



York Cross-Disciplinary Centre for Systems Analysis

Evolution, Evolvability, and Change Workshop

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Are there Ergodic limits to Evolution

Abstract:

There is a fruitful and developing programme exploring analogies between evolution and the statistical mechanics of complex matter [1,2]. Both treat exponentially large spaces of configurations (possible genomes/possible microstates) which is explored by stochastic dynamics (random mutation/thermal motion). Both admit maximisation/minimisation criteria (fitness/free-energy). There are even evolutionary analogies of temperature (inverse population size) [3] and free energy ("free fitness") [4].



Beneath the notion of thermodynamic equilibrium is the assumption of 'ergodicity' - the exploration of configuration space in a representative way, with an induced characteristic timescale to attain equilibrium. 'Ergodic times' are typically much less than the exponentially long times required for a complete search. For example, for a polymer of N subunits, the timescale for equilibration increases as N^2 rather than the z^N of a complete search. The strong dependence of these timescales on system size means that, even if a large system is not in equilibrium, some of its subsystems may be. We consider an illustrative example of the insect compound eye, which also carries the advantage that its optimum (in acuteness of vision) relies on physics and can be calculated [5].

The ergodic exploration of systems and subsystems within evolution generates a discussion of timescales for representative exploration of genotypic spaces. This in turn suggests a strong connection to the phenomenon of *convergent evolution*, and the conjecture that this might be expected in subsystems whose fitness is optimised by well-defined phenotypical constraints, and whose ergodic time is less than the relevant evolutionary time.

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- [3] G. Sella and Hirsh AE, *Proc Natl Acad Sci USA*, 102, 9541–9546. (2005)
- [4] B.S. Khatri, T.C.B. McLeish and R.P. Sear, *PNAS*, 106, 9564-9569 (2009)
- [5] T.C.B. McLeish, *J. Roy. Soc. Interface Focus*, 20150041 (2015)