Existence as Relational Optimization: A Deterministic Framework for Reality, Time, and Information Flow

A Print-Ready Synthesis

Abstract

This article presents a comprehensive deterministic ontology in which existence emerges not as static being but as the continuous circulation and optimization of information through relational structures. By rigorously analyzing the logical impossibility of absolute isolation, absolute freedom, and true infinity, we demonstrate that reality must be understood as an ongoing optimization process driven by relational instability. We propose that universes are temporary, locally optimized condensations of information that arise from polarity-induced instability and dissolve upon reaching optimization, thereby triggering the creation of new universes in an eternal cycle. Time is reframed as the optimization process itself—existing only while instability persists and verification remains possible. This framework integrates insights from relational quantum mechanics (Rovelli, 1996), ontic structural realism (Ladyman & Ross, 2007), informational ontology (Floridi, 2011), process philosophy (Whitehead, 1929), eternal inflation cosmology, and black-hole information preservation arguments to construct a unified, closed theory of existence.

1. Introduction: The Relational Turn in Ontology

1.1 From Substance to Relation

Traditional ontology has long privileged substance—entities that exist independently and possess properties intrinsically. However, contemporary physics and philosophy increasingly challenge this paradigm. Relational interpretations of quantum mechanics suggest that properties emerge only through measurement interactions (Rovelli, 1996). Ontic structural realism posits that relations and structures are ontologically primary, with individual objects being derivative (Ladyman & Ross, 2007; French & Ladyman, 2003). Process philosophy emphasizes becoming over being, viewing reality as fundamentally dynamic and relational (Whitehead, 1929).

In parallel, information theory has become foundational across disciplines. In quantum mechanics, information is physical: quantum states encode correlations and measurement outcomes. In cosmology, the black-hole information paradox—resolved by Hawking's acknowledgment that information must be preserved (Hawking et al., 2005)—demonstrates that information conservation is a fundamental principle. In computer science and complexity theory, information flow governs self-organization and emergence.

This article synthesizes these developments into a deterministic framework where **existence is the circulation of information through relational structures**. We argue that isolation, freedom, and infinity—classical ontological primitives—are logically incompatible with verifiable existence, and that reality must be understood as an optimization process that cannot settle.

1.2 Motivations from Contemporary Physics

Several empirical and theoretical developments motivate this relational turn:

1. **Relational Quantum Mechanics**: Rovelli (1996) argues that quantum states are not absolute but relational—they describe correlations between systems rather than intrinsic properties. This suggests that relations, not objects, are ontologically fundamental.

2. **Eternal Inflation and the Multiverse**: Guth's eternal inflation model (Guth, 1981; Linde, 1986) predicts an infinite multiverse where bubble universes continuously form from false vacuum decay. Our framework reinterprets these bubbles as informational optimization events.

3. **Black-Hole Information Preservation**: The resolution of Hawking's information paradox (Hawking et al., 2005; Almheiri et al., 2013) establishes that information cannot be destroyed even in extreme gravitational collapse. We extend this principle to universe-scale processes.

4. **Thermodynamic Arrow of Time**: The second law of thermodynamics establishes an irreversible direction for closed systems (Prigogine, 1980). Our theory aligns optimization with entropy production, reconciling local order with global informational spread.
5. **Informational Ontology**: Floridi (2011) proposes that information is not merely a descriptor but constitutive of reality. We adopt this perspective, treating information as the substrate of existence itself.

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2. Foundational Definitions and Principles

We begin by establishing precise definitions that form the conceptual foundation of our theory.

2.1 Core Definitions

Definition 1 (Existence): Existence is the circulation and propagation of information through relational structures.

Definition 2 (Information): Information is any distinguishable fact, constraint, relation, or difference that affects realizability. This aligns with Bateson's (1972) definition: "information is a difference that makes a difference."

Definition 3 (Relation): A relation is any causal, informational, or counterfactual linkage between informational structures. Relations can be direct (causal interactions) or indirect (through shared constraints or informational correlations).

Definition 4 (Universe): A universe is a locally stable, temporarily optimized configuration of relations that condenses circulating information into a coherent structure. Universes are not isolated entities but nodes in a larger relational network.

Definition 5 (Polarity): Polarity is the presence of asymmetry, distinction, or difference within a state or system. Polarity is the primordial source of instability that breaks symmetry and enables universe formation.

