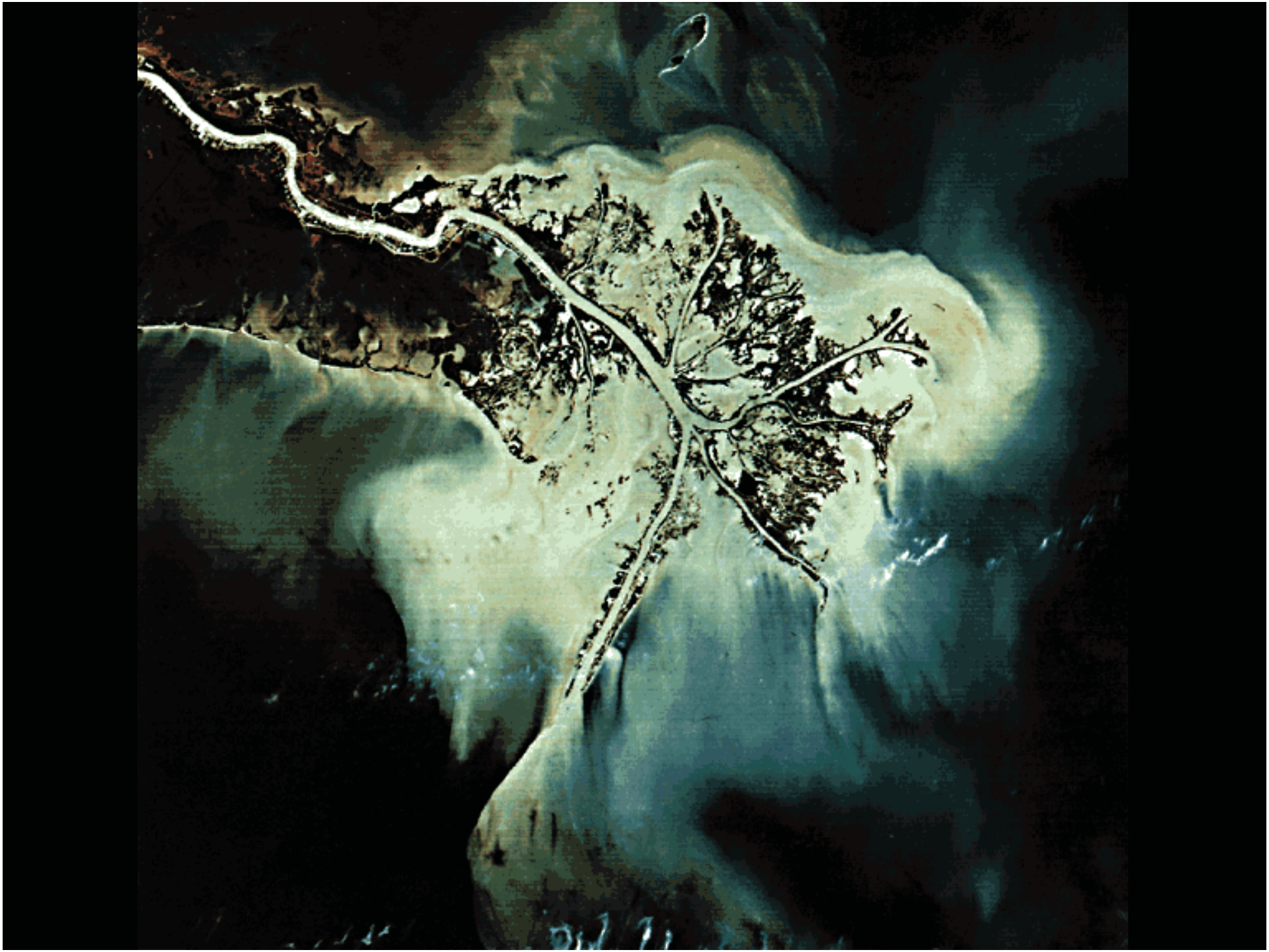


Minerals & Rocks that Preserve Fossil Records



Residence Time		Dominant Process Controlling Loss
	Least Stable	
$<1x10^4$ yrs	Ice	Climatic warming
$<1x10^6$ yrs	Halides, sulfates	Dissolution
$<2x10^8$ yrs	Metallic sulfides	Oxidation
$<3.5x10^8$ yrs	Clay-rich shales Water-laid pyroclastics Marine carbonates Metallic oxides	Metamorphism Recrystallization Dissolution
$<3.8x10^8$ yrs	Phosphates Silica	Deep burial Recrystallization Metamorphism
	Most Stable	

Farmer & Des Marais (1999)

