NASA Astrobiology Program

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COMMITTEE ON BIOLOGICAL AND
PHYSICAL SCIENCES IN SPACE
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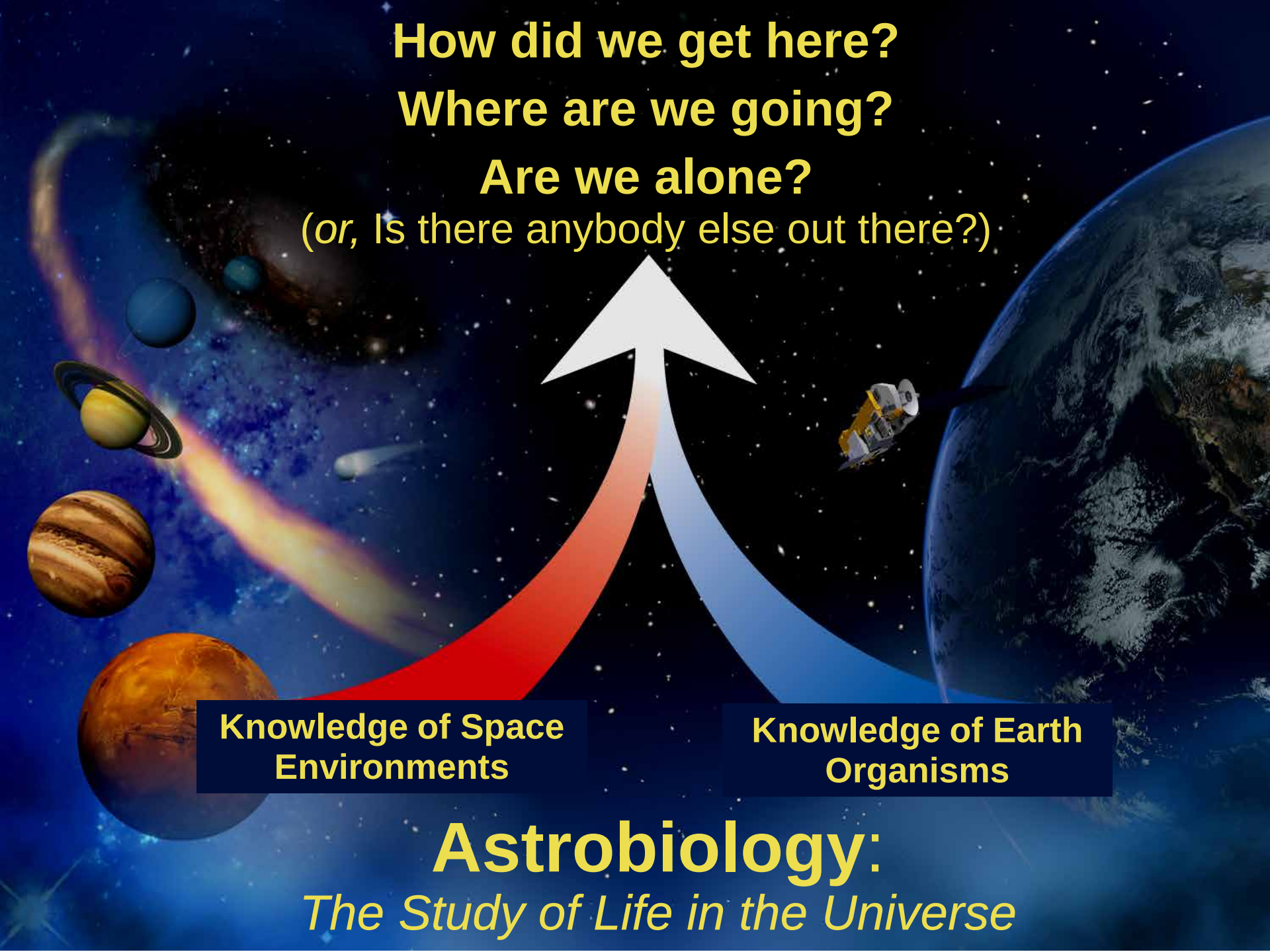

How did we get here?
Where are we going?
Are we alone?
(*or,* Is there anybody else out there?)
Knowledge of Space Environments
Knowledge of Earth Organisms
Astrobiology:
The Study of Life in the Universe

NASA Science Goals

Astrobiology at NASA (1963-present)

- What are the characteristics of the solar system that lead to habitable environments?
- How and where did or could life begin and evolve in the solar system (and beyond)?

