Constraint Carriers Before Codes

A Structural Account of Proto-Genetic Inheritance

Abstract

Proto-genetic structures are commonly described using informational and semantic metaphors: genes as codes, DNA as messages, replication as copying. This paper develops a strictly structural alternative. Without appealing to any origin-of-life scenario, chemical implementation, or semantic framework, it analyzes inheritance as the persistence of organizational constraints across lineage bifurcation events. The central claim is that inheritance precedes replication, and fidelity precedes semantics. Distributed organizational constraints are shown to be unstable under repeated lineage disruption, motivating the gradual emergence of localized structural constraint carriers: re-identifiable substructures whose presence is sufficient, under generic background conditions, to re-instantiate or stabilize system-defining constraints. Discrete, copyable regularities arise only later, as robustness-driven discretizations of carrier adequacy under perturbation, without introducing representation, meaning, or correctness conditions.

---

1. Introduction: Inheritance Without Semantics

Genetic inheritance is routinely described in informational terms. Genes are said to encode instructions, DNA to carry messages, and replication to copy content. While such language is often pragmatically useful in mature biological contexts, it obscures a more basic question: what must persist, structurally, for inheritance to occur at all?

This paper rejects the assumption that inheritance is fundamentally representational or code-based. Instead, inheritance is treated as a structural phenomenon grounded in re-identifiability across lineage bifurcation. Replication, coding, and semantic interpretation are treated as downstream achievements, not as primitives.

Scope discipline: This paper does not propose an origin-of-life model, adjudicate between empirical scenarios, or describe chemical mechanisms. Its aim is structural: to articulate conditions that any inheritance-capable lineage must satisfy, independent of physical implementation.

---

2. Structural Preliminaries

This section introduces the minimal structural vocabulary required for the analysis. No biological, chemical, or semantic assumptions are presupposed.

2.1 Systems and Re-Identifiability

A system is a region of relational organization that maintains re-identifiability across ordering under perturbation via constraint coherence. Identity persistence is grounded in continuity of organizational constraints, not material sameness.

2.2 Organizational Constraint Sets

An organizational constraint set, denoted K, is a specified set of relations and constraints that delimit a system's viable transition region and constrain re-identifiability. K is defined independently of persistence outcomes. Loss of K entails loss of re-identifiability.

2.3 Background Conditions

Background conditions, denoted B, are the minimal non-specific environmental or substrate conditions required for any instance of the system type to exist at all. B is broadly available and not lineage-differentiating.

2.4 Lineage Bifurcation

A lineage bifurcation event is any discontinuity that produces multiple successor regions, each of which must independently satisfy re-identifiability conditions in order for the lineage to continue. No specific biological division mechanism is assumed.

2.5 Structural Inheritance

Inheritance is defined as the persistence of organizational constraint sets across sequences of lineage bifurcation events. Replication is treated as a sufficient but not necessary mechanism for inheritance.

---

3. Distributed Constraint Inheritance

We begin with inheritance regimes in which system-defining constraints are fully distributed. In such regimes, no proper subregion of the system is sufficient, under background conditions, to re-instantiate the full constraint set.

After a lineage bifurcation, successor regions inherit only partial fragments of the original organization. Re-identifiability requires reconstruction of global relational structure. Inheritance in this regime is therefore reconstructive and sensitive to disruption, environmental noise, and reconstruction dimensionality.

The significance of this regime is not mere persistence, but the locus of failure it imposes: inheritance failure arises from the inability to reconstruct high-dimensional global organization after bifurcation.

Repeated lineage bifurcation exposes the instability of distributed inheritance. Reconstruction failures accumulate, limiting lineage depth without invoking purpose, optimization, or selection as explanatory primitives.

---

4. Emergence of Localized Constraint Carriers

This section explains how inheritance can transition from reconstructive to carrier-mediated regimes without discontinuity or semantic presupposition. The novelty of the present account lies not in the observation that localization improves stability, but in explaining why lineage bifurcation structurally destabilizes reconstructive inheritance relative to carrier-mediated regimes.

4.1 Redundancy and Bundling

Under persistence filtering, subconstraints within K tend to become redundantly instantiated. Redundancy improves reconstructive success and enables correlated co-location of subconstraints into local bundles.

4.2 From Bundles to Sufficiency

As bundling strengthens, certain localized regions reduce reconstruction dimensionality. A localized region becomes a constraint carrier when, together with background conditions, it is sufficient to re-instantiate or stabilize the full organizational constraint set.

4.3 Two Routes to Carrier Sufficiency

Constraint-seeding. A localized carrier initiates a constrained reconstruction trajectory that reliably re-enters the viable constraint region.

Constraint-locking. A localized carrier suppresses drift by excluding transitions that violate system-defining constraints.

These routes are non-exclusive and require no representational content.

