# The Role of Epigenetic Modifications in Evolution: Understanding How Environmental Factors

## Shape Heritable Gene Expression Across Generations

**Damla Naz Haymanalı**
Dubai College

***Abstract*—Epigenetic modifications provide a mechanism through which environmental factors can induce heritable changes in gene expression without altering the underlying DNA sequence. While the Modern Synthesis emphasises genetic mutation and natural selection as the primary drivers of evolution, growing evidence highlights the role of DNA methylation, histone modifications, and non-coding RNAs in enabling phenotypic plasticity and transgenerational inheritance. These mechanisms allow organisms to respond to environmental conditions more rapidly than genetic changes alone would permit, and in some cases, these responses are transmitted across generations via the germline. Empirical studies from both plant and animal systems demonstrate how exposures to stress, nutritional changes, and chemical disruptors can leave stable epigenetic marks. Additionally, large-scale genomic rearrangements such as chromoanagenesis point to the potential for abrupt structural variation to interact with epigenetic processes. Incorporating such findings within the framework of the Extended Evolutionary Synthesis expands traditional evolutionary models, offering a more integrated understanding of how environmental stimuli shape heritable variation and influence evolutionary trajectories over both short and long timescales.**

The Modern Evolutionary Synthesis (MS), formulated in the early 20th century, remains the dominant theoretical framework in evolutionary biology, integrating Mendelian genetics with Darwinian natural selection to explain the mechanisms driving phenotypic variation and adaptation [1]. This neo-Darwinian paradigm is based on the premise that heritable genetic variation arises primarily through random mutations in the DNA sequence. Natural selection acts upon these variations, favouring traits that present a selective advantage while eliminating harmful mutations over successive generations. The MS conceptualises evolution as a gradual and incremental process, controlled by mutation, genetic drift, gene flow, and selection within populations. However, this gene-centric view of evolution has been increasingly challenged by emerging research in epigenetics, which demonstrates that environmental influences can induce heritable modifications in gene expression without altering the underlying DNA sequence [2]. While the MS assumes that heritable variation arises solely from genetic mutations, epigenetics provides an alternative mechanism

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