101. Mutations in the Gene Regulatory Network Facilitate Adaptation to Variable Environments

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Project Goals: The main goal of this project is to delineate regulatory network readjustments that drive adaptation to variable environments and impact trajectory of evolution. We are investigating the fitness benefit of accumulating mutations in a GRN or the precise mechanism(s) by which they facilitate evolution of a generalist. Ultimately, we aim to develop predictive understanding of organismal and community fitness under dynamically changing environments.

Abstract: Upon subjecting generalists to long-term directed evolution in uniform growth conditions, mutations in regulatory genes often appear early, and prior to erosion or specialization of metabolic functions. Given that regulation is important for effecting physiological readjustments, we predicted that regulatory mutations are less likely to be adaptive to a variable environment. Unexpectedly, the generalist Desulfovibrio vulgaris Hildenborough (DvH) rapidly went to extinction when it was required to repeatedly switch between two principal ecologically-relevant lifestyles: an independent sulfate-respiring lifestyle and a lifestyle that does not require sulfate-respiration but depends on syntrophic interaction with a methanogenic archaeon -- Methanococcus maripaludis (Mmp). Disruptive mutations in the DvH regulatory network, by contrast, stabilized this dynamic lifestyle switching, significantly prolonging time to extinction. Global transcriptome analyses demonstrated that the regulatory mutations facilitated adaptation by potentially minimizing the energetic burden associated with up and down regulating genes during environmental shifts. Even under uniform selection pressure, the serial transfers that are necessary for long-term evolution experiments also impose repetitive environmental shifts, explaining why regulatory mutations appear early.

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