Appendix: Structural Limitations of Contemporary Ontologies

1. Introduction: Why Frameworks Fail Gracefully

Modern physical theories capture essential structure within their domains, yet none fully explain the generative origin of physical law or the emergence of geometry, collapse, or informational structure. This is not a defect. Rather, it reflects the difficulty of constructing a unified ontology across disparate scales.

In the collapse-first ontology of Quantum Collapse Geometry (QCG), a general principle emerges: certain classes of theories encounter predictable limitations when they elevate emergent structures to primitive assumptions. This appendix outlines this principle in a neutral, structural, and theory-agnostic manner.

2. The Principle of Emergent–Primitive Misassignment

A generative ontology must distinguish between:

- **primitive structures**, which are ontologically fundamental, and
- **emergent structures**, which arise from underlying generative dynamics.

When a framework treats an emergent structure as primitive, it inherits a predictable failure mode:

> *A theory that promotes an emergent layer to a primitive assumption will lose access to the regime in which the generative mechanisms operate, and therefore will be unable to achieve complete unification.*

This principle is universal. It applies to geometric, algebraic, informational, and computational frameworks alike.

3. Classes of Misassignments and Their Predictable Limitations

These structural limitations are not criticisms but reflections of how deeply different frameworks illuminate different levels of the generative hierarchy.

Geometry-first frameworks. When geometric structure is taken as primitive, difficulties naturally arise at scales where geometry must itself emerge. Such theories excel in regimes with stable curvature and locality but encounter challenges in deriving the metric, dimensionality, or causal order from first principles.

Field-first frameworks. When fields or amplitudes are taken as ontologically fundamental, collapse appears external or ad hoc. These frameworks succeed in modeling particle interactions yet struggle to explain measurement, decoherence, or the origin of field configurations.

Symmetry-first frameworks. Approaches that elevate symmetries to the foundational level may encounter limits where symmetries must break due to generative dynamics. They provide powerful descriptions but have difficulty deriving the symmetries themselves.

Information-first frameworks. When information is treated as primitive, collapse becomes paradoxical: Does collapse create information, destroy it, or select among possibilities? In QCG, information is a coarse-grained consequence of collapse, and thus no such paradox arises.

Computation-first frameworks. Discrete computational models struggle to recover continuum behavior, geometric stability, and amplitude structure if computation is emergent rather than fundamental. These approaches excel in modeling discrete aspects but face obstacles in continuous-limit physics.

Purely algebraic frameworks. When algebraic structure defines the ontology, collapse appears non-algebraic, forcing it outside the theory. These frameworks succeed formalistically but face ontological gaps.

4. The QCG Perspective: Why These Limitations Are Expected

In a collapse-first ontology:

1. collapse generates coherence,
2. coherence generates structure,
3. structure generates geometry, and
4. geometry generates effective laws.

Thus, any framework that elevates an emergent layer to a primitive one will naturally encounter limitations at the scale where that layer is generated.

The result is not that such theories are "wrong." Rather, they are *correct within the regime where their primitives are valid approximations.* Their successes are genuine; their boundaries are structurally expected.

5. The Ecology of Theories

Every major physical framework captures important truths: they illuminate structure, solve problems, and describe stable domains. The limitations noted here are not flaws but reflections of appropriate partiality.

QCG does not replace existing frameworks. It contextualizes them within a single generative ontology, clarifying how they arise and why they are bounded.

6. Conclusion: A Gentle Architecture of Understanding

Recognizing that geometry, fields, symmetries, computation, and information are emergent from collapse-phase dynamics makes the limitations of existing frameworks predictable and conceptually natural.

QCG provides not a critique but a map—a structural understanding of how different theories inhabit various layers of the same underlying generative landscape.

Appendix: Collapse as a Categorical Operator (QCG)

Setting. Let $\mathcal{Q} \equiv \mathrm{CPM}(\mathrm{FHilb})$ denote the †-compact closed category whose objects are finite-dimensional Hilbert spaces and whose morphisms are completely positive (CP) maps. Fix a finite outcome set B and a *classical object* C_B in $\mathcal{Q}$, i.e. a special commutative †-Frobenius algebra (copy/delete structure) representing classical data with outcomes in B. Let

$$D : \mathcal{Q} \to \mathcal{Q}$$

be an *idempotent comonad* (the "decoherence" functor), selecting a coherence-stable subalgebra (e.g. a pointer basis / twistor-phase patch). Thus $D^2 \cong D$ and D is strong monoidal.

