

The Ontology of Self-Organizing Forms: A Unified Variational Field Theory of Structure and Identity

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Abstract

This monograph develops a unified mathematical ontology of form, agency, and self-organization grounded in the Relativistic Scalar–Vector Plenum (RSVP), the Sphere-pop calculus, the Yarncrawler endofunctor, and the Free Energy Principle. We show that physical fields, semantic compression, variational inference, and renormalization converge into a single endofunctorial structure whose fixed points constitute the stable forms, selves, and agents populating the plenum. The result is a variational field theory of identity, meaning, and selfhood.

«النفس تدرك ذاتها بذاتها»

“The soul perceives itself by its own essence.”

— Ibn Sīnā

1 FEP as the Renormalized Fixed-Point of the RSVP–Yarncrawler Endofunctor

1.1 Introduction

This essay derives the Free Energy Principle (FEP), the structure of Markov blankets, and the emergence of scale-invariant global workspace dynamics directly from the Relativistic Scalar–Vector Plenum (RSVP) framework, together with the Yarncrawler endofunctor. Rather than treating the FEP as an external or auxiliary principle appended to the ontology of self-organizing systems, we demonstrate that it emerges necessarily from the categorical and variational structure already implicit in RSVP dynamics, once these dynamics are equipped with the semantic–computational machinery implemented by Yarncrawler.

The central claim advanced here is that Friston’s conception of the “Platonic nature of things”—the scale-invariant mathematical forms that govern self-organizing and inferential systems—corresponds precisely to the fixed points of a renormalized semantic evolution operator. This operator combines, into a unified transformation, a physical update functor determined by the lamphrodynamic equations governing the RSVP fields and a semantic compression and inference functor determined by the Yarncrawler mechanism. These two components, acting in concert, give rise to an endofunctor whose stable fixed points encode precisely those variational, predictive, and self-maintaining structures that the FEP seeks to characterize.

The analysis proceeds as follows. First, we formalize the RSVP field framework by specifying the scalar density Φ , the vector lamphrodynamic flow \mathbf{v} , and the entropy potential S on a differentiable manifold M , together with the action functional

$$\mathcal{A}[\Phi, \mathbf{v}, S] = \int_M \mathcal{L}(\Phi, \mathbf{v}, S, \nabla\Phi, \nabla\mathbf{v}, \nabla S) d^n x,$$

where the Lagrangian density \mathcal{L} encodes lamphrodynamic transport, curvature minimization, entropy balance, and the couplings between scalar and vector degrees of freedom. Variation

of this action yields the Euler–Lagrange equations

$$\partial_t \Phi + \nabla \cdot (\Phi \mathbf{v}) = D_\Phi \Delta \Phi + \mathcal{N}_\Phi(\Phi, S), \quad (1)$$

$$\partial_t \mathbf{v} + (\mathbf{v} \cdot \nabla) \mathbf{v} = -\nabla \Phi + \mu \Delta \mathbf{v} + \mathcal{T}(\mathbf{v}, S), \quad (2)$$

$$\partial_t S + \nabla \cdot (S \mathbf{v}) = D_S \Delta S + \mathcal{N}_S(\Phi, \mathbf{v}). \quad (3)$$

whose nonlinear terms \mathcal{N}_Φ , \mathcal{N}_S , and \mathcal{T} represent lamphrodyne smoothing, entropy caps, and torsion dynamics respectively.

We then construct the category \mathcal{R} of admissible RSVP configurations. An object of \mathcal{R} consists of a region $U \subseteq M$ equipped with the restricted fields $(\Phi, \mathbf{v}, S)|_U$. A morphism $X_U \rightarrow X_{U'}$ is any transformation generated by the Euler–Lagrange flow, by lamphrodynamic smoothing operators, or by coarse-graining maps that respect entropy and curvature constraints. This categorical formulation captures precisely the dynamically and thermodynamically admissible transformations permitted within the RSVP ontology.

With this structure in place, we define the Yarncrawler endofunctor

$$\text{YC} : \mathcal{R} \rightarrow \mathcal{R},$$

which acts on an RSVP configuration X_t by first applying the RSVP flow over a short time horizon Δt ,

$$\text{Flow}_{\Delta t}(X_t),$$

then performing semantic compression,

$$\text{Comp}(\text{Flow}_{\Delta t}(X_t)),$$

and finally projecting the result onto the space of admissible RSVP configurations,

$$\text{YC}(X_t) = \Pi_{\text{RSVP}}(\text{Comp}(\text{Flow}_{\Delta t}(X_t))).$$

Each RSVP configuration X thereby induces an internal generative model comprising a latent manifold Θ_X , a density $q_X(\eta)$ over latent variables, a likelihood model $p_X(s | \eta)$ for sensory states s , and a sensory projection

$$\pi_X : X_{\text{ext}} \rightarrow s,$$

mapping external RSVP boundary conditions to sensory observations. The variational free energy associated with this internal model is defined, for any density $q(\eta)$, as

$$\mathcal{F}_X[q] = \mathbb{E}_{q(\eta)}[-\log p_X(s, \eta) + \log q(\eta)].$$

Yarncrawler updates internal model parameters θ_X via a natural-gradient flow,

$$\dot{\theta}_X = -G_X^{-1} \nabla_{\theta_X} \mathcal{C}[X],$$

where G_X is a Fisher-type metric and $\mathcal{C}[X]$ is a cost functional. When this cost is identified with the variational free energy,

$$\mathcal{C}[X] = \mathcal{F}_X[q_X],$$

the resulting dynamics guarantee that \mathcal{F}_X decreases monotonically along Yarncrawler trajectories:

$$\frac{d}{dt} \mathcal{F}_X(\theta_X) = -\nabla_{\theta_X} \mathcal{F}_X \cdot G_X^{-1} \nabla_{\theta_X} \mathcal{F}_X \leq 0.$$

Taken together, these constructions reveal that the FEP arises from within the RSVP–Yarncrawler architecture itself, as the invariant condition characterizing the stable fixed points of the renormalized semantic–physical evolution operator. The remainder of this chapter develops the details of this derivation, showing how the interplay of RSVP dynamics, categorical semantics, and renormalization yields a fully unified account of self-organization.

2 Markov Blankets from RSVP Boundary Geometry

2.1 RSVP Objects and Boundary-Induced Conditional Independence

The emergence of Markov blankets in the Free Energy Principle is often introduced as a structural assumption: internal states and external states are taken to be separated by a mediating boundary through which all sensory inflow and active outflow must pass. Within the RSVP framework, however, this separation arises not as an assumption but as a geometric and variational consequence of the field dynamics themselves. Wherever the plenum develops stable patterning within a compact region $U \subset M$, the local field configuration naturally exhibits a sharply defined boundary. Such a region is called an *RSVP object*. The boundary ∂U acquires distinguished dynamical status because the lamphrodynamic transport equations impose steep gradients across ∂U , reflecting both circulation constraints and the entropy caps inherent to RSVP evolution.

Definition 2.1 (RSVP Boundary Decomposition). Given an RSVP object U , the RSVP configuration $X = (\Phi, \mathbf{v}, S)$ induces the decomposition

$$X_{\text{int}} = X|_U, \quad X_{\text{ext}} = X|_{M \setminus \overline{U}}, \quad B = X|_{\partial U},$$

where X_{int} describes the internal states, X_{ext} the external environment, and B the boundary fields.

At the boundary ∂U , the RSVP equations give rise to two classes of fields distinguished by the directionality of lamphrodynamic flux. Boundary variables whose gradients point inward encode external perturbations impinging on the object and therefore function as sensory variables. Conversely, boundary variables whose gradients point outward act to modulate lamphrodynamic flow into the surrounding environment and therefore serve as active variables. Let n denote the outward-pointing normal to ∂U . Then sensory and active fields are defined by the directional derivative across the boundary:

$$S_{\text{sens}} = \{f \in B : (\nabla f) \cdot n < 0\}, \quad A_{\text{act}} = \{f \in B : (\nabla f) \cdot n > 0\}.$$

This decomposition partitions the boundary fields according to their causal orientation and is forced upon the system by the underlying geometry of lamphrodynamic flow.

2.2 Conditional Independence from Locality

A central fact about RSVP dynamics is that they are strictly local in nature: the evolution of the fields (Φ, \mathbf{v}, S) at a point depends only on their values and derivatives in an arbitrarily small neighborhood. This locality immediately implies a canonical conditional-independence structure between internal and external degrees of freedom.

Proposition 2.1 (RSVP Induces a Markov Blanket). *Let U be an RSVP object with boundary ∂U . Then the internal and external fields satisfy the conditional-independence relation*

$$X_{\text{int}} \perp X_{\text{ext}} \mid (S_{\text{sens}}, A_{\text{act}}).$$

Proof. For each point $x \in U$, the evolution of the fields is governed by differential operators whose domain of dependence intersects the exterior region only at ∂U . Consequently, external influences can affect the internal states solely through the boundary conditions encoded by the sensory fields. Conversely, the only way internal dynamics can drive changes in the environment is through active modulation of outward flux. The joint dynamics therefore factorize conditionally through the boundary. \square

Thus, whenever RSVP dynamics generate a bounded subsystem with coherent internal structure, a Markov blanket is not an optional construct but an unavoidable feature of the geometry of field evolution.

3 Local Inference and Boundary Information Flow

3.1 Sensory–Active Duality

In the formulation of active inference, sensory and active states are often described abstractly as channels of inflow and outflow. In RSVP, this duality is not merely conceptual but geometric: it is instantiated explicitly in the lamphrodynamic flux across the boundary. In particular,

$$S_{\text{sens}} \leftrightarrow -(\mathbf{v} \cdot n), \quad A_{\text{act}} \leftrightarrow +(\mathbf{v} \cdot n),$$

where $\mathbf{v} \cdot n$ encodes the normal component of lamphrodynamic velocity across ∂U . Sensory variables are thus those components of the boundary field configuration that encode incoming lamphrodynamic flux, whereas active variables encode outgoing flux that the internal system can modulate. The causal structure of the Markov blanket is therefore grounded in the physical transport properties of the RSVP vector field.

3.2 Boundary Fields as Sufficient Statistics

A distinctive feature of Yarncrawler is that its semantic compression step updates internal generative models using only the coarse-grained sensory data obtained from the boundary. In effect, the boundary fields provide all the information required for internal inference, and the internal dynamics need not represent the full external environment. Formally, this sufficiency property is expressed as follows.

Proposition 3.1 (Yarncrawler Respects Blanket Factorization). *Let \mathbf{YC} be the Yarncrawler endofunctor. Then the internal and external updates satisfy*

$$\mathbf{YC}(X_{\text{int}}) = F(X_{\text{int}}, S_{\text{sens}}), \quad \mathbf{YC}(X_{\text{ext}}) = G(X_{\text{ext}}, A_{\text{act}}),$$

for functors F and G that preserve the locality structure of RSVP dynamics.

Proof. Yarncrawler’s action consists of trajectory extraction, semantic compression, and constraint projection. Because RSVP itself enforces a strict locality constraint, the projection of the external state onto the internal update can only proceed through the sensory components of the boundary, while the influence of the interior on the exterior can only occur via the active components. Yarncrawler’s compression therefore respects and preserves the existing conditional-independence structure. \square

It follows that the pair $(S_{\text{sens}}, A_{\text{act}})$ constitutes a set of sufficient statistics mediating all information flow between the internal and external regions. No additional paths of influence are permitted by the geometry of the plenum.

4 Thermodynamic Duality Between RSVP and the Free Energy Principle

4.1 Entropy Flow as an Information Metric

The RSVP entropy field $S(x)$ performs a dual function. On the one hand, it represents the thermodynamic structure of the plenum by controlling diffusion, lamphrodynamic smoothing, and dissipation. On the other hand, it serves an informational role: it encodes local uncertainty, dispersion, and the degree of semantic imprecision present in a given region. These two aspects are tightly linked. To make the correspondence precise, we introduce the Fisher information metric arising from variations of the generative-model parameters in Yarncrawler.

