

Update on the NASA Astrobiology Institute

Carl Pilcher, Interim Director
NASA Astrobiology Institute
NASA Ames Research Center

September 17, 2015

NAI: A 'Virtual' Institute Without Walls

- Competitively-selected science teams, each a consortium (currently 12 teams)
- ~600 members at ~100 participating institutions
 - ~320 “senior” scientists
 - ~280 postdocs and students
 - ~20 members of the US National Academy of Sciences
- Managed/integrated by a central office at NASA Ames Research Center

CAN 6 TEAMS (start Jan. 1, 2013)

- Massachusetts Institute of Technology
- University of Illinois at Urbana-Champaign
- University of Southern California
- University of Wisconsin
- VPL at University of Washington

CAN 7 TEAMS (start Jan. 1, 2015)

- NASA Goddard Space Flight Center
- NASA Ames Research Center
- NASA Jet Propulsion Laboratory
- SETI Institute
- University of Colorado in Boulder
- University of California, Riverside
- University of Montana in Missoula



Synergy Research Themes of the NAI

Serpentinizing Systems

(Univ. of Colorado, USC, SETI Inst., JPL, U.C.-Riverside, Univ. of Montana, Univ. of Wisconsin, Univ. of Illinois)

Habitable Planetary States, the Evolution of Microbial Life, and their Astronomical Biosignatures

(U.C.-Riverside, Univ. of Montana, Univ. of Washington, Univ. of Wisconsin, MIT, SETI Inst., JPL, Univ. of Colorado, USC)

Planetary Inventory of Organics and Water, and the Origin of Life

(GSFC, U.C.-Riverside, MIT, Univ. of Illinois, NASA Ames)

Environmental Change and Biosignatures

(SETI Inst., Univ. of Wisconsin, Univ. of Colorado, USC, U.C.-Riverside, MIT, others)

GeoBioCell Applications

(Univ. of Illinois, Univ. of Montana, USC, Univ. of Wisconsin, JPL, Univ. of Colorado, U.C.-Riverside, GSFC)

Evolution of Complex Life

(Univ. of Montana, MIT, SETI Inst., U.C.-Riverside, USC, Univ. of Colorado)



Synergy Themes

Serpentinizing Systems Science Working Group (SSSWG)

(Univ. of Colorado, USC, SETI Inst., JPL, U.C.-Riverside, Univ. of Montana,
Univ. of Wisconsin, Univ. of Illinois)

- Group led by Alexis Templeton (U. Col.) and Ken Nealson (USC)
- Objectives are: 1) expand activities that directly relate to the identification, interpretation and astrobiological significance of serpentinizing systems, and (2) to create pathways for broad scientific engagement in SSS within the Astrobiology community
- Charter to be presented and discussed next week at in-person NAI EC meeting
- Group held organizational meeting during AbSciCon 2015 (42 attendees)
- Plans for a field trip to one or more sites of active low-temperature serpentinization: likely targets include the Cedars, CA and/or California Coast Range Microbial Observatory
- Coordinating a 2-3 day SSS “Workshop Without Walls”



Synergy Themes

Habitable Planetary States, the Evolution of Microbial Life, and their Astronomical Biosignatures

(U.C.-Riverside, Univ. of Montana, Univ. of Washington, Univ. of Wisconsin, MIT, SETI Inst., JPL, Univ. of Colorado, USC)

- Tim Lyons provided an early Earth perspective (*Early Microbial Evolution and the Emergence of Complexity*) in Frank Rosenzweig's session "Astrobiology and Extremes" at the July Gordon Research Conference on Microbial Population Biology
- NAI members working in this theme area and NExSS* are co-organizing a WWW in February 2016 that will focus on interior/atmosphere interactions (as illuminated by Earth's environmental history) and false positive and false negative (remote-sensing) biosignatures

*(NExSS) *Nexus for Exoplanet System Science*



Synergy Themes

Planetary Inventory of Organics and Water, and the Origin of Life

(NASA Ames, NASA Goddard, Univ. of Illinois, U.C.-Riverside, MIT, others)

- Roger Summons (MIT), Scott Sandford (Ames), and Jason Dworkin (GSFC) were awarded support for a one-year postdoctoral fellowship from the Simons Collaboration on the Origins of Life (SCOL) of the Simons Foundation.
- Position now open: “MIT Postdoctoral Associate in Astrobiology, Earth, Atmospheric and Planetary Sciences (EAPS), to work on research that will focus on analytical studies of organic matter in astrochemical analog materials such as meteorites and ices in order to identify amphiphiles.”
- Roger Summons visited Scott Sandford’s lab (with Jason Dworkin on phone) at Ames to discuss postdoc and begin design of initial experiments.



Synergy Themes

Rapid Environmental Change and Detection of Biosignatures

(SETI Inst., Univ. of Wisconsin, Univ. of Colorado, USC, U.C.-Riverside, MIT, others)

- Science Working Group (SWG) proposal developed by Nathalie Cabrol and Isik Kanik was discussed at the April EC videocon
- Purpose of the SWG is to:
 - explore the impact of rapid environmental change on habitability potential, biosignature potential, and biosignature preservation on Mars and on the icy bodies of the Outer Solar System (OSS)
 - produce recommendations of direct relevance to missions, instruments and exploration strategies, and landing site selection activities for both the Mars and the OSS communities
- SWG charter to be further refined at upcoming in-person NAI EC meeting



Synergy Themes

GeoBioCell Applications

(Univ. of Illinois, Univ. of Montana, USC, Univ. of Wisconsin, JPL, Univ. of Colorado, U.C.-Riverside, NASA Goddard)

- The GeoBioCell is a microfluidics based synthetic ecology, which allows the experimenter delicate control over nutrient flow and gradients, while at the same time spatially partitioning microbes into demes where they can mix and interact.
- The goal of these carefully controlled experiments is to quantify how environmental interactions can drive genome instability and evolution in populations, on laboratory time scales.

Evolution of Complex Life

(Univ. of Montana, MIT, SETI Inst., U.C.-Riverside, USC, Univ. of Colorado)

- Multiple projects centered around the unifying theme: how do cooperative vs. competitive interactions play out in driving major transitions that occur when independently replicating entities combine into a larger, more complex whole?
- Initial project seeks to identify and understand pressures that select specifically for more efficient extracellular electron transfer processes involved in solid-phase mineral oxidation. These studies could provide new insight into how variation in substrate availability (i.e., a selective pressure) might drive physiological diversification to maximize the potential for



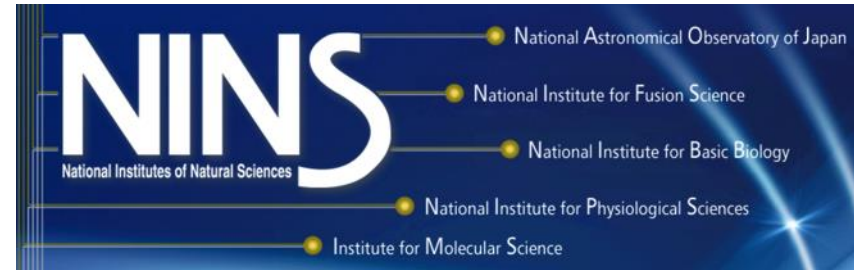
2015 NAI Director's Discretionary Fund (DDF)

