

Mortality as Emergence Collapse

An Operator-Theoretic Reading of Bioelectric Morphogenesis

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Abstract

Genetic explanations of biological form and mortality reach their limits as soon as phenomena such as robust regeneration, form correction, and goal-directed self-organization come into view. Work on bioelectric morphogenesis, particularly by Michael Levin, shows that morphological stability is determined to a significant extent by distributed bioelectric feedback loops and persistent goal states that are not reducible to genetic coding.

The present contribution proposes an operator-theoretic reading of these findings. Emergence is not understood here as a singular event, but as a cyclical process that mediates between a space of possibilities, partial stabilization, and manifest form formation. Mortality appears, in this perspective, not primarily as a genetic defect or an accumulation of damage, but as an irreversible breakdown of this emergence cycle.

This framing allows for a coherent classification of regeneration, cancer, and aging processes as different modes of disturbed or reconfigured operator closure of biological order. The approach is intended as a theoretical complement to bioelectric morphogenesis and aims to make explicit the conditions of form stability and their limits.

1. Problem Statement: The Limits of Genetic Explanations

The classical molecular-biological explanation of development and form stability is based on the assumption that genes function as the primary carriers of biological information and that morphological order emerges essentially from genetic regulation. However, this model reaches its limits where organisms maintain or restore stable goal states even though local structures have been massively altered or destroyed.

In particular, phenomena such as:

- goal-directed regeneration after tissue loss,
- form corrections following experimental interventions,
- as well as the stability of global body plans despite local variations

cannot be adequately explained as a linear consequence of genetic activation.

These findings suggest that genes constitute necessary, but not sufficient, conditions of morphological order. What is decisive is not solely which molecular processes take place, but how biological systems stabilize and reconfigure order over time.

The central question thus shifts from genetic causality to systemic organization.

2. Bioelectric Morphogenesis: Order Beyond Genetic Control

Work on bioelectric morphogenesis, particularly by Michael Levin, has shown that morphological order does not arise exclusively from genetic regulation, but is determined to a significant degree by bioelectric states and their collective dynamics. Membrane potentials, ion fluxes, and electrical gradients do not function merely as local signals, but as distributed control structures that coordinate developmental trajectories across space and time.

These bioelectric patterns are capable of representing goal states of form, which Levin explicitly describes as *goal states* or morphogenetic target states. They enable organisms to return to stable configurations after massive interventions—such as tissue loss, cellular rearrangement, or experimental manipulation—without requiring a corresponding genetic recoding.

Central to this account is the concept of a persistent pattern memory: morphological order is not fully localized in material structures, but in dynamic states that serve as references for correction and regeneration. Development thus appears not as the mere unfolding of a plan, but as a feedback-based process that detects and compensates deviations.

The explanatory focus therefore shifts fundamentally. In place of hierarchical control by genes emerges a model of distributed control, in which biological systems actively maintain and reconfigure their form. This perspective opens an approach to regeneration, cancer, and aging that cannot be reduced to defects of individual components.

3. Emergence as a Cyclical Process

In many theoretical approaches, emergence is understood as a punctual event: as the transition from disordered complexity to stable structure. Such an understanding, however, remains insufficient to explain the temporal persistence of biological form. Form is not a result that emerges once, but an order that must be continuously maintained.

Emergence is therefore conceived here as a cyclical process comprising three structurally distinguishable, yet inseparably intertwined phases:

- **Submergence** designates the embedding of the system in an open space of possibilities, in which alternative organizational forms remain potentially available.
- **Indimergence** describes the partial stabilization of relations, feedbacks, and control loops that temporarily fix order without fully closing it.
- **Emergence** refers to the manifest expression of functional form in which these relations become effective.

These phases are not sequential in the sense of a completed developmental trajectory, but are recursively interconnected. Biological form exists only as long as the transition between possibility, stabilization, and manifestation is actively maintained.

From this perspective, stability is not a static state, but an operative achievement that requires a continuous re-binding to a space of possibilities under sustained feedback. Emergence thus does not describe the origin of order, but its ongoing reproduction under conditions of structural openness.

4. Mortality as the Breakdown of the Emergence Cycle

Against the background of a cyclical conception of emergence, mortality can be newly defined. Rather than understanding it primarily as the consequence of genetic defects, molecular accumulations, or energetic exhaustion, mortality appears here as the irreversible breakdown of the emergence cycle that stabilizes biological form over time.

As long as submergence, indimergence, and emergence recursively interlock, a biological system remains capable of recognizing, compensating for, and correcting deviations. If this cyclical feedback is permanently interrupted, however, the system loses its capacity for self-reference. Order can then no longer be related to a more general space of possibilities.

From this perspective, chaos is not the cause, but the result of the collapse of operator closure. The observable disintegration of biological processes points to a failure of translation between levels—such as between local dynamics and global goal states—rather than necessarily to a lack of information or energy.

Mortality thus marks not merely a limit of biological performance, but a structural limit of emergent order, beyond which recursive self-reference can no longer be maintained. It designates the point at which the operative reconfiguration of the system is no longer possible and the binding to stabilizing goal states is permanently lost.

5. Regeneration, Cancer, and Aging as Modes of Disturbed Emergence

The cyclical emergence perspective allows for a coherent classification of central biological phenomena without resorting to reductionist or teleological explanations. Regeneration, cancer, and aging processes can be described as different modes of disturbance or reconfiguration of the emergence cycle.

From this viewpoint, regeneration does not appear as a repetition of original development, but as a reactivation of the emergence cycle. Bioelectric goal states function as reference points against which deviations can be recognized and corrected. What is decisive is not the complete reconstruction of earlier states, but the restoration of operative feedback between possibility, stabilization, and manifestation.

Cancer, by contrast, can be understood as a case of partial decoupling. Local processes retain their internal dynamics, but lose their integration into global feedback structures. The system fragments into competing partial orders whose autonomy is no longer regulated by higher-order goal states. Pathology thus arises not through mere disorder, but through misdirected stabilization under conditions of lost global feedback.

Aging, finally, can be interpreted as a gradual fragilization of cyclical closure. With increasing time, the binding between emergent form and the space of possibilities becomes more unstable; corrections become slower, less complete, or fail to occur. Aging, in this sense, is not mere wear, but a temporal erosion of operator reconfigurability.

This reading connects bioelectric findings with a structural theory of emergent order and makes it possible to understand mortality as a boundary phenomenon without reducing it to individual causes.

6. Implications and Outlook

The operator-theoretic reading of bioelectric morphogenesis proposed here complements existing models by introducing an explicit theory of cyclical emergence. It makes visible that morphological stability can be understood neither as a static state nor as the mere result of genetic processes, but as an ongoing operative closure between possibility, stabilization, and manifest form.

In this perspective, mortality does not appear as an isolated biological failure, but as a boundary phenomenon of emergent order. This framing makes it possible to consider regeneration, cancer, and aging processes within a shared structural reference framework without leveling their respective internal logics.

For future research, this raises the question of to what extent targeted interventions in bioelectric regulatory circuits can be understood as reconfigurations of operator cycles. Such an approach could contribute to a more precise determination of the conditions under which biological form is restorable and to a systematic investigation of the limits of biological plasticity.

The present contribution does not present itself as a replacement for existing biological explanations, but as a theoretical extension that makes explicit the structural preconditions of form stability. In this sense, it aims to embed bioelectric morphogenesis within a more general emergence context that renders the finitude of biological order intelligible without reducing it.

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