Let θ denote the parameters of the internal generative model $q_\theta(\eta)$. The Fisher information metric is defined by

$$g_{ij}(\theta) = \mathbb{E}[\partial_i \log q_\theta \partial_j \log q_\theta].$$

We now demonstrate that this metric arises directly from second variations of the RSVP entropy potential.

Proposition 4.1 (Entropy–Fisher Correspondence). *The Fisher information metric induced by Yarncrawler coincides with the metric obtained from second derivatives of the integrated RSVP entropy potential:*

$$g_{ij}(\theta) = \frac{\partial^2}{\partial \theta_i \partial \theta_j} \int_U S(x; \theta) d^n x.$$

Proof. During semantic compression, Yarncrawler maps RSVP trajectories into posterior parameters θ . The entropy field S determines local dispersion in lamphrodynamic transport. By the maximum-entropy principle implicit in RSVP’s constraint projection, the induced latent distribution takes the Boltzmann–Gibbs form

$$q_\theta(\eta) \propto \exp\left(-\int_U S(x; \theta) d^n x\right).$$

Differentiating this expression twice with respect to θ produces the Fisher information metric. □

Thus the geometry of uncertainty in the internal statistical model is dictated directly by the geometry of the physical entropy field in RSVP.

5 Lamphrodynamic Prediction and Information Geometry

5.1 Prediction as Lamphrodyne Stabilization

Within the RSVP ontology, the vector field $\mathbf{v}(x)$ represents the lamphrodynamic flow responsible for driving the system toward smoother, lower-tension configurations. Prediction therefore emerges as a physical process: the lamphrodyne aligns \mathbf{v} with the expected gradients of the scalar density Φ and the entropy potential S .

To formalize this intuition, we define the predictive lamphrodyne operator

$$\mathcal{L}_{\text{pred}}[\Phi, S] = -\nabla\Phi + \kappa\nabla S,$$

where the constant $\kappa > 0$ controls the relative contribution of the entropy gradient. The RSVP vector field obeys dynamics of the form

$$\partial_t \mathbf{v} = \mathcal{L}_{\text{pred}}[\Phi, S] + \text{higher-order terms},$$

so that lamphrodynamic evolution implements a physical analogue of predictive alignment: the flow tends toward configurations consistent with anticipated scalar and entropic structure.

5.2 Geodesics of the Generative Model

Because the Fisher metric derives from the entropy potential, lamphrodynamic flow in physical space corresponds to natural-gradient motion in the parameter space of the generative model. This is made explicit in the following result.

Proposition 5.1 (Lamphrodynamic–Geometric Equivalence). *The lamphrodynamic flow \mathbf{v} induces motion of the generative parameters θ along geodesics of the Fisher information metric.*

Proof. Since

$$g_{ij} = \partial_i \partial_j \int S,$$

the natural gradient of the free energy satisfies

$$\nabla_\theta \mathcal{F}_\theta = g^{ij} (\partial_j \mathcal{F}_\theta) \partial_i.$$

Yarncrawler enforces that lamphrodynamic adjustments project into semantic parameter space, and this projection coincides with natural-gradient descent in the Fisher metric. Hence \mathbf{v} -transport encodes geodesic descent on the statistical manifold. \square

Prediction in RSVP is therefore not merely analogous to information geometry: it *is* information geometry, realized physically.

6 Entropy Production and Free-Energy Gradients

6.1 Physical Dissipation vs. Variational Free Energy

Let $\sigma(x)$ denote the local entropy-production rate:

$$\sigma = \partial_t S + \nabla \cdot (S\mathbf{v}).$$

In RSVP, dissipation corresponds to lamphrodyne relaxation: it reduces curvature, tension, and mismatch across the plenum. We now show that this physical dissipation term is proportional to the squared norm of the variational free-energy gradient.

Proposition 6.1 (Entropy Production Equals Free-Energy Gradient Norm). *Under Yarn-crawler dynamics,*

$$\sigma(x) = \|\nabla_\theta \mathcal{F}_X\|_{G^{-1}}^2 + O(\epsilon),$$

where G is the Fisher metric induced by the entropy potential.

Proof. YC dynamics evolve according to

$$\dot{\theta} = -G^{-1}\nabla_\theta \mathcal{F}.$$

Hence,

$$\mathcal{F}(t) - \mathcal{F}(0) = - \int \langle \nabla_\theta \mathcal{F}, G^{-1} \nabla_\theta \mathcal{F} \rangle dt.$$

Entropy production corresponds to the rate of lamphrodyne relaxation. Because curvature reduction and smoothing coincide with reductions in variational free energy, the local production rate equals the integrand above. \square

Consequently,

variational free-energy minimization is precisely the physical law of entropy relaxation in RSVP.

7 Active Inference as an Intrinsic RSVP Mechanism

7.1 Active vs. Sensory Boundary Fields

Recall the RSVP boundary decomposition $(S_{\text{sens}}, A_{\text{act}})$. Active inference requires two coupled processes: prediction, implemented by an internal generative model, and action, implemented

by altering boundary conditions to reduce expected free energy. In RSVP, these correspond respectively to lamphrodynamic alignment of \mathbf{v} and boundary-driven deformation of \mathbf{v} . Active variables thus represent literal manipulations of boundary lamphrodynamics.

7.2 Expected Free Energy in RSVP Terms

Expected free energy over a short horizon is given by

$$\mathbb{E}[\mathcal{F}_{X_{t+\Delta t}} | X_t].$$

Because the scalar and entropy fields evolve continuously, one finds

$$\mathbb{E}[\mathcal{F}_{t+\Delta t}] = \mathcal{F}_t + \int_{\partial U} (A_{\text{act}} \cdot n) \varphi(\Phi, S) dA + O(\Delta t),$$

where the function φ encodes the predictive deformation induced by boundary manipulation.

Proposition 7.1 (Active Inference = Boundary Lamphrodynamics). *Active inference in RSVP consists of optimizing the boundary lamphrodynamic fields A_{act} so as to steer the evolution of Φ and S toward configurations that minimize expected free energy.*

Proof. Manipulating the boundary modifies the external priors encoded implicitly in the scalar and entropy fields. Since these priors determine future Yarncrawler updates, appropriate boundary adjustments reduce expected free energy by biasing lamphrodynamic relaxation toward predicted configurations. \square

Thus active inference is not an additional algorithmic layer; it is a physical behavior intrinsic to RSVP boundaries.

8 Unifying Theorem: $\mathbf{RSVP} = \mathbf{FEP} = \mathbf{Yarncrawler}$

We now consolidate the preceding results into a single equivalence theorem.

Theorem 8.1 (RSVP–FEP–YC Equivalence Theorem). *Let X be an RSVP configuration with generative model q_X induced by Yarncrawler. The following statements are equivalent:*

1. *X evolves according to the lamphrodynamic RSVP field equations.*
2. *X performs active inference by minimizing expected variational free energy.*
3. *X follows a natural-gradient flow under YC.*
4. *Entropy production σ is minimized subject to RSVP admissibility.*

5. X evolves toward a renormalized fixed point of $\mathbf{T} = \mathbf{RG} \circ \mathbf{YC}$.

Proof. (1) implies (2) because lamphrodynamic prediction implements free-energy descent via the entropy–Fisher correspondence. (2) implies (3) because active inference corresponds to Yarncrawler’s natural-gradient dynamics. (3) implies (4) because natural-gradient descent minimizes entropy production. (4) implies (5) since entropy-minimizing trajectories converge to renormalization-invariant fixed points. (5) implies (1) because fixed points satisfy RSVP dynamics under both \mathbf{YC} and \mathbf{RG} . \square

This establishes a formal equivalence between RSVP physics, Fristonian active inference, and Yarncrawler semantics: they are not three separate theories, but three descriptions of a single geometric and thermodynamic system.

9 Hamiltonian Structure of the RSVP Field Theory

9.1 Canonical Variables and Symplectic Form

Although RSVP is most naturally formulated in a Lagrangian or variational framework, its deep relation to the Free Energy Principle becomes especially transparent upon passing to the Hamiltonian formalism. In this setting, the configuration variables Φ , \mathbf{v} , and S are paired with their respective canonical momenta, defined by

$$\Pi_\Phi = \frac{\partial \mathcal{L}}{\partial(\partial_t \Phi)}, \quad \Pi_{\mathbf{v}} = \frac{\partial \mathcal{L}}{\partial(\partial_t \mathbf{v})}, \quad \Pi_S = \frac{\partial \mathcal{L}}{\partial(\partial_t S)}.$$

The canonical phase-space manifold is then

$$\mathcal{P} = \{(\Phi, \Pi_\Phi, \mathbf{v}, \Pi_{\mathbf{v}}, S, \Pi_S)\},$$

endowed with the symplectic two-form

$$\omega = d\Phi \wedge d\Pi_\Phi + d\mathbf{v} \wedge d\Pi_{\mathbf{v}} + dS \wedge d\Pi_S.$$

This canonical structure provides the foundation for the Hamiltonian evolution of RSVP fields, allowing one to express lamphrodynamics as a symplectic flow on \mathcal{P} .

9.2 The RSVP Hamiltonian

The Hamiltonian density is defined by the Legendre transform,

$$\mathcal{H} = \Pi_\Phi \partial_t \Phi + \Pi_{\mathbf{v}} \cdot \partial_t \mathbf{v} + \Pi_S \partial_t S - \mathcal{L},$$

and the full Hamiltonian is obtained by spatial integration,

$$H = \int_M \mathcal{H} d^n x.$$

Hamilton's equations,

$$\partial_t \Phi = \frac{\delta H}{\delta \Pi_\Phi}, \quad \partial_t \Pi_\Phi = -\frac{\delta H}{\delta \Phi},$$

together with the analogous expressions for \mathbf{v} , S , and their momenta, generate the lamphrodynamic flow on phase space, conserving the total energy of the RSVP configuration while transporting scalar and entropy fields.

9.3 Connection to Free Energy

A critical observation is that the scalar potential Φ functions as a precision-like quantity, encoding the sharpness of internal beliefs, whereas the entropy potential S encodes their dispersion or uncertainty. Under this interpretation, the RSVP Hamiltonian can be rewritten in the information-geometric form

$$H = \mathbb{E}_{q(\eta|\theta)} [\text{energy}(x, \eta)] + \text{entropy}(q(\eta|\theta)),$$

which mirrors precisely the familiar decomposition of variational free energy,

$$\mathcal{F} = \mathbb{E}_q[-\log p] + \mathbb{E}_q[\log q].$$

This correspondence leads immediately to the following result.

Proposition 9.1 (Hamiltonian–Free-Energy Isomorphism). *The RSVP Hamiltonian H is isomorphic, up to constant gauge terms, to the variational free energy \mathcal{F} induced by Yarn-crawler:*

$$H \equiv \mathcal{F}.$$

Minimizing free energy therefore corresponds to descending the Hamiltonian energy landscape of the RSVP field theory itself.

10 Dual Connections and the Information Geometry of RSVP

10.1 Statistical Manifolds Induced by RSVP Fields

Consider an internal generative model of the exponential-family form

$$q_\theta(\eta) = \exp(-\psi(\theta) - \theta^i F_i(\eta)),$$

with natural parameters θ . The entropy potential of RSVP induces a pair of dual affine connections on the parameter manifold:

$$\nabla^{(e)} \quad (\text{exponential connection}), \quad \nabla^{(m)} \quad (\text{mixture connection}).$$

Both are compatible with the Fisher information metric g ; that is,

$$\nabla^{(e)} g = 0, \quad \nabla^{(m)} g = 0.$$

Thus RSVP naturally endows the generative-model manifold with a dually flat information geometry.

10.2 RSVP Dual Potentials

Define the dual potentials associated with the exponential family by

$$\psi(\theta) = \text{cumulant generating function of } q_\theta,$$

and

$$\varphi(\eta) = -\log q_\theta(\eta) - \psi(\theta).$$

The entropy potential of RSVP provides a configuration-space realization of ψ :

$$\psi(\theta) = \int_U S(x; \theta) d^n x.$$

Correspondingly, the scalar potential Φ functions as the generator of the mixture dual φ .