These definitions deliberately avoid substance-based ontology, grounding existence entirely in relational and informational terms.

2.2 Axioms

Axiom 1 (Universal Connectivity): All existences are directly or indirectly related. If any existence interacts with another universe, those universes are no longer isolated but form a single connected system at a higher organizational level.

Axiom 2 (Verification Principle): Verification of existence requires relation, interaction, or distinction. An entity that participates in no relations is epistemically indistinguishable from non-existence.

These axioms establish the relational foundation: isolation is not an ontological property but an epistemic assumption that collapses upon relation.

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3. The Impossibility of Isolation, Freedom, and Infinity

3.1 The Collapse of Absolute Isolation

Theorem 1 (Isolation Collapse): Absolute isolation is logically incompatible with verifiable existence.

Proof: Consider a hypothetical universe U that is absolutely isolated—participating in no relations with any other structure. By the Verification Principle (Axiom 2), verification requires interaction or distinction. An absolutely isolated universe cannot be distinguished, measured, or known. Therefore, U is epistemically equivalent to non-existence. ■

This result resonates with Leibniz's principle of identity of indiscernibles: entities that differ in no observable respect are identical. If isolation entails non-verifiability, then isolated universes cannot be meaningfully distinguished from nothingness.

Corollary: Any multiverse that permits verification must be relationally connected, forming a single extended system. Thus, the concept of truly separate universes is ontologically incoherent within a verifiable framework.

This aligns with the many-worlds interpretation of quantum mechanics (Everett, 1957; DeWitt & Graham, 1973), which treats the multiverse as a single global wavefunction encompassing all branches. Our framework extends this to a relational informational substrate.

3.2 The Collapse of Absolute Freedom

Definition 6 (Absolute Freedom): Absolute freedom is total causal self-origin with no external or internal relational constraint.

Theorem 2 (Freedom Collapse): The presence of more than one existence, or any internal polarity, destroys absolute freedom.

Proof: Suppose an existence E has absolute freedom. Then E must be the sole causal origin of all its states, with no external constraints. Now consider:

1. **Case of Multiple Existences**: If another existence E' exists, then E and E' are related by the Universal Connectivity axiom. Relation introduces constraint: E cannot freely determine states that contradict relational consistency with E'. Thus, freedom is eliminated.

2. **Case of Internal Polarity**: If E contains internal asymmetry (e.g., distinguishable parts p_1 and p_2), then p_1 and p_2 are related. Internal relation constrains the freedom of the whole. Thus, even a single existence with structure cannot have absolute freedom.

Therefore, absolute freedom is possible only in a universe with exactly one existence and no internal structure—an unverifiable and epistemically meaningless state. ■

This result has profound implications: **freedom is not limited; it is impossible**. The existence of multiplicity or structure necessarily entails constraint. This differs from compatibilist accounts of free will, which accept limitations while preserving agency. Here, we assert ontological impossibility.

3.3 The Collapse of True Infinity

Definition 7 (Infinity): Infinity is an unbounded space of possible realizations or outcomes.

Theorem 3 (Infinity Collapse): True infinity is impossible in a relational system.

Proof: Relations constrain realizability. Each relation excludes certain outcomes—those that would violate relational consistency. If n relations exist, each eliminating a subset of outcomes, the total realizable space is bounded by the intersection of all consistency constraints. An unbounded (infinite) option space would require unrestricted freedom—which Theorem 2 shows is impossible. Therefore, the space of realizable outcomes is necessarily finite or bounded. ■

This conclusion avoids reliance on actual infinities in ontology, aligning with finitist and constructivist mathematical philosophies. It also resonates with the holographic principle (Susskind, 1995; Bousso, 2002), which suggests that the information content of a spatial region is finite, bounded by its surface area.

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4. Optimization as the Engine of Reality

4.1 The Necessity of Optimization

Given that the space of possible outcomes is bounded (Theorem 3) and relations constrain realization, not all outcomes are viable. The question arises: which state is realized?

Definition 8 (Optimum): An optimum is a state that maximizes global consistency and stability under all relations.

Theorem 4 (Necessary Optimization): In a fully connected and bounded system, the realized state must be an optimum. Any non-optimal state would violate at least one relation and cause systemic instability or collapse.