- \$250K available for this internal opportunity, ~ 5-10 awards
- Priority in selection will be given to proposals that are characterized by one or both of the following programmatic considerations:
 - Integrates the research of, and realizes synergies among, the current NAI teams (Synergy Themes),
 - Enhances collaborations with NAI's international partners
- The Lead Investigator for a proposal must be affiliated with a current NAI team, but the proposing group can include collaborators from outside the NAI
- Due Date: October 31, 2015

See: astrobiology.nasa.gov/nai/funding/



New International Partner: Japan AstroBiology Consortium (JABC)



- The National Institutes of Natural Sciences (NINS) and the Earth-Life Science Institute (ELSI) have joined to establish the Japan AstroBiology Consortium (JABC)
- The mission of the JABC is to develop the field of astrobiology, to support a community of astrobiology researchers (especially young investigators), and to be a hub for international relationships
- The President of NINS, Dr. Katsuhiko Sato will serve as the first President of the JABC, and ELSI will be the secretarial organization of the JABC
- NINS has also established a new institute, the Astrobiology Center (ABC), dedicated to the study and development of astrobiology.

See: astrobiology.nasa.gov/nai/international-partners/

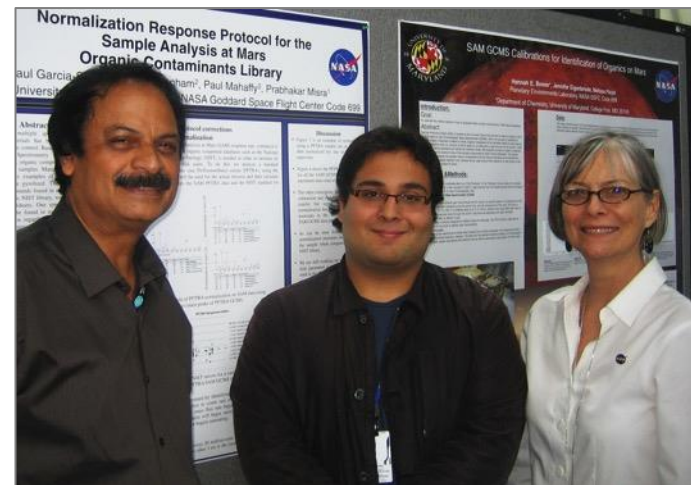
Minority Institution Research Support Program (MIRS)

2015 MIRS Fellows

Dr. Yassin Jeilani, Spelman College

Host: Michael Callahan, NASA Goddard Space Flight Center,

“Formamide Chemistry under Drying Lagoon Conditions”



Dr. Erik Melchiorre, California State University, San Bernardino

Host: Dr. Timothy Lyons, University of California, Riverside,

“Planetary Habitability and the Origins of Life: Evaluating Mineralogical Evidence for Extremophile Habitability Within Serpentinizing Environments of Early Earth”



NASA Astrobiology Postdoctoral Program Fellows

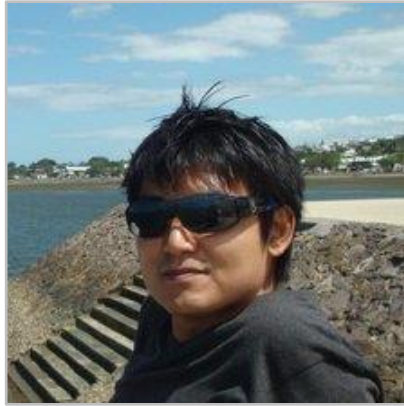
March 2015



Ashleigh Hood

Advisor: Noah Planavsky
(NAI UCR Team/Yale)

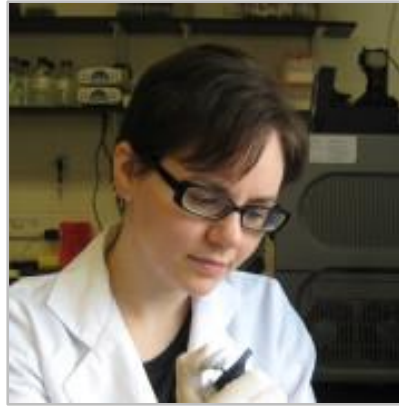
Topic: *"Integrated geochemical-
petrographic insights
on Earth's oxygenation
from Precambrian
carbonates"*



Nagayasu Nakanishi

Advisor: Mark Martindale
(Exobiology, U of Florida)

Topic: *"Investigating the
early evolution of
neuronal signaling
mechanisms in animals"*



Stephanie Weldon

Advisor: John
McCutcheon (NAI U of
Montana Team)

Topic: *"Swapping
partners mid-dance:
Symbiotic replacement
in a tightly integrated
intrabacterial,
intracellular nested
mutualism"*



Kristin Woycheese

Advisor: Shuhei Ono
(NAI CU-Boulder
Team/MIT)

Topic: *"Methane and
sulfur isotope
biogeochemistry of
terrestrial
serpentinizing fluid
seeps in the
Zambales ophiolite
complex"*

**Program will be managed by USRA in early 2016*

NPP Fellows at AbSciCon 2015



NASA/Library of Congress Blumberg Astrobiology Chair (2015-2016)



Nathaniel Comfort

*The History of Medicine Department,
Johns Hopkins University*

Title of proposed research:

The Origins of Life in the Genome Age

"As the Blumberg Chair of Astrobiology, I would research and write the history of the genomic revolution in origin-of-life research, and nucleate interdisciplinary scholarly conversations about the investigation of and reflection on life's origins."

5 interlocking thematic foci:

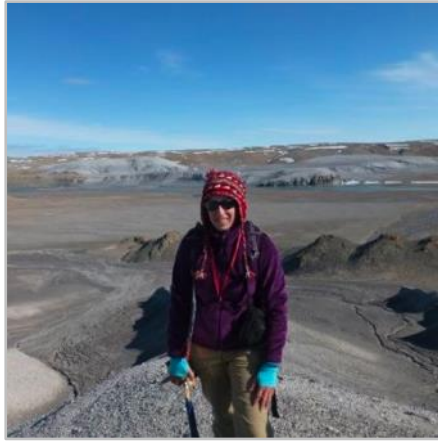
- The history of RNA world research (1965-2000)
- The origins of DNA and its relation to the origin of life (1965-2000)
- How comparative genomics shaped origins-of-life research (~1988-2010)
- The relationship of the origins of life to synthetic biology (~1964-present)
- Genomic contributions to the science of "universal life"

Lewis & Clark Fund for Exploration and Field Research in Astrobiology--Award Recipients 2015



Holly Farris
U Arkansas,
Fayetteville

Field Trip to explore survivability of halophiles through deliquescence in the Atacama Desert, Chile



Rebecca Greenberger
Brown University

Will travel to the Semail Ophiolite, Oman to map mineralogies at seeps as an analog for serpentine and carbonate-bearing rocks on Mars.