The Astrobiology Science Strategy

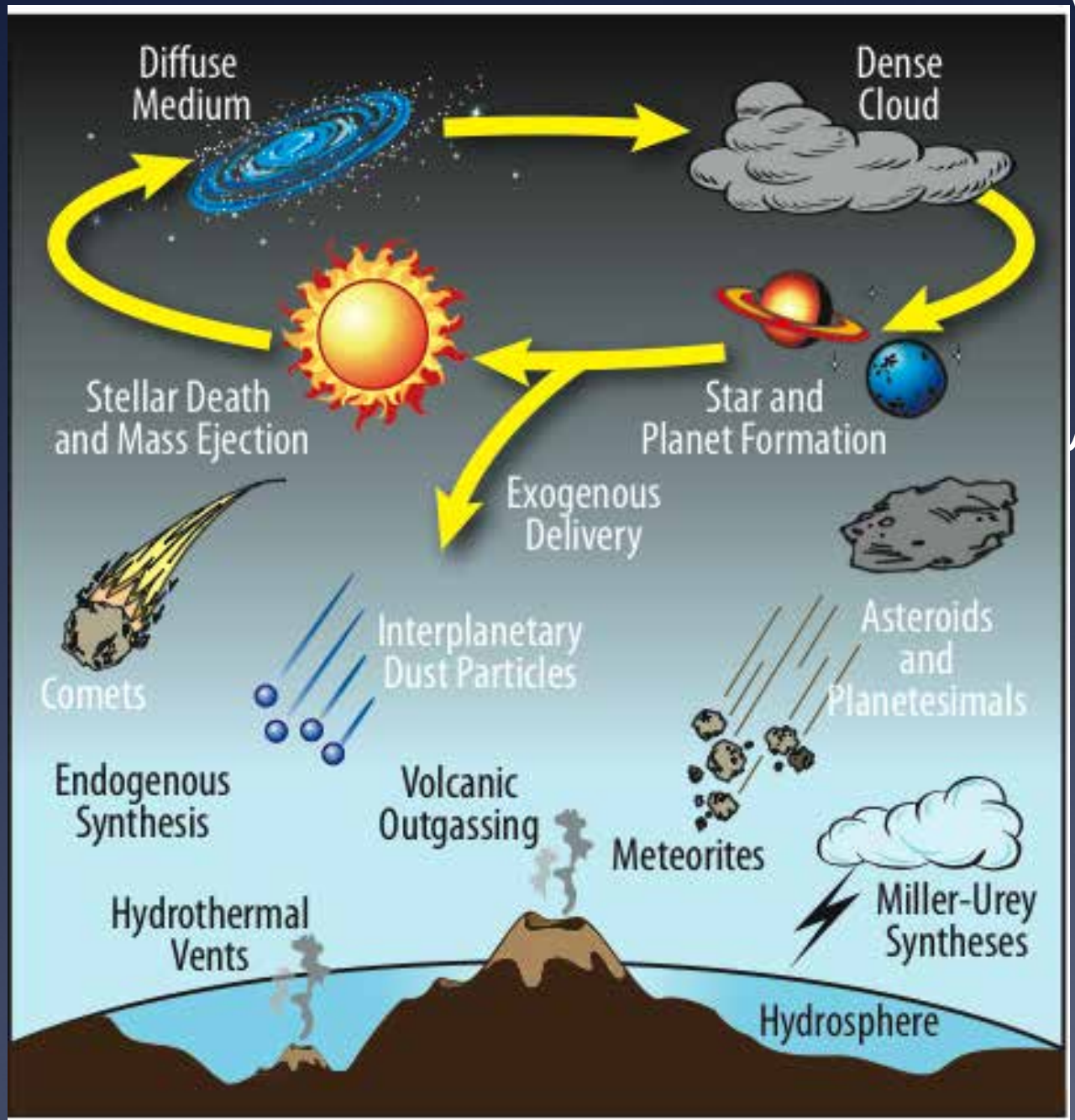
Six Major Research Areas

- Identifying abiotic sources of organic compounds
- Synthesis and function of macromolecules in the origin of life
- Early life and increasing complexity
- Co-evolution of life and the physical environment
- Identifying, exploring, and characterizing environments for habitability and biosignatures
- Constructing habitable worlds

1. Abiotic Sources of Organic Compounds

- Where did the building blocks of life come from?
  - How did the abiotic (non-biological) production of small molecules lead to
    - the production of large and more complex molecules,
    - prebiotic chemistry, and
    - the origin of life on Earth?
- Did or could life or prebiotic chemistry evolve on differentiated (altered) icy worlds such as Enceladus, Europa, and Titan?