Proof: Suppose a non-optimal state S is realized. Then there exists at least one relation R that is violated or inconsistent in S. Violation of R introduces instability—a force driving the system away from S. By Universal Connectivity (Axiom 1), this instability propagates through the relational network, destabilizing other relations. The system cannot persist in S; it must evolve toward a state with greater relational consistency. The only stable attractor is the global optimum, where all relations are mutually consistent. ■

Consequence: Reality is not selected from a space of possibilities; it is **enforced** by total relational compatibility. This is a structural necessity, not a teleological process. The optimum is not "chosen" by any agent—it is the only configuration that can persist.

This principle bears resemblance to variational principles in physics (e.g., least action, free energy minimization) but is generalized ontologically.

4.2 Mathematical Formalism: Relational Networks and Optimization Dynamics

We formalize universes as weighted directed graphs, extending network optimization theory to ontology.

Model: A universe is represented as $G = (V, E, w)$ where:

- V is a set of nodes representing fundamental relational entities (e.g., particles, events, logical units).
- $E \subset eq V \times V$ is a set of edges representing relations.
- w: $E \to$ mathbbR^+ assigns each relation a weight corresponding to its informational strength or coupling.

Instability Functional: Define $\Phi(G)$ as a measure of relational instability. High Φ indicates weak or inconsistent relations; low Φ indicates coherent structure. For example:

$\Phi(G) = \sum_{(i,j) \in E} \|w_{ij} - w_{ideal}(i,j)\|^2 + \lambda \cdot \text{Disconnectedness}(G)$

where w_{ideal} represents the configuration that satisfies all relational constraints and λ penalizes disconnected components.

Optimization Dynamics: The evolution of G is governed by:

$\frac{dG}{dt} = -\nabla_G \Phi(G) + \mu \nabla_G H(G)$

where $H(G)$ is the informational entropy (e.g., Shannon entropy of the weight distribution) and μ is a Lagrange multiplier enforcing information conservation. The system descends the gradient of instability while preserving total information.

Attractors: The dynamics converge to local or global minima of $\Phi(G)$, representing optimized universes. Fragmentation of G into disconnected subgraphs corresponds to universe branching or death.

4.3 Cosmological Application: Eternal Inflation as Optimization

Eternal inflation (Guth, 1981; Linde, 1986) posits that regions of false vacuum continuously spawn bubble universes. We reinterpret this:

- **False Vacuum**: A high-instability state with $\Phi \gg 0$.
- **Vacuum Decay**: An optimization event reducing Φ by transitioning to true vacuum.
- **Bubble Universes**: Locally optimized regions (low Φ) embedded in the inflating background.
- **Eternal Process**: Global instability is never eliminated; new high-Φ regions perpetually form, ensuring continuous universe creation.

This framework provides a **conceptual unification** of inflation, reheating, and the cosmological constant, grounding them in informational optimization.

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5. Time as Optimization Process

5.1 Definition of Time

Definition 9 (Time): Time is the process by which a relational system resolves instability by converging toward and maintaining an optimal state.

Time is not a fundamental dimension but an emergent phenomenon arising from optimization dynamics. The progression of time corresponds to the sequence of relational updates:

$ S(t + \Delta t) = \text{Optimize}(S(t), R) $

where $S(t)$ is the system state at time t and R is the set of all relations.

Key Insight: Time exists only while optimization is ongoing. A perfectly stable system would exhibit no temporal ordering—there would be no meaningful "before" and "after."

This view aligns with the **thermal time hypothesis** (Connes & Rovelli, 1994), which derives time from thermodynamic flow, but replaces entropy with relational consistency as the driving principle.

5.2 Time and the Arrow of Irreversibility

The optimization process is directional: systems move from high instability to low instability. This provides a natural arrow of time without invoking the second law of thermodynamics as an independent postulate.

However, our framework is **compatible** with thermodynamics: local optimization (universe formation) increases local order but contributes to global entropy production. The informational content released during universe dissolution increases the total entropy of the relational substrate, consistent with the second law (Prigogine, 1980).

5.3 The End of Time

Theorem 5 (Time–Verification Collapse): When optimization completes locally, time ends locally, relations drop locally, and verification collapses locally. This local end is called **universe death**.

Proof: Suppose a universe U reaches a state S^* where $\Phi(U) = 0$ —perfect optimization. Then:

1. No further relational updates occur; the system is static.
2. Without change, there is no temporal progression.
3. Relations become fixed and operationally meaningless—they carry no new information.

