Section 5. Reconstructing Causality Without Fundamental Time

Mini-Introduction

With the arrow of time now derived as an inevitable consequence of collapse ordering and entropic irreversibility, we are finally prepared to confront one of the deepest assumptions embedded in physical reasoning: that causality requires time.

In classical physics, causality is defined temporally—causes precede effects along a time axis. In relativity, causal structure is encoded geometrically through light cones embedded in spacetime. In quantum theory, causal order is often treated ambiguously, oscillating between unitary evolution and measurement collapse, both still implicitly ordered by an external time parameter.

CUWF departs radically from all of these frameworks. Because time in CUWF is not fundamental but an emergent record of collapse, causality cannot be defined in time. It must be reconstructed from a deeper, pre-temporal structure.

Section 5 introduces a collapse-based notion of causality that does not rely on temporal precedence, spacetime geometry, or global simultaneity. In CUWF, causal relations arise from irreversible structural commitment: a collapse event constrains the space of possible future collapses by eliminating degrees of freedom and fixing relational structure.

This section shows that causality in CUWF is structural rather than temporal, asymmetric without requiring a time axis, local without requiring spacetime cones, and compatible with quantum nonlocality without retrocausality. By rebuilding causality directly from collapse ordering and entropic

constraints, CUWF reveals that causal direction does not follow from time. Time follows from collapse, and causality follows from collapse as well.

Once time is removed from the foundation of physics, causality must be rebuilt as well. In classical thought, causal order is inseparable from temporal order: a cause is what happens first, an effect is what happens later, and the arrow of causality is simply identified with the arrow of time. But CUWF has already shown that time is not fundamental. It is generated only through collapse, sampled only by structured subsystems, and absent at the wave level.

If that is true, then sequence-based causality cannot be fundamental either. Section 5 therefore undertakes the next necessary step of the CUWF program: reconstructing causality from collapse, entropic geometry, and structural constraint rather than from temporal succession.

This reconstruction proceeds in five stages. First, classical causality is examined as a derivative framework based on temporal ordering. Second, sequence-based causation is removed. Third, a collapse-based causal structure is introduced. Fourth, entanglement is reinterpreted as the clearest manifestation of sequence-free causality. Fifth, retrocausality and causal paradoxes are dissolved as artifacts of time-based intuition rather than features of reality itself.

5.1 Classical Causality as Temporal Ordering

In classical physics, causality is inseparable from time. To call one event the cause of another is already to assume that the first occurs earlier and the second later along a shared temporal axis. Causal structure is therefore not independent. It is derived entirely from temporal succession.

In Newtonian mechanics, this relation is formalized through deterministic evolution equations. A system's state at time t determines its state at all future times $t + \Delta t$, given appropriate conditions. If A

and B are two events, then A is taken to be the cause of B if and only if A occurs at t_1 and B occurs at t_2 with $t_1 < t_2$. In this framework, the temporal inequality itself is sufficient to define causal order.

Time therefore plays two roles simultaneously. It orders events sequentially and enforces asymmetry between cause and effect. The arrow of causality becomes identical with the arrow of time. To ask whether an effect could precede its cause is simply to ask whether time could run backward.

- A single universal clock.
- A shared notion of simultaneity.
- A total ordering of all events.

These assumptions make classical determinism possible, but they also reveal the fragility of the framework. Without a global time parameter, classical causal order collapses. Modern physics has already exposed those weaknesses: relativity destroys global simultaneity, quantum theory introduces nonlocal correlations, and measurement collapse breaks deterministic evolution.

From the CUWF perspective, classical causality is not wrong within its regime. It is derivative. It presupposes precisely the structures—fundamental time, continuous temporal flow, and deterministic time slices—that CUWF denies at the deepest level. Classical causality must therefore be reinterpreted as an observer-level approximation that arises only in regimes where collapse density is high and time appears smooth.

5.2 CUWF Removal of Sequence-Based Causation

Section 5.1 shows that classical causality depends entirely on temporal sequence. CUWF removes that dependence altogether. Because time is not fundamental but emergent from collapse, causality cannot be defined as a relation between events ordered in an already-existing timeline. It must instead be rebuilt from the deeper structure that exists prior to time.

