NASA Astrobiology Program

June 2, 2016

Washington, DC

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The Astrobiology Science Strategy

- Broad participation in creation:
  - 33 Lead Authors
  - 77 Contributors
  - 744 members of *astrobiologyfuture.org*
  - 12 reviewers who made invaluable contributions.
- Goal was to create an "inspirational and aspirational" document.
- A PDF version is available on the Web. (Limited Printed Copies)
  - Will be "wiki-fied" to make it a living document.

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

Astrobiology Program Funding Priorities

- Identified by Gaps in Investment Portfolio
- Identified through Topical Workshops
  - National Academies
  - NASA
- Science Needs in Support of Ongoing and Future Missions
  - Curiosity
  - OSIRIS-Rex
  - ExoMars
  - Mars 2020
  - Europa
- Partnerships with Other Agencies
  - NSF- Center for Chemical Evolution
  - NSF- Ideas Lab
- National Science Priorities
  - Microbiome Initiative
  - Ocean Worlds

NASA Microbiome

- NASA's Science Mission Directorate (SMD) has invested in research on the probable first common ancestor, reconstructing microbiomes from early days on Earth, and characterizing microbiomes from extreme environments.
- NASA's Planetary Protection Office funds genetic inventories of the microbiome in space assembly facilities and outbound spacecraft and instruments.
- NASA's $25 million Ocean Worlds may develop technologies for assessing microbiomes in extreme environments and deep oceans, a requirement for discovering life away from Earth.

NASA Microbiome

NASA's Human Exploration and Operations Mission Directorate (HEOMD) has started a new Space Life Sciences research project called GeneLab. The GeneLab project will conduct strategic missions to facilitate the collection and integration of various types of bioinformatics analytics from Space Life Sciences experiments on the International Space Station (ISS).

Another area of priority area in HEOMD is establishing a research program analyzing the microbiome of plants, and demonstrating the roles of microbial-plant systems in long-term life support systems.

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NASA Microbiome

NASA Johnson Space Center, Human Research Program has the Study of the Impact of Long-Term Space Travel on the Astronauts' Microbiome. The Microbiome experiment has investigated the impact of space travel on both the human immune system and an individual's microbiome (the collection of microbes that live in and on the human body at any given time).

To date they have been studying 9 astronauts and now have a new focus, the Twins Study (Kelly twin astronauts).

Concepts for Ocean worlds Life Detection Technology (COLDTech)

- Supports the development of spacecraft-based instruments and technology for surface and subsurface exploration of ocean worlds such as Europa, Enceladus, and Titan.
- The goal of the program is to develop and reduce the technical risk of instruments and technology for potential future missions so that they may eventually be proposed in response to future announcements of opportunities (AOs) for flight missions.

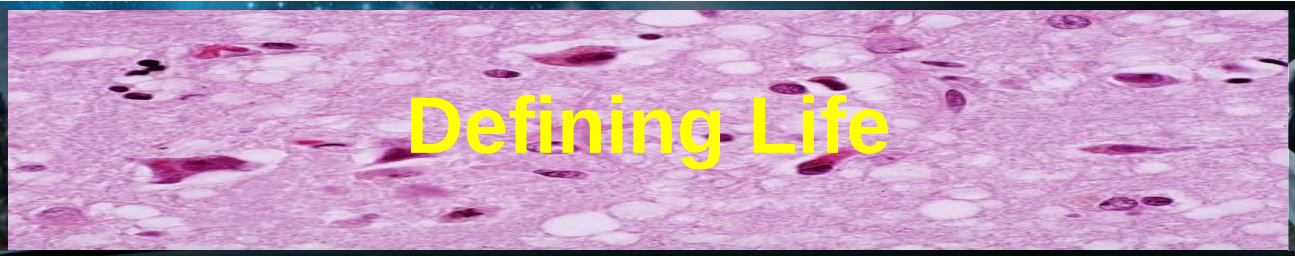
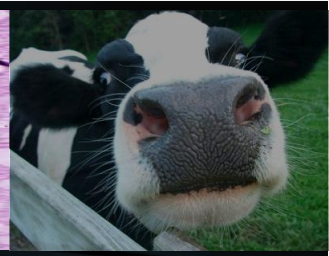
Concepts for Ocean worlds Life Detection Technology (COLDTech)

COLDTech seeks to:

A) develop and advance the maturity of science instruments, especially those focused on the detection of extant or extinct life in the ocean worlds of the outer Solar System,

B) sample acquisition, delivery and analysis systems for such missions, and,

C) spacecraft technologies required to access the oceans.

