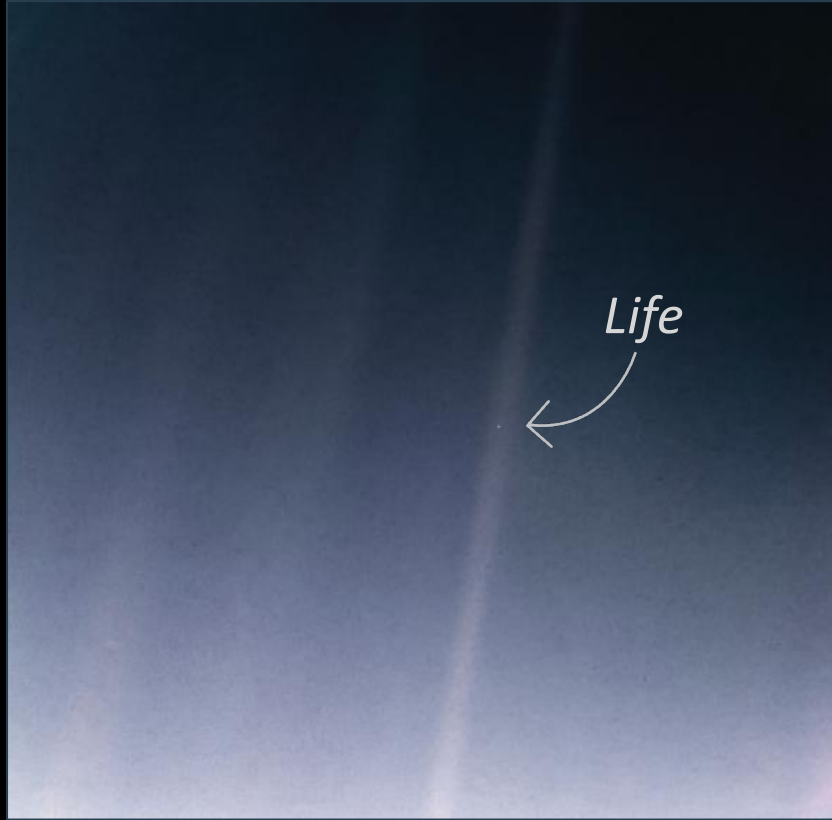


The limits of parsimony

Agnostic methods for designing life detection

Heather Graham
NASA Goddard Agnostic Biosignature Collective



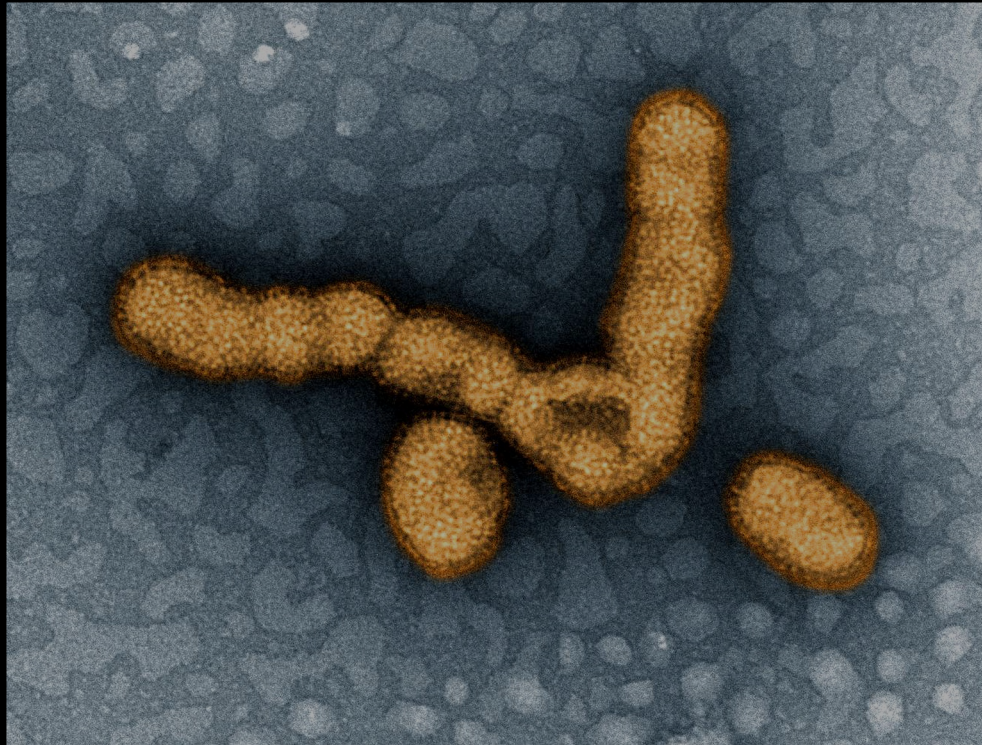


Life

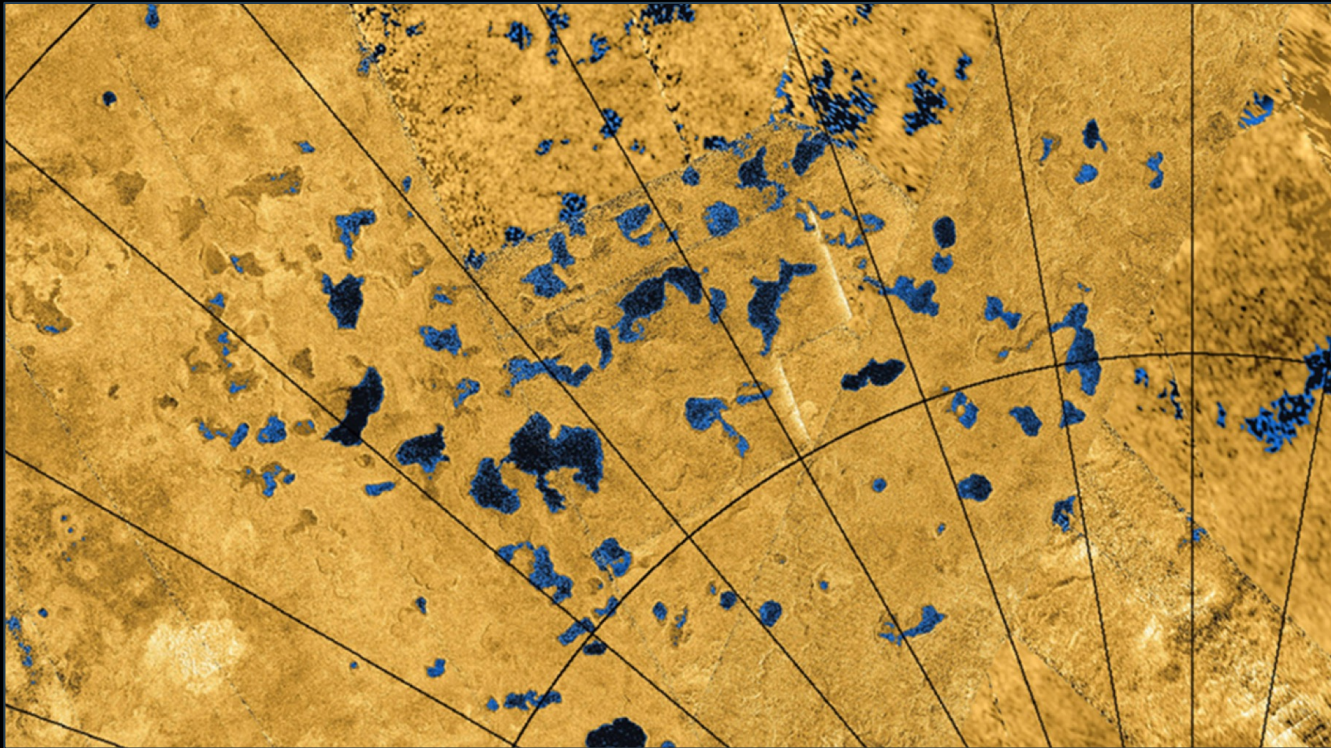