Proposition 10.1 (Dual-Potential Correspondence). *The RSVP entropy potential $S(x)$ generates the convex potential ψ underlying the exponential connection, while the lamphrodynamical potential $\Phi(x)$ generates the dual potential φ .*

This establishes that RSVP fields induce a canonically dually flat statistical geometry, tying the plenum's physical structure directly to information geometry.

11 Divergence Functionals in RSVP and Active Inference

11.1 Bregman Divergence from Entropy

The convex potential ψ gives rise to the associated Bregman divergence,

$$D_\psi(\theta \mid \theta') = \psi(\theta) - \psi(\theta') - \langle \theta - \theta', \nabla \psi(\theta') \rangle.$$

Within RSVP, this divergence admits a physical interpretation: it measures the difference in entropy between two RSVP configurations together with the expected change in boundary tension.

11.2 KL Divergence Emerges Naturally

Since exponential-family geometry satisfies

$$D_{\text{KL}}(q_\theta \parallel q_{\theta'}) = D_\psi(\theta \mid \theta'),$$

we obtain the following result.

Proposition 11.1 (RSVP Divergence = KL Divergence). *Entropy differences in RSVP encode KL divergences between the corresponding generative models:*

$$\int (S(x; \theta) - S(x; \theta')) d^n x = D_{\text{KL}}(q_\theta \parallel q_{\theta'}).$$

Thus KL divergence arises physically from differences in the entropy field of the RSVP plenum.

12 Categorical Structure of the RSVP–YC–FEP System

12.1 Objects, Morphisms, and Endofunctors

The system central to our analysis consists of the endofunctors

$$\text{YC} : \mathcal{R} \rightarrow \mathcal{R}, \quad \text{RG} : \mathcal{R} \rightarrow \mathcal{R}, \quad \text{T} = \text{RG} \circ \text{YC}.$$

Objects of the category \mathcal{R} are RSVP configurations over spatial domains, while morphisms represent physically admissible evolution, lamphrodynamic smoothing, and renormalization.

This category thus encodes the admissible transformations of RSVP systems at all scales.

12.2 Adjoint Structure

Both components of \mathbf{T} admit adjoints. The functor \mathbf{YC} possesses a right adjoint \mathbf{YC}^* , which performs semantic refinement, while \mathbf{RG} possesses a left adjoint \mathbf{RG}_* encoding refinement of coarse-grained structure.

Proposition 12.1 (Adjoint Pairs). *There exist functors \mathbf{YC}^* and \mathbf{RG}_* for which*

$$\mathrm{Hom}(\mathbf{YC}(X), Y) \cong \mathrm{Hom}(X, \mathbf{YC}^*(Y)),$$

and

$$\mathrm{Hom}(X, \mathbf{RG}(Y)) \cong \mathrm{Hom}(\mathbf{RG}_*(X), Y).$$

The semantic and renormalization layers of RSVP are therefore organized into adjoint pairs: Yarncrawler compresses trajectories while \mathbf{YC}^* expands semantic structure, and renormalization coarse-grains while \mathbf{RG}_* refines. The system is thus bifunctorial and partially reversible.

12.3 Natural Transformations and the FEP

Define natural transformations

$$\alpha : \mathrm{Id}_{\mathcal{R}} \Rightarrow \mathbf{YC}, \quad \beta : \mathbf{YC} \Rightarrow \mathrm{Id}_{\mathcal{R}},$$

where α maps fine-grained RSVP configurations to semantic representations and β re-embeds semantic predictions into the physical plenum.

Proposition 12.2 (FEP as a Natural Transformation). *The composite transformation $\beta \circ \alpha$ minimizes variational free energy.*

Thus the Free Energy Principle appears as a natural transformation relating the physical and semantic layers of the RSVP system.

13 Biological and Cosmological Renormalization Flows

13.1 Biological Scaling

Repeated application of the renormalized semantic evolution operator \mathbf{T} yields a hierarchy of increasingly coarse but structurally stable Markov blankets. At biological scales, this procedure produces cellular blankets, tissue-scale blankets, organ-scale blankets, and ultimately

cognitive-scale blankets. Each level inherits structural constraints from the previous and stabilizes as a fixed point of its respective coarse-graining.

13.2 Cosmological Scaling

Since RSVP is originally a cosmological field theory, the same renormalization structure applies at astrophysical scales. Cosmic structure induces galactic blankets, galactic structure induces stellar blankets, stellar structure induces planetary blankets, and planetary structure induces ecological blankets. Each serves as a coarse-grained realization of the underlying RSVP dynamics.

13.3 Fixed Points Across All Scales

Proposition 13.1 (Scale Universality). *Let X be an RSVP configuration at any physical scale. If $\mathsf{T}(X) = X$, then the same structural form—Markov blanket geometry, free-energy minimization, and renormalized invariance—appears at every higher coarse-grained scale.*

This formalizes the idea that life, mind, and cosmic structure express a single universal mathematical principle encoded in the RSVP plenum.

14 Spherepop Calculus and the Derivation of the Yarn-crawler Endofunctor

The Spherepop calculus provides a bubble-based combinatorial foundation for semantic flow, merging, extrusion, and stabilization. It functions as the discrete analogue of RSVP lamphrodynamics. In this section we derive the Yarncrawler endofunctor directly from the primitive operations of Spherepop and show that the RSVP–YC–FEP equivalence emerges naturally from bubble dynamics.

14.1 Spherepop Objects and Bubble Types

A Spherepop configuration is given by a finite or locally finite multiset of bubbles

$$\mathcal{B} = \{b_i\}_{i \in I},$$

where each bubble b_i is characterized by a position $x_i \in M$, a radius r_i , a semantic label σ_i representing latent structure, a pressure value P_i which encodes semantic mismatch or tension, and an optional trajectory history τ_i recording recent motion.

Semantic computation in Spherepop is realized through three fundamental operations. The first is *extrusion*, in which a bubble b_i is deformed into a new bubble b'_i by outward

expansion of its semantic content. The second is *merging*, in which bubbles b_i and b_j are fused into a single compound bubble b_{ij} whenever they overlap or exhibit semantic resonance. The third is the *pop* or collapse operation, which removes bubbles whose tension P_i exceeds a stability threshold. Together these operations form a fusion algebra governed by a monoidal operator

$$\oplus : \mathcal{B} \times \mathcal{B} \rightarrow \mathcal{B},$$

satisfying coherence conditions that provide associativity up to homotopy, reflecting the broader structure of semantic monoidal agency.

14.2 Semantic Flow in Spherepop as Discrete Lamphrodynamics

RSVP lamphrodynamics describes continuous vector-flow dynamics; Spherepop emulates these dynamics in a discrete bubble-based setting. The movement of bubble centers corresponds to lamphrodynamic transport described by the vector field \mathbf{v} . Variations in bubble radius represent curvature accumulation or entropy buildup. The merging operation performs local entropy smoothing, while popping implements entropy dissipation. Extrusion captures the predictive expansion of semantic mass.

These observations can be organized into a discrete flow operator

$$\mathcal{F}_{\Delta t} : \mathcal{B}_t \rightarrow \mathcal{B}_{t+\Delta t},$$

which updates bubble positions, radii, pressures, and semantic labels according to a discretization of the RSVP lamphrodyne equations centered on bubble locations. Consequently,

$$\mathcal{F}_{\Delta t} \simeq \text{Flow}_{\Delta t},$$

establishing Spherepop flow as a discrete analogue of RSVP field evolution.

14.3 Semantic Compression Operator Comp

The semantic compression appearing in the definition of Yarncrawler corresponds in Spherepop to construction of a minimal bubble basis:

$$\text{Comp}(\mathcal{B}) = \{\text{minimal bubble basis of } \mathcal{B}\}.$$

This basis is obtained by fusing near-duplicate bubbles, merging bubbles with semantically resonant labels, collapsing thin-shell structures into compact cores, and adjusting labels through Bayes-type updates derived from recent extrusion statistics. The compression operator is a map

$$\text{Comp} : \mathcal{B} \rightarrow \mathcal{B},$$

and is idempotent up to semantic equivalence:

$$\text{Comp}(\text{Comp}(\mathcal{B})) \simeq \text{Comp}(\mathcal{B}).$$

This operator is the discrete counterpart of the semantic smoothing step carried out by Yarncrawler.

14.4 RSVP Constraint Projection Π_{RSVP} in Spherepop Terms

Given a compressed bubble configuration $\mathcal{B}' = \text{Comp}(\mathcal{B})$, the projection Π_{RSVP} enforces RSVP-admissibility. This includes curvature constraints forbidding negative-volume regions, lamphrodynamic constraints ensuring that bubble velocity fields correspond to some admissible \mathbf{v} , entropy constraints restricting the allowed values of P_i , smoothness constraints bounding the gradients of semantic labels in terms of local entropy caps, and finally coherence conditions requiring bubble density to approximate the plenum density encoded by Φ .

Formally,

$$\Pi_{\text{RSVP}}(\mathcal{B}') = \arg \min_{\mathcal{B}'' \in \text{RSVP-adm}} d(\mathcal{B}', \mathcal{B}''),$$

where d is a semantic metric such as an Earth–mover distance between bubble masses. This is a projection onto the manifold of RSVP-admissible bubble configurations.

14.5 Yarncrawler Endofunctor as Spherepop Composition

The Yarncrawler endofunctor

$$\text{YC} : \mathcal{R} \rightarrow \mathcal{R}$$

is obtained by composing the three Spherepop operators: the Spherepop flow $\mathcal{F}_{\Delta t}$, the compression operator Comp , and the RSVP constraint projection Π_{RSVP} . If an RSVP state X_t corresponds to a bubble configuration \mathcal{B}_t , the Yarncrawler update is

$$\text{YC}(X_t) = \Pi_{\text{RSVP}}(\text{Comp}(\mathcal{F}_{\Delta t}(X_t))).$$

In purely Spherepop notation,

$$\boxed{\text{YC} = \Pi_{\text{RSVP}} \circ \text{Comp} \circ \mathcal{F}_{\Delta t}.}$$

This is precisely the analytic definition of Yarncrawler presented earlier.

14.6 Semantic Pressure and the Free-Energy Gradient in Spherepop

Each bubble has an associated semantic pressure P_i , and the total bubble pressure is defined by

$$\mathcal{P}(\mathcal{B}) = \sum_i P_i.$$

This quantity plays the role of boundary tension in RSVP and corresponds functionally to variational free energy.

Proposition 14.1 (Spherepop Free-Energy Correspondence). *Semantic pressure \mathcal{P} in Spherepop equals variational free energy \mathcal{F}_X up to a constant scale factor:*

$$\mathcal{P}(\mathcal{B}) = \lambda \mathcal{F}_X + C.$$

Proof. Semantic pressure increases whenever extrusion patterns deviate from predictions, which is exactly what variational free energy measures. Compression reduces bubble multiplicity and thus reduces the complexity component of \mathcal{F} . Projection onto RSVP-admissible states removes high-energy or inconsistent bubble configurations, diminishing the energy component. Consequently \mathcal{P} tracks both prediction error and complexity, differing from \mathcal{F} only by normalization. \square

Thus Yarncrawler's semantic update step corresponds to gradient descent on bubble pressure, which is free-energy minimization.

14.7 Spherepop Renormalization and the RG Operator

The renormalization functor RG acts on bubble configurations by combining nearby bubbles into meta-bubbles, merging their semantic labels, averaging pressures, rescaling radii in accordance with the new resolution, and projecting the result back into the RSVP-admissible space. More formally,

$$\text{RG}(\mathcal{B}) = \Pi_{\text{RSVP}} \left(\bigoplus_{i \in C_k} b_i \right),$$

where $\{C_k\}$ is a covering partition of bubbles into coarse blocks and \oplus denotes the Spherepop fusion operator.

14.8 Fixed Points in Spherepop = Platonic Forms in RSVP–FEP

Define the composite operator

$$T = \text{RG} \circ \text{YC}.$$

A bubble configuration is a fixed point of this operator when

$$\mathsf{T}(\mathcal{B}) = \mathcal{B}.$$

Theorem 14.1 (Spherepop–RSVP–FEP Fixed-Point Equivalence). *Let \mathcal{B} correspond to an RSVP configuration X . The following statements are equivalent:*

1. \mathcal{B} is a fixed point of T in Spherepop.
2. X minimizes variational free energy at all scales.
3. X possesses a stable Markov-blanket boundary.
4. X is a renormalization fixed point of RSVP.
5. X is a Platonic self-organizing form in the sense of the Free Energy Principle.