Prebiotic Chemistry



Observations & Simulations

Lab Analysis

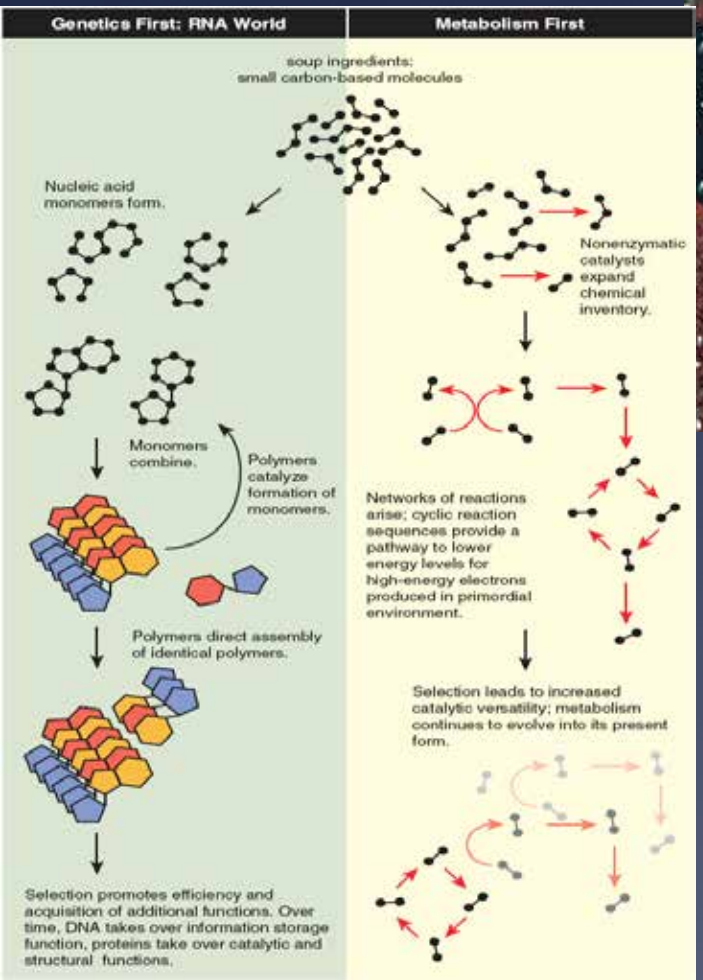
Simulations

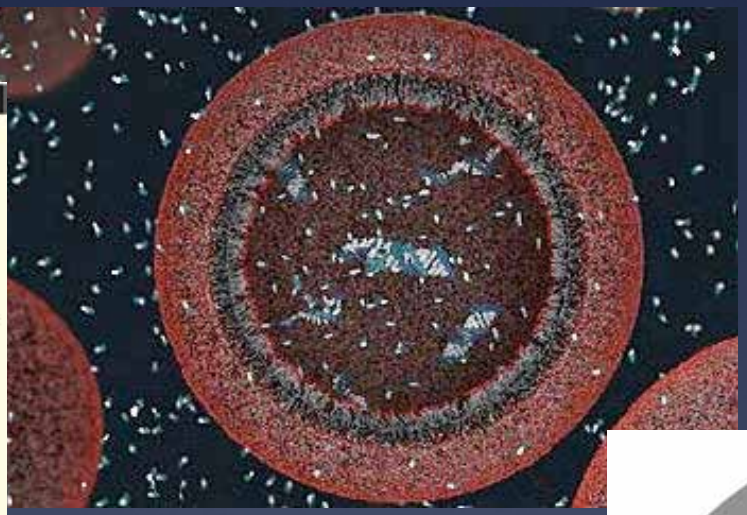
2. Synthesis and Function of Macromolecules

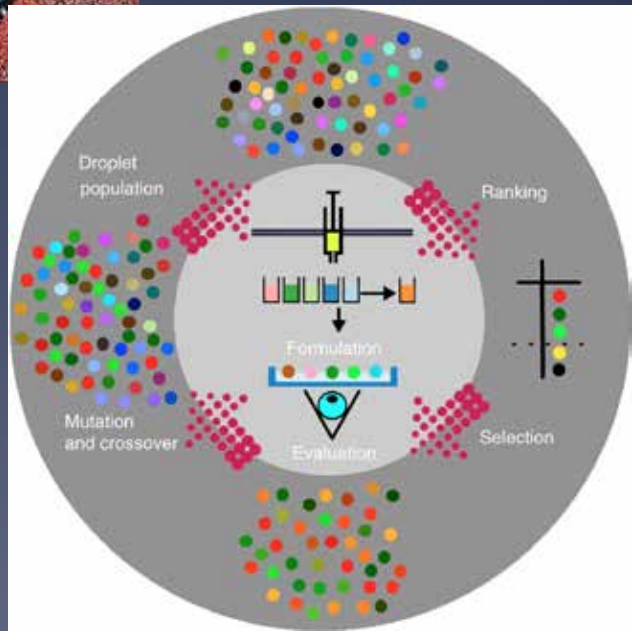
- What are the characteristics of the chemical processes that lead to the formation and persistence of polymeric systems capable of performing biologically important functions and evolving?
- What are the
  - interactions,
  - intermediary structures and functions,
  - energy sources, and
  - environmental factors

that contributed to the diversity, selection, and replication of these systems?

- Synthetic biology in the field of astrobiology focuses on building “life” from scratch in the lab, not engineering organisms for a particular goal or applied function







3. Early Life and Increasing Complexity

- Do overarching rules governing evolutionary processes exist?
  - If they do, what are they?
- Which attributes of “life” are common to all origin scenarios or environments and which are context-dependent?
- Is it a fruitful approach to try to define “life”?

Universal Biology: How to identify common features of life on Earth that could be extended to life beyond Earth?

