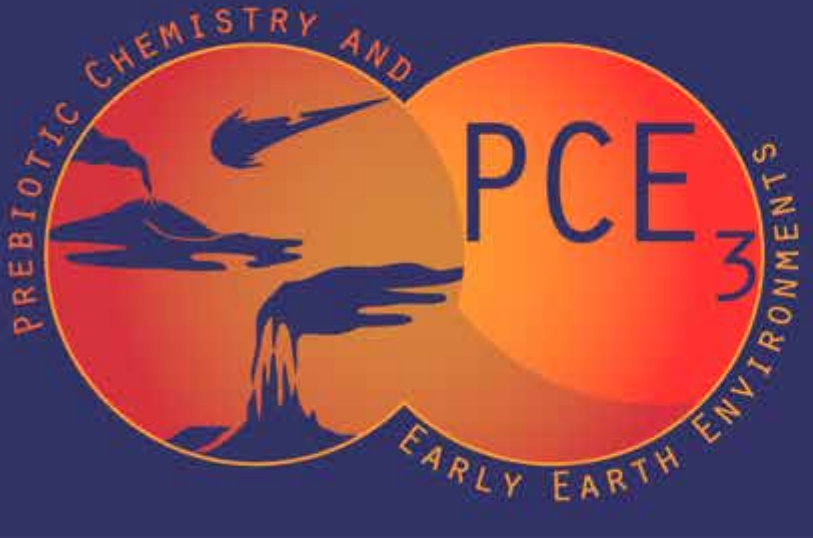
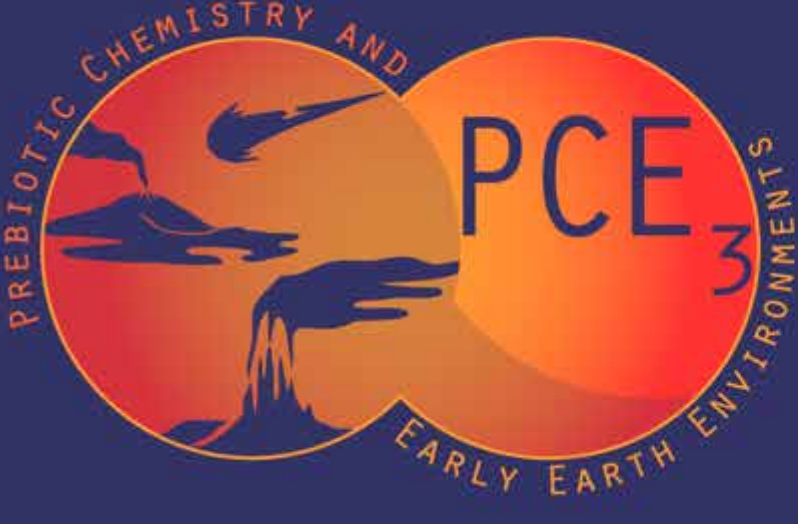
Prebiotic Chemistry & Early Earth Environments Consortium



Karyn L. Rogers
Ram Krishnamurthy
Timothy Lyons
Loren Williams



THE GOAL

Investigate the delivery, synthesis, and fate of small molecules under the conditions of the Early Earth and the subsequent formation of proto-biological molecules and pathways that lead to systems harboring the potential for life.

