

Environmental Influence on Mutational Processes: A Dialectical Materialist Perspective

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ABSTRACT

This article examines the mutational process from the standpoint of dialectical materialism, challenging the prevailing notion of mutation as a purely random phenomenon. By analyzing classical and contemporary biological data—such as the Cairns experiment on adaptive mutation, stress-induced mutagenesis (SOS response), and the molecular action of nucleotide analogs—it becomes clear that the environment plays a fundamental role not only in selecting but also in initiating mutations. This insight reframes mutagenesis as a materially conditioned and environmentally mediated process. Through dialectical categories such as necessity, contingency, and the “whole and moment” framework, the paper integrates philosophical analysis with empirical data to propose a systemic, causally intelligible theory of mutation. The implications of this approach extend to evolutionary theory, genetics, and systems biology.

Keywords: mutation, environment, dialectical materialism, Cairns experiment, evolutionary theory.

Introduction

Modern evolutionary biology largely relies on the theory of random mutations and natural selection. However, emerging knowledge in genetics, epigenetics, and molecular biology reveals that the environment is not only a selector but may also serve as a direct stimulator of mutation occurrence. Evidence such as John Cairns' experiments, SOS mutagenesis mechanisms, and the influence of nucleotide analogs suggests that mutational processes may be material responses to environmental stimuli, rather than random mechanical errors. In this paper, we analyze this framework through the lens of dialectical materialism.

1. Dialectical Materialist View on Randomness and Necessity

In dialectical materialism, randomness is not an absolute or causeless phenomenon. Rather, it reflects a part of necessity not yet revealed or fully understood. In evolutionary processes, randomness often points to the limits of current scientific understanding. Environmentally induced mutations, rather than contradicting natural law, can be interpreted as their concrete manifestation.

2. Questioning the Randomness of Mutation

In John Cairns' experiment [1], bacteria developed mutations specifically in loci required for lactose metabolism, implying not randomness but environmentally driven mutational responses. This challenges the idea that mutations are entirely stochastic. Similarly, in the SOS repair mechanism, microbes respond to stress through activation of specific mutagenic pathways [2].

3. Nucleotide Analogs as Environmental Mediators

Nucleotide analogs introduced into cells by environmental factors (e.g., 5-bromouracil, azacytidine) directly influence genetic mechanisms. Their intracellular accumulation increases mutation rates under specific chemical conditions.

This exemplifies how material environmental factors—rather than abstract randomness—can determine molecular genetic changes.

4. Dialectics of “Whole and Moment”: Environment and Life

The Hegelian concept of “whole and moment,” as interpreted through Engels' dialectical materialism, aligns well with biological systems: the environment represents the “whole,” which defines and shapes the “moment”—life. Mutational events do not occur in isolation; they are moments, that is, reactions to the totality that is the environment. This relationship generates new evolutionary pathways.

5. Possible Conflicts and Responses

(a) Does this contradict neo-Darwinism?

Your perspective does not deny natural selection but refines discourse at the level of mutation. The environment is not only a subsequent selector but a primary regulator. This aligns with modern findings on specific mutagenesis mechanisms [3]

(b) How do we address statistical evidence for randomness?

Many phenomena appear random simply because their underlying laws remain undiscovered. For dialectical materialism, randomness is a temporary category that knowledge will replace with causal explanation as science progresses.

(c) Are philosophical categories merely metaphors?

No. “Whole and moment” is not just metaphorical but a model of systemic interdependence, comparable to systems biology. Life exists only in interaction with its environment, a dialectical unity.

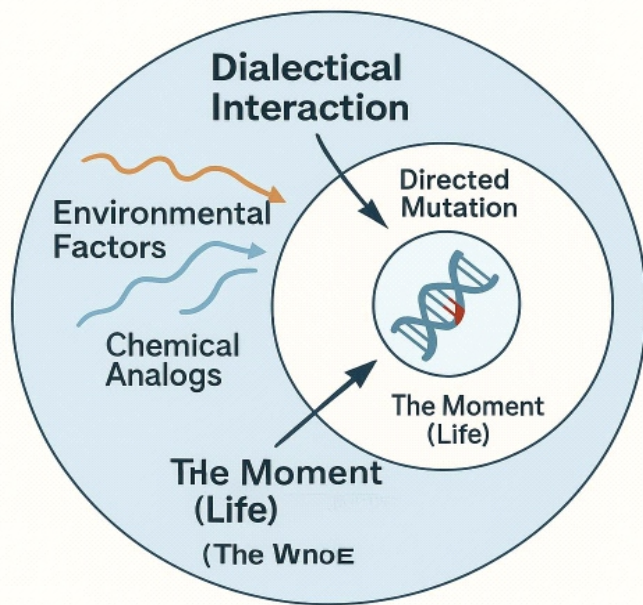


Figure1: Dialectical Interaction Between Environment and Life in Mutagenesis

This figure illustrates the dialectical relationship between the environment (the "Whole") and living organisms (the "Moment") in the context of mutation. According to this perspective, mutations do not arise randomly but as necessary and material responses to environmental

pressures. Environmental factors—such as chemical exposure, stress, or nutrient availability—intervene directly by increasing the presence of mutagenic agents (e.g., nucleotide analogs) or activating pathways like the SOS response. The organism, embedded in and shaped by its total environment, undergoes changes that are both induced and constrained by this context.

This visual model reflects the dialectical materialist view that randomness is an expression of as-yet-unrevealed necessity.

Conclusion

Mutation, as a biological phenomenon, should not be interpreted solely as a random event. It is often a material response of genetic structures to environmental influence. From the viewpoint of dialectical materialism, such phenomena are expressions of necessity, governed by yet-to-be-explored natural laws. This approach broadens scientific understanding of mutation and offers a philosophical reorientation in evolutionary biology.

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