FINGERPRINTING NONTERRAN BIOSIGNATURES. S. S. Johnson[1], A. D. Ellington[2], E. V. Anslyn[2], H. V. Graham[3], and P. R. Mahaffy[3], [1]Georgetown University, 37th and O Streets NW, Washington, DC, 20057 (sarah.johnson@georgetown.edu), [2]The University of Texas at Austin, [3]NASA Goddard Space Flight Center

As we design instrumentation for future missions to Ocean Worlds, we can, should, and will apply traditional biosignature approaches: looking for isotopic signatures, particular classes of molecules, evidence of enantiomer excess, and patterning within the molecular weights of fatty acids or other lipids. Sequencing technology has also been proposed to look for nucleic acids based on a shared ancestry hypothesis [1], though shared ancestry is arguably less tenable as we proceed deeper into the Solar System. We propose a new approach that also harnesses the power of sequencing—not to detect DNA or RNA-based life, but rather as a tool for detecting agnostic biosignatures.

Oligonucleotides naturally form secondary and tertiary structures and can have extremely high affinity and specificity for binding other molecules, be they other nucleic acids, proteins, or small organic compounds [2] (See Fig. 1). Short DNA sequences can form complex structures that, like antibodies, will bind to analytes in a sample. However, unlike antibodies, oligonucleotides can be directly sequenced, enabling recovered sequences to serve as "images" of binding chemistry, regardless of sample source.

This same concept is at the heart of SELEX [3], a combinatorial chemistry technique with deep heritage that is popularly used to select high-affinity single-stranded DNA or RNA, also known as aptamers, to target a wide variety of small and large molecules including surface proteins on tumor cells and other biomarkers. But instead of selecting for oligonucleotide sequences that specifically bind to preselected target ligands, millions of randomly generated single-stranded DNA sequences can be introduced to a tiny liquid sample. A small portion of these random oligonucleotides will then bind to analytes, such as the sur faces of cellular compartments, and the full binding patterns that result in the presence of the entire library can be analyzed. This pattern recognition, known as "chemometrics," represents a set of statistical analysis protocols that can be applied to find patterns in chemical data sets [for examples, see 5-10], which in turn can be used to fingerprint nonterran biosignatures.

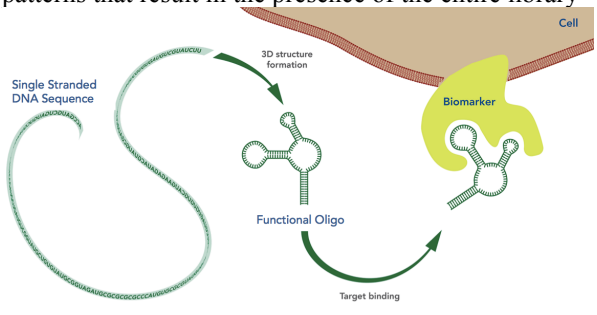

Figure 1: Secondary and tertiary structure transform ssDNA sequences into functional olionucleotides, which will bind to a variety of analytes. Adapted from [4].

There are multiple possibilities for signal detection, including handheld nanopore sequencers as well as DNA microarrays, where, upon hybridization, data in the form of a pattern of fluorescence can be simply and quickly optically imaged. The former is of particular relevance to Mars, where data transfer limitations are less stringent and detailed sequence information might also be utilized for testing a shared ancestry hypothesis, the latter better approximates the technical limitations of an Ocean Worlds mission.

A principle advantage of this approach is its sensitivity. It is likely that the amount of biomass produced lithoautotrophically on the ocean worlds of Europa and Enceladus would be extremely small compared to the biomass produced photosynthetically on Earth [11]. If a plume flyby were to only collect the equivalent of a few tens to a few hundreds of cells, it would require exquisite sensitivity within the suite of life detection instruments. By utilizing the polymerase chain reaction, or PCR, the signal associated with a small input can be amplified a billion fold within a few hours.

The discovery of extraterrestrial ocean worlds has motivates the scientific community to expand our horizons beyond terrestrial biochemistry. **Without presupposing any particular molecular framework, this chemometric life detection approach could be used from Mars to the far reaches of the solar system, all within the framework of a miniaturized device drawing little heat and power.** It would allow for truly agnostic biosignature detection, enabling us to fingerprint intricate patterns of binding chemistry.

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