WHO WE ARE

Karyn L. Rogers

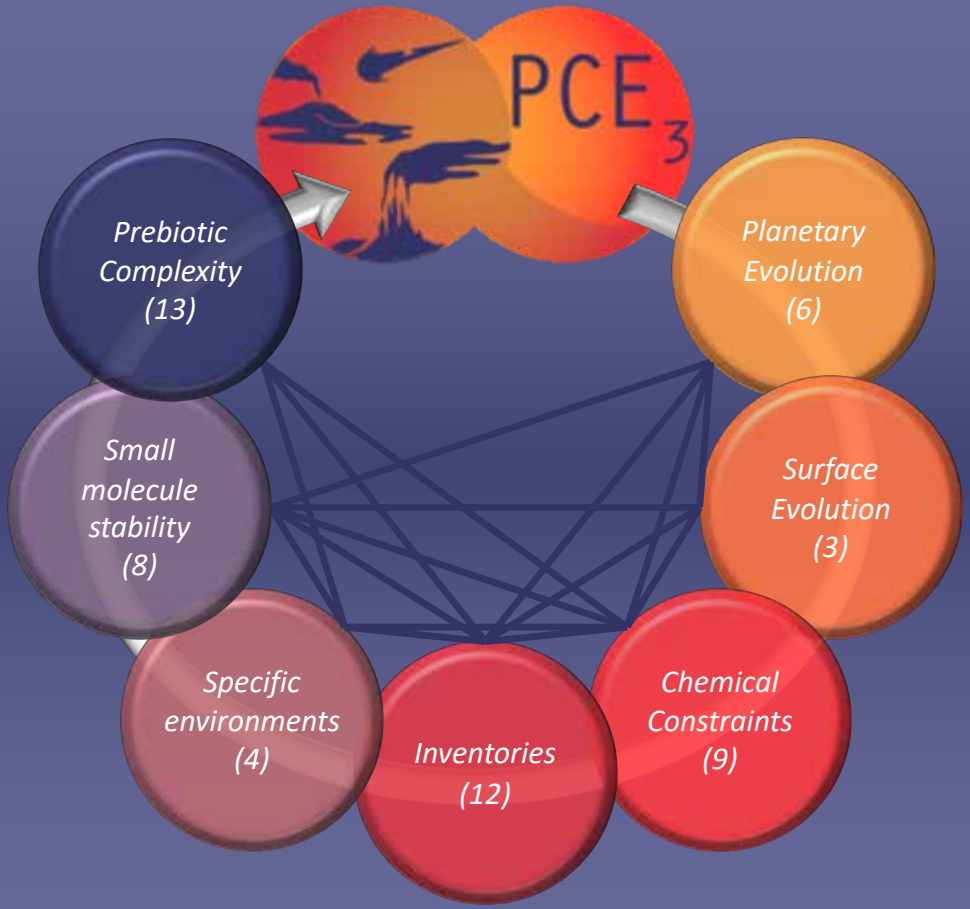
Ram Krishnamurthy

Tim Lyons

Loren Williams

STEERING COMMITTEE

Vladimir Airapetian
Ahmed Badran
Steven Benner
Roy Black
Dennis Bong
Donald Burke
Aaron Burton
George Cody
George Cooper
Rajdeep Dasgupta
Jason Dworkin
Jamie Elsila-Cook
Paul Falkowski
George Flynn
Robin Garrod
Eric Hayden
Marc Hirschmann
Nick Hud
Christine Keating
Roxana Lupu
James Lyons
Ulrich Muller
Matthew Pasek
Rick Remsing
Scott Sandford
Rachel Smith
Geronimo Villanueva
David Woon



WHAT WE DO

- Community Integration
- Transformative Collaboration
- Cross-disciplinary learning: language, uncertainties, communication
- Expanding cross-cutting research

OBJECTIVES

- Integrate the early Earth and prebiotic chemistry communities and break down disciplinary barriers that stymie the pursuit of plausible prebiotic chemistry pathways.
- Develop robust and fully-parameterized models of early Earth environments that can be explored both experimentally and theoretically for their potential to host prebiotic chemical pathways.
- Promote novel and innovative experimental and theoretical approaches to exploring the origins of life abiotic → prebiotic → biotic transition.
- Identify planetary conditions that can or cannot give rise to life's chemistry and thus inform the exploration for life throughout the universe.
- Characterize geochemical and geophysical constraints of early Earth environments that can be applied to test, verify, validate, and guide existing and future experimental and theoretical prebiotic chemistries.

PC

Precursors

- HCN
- Formamide
- Phosphate
- Acetate
- Thiols

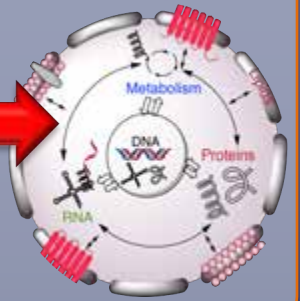
Monomers

- Amino acids
- Sugars
- Nucleobases
- Fatty Acids
- Metabolites

Polymers

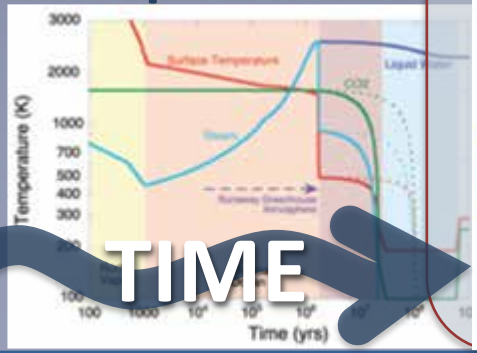
- Proteins
- DNA/RNA
- Carbohydrates
- Lipids
- Metabolisms