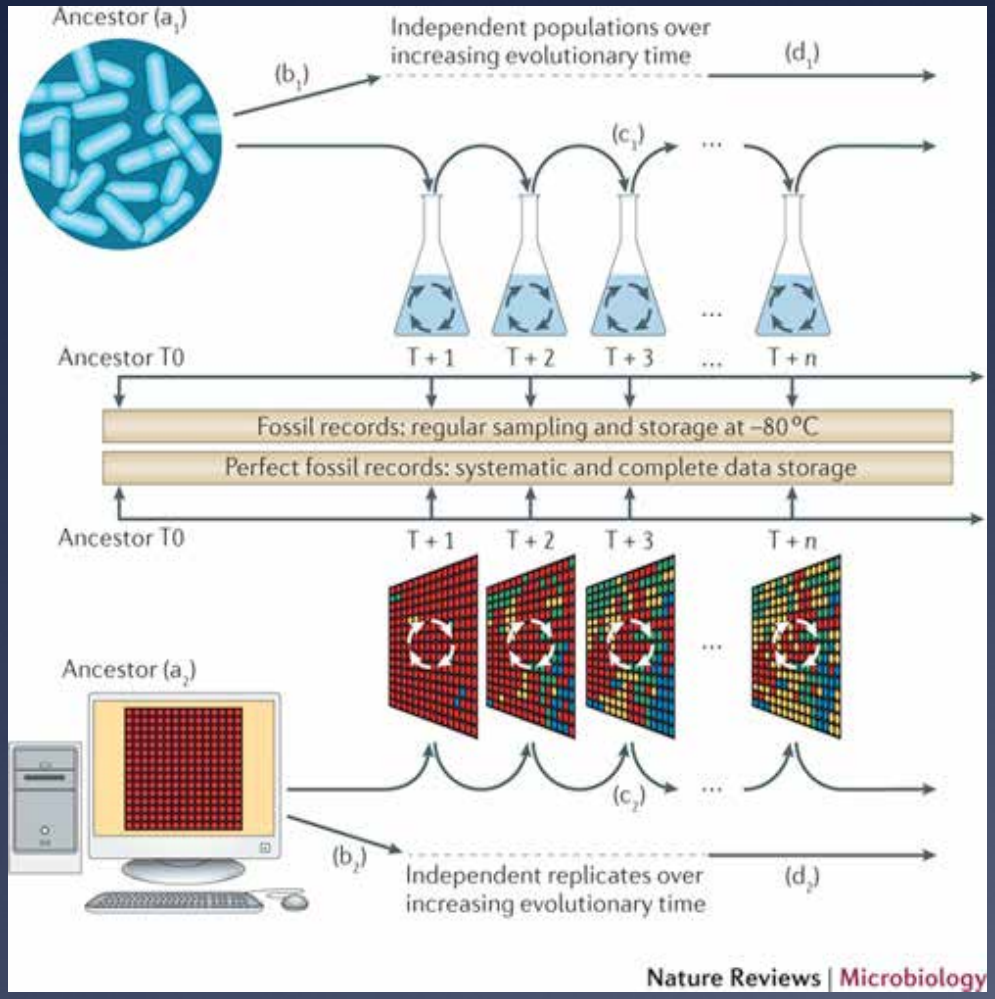
Universal Biology: A physicist view of biology that leads to an abstraction of function and features that can then be attributed to Universal systems.

WHY IS THIS IMPORTANT?

