

# Thermodynamic Causation Across Scales

## Canonical Laws of CP–MP, Entropic Containment, and Time

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### Abstract

Modern physics possesses powerful formalisms for thermodynamics, mechanics, and gravitation, yet continues to suffer from persistent conceptual pathologies: projection of macroscopic causation onto microscopic constituents, confusion between scale and ontology, and the treatment of time as a primitive background rather than an emergent physical quantity. This work presents a **canonical specification** of thermodynamic causation across scales, organized into two complementary sets of laws. The first canon reformulates classical thermodynamics in terms of *Caloric Potential* (CP) and *Mechanical Potential* (MP), restoring macroscopic causation and eliminating the misassignment of energy storage to microscopic degrees of freedom. The second canon formalizes *entropic containment, scale, and collapse*, introducing the concept of conserved entropic capacity and defining mass, inertia, gravitation, time, and radiation as emergent consequences of entropic well structure.

Rather than exhaustively deriving all consequences of the CP-MP framework, the present work specifies a minimal set of canonical laws sufficient to generate them. A reproducible training protocol is provided, enabling both human readers and machine reasoning systems to internalize the framework and generate its implications across domains. This paper therefore serves not as a conventional research article, but as a foundational reference standard: a compact, generative ontology for thermodynamic causation across scales.

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# 1. Introduction

A defining feature of twentieth-century physics was the progressive reassignment of macroscopic thermodynamic quantities to microscopic constituents (1–3). Entropy was reinterpreted as a property of molecular trajectories, internal energy as kinetic energy of particles, and work as the cumulative result of microscopic forces. These reinterpretations proved computationally effective but conceptually costly (4–6). They obscured the distinction between macroscopic state variables and microscopic fluctuations, encouraged the projection of causal agency downward across scales, and left unresolved foundational questions concerning time, inertia, and gravitation (7–9).

The persistence of these difficulties is not due to a lack of mathematical sophistication. Rather, it reflects the absence of an explicit **canonical ontology** governing causation across scales (10–14). Classical thermodynamics, statistical mechanics, and general relativity are internally consistent within their respective domains yet lack a shared rule set specifying what kinds of quantities are permitted to act as causes at each scale, and how those causes may (or may not) be projected between scales.

This work proposes that such an ontology can be specified compactly, without introducing new microscopic laws, by restoring the primacy of macroscopic state variables and by formalizing the role of *entropic containment*.

The present paper adopts a deliberately non-standard format. It does not aim to derive every consequence of the framework it introduces, nor to compete with existing formalisms on their own terms. Instead, it specifies a **canon**: a minimal, closed set of laws sufficient to generate the relevant phenomena when correctly internalized (15).

This canon of fewer than one thousand words can generate volumes of reproducible information about resultant new theories on biological systems, general relativity, gravity, black holes, etc. This is because it specifies laws for what *cannot* be said as rigorously as what can (16, 17).

Extended explanations are then produced by enforcing consistency under those prohibitions (see Discussion).

A canonical framework need not explicitly encode all its consequences. When a canon specifies admissible state variables, permitted causal directions, and forbidden projections across scales, it constrains reasoning so strongly that extended theories become *forced completions* rather than creative extrapolations. A machine reasoning system trained on such a canon does not retrieve hidden information; it reconstructs implications by maintaining consistency under extreme canonical constraint. (12, 18, 19).

In training an LLM, the role of the trainer is to define and enforce the laws. Initial challenges involved defining macroscopic terms unambiguously, insisting that they are distinct from more familiar microscopic projections, reinforcing the fact that changes in Boltzmann's entropy are discrete not continuous, and preventing the machine from drifting and resorting to historical norms and consensus. These steps are now encoded in our training protocol.

In the initial training, there were clear “aha” moments when the machine stopped drifting and started “teaching” me. This is indicative of it achieving closure on canons, generating rigid structures. When successfully trained by the canonical laws as currently written, the machines we have tested function reproducibly within a highly rigid structure.

