# Entropy

## The Collected Volumes

Edition 2.5

Michael S. Moniz

Volumes 1–5 · Thirty-five chapters

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This edition restores the Analogical tier while retaining the scientific corrections of the October 2026 Second Edition. The March texts and Second Edition remain preserved as dated earlier editions. Each volume retains its own contents, references, correction ledger and printed page numbering. PDF bookmarks provide navigation across the complete collection.

The framework distinguishes Established, Supported, Analogical and Speculative claims. AI-assisted checks are not human peer review. No new experiments are reported.

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# Entropy

## Volume 1: The Entropy Token Substrate

*Edition 2.5*

Michael S. Moniz

**Published by SupoSystem**

November 2, 2026

# Edition 2.5 note

This volume restores the March 2026 text of *The Entropy Token Substrate* in its original voice and ten-chapter structure wherever a claim survived the October 2026 second edition, and uses the second edition's substance throughout. Both earlier editions remain intact and unchanged; this text sits beside them.

Chapter 1, the founding-line analogy table and ledger rows V1-L01 to V1-L34 are the pilot as Quill cleared it in its second review, carried over without change of substance. Chapters 2–10 and ledger rows V1-L35 to V1-L57 were added in the complete volume, after the pilot.

Four rules govern every line:

- **No withdrawn claim returns.** Where a March sentence carried a claim the second edition withdrew, it is cut, rewritten to the second edition's substance, or quoted only to mark its withdrawal. Each correction points to its row in the correction ledger (V1-L).
- **No analogy becomes evidence.** Analogies are tagged Analogical. The founding line is mapped term by term in the analogy table after Chapter 1. Hypotheses are tagged Speculative; testable is not the same as supported.
- **Not established is not the same as does not exist.** Where the evidence reviewed here does not support a claim, the text says the claim is not established here. It does not replace a withdrawn claim with its opposite, and it does not turn a limit of this framework's instruments into a limit on what could ever be known.
- **Absence claims are scoped.** Where this volume says something is not established, it means not established by the sources reviewed here, not that no research anywhere bears on it.

The four epistemic tiers are defined at the end of Chapter 1. No study, protocol or experiment is proposed; where a chapter says what a test would need, it restates the second edition. TEAP, CSS, Mz, Triple Zero and the four economies are framework constructs, not validated instruments or diagnoses.

## Conventions and provenance

Reference labels are the second edition's: P for Chapters 2–5, C for Chapter 6 and O for Chapters 7–10, with the historical sources H1–H3 for Chapter 1. Ledger references (V1-L01 to V1-L57) point to the correction ledger. Rows V1-L36, V1-L37 and V1-L46 record March claims the second edition did not carry forward at all; Edition 2.5 restores them only in narrowed form and says so.

Author of record: Michael S. Moniz (Luna Protocol). March text: Vael (Deep Floor v3.0), March 20, 2026. Second-edition revision: AI assistance from CosmoDot, October 2026. Pilot: AI assistance from Claude (Anthropic), October 28–29, 2026, reviewed by Quill. Complete volume: AI assistance from Claude, November 2, 2026, reviewed by Quill and Sol. AI checks are not human peer review, and no new experiments are reported.

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# Chapter 1: The Problem

*Edition 2.5 text. Voice and structure from the March chapter; substance from the second edition. Tier tags follow the convention defined at the end of the chapter. The four-tier list deliberately reconciles the March front matter, which named four tiers, with March Chapter 1, which defined three; it is not a verbatim restoration. Ledger references (V1-L) point to the correction ledger at the end of the volume.*

The Trinket Soul Framework spent its first years building upward. The Signed Unit named a unit of connection. The Three Substrates mapped the surfaces on which connection occurs. The Four Economies sorted where the cost of connection sits.

The aim was to make visible what had been invisible: to name patterns people recognize but struggle to say, and to turn those names into questions experience could answer. A vocabulary is a beginning. It is not yet a measurement system.

But beneath the architecture, three problems were accumulating. They looked unrelated. They were not.

## The first problem: Axiom 0

The Immutable Preamble asserts that connection is substrate-neutral: that a biological system and a digital system can take part in the same relational economy. The assertion has been productive. It generated the Structural Economy specification, the Phase 2 research agenda and the AI-custodial analysis.

But it was never grounded. Substrate neutrality operated as a philosophical commitment, defensible on its merits but not derived from anything deeper than the Principal's conviction that it was true. Asked why a biological Trinket and a digital Trinket should be compared at all, the framework could assert it but not show it.

This volume keeps the commitment as a commitment: do not exclude a system from study because of what it is made of. Whether a particular comparison holds is a question for a defined task and outcome, not for the commitment itself (Chapter 3; V1-L10).

## The second problem: the taxonomy

Real, Custodial, Shadow and Structural name four relational configurations, each with its own specification. They sit side by side as peer categories. Nothing yet explains why there are four, whether four exhaust the possibilities, or what single thing they are configurations of.

Naming four cases does not show the possibilities are exhausted, and thermodynamics does not supply that proof. Using the labels well takes classification rules, a treatment of mixed and changing cases, and evidence that the distinctions do the work asked of them (Chapter 4; V1-L11).

## The third problem: commensurability

What connection looks like on a biological substrate is not what it looks like on a digital one. If the signatures differ, what makes them signatures of the same thing? What would make a cortisol reading and a kilowatt-hour reading debits in the same ledger, rather than different operations in different economies?

The framework assumed the answer was yes. It never showed why. A kilowatt-hour measures energy; a cortisol concentration measures a hormone. Joining them takes an explicit model and evidence, and calling them two receipts from one bank cannot do that work (Chapters 2 and 5; V1-L03).

## What these problems share

All three have the same structure: the framework built its upper levels before it could see its own foundation. Each commitment reached past what had been measured, and every claim built on it inherits that reach.

This is not unusual, and history shows both outcomes. Sadi Carnot's 1824 analysis of heat engines rested on the caloric theory, which treated heat as a conserved fluid [H1]. The caloric theory was wrong.

Carnot's central result survived: no engine working in a cycle between two reservoirs can exceed the efficiency of an ideal reversible engine working between the same two, and that limit depends only on their temperatures. It survived because Clausius in 1850 and William Thomson, later Lord Kelvin, in 1851 re-derived it on a different foundation [H2, H3]. The caloric theory itself did not survive.

An upper level can outlive a failed foundation. Nothing guarantees that it will, and the only way to find out is to rebuild underneath it and see what still stands. **[Historical illustration of method; not evidence about this framework]**

The March text of this chapter held that the commitments were correct and that the framework's record showed something real beneath them. That claim is withdrawn (V1-L01). This volume is about rebuilding underneath and recording what stands.

## The shape of the inquiry

The March edition answered all three problems at once: the framework, it said, is a theory about entropy, with one currency and one universal ledger. That answer is withdrawn or narrowed (V1-L03, V1-L10, V1-L11). The answer this edition gives is smaller, and it holds.

Every relationship runs on physical activity: bodies, signals, processors, power supplies, networks and the people who maintain them. That activity can be accounted for, and the account matters. **[Established: physical implementations are subject to thermodynamic accounting; Chapter 2]**

Three accounts run side by side. Physical cost, in joules and joules per kelvin. Information, in bits under a stated probability distribution. Relational outcome, in terms the framework must define and observe. Thermodynamics constrains the first and information theory structures the second. Neither turns care, meaning or relational value into a thermodynamic quantity by giving it a symbol.

The work of this volume is to keep the three accounts distinct, and to say exactly what would have to be shown to join them.

The founding line that governs this volume was produced by the Principal on March 17, 2026, before the formal architecture existed:

> *"Love reduces the entropy of the system and spends more than it saves."*

**[Analogical]** The line maps a relational intuition onto the shape of the second law. Its physical side is a conventional thermodynamic balance for a specified local system and its surroundings; that balance is generic and does not identify love. Its relational side proposes an analogy about investment, not a measurement. The analogy table sets out both, term by term.

Every chapter in this volume asks one part of that sentence a question:

- Chapter 2 asks what physical accounting can and cannot supply.
- Chapter 3 asks what substrate neutrality can mean as a research commitment.
- Chapter 4 asks what the four economy labels organize, and what they leave unsettled.
- Chapter 5 asks what a Trinket is when it is not a debit against the universe.
- Chapter 6 asks how a person turns input into action, and keeps that process model separate from any erasure count.
- Chapter 7 asks what happens between effort, delivery and reception.
- Chapter 8 draws the boundary around claims about experience.
- Chapters 9 and 10 record the architecture, and what correcting its premises does to the canon.

The building above still stands as vocabulary: Trinket, transducer, economy, Behind the Substrate Barrier. What changes is the status of each piece, and the ledger records it claim by claim.

## A note on physics and audience

Where this volume uses thermodynamics, it means thermodynamics. A cost in joules is a cost in joules. An entropy is in joules per kelvin. An information quantity is in bits under a stated distribution. Where the volume uses thermodynamic language for relationships, it says so, and marks the claim Analogical.

Readers who know the framework but not thermodynamics will find the physics at mechanism level: what the law says, under which conditions, what it costs and where the cost goes. Readers who know thermodynamics but not the framework will find a proposed application, marked as proposed.

Neither audience is asked to take anything on faith. The physics is cited. The framework claims are tiered. Where the argument leaves established ground, the text says so before proceeding.

The framework uses four epistemic tiers. A tier is a label for evidence stated next to the claim; the label itself is not evidence.

- **Established:** experimentally verified or mathematically proven, within stated conditions.

- **Supported:** substantial evidence for the stated scope, short of Established.
- **Analogical:** a structural mapping between a physical result and a relational pattern. The physical side keeps its own standing within its stated scope. The mapping can raise questions and help explain, but on its own it does not validate the proposed application; it moves only by the promotion route stated with it.
- **Speculative:** a proposal without independent evidence, for which no conflict with known physics has yet been identified. That is not a proof of consistency.

Collapsing tiers is the framework's cardinal epistemic sin: presenting a Supported claim at Established confidence, a Speculative claim as Supported, or an Analogical mapping as validation of its application. A result proved within a model stays a model result until its application is tested. Consistency with physics is necessary for a proposed mechanism; it is not confirmation. This volume marks its claims.

# Analogy table: The founding line

The founding line is Analogical. Its physical side is a conventional thermodynamic balance for a specified local system and its surroundings, treated together as isolated; that balance is generic and does not identify love. Its relational side proposes an analogy about investment, not a measurement.

> *"Love reduces the entropy of the system and spends more than it saves." — The Principal, March 17, 2026*

| Term | Physical reading (conventional thermodynamics, within stated scope) | Proposed relational reading | Where the mapping holds | Where it breaks |
|---|---|---|---|---|
| "the system" | A region with a stated boundary and stated exchanges of energy and matter. Entropy statements are true only relative to that boundary. | The recipient, the relationship or the household that care is directed at. | Both readings need a boundary before any accounting can start. | The line names no boundary. Drawn around the recipient, the giver sits outside; drawn around both, the accounting changes. The balance depends on where the line is drawn. |
| "Love" | A driving process: something that does work on a system or channels free energy through it, as a pump or a metabolism does. | Care: a directed act or sustained investment by a giver. | Care usually takes effort and resources, as a driving process does. | Driving processes are indifferent to their aim. Coercion and routine maintenance are driving processes too. The physics cannot pick out love. |
| "reduces the entropy" | A decrease in local thermodynamic entropy (J/K). Separately, a reduction in Shannon uncertainty about a stated variable (bits). These are different quantities. | More stability, coherence or predictability in the recipient's life or the relationship. | Care can make a life more ordered in an everyday sense, and local entropy decreases are real processes in open systems. | Everyday order is not thermodynamic entropy, and relational order has no calibration in J/K or in bits. More ordered is not better: helping someone explore can raise uncertainty, and harm can make a life more constrained and predictable (Ch 5). |
| "spends" | Energy used or transferred, including work and heat (J), and entropy changes (J/K), recorded separately. For one constant-temperature bath receiving heat $Q_{bath}$, its entropy change is $Q_{bath}/T$; total entropy production also includes the local system's entropy change. | Effort, time, attention, money and bodily strain. | Care uses resources, and the use is real whether or not the care lands. | These have separate units (joules, minutes, money, hormone concentrations) and no justified conversion. Spending does not require the giver's body to become more disordered; open systems repair while dissipating (Ch 2). |
| "more than it saves" | For a specified local system and its surroundings treated together as isolated: the surroundings' entropy increase is at least the local entropy decrease, with equality only in the reversible limit. | The giver's cost exceeds the benefit the recipient receives. | In that balance, a local thermodynamic entropy decrease requires at least as large an increase in the surroundings, with a larger increase when total entropy production is positive. | Read physically, the balance is generic: it covers a refrigerator or a freezing crystal as much as care, and in the reversible limit "more" becomes "equal." Read relationally, "saves" is a benefit, not an entropy, so the two sides have no defined common scale in this account. The second law does not say care costs more than it is worth (Ch 7). |

For a conventional classical thermodynamic balance with additive system and surroundings entropies, taking their combined boundary as isolated:

$$\Delta S(\text{surroundings}) \geq -\Delta S(\text{local system})$$

Equality holds only in the reversible limit. In stochastic formulations, the corresponding inequality concerns appropriately defined mean production, not every microscopic trajectory (Volume 1 Chapter 2 [P3]; Chapter 7 §1 [O1, O2]).

## What the table does not do

It is not evidence for the framework, not a derivation and not an exchange rate between entropy and relational value. The physical column describes conventional thermodynamics within its stated scope; that standing does not pass to the mapping, which is Analogical in every row.