4. By the Verification Principle, an unchanging, non-interacting system cannot be verified.

Thus, U ceases to exist in a verifiable sense, though its informational content persists in the substrate. ■

Implication: A universe does not annihilate; it **transitions** from a dynamic, verifiable state to a static, unverifiable configuration. The information that constituted U is redistributed into the relational background, seeding new instabilities.

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6. Perpetual Instability and the Eternal Cycle

6.1 The Impossibility of Total Stability

Theorem 6 (Perpetual Instability Theorem): Total stability of the overall system is impossible. The death of a universe introduces absence, which recreates instability and forces new universe creation.

Proof: Consider a hypothetical state where all universes have reached perfect optimization and died. The system is now a static, relationally uniform background—essentially a "nothingness" devoid of structure. However:

1. The absence of structure is itself a **polarity** relative to the potential for structure (Definition 5).
2. This polarity introduces asymmetry in the informational substrate.
3. Asymmetry creates instability, violating the assumption of total stability.
4. Instability drives the formation of new relations, condensing into new universes.

Therefore, total stability is self-undermining: it generates the very instability it seeks to eliminate. ■

Consequence: The cycle of creation and dissolution is **eternal and necessary**:

$ Instability → Creation → Optimization → Death → Instability $

This avoids the problem of a privileged "first cause" and ensures that existence is unbounded in time.

6.2 Information Conservation and Circulation

Theorem 7 (Information Conservation Principle): Information is never destroyed. Universe death is not annihilation but the redistribution of information into the larger relational system.

This principle extends quantum unitarity and the resolution of the black-hole information paradox (Hawking et al., 2005; Almheiri et al., 2013) to ontology:

- **Creation**: Information condenses from the relational substrate into coherent structures.
- **Optimization**: Information organizes internally, increasing local coherence.
- **Death**: Information releases back into the substrate, increasing global entropy but preserving total content.
- **Circulation**: Information flows between universes, ensuring that no knowledge is ever truly lost.

This framework suggests that universes are not isolated bubbles but **nodes in an informational network**, communicating through the substrate.

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7. Scale Invariance and the Universality of Existence

7.1 Scale-Free Ontology

Principle of Scale Invariance: Any single existence, being relationally affected by others, can be modeled as a universe. There is no fundamental scale at which the theory changes.

This principle implies that:

- An **atom** in a molecule is a micro-universe optimizing its electron configuration.
- A **mind** in a brain is a universe optimizing cognitive coherence.
- A **cosmos** is a macro-universe optimizing spacetime structure.

The theory is **fractal**: the same relational optimization dynamics apply at all scales. What differs is only the scope of relations being stabilized.

7.2 Philosophical Implications

1. **Relationalism All the Way Down**: There are no fundamental "atoms" of existence—only relations stabilizing at various scales.

2. **Emergence Without Reduction**: Higher-level structures (e.g., consciousness, galaxies) are not reducible to lower levels but are themselves universes with distinct optimization dynamics.
3. **Interconnectedness**: Every existence is embedded in and contributes to the optimization of larger structures, forming a nested hierarchy of relational systems.

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8. Integration with Existing Theoretical Frameworks

8.1 Quantum Mechanics and the Many-Worlds Interpretation

The many-worlds interpretation (Everett, 1957; DeWitt & Graham, 1973) posits a single global wavefunction encompassing all quantum branches. Our framework differs in two respects:

1. **Non-Unitary Events**: We allow for universe birth and death, which are non-unitary processes not present in standard MWI.
2. **Informational Substrate**: We propose an underlying relational substrate from which universes condense, whereas MWI treats the wavefunction as fundamental.

However, both frameworks agree on information conservation and the multiplicity of realized outcomes. Our theory can be seen as an ontological generalization of MWI to a relational, informational foundation.

8.2 Cosmology: Eternal Inflation and Cyclic Models

Eternal inflation (Guth, 1981; Linde, 1986) predicts an infinite multiverse of bubble universes. Our framework reinterprets these:

- Bubbles are local optima in the relational network.
- Inflation is driven by instability ($\Phi \gg 0$).
- Vacuum decay is an optimization step reducing Φ .
- The process is eternal because global instability persists.