Life



E3

Atmospheric Evolution

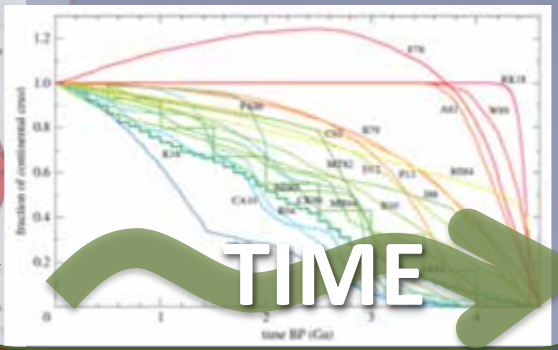


TIME

Impact History

TIME

Crustal Evolution



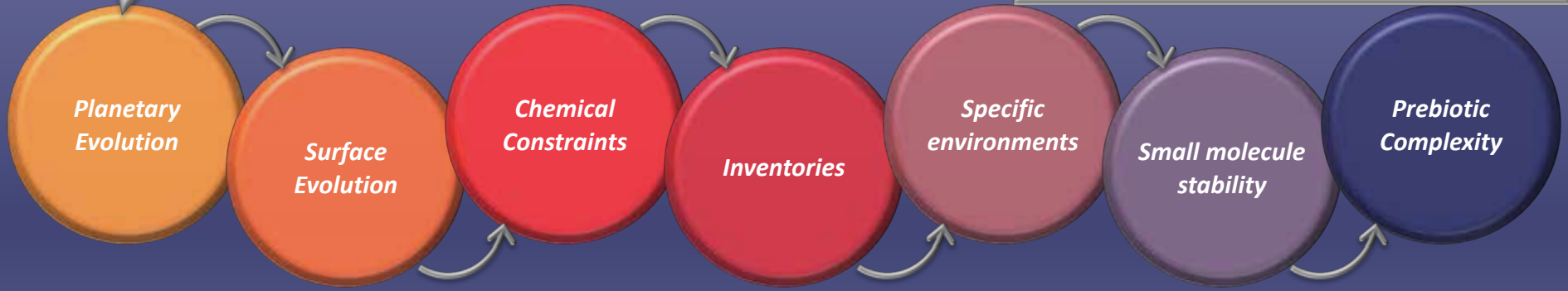
TIME

PC

E_3

Origin of Life Hypothesis:
Wet/dry cycles are necessary for proto-polymers, and water-based biochemistry to emerge.

Planetary Origin of Life Potential?



How/when did continents emerge?

Is only emergent land necessary?

Were there building blocks present?

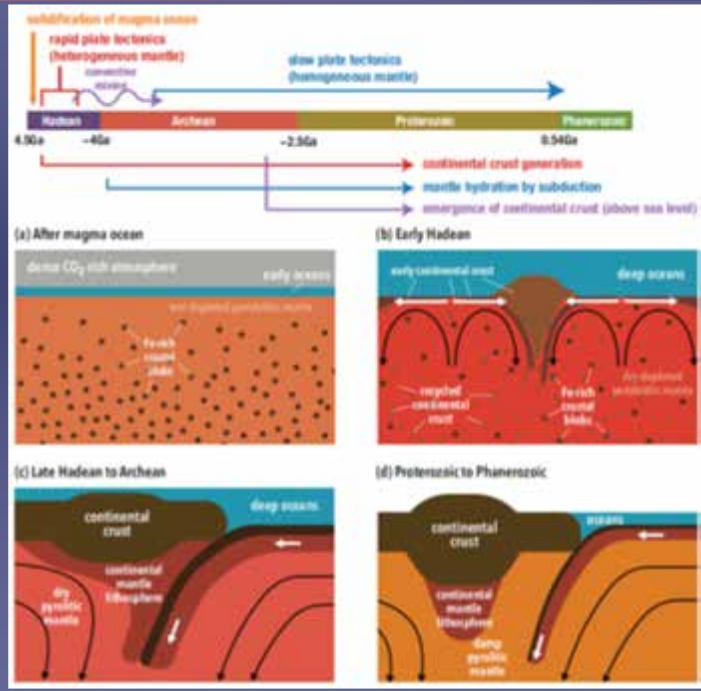
What are the environmental parameters?

What are the organic reactions?

What environmental and chemical dynamic lead to productive biochemistry?

Magma oceans & crustal evolution

- Early Hadean
  - Continental (felsic) crust exposed on the seafloor
  - “Fast” plate tectonics
  - Exposed peridotite on the seafloor hosts serpentinization
  - Peridotite weathering draws down CO_2
- Early Archean
  - Transition to homogeneous mantle and slower plate tectonics
  - Ocean volume decreases with subduction and dry land masses emerge



Korenaga, J, submitted 2020, Precambrian Research.

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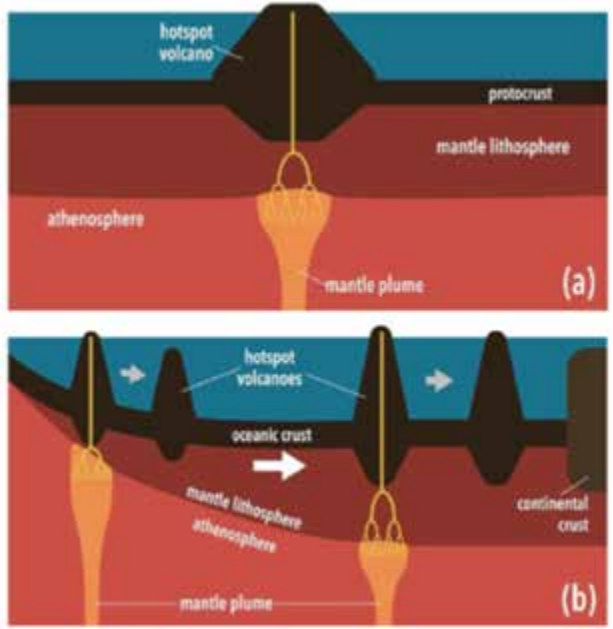
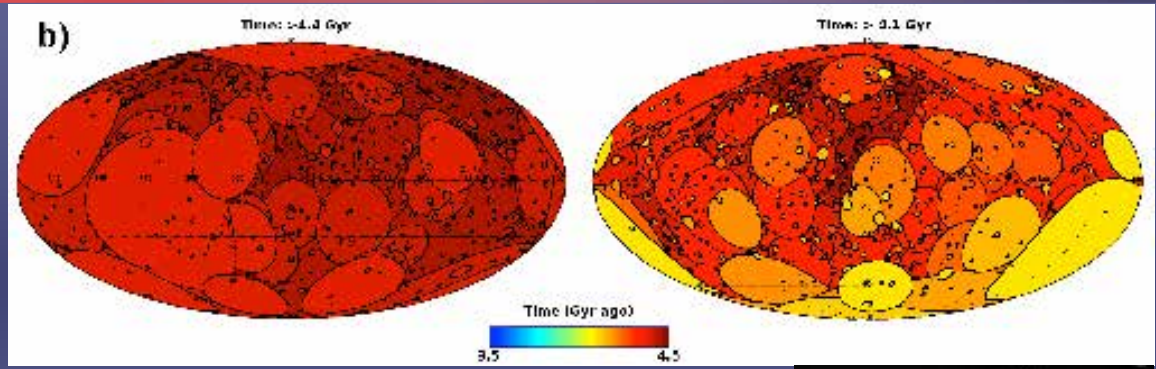
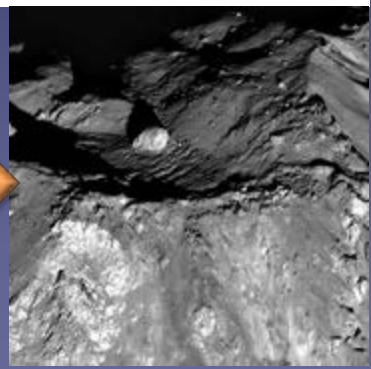
Exposed landmass?





