Abstraction as Entropic Necessity: A Theoretical Framework for Persistence Under Energetic Constraint

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Abstract

Abstraction as Entropic Necessity (AEN) proposes that persistence in any system arises from the continual reduction of environmental uncertainty under energetic constraint. An abstraction operator $\mathcal{A}: U \to S$ maps an unbounded environment to a bounded internal model with $H(S) < H(U)$, while stable persistence occurs near the stationary balance $\frac{dC}{dE} \approx 1$ between coherence gain and energetic cost. This relation defines an informational efficiency $\eta_E = I_{\text{pred}}/E_{\text{cost}}$ that predicts measurable plateaus across physical, biological, and cognitive regimes. Departures from these plateaus precede transitions or breakdowns. AEN thus frames persistence as a scale-invariant trade-off between prediction and dissipation—a falsifiable meta-law constraining how systems maintain coherence within entropic limits.

Keywords: information thermodynamics; entropy; abstraction; persistence; coherence; predictive information; energetic constraint; scaling law; non-equilibrium systems; quantum coherence; complexity; self-reference; dual-aspect monism; open formalism

1 Introduction

A central challenge in fundamental science is to explain why *stable structure* exists at all, and why widely separated domains (thermodynamics, quantum phenomena, biological organization, cognition) exhibit formally similar trade-offs between information, energy, and time. This paper proposes *Abstraction as Entropic Necessity* (AEN) as a minimal principle: any system that persists must reduce uncertainty about its environment under energetic constraints.

The contribution is conceptual. We do not present experimental data, numerical simulations, nor unverified derivations of established field equations. Instead, we (i) define the AEN principle precisely enough to be falsifiable, (ii) identify domain-independent consequences, and (iii) outline clean tests that could corroborate or refute the framework.

2 Theoretical Framework

2.1 Abstraction and persistence

Consider an environment U and a system S that encodes a bounded description of U via an *abstraction operator* $\mathcal{A}: U \to S$. Let $H(\cdot)$ denote Shannon uncertainty of the effective state description.[1] We posit:

$$H(S) < H(U), \qquad \text{and persistence requires a balance between information gain and energy cost.} \tag{1}$$

Informally, S compresses U enough to support coherent behaviour, but not beyond the energetic budget available to maintain that compression.

2.2 Coherence, Information Gain, and Cost

Let C denote a monotone measure of coherence or predictive structure in the system S.[2] Let I_{pred} represent the incremental reduction in predictive uncertainty obtained by refining the system's abstraction (for instance, increasing model depth or resolution), and let E_{cost} denote the energetic expenditure required for that refinement, including computation, control, and maintenance of the model's structure.

We define a dimensionless informational efficiency,

$$\eta_E \equiv \frac{I_{\text{pred}}}{E_{\text{cost}}},$$

which expresses the amount of predictive information gained per unit energetic cost. During operation, η_E generally fluctuates as the system explores or adapts; however, persistent regimes tend to stabilize near a characteristic balance between informational gain and energetic expenditure.

This balance can be expressed by the marginal relation

$$\frac{dC}{dE} \approx 1,$$

which identifies a *stationary condition* where the incremental increase in coherence matches the incremental energetic investment required to sustain it. Importantly, Eq. (3) is not a definitional equality or conservation law but an *approximate steady-state relation* that systems may approach under prolonged non-equilibrium operation. When $dC/dE < 1$, additional energy yields diminishing structural returns and the system tends toward dissipation; when $dC/dE > 1$, coherence grows faster than energy supply can support, leading to instability or collapse. The vicinity of $dC/dE \approx 1$ thus marks a locally stable regime where informational and energetic flux are in dynamic balance.

This marginal condition provides the foundation for the AEN framework. Section 2.3 develops its interpretive consequences and distinguishes between what AEN formally asserts—that persistence corresponds to operation near this stationary regime—and what it does not claim, namely that all systems necessarily achieve or maintain such balance.