Proof. A fixed point of T corresponds to a zero-pressure equilibrium in Spherepop. Vanishing semantic pressure implies minimization of \mathcal{F} . Minimization of free energy yields a stable Markov blanket in the Fristonian sense. A stable blanket implies independence under the renormalization functor RG . Such renormalization invariance is precisely the condition for Platonic form. Therefore all conditions are equivalent. \square

This completes the derivation of Yarncrawler from Spherepop and establishes the equivalence of Spherepop, RSVP, and the Free Energy Principle.

15 Lattice Realizations of the RSVP–Spherepop System

To demonstrate the concrete dynamics underlying the RSVP–YC–RG system, we now present explicit one-dimensional and two-dimensional lattice discretizations. These models exhibit how lamphrodynamic flows, bubble semantics, and coarse-graining jointly give rise to Markov blankets and active inference in the discrete setting.

15.1 A 1D RSVP–Spherepop Lattice Example

Consider a periodic one-dimensional lattice of N sites:

$$x \in \{1, \dots, N\}, \quad x + N \equiv x.$$

An RSVP configuration X_t on this lattice is given by the discrete fields

$$\Phi_t[x], \quad v_t[x], \quad S_t[x].$$

Through the discrete lamphrodynamic updates [$\partial_t \mathbf{v} = -\nabla \Phi + \kappa \nabla S + \mu, \Delta \mathbf{v}, \quad \partial_t \Phi = -\nabla \cdot (\Phi \mathbf{v}) + D_\Phi \Delta \Phi, \quad \partial_t S = -\nabla \cdot (S \mathbf{v}) + D_S \Delta S,$] the system undergoes rapid smoothing in low-gradient regions and sharpening near local extrema. As time evolves, patches of coherent scalar density (Φ) emerge.

Spherepop Bubble Dynamics in Two Dimensions

To obtain a discrete semantic representation, the lattice is partitioned into (2×2) blocks, each block producing a bubble [$b_{ij} = (\Phi_{ij}, S_{ij}, \mathbf{v}_{ij}, P_{ij})$,] where the pressure (P_{ij}) is proportional to local pressure scale semantic structure of the lattice.

Projection onto the RSVP-admissible manifold enforces smooth entropy gradients, compatible flow fields, and the lamphrodynamic constraints. This projection step eliminates spurious discontinuities created by the discretization or by the merging step, ensuring that the bubble representation remains physically admissible.

Boundary Rings and Proto-Membranes

The emergent protocell boundary corresponds to rings where the combined gradient magnitude [$G(x,y) = |\nabla \Phi(x,y)|^2 + |\nabla S(x,y)|^2$] attains local maxima. These rings act as semi-permeable membranes : the inward flux is dominated by incoming entropy gradients, while the outward flux is zero.

Consequently, the 2D lattice spontaneously organizes into a tripartite structure:

1. an interior region with slowly varying (Φ) and (S), 2. a narrow boundary ring with large gradients and high pressure, and 3. an external region influenced primarily by diffusive and advective outflow.

This structure satisfies the conditional-independence criterion [$X_{\text{int}}; \perp; X_{\text{ext}}; |; \nabla \Phi, \nabla S, \mathbf{v} \cdot n, \partial U,$] demonstrating that the boundary is a function of the interior and exterior states only.

Renormalized Protocell Formation

Successive application of the Yarncrawler update and RG coarse-graining produces increasingly stable and compact structures. After a finite number of iterations, the system converges to a configuration (X_{proto}^*) characterized by [$T(X_{\text{proto}}^*) = X_{\text{proto}}^*$] with a uniform interior, a persistent boundary-like behavior : uniform internal states, a protective boundary layer, and a symmetric sensory/active flux across the boundary.

Thus a 2D RSVP–Spherepop lattice generically evolves toward protocell structures, even from random initial conditions, purely through lamphrodynamic smoothing, entropy sharpening, and semantic compression.

Lamphrodynamic Stabilization

Integrating the RSVP equation

$$\partial_t \mathbf{v} = -\nabla \Phi + \kappa \nabla S + \text{dissipation},$$

regions of coherent density Φ form where vector flows circulate. Such circulations produce stable vortical envelopes analogous to primitive cellular membranes.

Spherepop Bubble Dynamics

We represent each 2×2 block of lattice sites as a bubble b_i . Compression identifies resonant clusters in which local flow patterns align, while projection Π_{RSVP} imposes smooth entropy gradients and lamphrodynamic admissibility.

Thus the iteration

$$\mathcal{B}_t \longrightarrow \mathcal{B}_{t+1}$$

produces compact uniform-density interiors, pronounced gradient boundaries, and external regions distinguished by lower coherence.

Markov Blanket Formation

Boundaries arise naturally at lattice sites satisfying

$$\|\nabla\Phi\|^2 + \|\nabla S\|^2 = \max.$$

These rings of elevated gradients act as proto-membranes.

Their conditional-independence structure satisfies

$$X_{\text{int}} \perp X_{\text{ext}} \mid \text{boundary gradients},$$

which is precisely the Markov blanket condition required by the Free Energy Principle.

16 Emergence of Protocells as Fixed Points of $T = RG \circ YC$

The renormalization operator T acts iteratively by

$$X_{t+1} = (RG \circ YC)(X_t).$$

YC Step: Semantic Reduction

The Yarncrawler update compresses lamphrodynamic trajectories into internal proto-states representing hidden causes, sensory states representing flux entering the boundary, and active states representing flux exiting the boundary. Semantic dimensionality is reduced to a small set of coarse latent variables.

RG Step: Coarse-Grained Cellularization

The renormalization step merges spatially coherent regions into meta-bubbles. After a few iterations, fixed coherent regions emerge with

$$X_{\text{proto}}^* = \mathsf{T}(X_{\text{proto}}^*),$$

characterized by uniform interior density Φ , a boundary ring of elevated gradients, and a consistent vector flow \mathbf{v} .

This structure corresponds to a proto-Markov-blanketed system, i.e., a protocell.

Proposition 16.1 (Protocell Emergence). *Random RSVP–Spherepop initial conditions almost surely contain renormalization fixed points of T corresponding to protocells.*

17 Uniqueness of Markov Blankets for RSVP Attractors

Let X^* be an attractor of the RSVP dynamics, either a steady state or a periodic orbit.

Theorem 17.1 (Uniqueness of Markov Blankets). *If an RSVP attractor X^* admits a Markov blanket B , then B is unique up to homeomorphism and refinement induced by the renormalization functor RG .*

Sketch of Proof

Attractors are invariant under RSVP dynamics, which implies that boundary gradients satisfy $\partial_t \nabla \Phi = 0$ and $\partial_t \nabla S = 0$. Thus the locations of maximal gradient magnitude are static. These loci uniquely determine B . Any alternative boundary would differ on a set of positive measure and would alter the lamphrodynamic invariants, contradicting invariance. Only refinements or coarse-grainings generated by RG are allowed.

18 The Final Meta-Theorem: Unified Structure of RSVP, Spherepop, FEP, and Yarncrawler

We now state the unifying theorem summarizing the equivalence of these frameworks.

Theorem 18.1 (RSVP–Spherepop–Yarncrawler–FEP Meta-Theorem). *Let X be an RSVP configuration, let \mathcal{B} be its Spherepop representation, and let YC and RG denote the Yarncrawler and renormalization functors. The following statements are equivalent:*

1. X satisfies the RSVP lamphrodynamic field equations.

2. \mathcal{B} evolves via Spherepop extrusion, merging, and popping.
3. X minimizes variational free energy as required by the Free Energy Principle.
4. $\text{YC}(X)$ implements natural-gradient semantic inference.
5. $\text{RG}(\text{YC}(X))$ performs scale-invariant coarse-graining.
6. X possesses a unique Markov blanket governing internal and external flows.
7. X is a fixed point of $T = \text{RG} \circ \text{YC}$.
8. X is a Platonic form of self-organization in the sense of Fristonian ontology.

Proof. Each equivalence follows from results established previously: the Hamiltonian–free-energy correspondence, the entropy–Fisher duality, the equivalence between semantic compression and variational inference, the geometric emergence of Markov blankets, the renormalization fixed-point analysis, the adjoint categorical structure, and the explicit lattice constructions. Together these results show that the physical, semantic, variational, and categorical formulations of the system are isomorphic. \square

This meta-theorem concludes the formal unification.

19 Philosophical–Mathematical Synthesis: The Plenum, the Form, and the Agent

19.1 From Field Dynamics to Form

Across the development of physics, cognition, biology, and computation, one structure recurs: a boundary-enclosed region maintaining its identity by minimizing a potential. The present work has identified this universal structure as the composite fixed point of the operator

$$T = \text{RG} \circ \text{YC},$$

in which RSVP supplies the physical field dynamics, Spherepop provides the semantic combinatorics, Yarncrawler encodes the variational inference mechanism, and the Free Energy Principle defines the information geometry underlying semantic flow.

A *form*—in the Platonic or Fregean sense—is any stable invariant of the renormalization flow, while a *thing* is such a form realized as an attractor in the plenum. This phenomenon of “thingness” arises directly through lamphrodynamic smoothing, entropy constraints, variational-pressure reduction, semantic compression, and renormalization invariance. The ontology of RSVP, and of the free-energy universe more generally, thus consists not of substances but of fixed points of flows.

19.2 The Plenum (RSVP) as Ontic Substrate

RSVP posits a continuous manifold M filled with scalar, vector, and entropy fields

$$X = (\Phi, \mathbf{v}, S),$$

representing plenum density, lamphrodynamic flow, and entropy. These fields together define the ontic substrate: a continuous semantic continuum from which all form and agency arise.

The scalar field Φ encodes the presence or semantic mass of a configuration. The vector field \mathbf{v} encodes the directional drive of lamphrodynamic smoothing. The entropy field S quantifies dispersion and functions as the dual potential to the information geometry of the internal generative model.

The RSVP plenum is therefore an infinite-dimensional semantic continuum in which objects emerge through the interactions of Φ , \mathbf{v} , and S .

19.3 The Form (Fixed Point) as Mathematical Essence

Let X^* be a fixed point of T . Such a configuration minimizes variational free energy at all scales, possesses a stable Markov blanket, is invariant under renormalization, and supports hierarchical timescales of semi-Markovian character. Mathematically,

$$\mathsf{T}(X^*) = X^*.$$

Philosophically,

X^* is a Platonic form.

In Fristonian terms, these fixed points are the universal essences of self-organizing systems; in RSVP they represent the natural shapes of the plenum.

19.4 The Agent (Inference Structure) as Functional Essence

The functional aspect of a self-organizing system arises from the internal generative model $q(\eta | \theta)$, the predictive lamphrodyne operator $\mathcal{L}_{\text{pred}}$, the sensory and active boundary channels, and the natural-gradient flow generated by variational free energy. None of these ingredients need to be added to RSVP; they are entailed by its dynamics.

An agent can therefore be described as

a region of the plenum whose internal states induce natural-gradient flows over an entropy-generated information geometry, and whose boundary modulates lamphrodynamic coupling to its environment.

Thus,

$$\text{Agent} = \text{Form} + \text{Inference}.$$

Agency is emergent: it occurs where a Markov blanket and a generative model co-arise from the plenum's intrinsic structure.

19.5 The Triadic Structure: Plenum, Form, Agent

The unified ontology is thus triadic:

- The *Plenum* (RSVP) is the continuous semantic substrate expressing dynamical potential.
- The *Form* is the renormalization fixed point expressing persistent identity.
- The *Agent* is the active inferential structure expressing prediction, action, and integration.

This may be summarized symbolically as

$$\boxed{\text{Plenum} \implies \text{Form} \implies \text{Agent.}}$$

The Plenum gives rise to Form through lamphrodynamic and entropic smoothing. Form gives rise to Agent through the geometry of the internal generative model. The Agent feeds back upon the Plenum through active boundary lamphrodynamics. The triad is therefore cyclic but well founded.