Hotspot volcanic islands

Impact-generated topography



Bada & Korenaga, Life, 2018, 8,55.
Marchi et al., Nature, 2014, 511, 578.
LROC NAC M162350671L,R [NASA/GSFC/ASU].

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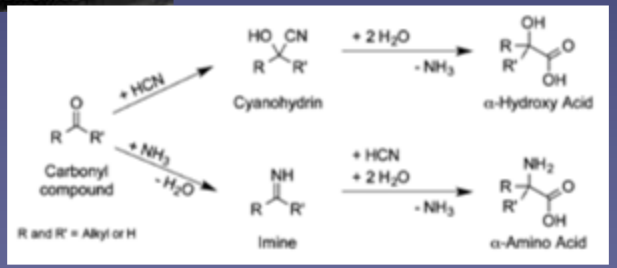
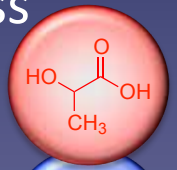
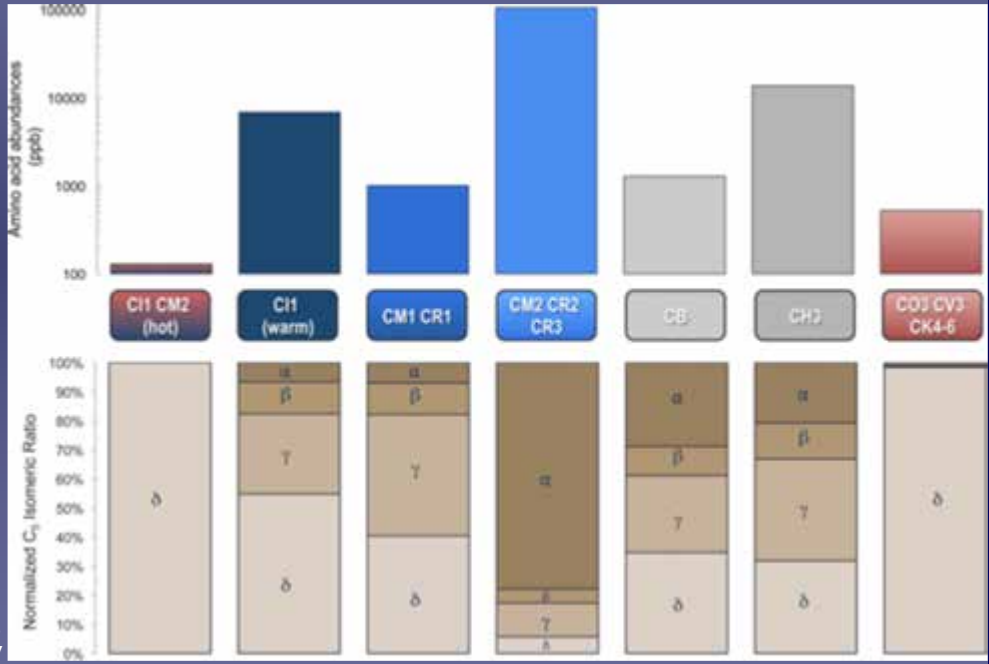
Delivery of building blocks?