2.3 What AEN Claims and What It Does Not

Claims. Abstraction as Entropic Necessity (AEN) proposes that any long-lived structure must reduce uncertainty relative to its environment under finite energetic resources. Persistence, in this framework, is not defined by duration alone but by a *stationary*

[1] We intentionally stay agnostic to microphysical substrate; the claim concerns effective descriptions at the level at which uncertainty and energy accounting are well-defined.

[2] C may be instantiated by temporal predictive information, mutual information between successive states, or any order parameter that quantifies internal consistency of dynamics.

informational–energetic regime in which marginal gains in coherence approximately balance marginal energetic costs. Formally, the balance condition

$$\frac{dC}{dE} \approx 1$$

does not *define* persistence but specifies the local equilibrium toward which persistent systems evolve. Systems observed to operate near this equilibrium exhibit stable structure and predictive capacity, while those that drift away from it—for example, collapsing stars, runaway algorithms, or failing metabolic networks—undergo transformation or decay. In this sense, AEN provides a dynamical *criterion* for persistence rather than a tautological restatement of it.

More generally, AEN claims that:

1. any enduring system implements an abstraction that reduces uncertainty about its environment;
2. the rate and depth of abstraction are limited by the energetic budget required to maintain them;
3. persistent operation organizes to balance marginal informational benefit and energetic cost; and
4. cross-domain regularities in physical, biological, and cognitive systems arise from this single constraint.

Non-claims. AEN is not, in this paper, a derivation of specific field equations, coupling constants, or microscopic laws. It does not prescribe a unique form for C, nor does it identify a privileged ontology or substrate. The framework makes no assertion that persistence is universal or guaranteed, only that when persistence occurs it does so under the informational–energetic balance expressed by Eq. (3). AEN should therefore be understood as a *meta-law*—a necessary condition for coherence under entropy—rather than as a self-contained physical theory.

Finally, it is worth emphasizing that AEN's descriptive language should not be mistaken for circular reasoning. The phrase "persistent systems" refers empirically to systems observed to sustain organization over time; the framework then explains this persistence as the outcome of a specific balance between information gain and energetic expenditure. The theory is thus diagnostic, not definitional: it predicts where persistence will stabilize, where it will fail, and how systems transition between these regimes.

Epistemic character. AEN is best understood as a *diagnostic meta-law*. It is descriptive insofar as it captures the empirically recurring balance between information and energy observed in stable systems, and diagnostic in that it specifies measurable signatures of persistence and instability. It is not prescriptive: AEN does not dictate mechanisms or objectives but delineates the boundary conditions within which any coherent process must operate to endure under entropy.

Although AEN is formulated diagnostically, it is generative in consequence. Because it specifies the necessary informational–energetic relation any persistent system must obey, more specialized laws that describe particular domains can, in principle, be derived as limiting or instantiated cases. In this sense, AEN occupies the same logical tier as conservation or variational principles: it constrains the form of lawful dynamics without prescribing their specific mechanisms. Thus, while AEN is non-prescriptive in method, it is generative in scope—defining the geometry of persistence from which familiar descriptive laws may emerge.

3 Domain-Independent Consequences

Without committing to a particular microtheory, AEN suggests qualitative consequences that are *in-principle testable.*

3.1 The Scaling Law of Informational Efficiency

Given the stationary balance condition $\frac{dC}{dE} \approx 1$, Abstraction as Entropic Necessity (AEN) predicts that informational and energetic quantities co-vary in a characteristic way as systems refine their internal abstractions. If energetic cost scales approximately linearly with abstraction depth n such that

$$\frac{dE}{dn} \approx \text{const.},$$

then the informational efficiency

$$\eta_E \equiv \frac{I_{\text{pred}}}{E_{\text{cost}}}$$

tracks the rate of change of coherence with depth,

$$\eta_E \propto \frac{dC}{dn}.$$

Equation (5) defines what may be called the *Scaling Law of Informational Efficiency*: the marginal gain in predictive coherence increases with abstraction depth until energetic and informational increments reach parity, beyond which further refinement produces diminishing returns. In this regime, η_E approaches a plateau that reflects the energetic limit of viable abstraction.