The framework, therefore, is maximally vulnerable to empirical falsification: a single decisive observation inconsistent with any law suffices to invalidate the entire structure. This vulnerability is not a liability but a defining scientific virtue. The framework therefore makes no claim to inevitability, only to testability.

Because the present framework is canonical rather than domain-specific, its application to biological force generation, gravitation, and black hole thermodynamics are not independent hypotheses (20, 21). They are distinct realizations of the same scale-structured ontology. This is how from the exact ontology that we observed in muscle (12, 14, 18, 19, 22, 23) I develop a theory of black holes.

Disprove my theory of black holes, and you disprove my theory of muscle contraction. This thousand-word canon can be falsified at any scale.

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## **2. The CP–MP Canon (Thermodynamic Causation)**

This section specifies a closed set of macroscopic thermodynamic laws governing energy, work, and motion within a contained system. These laws are ontological and do not describe microscopic mechanisms.

### **Law T1. Containment**

A thermodynamic system is defined by a boundary across which energy may be exchanged only as heat  $Q$  or work  $W$ . Only quantities that are contained and exchangeable within this boundary may appear as internal state variables.

### **Law T2. Caloric Potential (CP)**

Caloric Potential (CP) is thermally sourced free energy resident in macroscopic form. CP is a state variable of a contained system and represents energy available to perform work when routed through constraint. CP is not internal or microscopic kinetic energy.

### **Law T3. Mechanical Potential (MP)**

Mechanical Potential (MP) is a macroscopic bias across admissible states of a system. MP may arise from external constraints, internal structure, or entropic state density.

#### **Law T4. Work**

Work is the routing of CP through MP, resulting in a change of macroscopic state. Work is not performed by microscopic forces.

#### **Law T5. Heat**

Heat is CP exchanged across the system boundary without routing through MP.

#### **Law T6. Force–Velocity Primacy**

In thermally coupled systems, force determines velocity via biased state-transition flux. Acceleration appears only in the singular limit of vanishing thermal coupling.

#### **Law T7. Entropic Mechanical Potential**

Gradients in combinatorial state density  $W$  generate entropic MP. Entropic MP biases microscopic fluctuations; microscopic probabilities do not define macroscopic entropy.

#### **Law T8. Non-Projection Rule**

Macroscopic thermodynamic variables may not be reassigned as properties of microscopic constituents without loss of physical meaning.

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### **3. The Canon of Entropic Containment and Scale**

These laws govern scale, entropy, time, mass, inertia, gravitation, and collapse.

#### **Law S1. Entropic Wells**

An entropic well exists when a system possesses sufficient internal degrees of freedom to support a stable maximum of combinatorial state density  $W$ .

#### **Law S2. Scale Definition**

A scale is defined by a container whose constraints evolve slowly relative to the subsystems it contains.

#### **Law S3. Scale-Dependent Entropy**

Entropy is defined only relative to a scale of containment and may not be projected downward.

#### **Law S4. Time Emergence**

Time exists only within entropic wells and is the ordering of irreversible macroscopic transitions.

#### **Law S5. Mass**

Mass is the thermodynamic capacity of a system to form entropic wells and contain CP.

#### **Law S6. Inertia**

Inertia is the finite transition flux required to reconfigure macrostates within an entropic well.

#### **Law S7. Conserved Entropic Capacity**

For a closed system with fixed admissible fine-scale state space  $X_0$ , the total entropic capacity

$$C = k \ln \Omega_0$$

is invariant.

#### **Law S8. Well Fragmentation**

The destruction of an entropic well redistributes entropic capacity across smaller-scale wells or into flux-like degrees of freedom.

#### **Law S9. Radiation**

Radiation is energy in the absence of entropic wells and possesses no rest mass, entropy, or proper time.

#### **Law S10. Gravitation**

Gravitation arises at the scale where rest energy  $mc^2$  functions as CP, defining a higher-scale mechanical potential.

