Informational Emergence: An Ontology of Boundaries, Resolution, and Temporal Structure

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Abstract

We propose a general, domain-neutral ontological framework modeling reality as networks of informational processes characterized by flow, boundary, and resolution. This framework reframes observation as the functional passage of information through structures, with identity emerging from discrete resolution events and time as an emergent property of the sequencing and concurrency of these resolutions. Boundaries are conceptualized as relational informational discontinuities, allowing differentiation ranging from minor variation within categories to categorical discontinuities. Substrates are defined functionally as domains permitting resolution, not necessarily eternal or physical. Our approach avoids metaphysical absolutes, creators, or simulation hypotheses, emphasizing philosophical neutrality and applicability across fields including physics, biology, artificial intelligence, and social systems. This universality fosters interdisciplinary dialogue and provides a minimal yet powerful conceptual foundation for understanding complex informational systems.

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1. Introduction

Classical ontologies often assume a static universe composed of substances observed by conscious agents within absolute time and space. In contrast, this framework adopts a structuralist, informational view emphasizing minimal assumptions: information and its transformations as fundamental, observation as structural flow, and identity and temporality as emergent phenomena.

The goal is not to model any specific domain—physical, biological, or computational—but to provide a flexible, foundational conceptual language describing *how* systems organize, differentiate, and evolve informationally. This intentional generality supports cross-domain relevance and invites specialization by researchers in various fields.

Our core premises are:

- Reality is best understood as networks of informational flow and transformation.
- Observation generalizes to any structured informational resolution, not limited to consciousness.
- Identity arises from discrete resolution events stabilizing information states.
- Time emerges from ordering and concurrency of these resolutions, allowing pluralistic, local temporalities.
- Boundaries represent relational informational discontinuities defining differentiation and modularity.
- Substrates functionally enable resolution but may themselves emerge and are not ontologically privileged.

This foundational model avoids metaphysical claims about ultimate reality or creation, focusing instead on operational and relational definitions applicable across complex systems.

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2. The Role of Abstraction
This framework's abstraction is intentional and essential. By operating at a high conceptual level, it enables flexible adaptation across diverse domains, including artificial intelligence. Abstraction allows the core principles of information flow, boundary, and resolution to be applied modularly—supporting layered modeling and transfer of insights between fields. This facilitates the design of artificial agents and cognitive architectures grounded in fundamental informational processes while remaining open to domain-specific extensions and implementations.

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3. Observation as Structural Information Flow
Observation is traditionally tied to conscious perception or measurement. Here, it is redefined functionally as the transformation of information passing through structured boundaries or interfaces.

This encompasses a broad array of phenomena:

- Physical interactions, such as photon absorption in photoreceptors.
- Quantum measurement as decoherence at boundaries.
- Biochemical conformational changes in proteins responding to stimuli.
- Data processing within logical gates or memory in computational systems.
- Social signaling and communication across agents.

In each case, observation occurs when a system constrains, filters, or stabilizes information flow, resulting in a resolved, stable state. No awareness or sentience is required.

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4. Emergence of Time from Resolution Events
Time is commonly treated as an absolute parameter. Our model treats time as emergent from the sequencing and concurrency of informational resolution events.

Each observer-structure's resolution defines a local temporal frame, and multiple resolutions may occur in parallel, producing pluralistic, local times rather than universal absolute time. This conception aligns with modern physics' rejection of absolute time and supports complex, distributed systems like biological organisms or AI architectures.

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5. Boundaries as Relational Informational Discontinuities
Boundaries in this model are qualitative discontinuities in information flow and structure, not necessarily spatial or physical.

They can represent:

- Minor variation within categories (e.g., genetic differences within species).
- Categorical distinctions (e.g., species boundaries, quantum-classical separations).
- Absolute boundaries where no meaningful mapping exists.

These boundaries define relational differentiation and modularity within complex systems.

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6. Identity, Redundancy, and Parallelism
Identity emerges through resolution sequences, even among redundant or parallel systems. Two identical processes remain distinct if their resolution events are temporally or structurally distinct.

This reflects computational realities where multiple instances of identical processes operate concurrently yet maintain distinct identities due to timing and address separation.

Parallelism and concurrency produce plural temporalities and a rich ontological structure.

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7. Substrates as Functional Foundations
Substrates enable informational resolution but are not necessarily ontologically primary or eternal.