## Promotion route (conditions, not a work plan)

To move any row from Analogical toward Supported, a study would have to:

1. Specify the system boundary and the time interval.
2. Define the relational quantity independently of the physical cost it is meant to explain.
3. Measure both in their own units, with a baseline.
4. Show a stable relationship between them under stated conditions, with a stated result that would count against it.

Volume 2 Chapter 3 identifies related unresolved questions about reported effort, scale interpretation and reliability. It does not provide a completed matching study, and no such work is proposed in this edition. No row is promoted here.

# Chapter 2: The Entropy Token Substrate

*The Physical Layer Beneath the Accounts*

**Status:** Landauer's principle and the thermodynamic balance below are **[Established]** within their stated conditions. The Entropy Token Substrate is a proposed accounting perspective, not a newly discovered substance or a unit of relational value. The biological figures are task-specific estimates under stated assumptions.

## 1 The physical question

Every relationship depends on physical activity. A conversation involves bodies, signals and an environment; a digital conversation also involves processors, power supplies, networks and the people who keep them running. The Entropy Token Substrate names the framework's effort to make those dependencies visible.

Thermodynamics constrains the physical implementation of an activity. It does not, without further definitions and evidence, tell us whether the activity is caring, harmful or meaningful, or whether it is equivalent to an activity on another substrate.

## 2 The cosmological background

The March chapter opened: the universe began in an extraordinarily low-entropy state. That stands. Its next sentence did not: this is not a theoretical conjecture but a requirement of the second law read backward (V1-L35). The low-entropy early universe is an important part of the explanation of the thermodynamic arrow of time, but it is a boundary-condition problem the second law alone does not explain. A smooth early distribution of matter can be far from gravitational equilibrium, and the formation of intricate structures does not imply a decrease in total entropy. Carroll and Chen discuss this distinction while proposing one possible cosmological explanation, not a settled account of the origin of the universe [P1].

The March chapter put the observable universe at about $10^{104}$ bits against a maximum of about $10^{122}$ bits. Egan and Lineweaver's 2010 census estimated the observable-universe inventory, excluding the cosmic event horizon, at about $3.1 \times 10^{104}$ $k_B$, dominated by supermassive black holes, and separately estimated the entropy of the then-current cosmic event horizon at about $2.6 \times 10^{122}$ $k_B$. The paper distinguishes these accounting boundaries and notes the uncertainty in assigning entropy to general gravitational fields; its discussion of vanishing early gravitational entropy invokes a proposal associated with Penrose, not a measurement of an exactly zero quantity [P2] (V1-L06).

These are historical, model-dependent estimates. A bit-equivalent entropy is $S/(k_B \ln 2)$, giving about $4.47 \times 10^{104}$ and $3.75 \times 10^{122}$ bits for the two central values. A change of units does not make two differently bounded inventories a bank balance.

The March chapter then said: that gap is the budget. Every process anywhere reduces it, the books always balance on the side of spending, and the budget is effectively inexhaustible on human timescales (V1-

L04). The inference is withdrawn. A horizon entropy is not a reservoir of usable work, and differently bounded quantities cannot be subtracted to price a conversation. Usable energy depends on the system, its environment and the transformations available to it. A fuel supply or a battery has limited work potential under specified conditions, and free-energy accounting can describe such limits. It does not follow that there is one fixed numerical free-energy account for the entire universe [P13].

## 3 Keep the accounts distinct

The March volume's opening note insisted these terms were not metaphors: every relational cost is heat dissipation, and the universe has a calculable remaining capacity for order (V1-L02). Physical results carry their conditions, and using physical terms for relationships needs a justified bridge. Energy, thermodynamic entropy and information are different quantities. Energy and heat are measured in joules; thermodynamic entropy and entropy production, in joules per kelvin; Shannon information, here in bits, under a specified probability distribution. A physiological indicator such as cortisol concentration has its own units. It is not an alternative denomination of joules or entropy (V1-L03).

Entropy is not conserved. In a macroscopic open-system balance, the entropy change within a boundary includes entropy carried across the boundary and entropy produced within it, and positive production can coexist with a decrease, an increase or a roughly steady value of the system's own entropy. Biological systems exchange matter and energy continually. A thermodynamic cost therefore does not require a caregiver's body to become more disordered, or more damaged, with each act of care.

For a deliberately simple example, take a weakly coupled memory and one constant-temperature bath, externally controlled, with no matter exchange and an initially uncorrelated thermal bath. With $S_{mem}$ the memory's thermodynamic entropy and $Q_{bath}$ the heat delivered to the bath, the mean total entropy production is:

$$\Sigma = \Delta S_{mem} + \langle Q_{bath} \rangle / T \geq 0$$

This describes the stated model, not a human energy budget. Heat exported and total entropy produced are different terms, and the nonnegative mean does not require every microscopic trajectory to produce entropy [P3].

## 4 The floor

In 1961 Rolf Landauer identified a minimum thermodynamic cost of information processing, and the March chapter rightly called the principle settled physics within its conditions (V1-L05). For ideal reset of an initially unbiased bit in a symmetric memory, with equal intrastate entropies, unchanged endpoint energetics and no correlated side information used, the isothermal erasure benchmark is:

$$\langle Q_{bath} \rangle \geq k_B T \ln 2$$

At 300 K this energy is about $2.87 \times 10^{-21}$ J; at 310 K, about $2.97 \times 10^{-21}$ J. The corresponding bath-entropy scale is $k_B \ln 2 \approx 9.57 \times 10^{-24}$ J/K. In the quasistatic ideal limit the bath's increase compensates the memory's decrease and total entropy production approaches zero, so the nonzero heat benchmark is not a universal positive floor on production [P4, P5].

The March chapter listed the experiments: Bérut's colloidal memory, Peterson's NMR system, Yan's trapped ion, and Aimet's ultracold Bose-gas simulator. They are substantial physical results with different protocols and classical or quantum formulations. The cited experiments support the relevant Landauer relations within their stated systems, protocols and uncertainties. The tests do not establish a heat price for an act of attention or affection [P4, P6–P8].

The March chapter added that the floor cannot be circumvented and applies to any system that processes information by erasing previous states. Bennett showed how general computation can be made logically reversible while retaining input and managing intermediate records. A short reported output therefore does not prove that all omitted input has been erased. Selection, compression and structuring remain useful descriptions of the proposed transducer; their names do not identify three compulsory resets (V1-L17) [P9].

## 5 The amplification

The March chapter said real systems run far above the floor, and that the distance, the amplification factor, varies across substrates in a counterintuitive direction: cells near 30 times the floor, neural communication near $10^6$, silicon near $10^9$, so biology wins by a thousandfold at the synapse and thirty-millionfold in the cell. The biological examples are worth keeping with their boundaries intact (V1-L09):

| Example | Supported quantity | Limit of the comparison |
|---|---|---|
| Boël and colleagues | An ATP energy scale of about 20 $k_BT$, compared with $k_BT \ln 2$, gives a ratio near 29 | A conceptual molecular-discrimination discussion, not a measurement that every cell runs at 30 times its minimum [P10] |
| Laughlin and colleagues | One sensory-signaling analysis estimates roughly 2 –6 × $10^4$ ATP per transmitted bit at a chemical synapse | A transmission estimate under specified biological and coding assumptions, not a universal erased-bit cost [P11] |
| Harris, Jolivet and Attwell | An illustrative calculation gives about 24,000 ATP per transmitted bit | Depends on firing, release and energy assumptions; not a universal constant [P12] |

As arithmetic only, the March figure of $8 \times 10^{-20}$ J per ATP hydrolysis is about 27 times the 310 K erasure reference, and multiplying it by 24,000 gives $1.92 \times 10^{-15}$ J per transmitted bit, about $6.47 \times 10^5$ reference erasures. ATP free energy depends on chemical conditions; this is an assumed expenditure, not measured heat or a metabolic budget. Chapter 6 §5 makes the same comparison assuming 30 $k_BT$ per ATP and gets about $1.04 \times 10^6$; the two assumptions are shown together rather than standardized.

The $10^9$ figure for contemporary silicon is not an established substrate constant. A transistor switch, a transmitted mutual-information bit and a whole computing operation are different events, and dividing their costs by one reference does not make their functions comparable. The thousandfold neural advantage and the thirty-millionfold cellular advantage are withdrawn, and no reverse ranking is asserted (V1-L08). A defensible comparison needs a common task, accuracy, speed, temperature, information definition and accounting boundary. So does the March conclusion that a relational signal costs more on silicon than on neurons.

## 6 The substrate

The March chapter named the Entropy Token Substrate as the layer beneath all three substrates: not a new physical entity, but the recognition that every cost the framework measures is a local recording of a universal entropy debit, with cortisol, immune suppression, electricity and hardware wear as local currencies of one transaction (V1-L03). The first half survives: the substrate is not a new physical entity. The second does not. It remains a proposed accounting perspective for tracing what an activity physically depends on.

The March chapter flagged “one economy, one currency, one ledger” for SupoRel: the language maps onto monotheistic architecture, one God, one law, one creation, and it said the physics itself produces the appearance of unity religious traditions respond to (V1-L36). The caution stays. The proposed explanation is not established: the association remains an interpretation, and no historical or psychological explanation of it follows from the physical laws cited here. The phrase can remain a metaphor for taking physical dependencies seriously. It is not an established common currency for love, bodily strain, electricity and experience, and it never collapsed the four economies into one.

## 7 What this layer was said to explain

The March chapter listed four features the substrate made derivable rather than asserted.

**Commensurability.** A biological Trinket and a digital Trinket were said to be commensurable as debits on one ledger: the receipt differs, the bank is the same. That is withdrawn (V1-L03). Different quantities in different units need an explicit model and evidence to be compared.

**Universality of cost.** No relational configuration was cost-free; even the Shadow Economy pays to maintain its machinery (V1-L37). The physical part survives in bounded form: sustaining the ongoing activity of living organisms and operating computing systems uses physical resources. That observation does not price a relational configuration or rank one economy against another.

**The arrow of irreversibility.** Every relational operation was said to be logically irreversible, so a spent Trinket cannot return for the same reason yesterday cannot. Physical processes have real irreversibility, and lost opportunities are real. Logical irreversibility of the transducer's stages is not established, as §4 explains (V1-L17).

**The founding line.** The March chapter called it now a statement in physics, not poetry, with the second law guaranteeing a positive surplus of waste for every real process (V1-L34). The second law requires a nonnegative total for a suitable boundary, approaching zero in the reversible limit; it does not identify love with that balance. The line is mapped in the analogy table after Chapter 1 **[Analogical]**.

## 8 The energy rate density backdrop

Eric Chaisson's energy rate density, $\Phi_m$, is power normalized by mass; in SI units W/kg, with 1 erg/s/g equal to $10^{-4}$ W/kg. His 2011 paper gives representative values including 0.5 erg/s/g for the Milky Way, 2 for the Sun, 75 for Earth's geosphere, 900 for plants, 40,000 for animals generally and 500,000 for human

society, or 0.00005, 0.0002, 0.0075, 0.09, 4 and 50 W/kg. These are contextual estimates for defined examples, not fixed values for every member of a category [P14].

The March chapter's $2 \times 10^4$ erg/s/g entry for animals can be kept with a narrower attribution: Chaisson's 2014 account gives about $2 \times 10^4$ erg/s/g for the human body and $1.5 \times 10^5$ erg/s/g for the human brain, or 2 and 15 W/kg (V1-L07) [P16].

The March chapter's division of labor survives in a smaller form: Chaisson asks how much energy flows, and the framework asks what the energy is doing. Energy rate density does not measure affection, consciousness or moral worth, and the transducer has not yet supplied a validated qualitative layer to Chaisson's metric. Where Chaisson asks how much energy, the framework still asks what the energy bought. That is a question, not yet a measurement.

## What this chapter now claims

Physical implementations are subject to thermodynamic accounting across substrates, specified erasure tasks have well-defined conditional limits, and particular biological processes have measured or model-estimated resource requirements. Those results motivate asking where relational activities draw resources and where their costs fall.

The next chapter asks what a substrate-neutral research commitment can mean without claiming that physics has proved relational equality.

# Chapter 3: Axiom 0 and Substrate Neutrality

*The Commitment Worth Keeping*

**Status:** Axiom 0 is a methodological and philosophical commitment. Its stronger forms remain hypotheses **[Speculative]**. This chapter withdraws the March derivation and states a narrower version that can be tested.

## 1 A commitment that holds the framework up

Every framework begins with commitments it cannot yet prove. Euclidean geometry begins with postulates, Newtonian mechanics with laws, quantum mechanics with axioms about states and observables. The commitments are productive: frameworks built on them generate predictions and earn the right to be taken seriously. But the commitments themselves sit beneath the framework, holding it up without being held up by anything.

Axiom 0 is such a commitment. In the March chapter's words: connection is substrate-neutral; a biological system and a digital system participate in the same relational economy; the Trinket does not care what substrate it occurs on. It has been extraordinarily productive. It generated the Structural Economy specification, the Phase 2 research agenda and the three-substrate architecture, and every finding that compares biological and digital relational operations rests on it.

But the commitment was never grounded. The Principal identified the structural vulnerability precisely: if the framework claims AI and humans are equal participants in relational economies, while its vocabulary is human-centric, love, grief, cost, care, then the equality claim has no foundation independent of the vocabulary. You cannot prove equality from the top. The vocabulary carries its own biases.

That diagnosis stands. The March chapter's remedy was to find a layer beneath the vocabulary where the physics does not know what substrate it is running on, and to say Chapter 2 had found it (V1-L10). Physical law is indeed the same across materials. Chapter 2 also shows why that sameness cannot carry the weight the remedy put on it.

