# The Thermal Time Hypothesis

Time from State, not Background: A Minimal Note

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**Context: Why "time" is suspicious.** In generally covariant physics there is no preferred external time parameter. Yet we observe directed behaviour: equilibration, ageing, decay. The Thermal Time Hypothesis (TTH) proposes that the parameter we call time is emergent from the statistical state itself.

**The Proposal.** Given a system and a reference state, the state determines a preferred one-parameter flow on the algebra of observables. That flow is the system's **thermal time**. Ordinary clock time is the special case where the state is thermal with respect to a Hamiltonian and a background time already exists.

**Core statement (minimal form):**
A faithful equilibrium state selects a unique modular flow on observables. Interpret that flow as physical time.

## 1. What it says

TTH is a statement about **state-defined dynamics**. You do not start with an external parameter and then define evolution. You start with a state (your information about the system) and ask what intrinsic canonical flow that state defines.

In operator-algebra language, the state determines a modular automorphism group. In physics language, the state picks the transformations that preserve its equilibrium structure, and those transformations define the "ticks" of thermal time.

## 2. Recovering ordinary time

If the state is Gibbs for some Hamiltonian, the modular flow coincides with Hamiltonian time evolution, up to a constant rescaling. The nontrivial content is the opposite direction: even when no background time is preferred, a state can still pick a preferred flow. Time is therefore **relational**: it belongs to the pair (system, state).

## 3. Operational reading

An observer only accesses a coarse-grained algebra. Their state assignment is effectively thermal on that algebra, and the induced modular flow is their natural "clock". Different coarse-grainings can, in principle, imply different thermal times.

## 4. Quantum gravity relevance

The Hamiltonian constraint removes external time from the fundamental description. TTH restores dynamics by choosing a physically motivated state, then using its modular flow as the clock. The "problem of time" becomes: which states define useful flows for the observables you care about.

## 5. UIH viewpoint

UIH treats both relaxation and coherent motion as geometry: $K = G + J$ defines dissipative and reversible flows, and characteristic timescales arise intrinsically. TTH is the equilibrium counterpart: **the state picks the clock**. In both, experienced time is the parameter of a canonical, state-selected flow.

## 6. What to compute

To make TTH concrete, specify (i) the accessible algebra (coarse-graining), (ii) the reference state (equilibrium or steady state), and (iii) the induced modular flow and whether it matches effective dynamics. If two coarse-grainings give different flows, "time" is observer-dependent; if the modular flow reduces to Hamiltonian time in a suitable limit, ordinary physics is recovered.