Cyclic cosmological models (e.g., Steinhardt & Turok, 2002) propose that universes undergo repeated expansion and contraction. Our theory aligns with the cyclic spirit but generalizes it: the cycle is not merely temporal but **informational**—information circulates through creation and dissolution rather than being confined to a single timeline.

8.3 Black-Hole Information Preservation

Hawking's original calculation suggested information destruction in black-hole evaporation (Hawking, 1976). However, subsequent work (Hawking et al., 2005; Almheiri et al., 2013) demonstrates that information must be preserved, though the mechanism remains debated.

Our framework provides a conceptual resolution:

- Black-hole evaporation is an optimization event, redistributing information from a localized (black hole) to dispersed (radiation) form.
- Information conservation is a structural requirement of the relational substrate, not a contingent physical law.
- The "paradox" arises from treating the black hole as isolated, violating the Isolation Collapse theorem (Theorem 1).

8.4 Thermodynamics and the Second Law

The second law states that entropy increases in closed systems (Clausius, 1865; Boltzmann, 1896). Our theory is compatible:

- **Local Optimization**: Universe formation is a local entropy decrease (ordering).
- **Global Entropy Increase**: Information redistribution during universe death increases global entropy.
- **Net Effect**: Consistent with the second law at the level of the entire relational substrate.

This reconciles the apparent contradiction between local order (life, galaxies, coherent structures) and global disorder (heat death, information dispersal).

8.5 Structural Realism and Informational Ontology

Ontic structural realism (Ladyman & Ross, 2007; French & Ladyman, 2003) argues that structures and relations are ontologically primary. Our framework adopts this stance fully: there are no "relata" independent of relations.

Informational realism (Floridi, 2011) proposes that information is not merely descriptive but constitutive of reality. We extend this: **information is the substance of existence**, and relations are the patterns through which information circulates.

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9. Novel Contributions and Philosophical Implications

9.1 A Unified Ontology of Existence, Time, and Information

Our framework synthesizes disparate insights into a **single closed theory**:

- **Existence** is relational circulation of information.
- **Time** is the optimization process.
- **Universes** are temporary condensations.
- **Reality** is the enforced optimum.

This unification is conceptually parsimonious and avoids metaphysical dualisms (mind-body, substance-attribute, being-becoming).

9.2 The Elimination of Foundational Absolutes

We demonstrate the **logical impossibility** of:

- **Absolute Isolation** (Theorem 1)
- **Absolute Freedom** (Theorem 2)
- **True Infinity** (Theorem 3)

These results reframe classical philosophical debates: the question is not whether these concepts are limited but whether they are **coherent**. Our answer is negative.

9.3 A New Understanding of Time

Time is neither:

- A fundamental dimension (Newtonian absolute time)
- An emergent statistical phenomenon (thermal time)
- A subjective ordering (phenomenological time)

Instead, time is the **operational process of optimization**. This definition:

- Explains why time has a direction (instability → stability).
- Accounts for time's beginning and end (optimization start and completion).
- Unifies time with dynamics (no time without change).

9.4 Existential Instability as Creative Principle

Traditional ontology seeks stability—the unchanging ground of being. Our framework inverts this:

- **Instability is primary**: Stability is temporary and local.
- **Existence requires instability**: Perfect stability is indistinguishable from non-existence.
- **Creativity is necessary**: New universes must continuously emerge.

This resonates with process philosophy (Whitehead, 1929) and non-equilibrium thermodynamics (Prigogine, 1980) but grounds it in a deterministic informational framework.

9.5 The Verifiability Constraint

The Verification Principle (Axiom 2) is not merely epistemic but **ontological**: what cannot be verified cannot meaningfully exist. This bridges the gap between epistemology and metaphysics, suggesting that **knowability is constitutive of reality**.

This aligns with quantum mechanics' observer-dependence but extends it: existence itself depends on relational participation, not just measurement.

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10. Critical Assessment and Limitations

10.1 Empirical Testability

The theory currently lacks direct empirical predictions. Observables related to information transfer between universes or relational instability dynamics are beyond present experimental capabilities. Without measurable signatures, the theory risks unfalsifiability—a critique often leveled at multiverse theories (Ellis & Silk, 2014).