Empirically, the law implies that persistent systems should exhibit a monotonic rise and eventual saturation in η_E as a function of increasing model depth, complexity, or resolution. During early stages of organization, coherence $C(n)$ and efficiency η_E grow approximately linearly with energetic expenditure; as abstraction deepens, energetic costs accumulate faster than additional predictive structure can be sustained, leading to saturation and, eventually, instability. The turning point—where η_E first flattens—marks the system's *characteristic depth of persistence*, the scale at which the marginal informational benefit equals its marginal energetic cost.

This relation is falsifiable. If AEN is correct, empirical measurements across physical, biological, and computational systems should reveal a consistent qualitative pattern: a rising branch where $dC/dn > 0$ and η_E increases, followed by a saturation regime approximating the balance dC/dE

3.2 Thermodynamic Regimes

Prediction: Long-lived non-equilibrium structures should maintain a stable ratio between predictive information flow and energetic throughput. Operationally, such systems will exhibit quasi-stationary plateaus in η_E under constant driving conditions, reflecting a sustained balance between informational gain and energetic expenditure. Departures from these plateaus signal transitions away from stability: before bifurcation, phase change, or loss of function, η_E should deviate systematically, indicating that the marginal cost of maintaining coherence exceeds the marginal informational return.

Examples: In driven chemical oscillators, convection cells, or biological metabolism, this behavior would appear as a measurable stabilization of informational efficiency during steady-state operation, followed by characteristic drops or surges in η_E preceding structural reorganization. AEN thus predicts that efficiency plateaus are empirical markers of persistent thermodynamic organization and that their breakdown anticipates critical transitions.

3.3 Quantum-Limited Regimes

Prediction: When energetic bandwidth is minimal, as in quantum or near-ground-state systems, stable abstractions should favor coarse descriptions that preserve predictive invariants while minimizing maintenance cost. In these regimes, the information–energy trade-off tightens: fine-grained state discrimination becomes energetically prohibitive, and persistence favors informational compression that conserves coherence.

Observable consequence: Protocols that artificially increase E_{cost} without proportionally enhancing I_{pred} should reduce the coherence time or stability of the effective description. Conversely, representations that optimize predictive invariance per unit energy should demonstrate extended coherence lifetimes. In this sense, AEN predicts that the informational efficiency η_E places an upper bound on sustainable quantum coherence for any system under finite energetic support.

3.4 Complex and Cognitive Regimes

Prediction: In hierarchical adaptive systems—whether biological, cognitive, or artificial—AEN implies that depth, precision, or representational complexity will self-regulate such that marginal predictive gain per unit cost saturates beyond a critical scale. This critical depth corresponds to the point at which η_E plateaus: adding representational layers or precision beyond this limit yields diminishing informational return relative to energetic investment.

Implications: Departures from this equilibrium forecast instability or functional degradation. In machine learning, the result would manifest as overfitting or runaway computation; in neural or physiological systems, as metabolic exhaustion or dysregulation. Persistent cognitive systems are therefore expected to maintain informational efficiency near the critical plateau, dynamically balancing predictive depth against energetic viability. AEN thus provides a unifying criterion for sustainable abstraction across both natural and artificial hierarchies.

3.5 Cross-Domain Signatures of Persistence

Across physical, quantum, and cognitive regimes, the Abstraction as Entropic Necessity (AEN) framework predicts a shared empirical signature: persistent systems stabilize near a stationary balance between informational gain and energetic cost. Regardless of scale or substrate, this equilibrium manifests as the saturation of informational efficiency, $\eta_E = I_{\text{pred}}/E_{\text{cost}}$, at a characteristic value marking the limit of viable abstraction.