Definition 1 (Instrument and per-outcome collapse)**.** *A (quantum)* instrument *for observable B on $H \in \mathrm{Ob}(\mathcal{Q})$ is a CP map*

$$\mathrm{Instr}_B : H \longrightarrow H \otimes C_B,$$

which outputs a (generally disturbed) post-measurement system together with a classical record in C_B. For $b \in B$, let $\varepsilon_b : C_B \to I$ be the counit selecting outcome b. The per-outcome collapse *is the CP map*

$$\kappa_b \;=\; (\mathrm{id}_H \otimes \varepsilon_b) \;\circ\; \mathrm{Instr}_B \;:\; H \to H,$$

followed (physically) by normalization.

Definition 2 (Global (unselective) collapse)**.** *The* global *QCG collapse operator on H is*

$$\mathrm{Coll}_H \;=\; \Big(\sum_{b\in B} \kappa_b\Big) \;\circ\; D_H \;:\; H \to H.$$

Equivalently, write $\mathrm{Instr}_B = \sum_{b\in B} \iota_b \circ \kappa_b$ *with injections $\iota_b : H \to H \otimes C_B$; then* Coll_H *is "decohere, instrument, then forget outcome".*

Naturality. For any CP map $f : H \to K$, we require that Instr_B and D be *natural* (compatible with morphisms), i.e.

$$(\,f \otimes \mathrm{id}_{C_B}\,) \circ \mathrm{Instr}_B^H \;=\; \mathrm{Instr}_B^K \circ f, \qquad D_K \circ f \;=\; f \circ D_H.$$

Under these standard assumptions:

Lemma 1 (Naturality of Coll)**.** *For every morphism $f : H \to K$ in $\mathcal{Q}$,*

$$\mathrm{Coll}_K \circ f \;=\; f \circ \mathrm{Coll}_H.$$

Proof. Compute

$$\mathrm{Coll}_K \circ f = \Big(\sum_b \kappa_b^K\Big) \circ D_K \circ f = \Big(\sum_b \kappa_b^K\Big) \circ f \circ D_H = f \circ \Big(\sum_b \kappa_b^H\Big) \circ D_H = f \circ \mathrm{Coll}_H,$$

using naturality of D, and $(f \otimes \mathrm{Id}) \circ \mathrm{Instr}_B^H = \mathrm{Instr}_B^K \circ f$, then composing with $(\mathrm{Id} \otimes \varepsilon_b)$ to move f through κ_b. □

Idempotence. Physically, collapsing onto a coherence-stable subalgebra is a projection: repeating it does not further change the state (up to normalization). Categorically:

Lemma 2 (Idempotence of Coll)**.** *For each object H in $\mathcal{Q}$, there is a canonical isomorphism*

$$\mathrm{Coll}_H \circ \mathrm{Coll}_H \;\cong\; \mathrm{Coll}_H.$$

Sketch. Since D is an idempotent comonad, $D_H \circ D_H \cong D_H$. Moreover, each ε_b is idempotent on the classical object, and the family $\{\kappa_b\}_{b\in B}$ forms an algebra for the endofunctor $T(X) = X \otimes C_B$ ("select a branch"). Hence

$$\Big(\sum_b \kappa_b\Big) \circ D_H \circ \Big(\sum_{b'} \kappa_{b'}\Big) \circ D_H \;\cong\; \Big(\sum_b \kappa_b\Big) \circ D_H,$$

i.e. a projector onto the D-stable, instrument-selected subalgebra. □

Commutative square (naturality).

$$\begin{tikzcd} H \arrow[r, "f"] \arrow[d, "\mathrm{Coll}_H"'] & K \arrow[d, "\mathrm{Coll}_K"] \\ H \arrow[r, "f"'] & K \end{tikzcd} \qquad \text{commutes in } \mathcal{Q}.$$

Interpretation. The QCG *collapse* is not a metaphysical bolt-on but a *structure-preserving* operator

$$\eta : \mathrm{Id}_{\mathcal{Q}} \;\Rightarrow\; \mathrm{Coll},$$

which is (i) *natural* in H, (ii) *idempotent* (projector), and (iii) *monoidal* up to the usual environment handling. In QCG terms, collapse is *coherence-selection* induced by an idempotent decoherence functor D and a measurement instrument, realized via a classical outcome interface C_B (twistor-phase geometry picks the coherent subalgebra).

Remark 1 (Cross-domain rhyme)**.** *The same categorical patterns appear in probabilistic conditioning (Giry/Dist monad) and in optimization as projections onto feasible/coherent sets. This matches the QCG thesis that physics, learning, and biology share a common coherence-selection operator.*