- Ranges in abundance
- Diversity of isomers
- Variety of C_{org}
- Variable L-excess







Elsila, JE, Aponte, JC, Blackmond, DG, Burton, AS, Dworkin, JP, and Glavin, DP. ACS Cent. Sci. 2016, 2, 370−379

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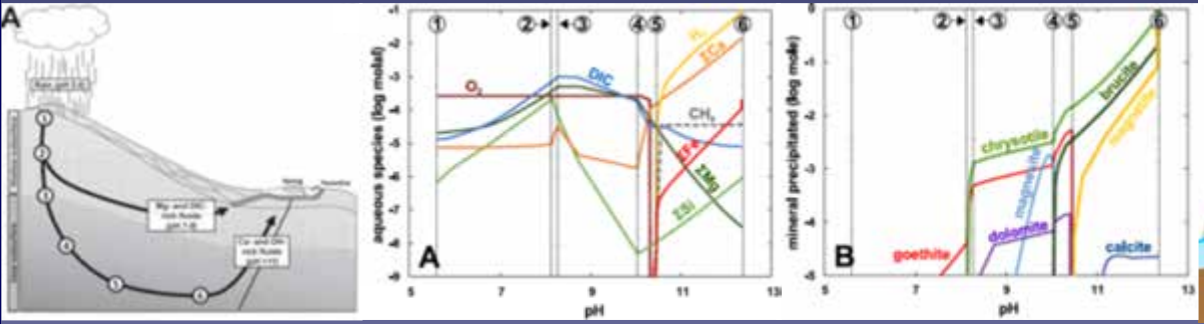
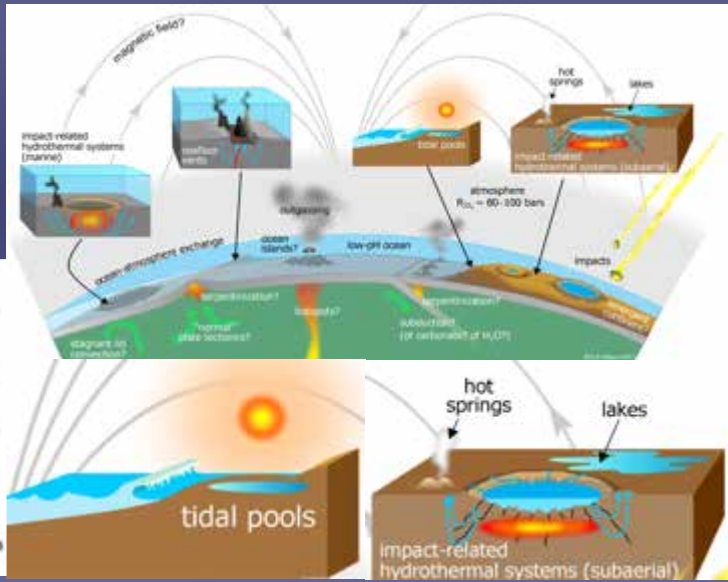
Local Environmental Context of Prebiotic Chemistry

- Fluid chemistry evolves during water:rock reactions
- Mineralogy, pH, redox co-vary and depend on physicochemical conditions





Leong & Shock, AJS, 2020, 320: 185

Images courtesy E. Bruce Watson

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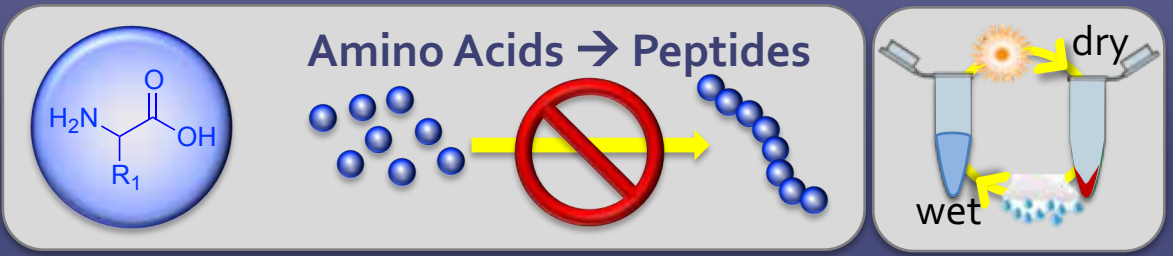
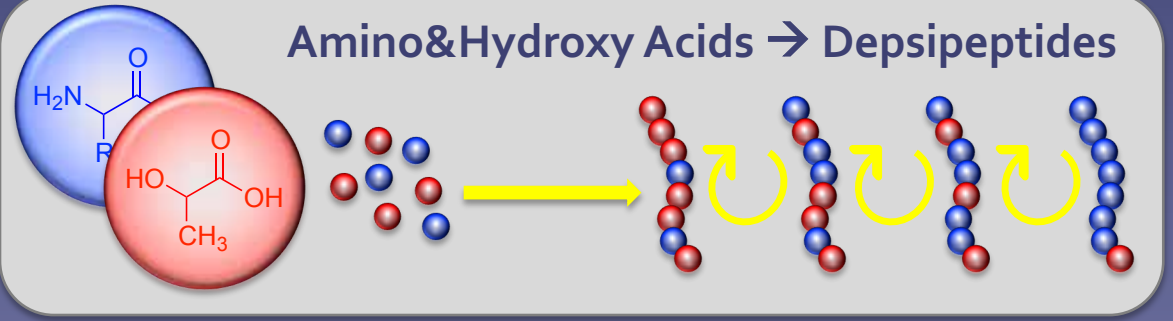
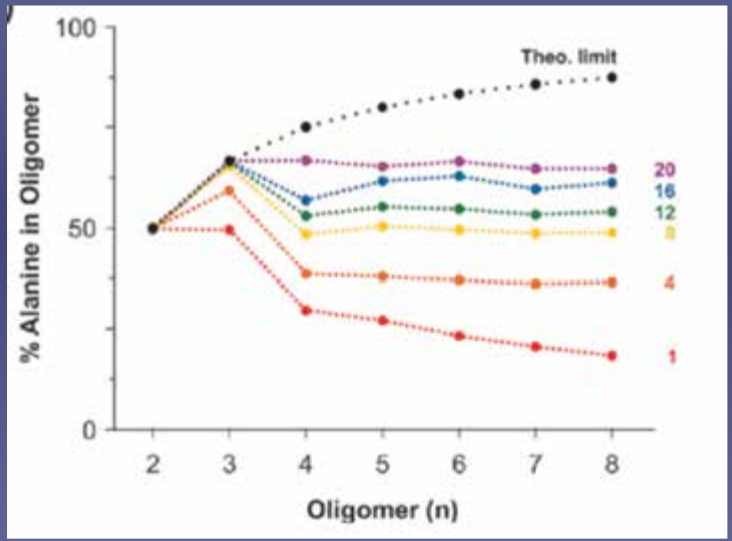
Making peptides via wet-dry cycles







