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A model of sympatric speciation through assortative mating

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Abstract

A microscopic model is developed, within the frame of the theory of quantitative traits, to study the combined effect of competition and assortativity on the sympatric speciation process, i.e., speciation in the absence of geographical barriers. Two components of fitness are considered: a static one that describes adaptation to environmental factors not related to the population itself, and a dynamic one that accounts for interactions between organisms, e.g. competition. A simulated annealing technique was applied in order to speed up simulations. The simulations show that both in the case of flat and steep static fitness landscapes, competition and assortativity do exert a synergistic effect on speciation. We also show that competition acts as a stabilizing force against extinction due to random sampling in a finite population. Finally, evidence is shown that speciation can be seen as a phase transition.

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1. The problem

The notion of *speciation* in biology refers to the splitting of an original species into two fertile, yet reproductively isolated strains. The *allopatric theory*, which is currently accepted by the majority of biologists, claims that a geographic barrier is needed in order to break the gene flow so as to allow two strains to evolve a complete reproductive isolation. On the other hand, many evidences and experimental data have been reported in recent years strongly suggesting the possibility of a *sympatric* mechanism of speciation. For example, the comparison of mitochondrial DNA sequences of cytochrome b performed by Schlieven and others [1], showed the monophyletic origin of cichlid species living in some volcanic lakes of western Africa. The main features of these lakes are the environmental homogeneity and the absence of microgeographical barriers. It is thus possible that the present diversity is the result of several events of sympatric speciation. An increasing number of studies referring both to animal and plant species lend further support to this hypothesis [2–9].

The key element for sympatric speciation is *assortative mating* that is, mating must be allowed only between individuals whose phenotypic distance does not exceed a given threshold. In fact, consider a population characterized by a bimodal distribution for an ecological character determining adaptation to the environment: in a regime of random mating the crossings between individuals of the two humps will produce intermediate phenotypes so that the distribution will never split. Two interesting theories have been developed to explain the evolution of assortativity. In Kondrashov and Kondrashov's theory [10] *disruptive selection* (for instance determined by a bimodal resource distribution) splits the population in two distinct ecological types that are later stabilized by the evolution of assortative mating. The theory of *evolutionary branching* developed by Doebeli and Dieckmann [11] is more general in that it does not require disruptive selection: the population first converges in phenotype space to an attracting fitness minimum (as a result of common ecological interactions such as competition, predation and mutualism) and then it splits into diverging phenotypic clusters. For example [12], given a Gaussian resource distribution, the population first crowds on the phenotype with the highest fitness, and then, owing to the high level of competition, splits into two distinct groups that later become reproductively isolated due to selection of assortative mating.

In the present paper we will not investigate the evolution of assortativity that will be treated as a tunable parameter in order to study its interplay with competition. In particular we will show that: (1) assortativity alone is sufficient to induce speciation but one of the new species soon disappears due to random fluctuations; (2) stable species coexistence can be attained through the introduction of competition; (3) competition and assortativity do exert a synergistic effect on speciation so that high levels of assortativity can trigger speciation even in the presence of weak competition and vice versa; (4) speciation can be thought of as a phase transition as can be deduced from the plot of variance versus competition and assortativity; (5) contrary to the traditional interpretation of Fisher's theorem, the mean fitness of the