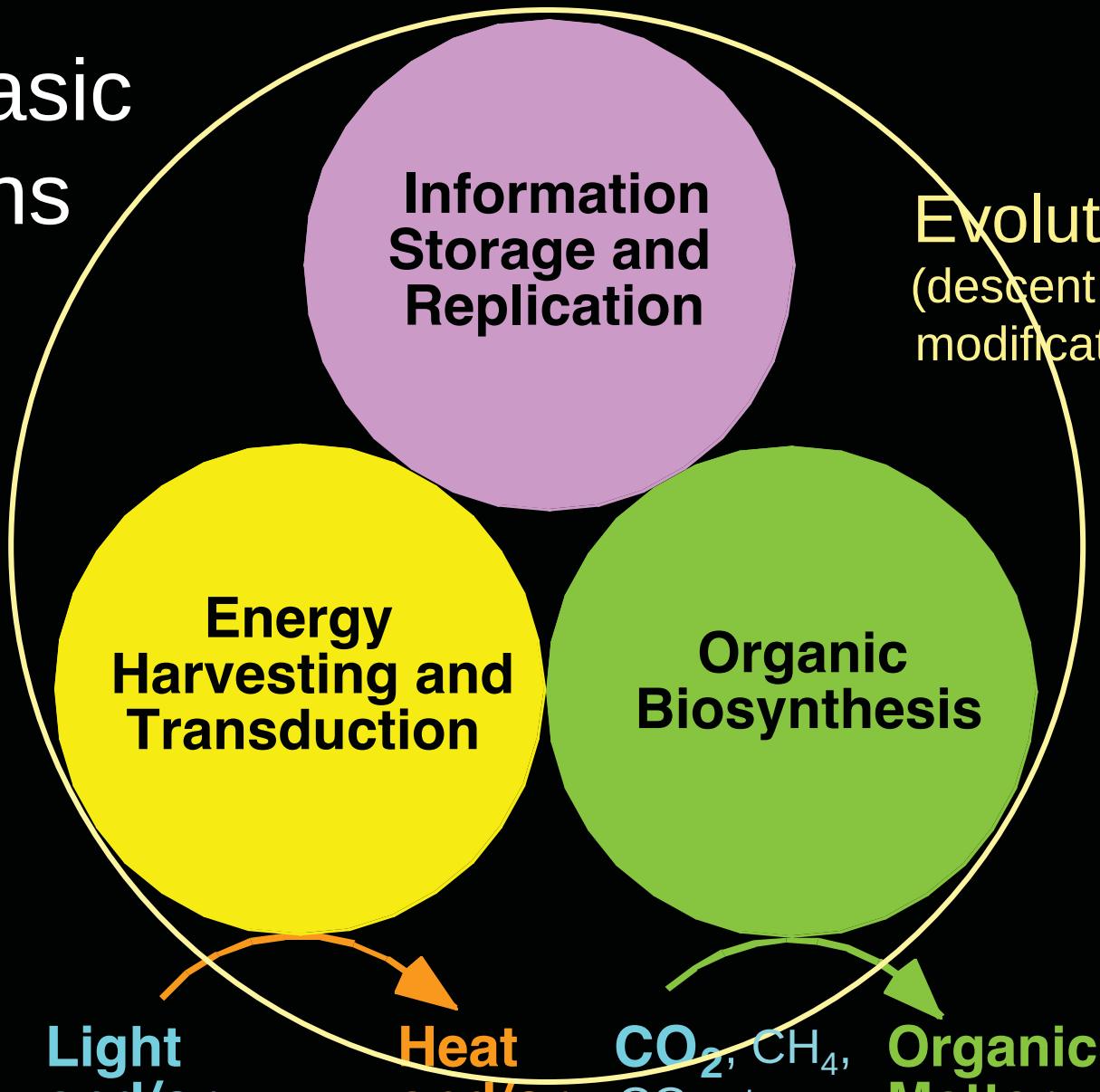


Biosignature

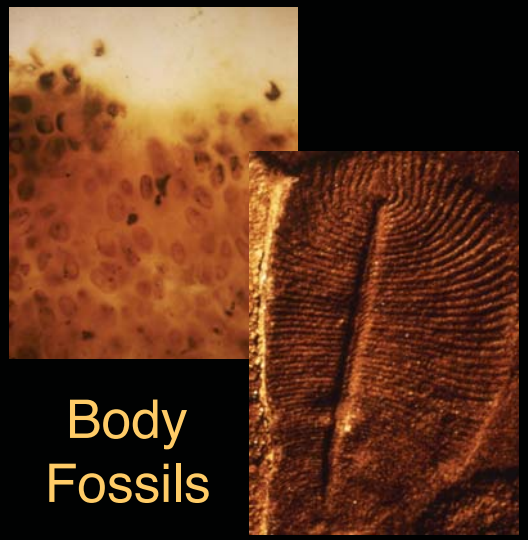
A biosignature is an object, substance and/or pattern whose origin specifically requires a biological agent.

The usefulness of a biosignature is determined not only by the probability of life creating it, but