Forsythe, J.G.; Yu, S-S.; et al. Angew. Chem. Int Ed. **2015,** 54, 9871-9875

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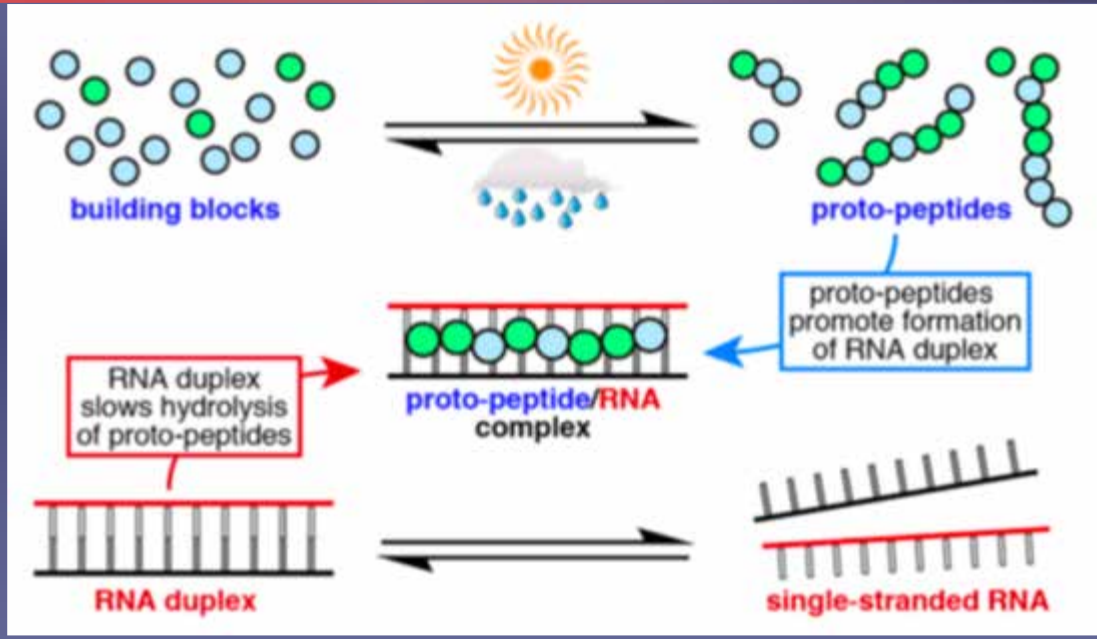
Chemical Mutualism

- Proto-peptides promote RNA thermal stability
- RNA slows proto-peptide hydrolysis
- Mutually-stabilizing interactions may imply a co-evolutionary pathway for proteins and nucleic acids



Frenkel-Pinter, M.; Hyanes, J. W.; Moheyeldin, A. M.; Martinc C, Sargon, A. B.; Petrov, A. S.; Krishnamurthy, R.; Hud, N.; Williams, L. D.; Leman, L.J.

