AGNOSTIC APPROACHES TO EXTANT LIFE DETECTION.  S. S. Johnson1, H. Graham2, E. Anslyn3, P. Conrad4, L. Cronin5, A. Ellington6, J. Elsila7, P. Gigrus6, C. House7, C. Kempes8, E. Libby9, P. Mahaffy7, J. Nadeau9, B. Sherwood Lollar10, and A. Steele4 1Georgetown University, 3700 O Street NW, Washington, DC, 20099, sarah.johnson@geoergeotwn.edu, 2NASA Goddard Space Flight Center, 3University of Texas at Austin, 4Carnegie Institute of Washington, 5University of Glasgow, 6Harvard University, 7Pennsylvania State University, 8Santa Fe Institute, 9Portland State University, 10University of Toronto.

Introduction: Without presupposing any particular molecular framework, the newly formed Laboratory for Agnostic Biosignatures (LAB) team is pursuing approaches to life detection that could help us identify unknowable, unfamiliar features and chemistries that may represent processes of life as-yet unrecognized.

Chemical Complexity: There are multiple ways to utilize high heritage instrumentation in more agnostic ways. For example, flight capable mass spectrometers have long been flown on spacecraft, designed to search primarily for patterns among the molecular weights of carbon-bearing organic molecules. However, mass spectrometers can also be configured to search for chemical complexity of any type of molecule (organic or inorganic) that would be unlikely or impossible to form spontaneously. Without making assumptions about the chemical structures of the molecules, recent work suggests there may be a threshold beyond which complex molecules are unlikely to form without supporting biological machinery [1].

Chemometric Approaches: Sequencing approaches, currently under development to search for nucleic acids and monitor terrestrial contamination [2-3], can also be utilized to explore sample complexity, regardless of whether life is based on nucleic acids [4]. This concept builds on the fact that oligonucleotides naturally form secondary and tertiary structures that can have affinity and specificity for a variety of molecules, from peptides and proteins [5], to a wide variety of small organic molecules [6,7], to inorganics such as mineral surfaces [8] and individual metals [9].

By accumulating large numbers of binding sequences that reflect different compounds in a mixture, statistical data analyses of oligonucleotide sequences and sequence counts enable patterns associated with increasing levels of complexity to be analyzed [Fig. 1]. This pattern recognition, known as “chemometrics,” could be used to distinguish samples with chemistries suggestive of biology—to “read” patterns of molecules that arise from the vast amount of information stored on the surface of a primitive microbial cell, and to do it with great sensitivity.

Disequilibrium Redox Chemistries: Disequilibrium redox chemistries that are inconsistent with abiotic redox reactions could also be used as an indicator of active metabolism. Unexpected accumulations of chemical elements or isotopes could indicate life, as could patterns of energy transfer. Many microbes can utilize solid-phase minerals as an electron acceptor, e.g. insoluble Fe(III) oxides. An agnostic means of detecting this microbial activity is to use an inert, conductive electrode (e.g. graphite) in the environment. The current density and other electrical attributes produced by microbes are notably distinct from abiotic oxidation [10]; thus this signal could be used as an agnostic biosignature.

Probabilistic Approaches to Data Analysis: While it is necessary to broaden our scope and design inclusive life detection strategies, agnostic approaches may be less definitive than, say, uncovering a hopane or DNA sequence. A data interpretation scheme that considers expectations and likelihoods and establishes critical thresholds for life detection based upon probabilistic models is thereby key. For instance, a Bayesian network for which the output is the probability there is a biosignature (i.e., P(biosignature | Data)) could be utilized to assess the probability of life, and thus convert measurements into likelihoods and thresholds.


Figure 1: A new concept for life detection harnesses the power of DNA sequencing for detecting life that is not based on nucleic acids. 1) DNA strands are mixed with samples. 2) Diverse folded oligonucleotides bind to complex surfaces and far fewer bind to a simple, repeating, structures. 3) Bound sequences can be amplified and sequenced, revealing the diversity of binding sites within a sample.