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Limiting Fitness Distributions in Evolutionary Dynamics

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Natural selection works on variation in fitness, but how should we measure "variation" to predict the rate of future evolution? Fisher's fundamental theorem of natural selection provides the short-run answer: the instantaneous rate of growth of a population's mean fitness is its variance in fitness. This identity captures an important feature of the evolutionary process, but, because it does not specify how the variance itself evolves in time, it cannot be used to predict evolutionary dynamics in the long run. In this paper we reconsider the problem of computing evolutionary trajectories from limited statistical information. We identify the feature of fitness distributions which controls their late-time evolution: their (suitably defined) *tail indices*. We show that the location, scale and shape of the fitness distribution can be predicted far into the future from the measurement of this tail index at some initial time. Unlike the "fitness waves" studied in the literature, this pattern encompasses both positive and negative selection and is not restricted to rapidly adapting populations. Our results are well supported by numerical simulations, both from the Wright-Fisher model and from a less structured genetic algorithm.

Keywords: evolutionary dynamics, limiting distribution, Fisher fundamental theorem of natural selection

I. INTRODUCTION

Evolutionary theory has often concerned itself with the issue of predicting the outcomes of evolution, along the lines

> If reproduction and survival are described by dynamics that satisfy properties [A] and [B], then a trait with properties [C] is more likely to be selected than a trait with property [D].

By its very nature, this outcome-centric approach deals with particular traits of particular systems, hence its conclusions are rarely generalizable. This does not mean, however, that broadly

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