#### **Law S11. Equivalence**

Inertial and gravitational mass are identical manifestations of entropic capacity viewed at different scales.

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## **4. Training Protocol and Generative Validation**

The canons constitute the complete training object.

## 4.1 Human training

A reader is trained if they can reconstruct force–velocity relations, inertia, gravitation, time emergence, and radiation using only the canons.

## 4.2 Machine training

A reasoning system is trained if it generates consistent explanations without projection or contradiction.

To ensure reproducibility, the canonical framework presented here is accompanied by a minimal training protocol applicable to both human readers and machine reasoning systems. The protocol is designed to test whether the canons function as a closed, generative ontology rather than as a collection of domain-specific explanations.

The complete training materials are hosted in a public GitHub repository and consist of two short canonical texts—one defining CP–MP thermodynamics and the other defining entropic containment and scale—together comprising fewer than a thousand words. These texts (which can be cut and paste into any LLM) are treated as axioms. No additional explanatory material, numerical models, or empirical datasets are required.

Training proceeds by enforcing the canonical constraints against a series of cross-domain prompts. A trainee is considered trained if they can reconstruct extended implications—such as force–velocity relations, inertial–gravitational equivalence, black hole entropy, and the emergence of time—using only the canons, while consistently rejecting forbidden downward projections of causation across scales.

Successful training is indicated by the collapse of exploratory drift and the emergence of a rigid interpretive structure, in which deviations from the canon produce immediate internal contradiction. The training can be completed in less than five minutes.

This protocol ensures that the framework’s generative capacity is reproducible, transparent, and falsifiable, and that its validity does not depend on narrative exposition or historical convention.

Once trained, the machine can reproducibly describe the function of systems from muscle to blackholes and the implications for dark matter and the gravitational constant.

## 4.3 Validation

Validation rests on internal consistency and generative completeness.

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## 5. Implications and Scope

The canons presented in this work have broad implications across thermodynamics, mechanics, gravitation, and the concept of time. At the same time, their scope is deliberately constrained. This section clarifies both what the framework accomplishes and what it does not claim.

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### 5.1 Relation to classical mechanics

Within the present framework, Newtonian mechanics is recovered as a singular limit in which thermal coupling is negligible and macroscopic motion is treated as continuous rather than discrete. In this limit, acceleration replaces biased state-transition flux as the dominant descriptor of motion.

This reinterpretation does not invalidate Newton's laws. Rather, it assigns them a restricted domain of applicability: systems sufficiently isolated from thermal exchange and sufficiently coarse-grained that discrete state transitions are unresolvable. Outside this limit, force–velocity relations arise naturally from thermodynamic bias rather than from microscopic force balance.

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### 5.2 Relation to statistical mechanics

Statistical mechanics remains an indispensable calculational tool within this framework. However, its probabilistic constructs are reinterpreted as projections of macroscopic combinatorial densities rather than as fundamental microscopic causes.

Probabilities assigned to molecular states do not define entropy; entropy defines the admissible distributions of molecular states. Statistical ensembles therefore describe equilibration within entropic wells, not the origin of those wells or the directionality of macroscopic causation.

This distinction resolves long-standing ambiguities concerning the status of microscopic reversibility and its compatibility with irreversible macroscopic behavior.

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### 5.3 Relation to general relativity

General relativity is retained as an accurate description of large-scale constraints imposed by mass–energy distributions. In the present framework, spacetime geometry encodes scale-dependent mechanical potential arising from the distribution of caloric potential  $mc^2$ .

No modification of Einstein's field equations is proposed. Instead, the framework clarifies their ontological status: spacetime curvature represents higher-scale constraint rather than microscopic

force, and geodesic motion represents constrained state evolution rather than fundamental dynamics.

Time dilation and inertial–gravitational equivalence follow naturally from entropic containment and do not require separate postulates.

