Life as a Metastable Constraint on Electromagnetic Equilibrium: From Photon Emission to Mitosis and Conscious Prediction

Hrishi Mukherjee

New Canada

Abstract

Life is often described as a property of matter, yet modern physics increasingly frames it as a process maintained far from thermodynamic equilibrium. In this work, life is interpreted as a symmetry-breaking, metastable organization that constrains electromagnetic energy flow while preserving informational invariants. A continuous physical line is traced from unavoidable photon emission in early metabolism, through mitosis as invariant replication under entropy, to consciousness as predictive regulation of boundary conditions. This unified perspective integrates thermodynamics, electromagnetism, and information theory without invoking additional ontological assumptions.

Keywords: Life, Electromagnetic Fields, Thermodynamics, Information Theory, Mitosis, Consciousness

1. Introduction

Life exists within a universe governed by fields, fluctuations, and equilibrium-seeking dynamics. Among these, electromagnetic (EM) interactions dominate chemistry, molecular bonding, heat exchange, and biological structure. While it is tempting to describe life as a disturbance of the EM field, such phrasing misidentifies the target. The electromagnetic field is already dynamic and symmetric; what life disrupts is equilibrium.

This paper advances a unified formulation: *life emerges as a self-sustaining, asymmetric destabilization of local thermodynamic equilibrium, implemented through electromagnetic interactions and protected by invariant informational structure*. This framing allows photon emission, biological replication, and consciousness to be understood as successive manifestations of the same physical principle.

2. Electromagnetic Interaction and Equilibrium

Electromagnetic interactions mediate nearly all biologically relevant forces. Molecular bonds, redox chemistry, ion gradients, and thermal radiation are all EM phenomena. Any organized chemical system above absolute zero must radiate energy, primarily as infrared photons, in accordance with thermodynamics.

Life does not oppose electromagnetism; it exploits it. The EM field acts as the primary interface through which living systems exchange energy with their environment while remaining locally ordered.

3. Photon Emission as the First Signature of Life

The earliest living systems were necessarily far from equilibrium. Metabolic activity generates excited molecular states that must relax. Most relaxation pathways dissipate energy as heat, but a nonzero fraction produce photon emission.

This emission is not communicative or adaptive in origin. It is the unavoidable energetic cost of maintaining structure:

$$\text{Maintained Order} \Rightarrow \text{Exported Entropy} \Rightarrow \text{Radiation}. \quad (1)$$

Thus, photon emission marks the first physical boundary between passive chemistry and active biological organization.

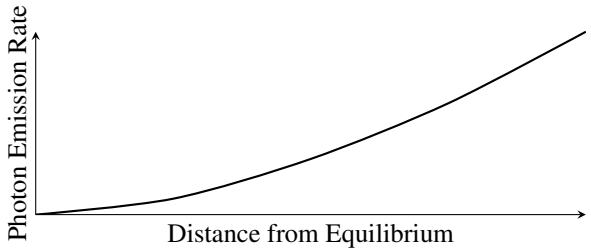

Figure 1: Photon emission increases as biological systems are driven further from thermodynamic equilibrium. Emission is a consequence of maintained order.

4. Mitosis as Invariant Replication Under Entropy

Mitosis represents a critical escalation: the active replication of informational invariants across time. Let $\mathcal{I}$ denote the set of biological invariants (genomic sequence, partial epigenetic state, organizational motifs). Replication implements the transformation

$$\mathcal{I}(t) \rightarrow \mathcal{I}(t + \Delta t) \quad (2)$$

within a noisy, thermodynamic environment.

Replication is therefore an error-correcting process that consumes energy to resist degradation. Photon emission and heat

dissipation are intrinsic costs of preserving identity against equilibration.

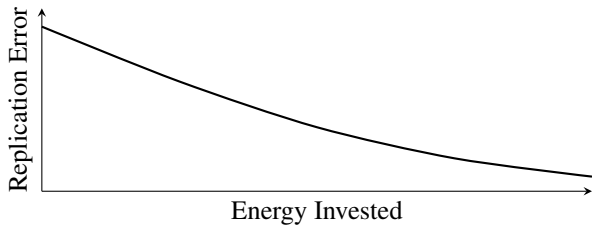

Figure 2: Mitosis suppresses replication error by expending energy, enforcing informational invariants against entropic noise.

5. From Replication to Prediction

Once replication stabilizes identity, selection favors systems that anticipate perturbations rather than merely react to them. This marks the transition from homeostasis to predictive regulation.

Neural systems instantiate this principle: sensory input corrects internal models, and action regulates future boundary conditions. Perception becomes inference, and behavior becomes control.

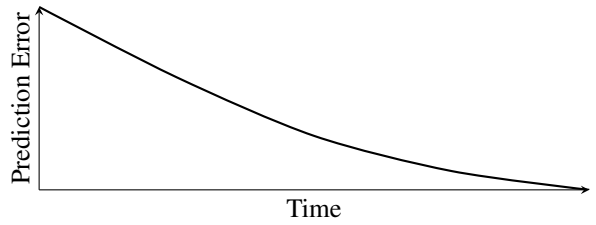

Figure 3: Predictive systems minimize error over time by regulating internal and external boundary conditions.

6. Unified Line: From Photons to Meaning

The preceding analysis yields the following unified statement:

> **Life begins by maintaining invariants against equilibrium, leaks photons as the energetic receipt, learns to copy itself through mitosis as information propagation, and culminates in consciousness when it predicts and regulates its own boundary conditions—allowing structured perturbations, such as music, to be experienced as meaning.**

No additional metaphysical assumptions are required. The sequence follows directly from thermodynamics, electromagnetism, and information theory.

7. Conclusion

Life is best understood as a metastable constraint system that uses electromagnetic interactions to remain far from equilibrium while preserving informational invariants. Photon emission records the energetic cost of this refusal; mitosis secures identity across time; consciousness extends the same logic into predictive regulation and subjective experience. Life is not a disturbance of the universe, but one of its most persistent patterns.

References

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