also by the *improbability* of nonbiological processes producing it.

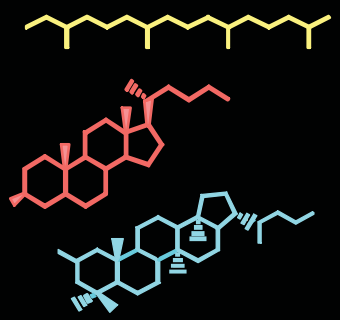
Life's Basic Functions



Fossil Biosignatures: What We Look For…

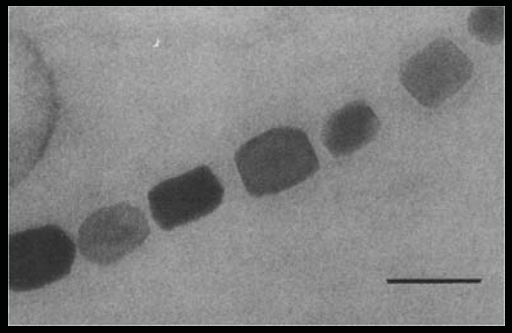


Body Fossils

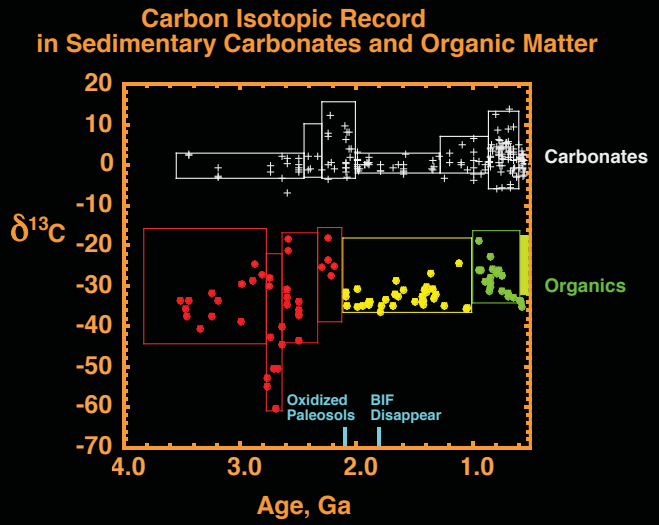


Chemical Fossils (Biomarkers)