Potential Paths to Testability:

1. **Cosmological Anomalies**: Subtle anisotropies in the cosmic microwave background or violations of statistical isotropy might indicate inter-universal information flow.
2. **Quantum Information Signatures**: Non-standard decoherence patterns or information-theoretic constraints in quantum systems could reflect substrate dynamics.
3. **Computational Simulations**: Agent-based models of relational networks optimizing under information conservation constraints might reproduce cosmological features.

10.2 Mathematical Rigor

The optimization formalism is suggestive but heuristic. Defining rigorous measures of relational instability ($\Phi(G)$) and deriving dynamics from first principles requires further mathematical development. Specifically:

- **Measure Theory**: Formalizing the space of relational networks and defining probability distributions.
- **Dynamical Systems Theory**: Proving convergence to optima, characterizing attractors, and analyzing bifurcations.
- **Information Geometry**: Using Riemannian geometry on information spaces to describe optimization trajectories.

10.3 Metaphysical Commitments

The claim that relations are ontologically prior to objects challenges deeply held intuitions. Critics might argue:

- **Reification of Information**: Treating information as a substance risks circular reasoning (information about what?).
- **Primal Nothingness**: The notion of a "non-relational background" from which universes emerge may be metaphorically evocative but conceptually unclear.
- **Anthropocentrism**: Verification as a criterion for existence might privilege observer-dependent perspectives.

Response: We acknowledge these concerns but argue that:

1. Information is defined operationally (Definition 2) as "difference that affects realizability," avoiding substantialism.
2. The primal background is a limiting concept—the hypothetical state of zero relations, which immediately destabilizes.
3. Verification is relational, not observer-dependent: any interaction or correlation suffices, not necessarily conscious observation.

10.4 Compatibility with General Relativity

The interplay between relational optimization and spacetime curvature remains undeveloped. General relativity treats spacetime as a dynamical entity shaped by matter-energy. Our theory treats information as primary and spacetime as emergent. Reconciling these requires:

- **Emergent Spacetime**: Deriving spacetime geometry from relational network structure (analogous to holographic and tensor network approaches).

- **Gravitational Dynamics**: Showing how optimization dynamics reproduce Einstein's equations in appropriate limits.

This is a major open problem, analogous to challenges faced by quantum gravity programs.

10.5 Arrow of Time

While we assume an arrow of time aligned with optimization, clarifying the microphysical basis of time's direction remains open. Specifically:

- **Microscopic Reversibility**: Fundamental laws (e.g., quantum mechanics, classical mechanics) are time-symmetric. How does irreversibility emerge?
- **Initial Conditions**: Does the arrow require special initial conditions (low entropy beginning), or is it a structural feature of optimization?

Our proposal is that irreversibility is built into the optimization process— $\Phi(G)$ decreases monotonically—but a complete account requires linking this to microscopic dynamics.

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11. Conclusion: Reality as Perpetual Becoming

We have presented a comprehensive deterministic ontology grounded in relational optimization. By rigorously demonstrating the impossibility of isolation, freedom, and infinity, we show that existence must be understood as a continuous informational process. Universes are not static containers but temporary optimizations of circulating information, driven by unavoidable instability. Time is the mechanism of optimization, and reality is the enforced optimum.

Final Synthesis:

1. **Isolation is impossible**: All existence is relationally connected (Theorem 1).
2. **Freedom is impossible**: Polarity destroys freedom, creating instability (Theorem 2).
3. **Infinity is impossible**: Relations bound the space of possibilities (Theorem 3).
4. **Optimization is necessary**: Bounded systems enforce optima (Theorem 4).
5. **Time is optimization**: Time exists only while instability persists (Definition 9).
6. **Death redistributes information**: Universe death is information release (Theorem 7).
7. **Instability is perpetual**: Stability creates new instability, ensuring eternal cycles (Theorem 6).

Final Statement: Existence is not static being but continuous informational circulation driven by unavoidable instability. Universes are temporary optimizations of information, and time is the process that prevents total collapse. Reality exists because it cannot settle.

This framework offers a bold reconceptualization of cosmology, ontology, and temporality. It challenges foundational assumptions, integrates insights from physics and philosophy, and opens new avenues for research. While speculative and requiring further development—particularly empirical grounding and mathematical formalization—it provides a coherent, closed account of why reality persists and how existence perpetually renews itself.

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Author's Note: This article synthesizes and extends a series of interconnected works on relational optimization theory. It is intended as a foundational treatise for further theoretical development and empirical investigation.