The crucial point is straightforward. Sequence-based causation relies on the premise that event A causes event B if A occurs before B. But CUWF has already established that time exists only at collapse events, that no time exists between collapses, and that wave-level reality is timeless. There is therefore no continuous temporal sequence through which causal influence could propagate. The very notions of before and after lose foundational meaning.

This does not mean that collapse events are unordered. It means their ordering is not temporal. Collapse ordering reflects irreversible reduction of degrees of freedom, elimination of alternatives, and fixation of relational constraints. It tells us what remains structurally possible after a collapse, not when an event occurs in time.

In classical causality, one imagines a chain of events A ⟶ B ⟶ C. CUWF replaces this with a different architecture. A collapse event does not cause a later event by sending influence forward in time. It constrains the space of possible later collapses. Causality becomes a relation among constraint sets.

- A collapse reduces N_eff.
- The reduced structure limits future-compatible outcomes.
- Subsequent collapses must remain compatible with prior commitments.

Causal influence is therefore not a signal propagating through time. It is a restriction propagating through configuration space. Questions about propagation speed or temporal delay dissolve because causality is not temporal at all. Apparent temporal sequences arise only because observers discretely sample collapse outcomes, store them as ordered memory, and reconstruct the pattern as cause then effect.

Once sequence-based causation is removed, familiar problems disappear with it: there are no causal loops, no backward-in-time influence, no need for simultaneity conventions, and no dependence on

spacetime foliation. Causality becomes asymmetric without time, irreversible without temporal flow, and structural rather than sequential.

5.3 Collapse-Based Causal Structure on Entropic Wave Geometry

Having removed sequence-based causation, CUWF now rebuilds causality from its own foundation. The result is a collapse-based causal structure defined not by temporal succession but by structural compatibility imposed on entropic wave geometry.

At the wave level, configurations coexist. Before collapse, no outcome is definite, no event has yet occurred, and no history exists. Asking which event happened first is therefore meaningless. What exists instead is co-occurrence: multiple possible outcomes jointly encoded within the same entropic-wave structure. Cause and effect, at this stage, are not temporally separated. They are jointly present as relational possibilities.

Collapse is the operation that converts co-occurrence into commitment. When collapse occurs, degrees of freedom are reduced, alternatives are eliminated, and relational constraints are fixed. Collapse does not transmit influence through time. It selects a compatible structure from the wave-level possibility space.

Once such a commitment has occurred, the universe is no longer free to realize arbitrary configurations. Each collapse imposes constraints on all future-compatible collapses. These constraints form a causal structure, but not a temporal chain. Formally, the structure may be represented as a network:

- nodes = collapse events,
- edges = compatibility constraints,
- direction = irreversible reduction of degrees of freedom.

This network is directed, acyclic, and non-temporal. It is directed because each collapse irreversibly restricts what may follow. It is acyclic because reopening discarded possibilities is forbidden. And it is non-temporal because the ordering expresses structural dependency rather than temporal precedence.

Collapse A is causally prior to collapse B if and only if B's admissible configuration space is constrained by A. This partial order replaces temporal causation entirely. At the level of observation, the structure is later reconstructed as a sequential narrative. But ontologically, causality is not something that happens in time. It is something that determines what may happen at all.

5.4 Entanglement as a Sequence-Free Causal Structure

Quantum entanglement is often taken as the hardest test for any account of causality that remains tied to time. Correlated outcomes appear instantaneously across spatial separation and seem to violate ordinary intuitions about propagation, delay, and sequence. Within CUWF, entanglement poses no paradox because causality is not defined temporally in the first place.

Entanglement is not an exception to causal structure. It is its clearest manifestation. In sequence-based frameworks, influence must propagate from past to future through spacetime and with finite speed. Entanglement violates exactly those expectations. That is why many theories are driven to hidden variables, retrocausality, or preferred reference frames. CUWF requires none of them.

In CUWF, entanglement exists entirely at the wave level. Before collapse, entangled subsystems do not possess independent outcomes at all. They share one relational wave structure. There is no message to send, no signal to propagate, and no temporal interval to cross. There is only shared structure.

When collapse occurs in an entangled system, degrees of freedom are reduced jointly and compatible outcomes are selected together as one structural commitment. No outcome causes the other, and no event precedes the other. Both emerge from the same collapse constraint.

