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Optimal Size for Emergence of Self-replicating Polymer System

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Abstract: Biological systems consists of a variety of polymers that are synthesized from monomers. Here catalysis emerges for a polymer beyond some length, which itself is synthesized by its catalysis. In the problem of the origins of life, it is important to elucidate how such autocatalytic polymerization has emerged and been sustained. The reaction system of self-replicating polymers, as analyzed by stochastic reaction dynamics, has two stable states, one with almost no catalysts and the other with sufficient catalysts to sustain the autocatalytic reaction. The transition from a state without catalyst to that with abundant catalysts is required for the emergence of primordial life, as was discussed by Freeman Dyson in his seminal book [1]. Transition time from the former to the latter gives a measure how autocatalytic polymerization systems is likely to emerge. We investigated such transition time by stochastic reaction dynamics, as a function of the volume of the system.

Transition time between bistable states generally increases with the system size. We find that, however, there is one optimal volume that minimizes the transition time in an autocatalytic polymerization system, which is generally given by the inverse of the catalyst concentration at the unstable fixed-point in the reaction rate dynamics, as estimated from a condition to have a single catalyst molecule. This result suggests that the space volume in a reaction system is an important factor for the origin of life. This is the universal relationship in the field of the origin of life, and is a result from theoretical physics. Also it provides a quantitative prediction for the synthesis of primitive catalytic reaction system for a protocell [2].

References: [1] F. J. Dyson, Origins of Life (Cambridge University Press, New York, 1985). [2] Y. J. Matsubara and K. Kaneko, Phys. Rev. E **93**, 032503 (2016).

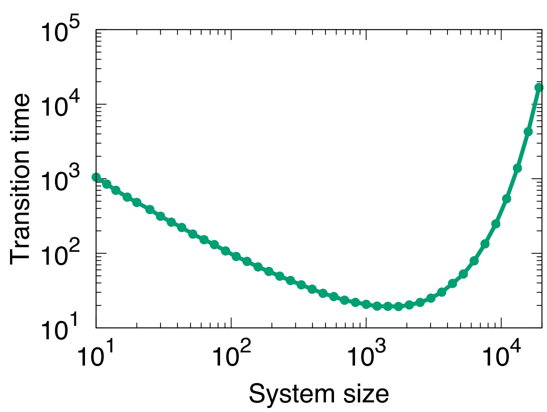

Figure – Transition time from the inactive to active states, plotted as a function of the system size. There is the optimal size that gives the minimum transition time. For each parameter and size, the time is computed as the average over samples of the master equation. Log-log plot.