Now: Postdoctoral Fellow,
Jet Propulsion Laboratory



Leanne Hancock
UC Riverside

Examined methane cycling in borderland basins and proximity controls along the California coast.



George Kasun
Portland State University

Examined recombination between RNA and DNA viruses in an acidic hot spring at Lassen Volcanic National Park.

Partnership between American Philosophical Society and NAI

Provides small grants (up to \$5K) to graduate students, postdocs, and early career scientists for astrobiology field research around the world

Profile of Early Career Collaboration Award Recipients (2015)



**Joshua
Krissansen-Totton**
U Washington

Travelled to GSFC, presented a seminar on atmospheric disequilibrium biosignatures to Harley Thronson's ATLAST study team, collaborated with Shawn Domagal-Goldman on a paper on exoplanet photometry and met with others to discuss modeling atmospheric composition.



Kira Lorber
University of Cincinnati

Travelling to the NASA Jet Propulsion Laboratory, Pasadena, CA to work with Dr. Kenneth Williford learning sample preparation and processing Carbon isotope analyses at the Astrobiogeochemistry Laboratory, and to the University of Wisconsin- Madison to conduct carbon isotope analyses at the Secondary Ion Mass Spectrometer (SIMS) laboratory with Dr. John Valley.



Jeff Ousterhout
University of Cincinnati



Peter Ilhardt
Pennsylvania State U

Travelled to work with Dr. James Moran at the Pacific Northwest National Laboratory, in Richland, WA to utilize a recently-developed instrument, Laser Ablation Isotope Ratio Mass Spectrometry (LA-IRMS) for $\delta^{13}\text{C}$ measurements of solid samples at micrometer-scale spatial resolution.

Astrobiology Research Focus Group (RFG)

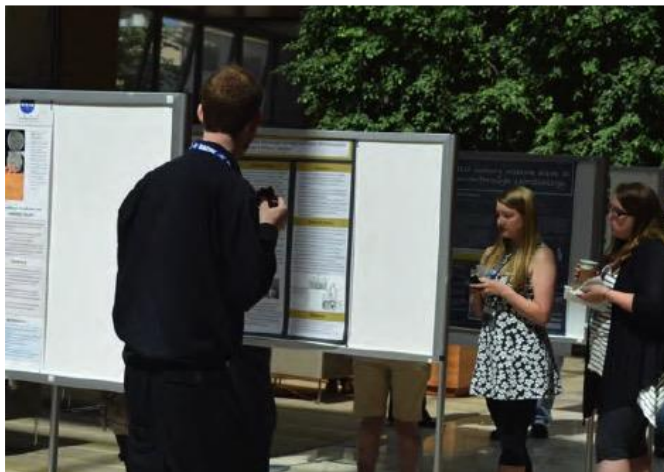
Astrobiology Graduate Conference (AbGradCon)

7th Annual AB RFG

- July 17-19, Kemp Natural Resources Station, Woodruff, WI
- Professional Development and Grant Writing Workshop, winning proposal, “Development of a Solid Phase Sorbent Material for a Methane Recovery Filter”
- 4 organizers, 10 participants

12th Annual AbGradCon

- July 19-23, University of Wisconsin, Madison, WI
- 55 participants from 27 institutions. 37 oral presentations, 22 poster presentations
- Education Public Outreach Night and Field Trip to Devil’s Lake



2015 Josep Comas i Sola International Summer School: “The Origin of Life: From Monomers to Cells”



40 students, 14 from the US



K-T Boundary Observation

June 29 – July 3, 2015

School Directors

Dr. Javier Gómez-Elvira (Centro de Astrobiología) **Prof. Victoria Meadows** (Univ. Washington)

Lecturers:

Dr. George Cody (Carnegie Inst. of

Video recordings and pdfs at
http://www.cab.inta-csic.es/en/multimedia/lista_videos/24

2016 topic: Analog Environments



International Astrobiology Summer Schools

Nordic/Hawaii Summer School

“Water, Ice and the Origin of Life in the Universe”

- Held in Iceland July 1–14, 2015
- Introduction to the role of water in the evolution of life in the cosmos
- 38 participants from 14 countries
- Lecturers included:
 - Dr. John Baross, Univ of Wash.
 - Dr. Jim Cleaves, Carnegie Inst. for Sci.
 - Dr. David DesMarais, NASA ARC
 - Dr. Wolf Geppert, Stockholm Univ
 - Dr. Karen Meech, Univ of Hawai’i
- Topics included:
 - investigation of colonization of volcanic rocks and glaciers with *in situ* life detection techniques
 - excursions to geologically and biologically interesting sites (lava caves, new lava fields)
 - 2 poster sessions for students and early career scientists



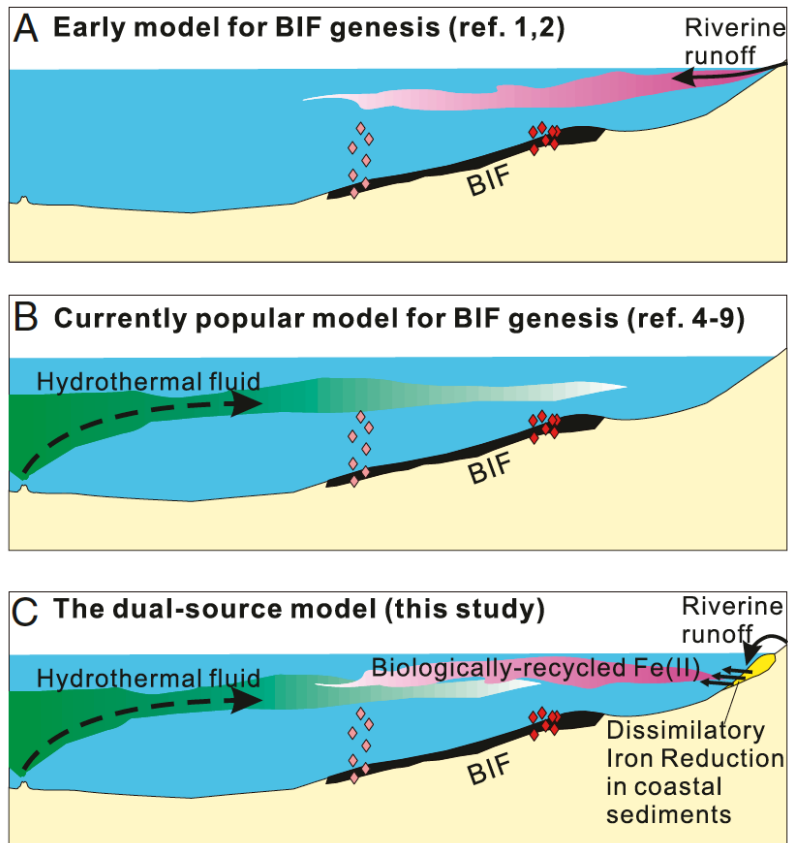
The top of the slide features a space-themed background. On the left, there is a colorful nebula with shades of blue, purple, and orange. To the right, a large, orange, cratered planet, resembling Mars, is partially visible. The title 'Director Search' is centered over this background in a white, sans-serif font.