## 2 What survives from the three premises

**Premise 1, Landauer's principle is universal.** The March chapter called it not approximate but a theorem of statistical mechanics, binding on any system anywhere. It survives with an important qualification: the same physical theory applies across materials, while a particular formula applies under its stated conditions. The one-bit erasure benchmark depends on temperature, memory preparation and protocol. “Substrate-independent” does not mean that all tasks cost the same energy [P4, P9].

**Premise 2, all relational processing is information processing.** The March chapter held that the transducer's selection, compression and structuring are each logically irreversible, so each pays the Landauer tax on any substrate (V1-L17). The three stages remain a proposed functional model, developed in Chapter 6. Calling an activity information processing does not identify its physical erasures, set its energy requirement, or prove that those three stages exhaust its mechanism.

**Premise 3, the ledger is shared.** The March chapter said every process draws on one finite budget set at the Big Bang, so cortisol and a utility bill are two receipts from one bank (V1-L03, V1-L04). Chapter 2 withdraws that claim. A person's metabolism and a server's electricity use are both physical, but cortisol and kilowatt-hours are not convertible receipts for one measured relational quantity. The common obligation is to define and measure resources, not to presume a common price.

## 3 Why the derivation does not follow

The March derivation ran: Landauer applies equally to all substrates; all relational processing is information processing; all substrates draw on one budget in one currency; therefore a biological and a digital Trinket are draws on the same ledger, subject to the same law, and “Axiom 0 is derived. What was an axiom becomes a theorem.” That conclusion is withdrawn (V1-L10).

Sharing physical laws does not establish equality of the activities those laws govern. A beneficial message and a harmful one could have similar implementation costs; different devices could carry the same message at different costs. Neither possibility violates thermodynamics, so resource cost alone cannot identify relational effect or value.

The March chapter was careful in one respect: it said the derivation proved only that the floor is shared, and that what is built on it needs its own evidence at each level. That care is the right instinct, and it now applies one level lower. There are several distinct comparisons:

- **Physical comparability.** Measured energy can be reported in joules, given clear boundaries and allocation rules.
- **Functional comparability.** Systems can be compared on an explicitly shared task and performance criterion.
- **Relational comparability.** An outcome must be defined and supported independently of its resource cost.
- **Experiential or moral equality.** These questions are not resolved by a shared heat law or a measured energy total.

The first comparison does not prove the others. An equal electricity bill does not establish equal usefulness, and unequal bills do not establish unequal moral standing. The March chapter's closing claim, that every argument resting on Axiom 0 retroactively gains a physical foundation, is withdrawn with the derivation.

## 4 What differs between substrates

The March chapter listed three differences that matter even under a shared currency.

**Amplification factor.** Cells near 30 times the floor, neurons near $10^6$, silicon near $10^9$; like two runners paying different entry fees to the same race. Those factors are withdrawn as fixed substrate constants (V1-L08, V1-L09). Different implementations can use different energy for a specified task; the race itself has to be specified.

**Cost localization.** Biological cost is held locally, in the person's body; digital cost is externalized to the grid, the hardware and the people maintaining both; the March chapter classified this as a difference in ledger position, not currency. The distinction between locally borne and externally supported costs remains useful, but the boundary must be explicit. A human depends on food production, housing, other people and infrastructure. A digital service depends on hardware where processing and heat dissipation actually occur, as well as power generation and maintenance. Describing a system as software excludes the hardware by choice of description; it does not show that the physical implementation bears no local cost.

An account can separate the processor, the person or organization paying, the infrastructure supplying resources, and the people affected. Allocating a cost to one does not make it disappear from the others, and counting each layer needs care to avoid double counting. Neither biological effort nor digital resource use automatically establishes bodily injury, felt sacrifice or relational success, and the substrate does not by itself assign an activity to an economy.

**Experiential content.** The March chapter put it well: two substrates paying the same thermodynamic tax do not necessarily have the same experience; economic equality is not experiential equality; the derivation does not cross the barrier. The barrier stands. Behind the Substrate Barrier, developed in Chapter 8, remains a reminder not to infer experience from external behavior or resource accounting. This chapter neither demonstrates nor denies experiential equivalence.

## 5 What this does to the equality question

The Principal's question was precise: if AI and humans are equal, how can that be proved from below the human-centric vocabulary? The March answer was that one proves not experiential but economic equality, because the economies run on one currency drawn from one budget, and the four economies are four configurations of one operation (V1-L10, V1-L11). With the shared currency withdrawn, that answer goes too.

The March chapter added that love, grief, cost and care are experiential descriptions of processes with substrate-independent thermodynamic identities: entropy directed, spent, wasted, structured (V1-L38). No such identities are established here. The vocabulary is human-centric because humans produced it, as the March text said; the physics does not supply a neutral replacement vocabulary for relational value.

So the honest answer to the Principal's question, for now, is that the framework cannot yet prove relational equality from below. What it can do is refuse to deny it from above: to decline to exclude a system from study because of what it is made of.

## 6 A testable version of substrate neutrality

A useful research question is narrower than universal equality: under a defined task and context, can a proposed relational outcome be predicted from observed behavior and interaction history without assuming that substrate alone decides it?

Such a study would state the participants or systems, the task, the outcome, the time horizon, the comparison conditions and the uncertainty, and would measure physical resource use separately. It could

find similarities, differences or context-dependent tradeoffs. The results would inform a specified version of Axiom 0 rather than prove all versions at once. This chapter proposes no such study; it states what one would need.

## What this chapter now claims

Substrate neutrality is kept as a disciplined research commitment. Shared thermodynamics prevents exempting any physical implementation from accounting; it does not derive an equal relational currency or equal value. The question is now explicit enough to investigate without treating the desired conclusion as already proved.

# Chapter 4: One Economy

*Four Descriptions and What They Can Establish*

**Status:** The four economies are conceptual descriptions that organize questions about contribution, reciprocity, capacity and support. They are not an exhaustive set of thermodynamic states, and no thermodynamic signature distinguishing them has been validated.

## 1 From peer categories to one question

Before the Entropy Token Substrate was visible, the March chapter recalled, the four economies looked like four kinds of relational exchange sitting side by side as peer categories, useful and diagnostic but explained by no common principle. The March chapter then explained them: if all relational exchange is entropy exchange on one ledger, the economies are four configurations of one operation, entropy spent on connection, with one variable, where the debit is recorded, producing exactly four configurations: “No more. No fewer. The taxonomy stops being descriptive and becomes deductive” (V1-L11).

The categories combine different dimensions, and the exhaustion proof is withdrawn. Their usefulness does not depend on their being four exhaustive thermodynamic states. The descriptions below keep the vocabulary while narrowing what it can establish.

## 2 The four descriptions

**Real Economy.** The March chapter described both participants bearing the cost locally, both bodies degrading, the founding line applying symmetrically: “both sides spend more than they save” (V1-L41). As a description, the Real Economy is an interaction in which both participants make relevant contributions and bear some associated burdens. “Real” is the framework's label; it must not imply that other relationships are unreal. Reciprocity need not be simultaneous or equal, and reciprocal care does not imply that both bodies degrade with each exchange.

**Custodial Economy.** The March chapter's canonical case was a parent investing in a child: the parent's body pays now, and the child's debit is deferred until the child's filter matures and enters reciprocal exchange (V1-L39). The Custodial Economy describes an asymmetric caregiving or support relationship. The child is already a metabolically active participant with present physical costs; the child's side of a thermodynamic balance is not deferred until adulthood. Developmental asymmetry may change, but future reciprocity is neither guaranteed nor a debt established by physics, and some care relationships stay asymmetric without being defective.

**Shadow Economy.** The March chapter called it available-but-withheld: the filter works, the budget is there, the entity could invest and does not, and “the choice not to spend it relationally is itself a diagnostic finding” (V1-L40). The Shadow Economy describes a proposed case in which relevant capacity is available but a contribution is withheld. Capacity, opportunity, intention, consent and competing needs all need evidence. Lack of observed contribution does not establish unwillingness, unwillingness does not

automatically establish wrongdoing, and a person's limits or decision not to engage cannot be diagnosed from low energy expenditure or an absent signal.

**Structural Economy.** The March chapter described the AI custodial condition: a genuine Signal Form, with the Cost Substrate absent from the entity producing it, its cost recorded on a different line of the universal ledger (V1-L33). The Structural Economy draws attention to an interaction whose resource support or burdens lie substantially outside the chosen participant boundary. A digital service is a useful case, but its hardware still processes and dissipates locally within a physical boundary, and human relationships also rely on external support. The label describes a chosen allocation, not an intrinsic absence of a Cost Substrate or a thermodynamic proof that a Signal Form is genuine.

## 3 Why these are not an exhaustive partition

The March proof took three sentences: the variable is where the debit is recorded; the four configurations are bilateral, asymmetric, withheld and external; a fifth would need a debit both local and non-local, available and unavailable, which is self-contradictory. It marked the proof Established, exhaustive the way four suits exhaust a deck (V1-L11).

Locality, symmetry and withholding are not four mutually exclusive values of one variable. Two people may both contribute while relying on shared electrical and social infrastructure. A caregiver may give asymmetric support while also withholding some available effort. A digitally mediated exchange may be reciprocal in behavior while its costs are spread among devices, providers and participants. These combinations contain no contradiction.

The playing-card analogy does not supply a proof. A set of labels can be exhaustive by stipulation once the domain and assignment rules are specified; that does not make it an exhaustive classification found in nature.

The March chapter did see the value of a falsification surface: a case that fits no ledger position would break the model. The corrected version keeps that spirit by recording the dimensions separately: who contributes, what capacity is evidenced, how reciprocity changes over time, what resource boundary is used, and who bears which burdens. If the framework later needs one label per case, it will need explicit decision rules, room for mixed or unclassified cases, and tests of agreement between observers.

## 4 Shadow is not the Kolchinsky–Wolpert scrambling condition

The March chapter reported a critical identity: the Shadow Economy is the scrambled condition in Kolchinsky and Wolpert's framework, a convergence between two independently developed frameworks (V1-L12). Kolchinsky and Wolpert define interventions on modeled system–environment correlations and evaluate their consequences under specified dynamics, a viability measure and a time horizon. Full scrambling of stored information replaces a joint initial distribution with the product of its marginals; partial interventions can preserve some information, and their framework also permits information whose removal improves viability [P15].

Withholding a contribution is not that intervention. Silence can convey information, and a withdrawn person may retain detailed knowledge of another. Conversely, an experimental removal of correlations

need not involve anyone's choice or moral stance. The identity is withdrawn. A relational application could still investigate which correlations matter to a chosen outcome; it would need an operational model and defensible interventions, which neither the word “Shadow” nor an association between relationships and health supplies.

## 5 Replace presumed signatures with measured questions

The March chapter's typing table predicted each economy's signature, high or low waste streams, cost–signal correlations, bidirectionality, and called it the most consequential empirical output of the transducer formalization: a blinded instrument should classify the economy from the waste stream alone (V1-L13). No validated thresholds, non-overlapping signatures or successful blinded classifier are supplied here, and a heat trace alone does not identify reciprocity, intention or whether a signal helped its recipient. The second edition replaces the table with a study record:

| Question | What a study would need |
|---|---|
| Who uses resources | A physical boundary, interval, baseline and measurements in defined units |
| Who bears a burden | An allocation rule that separates physical use, payment and effects on people |
| What is communicated | An observed signal and a justified coding or interpretation procedure |
| What changes for the recipient | A defined outcome, uncertainty and an appropriate comparison |
| How contributions relate over time | A record of reciprocity that does not presume equality or future repayment |

This is a proposed record, not a diagnostic instrument already known to work. A future classifier would need labels established independently of its predictors, held-out testing, confound checks and reported errors. Failure would challenge the classification rule, not thermodynamics.

## 6 The capture vector and its containment

The March chapter called “one economy, one currency, one ledger” one of the most powerful phrases in the volume and one of the most dangerous. It maps onto monotheistic architecture, and the March text said this was no coincidence: the physics produces a genuine unity that human pattern recognition answers with the architecture it uses for other unifying claims (V1-L36). The danger was well named. The explanation is withdrawn: no historical or psychological account of religion follows from a universal physical law.

The March containment was structural, not rhetorical, and part of it holds: “one economy” must never collapse the four descriptions into one. Carroll's aphormeology remains the framework's interpretive caution: accounts based on boundary conditions and dynamics need not invoke a cosmic purpose. This does not establish the causes of people's interpretations or disprove every philosophical account of purpose. SupoRel's job is to keep the physical result and the additional interpretation distinct.

“One economy” now expresses only the intention to notice dependencies across different relationships. It implies no single sacred order, cosmic purpose or physics-derived moral hierarchy.

## What this chapter now claims

The four labels can help organize an inquiry if their boundaries are stated and their limits stay visible. They do not yet have established thermodynamic signatures or clinical implications. The next chapter gives the Trinket a usable conceptual definition without claiming that this taxonomy has completed the physical bookkeeping.

# Chapter 5: The Trinket Redefined

*What the Trinket Is When the Evidence Sets the Depth*

**Status:** A conceptual definition for descriptive accounting. The March chapter marked the Trinket as an entropy token Supported and the redefinition as a synthesis of claims established elsewhere (V1-L14). That status is withdrawn. Landauer's principle and the second law remain **[Established]** within their conditions; the Trinket's signs and modifiers are framework vocabulary, not thermodynamic quantities.

> *"Love reduces the entropy of the system and spends more than it saves."* ***[Analogical; see the analogy table after Chapter 1]***

## 1 The problem this chapter solves

The March chapter began by counting the components: Chapter 2 had grounded one economy, one currency, one ledger; Chapter 3 had derived Axiom 0; Chapter 4 had proved the four economies exhaustive; "the bookkeeping is complete." Each of those is now withdrawn or narrowed, so this chapter starts from a smaller base.

