The 'selection first' path to life

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Approaches to the origin of life based on chemical evolution, e.g. autocatalytic networks, inevitably run up against the problem that while these systems can produce large sets of compounds, they become chemically inert and non-specific, lacking the intricate functional interactions characteristic of life. This is also seen experimentally [1, 2], and is known as the "tar problem". One approach to resolve this issue is to identify factors that can control the chemistry to produce sparse chemical subsets, e.g. the addition of borate salts to the formose reaction [3]. This approach suffers from a lack of diversity in the sparse subsets that may be produced, problematic for the system's evolvability. We observe that the chemical library may itself act as a source of potential adaptations as a result of physical processes acting upon the complex chemical library. A particular version of such a process is repeated sequestration of molecular combinations through precipitation, e.g. in a repeated wet-dry cycle. The process of repeated sequestration leads to selective amplification of small subsets of the library. We study selective amplification in a model chemical system where sequestration rates for the pairs given by a Maxwell-Boltzmann distribution of the pairwise binding strengths. The system appears to have a phase transition: if the temperature is cool enough, repeated sequestration governed by the dynamics can result in selective amplification of a subset of molecules. We quantify this selective amplification, and measure the diversity of the emergent chemical subsets. Note that the selective self-amplification we observe is not a single complex attractor produced, e.g., by autocatalytic chemistry; it is produced, instead by a physical sequestration process imposed on a rather simple pairwise binding chemistry. The subsets selected are dependent on environmental conditions, so a diversity of environments leads to a diversity of self-amplified sets, giving a more robust starting point for evolution than vertical descent from a common ancestor, and still capturing a version of adaptation that can drive evolution. We argue that the first version of evolution marking the origin of life acted on chemical subsets such as these, formed from selective amplification. Furthermore, we argue that this version of evolution precedes molecular replication (e.g. of RNA or DNA) as a source of informational persistence and variation in primordial evolutionary processes. We identify selective amplification as a mechanism to produce an intermediary between non-adaptive complex chemical systems and evolving populations of replicators. While the model system we study lacks historical contingency, it instead has environmental contingency which can explore a diverse space of 'solutions' to environmentally posed problems. We will discuss ways that our model system may be extended to produce historical contingency as well.

[1] S. L. Miller *et al.*, Science **117**, 528 (1953).
[2] C. Sagan and B. Khare, Nature **277**, 102 (1979).
[3] S. A. Benner, H.-J. Kim, M.-J. Kim, and A. Ricardo, Cold Spring Harbor perspectives in biology **2**, a003467 (2010).