Life



Life at small scale



How do explore beyond our common heritage?



Cassini Radar Image of Titan

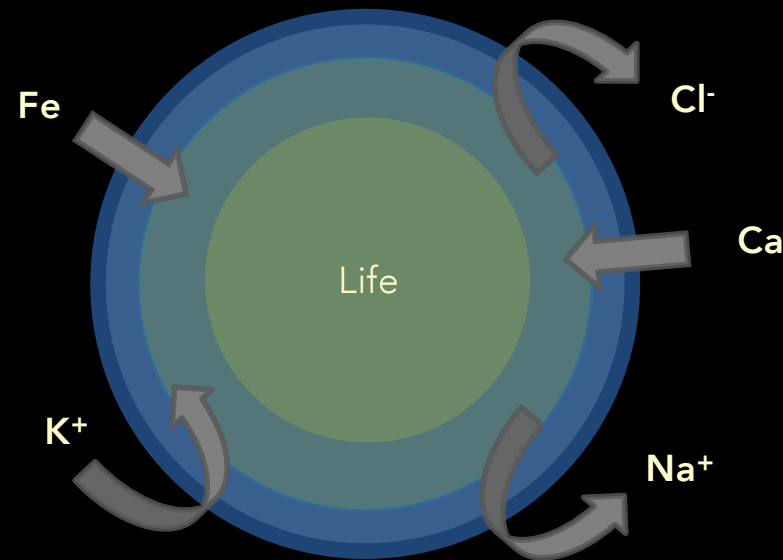
An **agnostic biosignature** is designed from fundamental observations rather than analogy