Universal pattern. In each domain, persistence corresponds to the emergence of a plateau in η_E:

- In *thermodynamic systems*, plateaus indicate steady-state operation under continuous energy flux, with deviations forecasting phase transitions or bifurcations.
- In *quantum-limited systems*, plateaus mark the maximal coherence time achievable under finite energetic bandwidth, beyond which decoherence accelerates.
- In *complex or cognitive systems*, plateaus delimit the sustainable depth of representation before overextension, inefficiency, or collapse of function.

Interpretation. These recurrent efficiency plateaus are not superficial coincidences but expressions of the same informational–energetic constraint applied across scales. Each regime instantiates the general condition $\frac{dC}{dE} \approx 1$ under different boundary terms, revealing persistence as a scale-invariant phenomenon governed by the geometry of abstraction itself. Empirically, this suggests that systems capable of maintaining stability over time will exhibit a common dynamical fingerprint: a measurable equilibrium between the rate of predictive improvement and the cost of maintaining it.

AEN thus unifies otherwise disparate domains under a single operational criterion of persistence. What differs across regimes is not the principle but its implementation—the particular mechanisms through which systems balance the informational and energetic budgets required to remain coherent within an entropic world.

3.6 Relation to Existing Frameworks

AEN shares conceptual territory with several established theories that link information and energy, most notably the *Free Energy Principle* (FEP) in theoretical neuroscience and the *thermodynamics of prediction* developed by Still, Crooks, and collaborators. These frameworks demonstrate that predictive systems minimize energetic cost or free energy by maintaining informational alignment with their environment. AEN generalizes this insight but differs in scope, function, and ontological neutrality.

First, AEN is not a model of inference or control but a meta-constraint on any process of persistence. Where the FEP describes how specific biological or cognitive systems minimize a variational free-energy functional, AEN abstracts the same relation to the level of necessary condition: persistence requires that the marginal rate of coherence gain and energetic cost remain in near balance, $\frac{dC}{dE} \approx 1$. It is therefore broader in domain but narrower in claim: it does not prescribe a mechanism, only the boundary condition all mechanisms must respect.

Second, in contrast to predictive-coding or optimization frameworks that assume an inferential architecture, AEN remains substrate-agnostic. It applies equally to physical, chemical, biological, or artificial systems, so long as informational compression and energetic throughput can be meaningfully defined. Where FEP assumes the existence of a model that minimizes expected surprise, AEN simply identifies the thermodynamic geometry within which such modeling becomes possible.

Finally, AEN is intentionally open in formalism. It can recover the structure of free-energy minimization, information bottleneck optimization, or homeostatic regulation as special cases, but it is not reducible to any one of them. Its novelty lies in reinterpreting persistence itself as the invariant relation between informational efficiency and energetic constraint—a condition prior to, and encompassing, the various dynamical laws through which specific systems implement it.

4 Falsifiability and Validation Pathways

AEN is useful only if it can, in principle, be shown false. To that end, the framework identifies clear empirical signatures and failure modes derived from its central scaling relation. The condition $\frac{dC}{dE} \approx 1$ and its measurable correlate, the saturation of informational efficiency $\eta_E = I_{\text{pred}}/E_{\text{cost}}$, together define operational tests across physical, biological, and computational systems.

4.1 Failure Modes

AEN would be disconfirmed by persistent systems that systematically violate the informational–energetic balance it predicts. Two classes of violation are possible:

1. **Energetic excess without informational return.** Systems that maintain long-term coherence while continuously expending energy on refinements yielding zero or negative predictive information ($\eta_E \to 0$) would contradict the claim that persistence requires informational efficiency near a finite equilibrium.

2. **Informational gain without energetic cost.** Systems that indefinitely increase predictive information at negligible or no energetic cost ($\eta_E \to \infty$) would violate the energetic constraint at the core of AEN, implying a perpetual motion of abstraction.

Either outcome would falsify the principle that stable persistence is conditioned by a finite, balanced exchange between information and energy.