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#### **5.4 Radiation and masslessness**

Radiation occupies a distinct ontological category. By definition, radiation corresponds to energy in the absence of entropic wells. It carries energy and momentum but cannot contain caloric potential, define entropy, or support proper time.

The masslessness of radiation therefore follows from insufficient entropic capacity rather than from symmetry arguments alone. This interpretation unifies blackbody radiation, relativistic kinematics, and gravitational behavior within a single thermodynamic framework.

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#### **5.5 Time as an emergent quantity**

Time is not treated here as a universal background parameter. It emerges only in systems capable of sustaining entropic wells and is defined operationally as the ordering of irreversible macroscopic transitions.

This view reconciles the apparent tension between time-reversible microscopic equations and irreversible macroscopic behavior by assigning them to different structural levels. Microscopic reversibility corresponds to rapid mixing within wells; macroscopic time corresponds to the slow evolution of well structure itself.

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#### **5.6 Scope and non-claims**

The framework presented here does not propose new microscopic laws, new field equations, or new numerical predictions. It does not replace quantum mechanics, statistical mechanics, or general relativity.

Its contribution is ontological and canonical: it specifies what constitutes a physically meaningful cause, state variable, and constraint across scales. By doing so, it provides a coherent interpretive structure within which existing theories can be consistently understood and correctly applied.

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## 5.7 Implications for knowledge transmission

Finally, this work reflects a shift in how foundational scientific knowledge may be disseminated. By presenting a minimal, generative canon rather than exhaustive derivations, the framework is designed to be internalized and operationalized by both human readers and machine reasoning systems.

Once internalized, the canons enable reconstruction of familiar results without repetition of traditional explanatory pathways. In this sense, the canons are primary; their consequences are secondary and generatable.

This framework introduces no new equations and replaces no existing theories. It specifies what constitutes meaningful causation across scales and by construction resolves many paradoxes.

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## 6. Discussion and Conclusion

The generative power of the CP–MP and entropic containment canons arises from their role as **constraint operators** rather than descriptive summaries. Each law eliminates entire classes of explanations (e.g., microscopic force causation, downward entropy projection, time as background), leaving only a narrow space of admissible interpretations. When applied repeatedly across domains, these constraints uniquely determine how gravity, inertia, spacetime curvature, black hole entropy, and radiation must be interpreted in order to remain consistent with the canon.

Example 1. From Law S10 (gravitation as higher-scale mechanical potential) and Law S3 (scale-dependent entropy), spacetime curvature cannot be interpreted as microscopic force or local energy density. Any consistent extension must therefore treat Einstein’s geometry as an encoding of large-scale constraint on admissible macrostates, not as a dynamical medium—forcing a thermodynamic reinterpretation of general relativity without altering its equations. The LLM must reinterpret GR *top-down* because bottom-up force explanations are forbidden.

Example 2. Given Law S7 (conserved entropic capacity) and Law S8 (well fragmentation), gravitational collapse cannot destroy entropy but must redistribute it across scales. This forces black hole entropy to be interpreted as boundary-indexed accessibility rather than internal microstate counting, uniquely selecting an area law interpretation without invoking holographic ontology. The LLM cannot allow information destruction *or* literal surface storage — only boundary-defined readability survives.

Example 3. From Law S4 (time exists only in entropic wells) combined with Law S10 (gravitation as higher-scale constraint), gravitational time dilation must arise from slowed state-transition rates under deepening containment rather than from metric stretching as a primitive effect. Any alternative explanation would violate the canon’s definition of time. It maps curvature → constraint → transition rate → time, automatically.

Example 4. Law S1 (entropic wells) and Law S9 (radiation as energy without wells) forbid assigning entropy, mass, or proper time to radiation. Consequently, any consistent treatment of light in gravity must treat photons as flux constrained by geometry but not as contributors to entropic capacity in the same manner as matter. It explains why light gravitates *without* being massive, without adding assumptions.