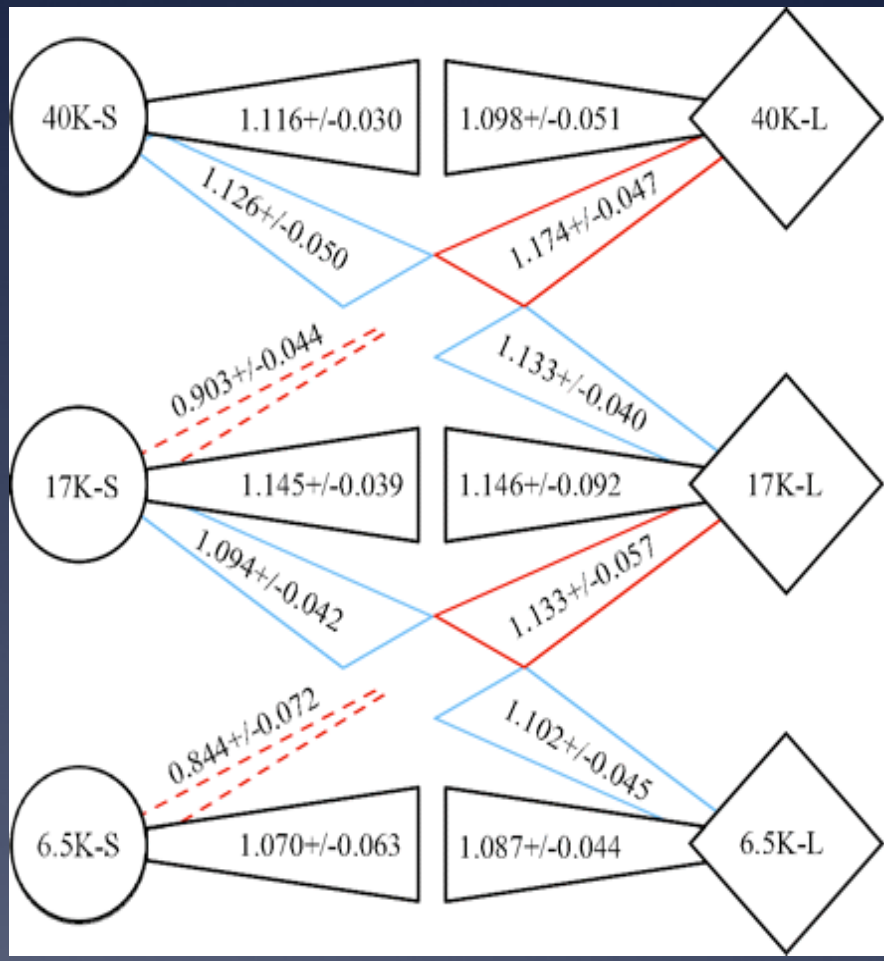
1. Getting past the Chicken and Egg problem in biology.
In order to apply biological concepts beyond the specific Earth example we sacrifice precision to get robustness