Life is an energetic response to an environment

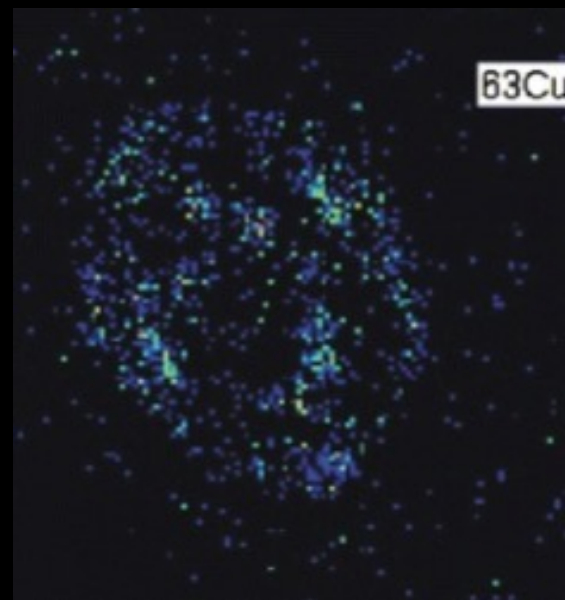
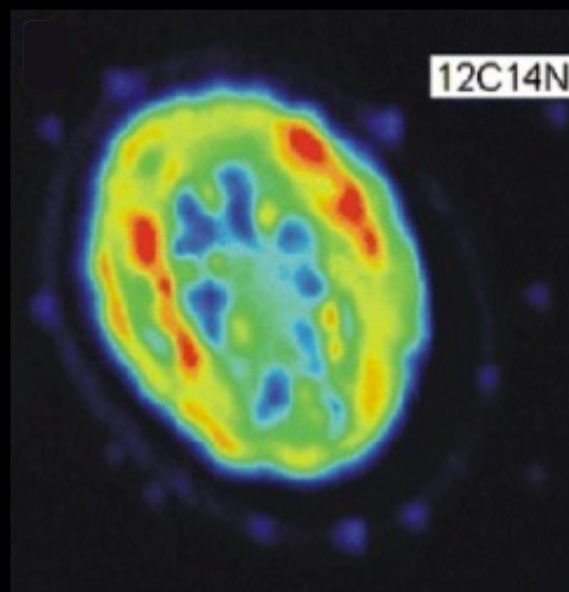
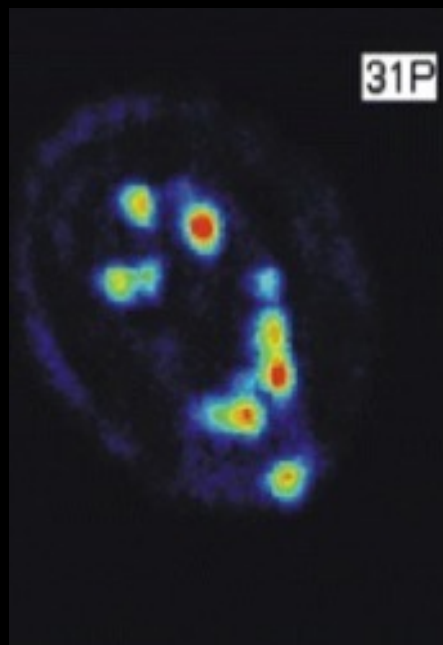


Organisms are open systems with **fluxes**
of matter and energy that are far
from equilibrium thermodynamics

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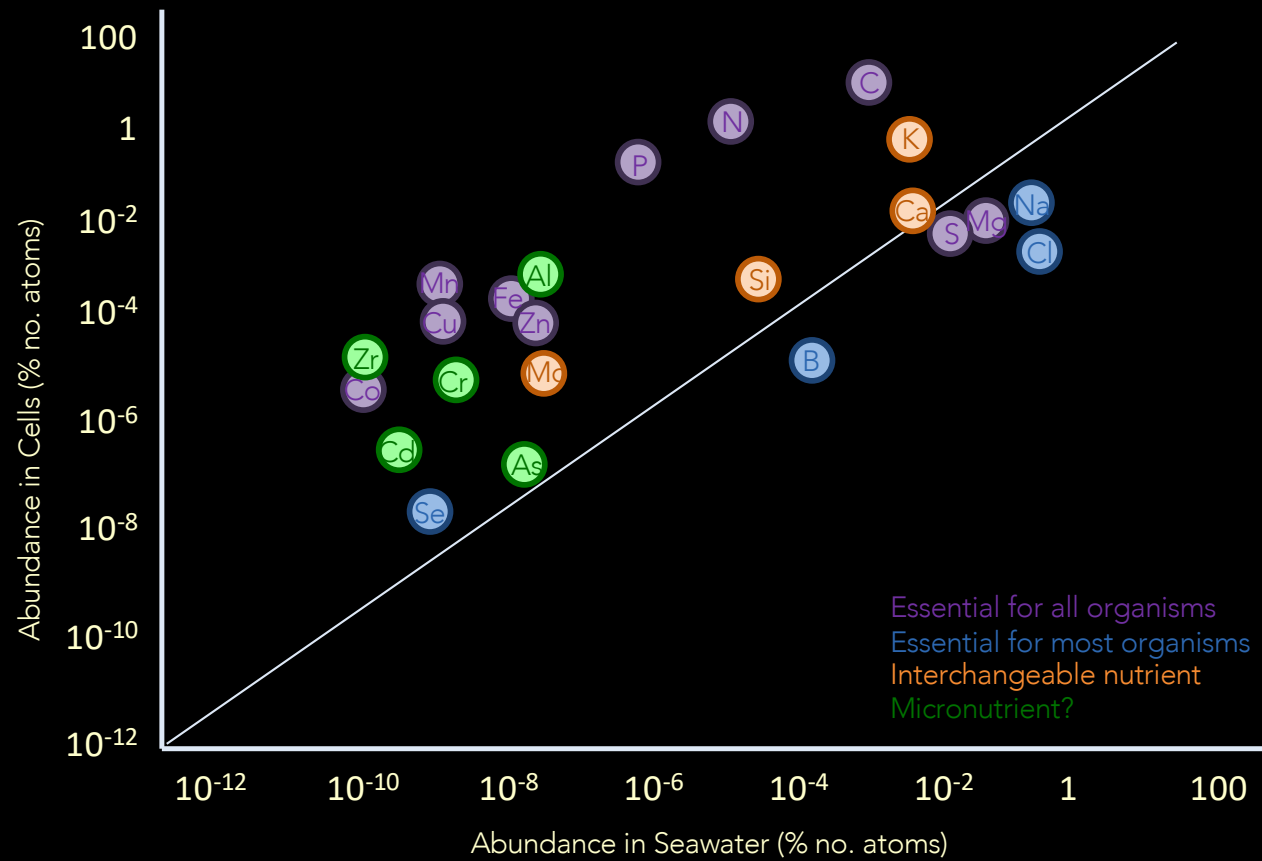


