The Evolution of Code from Collapse: A Theory of Oscillatory Symbol Genesis

Oscillatory Dynamics, Kolmogorov Compression, and Semiotic Emergence

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Abstract

We introduce a physical theory of symbolic code emergence grounded in oscillatory coherence dynamics, offering a new explanation for how meaning, memory, and language arise from collapse events in dynamical systems. Unlike standard genetic or computational models that assume pre-existing syntactic rules, we show how symbolic structure naturally arises from repeated, structured failures of phase coherence. Drawing from Kolmogorov complexity, bioelectric patterning, and nonergodic dynamics, we argue that codes are frozen memories of collapse events—compressions of repeated decoherence under bounded phase geometries. A collapse pattern is only meaningful to the extent that it becomes describable with fewer bits than its uncompressed representation. This transition from noise to symbol is the Kolmogorov threshold of code emergence. Our theory explains not only the origin of biological codes (e.g., the genetic code), but also the emergence of semantic layers in neural systems, artificial intelligence, and potentially cosmological constants. We argue that codes are entropy-minimizing parasites—stabilizing local structure by feeding on dynamical richness. Building on Levin's framework of ingressing patterns, we show how codes represent a specific class of physical manifestation resulting from constrained phase collapse when Platonic patterns interface with material systems. Our model reframes symbol formation as a thermodynamic compromise between predictability and adaptability, with profound implications for understanding life, consciousness, and the apparent fine-tuning of physical laws.

1 Introduction

The origin of symbolic codes represents one of the deepest mysteries in science. How does a universe of continuous fields and forces give rise to discrete symbols, rules, and meanings? The genetic code, with its arbitrary yet universal mapping between nucleotide triplets and amino acids, exemplifies this puzzle. Traditional approaches invoke frozen accidents (3), chemical affinities (14), or optimization principles (4). Yet these explanations begin with symbols already in place, failing to address how discrete coding emerges from continuous dynamics.

We propose a radically different approach: codes arise from the physics of coherence collapse in oscillator fields. When coupled oscillators fail to maintain phase coherence in predictable ways, these collapse events generate information. When the same collapse patterns recur in similar contexts, they become compressible—and this compression *is* the birth of a code.

Recent work by Levin (6) on "ingressing minds" provides a complementary framework, suggesting that patterns from a non-physical "Platonic space" actively inform physical systems. ('Platonic' here denotes an ontological shorthand for pattern space; no essentialist claim is required.) We extend this by proposing that oscillatory fields serve as the interface through which these patterns communicate with matter: not by encoding information about the patterns, but by providing a latent space through which patterns can influence dynamics prior to measurement. Codes emerge not as representations of these patterns, but as the informational residue left behind when Platonic forms interact with material constraints through this interface.

This framework unifies disparate phenomena across scales:

- **Biological codes**: Genetic, neural, and morphogenetic patterning
- **Cognitive codes**: Language, concepts, and symbolic reasoning
- **Physical codes**: The apparent fine-tuning of constants and laws
- **Artificial codes**: Emergent representations in neural networks

Our central thesis: **Codes are vampires**—they reduce entropy by feeding on dimensional freedom, offering stability at the cost of adaptive potential.

2 Theoretical Foundation

2.1 The Ontological Hierarchy: From Platonic Pattern to Physical Code

Before examining oscillator dynamics, we must establish the ontological structure underlying our theory. Following Levin's framework of ingressing patterns (6), we propose three distinct levels of reality. This tri-level structure echoes existing formalisms such as Deacon's dynamical depth hierarchy and Rosen's modeling relations, but offers a specific mechanism for inter-level communication:

1. **Platonic Space**: A realm of pure pattern existing independently of physical instantiation or measurement. These patterns are not information in Shannon's sense—they exist prior to any distinction between states.

2. **Latent Oscillatory Space**: The high-dimensional phase relationships between weakly coupled oscillators. This space serves as the interface through which Platonic patterns communicate with physical dynamics without yet being measured or collapsed into information. Whether patterns "exist" here or merely "act through" here is beyond empirical determination—what we can say is that patterns manifest their influence here as biases in the probability landscape of possible phase configurations, making certain collapse sequences more likely than others.

3. **Physical Information Space**: The realm of measured states, collapsed phases, and actual bits. This is where codes emerge—not as the patterns themselves, but as compressed records of how patterns touched matter.