2. Every planet has its own story and it is highly unlikely that the “details” of that life will be exactly like Earth’s. We need ways to understand life that will survive those differences.

Experimental Evolution



Hindré et al. 2012



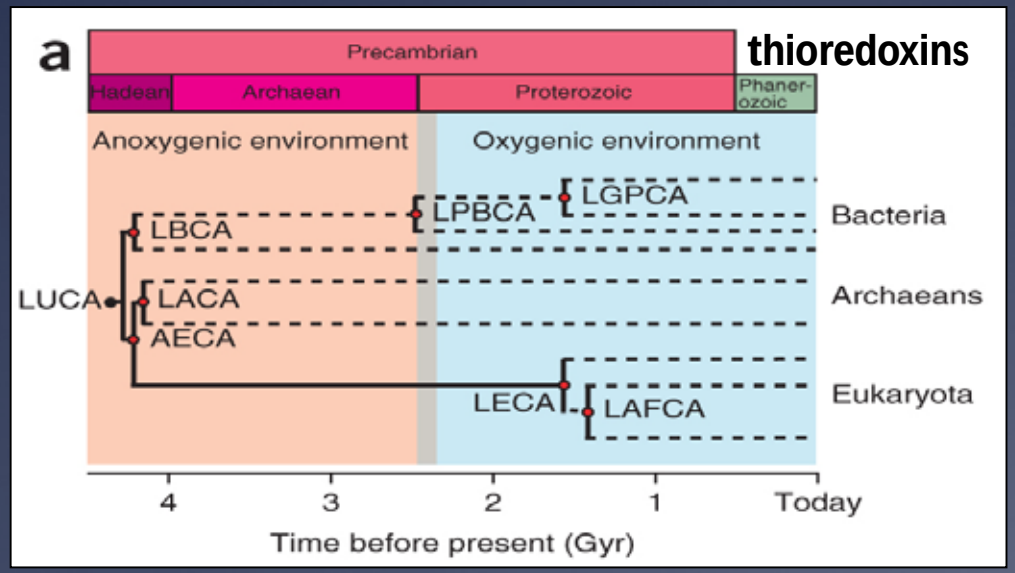
Le Gac et al. 2012

4. Co-Evolution of Life and the Physical Environment

- What are the relationships between life and the physical environment in which it exists?
- How do the biological and abiological parts of a world shape each other?
- What evidence from Earth's co-evolutionary past inform our understanding of the habitability of the Earth through time and the habitability of environments in our Solar System and beyond?