Life concentrates scarce elements into
discrete metastable entities that
are geochemically distinct

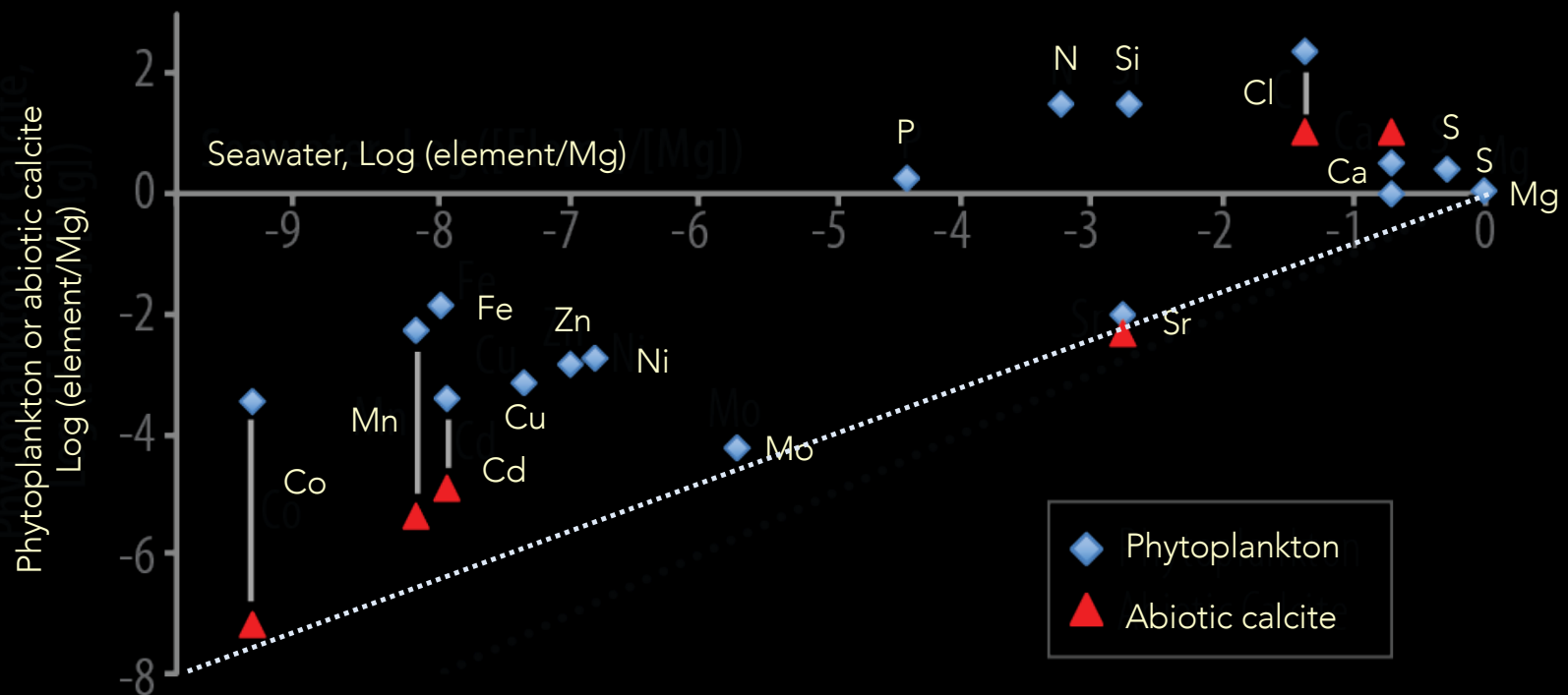


Williams & Da Silva 2000, *Coord Chem Rev*; Slaveykova 2009, *Anal & Bioanal Chem*

Fluxes can be generalized as "ecological stoichiometry"

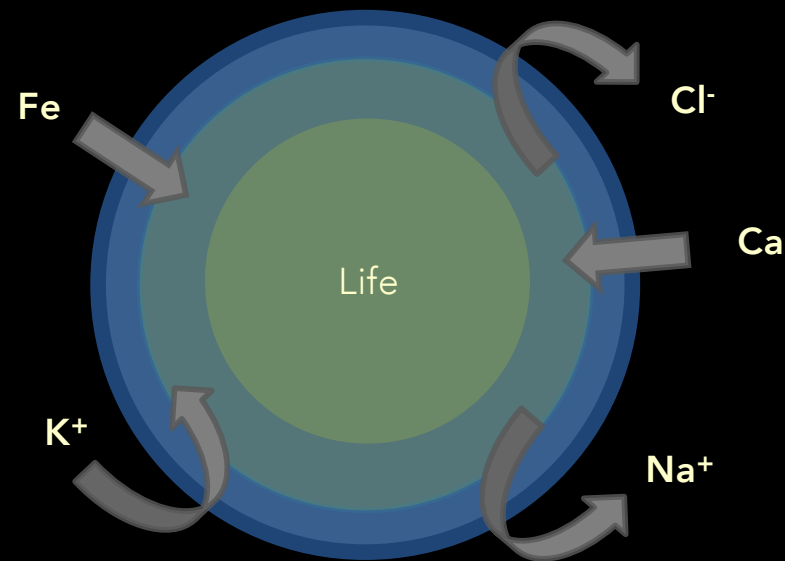


Fluxes can be generalized as "ecological stoichiometry"