Biofabrics



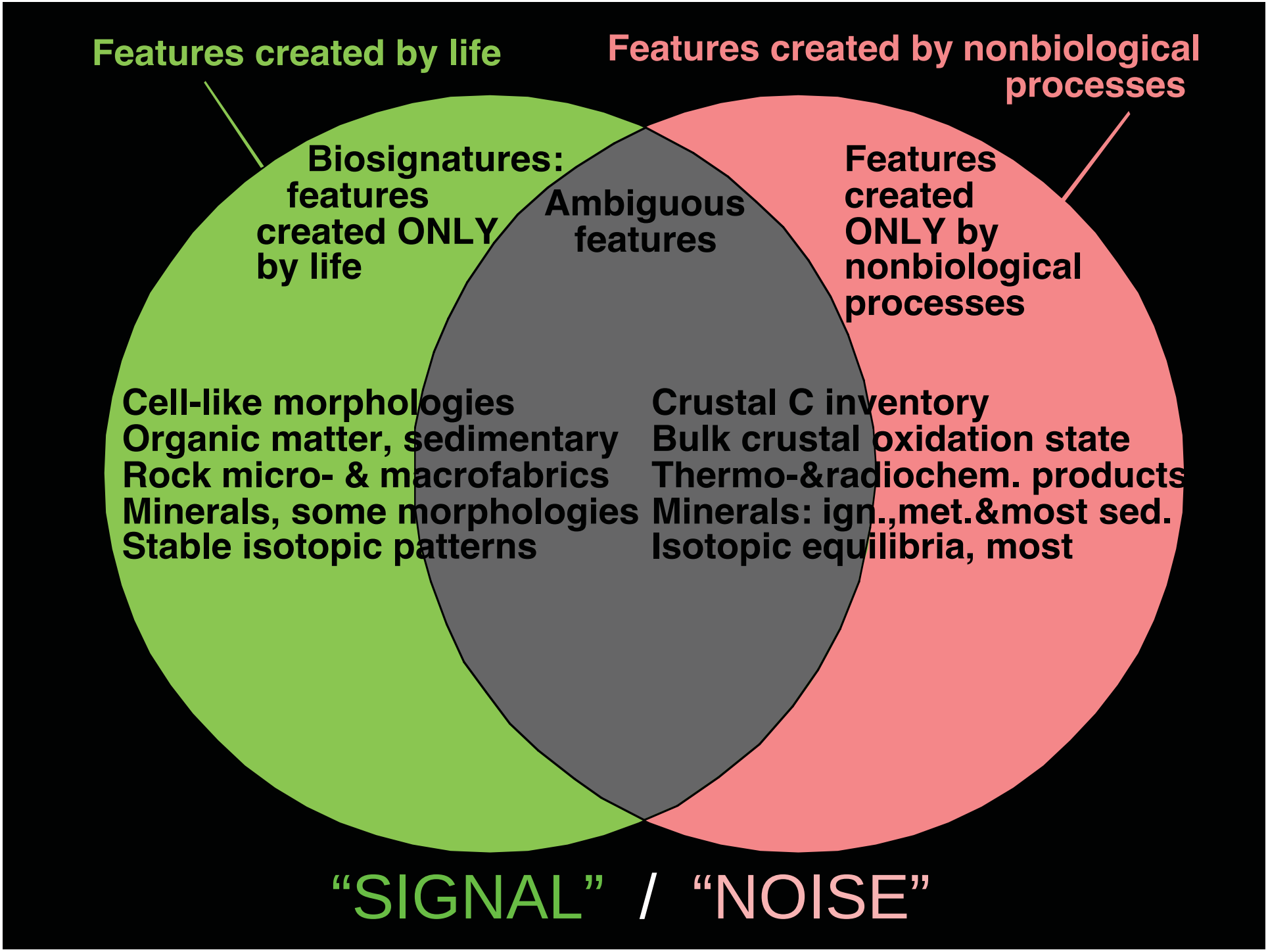
Biominerals



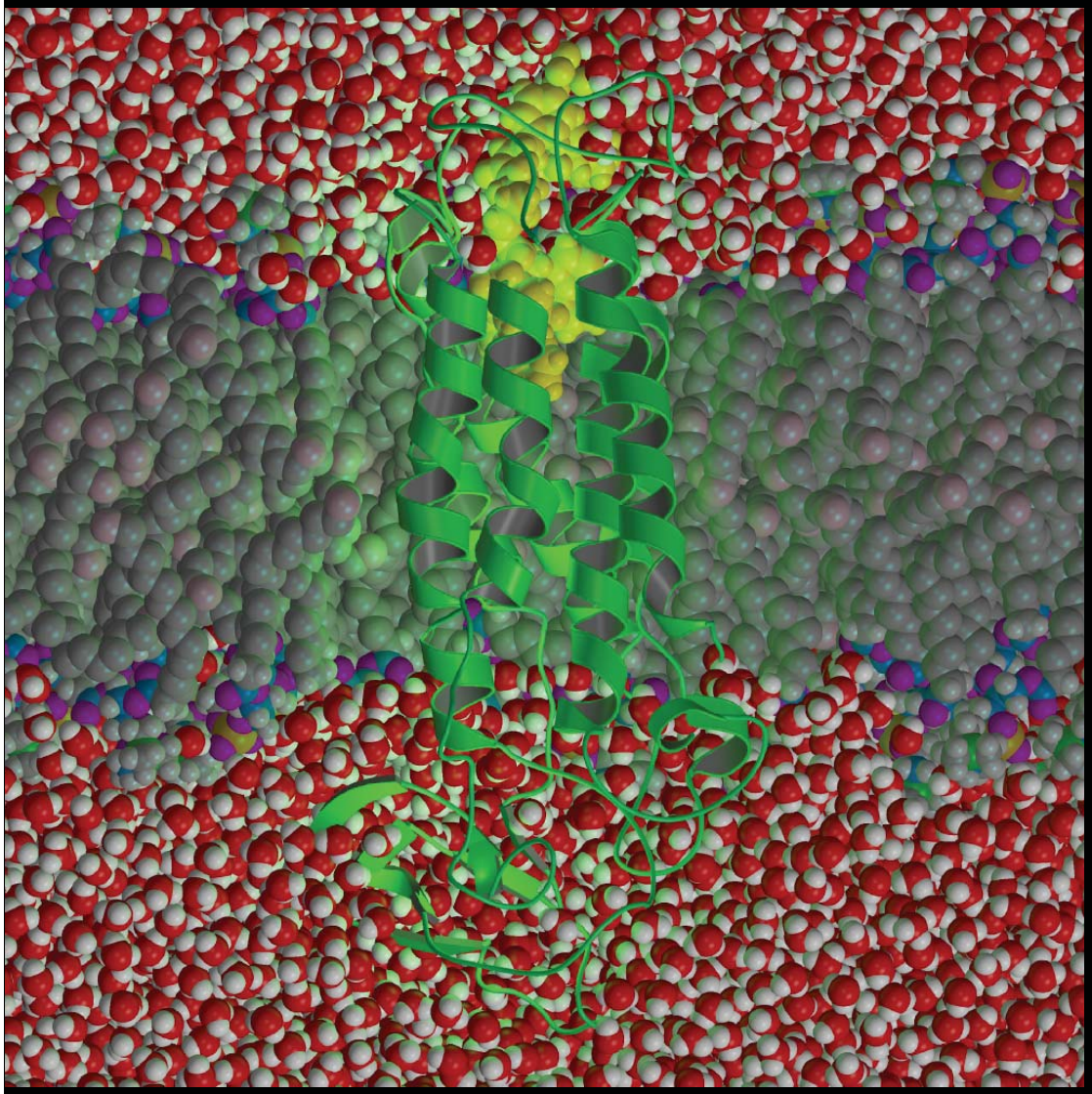
Stable Isotopes

Recognizing Biosignatures in Deep Time and Space

- Many biosignatures from recent geologic epochs are easily contrasted from abiotic features.
- But modern biosignatures arose after billions of years of evolution.
- In early geologic records the boundaries between biotic and abiotic features are far less distinct.