Questions such as which measurement happened first, or whether A influenced B or B influenced A, are therefore category errors. They presuppose temporal order precisely where CUWF says temporal order is absent. Before collapse, no event has occurred. After collapse, both outcomes are fixed and any ordering is only an observer-level reconstruction.

Entanglement should therefore be understood as a global constraint on allowed outcomes rather than as a signal. Collapse selects a configuration consistent with entanglement structure, conservation law, and entropic geometry. This constraint applies instantly in configuration space, not through time. Entanglement thus demonstrates causal structure without propagation, without delay, and without temporal mediation.

5.5 Resolution of Retrocausality and Paradoxes

One of the main reasons retrocausality is introduced in modern physics is the attempt to reconcile quantum correlations, relativistic constraints, and classical causal intuition under the assumption that causality must operate along a time axis. CUWF resolves these paradoxes at their root by removing time from the foundation of causality altogether.

Retrocausality appears necessary only in frameworks where causality is defined through temporal precedence. If A causes B because A occurs earlier than B, then quantum phenomena that disrupt ordinary ordering force theorists into hidden variables, backward influence, preferred frames, or causal loops. All such constructions presuppose that time is fundamental. CUWF rejects that premise.

In CUWF, causal structure is defined by collapse ordering rather than time. Once a collapse occurs, degrees of freedom are irreversibly reduced, alternative histories are eliminated, and structural

constraints are fixed. These constraints apply globally to future-compatible collapses. There is no sense in which a later collapse could influence an earlier one, because past collapse outcomes are already finalized and discarded possibilities cannot be reopened.

Delayed-choice experiments illustrate this clearly. In conventional language, later measurements appear to retroactively affect earlier system behavior. CUWF interprets this differently: before collapse, no definite history exists. The wave-level structure supports several consistent possibilities. Collapse then selects one globally consistent outcome set. Nothing is modified backward in time because there was no fixed past fact to modify. Collapse creates history; it does not revise it.

The same reasoning eliminates causal loops and time paradoxes entirely. Grandfather paradoxes, self-causing events, and closed causal curves all require time to exist as a manipulable dimension. CUWF does not allow that ontology. Because causality is constraint-based, collapse ordering is irreversible, and the constraint graph is acyclic, paradoxical structures cannot arise in the first place.

Retrocausality in CUWF is therefore not forbidden by an external rule. It is unnecessary because the conceptual machinery that would require it has already been removed. What appears as retrocausality in other theories is reinterpreted here as a misreading of timeless wave-level structure combined with later collapse-generated ordering.

Interpretive Summary

- Classical causality is sequence-based and therefore derivative rather than fundamental.
- CUWF removes sequence-based causation by removing fundamental time from the base ontology.
- Causal structure is rebuilt from collapse-based constraints on entropic wave geometry.
- Entanglement is the clearest example of sequence-free causality rather than a challenge to it.
- Retrocausality and time paradoxes dissolve once causality is reconstructed from collapse rather than temporal order.

Mini-Closure — Section 5

Section 5 has completed a full reconstruction of causality within the CUWF framework. By removing time from the foundation of causal reasoning, CUWF shows that causality does not arise from temporal sequence, propagation, or precedence. Instead, causal structure emerges from irreversible structural commitment imposed by collapse on entropic wave geometry.

Across Sections 5.1–5.5, the argument has established that classical, time-ordered causality is an observer-level narrative rather than a fundamental mechanism; that collapse ordering replaces temporal ordering as the true source of causal asymmetry; that causal influence operates as constraint propagation in configuration space rather than as signals traveling through time; that entanglement provides direct empirical evidence for sequence-free causal structure; and that retrocausality and all associated paradoxes dissolve once causality is reconstructed without a fundamental time axis.

In CUWF, causes do not precede effects in time. They restrict which effects are structurally allowed to exist.

This completes the conceptual separation between time and causality: time is an emergent record of collapse, causality is an emergent structure of constraint, and neither requires the other as a primitive ingredient.

With causality now grounded in collapse dynamics rather than temporal sequence, the CUWF framework is prepared to address its next integrative challenge: how time, causality, gravity, and cosmology arise together from a single entropic-collapse substrate. The next section moves beyond reconstruction and into synthesis.