

**QUANTIFYING EVOLUTIONARY PROCESSES: ROLES OF FUNDAMENTAL THEOREM OF
NATURAL SELECTION AND ADAPTIVE LANDSCAPE**

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ABSTRACT

Although there is a strong consensus that general laws in biology may exist, opinions opposing such suggestion are abundant. Based on the progress in both mathematics and biology during last 20 years, we have shown that it is indeed possible. Specifically, the evolutionary dynamics, Evolution by Variation and Selection, has been explicitly and quantitatively expressed in the unique and new form of a stochastic differential equation. Salient features of the evolutionary process of Charles Darwin and Alfred Russel Wallace are captured: the probabilistic nature of evolution, ascendancy, and the adaptive landscape. Four dynamical elements are introduced in such quantitative formulation: the ascendant matrix related to fundamental theorem of natural selection of Ronald Aylmer Fisher, the transverse matrix, the evolutionary potential function as adaptive landscape of Sewall Wright, and the stochastic drive. Inspired by the fluctuation-dissipation theorem in nonequilibrium statistical physics, a new formulation of fundamental theorem of natural selection is provided, to be free from defects known for decades in theoretical biology.

The new formulation has been applying to various problems across in biology: Wright-Fisher model in population genetics; the limit cycle type dynamics; gene switch of phage lambda infection to E Coli; cancer genesis and progression; developmental processes; metabolic network dynamics; neural network dynamics; etc. Those successes confirm that evolutionary dynamics is indeed the fundamental dynamical framework in biology, and beyond.

Keywords: evolution, nonequilibrium processes, adaptive landscape, potential function, fundamental theorem of natural selection, fluctuation-dissipation theorem, generalized Einstein relation