Director Search

- Review of the written applications has been completed.
- The review committee identified highly qualified candidates.
- Interviews with those candidates will occur in the near future.

Recent Publications

Biologically Recycled Continental Iron is a Major Component In Banded Iron Formations*



- Combined Fe- and radiogenic Nd-isotope signatures suggest that BIFs contain a major component of continentally derived iron that was mobilized by microbial iron reduction.
- This Fe source is in addition to submarine hydrothermal sources.
- The two Fe sources may be comparable, although their proportions change on 10^5 - 10^6 -year timescales, suggesting control by marine basin circulation.
- These results provide confirmation that the Precambrian oceans were dynamic.

*Weiqiang Li, Brian L. Beard, and Clark M. Johnson (2015) PNAS **112**:8193–8198.



Back-up Slides

CAN 7: University of Colorado

Rock-Powered Life: Revealing Mechanisms of Energy Flow from the Lithosphere to the Biosphere

PI is Alexis Templeton

How do the mechanisms of low temperature water/rock reactions control the distribution, activity, and biochemistry of life in rock-hosted systems?



Photo credit: Hannah Miller

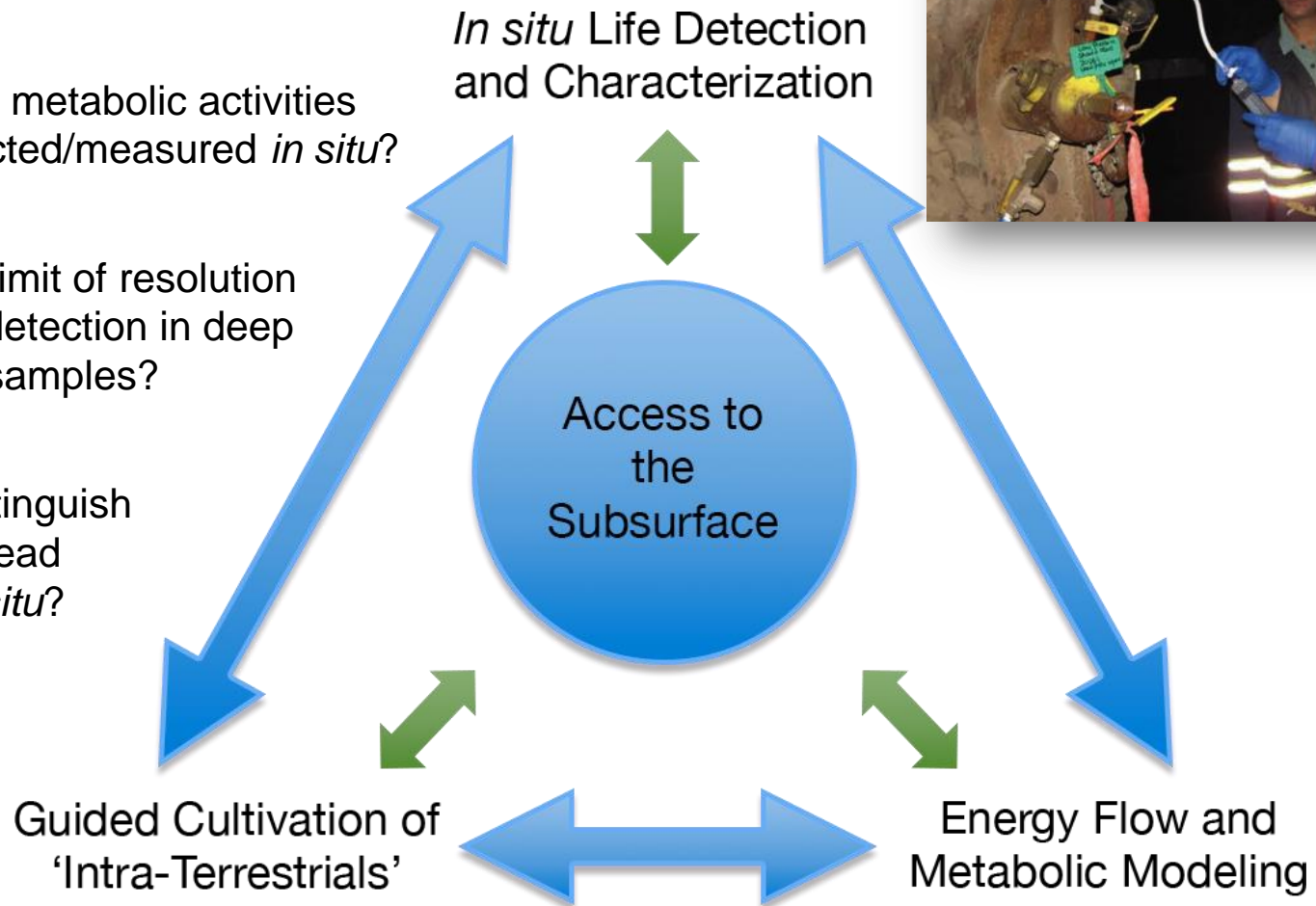
- Defining the pathways that control how energy is released from ultramafic rocks as they react with low-temperature fluids,
- Identifying and interpreting the process rates and ecology in systems undergoing water/rock reactions,
- Quantifying the geochemical and mineralogical progression of water/rock reactions in the presence and absence of biology,
- Characterizing microbial communities within rock-hosted ecosystems and evaluating their metabolic activities,
- Developing and testing predictive models of biological habitability during water/rock interaction.

CAN 6: University of Southern California

Life Underground

PI is Jan Amend

- What spectral/optical signals indicate the presence of biomass?
- What kind of metabolic activities can be detected/measured *in situ*?
- What is the limit of resolution of biomass detection in deep subsurface samples?
- Can one distinguish living from dead biomass *in situ*?

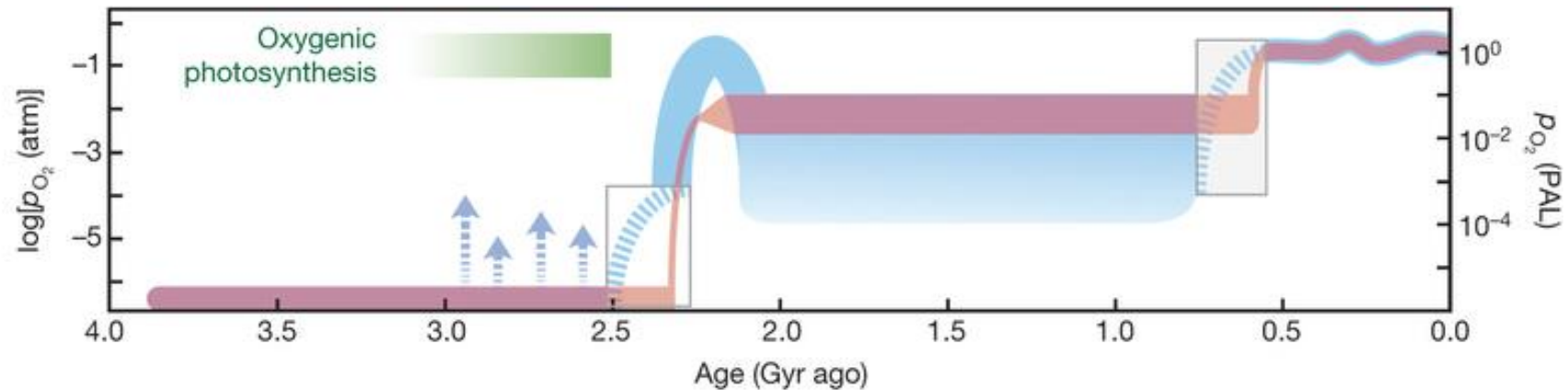


CAN 7: University of California, Riverside

Alternative Earths: Explaining Persistent Inhabitation on a Dynamic Early Earth

PI is Timothy Lyons

How has Earth remained persistently inhabited through most of its dynamic history, and how do those varying states of inhabitation manifest in the atmosphere?



