Disequilibria and Escapements; the engines that bring matter to life. Elbert Branscomb[1], Tommaso Biancalani[1], Nigel Goldenfeld[1] and Michael Russell[2], [1]Carl R. Woese Institute for Genomic Biology, UIUC, Champaign-Urbana, IL, USA, [2]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

Introduction: All of life's most essential and distinguishing processes are thermodynamically endergonic and must be driven anti-entropically "up-hill" – often very far – away from their equilibrium state [1][2]. Each such process acts, therefore, to create and sustain a specific physical-chemical disequilibrium. We posit that any plausible form of proto-life must similarly have been sustained by a basic kit of ongoing and inherently endergonic processes; at a minimum, carbon and nitrogen had to be continuously reduced from the more oxidized forms provided by the environment and, almost certainly, pyrophosphate had to be held out of equilibrium with respect to orthophosphate (to function as a primitive "ATP"). Therefore, the igniting event in the transition from inanimate to animate forms of matter was not simply a "chemical" one; i.e. the assembly of a soup of building blocks, much less of polymers capable of encoding and transmitting information. It was instead, we assert, the spontaneous emergence in an abiotic world of conditions that provided for the steady driving of a few specific and foundational endergonic processes. Therefore, demonstrating a convincing answer to how this could have come about is the key emergence-of-life challenge. However, there is widespread misunderstanding about how molecular-level endergonic processes are made to happen, and thus about what we should be looking for at the emergence of life. This poster presents an effort to clarify these issues based on considering a "toy" statistical-physics model of systems that can have the capability of driving thermodynamically uphill processes. Its main points are threefold: 1) that endergonic processes are not driven or powered by the "consumption" or "use" of energy (thus neither is life itself) but rather are, and can in principle only be, driven by the enslaved dissipation of another (larger) disequilibria via a process of *disequilibria conversion*; 2) that such conversions are necessarily mediated by physical devices that function as *escapement-controlled Brownian ratchet engines* which force the dissipation of the driving disequilibrium to be step-wise conditional on, or gated by, the completion of an instance of the driven reaction; and 3) that instances of the driven reaction are themselves produced by thermal fluctuations from the bath. Thus the driving reaction merely acts, via the escapement, to select from amongst the thermal impacts acting on the driven reaction just those that happen to move the later in the up-hill, work-producing direction - albeit it does so in a 2nd-law-abiding, daemon-free manner. We emphasize that these escapement-based disequilibria converting devices are true mechano-chemical engines, not just catalysts, that disequilibria conversions are not just mass action chemistry, and that in such conversions energy liberated in the driving reaction is not transferred to the driven reaction.

References: [1] Branscomb E. and Russell M., (2013) BBA, 1827, 62-78. [2] Russell M.J., et al., (2013) PTRS-B, 368: 20120254.

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