The crucial insight: information and codes don't contain the Platonic patterns; they merely record the scars left by pattern-matter interactions. The pattern's existence is independent of physical measurement—we can only observe its effects through the latent oscillatory interface. A Platonic pattern "ingresses" by shaping the contours of the latent space—influencing which phase relationships are stable and which are prone to collapse—without itself becoming information until collapse occurs.

2.2 Oscillator Fields and Coherence Dynamics

Consider a field of N coupled oscillators with phases $\phi_i(x, t)$ and natural frequencies ω_i, where x can denote a literal spatial coordinate or an abstract index over oscillator clusters. The dynamics follow a generalized Kuramoto model:

$$\frac{\mathrm{d}\phi_i}{\mathrm{d}t} = \omega_i + \sum_j K_{ij} \sin(\phi_j - \phi_i) + \xi_i(t) \tag{1}$$

where K_{ij} represents coupling strength and $\xi_i(t)$ is noise. Note that while we show the fully-connected form for clarity, sparse K_{ij} produces identical qualitative results. In the high-dimensional limit ($N \to \infty$), the system exhibits:

1. **Coherence regions**: Subsets of oscillators phase-lock into "bubbles"
2. **Phase gradients**: Smooth transitions between coherence regions
3. **Collapse events**: Sudden loss of coherence when coupling fails

The key insight: these collapse events are not random failures but structured symmetry-breaking that encodes information about the system's constraints.

2.3 Information Generation Through Collapse

When two coherence bubbles interact:

Resonant interaction: Phase difference remains bounded, no information created

- $\mathrm{d}\Delta\phi/\mathrm{d}t \approx 0$
- Mutual information $I(A; B) \approx H(A) \approx H(B)$

Non-resonant interaction: Phase drift leads to collapse

- $\mathrm{d}\Delta\phi/\mathrm{d}t \gg 0$
- New information generated at rate $\dot{I}$

We formalize bit generation as:

$$\dot{I} \sim \int_\Omega \left| \frac{\mathrm{d}}{\mathrm{d}t}(\phi_i - \phi_j) \right| \cdot \Theta(|\phi_i - \phi_j| - \Delta_c) \, \mathrm{d}\Omega \tag{2}$$

where Δ_c is the critical coherence threshold and Ω represents the set of oscillator pairs (dimensionless count). The integrand has units of rad s^{-1}. Here Θ is the Heaviside step function (1 if argument > 0, 0 otherwise). A "bit" represents not an abstract choice but a physical scar—a record of failed phase prediction. The critical threshold Δ_c scales inversely with coupling strength: for high K_{ij}, the collapse rate $\dot{I} \to 0$, highlighting the stability of strongly coupled systems.

These collapse events mark the onset of non-compressible phase deviation, producing locally irreversible distinctions—the physical basis of bit generation. Crucially, nonlocal predictability is lost at the moment of collapse, which is why subsequent compression becomes both possible and necessary. This irreversibility distinguishes genuine information creation from reversible phase modulation.

2.4 From Collapse to Code: The Kolmogorov Transition

Single collapse events have high Kolmogorov complexity—they're incompressible, unpredictable. But when similar collapses recur in similar phase geometries, patterns emerge:

$$K(\text{collapse}_n|\text{collapse}_1...\text{collapse}_{n-1}) \to \text{decreases with repetition} \tag{3}$$

A code emerges when:

$$\text{Code} = \arg\min_E \sum_i K(c_i|E) \tag{4}$$

where E is an encoding scheme that compresses the history of collapses $\{c_i\}$. Evolution selects for systems that find efficient compressions.

The key insight: a collapse pattern is only meaningful to the extent that it becomes describable with fewer bits than its uncompressed representation. This transition from noise to symbol is the Kolmogorov threshold of code emergence. This connects to fundamental principles in information theory (9; 2; 10):

- **Minimum Description Length (MDL)**: Codes minimize the joint description length of data plus model
- **Structure learning**: Similar to how compression-based ML models discover latent patterns
- **Semiotic threshold**: The point where physical events become signs

2.5 Collapse as the Genesis of the Sign

Our framework provides a physical basis for semiotics:

- **Collapse event** → *Signifier*: The physical trace of decoherence
- **Repeated collapse pattern** → *Sign*: A recognizable, recurring structure
- **Compression scheme** → *Syntactic stabilizer*: The rule that makes the sign meaningful
- **Measurement/observation** → *Interpretant*: The act that actualizes meaning

This grounds Peirce's triadic theory of signs in physical dynamics: signs emerge not from convention but from the physics of repeated coherence failure. The genetic code, language, and even mathematical symbols all follow this pattern—they are scars of ancient collapses that became so regular they crystallized into reusable forms.