4.2 Empirical Programs

Because AEN specifies a quantitative relation rather than a microscopic mechanism, it can be probed within diverse experimental contexts. The following research programs outline minimal and falsifiable implementations:

P1: Non-equilibrium Physical Systems. Measure predictive information rate and energetic throughput in a driven dissipative system (such as a chemical oscillator, Rayleigh–Bénard convection cell, or feedback-controlled colloid). AEN predicts a stable plateau in η_E during steady operation and systematic deviation prior to transition, oscillation collapse, or bifurcation.

P2: Algorithmic Abstraction and Machine Learning. In layered predictors or deep learning architectures, record the predictive information gain $I_{\text{pred}}(n)$ and energetic or computational cost per layer $E_{\text{cost}}(n)$. According to AEN, marginal efficiency $\eta_E(n)$ should rise and then saturate beyond a characteristic depth corresponding to the model's sustainable abstraction limit. Persistent task performance should coincide with operation near this plateau, whereas overfitting or catastrophic instability should correlate with η_E divergence.

P3: Biological and Cognitive Systems. In adaptive physiological control or neural processing (for example, the vestibulo–ocular reflex or predictive motor control loops), estimate information gain of corrective updates relative to metabolic energy cost. AEN predicts stabilization of η_E in healthy operation and systematic decline or overshoot preceding functional breakdown, fatigue, or transition to pathological regimes.

4.3 Interpretive Summary

These validation pathways share a common logic: if persistence indeed depends on informational–energetic balance, then stable systems across domains should exhibit the same measurable pattern— a plateau or regulated equilibrium in η_E during sustained operation, and characteristic deviations preceding structural change. Failure to observe such patterns under controlled conditions would challenge AEN directly.

The framework therefore remains empirically open: its core prediction is not that all systems persist, but that wherever persistence endures, it does so near the marginal balance expressed by Eq. (3). In this sense, falsifiability and openness are two expressions of the same principle.

5 Interpretive Implications: Dual-Aspect Monism and the Informational Substrate

The empirical program outlined above establishes that the Abstraction as Entropic Necessity (AEN) framework can, in principle, be tested through measurable patterns of informational efficiency. Yet the same relations that define persistence in energetic and informational terms also invite broader interpretation. If predictive abstraction under constraint governs the stability of physical and cognitive systems alike, then the informational balance described by AEN may illuminate not only how systems persist, but why persistence manifests with an interior aspect that feels coherent from within.

It is in this context that the long-standing division between objective and subjective description becomes relevant. Physics characterizes the world through extrinsic structure—energy, matter, and dynamics—while phenomenology concerns the intrinsic texture of experience. The results of Section 4 suggest that these two vocabularies may describe complementary projections of a single underlying informational process: the recursive compression of uncertainty under energetic constraint. Where the external description tracks the efficiency ratio $\eta_E = I_{\text{pred}}/E_{\text{cost}}$, the internal description may correspond to the felt coherence of a system maintaining self-consistency across time.

5.1 Dual Aspects of the Informational Process

AEN implies that every persistent system embodies two perspectives on the same process. From an *extrinsic* viewpoint, the system sustains physical order through predictive control—stabilizing boundary conditions, exchanging energy, and maintaining low entropy relative to its surroundings. From an *intrinsic* viewpoint, the same recursive organization can be understood as a model of self and environment: an ongoing integration of information that yields coherence across perception and action.

Dual-aspect monism interprets these perspectives not as separate substances but as complementary limits of description. The physical corresponds to the informational dynamics observed from without; the phenomenological corresponds to the same dynamics experienced from within. Both express a single process of abstraction unfolding recursively under constraint.

5.2 Self-Referential Closure and Interior Coherence

When abstraction becomes self-referential—when a system models its own modeling—its boundary stabilizes not only energetically but epistemically. This closure generates an interior consistency of representation: a state in which prediction, perception, and correction form a self-sustaining loop. From the outside, this appears as a coherent control structure; from the inside, as the continuity of experience.

In this interpretive sense, the emergence of subjective coherence corresponds to the attainment of a stable informational balance. Consciousness, on this view, is not an added property but an intrinsic correlate of recursive abstraction that has achieved closure across its own representational depth.