Alternative Earth 1	Resolve when oxygenic photosynthesis first left traces in Earth's atmosphere and whether (and, if so, why) there was a lag between oxygen's first biological production and its persistent accumulation.
Alternative Earth 2	Determine whether Earth's surface underwent a unidirectional oxygen rise—as typically envisioned—or whether (and why) this early history was characterized by a series of rises and falls.
Alternative Earth 3	Determine whether surface oxygen concentrations maintained sufficiently low levels, for perhaps a billion years of Earth's history, to play a direct role in when animals first hit the scene and diversified.

CAN 6: University of Wisconsin

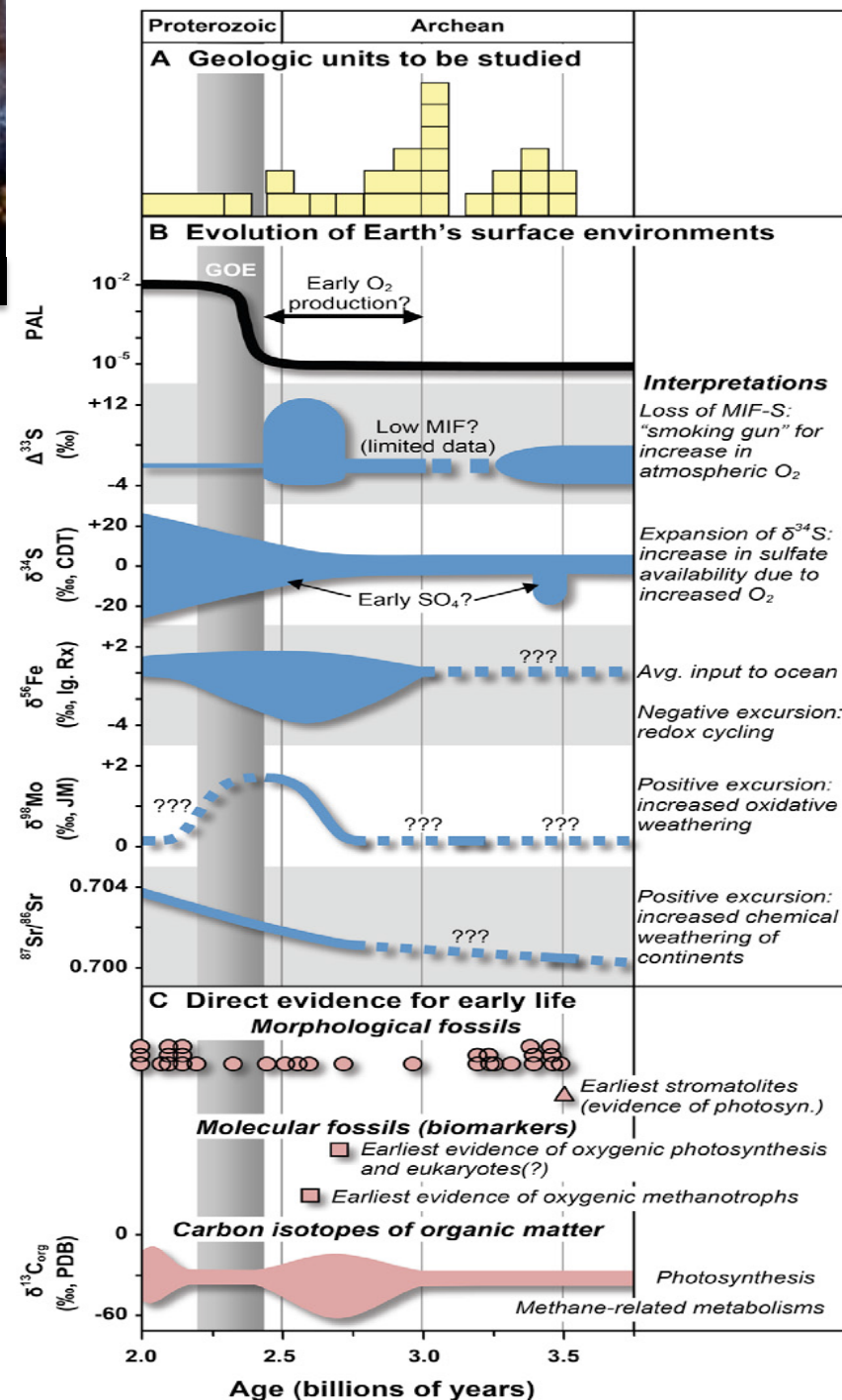
Habitability, Life Detection, and the Signatures
of Life on the Terrestrial Planets

PI is Clark Johnson

. . to develop, using Mars analog environments, new approaches for the detection of biomolecules, and increase our knowledge of biomolecule-rock substrate interactions

. . to develop a mechanistic understanding of the proxies that have been used to interpret ancient rocks and ancient microbial ecology – and to develop new proxies focusing on three mineral groups: clays, Fe-Si oxides, and carbonates

. . to use the ancient rock record on Earth, largely using isotopic tracers, to understand the co-evolution of the environment and a diverse range of microbial metabolisms – providing an essential interpretive context for studies of ancient rocks on Mars



CAN 7: The SETI Institute

Changing Planetary Environments & the Fingerprints of Life


PI is Nathalie Cabrol

The Signatures of Habitability:
Mars Ancient Mineral Record and
Terrestrial Aerial Imagery

**Taphonomic Windows &
Biosignature Preservation:**
Earth Analogs

**Environmental Control on the
Survival & Preservation
Potential of Organic Molecules**

**Adaptive Detection of
Biosignatures:** Applying Data
Fusion, Novelty Detection, and
Autonomous Detection of
Biogenicity



Develop a roadmap to biosignature
exploration in support of NASA's decadal
plan for the search for life on Mars