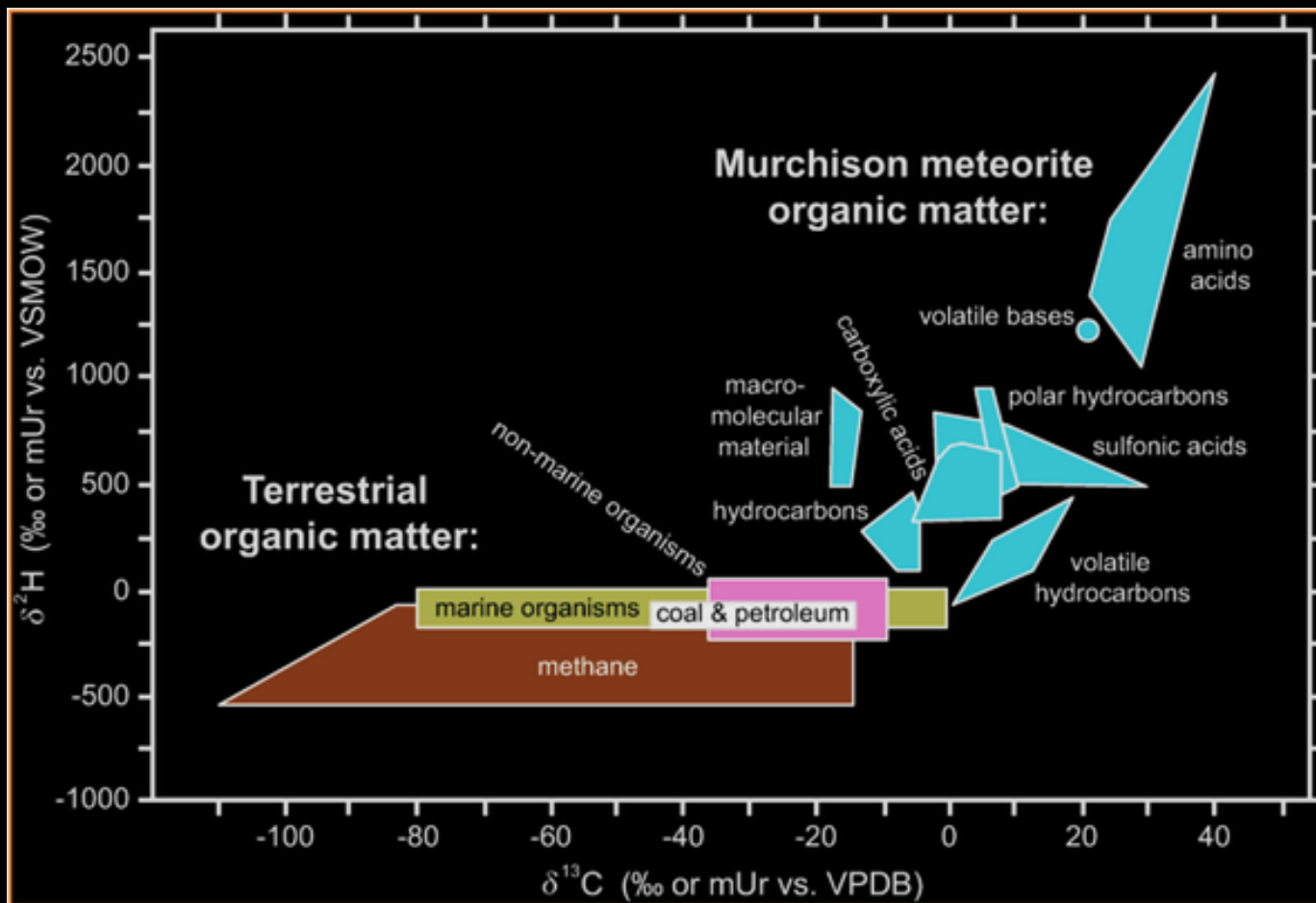


The currencies of **energy** and **materials** are inextricably linked
by the chemical equations of **metabolism**

