The Realisability Axiom

A One-Page Foundation for Distinction Dynamics

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Abstract

We state the single axiom underlying Distinction Dynamics (DD) and its immediate consequences. This note serves as the canonical entry point for the DD research program.

The Axiom

Axiom 1 (Realisability)**.** *A structure is* ***physically realisable*** *if and only if it admits a faithful embedding into a unitary, information-preserving process algebra.*

Unpacking the terms:

- *Faithful embedding*: the structure's relations are preserved, not merely mapped
- *Unitary*: every process has an inverse; no information is created or destroyed
- *Information-preserving*: distinguishable inputs yield distinguishable outputs
- *Process algebra*: composition of processes is associative with identity

The axiom encodes one intuition: *to exist physically is to be distinguishable, and distinctions must be stable under composition.*

Why Quantum Mechanics (Not Just Any GPT)

General Probabilistic Theories (GPTs) permit structures beyond quantum mechanics. Why does DD select QM specifically?

Proposition 2 (Hilbert Space from Realisability)**.** *A GPT satisfying:*

1. *Purification (every mixed state arises from a pure state of a larger system)*
2. *Invertibility of pure transformations*
3. *Continuous reversibility (no discrete jumps in state space)*

is necessarily described by a complex Hilbert space.

Sketch. Conditions (1)–(3) are precisely the realisability requirements applied to state spaces. Chiribella–D'Ariano–Perinotti (2011) and Masanes–Müller (2011) prove that these conditions uniquely select quantum theory. Non-Hilbert GPTs violate at least one condition—typically invertibility of transformations or continuous composition.

DD inherits quantum structure not by postulate but by consequence.

The Philosophical Core

> **Existence is not the presence of entities, but the closure of distinctions under realisation.**

This positions DD as:

- Not metaphysics (no claims about "what there is" prior to distinction)
- Not physics (no dynamical equations or predictions of trajectories)
- An **ontology of constraints**: what structures can exist given that existence requires distinguishability

DD answers: "Why this structure?" not "What happens next?"

Scope and Limitations

DD is a **constraint theory**, not a dynamical theory. It does not:

DD does not explain	**Because**
Numerical coupling constants	Requires dynamics (RG flow, matching)
Specific mass values	Requires Yukawa textures, not just structure
Vacuum selection	Requires cosmological initial conditions
Spacetime dimensionality	Separate constraint (future work)
Quantum gravity	Beyond current scope

These are not failures but **scope boundaries**. DD constrains the space of possible theories; dynamics selects trajectories within that space.

What DD Does Derive

From the Realisability Axiom alone:

1. **Quantum structure**: Hilbert space, Born rule, unitarity
2. **Division algebras**: $\mathbb{R}, \mathbb{C}, \mathbb{H}, \mathbb{O}$ as the only carrier structures (Hurwitz)
3. **Gauge group**: $SU(3) \times SU(2) \times U(1)$ from octonionic automorphisms
4. **Hypercharge quantisation**: unique assignment via anomaly cancellation (Geng–Marshak)
5. **Three generations**: lower bound from CP violation, upper bound from sedenion structure
6. **Mass hierarchy**: monotonicity with distinction depth (ordering, not values)

The Standard Model emerges as the *unique* realisable structure—not the simplest, but the only one.

Entry Points

- **Main paper**: "Realisability Constraints and the Emergence of Standard Model Structure"
- **Companion**: "Distinction Dynamics as a Constraint Theory"
- **Background**: Chiribella et al. (2011), Baez (2012), Furey (2018), Gresnigt (2023)