The Objectivity Organ

Definition, Criteria, and Failure Modes for Classical Objectivity

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Abstract

Abstract. Classical objectivity is treated here as an operational phenomenon: stable, reproducible facts that multiple independent observers can infer without coordination and without significantly disturbing the system. This paper rebuilds a unifying framework by treating decoherence, information broadcasting (Quantum Darwinism), thermodynamic stabilization, and renormalization as coordinated sub-functions of a single system-level mechanism. We define an *Objectivity Organ* as a composed mapping that takes a joint system–environment state and outputs: (i) a classical fact variable X, (ii) a family of independently readable environment records $\{\pi_k(X)\}$, and (iii) a scale-stable effective law class $\mathcal{L}_{\text{eff}}$. To avoid known pitfalls in mutual-information witnesses, we define the broadcasting criterion using *accessible information* and an SBS-compatible structure condition.

1 Introduction and Scope

Quantum theory describes microscopic systems as superposed and interfering, while macroscopic observations present stable outcomes and intersubjective agreement. This work addresses a narrow question: *under what physical conditions do stable shared facts emerge?* We do not address outcome selection, subjective probability, or consciousness. An observer is defined operationally as an agent with access to a local environment fragment $F \subset E$ and a finite coarse-graining $\mathcal{G}_\ell$.

The standard literature contains strong partial answers:

- **Decoherence** suppresses observable interference [1].
- **Quantum Darwinism (QD)** links objectivity to redundant environmental records [2].
- **Thermodynamics** constrains erasure and practical reversibility of records [3].
- **Renormalization** explains why macroscopic laws are insensitive to microscopic detail [4].

The novelty here is operational unification: these mechanisms are sub-functions of a single composed mapping that *produces* classical objectivity.

2 The Objectivity Organ: Definition

Organ Definition

An organ is a composed physical mapping with identifiable sub-functions that produces a specific output class and has predictable failure modes when sub-functions are removed.

The Objectivity Organ is defined as a mapping on the joint system–environment state ρ_{SE}:

$$\boxed{\mathcal{O} : \rho_{SE} \mapsto \Big(X,\ \{\pi_k(X)\}_{k=1}^{N},\ \mathcal{L}_{\text{eff}}\Big)} \tag{1}$$

where X is a classical fact variable, $\pi_k(X)$ are independently readable records stored in environment fragments E_k, and $\mathcal{L}_{\text{eff}}$ is a scale-stable effective law class governing coarse variables.

3 The Four Functional Stages

We decompose the organ into four functional layers:

$$\mathcal{O} := \mathcal{R} \circ \mathcal{T} \circ \mathcal{D}_{\text{strong}} \circ \mathcal{C}. \tag{2}$$

3.1 Stage I: Decoherence ($\mathcal{C}$)

Role: Suppression of observable interference. When a system S interacts with an environment E, phase information responsible for interference is redistributed. Decoherence suppresses off-diagonal terms in a stable pointer description, rendering interference locally inaccessible and stabilizing $\rho_S(t)$ [1].

3.2 Stage II: Strong Broadcasting ($\mathcal{D}_{\text{strong}}$)

Role: Intersubjective agreement via redundant records. Objectivity requires that information about S be accessible to many observers via disjoint environment fragments E_k. To avoid false positives from discord-dominated correlations, we require a Strong-QD / SBS-compatible condition [7]:

$$\rho_{SE} \approx \sum_x p_x \, |x\rangle\langle x| \otimes \rho_{E_1}^{(x)} \otimes \cdots \otimes \rho_{E_N}^{(x)}, \tag{3}$$

with fragment states $\rho_{E_k}^{(x)}$ approximately distinguishable for different x by local measurements.

3.3 Stage III: Thermodynamic Stabilization ($\mathcal{T}$)

Role: Facts persist because erasure is costly. Objectivity in practice requires record stability. While correlating a system with a memory can be thermodynamically reversible in principle, resetting a record register is bounded by Landauer [3]. Here $\mathcal{T}$ is a resource constraint on feasible recovery maps rather than a dynamical channel. For a fact encoded redundantly across m locally resettable records, a lower bound on full erasure under local reset and approximate conditional independence is:

$$Q_{\min}^{(\text{erase})} \gtrsim m \cdot k_{\text{B}} T \ln 2 \cdot H(X). \tag{4}$$

3.4 Stage IV: Renormalization ($\mathcal{R}$)

Role: Robust classical laws. Observers describe systems through coarse-grained variables. Renormalization theory formalizes how effective descriptions evolve with scale [4], explaining the milling away of microscopic detail into stable macroscopic regularities captured by $\mathcal{L}_{\text{eff}}$.