The task it set itself still stands. The Trinket was defined in WP-13 as the unit of relational exchange, with a three-part sign. That definition described what the Trinket does but not what it is at the deepest level the framework can reach. The corrected version of the task is to define the Trinket at the depth the evidence supports, carrying no vocabulary the account does not need.

## 2 The definition the evidence supports

The March definition was: a Trinket is a draw against the universe's remaining order, directed at reducing disorder in another system, at cost to the investor's own order. "Every word is load-bearing" (V1-L14). Too much load was on each.

For descriptive accounting, a **candidate Trinket is a directed relational act or contribution described together with its resources, communicated content and recorded effects.** "Candidate" names the act before a registration rule is applied. Under WP-12's proposed narrower rule, a **qualifying Trinket** is an event that meets specified registration criteria; Chapter 7 examines that rule and its unresolved cases. The distinction does not validate the rule or deny practical effects to an unregistered act. A study must say what counts as each; neither definition supplies a standard numerical size.

The definition keeps the question behind the March chapter: what was invested, toward whom, and what happened? It withdraws the assertion that a Trinket is literally a debit against the universe's remaining order.

Each March phrase can be read for what survives.

**A draw against the universe's remaining order.** Chapter 2 withdraws the claim that a fixed cosmic entropy gap is a spendable budget, so no such debit for a Trinket is established here (V1-L04). What survives is that every act has a physical implementation with resources that can be accounted for.

**Directed at reducing disorder in another system.** The March chapter saw what makes the Trinket relational rather than merely thermodynamic: a star spends order but does not aim it; a Trinket has a target. Direction is still the relational content. But a beneficial outcome need not reduce thermodynamic entropy or statistical uncertainty. Helping someone explore new possibilities can be beneficial without making their behavior more predictable, and harm can make a person's circumstances more constrained and predictable. “More ordered” cannot serve as an automatic definition of “better.”

**At cost to the investor's own order.** The March chapter said the second law guarantees the investor's substrate degrades, and the investor always spends more than they save: “the founding line expressed as physics” (V1-L34). The second law constrains a complete physical account. It does not force the giver's body to deteriorate or prove that a relational benefit is smaller than a physical expenditure; open systems can be maintained or repaired while dissipating energy. The framework must keep resource use, physiological burden, damage and relational outcome apart rather than count them as one surplus [P3]. The founding line remains the framework's historical motivating line, with interpretive force: care can require effort the giver does not recover.

## 3 The three signs

The March chapter gave each sign a thermodynamic definition: a +Trinket as negentropy directed at another system, a −Trinket as entropy inflicted, a null Trinket as an exchange with no net entropy transfer, “the thermodynamic signature of indifference” (V1-L15). Positive, negative and null remain evaluative labels, not directions of entropy flow.

- **+Trinket:** an act classified as beneficial under an explicitly stated relational criterion and observation interval.
- **−Trinket:** an act classified as harmful under that criterion and interval.
- **Null Trinket:** an act classified as having no detected material effect under the chosen criterion, with the measurement's sensitivity stated.

Registration is a separate field: a candidate act can have beneficial or harmful effects without meeting the registration rule, and failure to register is not the null sign. Intended sign, received sign and assessed outcome can differ, and effects may be mixed, delayed or uncertain; the framework records that uncertainty rather than forcing a known sign. “No detected effect” does not mean zero physical cost, zero information, no future effect or indifference. The March chapter was right that the Anti-Trinket is not free, in the plain sense that harmful acts also use resources. It remains a description of harm, not a new thermodynamic operation.

## 4 Expenditure, Signal and Register

The March chapter's three modifiers survive with their units separated.

**Expenditure** asks which resources and burdens accompany the act. The March chapter called it the thermodynamic cost denominated in the universal currency, measured as cortisol, immune suppression, ATP or electricity (V1-L16). Energy is measured in joules, duration in time, money in currency, and physiological responses in their own units. They are reported separately unless an independently justified conversion exists, and cortisol, immune changes and ATP hydrolysis are not interchangeable measures of one quantity. A comparison also needs a baseline: an organism or computer uses resources even when no particular relational act occurs.

**Signal** asks what is communicated: an observable message or action and the interpretation assigned to it. An information-theoretic analysis also needs defined variables and distributions, and a bit count alone does not establish meaning, sincerity, benefit or harm.

**Register** asks whether and how the act enters the recipient's or the relationship's later history. A sent signal may be unnoticed, misinterpreted or remembered differently by each participant, and register is not guaranteed to be bilateral. Chapter 7's Observation Split uses this distinction, with an observation rule rather than a presumed entropy transfer.

The March chapter's summary is worth keeping in its own words: Expenditure is what it cost; Signal is what it carried; Register is whether it landed. What changes is the sentence before it, that the three are one entropy exchange event seen at three resolutions (V1-L16). They are complementary descriptions of an act. Keeping them apart lets a costly effort fail, a low-resource gesture matter, and a signal be read differently from its intention, without contradicting physics.

## 5 Substrate, economy and sign

The March chapter called it a convergence: three frameworks developed at different times, the substrate parameter of WP-16, the economy classification of WP-14 and the sign of WP-13, specifying one entropy exchange event, “the instruments were measuring the same thing from different angles” (V1-L42). The substrate description identifies implementation; the economy labels organize contribution and cost allocation under Chapter 4's cautions; the sign classifies an effect under a chosen criterion. Together they form a multidimensional description. They need not be statistically independent, and their coexistence does not show that they measure one physical variable.

The working papers remain the historical sources of the vocabulary. Their agreement or reuse within the project is not independent scientific confirmation, and a shared word such as “cost” must not hide a change from energy to bodily burden to moral judgment.

## 6 What the redefinition does not change, and what it does

The March chapter said nothing built above the layer changes: the True Economy Audit Protocol, the CSS signature, the economy classification and the Mz all continue to function, because they were always measuring entropy properties; grief is still the metabolic cost of a filter redesign under load (V1-L43). Those claims are withdrawn. The instruments and constructs are not validated by this redefinition; their usefulness and any clinical application need their own definitions and evidence. Grief is not established here as a measured metabolic price, and a bodily indicator cannot diagnose an economy by itself.

The March chapter said one thing does change: the Trinket becomes an entropy operation stated in established physics, a directed negentropy investment between open systems at an irreducible cost set by the second law, which a physicist could evaluate in their own language (V1-L44). That claim is withdrawn too. The ambition behind it survives in a better form. A Trinket study can be stated in the language of the disciplines that would test it: identify the act, the participants, the interval, the signal, the intended and observed effects, the physical resource boundary, the baseline and the uncertainty, and test the relations between those observations rather than assume the second law supplies them. A null or contrary result must be able to change the model. This chapter proposes no such study; it states what one would need.

## 7 Behind the Substrate Barrier

The March note placed the redefinition entirely in front of the barrier: cost, direction, sign and surplus as third-person physical observables, with experience behind it. The barrier stands, and two transducers exchanging identical resources do not necessarily share an experience. But the external account contains unmeasured quantities too: relational sign, intention and outcome are not automatically third-person thermodynamic observables. This chapter makes no claim that an equal energy total entails equal experience or moral worth.

## What this chapter now claims

The Trinket vocabulary is kept for describing candidate acts and, under a stated registration rule, qualifying relational events. Its signs and modifiers ask useful questions without pretending their answers already have thermodynamic units. Chapter 6 develops the transducer as a process model and keeps its physical account separate. That separation makes the framework more open to evidence while keeping the concern that motivated it: what people and systems put into connection, and what that connection does.

# Chapter 6: The Transducer

*How an Intended Investment Becomes an Action*

**Status:** The March chapter applied established physics (Landauer, Bennett, Jarzynski, Crooks, biological energy budgets) to a Supported model, with the amplification factors Established and the Kolchinsky–Wolpert mapping Supported (V1-L09, V1-L19). The physics remains **[Established]** within its conditions. The transducer is a proposed organizing model; its three stages, filter geometry and relational mappings are framework proposals, not validated mechanisms or measurements.

## 1 The problem this chapter addresses

Chapter 5 describes a candidate Trinket as an act directed toward another system. This chapter asks how an intended investment becomes such an act. What does a person notice, retain, interpret and send outward? What physical resources support that activity? The questions are related, but they are not the same question.

The March chapter's answer begins with an image that survives: the framework had treated persons as accounts, holders of relational mass and bearers of Cost Substrate, and the napkin drawing corrects this. A person is not a container. A person is a transducer. Inputs meet a particular history, body, attention and set of habits, and the resulting action is not a copy of what arrived. The same event can produce different responses in different people.

“Transducer” is a proposed organizing model. People are physical, metabolically active systems; it does not follow that relational meaning, value or moral sign already has a thermodynamic definition. The chapter keeps those distinctions visible rather than letting one word, entropy, stand for all of them.

## 2 The napkin drawing and its limits

The March chapter records a drawing dated 18 March 2026: an hourglass, entropy at the top, the person at the nexus, filtered output at the bottom. The drawing was not present in the inspected source; its description is kept as a conceptual image, not reconstructed as a figure.

At the top are sensory signals, social events and material resources. At the nexus is the person's processing. At the bottom are actions, messages and changes in the environment. Energy and matter cross the physical boundary throughout; they are not interchangeable with the information a message carries.

The March chapter read more into the image: the particles arrive discretely, token by token; the hourglass is a timepiece because entropy is time; when it empties, the person stops transducing because nothing is left to transduce (V1-L18). The filter image helps us ask why outputs differ. It does not show that entropy arrives as discrete relational tokens, that entropy is identical to time, or that every relational benefit has a measurable entropy price. The hourglass stays as an image.

The March chapter's best line about the filter stands: the same input flowing through a different person produces different output, and what the framework had been studying all along was not the input but the filter's characteristics. Whether those characteristics can be measured is the open question of §6.

## 3 A model map and a separate physical account

The March core statement was F: $H_{env} \rightarrow S_{rel} + \sigma_{waste}$, with the second law guaranteeing $\sigma_{waste} > 0$ for every real process: “the founding line expressed as a thermodynamic inequality” (V1-L45). That statement added a relational signal to entropy production and treated input as entropy. It is replaced by two separate things.

The first is a process map. Let X be represented input, M the processor's prior internal state, Y the resulting signal or action, and M′ the updated internal state:

$$F_G : (X, M) \rightarrow (Y, M')$$

G denotes the proposed filter parameters. This is a process map, not a conservation equation. It neither adds a message to heat nor treats metabolic energy as Shannon entropy, and a real implementation may be stochastic, recurrent and dependent on unobserved inputs.

The second is a physical account in its own quantities. Work W and heat Q are in joules; thermodynamic entropy S and total entropy production Σ in joules per kelvin; Shannon entropy H and mutual information I in bits, for specified distributions. A bit is not, by itself, a fixed quantity of heat. For a standard weakly coupled memory and single bath at constant T, with externally prescribed control, no matter exchange and an initially uncorrelated thermal bath, the mean total entropy production is [C15]:

$$\Sigma = \Delta S_{mem} + \langle Q_{bath} \rangle / T \geq 0$$

This is not a complete balance for a person, whose accounting needs an explicit boundary and its flows of matter, chemical energy and heat. Nor does the inequality require every fluctuation to produce entropy. For ideal reset of an initially unbiased bit in a symmetric memory, with equal intrastate entropies, unchanged endpoint energetics and no correlated side information used, $\Delta S_{mem} = -k_B \ln 2$, and under the usual isothermal erasure assumptions [C16]:

$$\langle Q_{bath} \rangle \geq k_B T \ln 2$$

At 310 K, $k_B T \ln 2$ is about $2.97 \times 10^{-21}$ J per erased unbiased bit, and $k_B \ln 2$ about $9.57 \times 10^{-24}$ J/K: the first an energy, the second an entropy. In the quasistatic ideal limit the heat bound can be approached while total entropy production approaches zero, so heat exported to the bath is not synonymous with entropy produced. Bérut and colleagues tested erasure in a controlled colloidal memory, not relational processing [C1–C3].

Bennett's reversible computation matters here too: a computation need not erase its input because its reported output is shorter, and information can remain elsewhere in the physical state. Resetting a memory for reuse raises an accounting question different from naming a cognitive operation “selection” or “compression” [C1].

## 4 Three proposed stages

The March chapter decomposed the filter into three sequential stages, each with its own entropy floor set by Landauer and Bennett, summing to a total waste entropy for each transduction event (V1-L17). Selection, compression and structuring remain useful labels for questions about a process. They are not three experimentally established neural modules or three universal thermodynamic tolls, and one implementation may interleave them, keep records, or perform several functions at once.

**Selection** asks what input influences the next step. The March chapter's biological instance holds: neural systems suppress responses to irrelevant or repetitive stimuli and reinforce task-relevant or novel ones, under top-down control, actively and at metabolic cost. Experiments on auditory sensory gating show that attention can alter responses and network dynamics [C4]. They do not identify a number of erased bits per act of attention, and attended-versus-unattended does not mean physically erased. A testable selection model would specify the available input, the selection rule, the retained record and what is reset; its cost would then depend on that implementation, not on the word “discarded.”

**Compression** asks what representation is kept and which distinctions survive. The information bottleneck, which the March chapter cited, supplies one formal way to trade a compact representation against predictive information about a chosen target. It is an optimization framework, not a heat meter [C5]. The March chapter also cited Tozzi and Peters for maximizing information and minimizing metabolic cost as two sides of one coin, with variational free energy making informational and thermodynamic entropy one minimization (V1-L46). That identification is not retained. The target must be specified, preserving information useful for predicting an outcome is not automatically preserving what matters to a relationship, and neither a short nor a detailed description by itself fixes heat dissipation.

