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# Chaos and Unpredictability in Evolution

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## Abstract

What would happen if we "replayed the tape of life", i.e., if the history of life were restarted and the biosphere would evolve anew? This is a question about evolution as a dynamical system: is evolution fundamentally chaotic, and hence unpredictable? The possibility of complicated dynamics driven by non-linear feedback mechanisms has revolutionized science in the latter part of the last century. Perhaps surprisingly, few of these insights have entered the realm of evolutionary biology. The concept of "survival of the fittest", central to much evolutionary thinking, embodies a perspective of evolution as a directional optimization process, and hence as a dynamical system that converges to an equilibrium in phenotype space, representing the optimally adapted type. This perspective may be correct for simple scenarios, but generally not when ecological interactions are taken into account for evolutionary processes. Ecological interactions generate frequency-dependent selection, as when the success of a certain food preference depends on the food preference of other individuals. In most organisms many phenotypic properties combine in complicated ways to determine ecological interactions, and hence frequency-dependent selection. Therefore, it is natural to consider models for the evolutionary dynamics generated by frequency-dependent selection acting simultaneously on many different phenotypes. We argue that complicated, chaotic dynamics of long-term evolutionary trajectories is common in a large class of such models when the dimension of phenotype space is large, and hence that the perspective of evolution as a process that eventually equilibrates in constant environments must be fundamentally revised.

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