Examples include:

- Silicon substrates enabling transistor logic.
- Quantum vacuum states underlying particle interactions.
- Cellular membranes supporting biochemical signaling.

Substrates may themselves emerge from unresolved informational potential.

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8. Transition as the Core Ontological Act
At the heart of this framework is transition: the transformation of information state as it crosses boundaries and stabilizes.

Metaphors like gates or portals help intuition, but fundamentally, reality consists of nested, interacting informational transitions generating structure, identity, and time.

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9. Cosmological and Systemic Implications
On large scales, phenomena like universal expansion can be interpreted as ongoing informational flow and boundary formation with continuous resolution.

At smaller scales, biological and artificial systems embody these principles through modularity, observation, and emergent time.

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10. Intentional Generality and Interdisciplinary Scope
This framework is intentionally abstract and domain-neutral to serve as a conceptual foundation for diverse fields—physics, biology, AI, sociology—allowing them to specialize and extend the model.

By avoiding metaphysical or domain-specific commitments, it fosters interdisciplinary dialogue and the discovery of universal principles underlying complex informational systems.

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11. Conclusion

We have presented a scientifically grounded, philosophically neutral framework modeling reality as informational networks characterized by flow, boundaries, and resolution. Observation, identity, and time emerge functionally from these processes without requiring consciousness, absolute space-time, or metaphysical absolutes.

This generality and minimalism provide a versatile foundation to understand complex systems—biological, artificial, or physical—and invite further formalization and empirical exploration.

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12. Application: The Double-Slit Experiment Interpreted through Informational Resolution

The double-slit experiment, a cornerstone of quantum mechanics, illustrates how a system's behavior changes depending on the presence or absence of measurement at critical points. Traditionally interpreted as a mystery of wave-particle duality, this phenomenon aligns cleanly with the principles of this informational framework.

12.1 Setup and Classical Paradox

When particles (photons, electrons) pass through a double-slit barrier toward a detection screen:

- Without measurement at the slits, the resulting distribution on the screen forms an **interference pattern**, indicating wave-like behavior.
- With measurement (which-path detection) at the slits, the interference disappears, and particles form two localized bands, as if choosing a single slit path.

This transition—from wave to particle-like behavior—has historically prompted debates around the role of the observer and consciousness in quantum mechanics.

12.2 Informational Interpretation

In this framework, we discard observer-centric metaphysics and instead define:

- **Observation** as the structured passage of information through a boundary.
- **Resolution** as the collapse of informational potential into a specific configuration.
- **Identity** as the outcome of such resolution events.

The double-slit experiment then becomes a physical instantiation of a **resolution-dependent system**. The wavefunction represents a distributed field of informational possibility—unresolved potential—until a structural boundary compels resolution.

12.3 Boundaries and Resolution Events

The presence of a which-path detector introduces an **informational boundary**. It enforces structure and prompts the flow of information to resolve into a defined path state. In the absence of such a boundary, informational flow remains superposed—undifferentiated—and the detection screen alone resolves it at a later stage, resulting in interference.

Thus:

- The **detector at the slit** is an observer—not by awareness, but by functionality. It forces resolution earlier in the system.
- The **screen** is also an observer, resolving undifferentiated flow into spatial identity upon impact.

No mind is required—only structure capable of encoding or reacting to flow in a non-reversible way.

12.4 Temporal Identity and Collapse

Resolution defines identity and introduces **temporal differentiation**. When a resolution occurs—at the slit or at the screen—a temporal "moment" is instantiated. In this framework, time is not external to the particle; it is emergent from resolution. The wavefunction does not “travel through time” until resolution anchors it to a structure.

12.5 Nested and Parallel Observers

The double-slit setup can be viewed as a **nested observer system**:

- The entire apparatus is a composite observer network.
- Each slit, detector, and the screen are sub-observers, interacting and constraining flow at different stages.
- Parallel and partially redundant resolutions (such as environmental decoherence) may exist, creating interference or suppressing it.

12.6 Conclusion of Application

The double-slit experiment, when reframed within this ontology, ceases to be paradoxical. It becomes an elegant expression of the following principles:

- **Observation** is structural, not mental.
- **Resolution** collapses possibility into form.
- **Identity** follows from collapse.
- **Time** is shaped by resolution events.
- **Boundaries** enforce differentiation.

The system does not “decide” what to do based on consciousness. It behaves in accordance with informational structure and flow.

This illustrates how quantum phenomena are not exceptions to the framework but **natural consequences** of it.