---

5. Fidelity Without Copying

Once localized structural constraint carriers exist, lineage viability depends primarily on whether each successor region contains at least one adequate carrier instance. Fidelity is defined as the structural probability that lineage bifurcation produces at least one adequate carrier, either through transmission or regeneration.

Carrier adequacy admits variation. Carriers occupy an adequacy region rather than a single identity. Redundancy, regeneration reliability, and perturbation tolerance jointly determine whether lineages remain viable across repeated bifurcation. Error thresholds arise structurally when perturbation exceeds what redundancy and regeneration can compensate.

---

6. Why This Is Not Semantics

Localized structural constraint carriers do not encode, represent, or refer. They participate in the re-instantiation or stabilization of organizational constraints.

Crucially, failure of carrier adequacy results in loss of re-identifiability, not misrepresentation. The system does not continue in an incorrect state; it ceases to be the same system at all. Breakdown is not falsity.

Stable coupling relations between carrier variants and organizational outcomes constitute constraint coupling, not coding. Semantic notions such as correctness, reference, and aboutness require value-organized counterfactual structure and are not presupposed here.

---

7. Implications and Limits

This account explains why inheritance precedes replication, why discrete carrier structures emerge, and why fidelity constraints become central before semantics. It remains neutral with respect to chemical implementation and empirical origin-of-life scenarios.

The analysis does not deny the reality or utility of genetic codes in mature biological systems. It claims only that such codes are downstream stabilizations built upon earlier, non-semantic inheritance regimes.

Conclusion

Inheritance can be understood without appeal to representation, meaning, or teleology. Localized structural constraint carriers emerge gradually from distributed organizational constraints as lineage bifurcation destabilizes reconstructive inheritance. Fidelity pressures explain the centrality of discrete, copyable structures without invoking semantic primitives. This structural perspective clarifies the preconditions for genetic inheritance while avoiding retrospective conceptual inflation.

Appendices

Appendix A: Formal Definitions

This appendix provides precise definitions used in the main text, stated independently of biological or semantic assumptions.

Constraint set (K). A constraint set K is a specified collection of relations that delimit a system's viable transition region and determine re-identifiability across perturbation. K is not defined by survival outcomes but by structural admissibility.

Background conditions (B). Background conditions are non-specific substrate or environmental features required for any instance of the system type to exist. They are assumed to be broadly available and non-differentiating across lineages.

Adequacy region (A). Given a space of possible carrier variants C, the adequacy region $A \subset C$ is the subset such that any $c \in A$, together with B, is sufficient to re-instantiate or stabilize K.

Appendix B: Lineage Viability and Supercriticality

Lineage continuation under repeated bifurcation can be analyzed using minimal branching conditions. For a bifurcation event producing m successor regions, let p denote the probability that a given successor contains at least one adequate carrier instance.

If the expected number of viable successors per event satisfies $m \cdot p \leq 1$, lineages almost surely terminate. Sustained lineage continuation requires $m \cdot p > 1$. This condition does not presuppose biological reproduction, population genetics, or selection; it follows from the structure of repeated bifurcation with viability-dependent continuation.

Carrier adequacy may arise through transmission or regeneration. Let p_T denote transmission probability and p_R denote regeneration probability conditional on non-transmission. Then $p = p_T + (1 - p_T)p_R$. Redundancy increases p_T, while reliable reconstruction mechanisms increase p_R. Neither can be arbitrarily low without lineage collapse.

Appendix C: Failure Surface Dimensionality

Reconstructive inheritance and carrier-mediated inheritance differ in their vulnerability to perturbation. Distributed constraint inheritance requires restoration of many-to-many global relations after bifurcation, yielding a high-dimensional failure surface. Localized structural constraint carriers reduce the inheritance condition to preservation or regeneration of at least one sufficient substructure, yielding a lower-dimensional failure surface.

Under increasing lineage stress—characterized by frequent bifurcation, disruption severity, or environmental noise—the probability of failure scales more rapidly for high-dimensional reconstruction than for localized carrier loss. This dimensional asymmetry explains the structural dominance of carrier-mediated inheritance without invoking optimization or design.

Appendix D: Semantic Collapse Analysis

A recurring interpretive error is to treat stable carrier–outcome coupling as semantic coding. This appendix clarifies why such readings are unwarranted.

First, adequacy is not correctness. A carrier variant outside the adequacy region does not misrepresent; it fails to sustain re-identifiability. The system does not persist in an incorrect state.

Second, coupling is not structural resolution. Stable relations between carrier classes and organizational outcomes reflect constraint dependence, not symbolic interpretation or rule-following.

Third, persistence filtering is not normativity. Lineages that fail to continue are filtered out, but no internal standard of correctness is thereby established.

Semantic notions such as meaning, reference, and misrepresentation require value-organized counterfactual structure and practices of assessment that are absent from the regimes analyzed here.