## Section 10. Thermodynamic Arrow Without Time-First Assumptions

Thermodynamics is often treated as the strongest empirical evidence for a fundamental arrow of time. Entropy increases. Systems equilibrate. Mixtures do not spontaneously unmix, and decayed structures do not spontaneously reconstruct themselves. Yet within the CUWF framework, this empirical arrow does not originate from time itself, nor from probabilistic inevitability taken in isolation. It arises as a consequence of collapse-driven history creation.

In this sense, thermodynamics does not generate the arrow. It inherits it.

### 10.1 Entropy Increase as a Consequence, Not a Cause

In traditional formulations, entropy is usually treated as a function that increases in time. This framing already presupposes a temporal direction before claiming to explain it. CUWF reverses the explanatory order. Entropy increase is not the source of directionality; it is something observed along realized history once directional realization has already taken place.

Let $\mathcal{H}_{\mathbf{n}}$ denote the set of realized history states after n collapse events. Entropy evaluated on realized macrostates may then be written schematically as:

$$S(\mathcal{H}_{\mathbf{n+1}}) \geq S(\mathcal{H}_{\mathbf{n}})$$

This inequality does not define an arrow in the primary sense. It reflects the monotonic accumulation of constraints established by history creation. Entropy increases because collapse produces records, records constrain future accessibility, and macrostates summarize those constraints at a coarse descriptive level.

Entropy is therefore best understood here as a summary-statistic of realized history rather than as an independent dynamical driver. The thermodynamic arrow records what directional history has done; it does not create that directionality from nothing.

### 10.2 Macrostates and Apparent Irreversibility

Thermodynamic irreversibility is often explained by appealing to macrostates: many microstates correspond to a smaller number of macroscopic descriptions, and systems tend to evolve toward overwhelmingly numerous macroscopic configurations. CUWF does not reject this insight, but clarifies its structural basis.

Macrostates are coarse descriptions of recorded constraints. Once collapse produces persistent records—environmental correlations, boundary changes, structural traces, and stabilized deformations—the set of accessible micro-configurations compatible with those records becomes increasingly restricted.

This may be expressed schematically as a monotonic restriction of accessible configuration space:

$$|\Omega(\mathcal{H}_{\mathbf{n+1}})| \leq |\Omega(\mathcal{H}_{\mathbf{n}})|$$

where $\Omega(\mathcal{H}_{\mathbf{n}})$ denotes the set of configurations compatible with the accumulated history $\mathcal{H}_{\mathbf{n}}$. Irreversibility therefore appears not because time flows forward as an external agent, but because macrostates encode the cumulative effects of realized history. The more records that exist, the narrower the configuration space compatible with them becomes.

Under this view, macroscopic irreversibility is not mysterious. It is the visible coarse-grained expression of constraint accumulation within a collapse-generated history structure.

### 10.3 Dissolving Loschmidt and Recurrence Paradoxes

Two classical objections dominate the thermodynamic discussion. Loschmidt's paradox asks why entropy should increase if microscopic laws are reversible. The recurrence paradox asks why entropy should not eventually decrease if the relevant state-space is finite and the system evolves long enough.

 

Within CUWF, both paradoxes weaken because they assume that realized history can be ignored or erased. Time-reversal arguments apply to reversible trajectories within $\Omega$, the space of possibilities. Recurrence arguments apply to motion within a fixed phase space. But collapse-driven history creation alters the domain itself.

Once a collapse event produces a record $h_i$, the accessible configuration space is redefined:

$$\Omega \longrightarrow \Omega \mid h_i$$

The system does not return to its original effective domain because the original constraints no longer exist in isolation. History has modified the space of accessibility. Subsequent realization proceeds under the burden of what has already been written.

Recurrence in the strong classical sense would require a reverse mapping of the form:

$$\Omega \mid \mathcal{H}_n \longrightarrow \Omega \mid \mathcal{H}_0$$

but this is structurally undefined for the same reason reverse collapse is undefined. The paradoxes therefore do not survive unchanged once history creation is included in the ontology. The assumptions required for full reversibility no longer hold across domains that have been restructured by realized records.

### 10.4 No Low-Entropy Universe Assumption Required

A common strategy in cosmology is to explain the thermodynamic arrow by postulating an extraordinarily low-entropy initial universe. CUWF makes this move unnecessary as a foundational explanation. The thermodynamic arrow does not require a globally privileged beginning in order to exist. It requires only collapse directionality, entropic asymmetry, and record accumulation.

Local collapse events generate local arrows. These arrows align statistically through interaction, coupling, and the propagation of constraint across scales. A coherent macroscopic thermodynamic arrow can therefore emerge without appealing to a cosmological miracle as the sole explanation of directionality.

Entropy gradients appear because history accumulates. They do not need to be imposed once and for all from a uniquely fine-tuned beginning. In this sense, the thermodynamic arrow is emergent, local, and structural rather than globally imposed by fiat.

The conclusion is not that cosmology becomes irrelevant, but that thermodynamic directionality should not be made to depend entirely on cosmological boundary conditions. Thermodynamics reflects the logic of realized history once time-first assumptions have been removed.

## Structural Resolution

The thermodynamic arrow can therefore be restated succinctly. Entropy increase is a consequence of realized history. Macrostates encode constraint accumulation. Classical reversibility paradoxes fail because history changes the effective domain of accessibility. No low-entropy-universe assumption is required as the ultimate source of thermodynamic direction. Thermodynamics does not contradict the CUWF account of the arrow. Once time-first assumptions are removed, it strongly supports it.