**“How do we identify and cache
the most valuable samples?”**

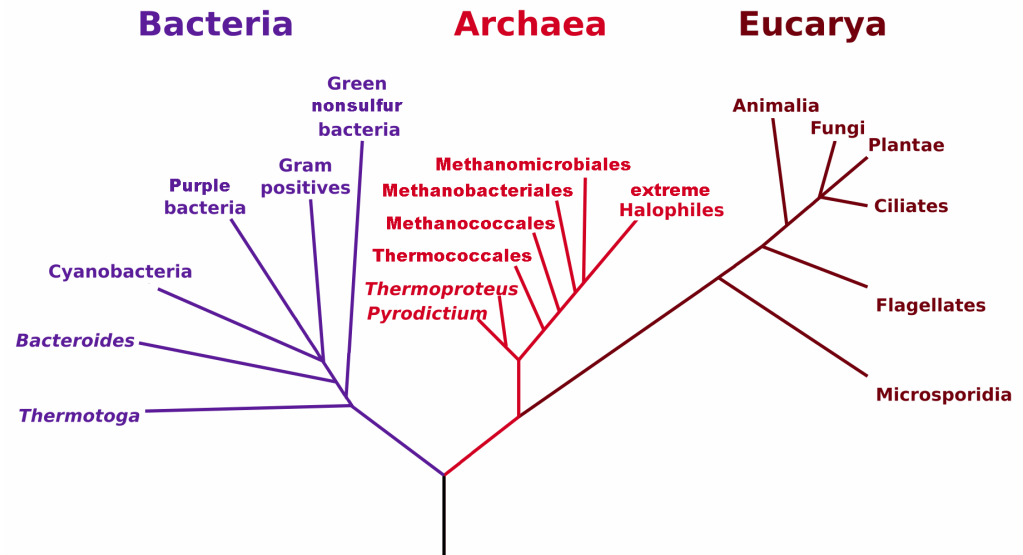
CAN 6: University of Illinois

Towards Universal Biology: Constraints from Early and Continuing Evolutionary Dynamics of Life on Earth

PI is Nigel Goldenfield

- Study the general physical principles underlying the emergence of life – a mathematical basis for the emergence of evolvable dynamical processes
- Investigate Life before the Last Universal Common Ancestor (LUCA) – the “progenote”, a hypothetical communal state of gene sharing that preceded cellular life, using detailed and sophisticated analyses of core translational machinery
- Examine how environmental conditions affect the speed with which evolutionary adaptation takes place, i.e., how the ability to evolve itself evolves

Phylogenetic Tree of Life



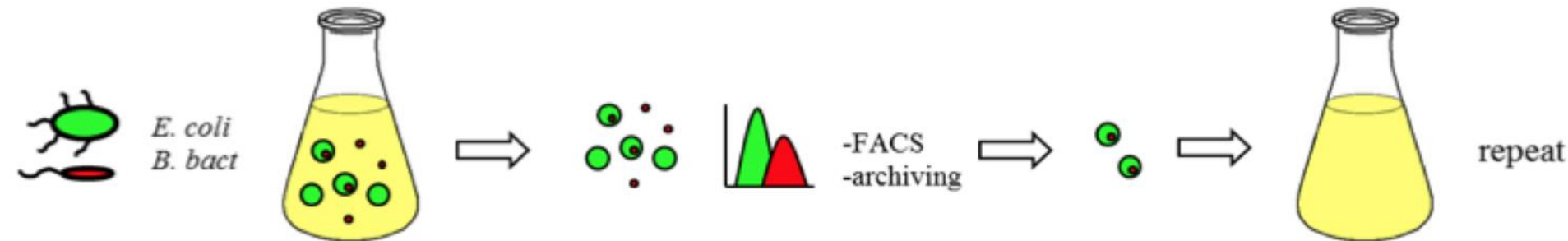
- Understand the emergence of cellular machinery following the progenote state – focusing on mining Archaeal genomes, searching for the ancestors at the root of the Eukarya-Archaeal branching and determining how genomes became more stable over evolutionary time

CAN 7: University of Montana

RELIVING THE PAST: Experimental Evolution of Major Transitions in the History of Life

PI is Frank Rosenzweig

What forces bring about major transitions in the evolution of biocomplexity?



Organized around five questions related to major transitions in the history of Life:

How do enzymes and metabolic networks evolve?

How did the eukaryotic cell come to be?

How do symbioses arise?

How does multicellularity evolve? and

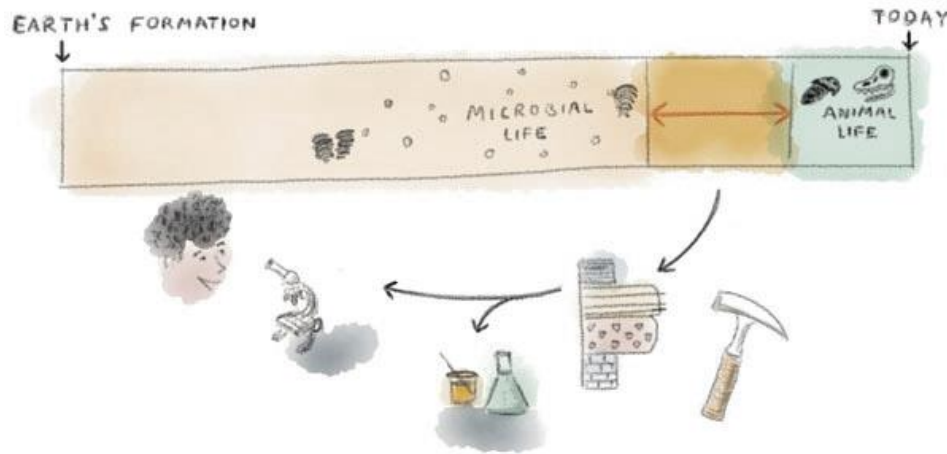
How do pleiotropy, epistasis and mutation rate constrain the evolution of novel traits?

A unifying theme underlying these questions is: how do cooperative vs. competitive interactions play out in driving major transitions that occur when independently replicating entities combine into a larger, more complex whole?

CAN 6: Massachusetts Institute of Technology

Foundations of Complex Life: Evolution, Preservation and Detection on Earth and Beyond

PI is Roger Summons



Questions to be addressed include:

