Fluctuating Fitness in Heterogeneous Environments: Birth-Death and Death-Birth Models in Structured Populations

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We study a stochastic evolution of specific structured, multi-type populations of fixed size. In particular, we explore the effects of a fluctuating environment and heterogeneity in populations living on the vertices of graphs, where interactions between individuals are restricted to the neighbor vertices. The relative fitness of types, which plays the role of natural selection, determines the strength of types with respect to each other. The update mechanism of our model includes Birth-Death (BD) and Death-Birth (DB) processes. In the former process, first, an individual is chosen from all individuals in the population to give birth, with a probability proportional to its birth fitness. Then, a second individual, among the neighbors of the first individual, is selected to die, with a probability proportional to its death fitness among all neighbors of the first individual. The second individual dies, and an offspring of the first individual replaces it. The DB process can be defined similarly, except that the first individual is selected to die, and the second individual is chosen to give birth. We study the BD and DB processes with various population structures, wherein the birth and death fitnesses may depend on time, space, and the frequency of types in the population. We specifically investigate the fixation and invasion probability and time, and compare our results with cases where the population is well-mixed and/or the fitness does not depend on time and space. These studies are particularly helpful in understanding the evolution of cancer cells in heterogeneous tumors in fluctuating microenvironments. For example, when the presence of a drug results in the emergence of drug-tolerant cells in the population.