2.6 The Symbol Emergence Process

To clarify the progression from resonance to symbolic system, we present the following framework:

3 Biological Code Evolution

3.1 The Genetic Code as Frozen Collapse

The genetic code didn't evolve through random assignment but through regularized phase collapse:

1. **Pre-biotic oscillators**: Chemical reaction networks with cyclic dynamics

Phase	Physical Process	Information Behavior	Symbolic Outcome
Entrainment	Coherence	No new information	None
Collapse	Decoherence	Information spike	Bit generation
Recurrence	Collapse regularity	Compression possible	Proto-symbol
Crystallization	Code fixation	Low-K scheme	Symbolic system

Table 1: The phases of symbol emergence from oscillatory collapse

2. **Collapse patterns**: Certain molecular conformations repeatedly fail to resonate
3. **Compression discovery**: Proto-ribosomes that could "predict" which collapses map to which outcomes
4. **Code crystallization**: The surviving lineage with the most compressible collapse-to-function mapping

Evidence:

- Codon degeneracy follows error-minimization (expected from collapse regularity)
- tRNA structure preserves phase-matching machinery
- Translation is fundamentally a resonance-reading process

3.2 Neural Codes and Consciousness

The brain exemplifies multi-scale code evolution:

- **Spike timing**: Phase offsets encode information
- **Cross-frequency coupling**: Different scales create nested codes
- **Semantic emergence**: Repeated activation patterns crystallize concepts

Consciousness itself may be the system's attempt to maintain global coherence while managing local collapses—generating a self-model from compression of its own decoherence history. This aligns with Levin's suggestion that minds are patterns that ingress into suitable physical architectures. Recent work on integrated information theory (11) provides complementary insights, though our framework offers a more mechanistic basis for information integration through collapse dynamics.

4 Codes as Dimensional Vampires

4.1 The Thermodynamic Trade-off

Every code offers a Faustian bargain:

Benefits:

- Reduced free energy $F = E[-\log P(\text{input})]$
- Increased predictability

- Stable information transmission

Costs:

- Reduced phase space dimensionality
- Constrained evolutionary potential
- Loss of resonant flexibility

This is why we call codes "vampires"—they achieve immortality (symbolic persistence) by draining the lifeblood (dimensional freedom) from their hosts.

4.2 Examples Across Scales

Domain	**Code**	**Stabilizes**	**Sacrifices**
Biology	DNA	Heredity	Biochemical novelty
Neuroscience	Language	Communication	Pre-linguistic thought
Society	Laws	Order	Spontaneous organization
Physics	Constants	Stable matter	Alternative physics

5 Cosmological Implications: Fine-Tuning as Emergent Symbolic Compression

Our framework offers a novel perspective on cosmological fine-tuning. Physical constants may represent:

1. **Collapse regularities** in primordial quantum fields
2. **Compressed** into stable values through cosmological evolution
3. **Selected** for universe-scale coherence maintenance

This suggests:

- Multiple universes with different "codes" (constants)
- Selection for compressible, stable configurations
- Fine-tuning as the anthropic shadow of code evolution

If physical constants are stabilized code residues of primordial collapse events, we might expect rare cosmological transitions—code-switching epochs—marked by shifts in symmetry-breaking behavior or changes in dimensional topology. Such transitions would leave observable signatures in the cosmic microwave background or in the distribution of fundamental forces across cosmic time. Specifically, step changes in the fine-structure constant α or gravitational constant G between Big Bang nucleosynthesis and Planck-era measurements could indicate code-switching events.

Following Levin's framework, physical constants may be the universe's most fundamental interface to Platonic patterns—the deepest level at which non-physical forms inform physical reality.