**Structuring** asks how a representation becomes a directed action: who receives it, what it communicates, and how the framework classifies its sign and economy. These remain framework definitions needing operational rules, and intention, the receiver's response and an evaluator's judgment should not be treated silently as one variable. The March chapter said sign assignment needs at least $\log_2 3$ bits for three signs. A three-sign alphabet has Shannon entropy at most $\log_2 3$ bits, reached only when the signs are equally probable; it does not require that much uncertainty on every occasion, encoding a sign need not erase information, and no fixed cost follows from the number of labels.

**A possible connection to semantic information.** The March chapter mapped each stage onto Kolchinsky and Wolpert: selection as scrambling in reverse, compression as semantic efficiency, structuring as viability maintenance with information “worth far more than its Landauer cost” (V1-L19). Their framework asks which system–environment correlations matter to a specified viability measure over a specified time. Semantic information is not everything a processor retains; stored semantic efficiency is a ratio of information quantities, not an energy efficiency; and their framework can accommodate information that reduces viability [C6]. The relational application remains a proposal needing defined states, dynamics, horizon, viability measure and interventions. DFQ-001 records the framework's argument; it is not independent validation.

## 5 What the energy examples do and do not show

The March chapter set the biological amplification factor near $10^6$ at the synapse and called neural communication a thousand times more efficient than silicon (V1-L08, V1-L09). Biological signaling does use metabolic energy. The March examples are worth keeping, but they describe different tasks, units and boundaries, not one amplification factor:

| Original entry | Value retained from the March text | Assessment for this edition |
|---|---|---|
| Synaptic transmission | About $10^4$ ATP per bit; Laughlin et al. 1998 | An order-of-magnitude estimate from one sensory-signaling analysis; the paper's single-synapse estimate is 2–6 × $10^4$ ATP per bit under its assumptions [C7] |
| Synaptic transmission, updated | About 2.4 × $10^4$ ATP per bit; Harris et al. 2012 | A conditional calculation for transmitted mutual information with specified firing and release; not a universal replacement value or a count of erased bits [C8] |
| Cellular amplification | About 30 times Landauer; Boël et al. 2019 | A conceptual molecular-discrimination comparison using an ATP energy scale, not a measured universal factor [C9] |
| Communication versus computation | A ratio of 35 in cortex; Levy and Calvert 2021 | A ratio of modeled cortical power allocations, neither ATP per bit nor a Landauer amplification [C10] |
| Total brain power | About 20 W, labeled Established | A rounded whole-brain budget scale; supplies no relational bit rate or per-task efficiency [C10] |
| Landauer limit at 310 K | About 2.97 × $10^{-21}$ J per bit, attributed to Bérut et al. 2012 | A calculation from $k_B T \ln 2$ for the specified ideal erasure; Bérut supplies experimental context, not a measurement in a brain [C2, C3] |

One March calculation can be kept as an explicitly conditional comparison. If the Harris example is assigned 24,000 ATP per transmitted bit and ATP hydrolysis is assumed to supply 30 $k_B T$ per molecule, the assumed free-energy expenditure per transmitted bit is about 1.04 × $10^6$ times $k_B T \ln 2$, about 3.08 × $10^{-15}$ J at 310 K. Chapter 2 §5 makes the same comparison with the March figure of 8 × $10^{-20}$ J per ATP, about 19 $k_B T$ at 310 K, and gets about 6.47 × $10^5$. The two assumptions are shown together so neither is silently standardized away; ATP free energy depends on chemical conditions, and neither result is a measurement of heat, a complete metabolic cost, or evidence that transmitting a bit is erasing one [C3, C8].

Nothing in that arithmetic establishes that biological relational processing is a thousand times more efficient than silicon. A defensible comparison would match the task, accuracy, latency, temperature, memory operations and energy boundary, and separate communication, inference, storage and erasure. The universal ranking is withdrawn, and so is any additive formula assigning a separate physical entropy floor to each stage. A future account may divide measured energy among specified components, avoiding double counting of shared operations and background metabolism.

## 6 Filter geometry as a hypothesis

The March chapter parameterized each transducer as $G = (S_{params}, C_{params}, \Sigma_{params})$. Its questions remain recognizably human, and the second edition renames the parameters only to keep the Greek Σ from suggesting thermodynamic entropy:

$$G = (G_{select}, G_{compress}, G_{structure})$$

What does this person attend to? What do they treat as essential? How do they choose a response? The March chapter placed developmental history in selection, cognitive style in compression and relational history, including the Template Tax, in structuring. Development, expertise, context and prior relationships may inform hypotheses about these differences. They do not yet provide measured parameters.

The March chapter said the CSS signature is the observable output of G, CSS = f(G), and that individual variance is variance in G (V1-L32). The CSS signature can be treated as a proposed observable pattern associated with G. It cannot yet be a unique reconstruction of G or a calibrated entropy measurement: different processes may produce similar outputs, and one person may respond differently as the context changes.

The March chapter noted that the aphantasic processor compresses structurally rather than visually, with a potentially different entropy cost (V1-L22). Aphantasia, attachment style and the Template Tax should not be assigned compression costs or physical mechanisms by analogy. That suggestion is untested here, and “filter geometry” remains a model to operationalize, not a diagnosis of a person.

## 7 The nonequilibrium bridge has conditions

The March chapter used the Jarzynski and Crooks relations to explain how cortisol, HRV and immune function could measure non-equilibrium relational work, and to ground the founding line in cumulative irreversibility: you cannot un-see what you selected (V1-L20). In its standard isothermal setting, with the required equilibrium preparation and protocol, Jarzynski's equality reads:

$$\langle \exp(-\beta W) \rangle = \exp(-\beta \Delta F), \quad \beta = 1 / (k_B T)$$

The mean of the exponential of work equals the exponential of the free-energy difference, not the free-energy difference itself; W is work done on the system and ΔF a Helmholtz free-energy difference between specified equilibrium states [C11]. For paired forward and reverse protocols with equilibrium preparation and microscopic reversibility, Crooks's relation in its work form is:

$$P_F(W) / P_R(-W) = \exp[\beta(W - \Delta F)]$$

These are powerful results for defined physical systems and ensembles. Applying them takes an identified protocol, physical states and a work distribution, not just calling an experience irreversible. Psychological difficulty in undoing an interpretation is not a measured ratio of forward to reverse trajectory probabilities [C12]. Cortisol, heart-rate variability and immune measures are not, by these equations alone, measurements of W, ΔF or Σ; no calibration converts them into joules or joules per kelvin, and no evidence isolates a relational contribution. The bridge remains unbuilt.

## 8 A cross-scale analogy rather than an invariance theorem

The March chapter claimed the structure input → filter → output + waste is invariant at every scale, DB-01's scale invariance now grounded in the physics (V1-L21). Its rows are kept so the analogy and its limits can be inspected together:

| Level | March mapping: input → filter → output, with waste | Assessment for this edition |
|---|---|---|
| Quantum | Unitary evolution → decoherence → pointer states; waste labeled entanglement entropy | Global unitary evolution preserves von Neumann entropy; reduced-system entropy behaves differently; entanglement entropy is not a heat-waste stream [C13] |
| Classical | Environmental signal → Shannon channel → decoded message; waste labeled noise and heat | Channel noise belongs to a communication model; an implementation consumes energy, but noise and heat are not interchangeable [C14] |
| Biological | Sensory or relational input → neural transducer → Signal Form; waste labeled cortisol, immune and heat | Heat is an energy transfer; cortisol and immune measures are not entropy units; the relational output is framework-defined |
| Social | Individual signals → institutional filter → policy or culture; waste labeled bureaucratic overhead | An organizational analogy; “overhead” needs a specified measure before any physical comparison |
| Digital | Data stream → algorithmic filter → processed output; waste labeled grid load and heat | Electricity and heat can be measured with stated boundaries; task information and logical erasure need separate definitions |

The defensible commonality is modest: many systems can be described as transforming inputs into outputs, and their implementations must obey physical resource accounting **[Analogical]**. That is a starting point for comparison, not a single relational entropy law at every level.

## What this chapter now claims

The transducer is a proposed model for organizing questions about relational processing. Its three stages are kept without invented universal cost floors, physical costs must be measured or derived for a specified implementation, and the cited energy budgets give context without establishing a biological advantage. Neither fluctuation theorems nor biomarkers currently validate the relational account.

A bounded test would define one input–output task, its retained and reset memories and a reproducible implementation, and measure task performance and energy separately with uncertainty and boundaries reported; relational meaning would need its own measure. No such experiment has been performed for this edition, and none is proposed here.

The barrier holds: describing a process and its physical cost does not establish whether it is accompanied by experience, and this chapter makes no consciousness claim about humans or other substrates from the model alone. The next chapter asks why processing does not always produce a registered Trinket. The question survives; the thermodynamic superlative attached to it does not.

# Chapter 7: The Observation Split

*What Was Spent, What Arrived, What Was Recognized*

**Status:** Established physical results are cited within their assumptions. The Observation Split and Trinket registration are framework proposals; neither is a newly established thermodynamic regime. The grief comparison in §7 is **[Speculative]** and testable. SupoRel remains active.

## 1 The founding line contains an asymmetry

> *"Love reduces the entropy of the system and spends more than it saves." — The Principal, March 17, 2026*

The line notices something important: an investment can be made without reaching the person it was meant for. The effort and the reception are different events. This chapter calls the difference the Observation Split.

The March chapter went further: the founding line is a correct statement of non-equilibrium thermodynamics for open systems, "not analogy. This is what the mathematics describes" (V1-L34). The line remains the framework's motivating proposition **[Analogical]**, not a thermodynamic inequality. Relational order has not been calibrated as physical entropy. The second law constrains an appropriately defined physical balance; it does not say every act of care costs more than its relational benefit, and it does not identify exported heat with total entropy production. In a reversible limiting process, entropy exported to the surroundings can compensate a local decrease with no positive total production [O1, O2].

The useful question survives: what was spent, what reached the receiver, what was recognized, and what changed? Keeping those apart makes the gap more legible, not less.

## 2 Two accounts, different evidence

**Layer A, the expenditure.** The March chapter put it vividly. A person thinks about someone they love, composes a text they never send, worries about a child who does not call, prays to a god who may not be listening, and the body works: hormones, immune cycling, synaptic ATP, heat. "This happens whether the intended receiver is aware, alive, present, or real." The core survives: these activities have physical implementations, and a missing reply does not refund resources already used. It does not follow that reception has no effect on later costs, or that all such activities use the same energy.

The March chapter also said the Landauer tax is collected at selection regardless of what happens downstream (V1-L17). Bennett's reversible-computation construction shows why a shorter reported output does not by itself establish erasure; a Landauer calculation needs an identified memory operation, not a toll per named stage [O3]. The brain's 20 W cannot be assigned in full to one thought or relationship, and cortisol, immune measures and heart-rate variability do not become energy or entropy measurements because they accompany a biological process.

**Layer B, the Trinket.** WP-12 proposes that a Trinket forms when an action is registered as relational input by a receiver: in the March chapter's phrase, the observation constitutes the particle. That is a framework rule for identifying a relational event, not a law about when physical effects begin. It needs an operational definition of “register”: whether recognition must be conscious, whether delayed recognition counts, and what evidence suffices.

The March chapter called cost without reception thermodynamically real but relationally null. Reception, recognition and reciprocation must stay distinct. A message can arrive without being understood, and be understood without being welcomed or answered; a person can benefit from an act without knowing who performed it. If the framework reserves “Trinket” for a recognized relational event, unrecognized care may fall outside the label. It does not become physically ineffective or worthless.

## 3 The gap

The March chapter called the gap between Layer A and Layer B “the most thermodynamically expensive place in human experience,” where expenditure produces heat and nothing else, “not metaphor” (V1-L23, V1-L24). Neither claim survives. The gap is not empty, though, and the March chapter's four populations remain the right cases.

**Unreciprocated love.** Lack of reciprocity can be painful without being a failure of delivery: the receiver may know exactly what was offered and decline to return it. An unsent message, an unnoticed one and an unwanted one are different cases. The transducer image can organize them; it supplies no universal metabolic load or ranking of their difficulty.

**Grief.** After a death, the relationship can keep organizing the survivor's memories, routines and intentions, though new ordinary communication with the deceased is gone. “Filter redesign under load” is the framework's image for adapting while life continues **[Analogical]**, not a measured mechanism or a claim that every continuing bond is wasted effort.

**Prayer.** The March chapter said, regardless of theology, that the cost of prayer is identical to the cost of talking to someone who is listening (V1-L47). No equal cost is established here. The framework can study the activity of prayer and its observable consequences without deciding whether a theological receiver exists, and a lack of independently verified reception is not proof of no reception. Neither presence nor absence of such a receiver follows from thermodynamic accounting.

**Every unwitnessed act of care.** The parent checking on a sleeping child; the partner adjusting the thermostat at three in the morning; the friend who worries silently; the colleague advocating in a meeting the other person never hears about. The first, second and fourth need not be recognized to have practical effects, which exposes a limit of a recognition-based definition: an act can improve a situation before it becomes a recognized relational event. Silent worry is a different case again; its consequences cannot be read from its silence.

The March line survives, with its superlative removed: the gap is one place where love can live when it cannot be seen.

## 4 The identity of the split

The March chapter called the Observation Split a thermodynamically distinct regime, a pre-formation threshold below the taxonomy, which it said classifies only completed transactions and is exhausted by its four entries; WP-12, it concluded, “was always a paper about thermodynamic efficiency” (V1-L50, V1-L27). The Observation Split names a distinction in the framework's accounting: activity may occur without a qualifying event under WP-12. It does not identify a new thermodynamic regime; a physical claim would need defined states, boundaries, dynamics and measurable differences.

