RESEARCH COORDINATION NETWORK GOALS

NfoLD is dedicated to advancing the science and technology required to search for evidence of life beyond Earth.

Our goal is to build a cohesive life detection community whose research and expertise becomes integral to all stages of astrobiology-themed interplanetary and exoplanet mission activity, from inception to operations.
WHAT WE DO

- Advance life detection strategy and capability
- Catalyze collaboration
- Support NASA programs and missions
- Foster community development
HOW WE DO IT

- Promote discourse relevant to life detection
- Act as a THINK-TANK for life detection science and technology
- Forum-style talks on SC research/techdev to discuss new life detection science and technology and build cross-discipline collaborations
- Provide life-detection feedback to Analysis Groups (MEPAG, OPAG)
- ECC journal clubs, career development activities, communication and research nuggets
**Who we are**

- **Co-leads** Brook Nunn, UW; Alfonso Davila, ARC; & Heather Graham GSFC

- 47 steering committee members (and their lab groups) funded through NASA basic research and technology development projects.

- 5 special mission focused steering committee members from missions and related themes.

- 76 Early Career Council members (primarily graduate students) engaged in life detection research.
HOW WE WORK TOGETHER

- Co-leads plan monthly programming with Steering Committee
- Ad-hoc committees collaborate on community-oriented events
- Early Career Council co-leads collaborate on programming
- NCOT organizes newsletter, blog, and social media communications
Connections between RCNs with Astrobiology Significance
My work focuses on:

- Biosignatures
- Analog Chemistry
- MS Detection Limits
- Habitability
- Geology
- Sample Handling
- Ocean Ecosystems
- Sensors
- Raman
- Modeling
- Dry Ecosystems
- GC
- Tech-Sampling
- Physics
- IR
- Multiplexing

What planetary bodies does your research focus on?

- Mars
- Europa
- Enceladus
- Other
- Titan
- Venus
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**Shallow-sea alkaline hydrothermal vents** are favorable environments for prebiotic chemistry on early Earth and potentially other planets

**SCIENTIFIC QUESTION:** Where did life first arise and thrive on early Earth? Studies have traditionally focused on three environments: 1) bottom of the ocean hydrothermal vents, 2) within the bulk water of the ocean itself, and 3) surface pools. Each of these three environments have major problems with driving prebiotic chemical reactions which are thought to lead to modern biochemistry. However, a site that could combine all three environments could overcome issues with any one type of site and provide access to a much larger suite of prebiotic chemical reactions. Do such sites exist on modern Earth, and were they likely to exist on prebiotic Earth? This study investigates the chemistry and life present at two similar locations, supporting current studies on prebiotic chemistry, and supporting future planetary missions that may investigate similar sites.

**SITE CHARACTERISTICS:** Shallow-sea alkaline hydrothermal vents. Two field sites:

**CONCLUSIONS:** These shallow-sea alkaline hydrothermal vents did show chemical reactions which support the "best of both worlds" for facilitating prebiotic chemistry. They have many of the favorable characteristics of deep-sea and land hydrothermal vents, including (1) bubbles, (2) nutrient-rich detritus from land, (3) agitation from waves and storms, (4) light, and (5) tides. This leads to a chemically diverse setting that can support many of the proposed reactions needed to form the first organism on the early Earth and potentially other planets, like Mars.


Illustration and text adapted from Barge and Price 2022 by Trent Thomas & Bradley Burcar @LifeDetection
Generalized Stoichiometry and Biogeochemistry for Astrobiological Applications

**Intro:** Elemental ratios in living things on Earth are related to environmental elemental abundances, ecological dynamics, and cell **size and** physiology. Generalized physiological models can be used to predict what elemental ratios may be found in extraterrestrial biological systems.

**Experiments & Results:** Models of elemental ratios within biological systems can be derived from cellular size and **macromolecular** abundances. These models can be combined with environmental abundances within ecological models of biogeochemistry to **predict the abundances in cells and the environment.**

**Significance:** By making **in situ** measurements of particle size, particle stoichiometry, and fluid/environmental stoichiometry, evidence for biological activity can be detected both at the cell and ecosystem level. This has implications for future astrobiological missions, as this biosignature is agnostic to life as we know it.

Polar Microbes Give Peptide Clues For Detecting Life on Icy Worlds

Introduction: Some of the moons around the giant gas planets (notably Jupiter and Saturn) likely have subsurface liquid oceans deep beneath their icy crusts. Living organisms (known as psychrophiles) are found in similar environments on Earth. If life exists in these extraterrestrial subsurface oceans, they would likely share similar adaptations and biochemistry to Earth-based psychrophiles. This new study, from a cross-departmental group at the University of Washington, explored conditions affecting the growth and long-term viability of psychrophiles, characterizing proteins that could be used to identify life in extraterrestrial oceans.