- Perhaps NO sharp distinctions existed between prebiotic features and biosignatures during the transition from the prebiotic realm to the biosphere.


Features created by life
Features created by nonbiological processes
Biosignatures: features created ONLY by life
Ambiguous features
Features created ONLY by nonbiological processes
Cell-like morphologies
Organic matter, sedimentary
Rock micro- & macrofabrics
Minerals, some morphologies
Stable isotopic patterns
Crustal C inventory
Bulk crustal oxidation state
Thermo-&radiochem. products
Minerals: ign.,met.&most sed.
Isotopic equilibria, most
"SIGNAL" / "NOISE"

Lipid biosignature features & functions



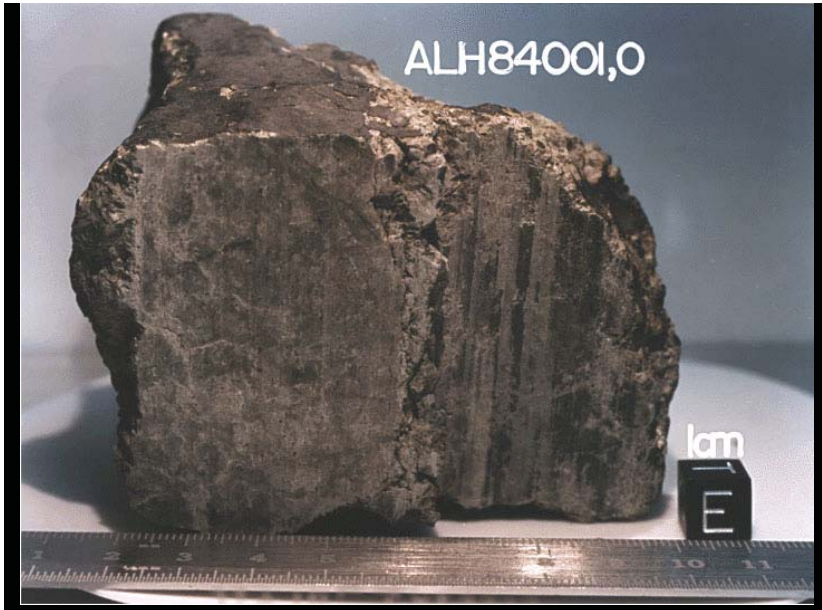
Compound class
- fatty acids S
- membranes, cells O

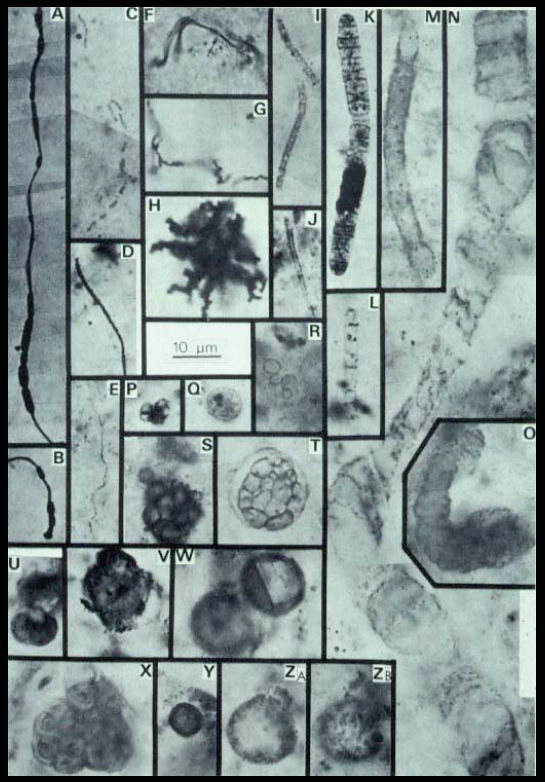
M.W. distribution
- n-C16 to n-C18 P
- isoprenoids S
- permeability