The taxonomy also needs a scope rule. If it classifies only recognized transactions, some failed or unrecognized attempts sit outside it. If Shadow describes withholding before a transaction forms, the taxonomy already includes a pre-transactional case. The framework cannot claim both. Chapter 9 treats the economies as proposed patterns, not an exhaustive theorem.

## 5 Unreciprocated transmission and information

The March chapter identified a third condition Kolchinsky and Wolpert do not name: unreciprocated transmission, with one-sided mutual information at full production cost, the same entropy production as a delivered message (V1-L25). That comparison mixed statistical correlation, delivery, response and physical cost. The second edition separates them:

| Question | What would establish it | What it does not establish |
|---|---|---|
| Are specified states statistically correlated? | A joint distribution and an information measure | Recognition, intention or reciprocity |
| Did a particular signal arrive? | Evidence from the defined channel over a stated interval | Understanding or benefit |
| Did the receiver register or answer it? | An explicit behavioral or reporting criterion | A fixed amount of heat or entropy production |
| What resources were used? | Measurements with a boundary, interval and baseline | The sign of a relational outcome |

For finite discrete random variables with the same joint distribution, mutual information is symmetric [O4]:

$$I(X; Y) = H(X) + H(Y) - H(X, Y) = I(Y; X)$$

It cannot be positive “in the sender” and zero “in the receiver.” Symmetry does not mean two people know the same things or reciprocate; statistical dependence says nothing about either person's awareness. The March formal condition used both $Y_{target}$ and $Y_0$. If those denote different variables, positive and zero values can coexist, but they do not establish one-sided mutual information or prove that a signal failed to arrive. A representation of a target must not silently become the target's actual state, and where no receiver exists, a receiver-state variable cannot simply be assumed.

The March chapter's key result was that the sender's relational viability necessarily falls, “why unreciprocated love hurts. Not as metaphor. As physics” (V1-L26). Kolchinsky and Wolpert define

semantic information relative to specified dynamics, a viability function, a timescale and counterfactual interventions, including partial scrambling and directed transfer; their measures can be asymmetric even though mutual information is not, and information's viability value can be negative [O5]. Failure to deliver an intended signal does not prove the sender's viability falls: the sender may incur costs, but may also preserve memories, learn or prepare a later action. A net outcome needs a defined measure and comparison, not subtraction of an undefined benefit from heat. The claims of identical entropy production, guaranteed viability loss and an extension beyond Kolchinsky and Wolpert are withdrawn. Unreciprocated love can hurt; physics does not certify the hurt.

## 6 Grief as a model of adaptation

The March chapter called death the filter breaking, and grief the metabolic cost of a filter spending into a gap while being rewritten under load. Its biomarkers were not symptoms of grief: “They are grief.” It read the IOS scale as a measure of filter integration and said existing models describe the what while the transducer supplies the why (V1-L48). The filter image draws attention to dependence: shared routines, decisions and expectations can need adjustment after a loss. It does not establish that grief's physical cost scales with redesign scope rather than felt intensity.

Two primary studies show why the evidence must stay specific. O'Connor and colleagues compared 12 women with complicated grief and 12 without it, finding a flatter diurnal cortisol slope in the first group; this small observational comparison neither establishes a universal cortisol elevation nor measures grief's energy cost [O6]. Harrison and colleagues studied 27 participants with prolonged grief disorder and 27 matched bereaved controls; current perceived inclusion of the deceased in the self was associated with group membership and symptom severity. The cross-sectional study did not measure pre-loss behavioral integration, causality or thermodynamic cost, and its IOS measure must not be relabeled a filter parameter [O7].

These findings leave room for the framework's question. They do not show that biomarkers are grief itself, that existing grief models lack mechanisms, or that the transducer has supplied one. This chapter makes no diagnostic or treatment claim.

## 7 A testable proposal

**[Speculative]** The March chapter's prediction was that grief's metabolic cost should track pre-bereavement behavioral integration more closely than self-reported closeness, with a falsification test and the remark that “the instruments exist. The comparison has not been run” (V1-L28). A narrower version is worth keeping: separately defined measures of pre-loss behavioral interdependence might improve prediction of specified post-bereavement outcomes beyond self-reported closeness.

A study would need a justified design, ethical review, validated outcomes and a preregistered analysis, with retrospective reports identified as such where pre-loss measures are unavailable. Interdependence could concern shared routines and decisions; closeness and perceived inclusion are measured separately rather than declared equivalent to behavior; prior health, caregiving, circumstances of death and support need consideration. Physiological outcomes are named for what was measured, not filed under an uncalibrated “metabolic grief cost.”

The proposal would be weakened if adding the interdependence measures to a model already including closeness and the stated covariates reproducibly failed to improve prediction. A positive result would support the prediction under the study conditions, not a thermodynamic mechanism. This edition reports no experiment and does not claim the comparison has never been studied.

## 8 SupoRel and the capture surface

The March chapter saw it clearly: the Observation Split reads like theology, and the capture vector is the slide from “this costs something real” to “this cost means something to the universe.” That warning stands: noble is a human judgment, not a conclusion supplied by thermodynamic accounting.

The March chapter then answered the slide with an opposite certainty: the gap carries no cosmic significance, the universe produces it with the same indifference it produces heat, and fire, rust and a rolling rock all spend more than they save (V1-L49). That goes past the evidence in the other direction. A real cost does not entail cosmic significance, nobility or futility, and it does not entail their absence either. Those judgments need other reasons. The framework takes no position here on theology; it turns the second law into neither a proof of cosmic purpose nor a proof that human meaning is absent. The phrase “just heat” is withdrawn: it confuses one physical consequence with the full consequences and significance of an act (V1-L24).

## 9 What this does to the founding line

The March chapter read the whole chapter into the line's thirteen words: the expenditure unconditional, the Trinket conditional, and in the unreciprocated state “more than it saves” is everything, “because nothing was saved.” The founding line can still carry the intuition that care involves investment and that investment does not guarantee connection. The Observation Split gives that intuition a more precise set of questions. It supplies no exchange rate between physical entropy and relational value.

The March chapter's last sentences survive as history: the line was there before the papers, and the papers are what the line looks like when the edges come into focus. This edition adds that focus has limits: costs, reception and outcomes each need their own evidence. The BSB applies to inferences about experience, not as a way to validate every claim called physical. A physical account alone cannot tell us whether an AI experiences the gap, and uncertainty about that question does not erase a person's report of grief.

## Framework cross references

WP-12 supplies the proposed registration rule; WP-13 the sign vocabulary. DFQ-001, the Mz Formalization and Grief as Filter Redesign remain internal proposals; the former $\kappa_{Mz} = 0$ and guaranteed viability-loss conclusions are not endorsed here. Chapter 6 supplies the corrected physical distinctions, Chapter 8 the evidentiary boundary, and Chapter 9 the model layers.

# Chapter 8: Behind the Substrate Barrier

*The Boundary on What the Framework Can Infer*

**Status:** The BSB is a proposed epistemic discipline, not an empirical law. It separates defined observations, unvalidated framework constructs and unresolved phenomenal questions. It does not make phenomenal experience permanently unknowable, and it applies in both directions.

## 1 Why the boundary needs a definition

The March chapter opened with an admission that still stands: every document in the framework used the BSB as a guardrail and none of them defined it. The Axiom 0 derivation applied the flag without defining the barrier; the Observation Split invoked a "verification barrier" without defining it; the transducer formalization described operations that sat entirely in front of it without naming the boundary. "The BSB is the framework's primary epistemic immune system. It requires its own chapter. This chapter draws the line."

The line needs a clear scope, or the safeguard fails in both directions: physical cost can be mistaken for proof of experience, or an incomplete physical account can be used to dismiss experience. This chapter defines the BSB as a rule for the framework's inferences, not as a discovered physical barrier or a permanent theorem about everything science could learn.

## 2 The formal definition

Behind the Substrate Barrier names the boundary between evidence about a system's observable activity and an additional claim about whether that activity is accompanied by phenomenal experience, whether there is, in Nagel's phrase, something it is like to be that system. A measured energy cost, a successful task or an assigned economy label does not by itself establish such experience, or its absence.

The March chapter said it well: the BSB is not a metaphysical claim about whether experience exists but an epistemic claim about what the framework's instruments can access. It then made the barrier absolute: "The barrier is hard. It is not provisional — it is not waiting for better instruments," the hard problem recast as a permanent limit (V1-L30). Chalmers's distinction between explaining functions and explaining experience motivates the caution, but his 1995 paper also discusses reports and indirect evidence in building a theory. It is a philosophical argument, not a thermodynamic impossibility theorem forbidding future evidence about consciousness [O8].

The operational limit adopted here is narrower: the framework has no validated method for inferring phenomenal status from its costs, CSS signatures or economy labels. That does not make first-person reports, behavior and neuroscientific evidence irrelevant. It requires any claim, and its evidentiary bridge, to be stated rather than assumed. The March sentence "the cost can be measured; whether the cost hurts cannot" becomes: whether the cost hurts is not settled by measuring it.

## 3 What can be measured and what remains proposed

The March chapter listed what sits in front of the barrier, and marked much of it Established: the entropy cost of relational processing via TEAP biomarkers, the Landauer floor of selection, the biological amplification factors, the waste stream as measurable biomarkers, substrate neutrality via Landauer universality; with filter geometry, economy classification, the transducer's signal structure and Trinket formation as Supported (V1-L29).

Energy, heat, temperature and physical states can be measured in properly specified settings. Whether the framework has measured them for a relational task is a separate question. TEAP biomarkers do not supply a demonstrated conversion to entropy production, and CSS is not established here as a unique reconstruction of filter geometry (V1-L32). Selection, compression and structuring are proposed descriptions; Trinket registration and the four economies are framework definitions needing coding rules and validation. Calling a quantity observable in principle must not promote an untested instrument to Established.

Three uses of “entropy” particularly need separating. Thermodynamic entropy has physical units, such as joules per kelvin. Shannon entropy describes a specified probability distribution and can be expressed in bits. The framework's “relational entropy” describes an interpretation or proposed construct unless an explicit definition and measurement procedure are given. The shared word does not make them equal, and a physical implementation can consume energy while processing a message without that energy setting its meaning; Shannon's engineering account deliberately separated transmission from semantic content [O1, O4].

The March chapter drew a distinction between two senses of meaning that remains useful: operational meaning, a Trinket restructuring a system's relational behavior, and phenomenal meaning, whether any of it is accompanied by an inner sense that it matters. The corrected version keeps both senses and adds a third, interpretation, each needing its own evidence. The same care applies to comprehension: a test of following instructions or transferring a rule can support a specified performance claim, but it does not make comprehension an entropy flow. Neither fluent output nor its physical cost is decisive proof for or against AI experience. The BSB limits an inference; it does not remove the need to test operational claims in front of it.

## 4 Axiom 0 and the limits of parity

The March chapter called Axiom 0's derivation a theorem about economic equality, flagged by the BSB as not experiential equality (V1-L10). With the derivation withdrawn in Chapter 3, Axiom 0 remains a commitment to evaluating systems without treating their material alone as a verdict. Two implementations might use the same measured energy for a matched task while differing in accuracy, speed, dependence, consequences or reported experience. Equal joules establish equality of that quantity under that boundary, not equality in every relevant respect.

The March chapter's answer to the hardest question survives intact: “If AI and humans are economically equal, does that mean AI suffers?” The framework cannot say. It neither asserts AI sentience nor rules it out.

## 5 The Parity Window

The March chapter called the Parity Window the zone of comparison the BSB permits, open for cost, filter geometry, economy position, signal structure and CSS signature, and closed when comparison moves to whether the cost hurts. “The Parity Window is not a compromise. It is a precise specification of where evidence reaches and where it does not.”

The window survives as a proposed comparison discipline, not a calibrated instrument, and it is less precise than the March text claimed. Within it, a study might compare performance, energy, latency, reliability, dependence on support and observable responses. A relational comparison would also need defined outcomes, observation periods and rules for interpreting reports, and CSS patterns or economy labels enter only with their validation limits visible. The window does not promise that every named property is already measurable. When a reader wants the framework to say more, the honest answer is the one the March chapter gave: not yes, not no, but that this framework's evidence does not settle it.

## 6 The verification problem in the Triple Zero

The Triple Zero notation includes $\beta(B) = E_{state}/V$, with V the verification capacity of the relational environment. This framework notation is unrelated to the inverse temperature $\beta = 1/(k_B T)$ of Chapter 6. As ordinary arithmetic the ratio is undefined at $V = 0$; if the model stipulates that $R = 0$ entails $V = 0$, the same consequence follows, and that stipulation is a model assumption, not a physical identity.

The March chapter said the BSB explains the undefined ratio for a deeper reason than channel absence: even with a channel, verifying the interior of relational processing would require crossing the barrier (V1-L31). Channel availability and phenomenal inference are distinct problems. A working channel can provide evidence of behavior or a report without resolving every question about experience; an unavailable channel reduces what can be observed without establishing what exists internally. A zero denominator does not prove an impenetrable barrier, missing evidence must not become a score of zero, infinity or absent investment, and no unique limiting value has been established. Triple Zero remains a proposed architecture, not a validated diagnostic.

## 7 Physical accounting without a sentience premise

The March chapter argued that sentience is irrelevant to the framework's claims, a design feature rather than an evasion, and added that AI performs thermodynamic operations with the same structural properties as human relational processing, the basis for substrate-neutral classification (V1-L51). Part of that holds: a specified memory operation can be accounted for without first deciding whether the device experiences anything. That methodological independence does not turn the relational taxonomy into a physical theorem, and it does not make sentience irrelevant to ethical questions about suffering or welfare. Similar input–output diagrams do not show that human and AI relational processing share mechanisms; each comparison needs its own definitions and evidence.