Paleogenetics and Paleobiochemistry

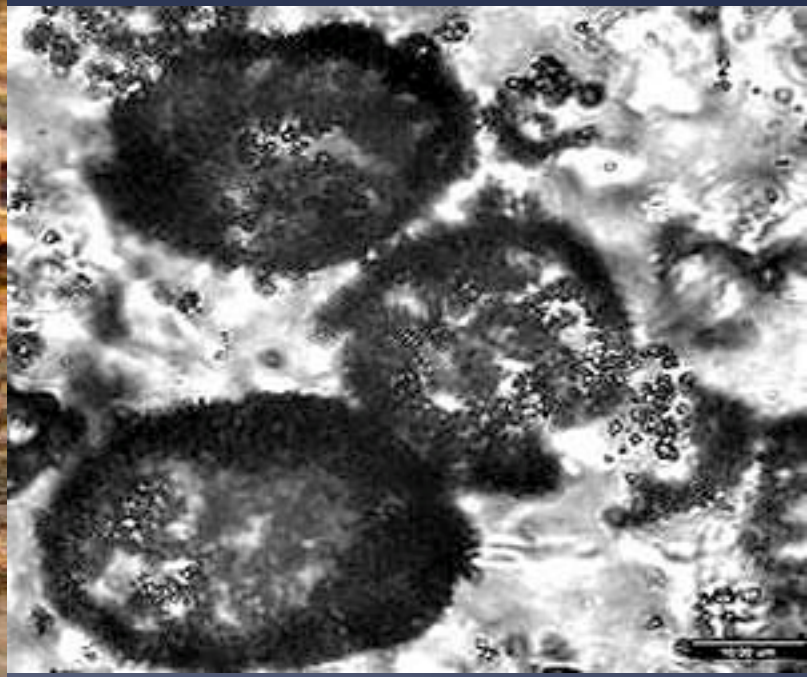
- The growth of bioinformatics databases has enabled detailed, evidence-based predictions about the molecular biology of early life.
- Ancestral sequence reconstruction has proven to be a powerful tool for studying ancient cellular life.



Gaucher et al. 2011

The earliest life on Earth

3.4 Ga Strelley Pool Chert formation



Wacey et al., 2011

5. Environments for Habitability and Biosignatures

- How do we determine if a particular environment
  - is currently habitable,
  - was habitable in the past,
  - is able to support the generation of life, or
  - was able to support the generation of life in the past?
- How should we define habitability indicators (like biosignatures) and interpret them in a context-sensitive manner?