Redistribution of materials represents **energy** and a selection mechanism

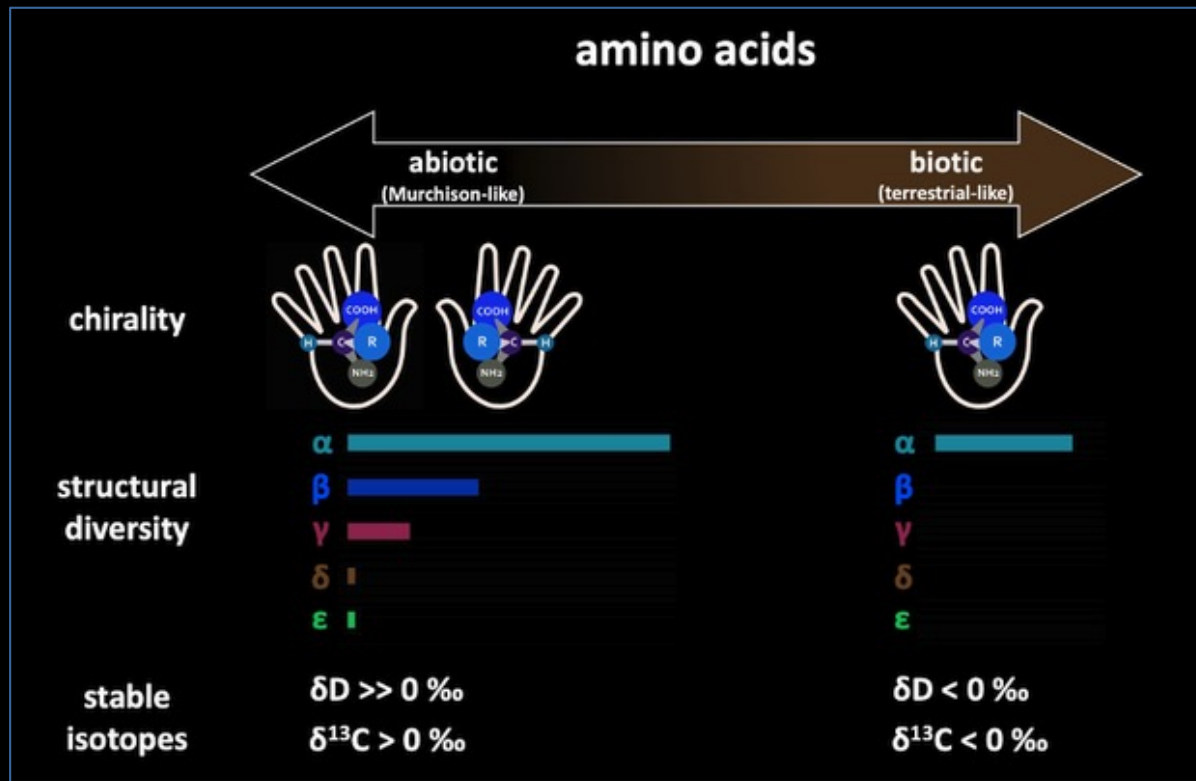


Redistribution of materials represents **energy** and a selection mechanism

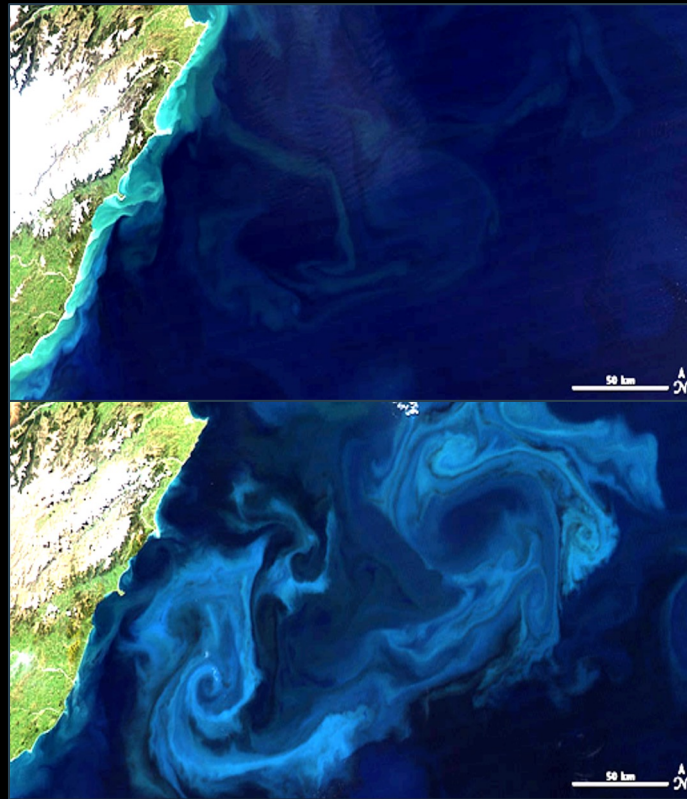


Adapted from Sephton & Botta, 2006; Intl J. Astrobio

Metabolite production reflects energy and a **selection mechanism**



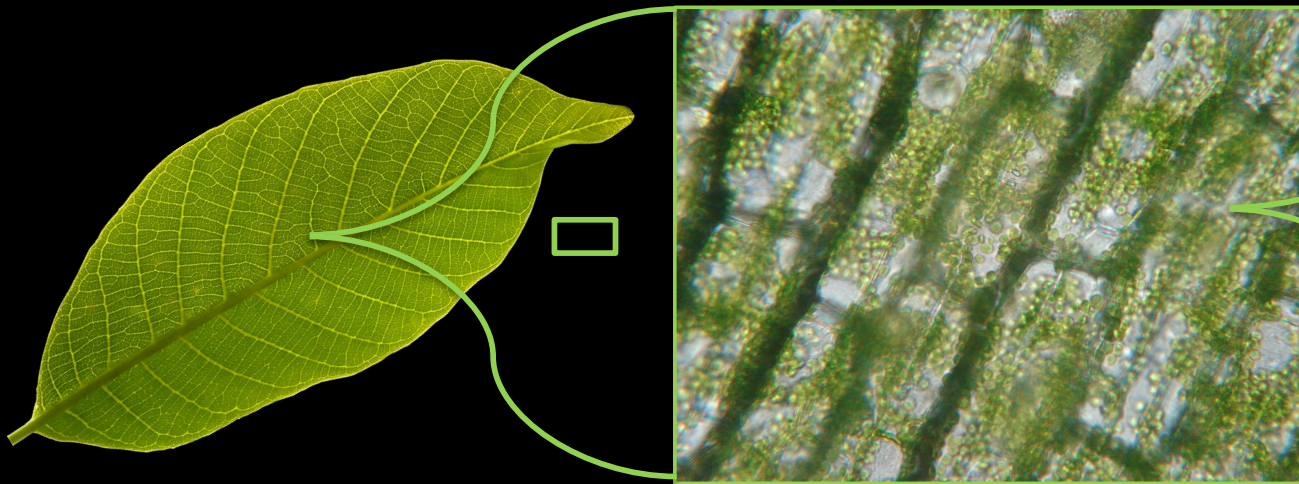
Life's redistribution of materials can occur at planetary scale