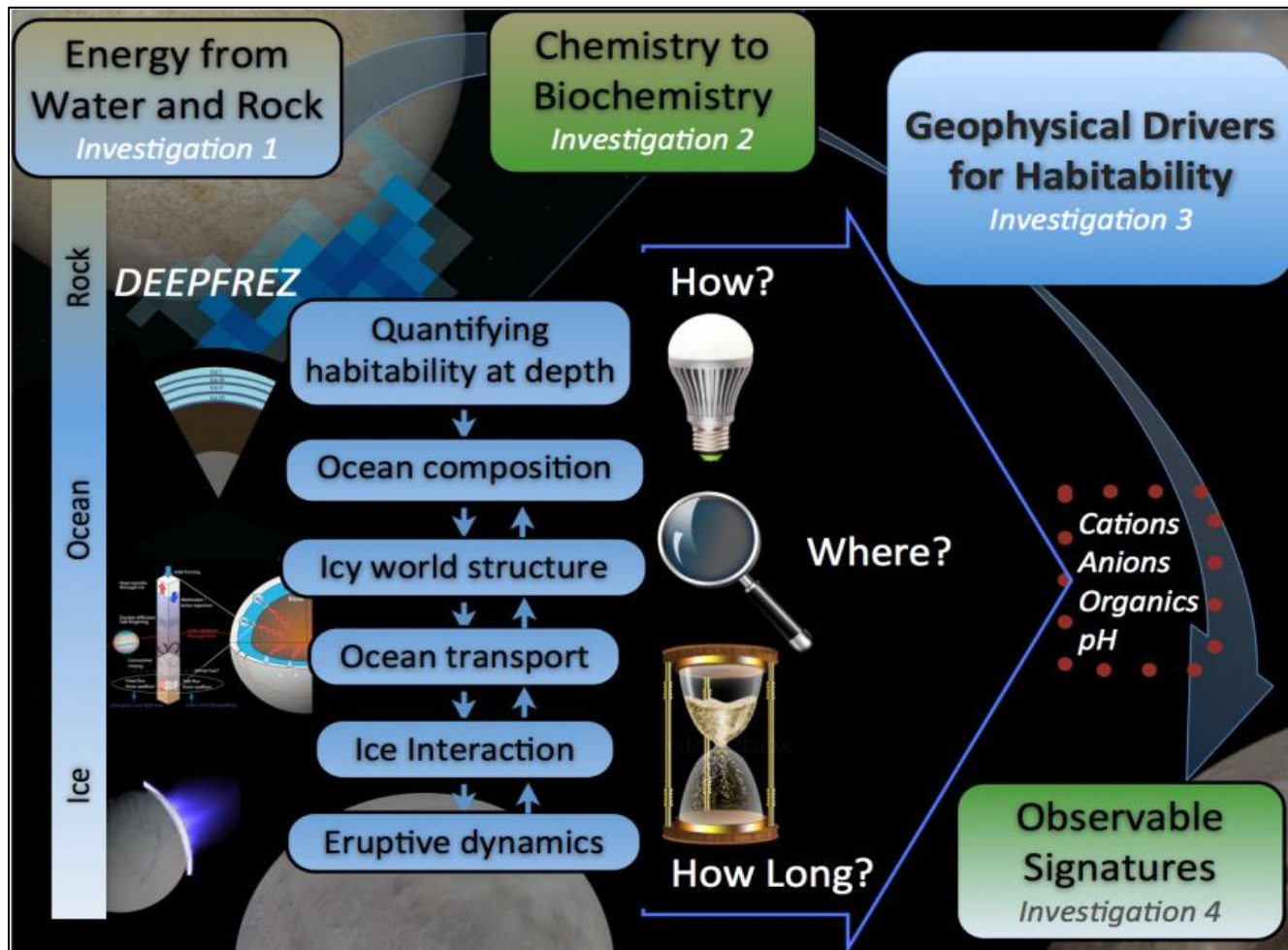
- What is the relationship between genomic and morphological complexity?
- What caused large Neoproterozoic (1000-542 million years ago) perturbations of the carbon cycle, and how do they relate to the emergence of biological complexity?
- What principles and mechanisms determine the preservation of organic matter and fossils, through time and in relation to ocean-atmosphere chemistry?
- What taphonomic insights drawn from these studies apply elsewhere, particularly Gale Crater on Mars?

CAN 7: Jet Propulsion Laboratory

Icy Worlds: Astrobiology at the Rock-Water Interface and Beyond

PI is Isik Kanik

How can geochemical disequilibria drive the emergence of metabolism and ultimately generate observable signatures on icy worlds?



CAN 6: University of Washington

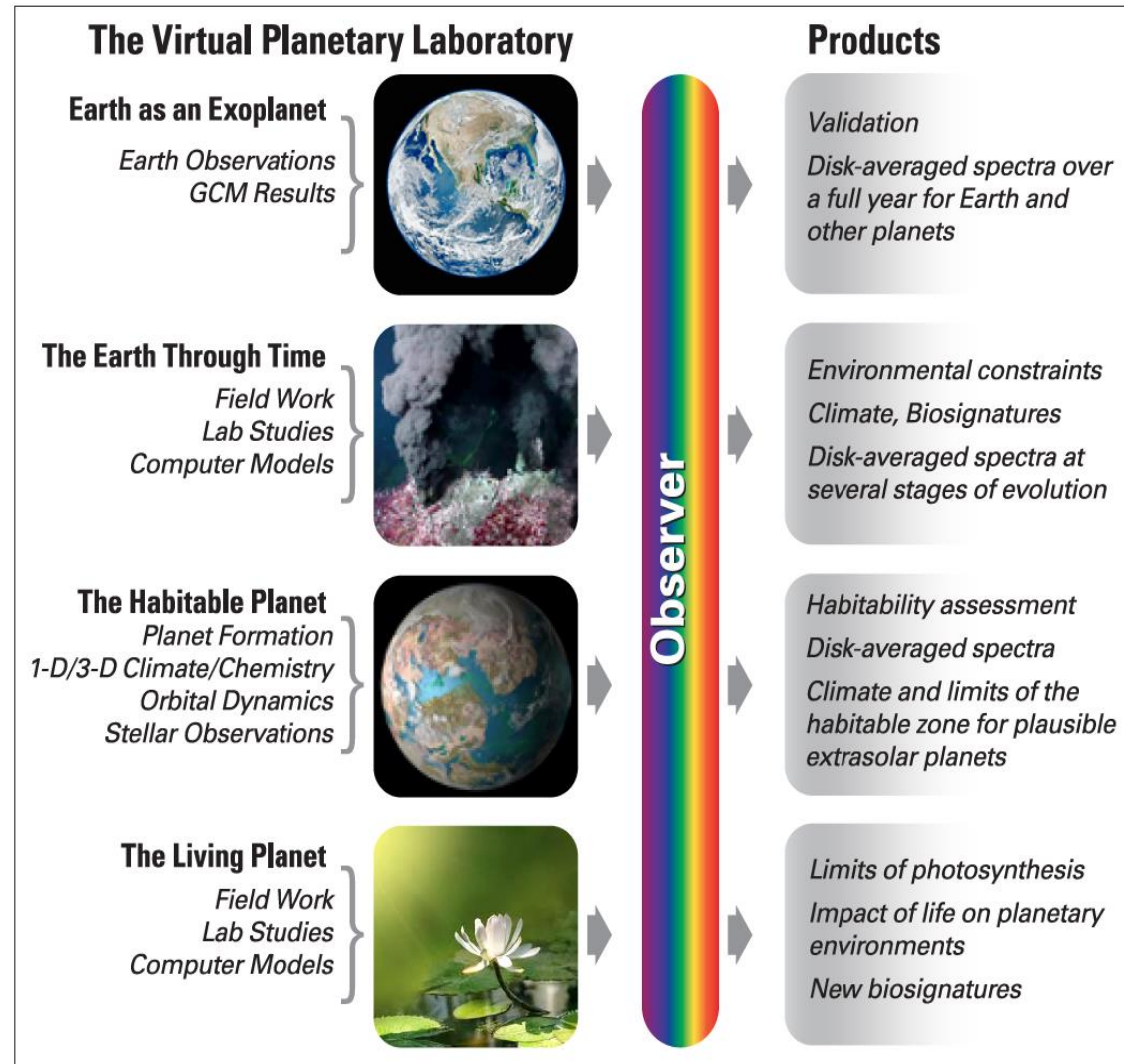
The Virtual Planetary Laboratory

PI is Victoria Meadows

.. to develop, refine and combine
1-D and 3-D climate,
photochemical, radiative transfer,
atmospheric escape, planetary
interior, biogeochemical,
biological productivity, vegetation,
orbital evolution and planet
formation models and,