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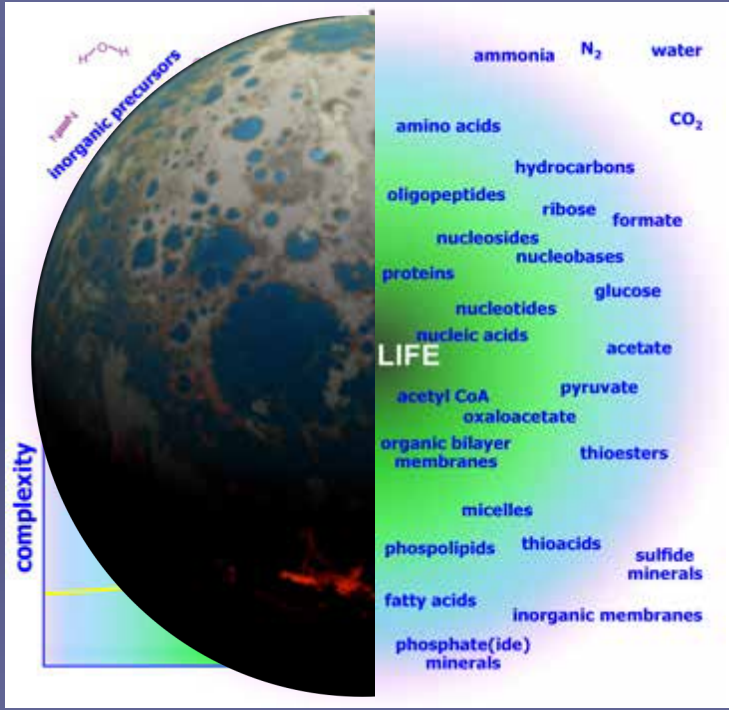
What Are We Missing?

What are the environmental parameters?

- Where is this evaporative pool?
- Hot spring, tidal, lake, spring, impacts?
- What is the local crustal mineralogy?
- Fluid chemistry
  - Marine or freshwater
  - Volcanic influence
  - Mineral interactions

https://www.liebertpub.com/doi/10.1089/ast.2019.2045

Planetary Pathways to Life



National Aeronautics and Space Act

Congressional declaration of policy and purpose

1. The expansion of human knowledge of the Earth and of phenomena in the atmosphere and space.

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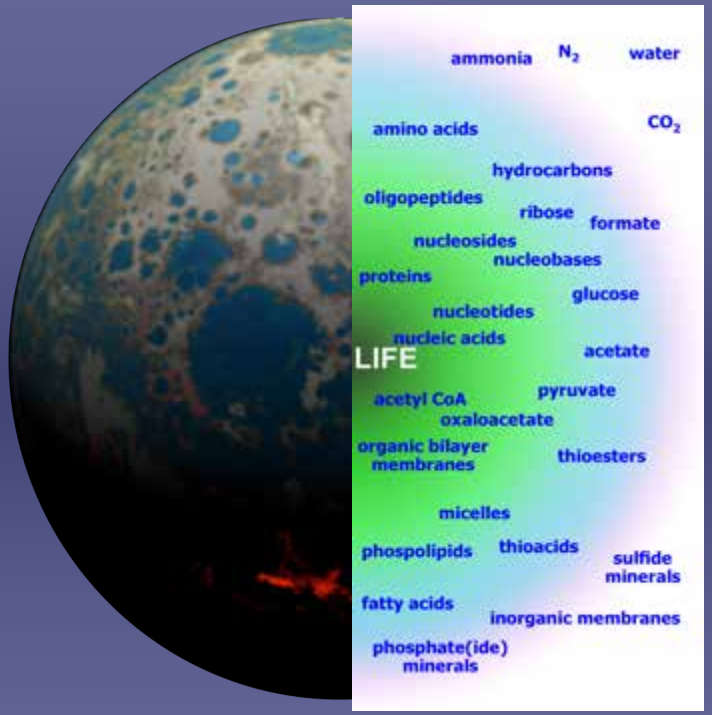
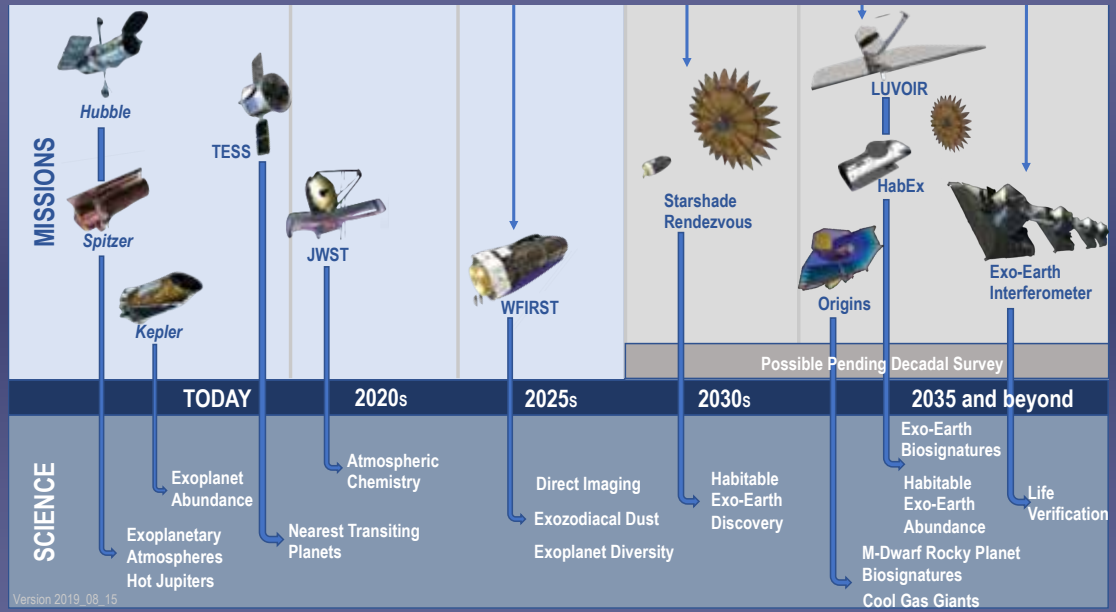
10. The search for life's origin, evolution, distribution, and future in the universe.