Experiments & Results: A marine psychrophile, *Colwellia psychrerythraea*, was grown for 4 months in 8 different sets of salinity and nutrient conditions and in two sub-zero environments. Analysis of the proteins suggested that the organisms use unique ways to process energy from the environment in order to survive under these harsh conditions. About 20 short protein fragments were identified as being useful for identifying organisms in similar environments.

Significance: This study shows how organisms develop unique proteins and biochemistry in sub-zero and extreme salt environments. Organisms that can live in these environments are extremely rare on Earth, but these conditions are remarkably similar to what we would see on other planets and moons within our Solar System. Instruments on current and future life-detection missions could be designed to detect these proteins, possibly allowing us to find signs of life as we continue to explore these planets and moons.

If life is present in subsurface oceans on icy worlds, can we use these cold adapted organisms on Earth to understand what to look for in our search for life in such places?

Deciphering the limits of life on Earth also provides us with a list of biomolecules that are enriched and detectable using mass spectrometers. Knowledge of what molecules can be found in these unique environments allows us to target them on off-planet explorations using similar instrumentation. - Brook L. Nunn
**Analyzing Mission Data**

**Organic molecules revealed in Mars’s Bagnold Dunes by Curiosity’s derivatization experiment**

**Background:** The search for organic molecules on Mars, one of the main goals of the Sample At Mars (SAM) instrument on board the Curiosity rover, is crucial to determining whether life existed, or currently exists, on Mars. SAM uses “wet chemistry” techniques to help release and analyze organic compounds from rocks and sand that will then be sent to the instrument for chemical analysis.

**Experiments & Results:** The first SAM wet chemistry experiment was performed on sand scooped from Gale crater’s Bagnold Dunes. For the first time on another planetary body, a chemical derivatization experiment was conducted, leading to the detection of benzoic acid for the first time on Mars. Benzoic acid could be produced from ancient biological material, or from the oxidation of meteoritic organic matter delivered to Mars. In addition to this interesting result, this experiment allows for the optimization of the future wet chemistry experiments to be done on Mars, possibly leading to the detection of more direct biological indicators, such as amino acids.

**Significance:** The first derivatization experiment performed on Mars has expanded our understanding of the range of organics that could be present in Martian sands. The success of this experiment offers new method for the search for chemical biosignatures on Mars and other potential habitable environments in our solar system.

ASSESSING LIFE DETECTION CLAIMS

Organics discovered in Allan Hills Meteorite were generated from fluid and CO₂ interaction with rocks on early Mars

INTRODUCTION: The Allan Hills 84001 (ALH84001) martian meteorite was found in Antarctica in 1984. This meteorite has been dated to crystallize ~4.09 Gya but been modified by fluid ~3.6 Gya on Mars. This ancient martian sample provides valuable window into the potentially habitable environment on early Mars. Carbon has been found in ALH84001 but it is unclear about whether it was formed via (1) abiotic production through several planetary processes, (2) biological production from potential life on Mars, or (3) simply contamination from Earth. Steele et al. set out to investigate the identity, origin, and formation mechanisms of the organic carbon found in ALH84001.

METHODS: Two thin rock sections were extracted. Each rock foil has been characterized via nanoscale spectral, imaging, structural, and isotopic analysis.

RESULTS: The collection of minerals found in ALH84001 are similar to those in Earth-rocks that have undergone reactions with water (i.e., serpentinization) and CO₂ (i.e., carbonation). The structure of the minerals show evidences of aqueous and/or hydrothermal alteration. Organic carbon is associated with products of this alteration. Hydrogen isotope show the organics are Martian.

KEY TAKEAWAYS: (1) Results from this analysis are consistent with a Martian origin of the organic matter in ALH84001 because the hydrogen isotope signature is unique to Mars. (2) The organic carbon likely formed abiotically, from water-rock reactions. (3) These water-rock reactions shaped Mars’s ancient environment and would have generated molecules important for the origin of any possible Martian life.

Steele, A., et al. "Organic synthesis associated with serpentinization and carbonation on early Mars." Science 375.6577 (2022): 172-177. Illustration and text adapted from Steele et al. 2022 by Brook L. Nunn, Ziqin (Grace) Ni, & Trent Thomas @ NfoLD
CONSORTIUM ACTIVITIES

- Monthly meetings cycle between mission-focused Think Tank events and a committee-focused forum
- Office hours for co-leads to meet with SC or ECC to brainstorm and plan group activities
- Special events that address a topic requiring community discussion
- ECC-focused events that provide interaction between senior researchers and up-and-coming talent
GOAL: promote internal feedback & improve life detection strategies
GOAL ➔ Provide mission-focused life detection advice from seasoned researchers
Workshops

