Bayesian analysis of the astrobiological implications of life's early emergence on Earth

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Life arose on Earth sometime in the first few hundred million years after the young planet had cooled to the point that it could support water-based organisms on its surface. The early emergence of life on Earth has been taken as evidence that the probability of abiogenesis is high, if starting from young-Earth-like conditions. We revisit this argument quantitatively in a Bayesian statistical framework. By constructing a simple model of the probability of abiogenesis, we calculate a Bayesian estimate of its posterior probability, given the data that life emerged fairly early in Earth's history and that, billions of years later, curious creatures noted this fact and considered its implications. We find that, given only this very limited empirical information, the choice of Bayesian prior for the abiogenesis probability parameter has a dominant influence on the computed posterior probability. Although terrestrial life's early emergence provides evidence that life might be common in the Universe if early-Earth-like conditions are, the evidence is inconclusive and indeed is consistent with an arbitrarily low intrinsic probability of abiogenesis for plausible uninformative priors. Finding a single case of life arising independently of our lineage (on Earth, elsewhere in the Solar System, or on an extrasolar planet) would provide much stronger evidence that abiogenesis is not extremely rare in the Universe.

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