Applying Epigenetics to 21st-century Evolutionary Theory

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For most of the 20th century, it was taken for granted that the sole hereditary basis of evolutionary change is random genetic (DNA) variation. The selection of variations and the generation of variations were assumed to be two independent processes. Since the 1990s, however, this view has been increasingly questioned. It has become clear, particularly though studies of epigenetics, that some variation does not depend on differences in DNA sequence, and that the selective environment can influence where and when heritable change occurs.

We will argue that phenotypic adjustments to novel and often stressful conditions involve processes that are akin to trial-and-error learning: there is ontogenetic exploration of different physiological responses at different levels of organization, and those responses that enable survival and reproduction are stabilized. These stabilized states can be transmitted between generations, and may lead to additional rounds of exploration followed by further ontogenetic and hereditary selection and stabilization. Epigenetic mechanisms play an important role in such processes of adaptation. We discuss several studies which exemplify these processes at the molecular level, and suggest that this type of physiological and epigenetic “learning” can lead to novel evolutionary adaptations. We believe that 21st-century evolutionary theory will require expanded and intertwined notions of variation-generation and of selection, and that the Price equation may provide a framework that can accommodate such a view.