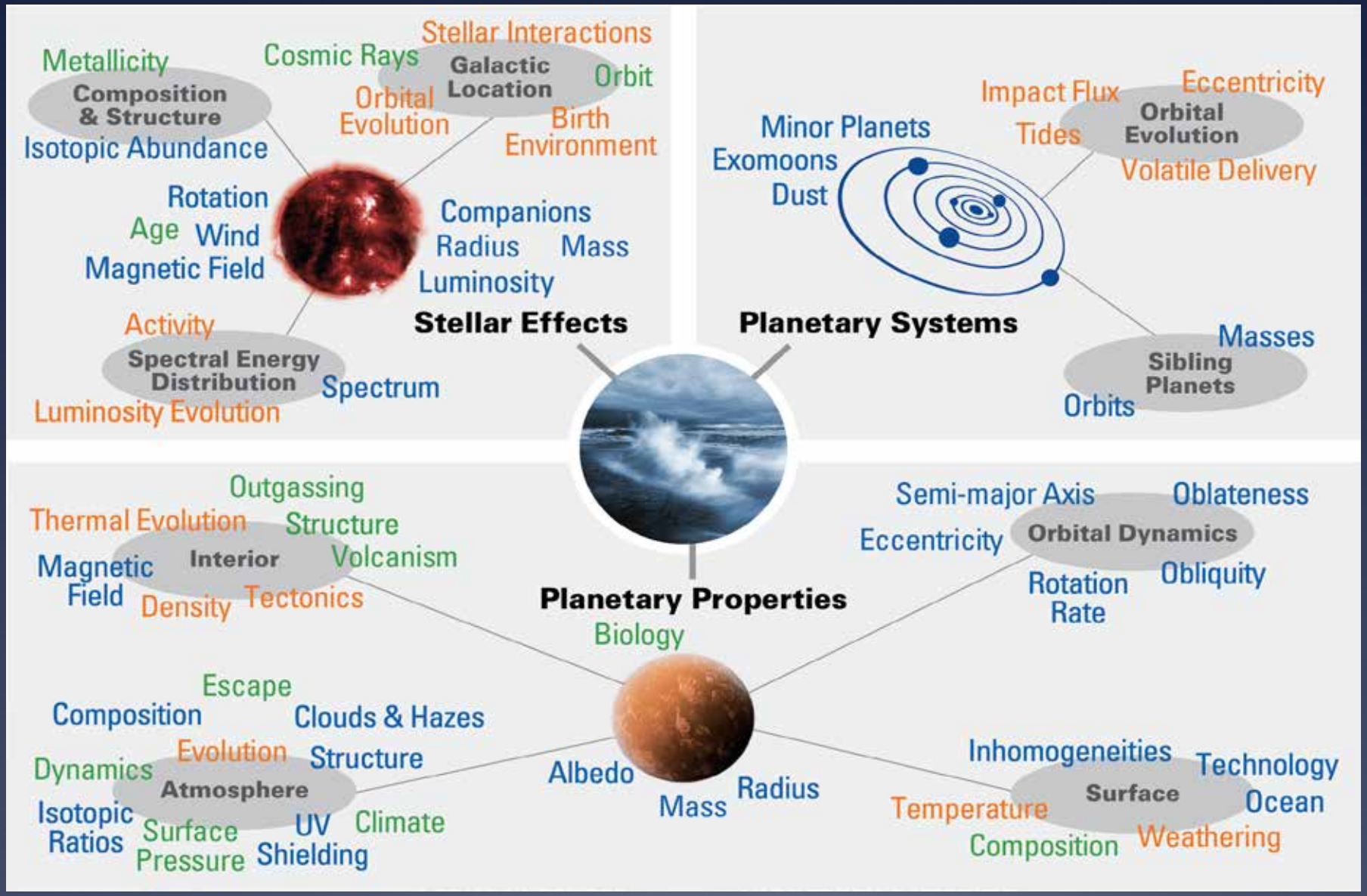
Characterizing habitability on earth and search for similar conditions beyond earth

6. Making Habitable Worlds

- How has our limited experience with habitability on Earth, alone, limited our basic understanding of the basic requirements for habitability?
- How can our limited understanding of habitability be applied to other environments in the Solar System and beyond?

Planets are Hard

Meadows and Barnes, 2018



Biology Synergies in SMD

Space Biology	Planetary Protection	Astrobiology
Supporting Earth life elsewhere	Prevention of finding Earth life elsewhere	Search for life elsewhere
Want to understand the limitations of Earth life to operate in built environments for human space exploration	Want to understand the limitations of Earth life to prevent the contamination of targets for the search for life	Want to understand the limits of Earth life to identify targets for the search for life
Use technology to monitor health and function of Earth life	Use technology to detect and remove Earth life	Use technology to detect life, including **unknown** life
Focus on impact of micro and macro-biology in the service of humans and habitats	Focus on preventing impact of microbiology	Focus on impact of biology on micro and macro environments and detection of biosignatures
Disciplines: Biology (incl. Biochemistry, Molecular biology, Bioinformatics, Ecology, etc.)	Disciplines: Biology, Engineering	Disciplines: Biology, Astronomy, Astrophysics, Geosciences, Heliophysics, Geophysics, Geology, Chemistry……

Synergy with Space Biology

- Facilitating Exploration Through Enabling Science and Research
- Understanding the Space Environment and How Biology Operates Therein
- Similar Techniques and Approaches


Questions???