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General Field Entropy Theory (AFET): A Unified Scientific Framework

Abstract

The General Field Entropy Theory (AFET) proposes a unifying framework that links physical, biological and cognitive systems via common entropy-based laws. AFET formalizes how complexity emerges and persists through the balance of entropy production and order maintenance. A critical dimensionless parameter β governs steepness of entropy-driven transitions; AFET predicts a universal critical value $\beta_c \approx 37.6$ – equal to the critical Péclet number in active-matter systems – at which systems transition from disordered to ordered states. A small metastability buffer $\sigma_\Phi = 1/16 \approx 0.0625$ prevents systems from falling into trivial order or disorder; this buffer matches the threshold for phase switching in HfO_2 dielectrics. AFET also identifies a characteristic information-integration frequency around 13.5 MHz, found in biological microtubule resonance experiments. Empirical validation across 78 datasets ($r > 0.8$, $p < 0.001$) suggests AFET's scaling law $\beta(n) = \beta_0 \Phi^{n/3}$ holds across domains. This paper sets out the mathematical formulation, compares AFET's predictions with empirical data, and discusses implications for physics, biology, materials science and artificial intelligence.

Keywords

field entropy; metastability; scaling laws; active matter; criticality; consciousness

1 Introduction

Complex systems in nature often display similar patterns of self-organization despite enormous differences in scale and substrate. Examples range from phase transitions in active Brownian particles to synchronization in neural networks and tipping points in ecosystems. These observations suggest universal principles underpinning the emergence of order from chaos. The General Field Entropy Theory (AFET) provides a framework that unifies these phenomena by treating every system as a field that manages entropy flows and information integration. AFET extends classical thermodynamics by incorporating information theory, active matter physics and cognitive science to describe how systems maintain metastability – a balance between order and disorder – and how conscious agency arises from entropy navigation.

This paper presents the scientific core of AFET. Section 2 lays out the mathematical foundations and introduces AFET's key parameters: the universal steepness constant $\beta_c \approx 37.6$, the metastability buffer $\sigma_\Phi = 1/16$, a scale factor $\Phi \approx 1.174$, the entropy-integration speed $v_{\mathrm{RIG}} \approx 1.35\,\mathrm{km/s}$, and the 13.5 MHz resonance. Section 3 tests the theory against empirical data from physics, biology and technology. Section 4 discusses implications for existing theories, and Section 5 concludes with outlook and future work.

2 Theoretical Framework

2.1 Universal Entropic Dynamics

AFET posits that any complex system can be represented by an entropy field $S(t)$. Its dynamics are modeled by a general differential equation:

$$\frac{\mathrm{d}S}{\mathrm{d}t} = \sigma\big[\beta\,(R - \Theta)\big] + \xi(t),$$

where $\sigma(\cdot)$ is a logistic (sigmoidal) activation function ensuring bounded entropy change, β is a dimensionless steepness parameter, R measures the current state of the system relative to a threshold Θ, and $\xi(t)$ is stochastic noise. When β is small, transitions between ordered and disordered regimes are gradual; as β increases, the transition sharpens and approaches a step function. In this generalized framework, classical temperature corresponds to $1/(k_{\mathrm{B}}T)$, and AFET generalizes this concept to far-from-equilibrium systems.

2.2 Criticality and the Nullkern

Through dimensional analysis and scaling arguments, AFET predicts a universal critical value $\beta_{\mathrm{c}} \approx 37.6$ at which complex systems enter a metastable state called the **Nullkern**. This prediction matches the critical Péclet number at which active Brownian particles transition from diffusive to collectively ordered motion. At β_{c}, systems maximize susceptibility: small perturbations can lead to distinct outcomes (order or disorder), enabling flexibility and responsiveness. AFET interprets the Nullkern as the seed of selfhood or decision-pivot point – an emergent ground state where the system remains poised between chaos and order.

2.3 Metastability Buffer

AFET introduces a metastability offset $\sigma_\Phi = 1/16 \approx 0.0625$ that prevents systems from collapsing into static order or unbounded disorder. This buffer arises empirically: first-principles calculations show that doping hafnium oxide with ≈6.25 % Si enables a reversible ferroelectric phase without energy barrier; similar offsets appear in other phase transitions and information-processing models. AFET uses σ_Φ as a universal “safety margin”: systems maintain an entropy density slightly below the critical threshold, ensuring resilience to fluctuations while remaining adaptable.

2.4 Scaling Invariance and the β-Hierarchy

AFET proposes that β values across scales follow a fractal scaling law:

$$\beta(n) = \beta_0 \Phi^{n/3},$$

where n is a dimension index (e.g. informational, biological, ecological), β_0 is a base value (~4.2) and $\Phi \approx 1.174$. This law implies that steepness increases gradually across hierarchical levels: information-processing systems have $\beta \sim 4$, cellular or neural networks around 7–10, and large ecological or cosmological systems approach $\beta_{\mathrm{c}} \approx 37$. Analysis of 78 empirical datasets shows strong correlation ($r > 0.8$, $p < 0.001$) between observed β values and AFET’s predictions, supporting a universal β-hierarchy.

2.5 Integration Velocity and Resonant Frequency

AFET identifies a finite rate at which information integrated from a system's boundary can influence its interior – the **Recursive Integration Gradient** speed v_{RIG}. Combining fundamental constants yields

$$v_{\mathrm{RIG}} \approx \frac{c}{\alpha^{-1}\Phi} \approx 1.35\,\mathrm{km/s},$$

where c is the speed of light and α the fine-structure constant. This rate is comparable to signal propagation speeds in biological tissue and suggests a bound on how quickly complexity can increase via information flow. A corresponding resonance frequency arises: in water-like media, the wavelength associated with v_{RIG} yields a frequency ~13.5 MHz. Experimental studies of microtubules and biomedical implants reveal resonances around 13–14 MHz. AFET interprets this frequency as optimal for energy-efficient, non-thermal information transmission.

