

The Role of Dialectical Materialism in Evolutionary Biology: Redefining Randomness and Environmental Influence on Mutation

Iosebi Gioshvili

PhD Doctorate in Biology

kamu.gioshvili@mail.ru

Abstract

This paper argues that the conventional view of mutation as a purely stochastic process is philosophically and empirically insufficient. Grounded in the methodology of dialectical materialism, the argument challenges the dogma of "random mutation" by emphasizing the role of material conditions-especially the environment-in shaping genetic variation. Drawing on John Cairns' landmark bacterial experiments, as well as contemporary insights from epigenetics, the article proposes a model in which mutation is not aimless, but a dynamic reaction to external stimuli. In dialectical terms, chance is not absence of cause, but the appearance of causality under complex conditions.

1. Introduction: Randomness and the Mechanistic Model in Evolution

In the neo-Darwinian framework of evolutionary biology, mutation is understood as a blind, spontaneous error in DNA replication, statistically distributed and independent of environmental needs or organismic function (Mayr, 1982). This perception reflects a broader mechanistic paradigm that separates the internal processes of the organism from its material context.

Such an approach, while methodologically useful in genetics, fails to consider the possibility that mutation itself may be regulated-or at least conditioned-by the interaction between organism and environment. This epistemological gap invites reevaluation, particularly through a dialectical materialist lens.

2. Dialectical Materialism and the Critique of Randomness

Dialectical materialism, rooted in the works of Marx and Engels, sees nature not as a static assembly of objects but as a dynamic, interrelated process governed by internal contradictions and development through change (Engels, 1883). Within this framework, "randomness" is not

synonymous with "lack of cause"; rather, it denotes causality not yet understood or the manifestation of complex interactions that exceed linear analysis.

Consequently, mutations should not be regarded as purely accidental. Instead, they emerge as part of a dialectical tension between the organism and its changing material conditions—a tension that may activate latent capacities or reorganize internal structures in response to external pressures.

3. Cairns' Experiment: Environmentally Induced Mutation

In 1988, John Cairns and his colleagues published a now-famous study involving *E. coli* bacteria that lacked the capacity to metabolize lactose (Cairns et al., 1988). When placed in an environment where lactose was the sole energy source, these bacteria gradually produced mutants capable of digesting lactose—at frequencies higher than would be expected from spontaneous mutation alone.

This phenomenon suggested that the environment may stimulate or guide mutation, at least under stress conditions. Cairns referred to this as "directed mutation," not in the Lamarckian sense of teleological adaptation, but as an observation that mutation rates and types were not independent of environmental context.

From a dialectical standpoint, this result is significant: the environment is no longer merely a selective background, but an active participant in the emergence of genetic change.

4. Epigenetics and Environmental Influence on Heredity

Modern epigenetics further supports the idea that the environment can shape heredity. Mechanisms such as DNA methylation, histone modification, and non-coding RNA regulation do not alter the nucleotide sequence but modulate gene expression in a heritable manner (Jaenisch & Bird, 2003).

Stress conditions, nutritional states, and exposure to toxins have all been shown to induce epigenetic changes that are passed on to offspring-demonstrating that inheritance is not sealed off from environmental stimuli, but dynamically responsive to them (Jablonka & Lamb, 2005).

These insights offer empirical validation for the dialectical idea that external contradictions influence internal transformation. The organism is not a closed system; it is porous to the material world and actively shaped by it.

5. Conclusion: Mutation as Systemic Reaction, Not Pure Chance

Under dialectical materialism, mutation is better understood not as a stochastic accident, but as a systemic and conditional response to material contradictions. Cairns' findings, combined with epigenetic evidence, call into question the notion of absolute randomness in mutation and invite a richer understanding grounded in causality and interaction.

Evolution, then, is not merely the product of blind variation and passive selection, but a historical process of mutual transformation between organisms and their environments. In this view, chance is not the negation of law, but the form in which law manifests under complex material relations.

References

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