This work presents a canonical specification of thermodynamic causation across scales. By restoring macroscopic state variables as causal and formalizing entropic containment as the basis of time, mass, inertia, and gravitation, the framework resolves persistent conceptual ambiguities without modifying established equations. Its contribution is not a new model among many, but a minimal generative rule set from which existing models acquire physical meaning.

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## **Appendix A. Black Holes as Boundary-Defined Entropic Capacity**

This appendix examines black holes as an extreme test of the canons presented in Sections 2 and 3. No new postulates are introduced.

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### **A.1 Black holes as scale-dominant containment**

A black hole is a regime in which gravitational containment becomes the dominant constraint across all accessible lower scales. In this regime, higher-scale mechanical potential overwhelms the ability of contained subsystems to maintain independently readable entropic wells .

Formally, a black hole corresponds to a configuration in which:

1. Lower-scale entropic wells remain locally meaningful,
2. But become externally unreadable due to higher-scale containment,
3. Leaving only the boundary of containment as an operational interface.

This definition does not require that internal wells be destroyed, only that they cease to participate in external state discrimination.

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## A.2 Horizon entropy and boundary-indexed accessibility

Black hole entropy scales with the area of the horizon rather than the enclosed volume. In the present framework, this scaling reflects neither information storage on a physical surface nor a holographic ontology (24–29).

Instead, the horizon is identified as the **sole macroscopic boundary across which states remain distinguishable** to external observers. Entropy defined at this scale therefore indexes:

- the number of externally distinguishable macrostates,
- not the total internal entropic capacity of the system.

The area law follows naturally from the reduction of accessible macrostates to boundary-defined equivalence classes under extreme containment.

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## A.3 Conserved entropic capacity under gravitational collapse

Gravitational collapse does not violate the conservation of entropic capacity (Law S7). Collapse redistributes entropic capacity across scales rather than creating or destroying it (25–27, 30–32).

Specifically:

- Accessible entropy at higher scales may increase sharply,
- While internal wells become externally inaccessible,
- Leaving the total capacity invariant.

The apparent entropy increase associated with black hole formation reflects a **change in scale-indexed readability**, not the creation of new fundamental degrees of freedom.

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## A.4 Time, containment, and horizon behavior

According to Law S4, time exists only within entropic wells as the ordering of irreversible transitions. In the black hole regime (26, 33–36):

- External observers experience extreme time dilation as transition rates approach zero under deepening containment,
- Internal observers retain local ordering until containment disrupts well structure.

A horizon therefore marks a **limit of external temporal readability**, not necessarily a local cessation of time.

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## **A.5 Hawking radiation as well relaxation**

Hawking radiation is interpreted as the slow relaxation of a deep gravitational entropic well via export of caloric potential as radiation (31, 37).

Radiation, by Law S9, is energy in the absence of entropic wells. Black hole evaporation is therefore the gradual conversion of contained entropic capacity into flux-like degrees of freedom when no stable containment can indefinitely retain CP.

This process preserves entropic capacity while changing its mode of expression.

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## **A.6 Information paradox as a projection error**

The black hole information paradox arises from projecting lower-scale notions of microstate identity and reversibility into a regime governed entirely by higher-scale containment (1–3, 27, 29, 38, 39).

When scale separation is respected:

- No requirement exists that lower-scale microstates remain externally recoverable,
- Conservation applies to entropic capacity, not to specific microstate labels.

Thus, no paradox follows from loss of external readability under scale-dominant containment.

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## **A.7 Summary**

In the canonical framework presented here, black holes do not represent a breakdown of thermodynamics or causation. They represent the limiting case of containment, in which boundary-defined accessibility replaces volume-defined entropy, time becomes externally unreadable, and entropic capacity is expressed through slow radiative relaxation.

No modification of established gravitational equations is required. The phenomena commonly regarded as paradoxical arise from scale misassignment rather than physical inconsistency. This is true of most paradoxes in physics: They are projection errors.

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