Defining Life

Life is chemistry with a history (and memory).

NASA: Life is a self-sustaining chemical system capable of Darwinian evolution.

Definition → General theory of living systems

E.g. Terran life: Uses water as a solvent; Is built from cells, exploits a metabolism that focuses on the C=O carbonyl group; Is a thermodynamically dissipative structure exploiting chemical energy gradients; and Exploits a two-biopolymer architecture that uses nucleic acids to perform most genetic functions and proteins to perform most catalytic functions.

How to detect Life?

LIFE DETECTION LADDER

Ladder Rung	Feature	Measurement	Instrument	Likelihood	Specific to Earth Life vs. Generic Life	Ambiguity of Feature	Ambiguity of Interpretation	False Positive	False Negative
Life (metabolism, growth, reproduction)									
Darwinian Evolution									
Growth and Reproduction									
Metabolism									
Suspicious biomaterials [not necessarily biogenic]									
Functional Molecules									
Potential Building Blocks									
General indicators									
Habitability									
Environmental conditions									

Ladder Rung	Feature	Measurement	Instrument	Likelihood	Specific to Earth Life vs. Potential for Generic Life	Ambiguity of Feature	Ambiguity of Interpretation (how likely produced abotically?)
Life (metabolism, growth, reproduction)	-	-	-	-	-	-	
Darwinian Evolution	changes in heritable traits in response to selective pressures	not possible		no	~	~	
Growth and Reproduction	concurrent life stages or identifiable reproductive form [growth and reproduction]	cell(like?) structures in multiple stages	microscope	low	Earth	What is a cell? What morphological differences exist?	low
Metabolism	isotopes	isotopes indicative of active metabolism	irMS	low/med	Earth (can you abstract?)	source, sink, context	low
	co-located reluctant and oxidant (e.g. oxygen and methane) [Inferred Persistence]	chemical concentrations of substrates and products involved in redox reactions	spectroscopy	med/high	Generic	mixed reactions, large inventory of chemistries	low-med

Ladder Rung	Feature	Likelihood	Specific to Earth Life vs. Generic Life	Ambiguity of Feature	Ambiguity of Interpretation
Suspicious biomaterials					
Functional Molecules	DNA				
	RNA				
	Lipids				
	Structural Preference				
Potential Building Blocks	complex organics	med	Generic		medium
	amino acids (e.g. glycine)	high	Generic		medium
	lipids (fatty acids, esters, carboxylic acids)	med/high	Generic	abiotic pathways to products	med-high
General indicators	distribution of metals [e.g. vanadium in oil reserves]	med	Generic	knowledge of background	medium
	patterns of complexity (organics)	high	Generic	documentation of differences between abiotic and biotic limited	medium
	chirality	high	Generic	How much of an excess is necessary?	high

Ladder Rung	Feature	Measurement	Instrument	Likelihood	Specific to Earth Life vs. Generic Life	Ambiguity of Feature	Ambiguity of Interpretation
Suspicious biomaterials [not necessarily biogenic]	-	-	-	-	-	-	-
General indicators	distribution of metals [e.g. vanadium in oil reserves]	deviation from background bulk concentrations (Preferences)	XRF	med	Generic	knowledge of background	medium
	patterns of complexity (organics)	deviation from random organic complexity distribution	LCMS	high	Generic	documentation of differences between abiotic and biotic limited	medium
	chirality	material produced by extraterrestrial life	LC-MS/MS	high	Generic	How much of an excess is necessary?	high

LIFE DETECTION Workshops

Agnostic Biosignatures (Late Summer, 2016)

Lee Cronin and Jen Eigenbrode

Extant Life on Ocean Worlds Workshop (Early Fall, 2016)

Stephanie Getty & GSFC

Workshop on Advanced Technologies for Life Detection on Icy Planets/Icy Terrain (2017)

Denise Podolski, Ron Turner, STMD


Questions???