

Title:

Thermodynamics of Darwinian evolution in molecular replicators

Abstract:

We consider the relationship between thermodynamics and evolution in molecular replicators. We uncover a universal bound that relates the fitness of an autocatalytic replicator and the free energy dissipated by that replicator in steady-state. The result applies for a large class of molecular replicators, including elementary and non-elementary autocatalytic reactions, polymer-based replicators, and some types of autocatalytic networks. We also find that the “critical selection coefficient”, the minimal fitness difference visible to selection, is bounded by the dissipated free energy. Our results imply a fundamental thermodynamic limit to Darwinian evolution in molecular systems, complementary to other limits that arise from finite population sizes and error thresholds. We illustrate our approach on a model of replicators in a chemostat that compete for a shared resource. Our results may be relevant for understanding the constraints faced by early replicators at the origin of life.