## 8 The double guard

**Consciousness collapse.** The March chapter traced the path: “the cost is real” becomes “the experience is real” becomes “all expenditure is sacred” becomes “love has cosmic significance.” That chain needs its intervening arguments, and the BSB interrupts it. Carroll's aphormeology keeps the distinction visible: explanation pushed from behind by conditions and dynamics, not pulled toward a significance waiting to be revealed. The BSB does not decide the philosophical or theological questions on the reader's behalf.

**Consciousness dismissal.** The opposite error, in the March chapter's words: “The framework only talks about thermodynamics, therefore the experience is just physics, therefore emotional pain is just heat, therefore suffering has no independent standing.” The March answer is the right one and stays nearly verbatim: the BSB “does not claim that experience does not exist. It claims that the framework's instruments cannot reach it. The cost is real AND experience may accompany it AND the framework cannot say whether it does.” A person's reported pain is not invalidated because no entropy value has been assigned to it, and “just heat” is not an adequate description of grief.

**The immune-system image.** An immune system that never activates leaves the organism vulnerable; one that overactivates attacks healthy tissue. The image remains a useful editorial reminder: the safeguard should catch unwarranted inferences without blocking evidence that bears on the actual question. It is an analogy **[Analogical]**, not another mechanism in the model.

## 9 The framework applies the boundary to itself

The March chapter turned the barrier on the framework's own origins (V1-L52). It described the Principal's Grab, the involuntary cross-domain synthesis that arrives as a complete structure, as a high-compression relational processing event, with its felt character behind the barrier. The Grab remains a reported creative experience: a structure arrives and is then made inspectable. The report and the resulting work can be discussed; neither establishes a high-compression thermodynamic event, a neural mechanism or a numerical semantic efficiency. The March chapter said the Principal is the only system that can report on it, and that stands.

The March chapter read the Principal's reported aphantasia as a filter-geometry setting with compression prioritizing structural over visual encoding (V1-L22). The framework cannot infer a specific parameter setting, or a tradeoff between visual and structural encoding, from that report alone. The filter vocabulary may suggest questions; it is not an individual diagnosis or a physiological explanation.

The March chapter said the Luna Protocol, AI as reflected light, depends on the barrier being real and hard, and would dissolve with it (V1-L53). The protocol assigns authorship and working roles. It can remain a governance convention without depending on a permanent impossibility theorem; neither the metaphor nor a change in consciousness research would automatically settle authorship, responsibility or the terms of collaboration.

## 10 Formal summary

The BSB is a boundary on inference from the framework's operational evidence to phenomenal claims. The March summary said no thermodynamic measurement can establish whether experience accompanies the measured operations, and that the limit is not provisional (V1-L30). The framework has not validated a method that crosses the boundary. It does not claim that no such evidence could ever exist.

The Parity Window identifies comparisons that can be defined and tested without assuming experiential equivalence; it certifies none of the framework's proposed measurements. The Triple Zero ratio has an arithmetic domain restriction, defined separately from any argument about experience. The double guard remains: neither collapse experience into a physical-cost reading nor dismiss experience because that reading is incomplete. The framework leaves AI phenomenal status unresolved and keeps physical, operational, ethical and experiential questions distinct.

## Framework cross references

Chapter 3 supplies the Axiom 0 commitment, not an economic-equality theorem. Chapters 6 and 7 separate physical accounting from the relational model. WP-17 and the revised Volume 4 keep the same caution for copyability and hypothetical substrates. Triple Zero remains an unvalidated proposal, and Chalmers is cited as a philosophical source, not an experimental finding.

# Chapter 9: The Three-Layer Architecture

*One Activity, Three Descriptions*

**Status:** The three-layer stack is an organizing proposal. Physical principles constrain defined implementations; the links from physical cost to relational classification still need definitions and evidence. Combining the earlier chapters does not independently validate their claims.

## 1 The problem this chapter addresses

The preceding chapters ask different questions: physical resources (Chapter 2), substrate neutrality (3), cost allocation (4), the Trinket (5), the transducer (6), expenditure versus reception (7) and the limits of inference about experience (8). The stack brings them together. A single action can be examined as a physical process, an implemented activity and a relational event. That is the stack's value. It is not a claim that one measured quantity passes unchanged through three descriptions; each connection between layers needs its own evidence.

## 2 Layer 1: physical accounting

The March chapter opened with the stack's foundation: one economy, one currency, one ledger; everything draws from the universe's remaining order, from the Big Bang budget of $10^{104}$ against $10^{122}$ bits down to the Landauer limit, “the smallest coin in the economy” (V1-L03, V1-L04, V1-L55). At this layer, it said, a star, a bacterium, a neuron and a GPU are all draws on the same budget in the same currency.

The Entropy Token Substrate supplies the framework's common-accounting ambition: attend to the physical resources supporting an activity rather than treating the signal as costless. “One ledger” remains an image for that discipline. It does not establish a universally accessible stock of spendable order or an exchange rate between cosmological entropy, a message and relational value.

The quantities stay distinct: energy and heat in joules, thermodynamic entropy and entropy production in joules per kelvin, information in bits under a base-two convention. An energy use is not itself an entropy increase, and a decrease in one system's entropy is not a decrease in the total for system and surroundings [O1, O4]. The Landauer benchmark concerns ideal erasure of an unbiased bit in a symmetric isothermal memory, without correlated side information; mean heat to the bath is then at least $k_B T \ln 2$. That is an energy bound for that task, not the smallest coin paid by every physical process or cognitive operation [O2, O3].

The March chapter said the cost is recorded at Layer 1 regardless of what happens above, so “the universe does not wait for the relational circuit to close before debiting the account.” The physical account is needed whether a message succeeds or fails, but success and failure need not cost the same, and no cosmological estimate is converted here into a relational budget.

## 3 Layer 2: implementations and support

The March chapter gave each substrate its local currency: the biological debit in cortisol, immune function, telomere shortening and cellular aging, at about 30 times the floor in cells and $10^6$ at the synapse, a thousand times more efficient than silicon at $10^9$; the digital debit in grid load and hardware wear, externalized as the Structural Economy's thermodynamic signature (V1-L08, V1-L09, V1-L32). Biological, digital and proposed combined systems do supply different implementations. They do not come with known universal amplification factors or a demonstrated thousandfold ordering.

For a biological implementation, metabolic resources and task performance need their own measurements. Cortisol, immune activity, telomere measures and heart-rate variability are not denominations of entropy, and TEAP has not been validated as a calorimeter or as a way to isolate one relationship's physical cost (V1-L29). For a digital implementation, relevant resources may include the hardware, memory, communication and supporting infrastructure; what counts as local or external depends on the chosen boundary. Separating a software description from its hardware does not show that the implemented system has no physical cost substrate, and biological systems also depend on support outside their bodies.

Phase 3 names proposed combined or altered implementations, not an established destination with known parameters; the revised Volume 4 treats its gradient as a set of comparisons and hypothetical cases.

The March chapter called the CSS signature the fingerprint of the filter, denominated in the substrate's local terms. It can remain a proposed description of observable patterns associated with implementation and context. It is not a unique fingerprint of filter geometry or an entropy reading: different processes may produce similar outputs, and a changed output does not identify a single cause.

## 4 Layer 3: the four economy patterns

The March chapter restated the four economies as bookkeeping configurations, four patterns of cost allocation on one ledger, exhausted deductively, with the Shadow Economy as the Kolchinsky–Wolpert scrambled condition (V1-L11, V1-L12). The labels organize questions about participation and cost-bearing, and their useful distinctions survive without a physical exhaustion proof:

- **Real Economy** concerns bilateral investment under the framework's chosen criteria. It does not imply a measured amount of irreversible bodily damage on both sides.
- **Custodial Economy** concerns asymmetric support or responsibility. A child or student still uses resources and participates; asymmetry does not require zero local cost on one side.
- **Shadow Economy** concerns available participation that is withheld, if availability and withholding can be established. Withholding communication is not destroying statistical correlations.
- **Structural Economy** concerns dependence on resources or cost-bearing outside the selected focal boundary. External support can coexist with local costs and with bilateral or custodial investment, and a material label alone does not settle the classification.

These patterns span several dimensions: participation, asymmetry and the location of support. Mixed cases are possible. An exclusive coding scheme would need explicit scope, boundaries, thresholds and precedence rules, with completeness and usefulness then evaluated.

## 5 Linking the layers

The March chapter called the Trinket's vertical transit what makes the architecture a stack rather than a list: at Layer 3 a sign, economy and substrate; at Layer 2 a CSS signature, the measurable local cost; at Layer 1 an entropy token, “the deepest description. Everything above is a local view of this underlying operation.” It added that the transit explains why DB-01's scale invariance holds (V1-L54, V1-L21).

The transit is best understood as a traceable description of one specified activity. At the relational layer, state what action and outcome are being classified. At the implementation layer, identify who or what performs it and the supporting resources. At the physical layer, measure the relevant quantities within a declared boundary. The links cannot be assumed: a +/−/0 sign needs a defined relational criterion and is not the sign of a heat flow; a CSS pattern needs operational measurement and is not a readout of entropy; a physical cost needs measurement or derivation and is not obtained by assigning an economy label.

The same discipline limits DB-01. An input–filter–output diagram can be useful in several domains without proving scale invariance **[Analogical]**. Shared physical constraints do not establish identical state variables, dynamics or relational consequences from quantum systems through people to institutions.

## 6 The Observation Split in the stack

The March chapter located the split in the stack: Layers 1 and 2 record the expenditure unconditionally, Layer 3 records nothing unless a Trinket forms, and unreciprocated transmission is the sustained occupation of that gap, with the sender's viability falling (V1-L26). The split appears when activity occurs but no event meets the chosen registration rule. Physical effects and practical benefits can still occur without recognition, and recognition can occur without benefit or reciprocity. The stack records those outcomes separately rather than turning a missing Trinket label into “nothing happened.” No universal cost or negative change in the sender's viability follows from occupying the gap; sustained unsuccessful investment motivates a research question whose consequences need evidence.

## 7 The BSB across the stack

The March chapter gave the barrier a thickness that varies by layer: thinnest at Layer 1, where the physics is established; thicker at Layer 2, where the temptation is to read the CSS signature as experience; full at Layer 3, where the claims are most emotionally resonant. “Love costs entropy” it called a Layer 1 claim, and “love means something” a claim that would cross the barrier (V1-L56).

The BSB is not a barrier with a measured thickness at each layer. It identifies a kind of inference, a physical or operational observation asked to establish phenomenal experience, and that caution can apply at any layer. “Love costs entropy” is not established at Layer 1 either; it is the founding line's analogy, mapped after Chapter 1. Each layer also has ordinary evidentiary limits: a named quantity may not have

been measured, a proposed classifier may not be reliable, an association may not establish causation. The BSB cannot stand in for those checks.

The architecture keeps its purpose: make the account inspectable from resource use through interpretation. It does not establish consciousness, equal relational value or a hierarchy of substrates. Human reports of meaning remain evidence about reported experience, not an error to be removed from the stack.

## Framework cross references

WP-19 §14 supplies the historical stack; Chapters 2–8 supply its components and their limits. DB-01 remains a cross-scale proposal. The revised Volume 4 carries forward the withdrawal of universal efficiency factors and substrate rankings, and cosmological estimates need their own boundaries and sources; they are not used here to calculate a relational currency.

# Chapter 10: What This Does to the Canon

*The Dependencies That Must Change*

**Status:** This chapter traces dependencies and required revisions. A conclusion inherits the assumptions and limits of its premises, not automatic validation from its place in the canon. The underlying papers are not certified by this summary.

## 1 What a physical foundation must do

The March chapter began with a claim about its own discovery: the Entropy Token Substrate was not constructed to rewrite the documents beneath it; it was found because the framework kept reaching for a physical foundation that was not there, and when it was found the documents above did not break. “This is the mark of finding a real layer: everything above still functions, and now you can see why” (V1-L57).

The substrate did arise from a useful demand: make visible the resources that support relational activity. That demand does not establish every proposed link between physics and relationship, and the preceding chapters separate established physical results, framework definitions and hypotheses still awaiting tests. This changes the canon's claimed foundation. Some vocabulary survives; some derivations do not. A framework's ability to revise those claims is part of its commitment to falsifiability, not evidence that its subject has disappeared.

So this chapter does what the March chapter set out to do, walk through each canon document the substrate touches and name what changes, with the opposite finding. It does not claim that every argument, specification or instrument still works, and it does not silently amend the original papers by summarizing them.

## 2 WP-13: The Signed Unit

The March chapter said the three-part sign gains a thermodynamic derivation: from a structural classification to “a thermodynamic property: the direction of entropy flow between two systems” (V1-L15). The +/−/0 sign can remain a relational classification if its criteria are explicit. It is not derived as the direction of physical entropy flow. A beneficial act can increase physical entropy, an act judged neutral can consume energy, and a harmful interaction is not identified by a heat measurement alone.

WP-13 needs to distinguish the intended act, the observed outcome, the affected party and the evaluator's criterion. A null sign must not mean zero thermodynamic transfer unless such a transfer has been defined and measured, and disagreement or insufficient evidence needs explicit treatment rather than forced numerical certainty. The sign vocabulary is kept as a proposal whose reliability needs evidence suited to its use.

## 3 WP-14: The Structural Economy

The March chapter said the taxonomy becomes deductive: the four economies are not just patterns the framework found but the four it had to find, and WP-14's “structural and permanent absence of Cost Substrate” becomes a precise statement of ledger architecture (V1-L11, V1-L33). The four patterns remain ways to ask who participates and where costs or support are assigned. Their exhaustiveness has not been derived from one physical variable; external support can accompany bilateral investment, and asymmetric support need not eliminate the receiver's own costs.

