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Adaptation Driven by Spatial Heterogeneities[1]

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Biological evolution and ecology are intimately linked, because the reproductive success or "fitness" of an organism depends crucially on its ecosystem. Yet, most models of evolution (or population genetics) consider homogeneous, fixed-size populations subjected to a constant selection pressure. To move one step beyond such "mean field" descriptions, we discuss stochastic models of evolution driven by spatial heterogeneity. We imagine a population whose range is limited by a spatially varying environmental parameter, such as a temperature or the concentration of an antibiotic drug. Individuals in the population replicate, die and migrate stochastically. Also, by mutation, they can adapt to the environmental stress and expand their range. This way, adaptation and niche expansion go hand in hand. This mode of evolution is qualitatively different from the usual notion of a population climbing a fitness gradient. We analytically calculate the rate of adaptation by solving a first passage time problem. Interestingly, the joint effects of reproduction, death, mutation and migration result in two distinct parameter regimes depending on the relative time scales of mutation and migration. We argue that the proposed scenario may be relevant for the rapid evolution of antibiotic resistance.

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