6 Mathematical Framework

6.1 Code Evolution Dynamics

We propose a PDE system coupling oscillator dynamics with information generation. This model is intended as a theoretical scaffold to capture the dynamical trade-off between coherence, information generation, and code stability. While it simplifies many biological or cognitive details, it provides a first-principles structure for simulating symbol emergence:

$$\frac{\partial \phi}{\partial t} = \omega + \nabla^2 \phi + K \cdot \sin(\Delta\phi) - \gamma I \quad (5)$$

$$\frac{\partial I}{\partial t} = \alpha |\nabla \phi|^2 \cdot \Theta(|\Delta\phi| - \Delta_c) - \beta C(I) \quad (6)$$

$$\frac{\partial C}{\partial t} = \text{compression\_rate}(I) - \text{decay} \quad (7)$$

where:

- $\phi(x, t)$ represents the oscillator phase field
- I represents information density from collapse events
- C represents code stability through compression
- γ couples information back to phase dynamics—information acts to constrain phase evolution, reducing the accessible phase space as codes crystallize
- α sets the information generation rate from both spatial phase gradients and temporal collapse events
- β controls how established codes organize raw information into structured patterns
- compression_rate is a functional representing the system's ability to discover and exploit regularities in I. For concreteness, one could use an MDL-style proxy: $\text{compression\_rate}(I) = \max(0, \lambda I - \sigma I^2)$ where λ measures learning rate and σ prevents overfitting

The feedback term $-\gamma I$ in the phase equation represents how accumulated information constrains future dynamics: as collapse events generate information, they create "grooves" in the phase landscape that bias future evolution. This is the mechanism by which codes become self-reinforcing—they shape the very dynamics that generate them.

Note that compression_rate(I) cannot be directly computed from Kolmogorov complexity (which is undecidable) but represents the system's heuristic discovery of compressible structures through evolutionary or learning processes. In practice, this might be implemented through neural networks, genetic algorithms, or other adaptive systems that approximate optimal compression.

6.2 Connection to Levin's Ingressing Patterns

Levin (6) proposes that patterns from Platonic space serve as "pointers" or "interfaces" that enable specific forms to manifest. Crucially, these patterns exist independently of physical measurement or information—they inhabit a realm beyond bits and entropy. Our theory provides a bridge: the Platonic patterns live in the high-dimensional latent space formed between weakly coupled oscillators, a space that exists prior to and independent of any collapse or measurement.

When oscillators collapse, they don't create the pattern—they merely leave informational scars where the pattern touched physical reality. The code is not the pattern itself but the fossilized imprint of where Platonic form met material constraint. This explains why codes seem both arbitrary (they're contingent on specific collapse histories) and necessary (they reflect deeper patterns that exist independently of their physical instantiation).

The oscillator field's latent space serves as the interface layer where:

- Platonic patterns exist as potential phase relationships
- Physical collapse events sample from this space
- Information emerges as the residue of pattern-matter interaction
- Codes crystallize as compressed memories of repeated samplings

This reframes our entire project: we're not studying how information creates patterns, but how patterns create information through their partial, imperfect manifestation in physical systems.

7 Testable Predictions and Experimental Directions

Our framework makes several concrete predictions that distinguish it from alternative theories of code emergence:

7.1 For Synthetic Biology

1. **Oscillator-driven code evolution**: Biochemical oscillator networks subjected to repeated, constrained collapse events should spontaneously develop compressible information patterns. Systems with controlled phase perturbations will evolve proto-codes faster than those with random noise.

2. **Nonergodic transitions**: As codes crystallize, oscillator systems will exhibit breaking of ergodicity—certain phase trajectories will become inaccessible, creating stable "attractor ruins" (12) that preserve collapse history. These ruins represent formerly complex attractors simplified by code stabilization.

3. **Code stability-flexibility trade-off**: Systems can be tuned along a spectrum by adjusting coupling strength K_{ij}. Weak coupling allows exploration of Platonic pattern space but unstable codes; strong coupling creates rigid codes but blocks access to new patterns.

7.2 For Neuroscience

1. **Semantic emergence timing**: The transition from random neural firing to meaningful representation should follow predictable compression curves. Early in development, collapse patterns have high Kolmogorov complexity; as learning proceeds, complexity drops sharply at semantic thresholds. This can be measured using compressor-based proxies such as Lempel-Ziv entropy of calcium imaging time-series.

2. **Cross-frequency code signatures**: Different frequency bands in neural oscillations represent different levels of the ontological hierarchy. Gamma-band collapses generate raw bits; theta-band organizes these into proto-symbols; delta-band crystallizes stable codes.