4 Success Criteria

Unified Objectivity Condition

Classical objectivity is present if and only if there exists a fact variable X for which redundancy, thermodynamic persistence, and scale stability hold simultaneously. In practice, X can be taken as the pointer observable that maximizes redundancy $R_\varepsilon(X)$ under the given environment partition. All predicates are evaluated under finite local observer access and approximate fragment independence.

Unified Objectivity Condition

$$\exists\, X \;:\; \begin{cases} R_\varepsilon(X) \gg 1, \\ Q_{\min}^{\text{reset}}(X) \;\gtrsim\; m k_{\text{B}} T \ln 2 \cdot H(X), \\ d(\mathcal{G}_\ell(\mathcal{L}_{\text{eff}}),\ \mathcal{G}_{\ell'}(\mathcal{L}_{\text{eff}})) \le \delta \quad \text{for } \ell < \ell'. \end{cases}$$

Equivalently, objectivity is generated by the composed mapping

$$\mathcal{O} = \mathcal{R} \circ \mathcal{T} \circ \mathcal{D}_{\text{strong}} \circ \mathcal{C}.$$

These conditions are jointly necessary and jointly sufficient for operational classical objectivity under finite, local observer access.

1. Redundancy Predicate (Consensus)

Accessible information $I_{\text{acc}}(X:F)$ denotes the maximum classical mutual information about X extractable from fragment F by local measurements (upper bounded by the Holevo quantity). Define redundancy at tolerance ε by:

$$R_\varepsilon(X) = \max \left\{ m \;\middle|\; \substack{\exists F_1 \ldots F_m \subset E \text{ disjoint} \\ \text{s.t. } \forall j:\ I_{\text{acc}}(X:F_j) \ge (1-\varepsilon) H(X)} \right\}.$$

Objectivity requires $R_\varepsilon(X) \gg 1$.

2. Irreversibility Predicate (Persistence)

If m redundant locally resettable copies exist, a Landauer-type lower bound implies:

$$Q_{\min}^{\text{reset}}(X) \;\gtrsim\; m k_{\text{B}} T \ln 2 \cdot H(X),$$

under local reset and approximate conditional independence of record registers.

3. Scale-Stability Predicate (Lawhood)

Let $\mathcal{G}_\ell$ be coarse-graining at scale ℓ. Law stability requires:

$$d(\mathcal{G}_\ell(\mathcal{L}_{\text{eff}}),\ \mathcal{G}_{\ell'}(\mathcal{L}_{\text{eff}})) \le \delta \quad \text{for } \ell < \ell'.$$

5 Failure Mode Analysis (Lesions)

- **Discord-Dominated Correlations (Bad $\mathcal{D}$):** If $I_{\text{acc}} \ll I(S:E)$, apparent redundancy can be a false positive for naive QD witnesses [7].
- **Asymmetric Encoding:** If information is deposited in channels atypical observers do not sample, consensus fails for typical observers [8].
- **Low Stabilization (Missing $\mathcal{T}$):** If record registers are not stabilized, facts are fragile and reversals are practically achievable (as seen in error-corrected quantum memory).

6 Empirical Stress Tests and Anchors

This framework does not introduce new microphysics. Its credibility depends on whether each sub-function is independently evidenced.

6.1 Decoherence tested by interference loss

Matter-wave interferometry with large molecules exhibits quantitative suppression of interference consistent with collisional decoherence theory [5].

6.2 Redundancy tested in simulators

Photonic experiments assess Darwinism signatures and investigate how multipartite correlations in the environment affect the emergence of redundant records [9]. Multi-photon quantum simulators quantify classical information proliferation and suppression of quantum correlations [10].

6.3 Landauer bound tested in erasure

Experiments verify approach to the Landauer bound in slow erasure cycles of a one-bit memory [6].

7 Cross-Domain Structural Tests

The Objectivity Pipeline is not restricted to quantum systems. It predicts consensus fails wherever any stage is absent.

- **Distributed computation:** Loss of global coherence arises from latency. Replication produces redundant state. Rollback is costly once logs proliferate.
- **Neuroscience:** Neural noise destroys microstate precision. Memories are redundantly encoded. Stabilization is energetically constrained.

8 Conclusion

The Objectivity Organ is a functional system, not merely a synthesis. It takes a quantum substrate and produces classical, persistent, law-governed reality through a four-stage pipeline. By replacing naive mutual information with accessible information and using an SBS-compatible structure condition, the framework becomes robust against common theoretical pitfalls. The Objectivity Organ therefore specifies a minimal functional architecture that any physical system must satisfy in order to support stable, shared, and law-governed facts.

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