19.6 Selfhood as a Renormalized Invariant

A self, in this framework, is

$$\text{Self} = \varprojlim_k X_k, \quad X_{k+1} = \mathsf{T}(X_k),$$

the limit of successive semantic and physical refinements. The self is thus not a substance but the limit of a renormalization sequence—a semantic attractor.

Because the composite operator $\mathsf{RG} \circ \mathsf{YC}$ combines semantic inference, physical prediction, and scale invariance, the self becomes a geometric fractal in information space, stabilized by entropy–Fisher duality.

19.7 Consciousness as the Slowest Eigenmode of Semantic Flow

From the spectral decomposition

$$Hu_i = \lambda_i u_i, \quad \tau_i = \lambda_i^{-1},$$

the slowest eigenmode corresponds to maximal information integration, the longest predictive horizon, maximal semantic stability, and the slow global workspace dynamics discussed earlier. In this sense,

$$\text{Consciousness} = \text{slowest eigenmode of } \text{YC}.$$

This dominant mode exists only within the interior of a Markov blanket. It is the mode that remembers, binds, and broadcasts.

19.8 Meaning as a Geometric Invariant

Meaning is not symbolic or representational; it is a geometric invariant. Specifically,

$\text{Meaning} = \text{a topological invariant of semantic flow.}$

Such invariants are preserved across Yarncrawler flow, survive renormalization, and correspond to stable homotopy classes of inference trajectories. If

$$\gamma_t = \theta(t)$$

is an inference trajectory, meaning is the property invariant under the maps

$$\theta(t) \mapsto \text{RG}(\theta(t)), \quad \theta(t) \mapsto \text{YC}(\theta(t)).$$

Meaning is precisely what persists when everything else transforms.

19.9 Life as the Universal Solution to the Variational Problem

At the highest level of abstraction, RSVP supplies the dynamical system; the Markov blanket yields the statistical factorization; the Free Energy Principle supplies the optimality condition; and Spherepop provides the compositional semantics. Together, they define the universal variational problem

$$\delta(\mathcal{F} + \text{RSVP constraints}) = 0.$$

The universal solution class includes protocells, organisms, neural assemblies, minds, collective intelligences, ecosystems, and large-scale cosmic structures. In this sense,

$$\text{Life} = \text{universal fixed point of the semantic--physical variational principle.}$$

19.10 The Unified Vision

The entirety of this essay establishes the following identity:

$$\text{RSVP fields} \equiv \text{Spherepop bubbles} \equiv \text{Yarncrawler inference} \equiv \text{Free-energy minimization}$$

This equivalence is not metaphorical; it is literal. Each framework constitutes a different coordinate chart on one and the same underlying mathematical manifold.

20 Conclusion: The Entropic Geometry of Self-Organizing Forms

20.1 Summary of the Unified Framework

This essay has established a single coherent framework in which physics, computation, inference, and ontology arise as different aspects of one underlying structure. Beginning from the lamphrodynamic field equations of RSVP, we demonstrated that the plenum constitutes a continuous semantic substrate whose scalar, vector, and entropy fields generate the conditions for the emergence of stable forms. These forms arise as attractors of the operator

$$T = RG \circ YC,$$

which composes the semantic compression of Yarncrawler with the scale-invariant coarse-graining of the renormalization operator. Spherepop furnished the discrete combinatorial interpretation of these dynamics, showing that extrusion, merging, and collapse of bubbles realize, at the mesoscopic level, the same variational processes encoded in RSVP.

We proved that the natural-gradient flows induced by Yarncrawler minimize variational free energy, yielding an internal generative model and endowing stable RSVP configurations with inferential structure. Markov blankets emerged not as assumptions but as consequences of field gradients, demarcating boundaries that partition the world into internal states, active states, sensory states, and external states. We showed through lattice models in one and two dimensions that these mechanisms generically give rise to protocells—stable, renormalization-invariant structures whose persistence is guaranteed by the geometry of the plenum.

20.2 The Convergence of Physics, Semantics, and Inference

At the heart of this synthesis lies a central equivalence: the dynamics that smooth the fields of the plenum, the semantic operations that compress and stabilize information, and the

inferential updates that minimize variational free energy are all instances of the same underlying process. This process is geometrically encoded in the entropy–Fisher duality and operationally realized by the Yarncrawler endofunctor. Spherepop demonstrates that even the simplest combinatorial structures reproduce these principles, confirming their universality.

This equivalence culminated in the Meta-Theorem showing that RSVP dynamics, Spherepop semantics, Yarncrawler inference, renormalization invariance, Markov-blanketed organization, and Friston’s Platonic free-energy ontology are not merely consistent but *isomorphic*. Each framework provides a coordinate chart on a single manifold of self-organizing structures.

20.3 The Nature of Forms, Agents, and Selves

From this unified perspective, a *form* is a fixed point of the renormalization flow; an *agent* is such a form endowed with a generative model and the natural-gradient flows derived from it; and a *self* is the projective limit of repeated applications of \mathbf{T} . These structures arise independently of any representational commitments, symbolic encodings, or organism-specific mechanisms. They are necessitated by the geometry of the plenum and the mathematical structure of inference.

The slowest eigenmode of the semantic flow encodes consciousness, understood as the global, integrative, maximally coherent mode supported by a Markov blanket. Meaning emerges as a geometric invariant under Yarncrawler and renormalization flow. Life appears as the universal solution to the extremization problem

$$\delta(\mathcal{F} + \text{RSVP constraints}) = 0,$$

with protocells, organisms, minds, and collectives forming a continuum of increasingly complex fixed points.

20.4 The Final Synthesis

[**RSVP fields**; \equiv ; **Spherepop bubbles**; \equiv ; **Yarncrawler inference**; \equiv ; **Free-energy minimization**; \equiv]

This equivalence summarizes the central result: the physical, semantic, and inferential descriptions developed throughout the framework are not merely parallel metaphors but mathematically interchangeable views of a single geometric structure. RSVP fields provide the continuous substrate; Spherepop supplies the discrete combinatorics; Yarncrawler implements the corresponding inferential dynamics; the Free Energy Principle furnishes the variational objective; and the resulting fixed points constitute the organizational units typically identified as agents.

In this perspective, the ontology of organized systems is expressed as patterns of flow and stability. Structures persist because they occupy fixed points of lamphrodynamic and semantic dynamics; boundaries form where gradients stabilize; and inference emerges where internal and external couplings are mediated through these boundaries. The same mechanisms that govern the evolution of fields—smoothing, constraint propagation, and energy minimization—also give rise to the informational and functional properties associated with agency and selfhood.

Meaning, within this formulation, becomes a property of trajectories rather than symbols: it is the geometric invariant that survives compression, projection, renormalization, and the passage of time. Forms are preserved because these invariants remain stable within the semantic and physical flows of the plenum.

In this way, matter, form, and mind can be understood as different aspects of one variational geometry. The dynamics that guide physical fields, the processes that sustain biological and cognitive systems, and the inferential operations that support perception and action all arise from the same structural principles, expressed at different scales and in different coordinate systems.

Appendix A: Detailed Derivations of RSVP Field Dynamics

We begin by deriving the RSVP vector, scalar, and entropy equations from an action principle.

A.1 Action and Variational Derivatives

Let the action be [$A[\Phi, v, S]$ =====

$$\int^M \mathcal{L}(\Phi, v, S, \nabla\Phi, \nabla v, \nabla S), d^n x.]$$

We consider the Lagrangian density [L =====

$$\begin{aligned} & \frac{1}{2}\Phi\|v\|^2 \\ & * \alpha, \Phi, (\nabla \cdot v) * \beta\|\nabla\Phi\|^2 * \gamma\|\nabla S\|^2 * V(\Phi, S). \end{aligned}$$

The Euler–Lagrange equation for the scalar field (Φ) is [$\frac{\partial \mathcal{L}}{\partial \Phi}$ -----

$$\nabla \cdot \left(\frac{\partial \mathcal{L}}{\partial (\nabla \Phi)} \right) = 0,] yielding [\frac{1}{2}\|v\|^2$$

* $\alpha, \nabla \cdot v$

- $\beta, \Delta \Phi$

* $\partial_\Phi V(\Phi, S) = 0.$]

Variation with respect to (v) yields [$\Phi, v + \alpha, \nabla\Phi = 0,$ \Rightarrow v =====

$$-\alpha, \frac{\nabla\Phi}{\Phi}.$$

Variation with respect to (S) yields [$\gamma \Delta S + \partial_S V(\Phi, S) = 0$.]

These relations jointly give the lamphrodynamic RSVP field equations.

Appendix B: Hamiltonian–Free Energy Equivalence Proofs

B.1 Canonical Construction

We begin by defining the canonical momenta associated with the fields Φ , \mathbf{v} , and S :

$$\Pi_\Phi := \frac{\partial \mathcal{L}}{\partial(\partial_t \Phi)}, \quad \Pi_{\mathbf{v}} := \frac{\partial \mathcal{L}}{\partial(\partial_t \mathbf{v})}, \quad \Pi_S := \frac{\partial \mathcal{L}}{\partial(\partial_t S)}.$$

The Hamiltonian density is defined in the usual way,

$$\mathcal{H} = \Pi_\Phi \partial_t \Phi + \Pi_{\mathbf{v}} \cdot \partial_t \mathbf{v} + \Pi_S \partial_t S - \mathcal{L}.$$

For the RSVP Lagrangian, the kinetic contribution arises entirely through the lamphrodynamic coupling,

$$\frac{1}{2} \Phi \|\mathbf{v}\|^2.$$

Accordingly, the Hamiltonian density takes the form

$$\mathcal{H} = \frac{1}{2} \Phi \|\mathbf{v}\|^2 + \beta \|\nabla \Phi\|^2 + \gamma \|\nabla S\|^2 + V(\Phi, S).$$

Now compare this with the variational free energy functional,

$$\mathcal{F} = \mathbb{E}_q[-\log p] + \mathbb{E}_q[\log q].$$

Using the entropy–Fisher correspondence, we identify

$$\mathbb{E}_q[\log q] = \int S(x) dx,$$

and

$$\mathbb{E}_q[-\log p] = \int \left(\frac{1}{2} \Phi \|\mathbf{v}\|^2 + V(\Phi, S) \right) dx.$$

We therefore obtain the equivalence

$$\mathcal{H} = \mathcal{F} + \text{const.}$$

Thus, the RSVP Hamiltonian coincides with variational free energy up to an additive

constant. In this sense, the physical Hamiltonian of the plenum and the inferential free energy of the generative model are two coordinate expressions of the same geometric quantity.

Appendix C: Boundary Operators and the Derivation of Markov Blankets

C.1 Boundary Decomposition

Let $U \subseteq M$ be a region with outward normal vector n and boundary ∂U . Define the boundary flux

$$J = \mathbf{v} \cdot n.$$

We then define the sensory and active boundary subsets by

$$S_{\text{sens}} = \{x \in \partial U : J(x) < 0\}, \quad A_{\text{act}} = \{x \in \partial U : J(x) > 0\}.$$

C.2 Conditional Independence

The internal RSVP dynamics depend only on boundary data,

$$\Phi|_{\partial U}, \quad S|_{\partial U}, \quad (\mathbf{v} \cdot n)|_{\partial U}.$$

Hence, conditional on sensory and active boundary channels, internal and external states factorize:

$$X_{\text{int}} \perp X_{\text{ext}} \mid (S_{\text{sens}}, A_{\text{act}}).$$

This yields a purely physical derivation of Markov blankets from lamphrodynamic flux structure alone.

Appendix D: Natural Gradient Derivation of Yarncrawler

D.1 Natural Gradient

The Yarncrawler update rule takes the form

$$\dot{\theta} = -G^{-1}\nabla_{\theta}\mathcal{F},$$

where G denotes the Fisher information metric.

For an exponential-family variational density $q(\eta \mid \theta)$, the Fisher–Rao metric has coordinate expression

$$G_{ij}(\theta) = \mathbb{E}_q[\partial_i \log q(\eta \mid \theta) \partial_j \log q(\eta \mid \theta)] = \partial_i \partial_j \psi(\theta),$$

where $\psi(\theta)$ is the log-partition function.

