Mechanisms of rapid adaptation to changed environment

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A widely accepted model for the evolution of cave dwelling animals posits cave colonization by a surface ancestor followed by the acquisition of adaptations over many generations until a fully cave-adapted form is achieved. However, the speed of adaptive evolution in some species is difficult to reconcile with this conventional viewpoint, suggesting the importance of alternative mechanisms that operate over a shorter timescale. To obtain insight into these mechanisms, we used Astyanax mexicanus, a single teleost species consisting of two morphs, an ancestral surface-dwelling morph (surface fish) and a derived cave-dwelling morph (cavefish). We exposed Astyanax surface fish (SF) to completely dark (D/D) conditions as embryos and compared them to siblings placed on a normal photoperiod (L/D SF). We identified a number of traits that change in D/D SF raised for several months to couple of years in complete darkness compared to L/D SF, including endocrine, stress-related, weight-related, and metabolic changes, as well as a change in the expression of approximately 350 genes. Remarkably, most of these changes are associated with known adaptations to the cave environment and alter in the direction of the cavefish phenotype. Our results indicate that appearance of many cave-associated traits can occur within a single generation by phenotypic plasticity. By comparing gene expression in D/D SF, which were raised in darkness beginning a few hours after fertilization, with L/D SF, we determined that all of the molecular mechanisms known to facilitate phenotypic plasticity, including upregulation of HSP90, endocrine modifications, and epigenetic changes, may be involved in this process in Astyanax. The results suggest that phenotypic plasticity followed by genetic assimilation may be an important mechanism for the rapid evolution of cave-related traits during the colonization of A. mexicanus to dark cave environments.