7.3 For Artificial Intelligence

1. **Oscillator-native architectures**: AI systems built on dynamical oscillator fields rather than static weights should exhibit more robust symbol grounding and semantic stability. Such systems would naturally develop internal codes through use rather than requiring pre-programmed representations.

2. **Compression-based learning metrics**: The learning progress of any system can be measured by tracking the Kolmogorov complexity of its internal state transitions. Sudden drops in complexity indicate code crystallization events.

8 Implications and Future Directions

8.1 For Biology

- Reframe evolution as search through compression space
- Predict novel codes in synthetic biology
- Design oscillator-based computers that evolve their own codes

8.2 For AI

- Build truly semantic AI through controlled coherence collapse
- Understand LLM representations as implicit codes arising from latent space collapse
- Design resonance-based learning without backpropagation
- Develop "oscillator-native symbolic AI" architectures

Current LLMs exhibit collapse of latent coherence into tokens, but lack structured collapse recurrence—their codes are brittle and non-evolving. In contrast, biological brains develop evolving internal compression schemes through repeated coherence-collapse cycles. Future AI architectures could exploit this principle: instead of static weight matrices, implement dynamic oscillator fields that evolve their own symbolic representations through controlled decoherence.

8.3 For Physics

- Investigate how fundamental constants emerged through evolutionary selection and subsequent freezing
- Search for cosmological code-switching events—rare transitions between metastable constant configurations
- Develop field theories with emergent symbolic layers
- Explore the pre-symmetry-breaking epoch: in a fully reversible regime, is time even meaningful? The "duration" of the pre-EWSB phase may be undefined, suggesting constants evolved in a timeless selection process before time itself crystallized

8.4 For Philosophy

- Ethics of resonance vs measurement
- Codes as filters on experience
- The political economy of symbolic compression

9 Conclusion

We have presented a unified theory of code evolution based on coherence collapse in oscillator fields. Codes emerge not through design or accident, but as thermodynamic solutions to the problem of repeated decoherence. They are, fundamentally, compressions of failure—memories of where resonance broke down, crystallized into reusable patterns.

This framework reveals codes as vampiric structures: they offer predictability and stability by feeding on dimensional freedom. Every symbol is a scar where possibility collapsed into structure—a physical record of the universe learning from its own failures.

Building on Levin's vision of ingressing patterns, we show how codes provide a specific mechanism through which non-physical forms crystallize in physical systems. Understanding code evolution as physical process rather than abstract design opens new avenues for creating adaptive systems, understanding consciousness, and perhaps even explaining why the universe seems so finely tuned for complexity.[1]

The deepest codes may be those we cannot see—the ones that constrain our very ability to resonate with alternatives.

Future work should focus on:

1. Experimental validation in biochemical oscillator networks
2. Applications to morphogenesis and regeneration (7; 13)
3. Development of "code-aware" AI architectures
4. Exploration of ethical implications for human society

As we develop this new science of collapse and compression, we must remember: every code we create or discover shapes not just what we can express, but what we can become.

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[1] These collapse-induced codes may form the basis of a universal symbolic substrate for physical law, akin to category-theoretic or topos-theoretic reformulations of physics. Furthermore, the directionality of code evolution—from high to low Kolmogorov complexity—may be linked to the thermodynamic arrow of time. The nonergodic nature of code formation, where systems lose access to certain phase configurations as codes stabilize, provides a physical basis for irreversibility beyond traditional thermodynamic considerations.

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A Glossary of Core Concepts

Data Availability Statement

No empirical data or computational code were generated for this theoretical study. The mathematical framework presented is intended for analytical treatment and future computational implementation.

Term	Definition
Collapse	Loss of local coherence in oscillator field producing irreversible phase deviation and bit generation
Code	Compressed memory of repeated collapse events; a low-Kolmogorov complexity scheme for predicting future collapses
Pattern	Platonic form existing prior to measurement; shapes probability landscape of oscillator dynamics
Latent space	High-dimensional phase field through which Platonic patterns communicate with physical reality
Bit	A local scar marking where phase prediction failed; the atomic unit of physical information
Symbol	A collapse pattern that has become compressible and reusable across contexts
Ingression	Process by which Platonic patterns influence physical dynamics without becoming information
Nonergodicity	Loss of access to certain phase trajectories as codes stabilize; the cost of symbolic stability