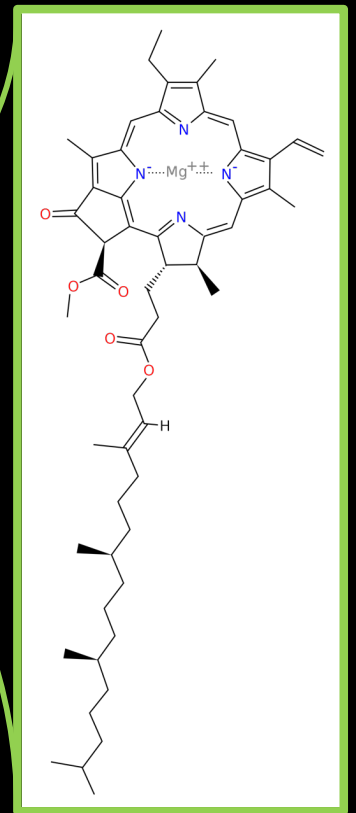
Organisms arrange **matter** and **energy** into highly ordered structures with intrinsic complexity

How do we look for life?

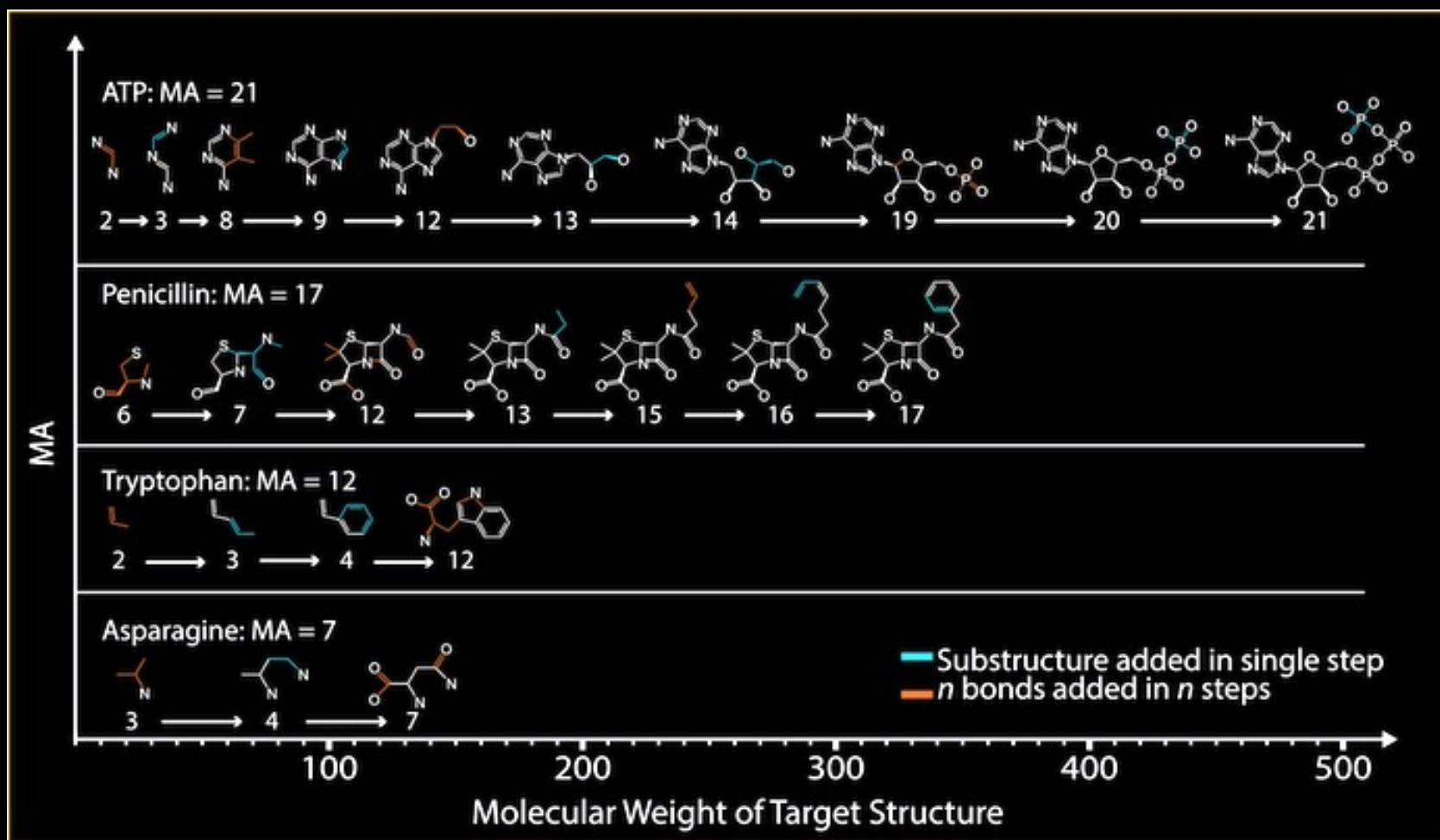
Highly ordered structure with **intrinsic complexity**