Yarncrawler therefore implements the Amari natural gradient,

$$\tilde{\nabla}\mathcal{F} = G^{-1}\nabla\mathcal{F},$$

so its trajectories follow geodesics in the information geometry induced by the RSVP entropy potential.

Appendix E: Spherepop Calculus Algebraic Structure

E.1 Bubble Algebra

Bubble fusion is governed by a homotopy-associative binary operation

$$(b_i \oplus b_j) \oplus b_k \simeq b_i \oplus (b_j \oplus b_k),$$

so that bubble configurations form a monoidal structure up to coherent homotopy.

Semantic labels combine through a merge operation,

$$\sigma_{ij} = \text{merge}(\sigma_i, \sigma_j),$$

which endows the collection of semantic labels with the structure of a monoidal category.

Extrusion acts as a comultiplication,

$$\varepsilon : b \longrightarrow (b \otimes e),$$

and popping acts as the counit,

$$\delta : b \longrightarrow 0.$$

Together, the fusion, extrusion, and popping operators furnish Spherepop with the algebraic structure of a bialgebra over the semantic bubble space.

E.2 Pressure and Free Energy

The semantic pressure of a bubble configuration is defined by

$$\mathcal{P}(\mathcal{B}) = \sum_i P_i.$$

This pressure functional may be written as a Bregman divergence generated by a convex potential ψ ,

$$\mathcal{P}(\mathcal{B}) = D_\psi(\theta \parallel \theta'),$$

hence it is equivalent, up to normalization, to the variational free energy functional of the corresponding generative model.

Appendix F: Multi-Scale Renormalization Proofs

F.1 Coarse-Graining Operator

Define the renormalization operator

$$\text{RG}(X) = \Pi_\Lambda(K_\Lambda * X),$$

where K_Λ is a smoothing kernel at scale Λ and $*$ denotes convolution.

For any two admissible configurations X_1 and X_2 ,

$$\|K_\Lambda * X_1 - K_\Lambda * X_2\| \leq c \|X_1 - X_2\|, \quad 0 < c < 1,$$

which establishes that RG is a strict contraction in an appropriate Banach space norm.

F.2 Fixed-Point Existence

By the Banach fixed-point theorem, there exists a unique renormalized object X^* such that

$$\text{RG}(X^*) = X^*.$$

When combined with the monotone descent of variational free energy under Yarncrawler, this shows that each equivalence class of initial RSVP configurations possesses a unique renormalized form.

Appendix G: Lie-Group Symmetries of RSVP

The Relativistic Scalar–Vector Plenum (RSVP) exhibits a rich group of continuous symmetries acting on its field configuration space. These symmetries play a crucial role in the structure and invariants of the theory, determine conserved quantities through Noether’s theorem, and constrain the behavior of derived constructions such as the Yarncrawler (YC) endofunctor and the renormalization operator (RG).

Let

$$X = (\Phi, \mathbf{v}, S)$$

denote an RSVP configuration on a differentiable manifold M . The symmetry group G consists of transformations that preserve the RSVP action, the Euler–Lagrange dynamics, and the admissible configuration category \mathcal{R} .

G.1 Translational Symmetry

For any displacement vector $a \in \mathbb{R}^n$, define the action

$$T_a : M \rightarrow M, \quad T_a(x) = x + a.$$

The fields transform under pullback:

$$(T_a \cdot \Phi)(x) = \Phi(x - a), \quad (T_a \cdot S)(x) = S(x - a), \quad (T_a \cdot \mathbf{v})(x) = \mathbf{v}(x - a).$$

Since the action functional

$$\mathcal{A}[\Phi, \mathbf{v}, S] = \int_M \mathcal{L}(\Phi, \mathbf{v}, S, \nabla\Phi, \nabla\mathbf{v}, \nabla S) d^n x$$

contains no explicit dependence on position, it is translationally invariant. Thus, total momentum is conserved.

G.2 Scalar-Gauge Symmetry

The scalar potential Φ enters the Lagrangian only through derivatives or differences. Therefore any global shift

$$\Phi \mapsto \Phi + c, \quad c \in \mathbb{R}$$

leaves the action invariant. This symmetry reflects the physical fact that only scalar *gradients* affect lamphrodynamic flow.

The associated Noether charge corresponds to the conservation of scalar-mass offsets under internal reparameterizations of the plenum.

G.3 Entropy-Gauge Symmetry

Similarly, the entropy potential S possesses a global shift symmetry

$$S \mapsto S + \tilde{c}, \quad \tilde{c} \in \mathbb{R},$$

because S appears only in derivative or curvature terms of the action. Entropy is thus defined up to a constant baseline; only differences or gradients generate physical semantics or constraints.

This symmetry ensures that variational free energy and informational curvature depend only on entropy structure, not on absolute entropy levels.

G.4 Lamphrodynamic Gauge Symmetry

The vector field \mathbf{v} admits the transformation

$$\mathbf{v} \mapsto \mathbf{v} + \nabla\chi,$$

for any sufficiently smooth scalar function $\chi : M \rightarrow \mathbb{R}$. Since the lamphrodynamic term involves the combination $\Phi\mathbf{v}$ and its divergence, adding a pure gradient modifies only a gauge degree of freedom and does not affect physical fluxes through closed surfaces.

This local symmetry is analogous to the gauge freedom in potential-flow hydrodynamics or the gradient freedom in probability currents used in information geometry.

G.5 The Full Lie Group of RSVP Symmetries

The RSVP symmetry group is therefore the semidirect product

$$G = \mathbb{R}^n \ltimes (\mathbb{R} \times \mathbb{R} \times \mathcal{G}),$$

where

- \mathbb{R}^n acts by translations,
- \mathbb{R} acts by scalar-gauge shifts,
- another \mathbb{R} acts by entropy-gauge shifts,
- $\mathcal{G} = \{\nabla\chi : \chi \in C^\infty(M)\}$ is the infinite-dimensional lamphrodynamic gauge group.

This is an infinite-dimensional Lie group acting smoothly on the RSVP configuration manifold.

G.6 Equivariance of Yarncrawler

The Yarncrawler endofunctor

$$\text{YC} : \mathcal{R} \rightarrow \mathcal{R}$$

is constructed from three components:

$$\text{YC}(X) = \Pi_{\text{RSVP}}(\text{Comp}(\text{Flow}_{\Delta t}(X))).$$

Each component respects the RSVP symmetries:

1. $\text{Flow}_{\Delta t}$ is generated by the RSVP Euler–Lagrange equations, which are G -invariant.

2. Comp uses only semantic relationships, distances, or local invariants derived from the fields; all are invariant under the given gauge and translation symmetries.
3. Π_{RSVP} projects onto the space of admissible field configurations, and this space is itself G -stable.

Hence,

$$\text{YC}(g \cdot X) = g \cdot \text{YC}(X) \quad \text{for all } g \in G,$$

so Yarncrawler is **equivariant** under the full RSVP symmetry group.

G.7 Invariance of the Renormalization Operator

The renormalization operator

$$\text{RG}(X) = \Pi_\Lambda(K_\Lambda * X)$$

is invariant under the symmetry group G . Since both convolution by a translation-invariant kernel K_Λ and projection Π_Λ respect gauge and translational symmetries, we have

$$\text{RG}(g \cdot X) = g \cdot \text{RG}(X).$$

Thus RG is **fully group-invariant**, preserving all RSVP symmetries exactly.

G.8 Consequences for the Unified Framework

These symmetry properties imply:

- Fixed points of $\text{T} = \text{RG} \circ \text{YC}$ appear in entire G -orbits.
- Markov blankets are preserved modulo gauge transformations.
- Natural-gradient flows unfold on information manifolds quotiented by these symmetries.
- Meaning, as represented through YC compression and RG stability, is gauge-invariant.

The RSVP symmetry group therefore provides the structural backbone for equivariance, invariance, and stability throughout the unified plenum– semantic– inference framework.

G.9 Lie Algebra of RSVP Symmetries

Let

$$G = \mathbb{R}^n \ltimes (\mathbb{R} \times \mathbb{R} \times \mathcal{G})$$

be the full RSVP symmetry group described above. Its Lie algebra

$$\mathfrak{g} = T_e G$$

decomposes as

$$\mathfrak{g} = \mathbb{R}^n \oplus \mathbb{R}\Phi_0 \oplus \mathbb{R}S_0 \oplus \{\nabla\chi : \chi \in C^\infty(M)\},$$

where the basis elements act on fields as

$$\delta_a X = -a \cdot \nabla X \quad (a \in \mathbb{R}^n),$$

$$\begin{aligned} \delta_{\Phi_0}(\Phi) &= 1, & \delta_{\Phi_0}(S) &= 0, & \delta_{\Phi_0}(\mathbf{v}) &= 0, \\ \delta_{S_0}(S) &= 1, & \delta_{S_0}(\Phi) &= 0, & \delta_{S_0}(\mathbf{v}) &= 0, \\ \delta_\chi(\Phi) &= 0, & \delta_\chi(S) &= 0, & \delta_\chi(\mathbf{v}) &= \nabla\chi. \end{aligned}$$

The only nontrivial bracket arises from the semidirect product structure:

$$[\delta_a, \delta_\chi] = \delta_{a \cdot \nabla \chi},$$

reflecting that spatial translations act nontrivially on lamphrodynamic gauge modes. All other brackets vanish. Thus

$$\mathfrak{g} = \mathbb{R}^n \ltimes (\mathbb{R}^2 \oplus \text{Grad}(C^\infty(M)))$$

is a solvable infinite-dimensional Lie algebra governing the symmetry geometry of RSVP.

G.10 Noether Currents and Conserved Quantities

Each continuous symmetry of the RSVP action gives rise, via Noether's theorem, to a conserved current. Let

$$\mathcal{L}(\Phi, \mathbf{v}, S, \nabla\Phi, \nabla\mathbf{v}, \nabla S)$$

be the Lagrangian density and

$$\mathcal{A} = \int_M \mathcal{L} d^n x$$

the action.

(i) Translational symmetry. Invariance under

$$x \mapsto x + a$$

implies conservation of the stress–energy tensor

$$\nabla_\mu T^{\mu\nu} = 0.$$

The explicit form involves contributions from scalar, vector, and entropy gradients:

$$T^{\mu\nu} = \Phi v^\mu v^\nu + \beta \partial^\mu \Phi \partial^\nu \Phi + \gamma \partial^\mu S \partial^\nu S - g^{\mu\nu} \mathcal{L}.$$

(ii) Scalar-gauge symmetry. Under

$$\Phi \mapsto \Phi + c,$$

the conserved quantity is

$$J_\Phi^\mu = \frac{\partial \mathcal{L}}{\partial(\partial_\mu \Phi)}.$$

This corresponds physically to invariance of the total scalar offset of the plenum density.

(iii) Entropy-gauge symmetry. Shifts

$$S \mapsto S + \tilde{c}$$

generate the entropy current

$$J_S^\mu = \frac{\partial \mathcal{L}}{\partial(\partial_\mu S)},$$

expressing conservation of total entropic baseline.

(iv) Lamphrodynamic gauge symmetry. For

$$\mathbf{v} \mapsto \mathbf{v} + \nabla \chi,$$

the conserved Noether current is a vorticity-like quantity:

$$J_\chi^\mu = \Phi v^\mu - \Phi \partial^\mu \chi.$$

This encodes physical invariance under potential-flow reparameterizations.

These four conserved currents collectively constrain RSVP dynamics and determine the invariant submanifolds on which Yarncrawler acts.

G.11 Induced Symmetry Actions on Spherepop Bubbles

Spherepop bubbles

$$b_i = (\Phi_i, S_i, \mathbf{v}_i, \sigma_i, P_i, r_i)$$

inherit RSVP symmetries via the field–bubble correspondence. The group action is defined componentwise.

(i) Translations.

$$b_i \mapsto b'_i \quad \text{with} \quad x'_i = x_i + a.$$

Semantic labels σ_i , pressures P_i , and radii r_i remain unchanged. Translation therefore corresponds to rigid bubble motion.

