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750 – 1000 word summary #3

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Adaptive Phenotypic Plasticity & Epigenetics

*Non-adaptive plasticity potentiates rapid adaptive evolution of gene expression in nature.*

Ghalambor et al 2015

*The epigenetic landscape of transgenerational acclimation to ocean warming*

Ryu et al 2018

*Epigenome-associated phenotypic acclimatization to ocean acidification in a reef-building coral*

Liew et al 2018

Phenotypic plasticity refers to the ability of an organism to alter its phenotype (i.e. appearance or tolerance to a stressor), often based on their environment. This capability leads to a large potential for adaptation within a species, especially when the trait is beneficial and has a bigger plasticity potential. Epigenetics refers to molecular mechanisms that influence the gene expression and change the phenotype of an organism without changing the genotype. In recent studies, both phenotypic plasticity and epigenetics have been proposed to be inherited, thus altering the fitness of an organism’s offspring. This transgenerational effect is yet to be fully elucidated but could have tremendous impacts on a population’s ability to adapt to their local environment under rapid climate change. Depending on the organism and study system, this theory could be difficult to provide evidence for, which leads to further speculation. For example, controlling several generations of corals has proven difficult because of the organism’s sensitivity and the variation in spawning.

One of the many questions that is driving recent research involves the unknown specifics between a trait’s plasticity and the trait’s evolution. More recent work provides evidence for heritable variation, which shows a weakness in the traditional theory that plasticity doesn’t affect evolution. Plasticity is non-adaptive when the variation strays away from the local optimum and is adaptive when variation allows for natural selection to act on certain traits that are best fit for a local environment.

Ghalambor test whether or not phenotypic plasticity, specifically in gene expression, constrains adaptive evolution. Their ultimate findings were that after transplantation of Trinidadian guppies to a low-predation environment, gene expression plasticity did not aid in adaptive evolution. Overall, the researchers suggest that adaptive plasticity constrains evolution, compared to non-adaptive plasticity increases the strength of directional selection, and therefore aids evolution. This experiment was able to identify an a priori prediction of evolutionary change with their older evolutionary descendent population being exposed to the same experimental conditions as the manipulated populations. The research team identified differences in transcription (gene expression) to be predator-induced plasticity, compared to differences between populations in the same conditions over several generations were because of heritable variation. The team’s main conclusion was that although plasticity aids in evolution, it is not because plasticity itself is adaptive, but because plasticity is under strong selection to change.

The results from Ghalambor provide another perspective on what exactly natural selection is acting on, and also has implications on the way we think about local populations surviving climate change stressors. The mechanisms by which organisms can adapt to their local environment, including epigenetics, is unclear.

Ryu uses several generations of a coral reef fish, *A. polyacanthus*, to demonstrate significant effects of DNA methylation and transgenerational acclimation on the organism’s fitness, specifically the population’s metabolic scope. This study focuses on the mechanisms that might be influencing evolution, compared to the previous study focusing on how a population’s plasticity is being selected on by evolution. It is unclear in what proportion each concept (i.e. epigenetics, transgenerational effects, breadth of plasticity) determines an organism’s phenotype and thus tolerance to climate change. Ryu demonstrated that this species of fish can alter their aerobic scope significantly better if their parental lines experienced the stress (transgenerational treatment) versus solely the offspring being exposed to the stressor (developmental treatment). The results suggest that a transgenerational, slow exposure scenario is more efficient than developmental or a transgenerational, rapid exposure scenario. Because of climate change, particularly rapid temperature change on a coral reef, the transgenerational and rapid scenario might be more likely to occur for corals. Since environmental change happens during the summer and generation times are longer than a single summer for corals, the hope of transgenerational effects for conservation might be less efficient than once thought. This is an example of using phenotypic plasticity and epigenetics as a way to advise conservation strategies like choosing locations for conservation trees. From this study, we might separate trees in different locations for each generation; the warmest location being for the 3rd/4th generation rather than the 1st generation used in the restoration trees. Although the take home messages of this paper were not conservation related, there is potential to use phenotypic plasticity and epigenetic mechanism knowledge to predict local adaptation in conservation strategies. Critical to this paper’s results is the connection between up and down regulations, DNA methylation to function. Many studies are working with non-model organisms or even partially annotated model organism genomes, which makes the environmental application and ties to adaptive evolution very difficult. (This paper addresses similar questions to those I want to ask in my dissertation!! Yay genomics!!)

Liew addresses a long-standing question in epigenetics of how the whole-genome methylation changes actually affect or correlate to a particular phenotypic change. After subjection to long-term pH stress, corals exhibited changes in transcription, and is shown to fine-tune expression of highly expressed genes. This study associated changes in pathways regulating cell cycle and body size, which are traits influenced by pH stress. Similar to the Ryu study, the authors highlighted the DNA methylation change to phenotype and particular, annotated genes.

It is thought that DNA methylation (one form of epigenetics) might be able to buffer organisms’ reaction to climate change. These mechanisms could give rise to tighter control of the organism’s phenotype and thus have implications on phenotypic plasticity, which would eventually impact the adaptation of a species or population. Although all experimental, these three papers addressed the question of functional and environmental application of epigenetics and plasticity to local adaptation.