MAR10-2009-001571

Abstract for an Invited Paper
for the MAR10 Meeting of
the American Physical Society

Evolutionary adaptation of phenotypic plasticity in a synthetic microbial system

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While phenotypic plasticity -the capability to respond to the environment- is vital to organisms, tests of its adaptation have remained indecisive because constraints and selection in variable environments are unknown and entangled. We show that one can determine the phenotype-fitness landscape that specifies selection on plasticity, by uncoupling the environmental cue and stress in a genetically engineered microbial system. Evolutionary trajectories revealed genetic constraints in a regulatory protein, which imposed cross-environment trade-offs that favored specialization. However, depending on the synchronicity and amplitude of the applied cue and stress variations, adaptation could break constraints, resolve trade-offs, and evolve optimal phenotypes that exhibit qualitatively altered (inverse) responses to the cue. Our results provide a first step to explain the adaptive origins of complex behavior in heterogeneous environments.