Complex molecules S
- enhanced functions

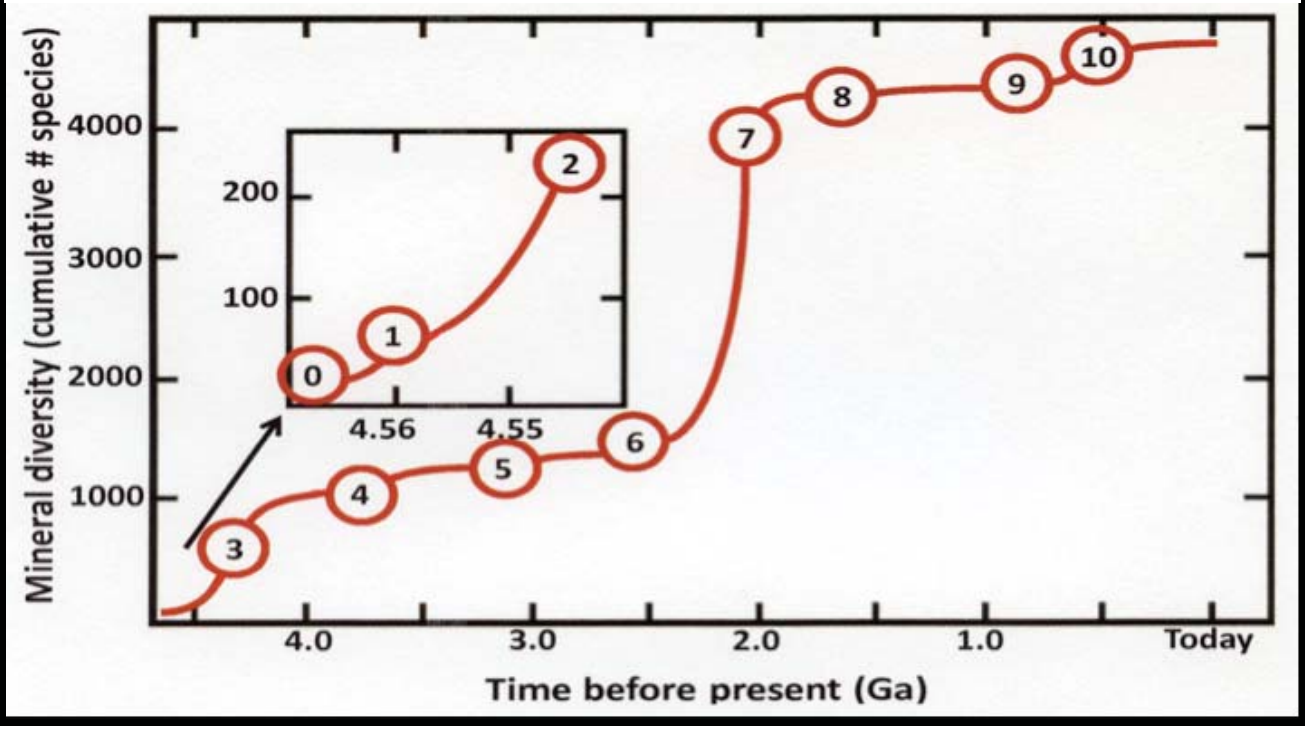
Stable isotopes P
- metabolism
- ecology

Biosignature type: Object Pattern Substance





Mineral Diversity on Earth vs Age (R. Hazen)



