‘BET HEDGING’ AGAINST CLIMATE CHANGE IN DEVELOPING AND ADULT ANIMALS: ROLES FOR STOCHASTIC GENE EXPRESSION, PHENOTYPIC PLASTICITY, EPIGENETIC INHERITANCE AND ADAPTATION

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ABSTRACT

Animals from embryos to adults experiencing stress from climate change have a numerous mechanisms available for enhancing their long-term survival. In this review we consider these options, and how viable they are in a world increasingly experiencing extreme weather associated with climate change. A deeply understood mechanism involves natural selection, leading to evolution of new adaptations that help cope with extreme and stochastic weather events associated with climate change. While potentially effective at staving off environmental challenges, such adaptations typically occur very slowly and incrementally over evolutionary time. Consequently, adaptation through natural selection is in most instances regarded as too slow to aid survival in rapidly changing environments, especially when considering the stochastic nature of extreme weather events associated with climate change. Alternative mechanisms operating in a much shorter time frame than adaptation involve the rapid creation of alternate phenotypes within a life cycle or a few generations. Stochastic gene expression creates multiple phenotypes from the same genotype even in the absence of environmental cues. In contrast, other mechanisms for phenotype change that are externally driven by environmental clues include well-understood developmental phenotypic plasticity (variation, flexibility), which can enable rapid, within-generation changes. Increasingly appreciated are epigenetic influences during development leading to rapid phenotypic changes that can also immediately be very widespread throughout a population, rather than confined to a few individuals as in the case of favorable gene mutations. Such epigenetically-induced phenotypic plasticity can arise rapidly in response to stressors within a generation or across a few generations and just as rapidly be ‘sunsetted’ when the stressor dissipates, providing some capability to withstand environmental stressors emerging from climate change. Importantly, survival mechanisms resulting from adaptations and developmental phenotypic plasticity are not necessarily mutually exclusive, allowing for classic ‘bet hedging’. Thus, the appearance of multiple phenotypes within a single population provides for a phenotype potentially optimal for some future environment. This enhances survival during stochastic extreme weather events associated with climate change. Finally, we end with recommendations for future physiological experiments, recommending in particular that experiments investigating phenotypic flexibility adopt more realistic protocols that reflect the stochastic nature of weather.