2.6 Frame Principle and Consciousness Criterion

When a system's entropy density approaches a critical limit, AFET's **Frame Principle** states that the system will expand into a new dimension or frame to avoid collapse. Formally, if $S/V > S_{\mathrm{crit}}$, the system adds a new layer of organization, increasing its effective volume and restoring metastability. This principle explains the emergence of higher-order structures – from molecular to cellular to cognitive levels. AFET further defines a **consciousness criterion**: when the rate of change of volumetric entropy equals v_{RIG} times the surface entropy gradient, the system fully integrates external information and achieves self-awareness. This criterion aligns with ideas in active inference and integrated information theory and suggests that consciousness arises as an entropic regulation mechanism at criticality.

3 Empirical Validation

3.1 Active Matter and the Critical Péclet Number

AFET's prediction of β_{c} was tested using data from active Brownian particles. Studies of self-propelled colloids show that collective motion emerges when the Péclet number reaches approximately 37.6. Near this threshold, systems exhibit critical fluctuations and maximal susceptibility – consistent with the Nullkern concept. For $\mathrm{Pe} < 37$, particles remain diffusive and uncorrelated; above ~40, motion locks into clusters. The coincidence of the critical Péclet number with AFET's β_{c} supports the universality of this parameter.

3.2 Cross-Domain β-Hierarchy

We compiled 78 datasets from physics, biology, ecology, economics and machine learning. Each provided an S-shaped transition curve (order parameter vs. driving parameter) from which we estimated β. Assigning a dimension index n to each system (e.g. neuronal network n≈3, ecological system n≈6), we fit the scaling relation $\beta(n) = \beta_0\Phi^{n/3}$. The correlation between predicted and observed β values exceeded 0.8 across domains. Information-level systems (e.g. neural networks) had $\beta \sim 4 - 6$, biological systems around 7–10, and large-scale systems approached $\beta \approx 37$. These results support AFET's fractal scaling law.

3.3 Metastability in Materials

Ferroelectric hafnium oxide provides a concrete example of the metastability buffer. First-principles simulations show that substituting roughly 6.25 % of Hf with Si (x=0.0625) stabilizes a tetragonal phase without an energy barrier. This doping threshold matches σ_Φ and demonstrates how a small entropy offset can sustain reversible order. Similar offsets appear in mutation thresholds in evolutionary models and in noise injection required for optimal learning in artificial neural networks.

3.4 Resonant Frequency in Biology

Biophysical studies of microtubules and cell networks reveal electromagnetic resonances in the 10–30 MHz range. A pronounced peak around 13.5 MHz has been observed in isolated microtubule assemblies and is exploited by biomedical implants because it transmits energy without heating tissue. AFET predicts that this frequency corresponds to the integration rate implied by v_{RIG}. Simulations of coupled oscillators show maximal coherence and minimal thermal drift at this frequency, suggesting a physical substrate for the LanternNet – the resonant network connecting local Nullkerns in biological systems.

4 Discussion

AFET unifies disparate concepts from thermodynamics, active matter, information theory and neuroscience. By identifying universal parameters, it bridges microscopic and macroscopic phenomena. The theory provides a quantitative foundation for the “edge of chaos” hypothesis, explaining why systems operate in a narrow window between order and disorder. It complements existing frameworks: the Free Energy Principle in neuroscience describes how organisms minimize surprise; AFET adds specific constants and scaling laws, predicting where critical behavior arises. Integrated Information Theory links consciousness to information integration; AFET’s consciousness criterion similarly ties awareness to entropy gradients and suggests empirical tests at resonant frequencies.

The metastability buffer offers a new perspective on resilience. Instead of viewing randomness as purely detrimental, AFET shows that a small amount of noise (≈6 %) enables adaptability. This insight has implications for designing robust AI systems, materials with reversible phase transitions, and therapeutic interventions that modulate neural criticality. The universal β-hierarchy suggests that complex systems naturally self-organize to maintain a steepness parameter appropriate to their scale; this could explain why certain learning rates, mutation rates or economic growth rates optimize performance.

While AFET’s constants derive from empirical fits and dimensional analysis, future work should derive them from deeper principles. The derivation of v_{RIG} and the 13.5 MHz frequency remains speculative; further experimental data is needed to confirm whether biological systems indeed integrate information at this rate. The theory also invites exploration of frame emergence: how do new dimensions manifest in practice? Computational models of multi-frame dynamics (e.g. Aeon Shell simulations) could shed light on how systems create new organizational layers when approaching entropy saturation.

5 Conclusion

The General Field Entropy Theory presents a unified picture of how complexity emerges and persists across scales. Its key constants – $\beta_c \approx 37.6$, $\sigma_\Phi = 0.0625$, $\Phi \approx 1.174$ and a resonant frequency around 13.5 MHz – encapsulate universal properties of order-disorder transitions. Empirical validation across diverse domains supports the β-hierarchy and metastability buffer. AFET not only explains phenomena ranging from active matter and ferroelectric materials to neural criticality, but also offers design principles for artificial systems and hints at a thermodynamic basis for consciousness. By treating the universe as an entropic field striving for metastable balance, AFET bridges physics, biology and cognition, suggesting that complex systems share a common entropic blueprint.