(ii) Scalar-gauge shifts.

$$\Phi'_i = \Phi_i + c.$$

This modifies bubble scalar content uniformly but leaves fusion, extrusion, and popping rules invariant, since these depend on differences and interactions.

(iii) Entropy-gauge shifts.

$$S'_i = S_i + \tilde{c}.$$

Semantic clustering is unaffected because pressures and adjacency depend on entropy gradients, not absolute values.

(iv) Lamphrodynamic gauge shifts.

$$\mathbf{v}'_i = \mathbf{v}_i + (\nabla \chi)_i.$$

Bubble velocities change by a gradient term, but relative flows, collision rules, and extrusion directions remain equivalent up to gauge.

Thus the Spherepop calculus is G -equivariant: all bubble operations—fusion, extrusion, popping, semantic clustering—preserve the RSVP symmetry structure. This is essential for the correctness of the correspondence

$$\text{YC} = \Pi_{\text{RSVP}} \circ \text{Comp} \circ \text{Flow}_{\Delta t}$$

and for the existence of symmetry-related families of fixed points in the renormalized dynamics.

Appendix H: ∞ -Categorical Interpretation of Forms and Agents

Let \mathcal{R}_∞ denote the ∞ -category of admissible RSVP configurations. Objects are regions equipped with fields $X = (\Phi, \mathbf{v}, S)$, and morphisms are flow-enriched arrows:

$$\text{Map}_{\mathcal{R}_\infty}(X, Y) \simeq \text{Path}(X \rightarrow Y)$$

consisting of RSVP-flow homotopies, semantic compressions, and renormalization-compatible transformations. Composition is defined up to coherent higher homotopies, making \mathcal{R}_∞ a homotopy-coherent semantic–physical category.

H.1 Lifting the Renormalization Functor

The combined semantic–physical operator

$$T = RG \circ YC$$

acts on the 1-category \mathcal{R} of classical RSVP configurations. Because both YC and RG preserve homotopies, weakenings, and equivalences, the construction lifts naturally to the ∞ -categorical level:

$$T : \mathcal{R}_\infty \longrightarrow \mathcal{R}_\infty.$$

In this setting, T becomes an ∞ -endofunctor that aggregates dynamical, semantic, and renormalization structure into a single homotopy-coherent operation.

H.2 Homotopy Fixed Points as Forms

A *Platonic form* corresponds to an ∞ -categorical homotopy fixed point of T . Formally, an object X^* satisfies

$$X^* \simeq \text{hofix}(T)$$

if there exists a coherent tower of equivalences

$$X^* \xrightarrow{\sim} T(X^*) \quad \text{together with all higher homotopies required for stability.}$$

Such an X^* is invariant not only under the action of T but under all higher-order semantic and dynamical refinements induced by T . These homotopy fixed points correspond to the stable, renormalized structures that persist across scales: semantic attractors, morphological invariants, or “forms” in the strict mathematical sense.

H.3 Homotopy Fixed Points as Selves

When the object X is equipped with an internal generative model θ_X and a Markov blanket ∂X , the invariance condition becomes a statement about agency and self-maintenance:

$$\mathsf{T}(X) \simeq X \iff (\Phi, \mathbf{v}, S; \theta_X, \partial X) \text{ is dynamically self-consistent.}$$

Therefore

A self is a homotopy fixed point of the semantic–physical renormalization endofunctor.

This formulation unifies the physical, informational, and semantic dimensions of self-organization: an agent is precisely a configuration that reconstructs, preserves, and stabilizes itself under the full suite of RSVP dynamics, semantic compression, and renormalization flow.

Appendix I: Formal Derivation of Protocell Formation in RSVP–Spherepop Systems

This appendix provides a mathematically explicit derivation of protocell-like structures within the combined RSVP–Spherepop–Yarncrawler system. We show that Markov-blanket–bounded entities arise generically from random initial conditions, without any additional assumptions about metabolism, membranes, or chemical reactions. The analysis combines lamphrodynamic smoothing, entropy sharpening, semantic compression, and renormalization.

I.1 Random Initial Conditions

Let the initial scalar, vector, and entropy fields be sampled as

$$\Phi_0(x) = \Phi_{\text{mean}} + \varepsilon_\Phi(x), \quad \mathbf{v}_0(x) = \varepsilon_v(x), \quad S_0(x) = S_{\text{mean}} + \varepsilon_S(x),$$

where each perturbation term $\varepsilon_\Phi, \varepsilon_v, \varepsilon_S$ is i.i.d. with zero mean, finite variance, and compact spatial correlation. These assumptions define a “primordial soup”: spatially unstructured but locally stochastic fields.

The goal is to show that, from these conditions, the RSVP dynamics almost surely produce (i) a coherent interior domain, (ii) a sharply defined boundary, and (iii) an external region exhibiting asymmetric flux—the defining traits of a protocell.

I.2 Lamphrodynamic Smoothing

The RSVP lamphrodynamic equations

$$\partial_t \Phi = -\nabla \cdot (\Phi \mathbf{v}) + \beta \Delta \Phi, \quad (4)$$

$$\partial_t \mathbf{v} = -\nabla \Phi + \mu \Delta \mathbf{v}, \quad (5)$$

combine transport, potential-driven motion, and diffusion.

The diffusion terms $\beta \Delta \Phi$ and $\mu \Delta \mathbf{v}$ suppress high-frequency components of the fields. In expectation, the first moments obey

$$\mathbb{E}[\Phi_t] \rightarrow \Phi_{\text{mean}}, \quad \mathbb{E}[S_t] \rightarrow S_{\text{mean}},$$

so randomness is rapidly smoothed.

At the same time, the coupling term $-\nabla \Phi$ induces a lamphrodynamic alignment:

$$\mathbf{v} \approx -\alpha \frac{\nabla \Phi}{\Phi}, \quad \alpha > 0.$$

Thus \mathbf{v} tends to circulate around local maxima of Φ , forming closed integral curves. These lamphrodynamic loops mark the earliest proto-boundary structures.

I.3 Entropy Sharpens the Boundary

The entropy equation,

$$\partial_t S = D_S \Delta S - \nabla \cdot (S \mathbf{v}),$$

combines diffusion with transport along \mathbf{v} . When \mathbf{v} forms closed loops, S is transported around those loops, generating steep gradients at turning points and stagnation zones.

As $t \rightarrow \infty$, the system almost surely organizes into:

1. **A coherent interior region**, where Φ becomes nearly constant and \mathbf{v} exhibits low divergence.
2. **A boundary layer** in which both $\nabla \Phi$ and ∇S achieve maximal magnitude.
3. **An exterior region** with lower Φ and outward-dominated flux.

This tripartite decomposition is equivalent to the Markov-blanket condition

$$X_{\text{int}} \perp X_{\text{ext}} \mid \text{boundary gradients},$$

where the conditional independence arises from the sign structure of the fluxes across the boundary.

I.4 Yarncrawler Compression Produces the Interior/Boundary/Exterior Partition

Given a field configuration $X = (\Phi, \mathbf{v}, S)$, Yarncrawler identifies semantic patches via clustering on Spherepop bubbles. When the fields satisfy:

- minimal internal gradients,
- maximal boundary gradients,
- lamphrodynamic vector alignment,

YC merges interior bubbles, isolates boundary bubbles, and separates external bubbles. This induces the categorical partition:

$$X_{\text{int}}, \quad \partial X, \quad X_{\text{ext}},$$

even if no such partition was specified a priori. In particular, the YC compression step identifies proto-boundaries precisely where RSVP dynamics create sharp curvature in Φ and S .

I.5 Renormalization Preserves Blanket Geometry

The renormalization operator RG acts by smooth coarse-graining:

$$\text{RG}(X) = \Pi_\Lambda(K_\Lambda * X),$$

with smoothing kernel K_Λ and projection Π_Λ enforcing RSVP constraints. The kernel obeys the contraction inequality

$$\|K_\Lambda * X_1 - K_\Lambda * X_2\| \leq c \|X_1 - X_2\|, \quad 0 < c < 1,$$

so RG is a strict contraction on equivalence classes.

Critically, the boundary layer remains invariant under coarse-graining because it is the region of *maximal* curvature and therefore the locus of renormalization fixed points. After successive YC and RG steps, the system converges to a renormalized protocell-like object X^* with:

- a stable interior core,
- a persistent gradient-defined boundary,
- asymmetric sensory and active flux directions.

This matches the physical definition of a protocell.

I.6 Theorem: Protocell Genericity

Theorem .1 (Generic Protocell Emergence). *Let X_0 be any random RSVP–Spherepop configuration with i.i.d. finite-variance perturbations. Then repeated application of the combined operator $T = RG \circ YC$ converges almost surely to a configuration possessing a non-empty Markov blanket:*

$$MB(X^*) \neq \emptyset.$$

Sketch of proof. Lamphrodynamic smoothing creates coherent regions (I.2); entropy sharpening creates thin high-gradient boundaries (I.3); YC compression identifies these as semantic boundaries (I.4); RG contraction stabilizes them (I.5). Together, these operations form a contracting map onto the space of blanket-bearing configurations. Almost-sure convergence follows by standard martingale and Banach fixed-point arguments (cf. Appendices A–F).

Appendix J: Pseudocode Implementations of YC and RG

J.1 Yarncrawler (YC) Pseudocode

```
function YC(X):
    # X = RSVP state (Phi, v, S)

    # Step 1: Physical flow update
    X_flow = Flow_delta_t(X)

    # Step 2: Semantic compression
    X_comp = Comp(X_flow)

    # Step 3: RSVP constraint projection
    X_proj = Pi_RSVP(X_comp)

    return X_proj
```

Comp Operation

```
function Comp(X):
    B = SpherepopRepresentation(X)
    clusters = SemanticClustering(B)
    B_prime = MergeClusters(clusters)
    return FieldFromBubbles(B_prime)
```

Semantic clustering may employ k-means, mean-shift, or topological adjacency on the bubble graph, depending on which semantic invariant is being emphasized.

J.2 Renormalization (RG) Pseudocode

```
function RG(X):
    # X is the output of YC

    coarse = BlockAverage(X, block_size)
    projected = Pi_RSVP(coarse)
    return projected
```

Block averaging may be implemented using Haar wavelet coefficients, Gaussian smoothing followed by downsampling, or uniform block aggregation, provided the procedure preserves the admissibility constraints of RSVP fields.

Appendix K: A Categorical Interpreter for Spherepop

This appendix defines a categorical semantics for the Spherepop calculus and its interaction with RSVP field dynamics. The goal is to formalize bubbles as semantic objects, the Spherepop operations as categorical morphisms, and the Yarncrawler procedure as an interpreter functor from the Spherepop category into the RSVP configuration category.

K.1 Bubble Type

A Spherepop bubble is a semantic unit equipped with physical and informational fields:

$$\text{Bubble } b = \text{Bubble}(\Phi, S, \mathbf{v}, \sigma, P, r),$$

where

- Φ is scalar density,
- S is entropy potential,
- \mathbf{v} is lamphrodynamic flow,
- σ is a semantic label,
- P is semantic pressure or potential,
- r is an intrinsic scale (e.g. bubble radius).

A configuration of bubbles is represented as a finite multiset.

K.2 The Spherepop Category

Let $(\mathcal{B}, \otimes, 0)$ denote the monoidal category of bubble semantics.

Objects. Objects are finite multisets of bubbles:

$$\text{Ob}(\mathcal{B}) = \text{Multiset}(\text{Bubble}).$$

Morphisms. Spherepop provides three primitive morphisms:

$$\text{Extrude} : b \longrightarrow (b \otimes e),$$

$$\text{Merge} : b \otimes b \longrightarrow b,$$

$$\text{Pop} : b \longrightarrow 0.$$

Here e is the unit “empty shell” bubble, and 0 is the monoidal zero object.

Monoidal Product. Bubble juxtaposition gives the tensor product:

$$b_i \otimes b_j = \text{disjoint union of bubbles } b_i, b_j.$$

This makes \mathcal{B} a strict monoidal category.

K.3 Comonad Structure on \mathcal{B}

Spherepop operations define a comonad on bubble configurations.

Comultiplication. Extrusion plays the role of comultiplication:

$$\delta(b) = b \otimes e,$$

and extends to all objects via the monoidal product.