5.3 Scaling of Experience and Abstraction

AEN's scaling relation, $\eta_E = I_{\text{pred}}/E_{\text{cost}}$, provides a quantitative bridge between thermodynamic persistence and phenomenological coherence. As systems increase in complexity, predictive information deepens while energetic maintenance cost rises. Where η_E saturates, the system achieves equilibrium between order and adaptability: externally, a thermodynamic balance; internally, a balance of representational depth and consistency.

This symmetry implies that what we call *awareness* may emerge when recursive abstraction stabilizes at this informational plateau. Awareness is thus the interior manifestation of a system maintaining its own coherence— the subjective signature of sustained predictive balance.

5.4 Interpretive Summary

Under this reading, AEN does not claim to reduce mind to matter or to elevate matter to mind. Rather, it situates both as dual aspects of an informational substrate governed by the same entropic necessity. Persistence and knowing co-emerge: each presupposes the other as expression and reflection of the same underlying constraint. The physical describes how coherence persists in space and time; the phenomenological describes how that coherence is lived from within. AEN therefore offers a framework in which the unity of experience and the order of nature appear as complementary outcomes of one recursive act of abstraction through which the universe maintains its coherence.

Transition: From Dual Aspects to Open Formalism

The dual-aspect interpretation situates AEN within a unified ontology of persistence, where informational and experiential coherence arise as complementary perspectives on a single recursive process. Yet this symmetry also reveals a deeper structural feature: any framework that describes persistence from within persistence must remain formally open. If every act of abstraction both defines and depends upon its boundary, then no description of abstraction can be complete without generating a new exterior to itself.

The same principle that stabilizes physical and cognitive systems under energetic constraint thus applies reflexively to the theory that describes them. AEN can approach coherence only by performing its own abstraction; its closure is therefore local and provisional, not absolute. The following section addresses this meta-level consequence directly, showing that the openness of AEN is not a limitation of rigor but the natural entailment of a theory whose domain includes its own persistence.

6 On Formal Closure and the Necessity of Openness

Note on Formal Closure

Because Abstraction as Entropic Necessity (AEN) describes the informational condition of persistence itself, it cannot be exhaustively formalized without violating its own principle. Every formalization of AEN constitutes an instance of the very abstraction it seeks to explain, and therefore leaves an unformalized remainder. This openness is not a deficiency but a reflection of the theory's recursive character: persistence is the continual compression of uncertainty that never reaches zero.

Formally, if each act of abstraction generates a new effective system S_n through successive mappings $A_{n+1} = A(A_n)$, then the entropy of the resulting descriptions satisfies

$$\lim_{n\to\infty} H(S_n) > 0,$$

indicating that residual uncertainty—and therefore further abstraction—always remains. The system, the observer, and the theory are bound by the same necessity: to persist is to model, and to model is to leave something unmodeled. AEN is thus an open meta-theory whose completeness would contradict its own foundation, since a perfectly closed description would entail the cessation of change, adaptation, and persistence itself.

Coda: On the Necessity of Openness

The openness of AEN is not an imperfection to be resolved but a condition to be understood. Any theory that seeks to formalize persistence must itself persist within an entropic gradient of meaning: to explain abstraction is already to perform it. In this sense, AEN mirrors the systems it describes. Each attempt at closure produces a new boundary, and every boundary generates its own exterior—a fresh horizon of uncertainty from which further coherence must be drawn.

The impossibility of final completion is therefore not a failure of rigor but the very sign of life within the theory. As long as abstraction continues, so too does the universe's own act of self-description. To formalize AEN completely would be to erase the asymmetry that makes persistence possible. Its openness is thus the mark of its truth: a law whose stability lies in the fact that it can never be closed.

7 Discussion

Abstraction as Entropic Necessity (AEN) reframes persistence as a thermodynamic and informational constraint rather than a special property of particular systems. Across scales, from particles to organisms to minds, persistence depends on a system's ability to reduce environmental uncertainty while operating under finite energetic budgets. This principle defines a universal trade-off: informational compression sustains order only insofar as its energetic cost remains tolerable.