Planetary Pathways to Life

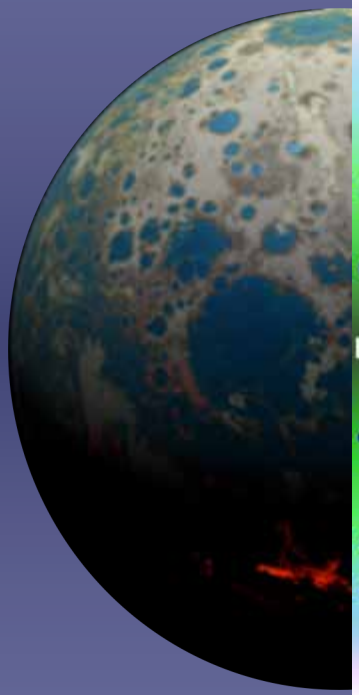


Exoplanet Exploration Program



- Identify planetary conditions that can or cannot give rise to life's chemistry and thus inform the exploration for life throughout the universe.

Planetary Pathways to Life



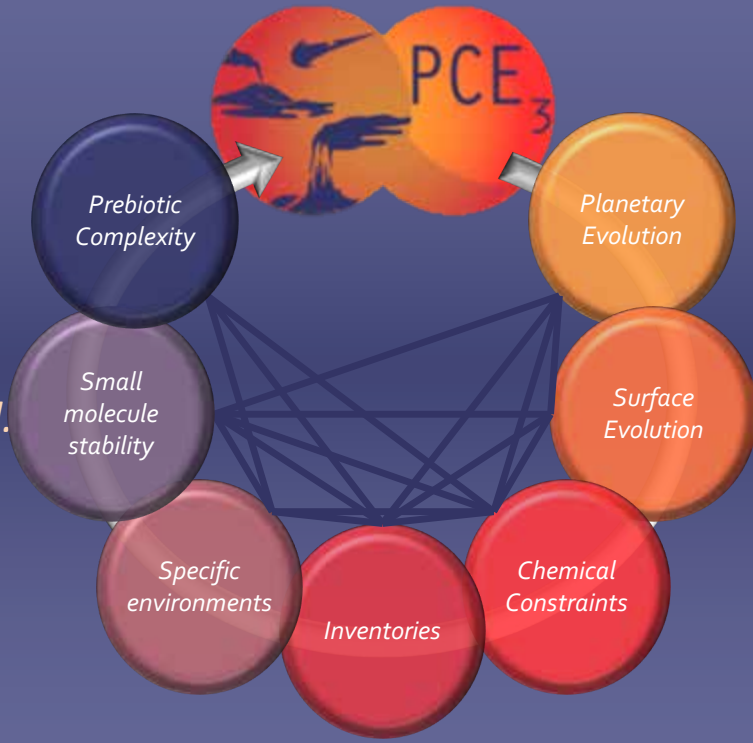
NOW Network for Ocean Worlds

NFoLD

ACTIVITIES

1. ***Community building – AbSciCon2019 kickoff***
2. ***Community engagement***
3. ***ICAR Theme***
4. ***Decadal White Papers***

   "Constraining prebiotic chemistry through a better understanding of Earth's earliest environments" Lyons et al.
5. ***3 new sessions at AbSciCon2021***
6. ***Upcoming workshops***
7. ***Lecture Series***



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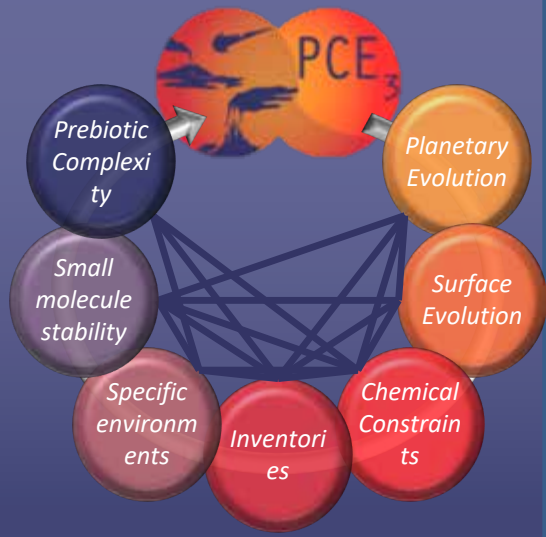

PCE$_3$ Community Workshop
I: Building a New Foundation

Fall 2020

Workshop Organizers: D. Trail, U. Muller, J. Elsila-Cook

1. Planetary formation & Early Impact History (Oct. 9):
2. Evolution of the Near Surface (Oct 16)
3. Inventories, Geological Settings, and Building Blocks (Oct 23)
4. Prebiotic Complexity (Nov 13)
5. Peering into the Past with today's biochemistry (Nov 20)

PCE$_3$ Community Workshop
II: New Directions

Spring 2020

Thank You