Standards of Evidence for Life Detection workshop with NExSS developed community guidelines for reporting biosignature detection
- 240 participants; 25% exoplanet, 57% solar system, 18% early Earth/paleobiology
- Extensive workshop report available online

Future of the Search for Life workshop explored connections between life detection science and technology.
- 100 participants from 350 applications; 67% scientists, 33% engineers
- Workshop report has been submitted to Astrobiology

Ocean Worlds Analog Field Site Assessment workshop with NOW developed a framework to rate the field site suitability based on a science question
- 54 participants; 60% planetary scientists, 40% earth scientists/oceanographers
- Workshop report being finalized in steering committee and presented at LPSC
EARLY CAREER COUNCIL ACTIVITIES

Educational: Journal club and informal research discussions

Career Development: Conference practice talks, writing workshops

Collaboration: ECC Research Roundup, Forum and Think Tank “take-overs”

Communication: Research nuggest, interviews, social media, blogging
THANKS!
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.
Planetary Evolution
Surface Evolution
Chemical Constraints
Inventories
Specific environments
Small molecule stability
Prebiotic Complexity
PC

Life Precursors
- HCN
- Formaldehyde
- Phosphate
- Acetate
- Thiols

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

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

Crustal Evolution

Atmospheric Evolution
Impact History

Crustal Evolution
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.
Precursors
- Planet-specific raw materials
- Chemical/physical gradients
- Dynamic feedstocks

Monomers
- Reactive small molecules
- Heterogeneous chemistry
- Hydrophobic/philic chemistry

Polymers
- Functional polymers
- Compartments
- Complex reaction networks

Life

Interior
- Exchange

Impact History
- Marchii

Surface & Orbital Dynamics

Howell & Pappalardo, 2020

PAC February 28, 2023
Exposed landmass?

(b) Mid-Hadean

dependent on Kg matrix

Fe-rich blobs

dependent on Kg matrix

(c) Early Archean

(d) Proterozoic to Phanerozoic

Bada & Korenaga, Life, 2018, 8,55.

PAC February 28, 2023
Delivery of building blocks
Planetary scenarios for synthesis

Naraoka et al., Science, 2023
Schmitt-Kopplin et al., SciAdv, 2023
Messy chemistry or abundant opportunities?

Environmental mechanisms

Amino Acids $\rightarrow$ Peptides

Amino&Hydroxy Acids $\rightarrow$ Depsipeptides

Frenkel-Pinter et al., ChemRxiv, 2022, 10.26434/chemrxiv-2022-s3cr2

Polymers

- Functional polymers
- Compartments
- Complex reaction networks

PAC February 28, 2023
What is PCE$_3$?

The Prebiotic Chemistry and Early Earth Environments Consortium (PCE$_3$) is a community of scientists striving to transform the origins of life community by breaking down language and ideological barriers and enhancing communication across the disciplinary divide between early Earth geoscientists and prebiotic chemists.
WHO WE ARE

- Seminar Organizing Committee
- Science Communications Team
- Workshop Organizing Committees
- TIPCEE Organizing Committee

Community At-Large
Team Members
Steering Committee
Co-Leads

prebioticchem.info and @PCE3_Sci
• PCE₃ Community Engagement
• PCE₃ Influence
• PCE₃ Community Workshops
• PCE₃ Scholarship & Discussion
• PCE₃ Community Expansion
• **PCE$_3$ Community Engagement**

• **AbSciCon PCE$_3$ gatherings**

• **prebioticchem.info**

• **NAS CAPS reporting**

• **NASA PAC**
PCE$_3$ Influence

- Decadal White papers
- Workshop reports
PCE$_3$ Community Workshops

“Building a New Foundation” 2021
D. Trail, U. Muller, J. Elsila-Cook

“Nano-to-Cosmic Studies of Complex Systems” 2022
Z. Adams and J. Glass

ACTIVITIES

25 speakers
255 synchronous attendees
23,000 YouTube views
Astrobiology special issue
PCE₃ Scholarship & Discussion

PCE₃ Seminar Series
- Organizers: James Eguchi, Albert Fahrenbach, Rebecca Guth-Metzler, Danielle Simkus
- Early Career organizers and speakers
- Every third Thursday

TIPCEE

Sustained 100+ audience for ~2 years
Mini-workshops on specific, often provocative, topics
- Quarterly
- ½ day, virtual
- 4-5 pre-recorded talks
- Moderated panel discussion and breakouts
- Expected outcomes: new collaborations, hypothesis papers, scientific & community evolution

**ACTIVITIES**

**Topics in Prebiotic Chemistry & Early Earth Environments**

**THE IMPACT OF IMPACTS**

**HYDROTHERMAL ORIGINS?**

**EVOLVING ATMOSPHERES**

**RNA... IS IT STILL A WORLD?**

**THE ABIOTIC PLANETARY BACKGROUND**

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