Structures at various scales

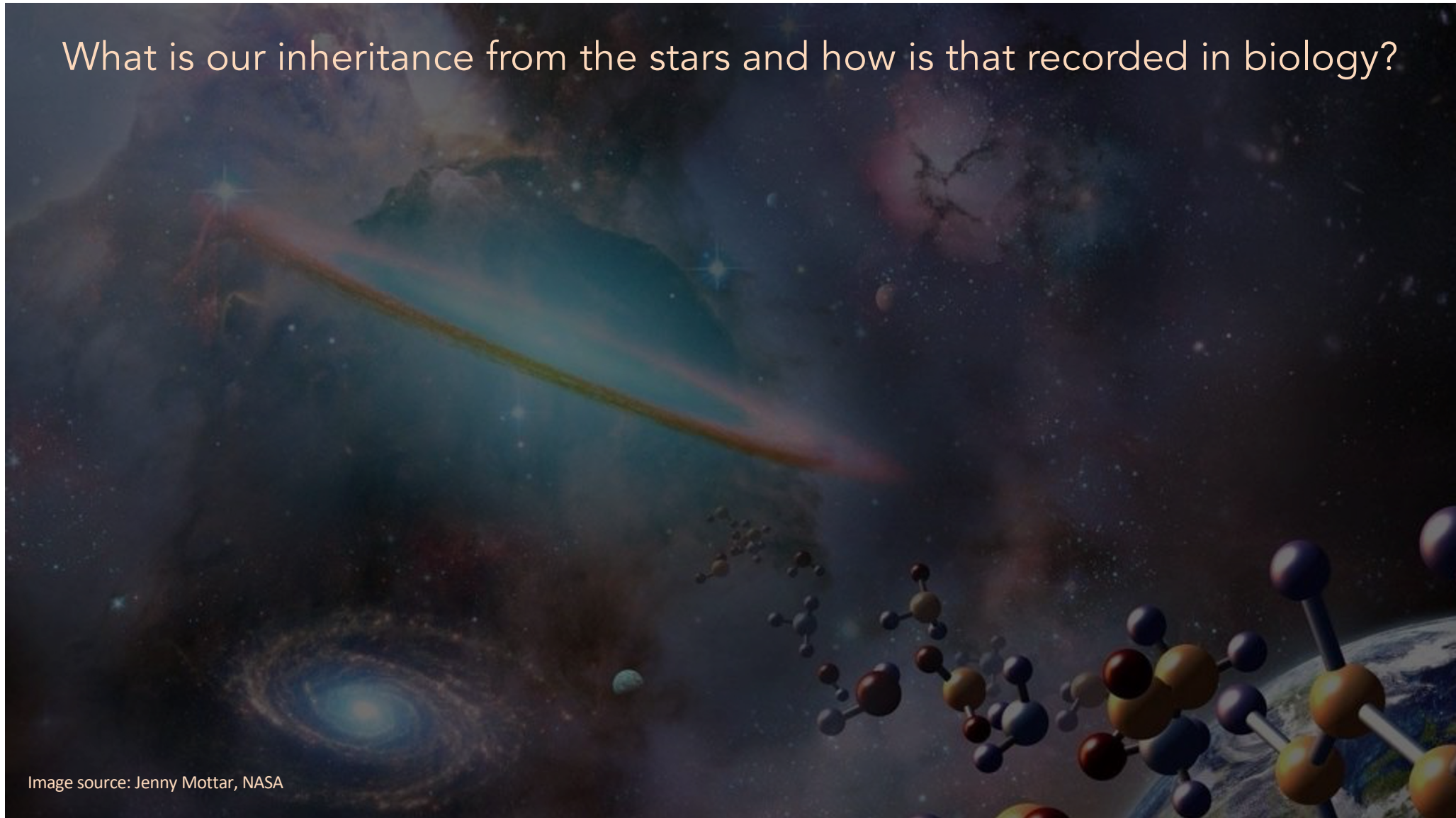


Metabolites reflects energy, selection mechanism and intrinsic complexity



What is our inheritance from the stars and how is that recorded in biology?

Image source: Jenny Mottar, NASA



What is our inheritance from the stars and how is that recorded in biology?



Meteorites and asteroids (like Bennu) are the closest thing we have to primordial planetary material.



Knowledge of the abiotic is required in order to design biosignatures based on fundamental observations rather than analogy

Many Thanks from the ABC lab!

Analytical organic chemistry

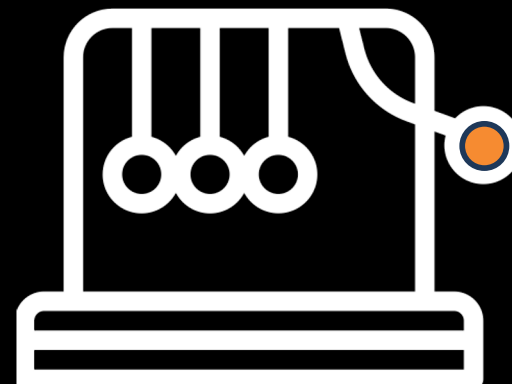
- Molecular complexity metrics
- Surface complexity metrics
- Position-specific isotope analysis
- Organic biomarkers in low biomass settings
 - Deep subsurface waters and chemical sediments

Geochemistry

- Mineralogical complexity and elemental abundance biosignatures
- Particle size and stoichiometry

Volatile analysis

- Volatile capture for in situ exploration
- Outgassing from Bennu samples



Contact me at
heather.v.graham@nasa.gov

- Summer internships for undergrads
- Postdoctoral fellowship opportunities
- New proposal venues for research collaboration