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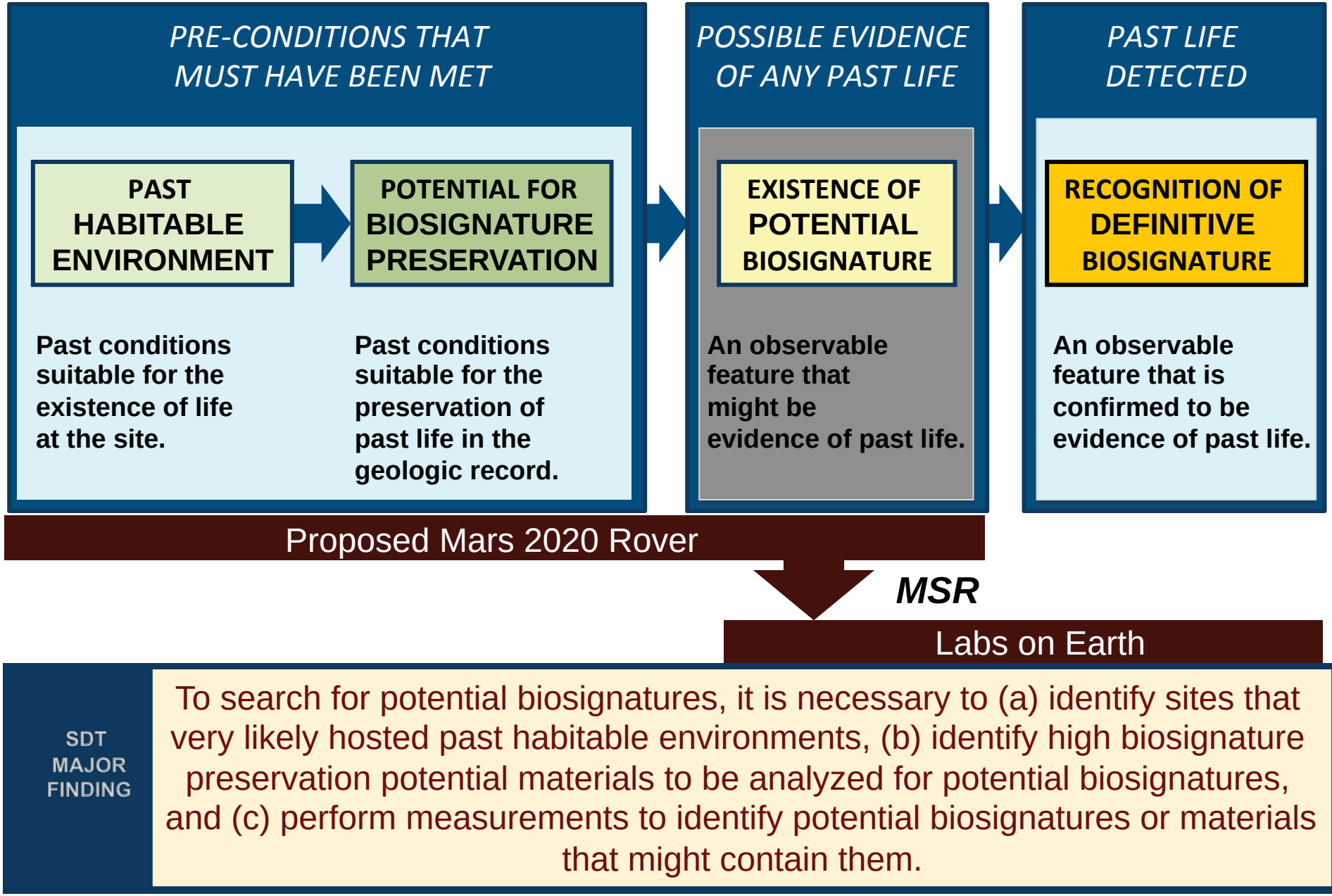
Scientific Process for Detecting Past Martian Life



End

image by David Deamer