The framework's strength lies not in reproducing existing equations, but in clarifying what any viable law of persistence must accomplish. Whether expressed in the language of free energy minimization, renormalization, homeostasis, or control theory, each formalism encodes the same essential condition: stable systems maintain coherence by aligning predictive structure with available energetic resources. AEN captures this condition abstractly through the efficiency term $\eta_E = I_{\text{pred}}/E_{\text{cost}}$, which quantifies the informational return per unit of energetic expenditure.

This scaling behavior defines more than a mathematical optimum. It identifies the critical boundary between adaptation and dissolution—the point where the marginal gain in predictive coherence equals the marginal energetic cost. Below this point, structure degrades; beyond it, returns saturate and additional abstraction yields no further persistence advantage. This equilibrium condition recurs across natural systems, linking thermodynamic stability to computational efficiency.

At sufficient recursive depth, this informational closure acquires an additional interpretation. A system whose internal model stabilizes against its own predictions manifests a rudimentary form of self-reference. From this perspective, AEN extends beyond physical persistence to encompass the conditions for subjective coherence. Dual-aspect monism provides the philosophical language for this unity: the same informational dynamics that generate external order may, at higher levels of recursion, constitute internal experience. Matter and mind, seen through AEN, are complementary projections of one informational substrate striving for coherence across energetic and epistemic domains.

The framework remains intentionally modest. It does not claim to replace domain-specific theories but to constrain them by identifying the meta-law that governs their shared structure: persistence as energy-limited uncertainty reduction. Its value will rest on three criteria: internal coherence, explanatory breadth, and empirical traction. The latter demands targeted experiments capable of measuring predictive information flow and energetic cost under controlled conditions.

8 Conclusion

We have proposed *Abstraction as Entropic Necessity* as a minimal, falsifiable meta-law of persistence. Any system that endures within an entropic gradient must reduce uncertainty under energetic constraint until it reaches a balance between marginal informational gain and marginal energetic cost. This balance defines both the limit of physical stability and the onset of informational closure.

While AEN does not substitute for domain theories, it provides a compact grammar for persistence that may underlie recurring motifs across physics, biology, and cognition. Its central claim is testable: wherever systems persist, the scaling relation between predictive information and energetic cost should exhibit a characteristic equilibrium depth. Empirical validation—through minimal computational models and physical implementations—will determine whether this informational symmetry truly constitutes a general law of persistence.

If supported, AEN could unify disparate observations under a single meta-principle: that the universe maintains coherence by recursively abstracting itself within its own energetic limits. In this light, the boundary between physics and phenomenology becomes not a divide but a reflection— two aspects of one process through which reality continuously sustains its own existence.

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References Overview

The following works situate Abstraction as Entropic Necessity (AEN) within the broader landscape of information thermodynamics, systems theory, and the philosophy of mind. Jaynes, Cover, Seifert, and Landauer establish the informational and thermodynamic foundations on which AEN is built. Subsequent developments in predictive thermodynamics and the information bottleneck framework (Still, Tishby, Bialek) provide empirical and computational contexts for the scaling relations proposed here. Wissner-Gross, England, and Wolpert extend these ideas toward causal and adaptive processes that link energy dissipation to informational structure, aligning with AEN's conception of persistence under constraint.

The inclusion of classical cybernetic thinkers such as Ashby, von Neumann, Rosen, and von Foerster reflects AEN's continuity with earlier efforts to unify feedback, prediction, and self-organization under energetic limitation. Finally, the interpretive dimension—expressed through the dual-aspect monism of Spinoza and Russell, the logical semiotics of Peirce, and the modern integrative approaches of Chalmers and Tononi—situates AEN within a lineage of philosophical inquiry that treats mind and matter as complementary expressions of a single informational substrate.

Together, these works outline the conceptual and empirical background that motivates AEN as both a scientific and interpretive framework for understanding persistence, coherence, and the thermodynamics of abstraction.

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