Informational polymers as unambiguous biomarkers for aqueous-based life

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Abstract:
The National Aeronautics and Space Administration (NASA) defines life as a "self-sustaining chemical system capable of Darwinian evolution," yet a NASA-developed ladder of life detection suggests that measuring such evolution is not feasible within the resource constraints of currently-envisioned life detection missions. If true, such missions cannot strictly verify whether life beyond Earth exists. We propose to resolve this issue in two ways. First, we argue that it is possible to make this measurement. By way of example, we report measurement of evolution in Bacillus subtilis 168 subjected to UV exposure, made solely with a small portable nanopore-based single molecule sequencing device, which is broadly compatible with the constraints of life detection missions, especially for Mars. Detected genetic differences suggest an inherent lifestyle tradeoff between adaptation to oxidative stress and growth rates, consistent with an observed slow-growth phenotype. Second, we argue that we can be confident in detecting life without measuring Darwinian evolution per se. For example, amino acid abundance distributions and lipid carbon chain length distributions have previously been proposed as unambiguous biomarkers. Here we focus on informational polymers, e.g. nucleic acids, which form the basis for heredity that enables evolution in all known life. Indeed, long charged polymers may be universal features of aqueous-based life due to their ability to separate information storage from physicochemical properties. The goal to detect not only DNA and RNA, but related or unrelated polymers, will require further development of nascent technologies to enable a broad-based search for life on Mars, Enceladus, and Europa. Informational polymers, in combination with other "unambiguous" biomarkers, can provide a high confidence in detection of life as we know it or as we don't know it.