.. as input to these models, to
obtain laboratory, field and
observational data from the
stellar, planetary and biological
sciences, and

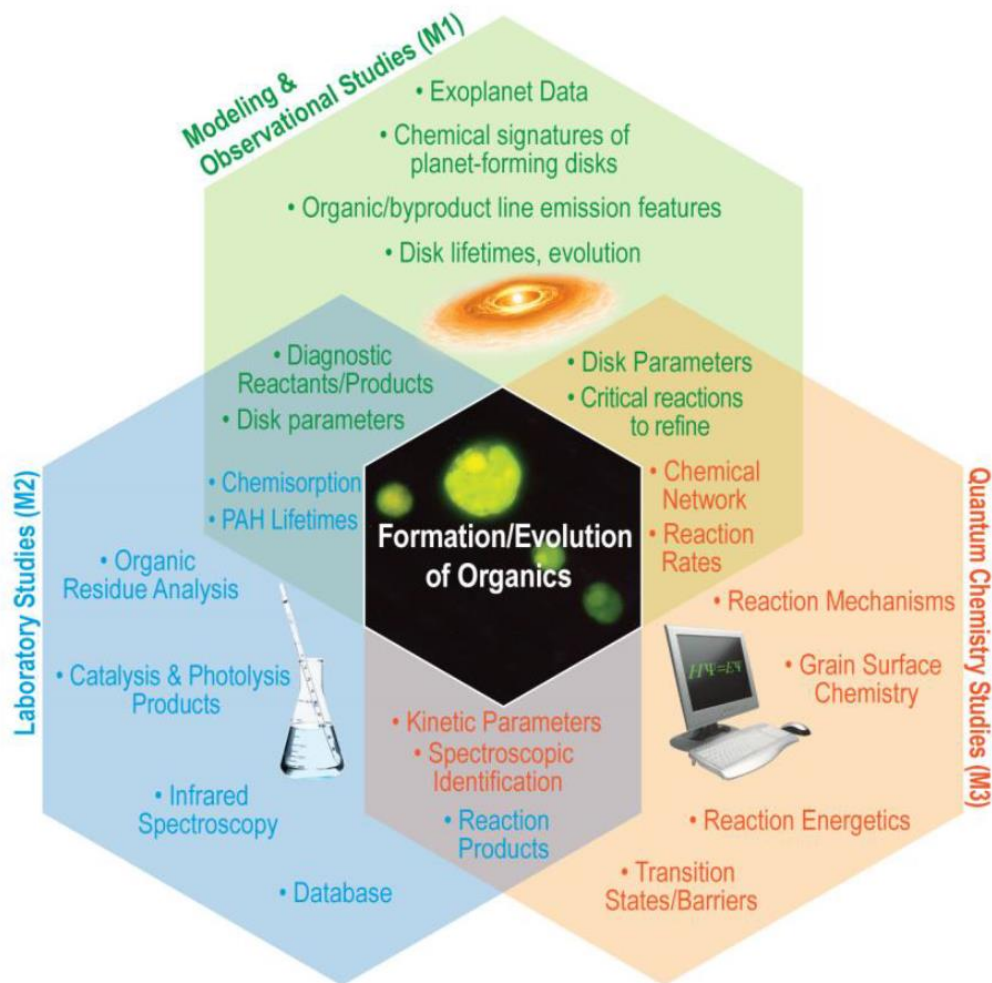
.. use these results to recognize
habitable worlds and to
discriminate between the spectra
of planets with and without life,
by understanding the signatures
of life in the context of their
planetary environment



CAN 7: NASA Ames Research Center

The Evolution of Prebiotic Chemical Complexity and the Organic Inventory of Protoplanetary Disks and Primordial Planets

PI is Scott Sandford



. . . to understand the chemical processes at every stage in the evolution of organic chemical complexity, from quiescent regions of dense molecular clouds, through all stages of cloud collapse, protostellar disk, and planet formation, and ultimately to the materials that rain down on planets - and to understand how these depend on environmental parameters like the ambient radiation field and the abundance of H₂O.

CAN 7: NASA Goddard Space Flight Center

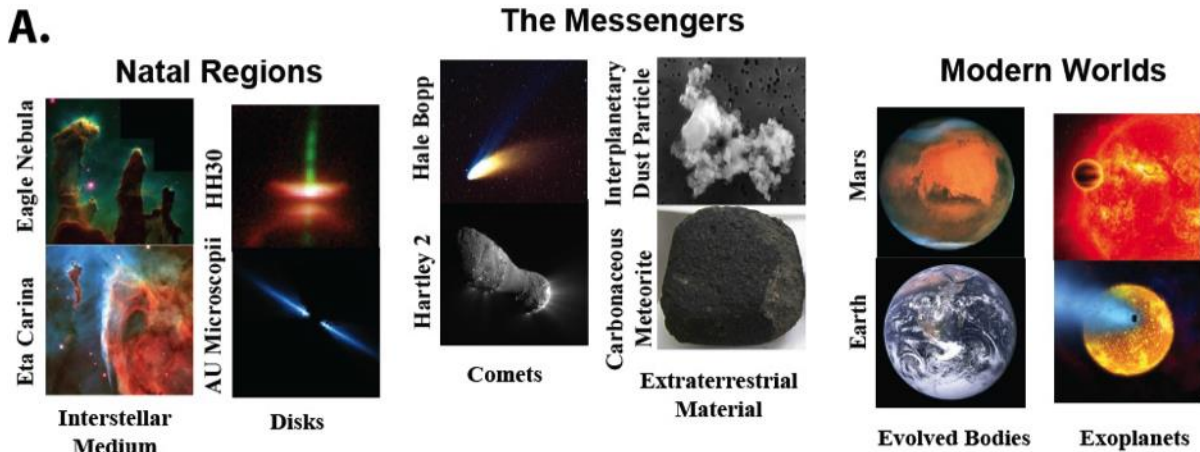
Origin and Evolution of Organics and Water in Planetary Systems

PI is Mike Mumma

Did delivery of exogenous organics and water enable the emergence and evolution of life? Why is Earth wet and alive?

- What material was delivered?
- How was prebiotic matter synthesized and processed?
- What dynamical mechanisms delivered these primitive bodies?
- Can we find evidence for habitability elsewhere in the present day Solar System?
- Develop instrument protocols for future *in situ* investigations.

A.



B. Searching the Skies