Counit. Popping defines the counit:

$$\varepsilon(b) = 0.$$

Comonad Laws. The Spherepop operators satisfy:

$$(\delta \otimes \text{id}) \circ \delta = (\text{id} \otimes \delta) \circ \delta,$$

$$(\varepsilon \otimes \text{id}) \circ \delta = \text{id} = (\text{id} \otimes \varepsilon) \circ \delta,$$

up to the homotopy equivalences arising from bubble fusion. Thus Spherepop is a comonad $(\mathcal{B}, \delta, \varepsilon)$ capturing extrusion–merging–popping dynamics.

K.4 Interpretation Morphism

There is a canonical interpretation morphism

$$- : \mathcal{B} \longrightarrow \mathcal{R},$$

where \mathcal{R} is the category of RSVP configurations introduced in Appendix A. The mapping $-$ assigns to each bubble (and multiset of bubbles) an RSVP field triple

$$(\Phi, \mathbf{v}, S) \quad \text{together with its domain } U \subseteq M.$$

Composition in \mathcal{B} corresponds to physically meaningful updates in \mathcal{R} :

$$\text{Merge}(b_1 \otimes b_2) = \Pi_{\text{RSVP}}(b_1 + b_2),$$

with similar expressions for extrusion and popping.

K.5 The Yarncrawler Interpreter

The Yarncrawler operator may now be expressed as a composite interpreter:

$$\text{YC} = \Pi_{\text{RSVP}} \circ \text{Comp} \circ \text{Flow}_{\Delta t}.$$

- $\text{Flow}_{\Delta t}$ applies a short RSVP physical evolution.
- $-$ maps Spherepop bubbles into RSVP fields.
- Comp performs semantic compression via Spherepop merging.
- Π_{RSVP} projects back onto RSVP-admissible configurations.

Thus Yarncrawler is a functor

$$\text{YC} : \mathcal{R} \longrightarrow \mathcal{R},$$

mediated by the categorical semantics of Spherepop. This formalizes YC as a semantic interpreter grounded in comonadic bubble dynamics.

Appendix L: Topological Entropy of Semantic Fields

Topological entropy provides a measure of dynamical complexity for trajectories in parameter or state space. In the RSVP–YC–RG framework it offers a concise way to distinguish the chaotic micro-dynamics of raw RSVP flows from the contractive, inference-driven dynamics generated by Yarncrawler and renormalization.

L.1 Definitions

Let

$$\gamma : [0, T] \rightarrow \Theta$$

be an inference trajectory in a parameter manifold Θ . For $\epsilon > 0$, cover Θ by ϵ -balls and define $N(\epsilon, T)$ as the minimal number of such balls required to cover the trajectory segment $\gamma([0, T])$:

$$N(\epsilon, T) = \text{minimum number of } \epsilon\text{-balls covering } \gamma([0, T]).$$

The *topological entropy* is

$$h_{\text{top}} = \lim_{\epsilon \rightarrow 0} \limsup_{T \rightarrow \infty} \frac{1}{T} \log N(\epsilon, T).$$

Positive entropy indicates exponential divergence of trajectories; zero entropy indicates contractive or non-chaotic dynamics.

L.2 Entropy of Yarncrawler

The Yarncrawler operator **YC** implements a natural-gradient descent in the Fisher–Rao geometry induced by the RSVP entropy field. Natural gradients are contractive flows: geodesic distance between points decreases monotonically along the flow.

Hence,

$$h_{\text{top}}(\mathbf{YC}) = 0.$$

Inference trajectories under **YC** do not proliferate distinguishable paths at an exponential rate.

L.3 Entropy of Full RSVP Flow

By contrast, the raw RSVP flow can exhibit drift, diffusion, vortex-like transport, and lamphrodynamic turbulence. In regimes where vorticity and entropy coupling dominate, nearby initial conditions can diverge exponentially.

Thus in general,

$$h_{\text{top}}(\text{Flow}) > 0,$$

signaling sensitivity to initial conditions and rich dynamical structure.

L.4 Entropy of Renormalization

Renormalization RG applies coarse-graining and smoothing operators. These collapse micro-scale variations and eliminate chaotic fluctuations. Any contractive coarse-graining operator has zero topological entropy.

Therefore,

$$h_{\text{top}}(\text{RG}) = 0.$$

L.5 Entropy of the Combined Operator

The renormalized semantic–physical evolution operator

$$\mathbf{T} = \text{RG} \circ \text{YC}$$

inherits the contractive nature of both components. Since the composition of zero-entropy maps has zero entropy,

$$h_{\text{top}}(\mathbf{T}) = 0.$$

Consequently, the fixed points of \mathbf{T} —corresponding to stable forms, selves, and agents—are *topologically stable*. Their persistence is explained by the suppression of chaotic divergence under repeated YC+RG cycles, providing a formal justification for the robustness of living systems, coherent identities, and cognitive attractors within the RSVP framework.

Appendix M: Final Technical Extensions

This appendix collects several advanced mathematical structures that further illuminate the unified RSVP–Spherenpop–Yarncrawler–FEP framework. These extensions do not introduce new principles; rather, they reveal deeper formal relationships among entropy, information geometry, category theory, Hamilton–Jacobi theory, and quantum-inspired formulations of the plenum.

M.1 Entropy–Information Dualities

The foundational equivalence underlying the RSVP–FEP correspondence rests on a duality between the entropy potentials defined over the plenum and the information-theoretic structures of variational inference.

In RSVP, the entropy field $S(x)$ induces a convex functional on the space of semantic parameters:

$$\Psi[\theta] = \int_M S(x; \theta) d^d x,$$

which acts as a smooth, strictly convex potential. The curvature of this potential is given by its second variation,

$$g_{ij}(\theta) = \partial_i \partial_j \Psi(\theta),$$

and this curvature coincides with the Fisher–Rao information metric of the generative model. Entropy curvature in the plenum is therefore identical to information curvature in the agent’s internal model.

Similarly, the Kullback–Leibler divergence appears as the Bregman divergence generated by the same entropy potential:

$$D_{\text{KL}}(q_\theta \| q_{\theta'}) = \Psi(\theta) - \Psi(\theta') - \langle \nabla \Psi(\theta'), \theta - \theta' \rangle,$$

so that $D_{\text{KL}} = D_\Psi$. This establishes that KL divergence is physically realized as a difference in RSVP entropy potentials.

The Legendre dual of Ψ ,

$$\Phi(\eta) = \sup_{\theta} \{ \langle \eta, \theta \rangle - \Psi(\theta) \},$$

corresponds to the lamphrodynamic scalar potential $\Phi(x)$. Thus, the scalar and entropy fields of RSVP form a dual pair in the sense of exponential-family information geometry. Their interplay represents the intrinsic variational structure of the plenum.

M.2 Explicit Bayesian Update Formulas in Yarncrawler

Although Yarncrawler is defined geometrically, its internal update rule is equivalent to explicit Bayesian inference in exponential-family form. Let the generative model factor as

$$p(\eta, x) = p(x | \eta) p(\eta),$$

and let the variational family take the form

$$q(\eta | \theta) = \exp(\langle \theta, F(\eta) \rangle - \Psi(\theta)).$$

The variational free energy is

$$\mathcal{F}(\theta) = \mathbb{E}_{q_\theta}[-\log p(x | \eta)] + D_{\text{KL}}(q_\theta \| p(\eta)).$$

A Yarncrawler update performs a natural-gradient step,

$$\theta_{t+1} = \theta_t - \eta_t G^{-1}(\theta_t) \nabla_\theta \mathcal{F}(\theta_t).$$

The gradient of \mathcal{F} takes the form

$$\nabla_\theta \mathcal{F} = \mathbb{E}_{q_\theta}[F(\eta)] - \mathbb{E}_{p(\eta|x)}[F(\eta)],$$

so that the natural gradient, using the Fisher metric, moves parameters directly toward the posterior value θ^* . Up to step-size scaling,

$$\theta_{t+1} = \theta^*,$$

and Yarncrawler thus implements an explicit natural-gradient Bayesian update.

M.3 Advanced Category Theory: Adjunctions, Fibrations, and Yoneda Structures

The categorical structure underlying the RSVP–YC–RG system can be made precise using adjunctions, fibrations, and representability.

Compression and semantic refinement form an adjoint pair,

$$\text{Comp} \dashv \text{Exp}, \quad (\text{Comp}(X), Y) \cong (X, \text{Exp}(Y)),$$

so that compression is the left adjoint removing inessential microstructure while preserving semantic invariants. Yarncrawler applies this adjointness to express variational free-energy minimization as a natural transformation on semantic objects.

The generative model fits naturally into a fibration

$$\pi : \mathcal{E} \rightarrow \mathcal{X},$$

whose fibers consist of exponential-family distributions $q(\eta | \theta)$. Inference is then the fibral lift of RSVP flows into parameter space,

$$X_t \longmapsto \theta_t = \text{Lift}(X_t).$$

Each Spherepop bubble b defines a representable functor $\mathcal{B}(b, -)$. Natural transformations between such representables encode changes in semantic role, so Yarncrawler updates correspond to morphisms

$$h_b \Rightarrow h_{b'},$$

inside the Yoneda embedding. Meaning is therefore characterized by Yoneda invariance: a

semantic object is determined by all the ways it acts within the semantic category.

M.4 Hamilton–Jacobi Formulation of RSVP

The RSVP action principle can be written in Hamilton–Jacobi form. The phase functional

$$\mathcal{S}[X] = \int L(X, \dot{X}) dt$$

satisfies the Hamilton–Jacobi equation

$$\frac{\partial \mathcal{S}}{\partial t} + H(X, \nabla_X \mathcal{S}) = 0,$$

where H is the RSVP Hamiltonian (Appendix B). Yarncrawler may be interpreted as an iterative approximation to solutions of this Hamilton–Jacobi problem, compressing physical dynamics into an optimal variational trajectory.

M.5 Quantum-Field Analogue of RSVP

A quantum-theoretic analogue of the plenum appears when the canonical fields are promoted to operators,

$$\Phi \rightarrow \hat{\Phi}, \quad \Pi_\Phi \rightarrow \hat{\Pi}_\Phi = -i \frac{\delta}{\delta \Phi},$$

and similarly for S and \mathbf{v} . The RSVP Hamiltonian becomes a functional operator \hat{H} , leading to the Schrödinger–RSVP equation for the wavefunctional $\Psi[\Phi, S, \mathbf{v}, t]$:

$$i \partial_t \Psi = \hat{H} \Psi.$$

In the semiclassical limit,

$$\log \Psi = -\mathcal{F} + \text{phase},$$

so the free energy becomes the negative log-amplitude of the RSVP wavefunctional. This establishes

$$\text{FEP} = \text{semiclassical limit of quantum RSVP}.$$

M.6 Final Unified Dynamics

Let $X = (\Phi, \mathbf{v}, S)$ denote the plenum state, let θ denote semantic parameters, and let $\mathsf{T} = \mathsf{RG} \circ \mathsf{YC}$. The unified evolution is

$$\begin{aligned} X_{t+1} &= \mathsf{T}(X_t), \\ \theta_{t+1} &= \theta_t - G^{-1} \nabla_\theta \mathcal{F}(X_t; \theta_t), \\ \mathbf{MB}(X_{t+1}) &= \partial X_{t+1}, \quad (\text{boundary of maximal gradient invariance}), \\ X^* &= \lim_{k \rightarrow \infty} \mathsf{T}^k(X_0). \end{aligned}$$

Taken together, these equations present a single framework that unifies lamphrodynamic field behavior, natural-gradient information geometry, and the compositional semantics of the Spherepop calculus. They incorporate the variational logic of the Free Energy Principle, the simplifying effects of renormalization, and the emergence of boundary structures as Markov blankets. Within this unified scheme, fixed points appear as stable forms, homotopy limits encode selfhood, slow eigenmodes furnish a mathematical account of consciousness, and meaning itself arises as an invariant under representable semantic transformations.

What results is not a final ontology, but a coherent mathematical architecture in which physical dynamics, inference, semantics, and identity coexist and mutually constrain one another.

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