Selective sweeps in variable environments

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A selective sweep is said to occur when a new, beneficial mutation appears in a population and rapidly spreads to fixation. Because the genetic background on which the mutation occurs also rises to high frequency, one of the consequences of a selective sweep is to reduce genetic variation at nearby sites on the affected chromosome. This effect will typically be strongest at the selected site itself, where all variation is lost immediately following the sweep, and will gradually decay to either side of this site, as recombination decouples the fates of adjacent sites from that of the beneficial mutation. In theory, this pattern of locally reduced diversity can be used to identify regions in a species' genome where selective sweeps have recently occurred.

Most models used to study selective sweeps assume that the strength of selection is constant in time and space, at least for the duration of the sweep. However, organisms live in variable environments, and it is likely that adaptive evolution sometimes proceeds by way of fixation of mutations which are beneficial in some but not all environments. For example, a mutation that confers resistance to drought might be favorable in years with little rainfall, but unfavorable in especially wet years. In this case, if droughts occur frequently, the overall advantage of the mutation may be such that it undergoes a selective sweep despite there being periods when it is selected against.

The goal of this project will be to apply diffusion theory to characterize the trajectory of a selective sweep in a varying environment, and then use coalescent simulations to study the pattern of reduced diversity in the vicinity of such a sweep.

Mathematical modeling and simulation will play a central role in this project, so a student should have completed BS3a (Applied Probability) and either know or be willing to learn to program in C/C++ or some comparable language.

References: (Best read in the order listed)

J. H. Gillespie (2004) Population Genetics. A Concise Guide, Johns Hopkins University Press. (Chapters 1-4).

W. J. Ewens (2004) Mathematical Population Genetics, Springer. (Chapters 4-5).

M. Przeworski, G. Coop, J. D. Wall (2005) The signature of positive selection on standing genetic variation. Evolution 59: 2312-2323.

K. M. Teshima and M. Przeworski (2006) Directional Positive Selection on an Allele of Arbitrary Dominance. Genetics 172: 713-718.

J. H. Gillespie (1973) Natural selection with varying selection coefficients - a haploid model. Genetical Research 21: 115-120.