A Probabilistic Intrinsically Calibrated Framework For Recognizing Complex Molecules as Biosignatures

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Introduction: Amongst the myriad chemicals generated by biological systems are many of high molecular weight and chemical complexity (e.g. proteins and nucleic acids). The chance of such molecules occurring naturally in any non-negligible abundance without the robust replication/duplication of a living system is extremely small; the state space is too large.[1-2] This leads to the question – where is the boundary of complexity and molecular weight above which we it would be too improbable for a substance to be created by simple sequences of reactions? What are the chemical structures that require life?

We propose that, alongside a robust definition of complexity, we can define regions of chemical space where abundance of a particular species, above a threshold for molecular weight and complexity, implies biological origin. In the definition of biological origin, we would also include synthesized molecules, their synthesis having been directed by biological agents (i.e. proxies for biology).

Results: By using analytical techniques that can map the spectra of unknown chemicals to their complexity, or set lower bounds for their complexity, a universal life detection system could establish biological origin for molecules found outside of the Earth. This system is agnostic to the type of biology – by screening for complexity, rather than specific substances, we could detect the products of living systems that are far different from our own. This concept was developed from the idea of historical or recursive complexity whereby complex systems are built up in steps using plausibly accessible steps whereby complex motifs can be taken from the past into the future.

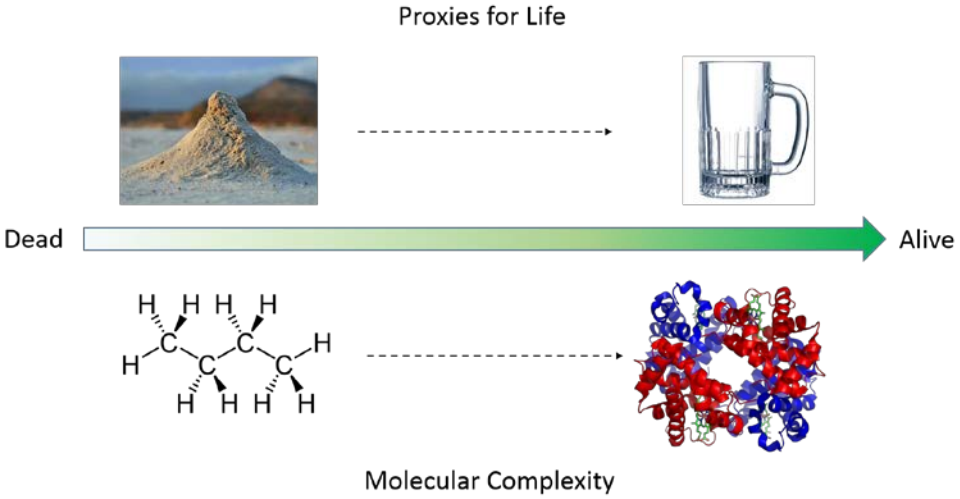

Figure 1: Where does a glass fall on the aliveness scale? As a proxy for life, it can be considered more "alive" than sand as it can only be produced by a sophisticated biological system in any abundance (beyond chance events).

Conclusion: Our overall aim will be to use the measure to be used to define boundaries on what it would take to synthesize the molecule through simple non-biological operations, and on the likelihood of the molecule existing outside of biology, and then to develop a mobile probe-based system to search for complexity as a biosignature.

References:

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2. C. Scharf, L. Cronin, *Proc. Nat. Acad. Sci, USA*, **2016**, 113, 8127-8132.
3. S. Marshall, L. Cronin, in preparation.