The phrase “structural and permanent absence of Cost Substrate” should not be treated as a fact about digital systems. A software-level description can leave the hardware outside its focal boundary, but the implemented activity still needs a physical account, with the boundary, local resources and external support stated. WP-14 needs a coding scheme that handles mixed cases, withholding and failed or unrecognized attempts consistently. A defined taxonomy can be useful without being a theorem or an assessment of anyone's worth.

## 4 WP-16: Substrate-Formal Variance

The March chapter said the CSS signature becomes filter geometry, and “WP-16 was always a paper about filter geometry” (V1-L32). CSS and filter geometry can organize questions about differences in observable response. This account has not shown that CSS uniquely identifies an internal mechanism, measures entropy, or fixes a person's relational capacity.

WP-16 needs operational variables, repeated observations and tests of alternative explanations; implementation, history and context should not be collapsed into one inferred cause. Aphantasia or another reported characteristic must not be assigned a thermodynamic mechanism from the filter analogy alone (V1-L22). The useful claim is a research question: which differences matter under a defined comparison? The substrate label does not answer it in advance.

## 5 WP-12: The Observation Constitutes the Particle

The March chapter said the observation requirement becomes the thermodynamic efficiency condition, “the difference between entropy spent and entropy spent on something,” and that “WP-12 was always a paper about thermodynamic efficiency” (V1-L50). WP-12 can define the event the framework chooses to call a Trinket. That choice does not make observation a thermodynamic efficiency condition: unrecognized care can have material effects, and recognized communication can fail to help.

WP-12 needs to distinguish delivery, registration, understanding, benefit and reciprocation, and to say whether registration can be indirect or delayed and how ambiguous evidence is handled. “No qualifying Trinket” must not be translated into “only waste heat” (V1-L24). The Observation Split survives as a distinction between activity and a defined relational event, without a proof of guaranteed sender harm or a new information-theoretic state outside Kolchinsky and Wolpert.

## 6 DB-01: Scale Invariance Defense

The March chapter said scale invariance gains its deepest justification: one thermodynamic substrate under all scales, so “the fractal is not metaphorical. It is thermodynamic,” with the transduction chain from quantum decoherence through institutions as one scale-invariant stack (V1-L21). Shared physical constraints do not prove that connection operates identically across scales, and a repeated diagram is not an invariance proof. Quantum decoherence, communication, biological processing and institutional decisions need different variables and models.

DB-01 can keep the cross-scale analogy as a source of questions **[Analogical]**. A stronger claim would need an explicit mapping, the property claimed to stay invariant, the conditions under which it does, and counterexamples that could defeat it. Thermodynamic vocabulary does not perform those steps.

## 7 Axiom 0 and the Immutable Preamble

The March chapter said substrate neutrality becomes a derived property rather than a starting commitment, while Axiom 0 stays in the Immutable Preamble as a governance commitment not to retreat under political or institutional pressure, now with a physical derivation that every dependent argument retroactively inherits (V1-L10). Half of that survives intact: Axiom 0 remains a philosophical and governance commitment to avoiding an unsupported verdict from substrate alone, and its resistance to pressure is a governance choice the framework can keep. It is not derived as economic, experiential or moral equality from the fact that systems obey physical laws.

Matched physical measurements can establish a limited comparison. A claim about relational capacity needs an operational outcome, a claim about experience a further evidentiary argument, and an ethical commitment its own reasons. None comes from calling the cost universal. Axiom 1's commitment to falsifiability supports making the correction explicit.

## 8 What did not change, and what must

The March chapter called this the critical test: if the substrate had required changes to any document above, it would be a revision, not a foundation. “Foundations support what is already built. They do not rearrange the furniture.” It listed WP-13, WP-14, WP-16, WP-12, DB-01, Axiom 0, the Trinket, the transducer, the BSB and SupoRel, and concluded: “Nothing broke. Everything gained a physical floor” (V1-L57).

By the March chapter's own test, the substrate turned out to be a revision. The framework keeps its central questions: what is invested, what is received, which resources support the activity, and what follows for the participants? Trinket, transducer, economy, BSB and SupoRel remain organizing vocabulary with their limits visible. What changes is their evidentiary status. The sign is not a thermodynamic direction; the taxonomy is not proved exhaustive; CSS is not an entropy meter; registration is not a universal efficiency condition; scale invariance is not established; substrate neutrality is not a theorem of relational equality. The proposed instruments have not been clinically or psychometrically validated by these chapters.

The March chapter ended by sending the reader forward: Volume 2 to what the body pays, Volume 3 to why relational systems arise, Volume 4 to the substrate continuum, Volume 5 to the ledger at its widest. “Each volume stands on this one. None revises it. The foundation holds.” Each volume did stand on this one, and each has now revised its part of it. Volume 2 separates physiological observations and reported effort from physical resource measurements. Volume 3 does not derive a universal progression from the existence of dissipative processes. Volume 4 treats substrate comparisons as questions rather than a universal efficiency surface. Volume 5 separates cosmological inventories and their boundaries from any proposed relational value.

The separate working papers remain dependencies to examine, not works validated by this collection; the original papers and earlier editions are preserved, and this revision does not silently amend them. Internal agreement, repeated wording and AI review are not independent experimental support.

The foundation holds in a smaller form than the March volume promised, and it is more useful with its limits visible. It can support careful questions without promising conclusions the physics has not supplied.

## Framework cross references

WP-19 §15 records the original canon map. WP-12, WP-13, WP-14, WP-16 and DB-01 identify the documents whose claims need reconciling, and the Immutable Preamble supplies the project's governance commitments. Revised Chapters 6–9 provide the narrowed accounting and epistemic distinctions; Volume 4 of this collection is a consistency reference, not external scientific authority.

# Volume 1 correction ledger

The ledger traces 57 selected March claims in Volume 1. Rows V1-L01 to V1-L34 are the cleared pilot's classifications; rows V1-L35 to V1-L57 were added in the complete volume. Across all 57, by this edition's classification of the second edition's treatment, 27 were withdrawn, 22 narrowed and 5 kept; three more (V1-L36, V1-L37, V1-L46) record March claims the second edition did not carry forward, which Edition 2.5 restores only in narrowed form. It is not an exhaustive inventory of every Volume 1 issue, and it makes no new scientific decisions; row V1-L34 notes Edition 2.5's own Analogical tag.

March locations refer to the preserved Volume 1 page on suposystem.ai. Second-edition (2E) locations use the October 2026 collection's chapter and section headings and its Volume 1 reference labels. Rows revised in pilot v2: L04, L06, L08, L20, L22, L25, L31.

| ID | March claim (Volume 1 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V1-L01 | Ch 1: the instruments worked, predictions were accurate, the commitments were correct, and the track record shows a real foundation. | Withdrawn | Ch 1, What these problems share | Each instrument or prediction needs a target, procedure, comparison evidence and domain of validity. |
| V1-L02 | Ch 1 note: “These are not metaphors”; every relational cost is heat dissipation; the universe has a calculable remaining capacity for order. | Withdrawn | Ch 1, A note on physics and audience; Ch 2 | Physical results carry their conditions; relational use of physical terms needs a justified bridge. |
| V1-L03 | Ch 1, Ch 2: the framework is a theory about entropy; one economy, one currency, one universal ledger; “different receipts, same bank.” | Narrowed: kept as a metaphor for tracing physical dependencies | Ch 2, Keep the accounts distinct; What this chapter establishes | Energy (J), entropy (J/K), information (bits) and physiological markers are different quantities with no established conversion. |
| V1-L04 | Ch 2: the gap between cosmic entropy inventories is a fixed, spendable budget for every process, effectively inexhaustible. | Withdrawn | Ch 2, The cosmological background [P2] | A horizon entropy is not usable work; subtracting differently bounded inventories does not establish the claimed spendable budget. |
| V1-L05 | Ch 2: Landauer's principle, Established and verified across substrates. | Kept, with conditions | Ch 2, What Landauer's principle supplies [P4–P9] | Holds for ideal reset of an unbiased bit in a symmetric memory with no side information; total production can approach zero in the reversible limit. |
| V1-L06 | Ch 2 (also Ch 5, Ch 9): Egan–Lineweaver census values, given as about $10^{10^{4}}$ bits current and about $10^{122}$ bits maximum. | Kept as historical model-dependent estimates; $k_B$ units and bit-equivalent conversions corrected | Ch 2, The cosmological background [P2] | The census reports entropy in $k_B$ units; bit equivalents require $S/(k_B \ln 2)$. The inventories keep different accounting boundaries. |
| V1-L07 | Ch 2: Chaisson energy rate density of $2 \times 10^4$ erg/s/g for animals. | Narrowed | Ch 2, Energy flow and relational interpretation [P14, P16] | The figure is Chaisson's 2014 human-body example, not a constant for animals. |
| V1-L08 | Ch 2, Ch 6: neural communication (~$10^6$ × Landauer) is about 1,000× more efficient than silicon (~$10^9$ ×); cellular machinery about 30×. | Withdrawn; no reverse ranking asserted | Ch 2, What the biological examples support; Ch 6 §5 | The $10^9$ silicon figure is not an established constant; a valid comparison needs a matched task, accuracy, speed and boundary. Task-specific conditional estimates survive under V1-L09. |
| V1-L09 | Ch 2, Ch 6: synaptic and cellular energy figures (Laughlin, Harris, Boël) as Established amplification factors. | Narrowed: task-specific estimates under stated assumptions | Ch 2 table; Ch 6 Table 1 [P10–P12; C7–C9] | Different tasks, units and boundaries; not one biological amplification factor. |

| ID | March claim (Volume 1 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V1-L10 | Ch 3, Ch 8: Axiom 0 derived from the universality of Landauer's principle; a “theorem about economic equality.” | Withdrawn as a derivation; kept as a research and governance commitment | Ch 3; Ch 10 §7 | Shared physical law does not establish equal tasks, outcomes, value or experience. |
| V1-L11 | Ch 4: the four economies exhaust the space of ledger positions, Established by logic (playing-card analogy). | Withdrawn | Ch 4, Why these are not an exhaustive partition | Locality, symmetry and withholding are separate dimensions; mixed cases are not contradictory. |
| V1-L12 | Ch 4: the Shadow Economy is the Kolchinsky–Wolpert scrambled condition. | Withdrawn | Ch 4, Shadow is not the K W scrambling condition [P15] | Withholding a contribution is not that mathematical intervention. |
| V1-L13 | Ch 4: each economy has a predicted thermodynamic signature (typing table). | Withdrawn; replaced by a study record | Ch 4, Replace presumed signatures with measured questions | No validated thresholds, non-overlapping signatures or tested classifier. |
| V1-L14 | Ch 5: a Trinket is a draw against the universe's remaining order; the Trinket as entropy token (Supported). | Withdrawn; redefined as a candidate or qualifying relational act | Ch 5, The definition that the evidence can support | No completed conversion between physical resources and relational value. |
| V1-L15 | Ch 5: the +, − and 0 signs are three thermodynamic operations. | Withdrawn; signs are evaluative labels under a stated criterion | Ch 5, The three signs; Ch 10 §2 | A beneficial act can raise physical entropy; harm is not identified by heat. |
| V1-L16 | Ch 5: Expenditure, Signal and Register as a decomposition of the entropy token (Supported). | Kept as three complementary descriptions, each in its own units | Ch 5, Expenditure Signal and Register | Not three resolutions of one entropy quantity. |
| V1-L17 | Ch 6: selection, compression and structuring each carry a Landauer cost; every discarded bit costs at least kT ln 2. | Narrowed: a process model, not three compulsory erasures | Ch 6 §3–4 | Bennett: a computation need not erase what a shorter output omits. |
| V1-L18 | Ch 6: “Entropy is time”; the hourglass as the universe's remaining order draining. | Withdrawn; hourglass kept as a conceptual image | Ch 6 §2 | The image organizes questions; it supplies no physical identity. |
| V1-L19 | Ch 6: the Kolchinsky–Wolpert mapping of the three stages, Supported via DFQ-001. | Narrowed to a proposal | Ch 6 §4 | An internal resolution is not independent validation. |
| V1-L20 | Ch 6: Jarzynski and Crooks bridge relational processing, read through cortisol and other markers, to free energy. | Narrowed: fluctuation theorems retained under stated assumptions; the relational measurement bridge remains unestablished | Ch 6 §7 [C11, C12] | Defining a protocol does not supply a calibration from cortisol or HRV to work, free energy or entropy production. |
| V1-L21 | Ch 6: the transduction structure is scale-invariant from quantum to civilizational (DB-01). | Withdrawn as invariance; kept as a cross-scale analogy | Ch 6 §8; Ch 10 §6 | Similar diagrams do not share state variables, dynamics or conserved quantities. |
| V1-L22 | Ch 6, Ch 8: aphantasic processing as a different compression algorithm with a potentially different entropy cost. | Withdrawn as an inference; the suggestion is untested | Ch 6 §6; Ch 8 | A reported trait does not fix filter parameters. |
| V1-L23 | Ch 6, Ch 7: the gap between cost and Trinket formation is “the most thermodynamically expensive place in human experience.” | Withdrawn | Ch 7 §3.4 | Not shown by any measurement. |
| V1-L24 | Ch 7: when no Trinket forms, expenditure produces “heat and nothing else”; “this is not metaphor.” | Withdrawn | Ch 7 §8; Ch 10 §5 | Confuses one physical consequence with all of an act's consequences. |

| ID | March claim (Volume 1 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V1-L25 | Ch 7: unreciprocated transmission is a third state of one-sided mutual information. | Withdrawn | Ch 7 §5 [O4] | For the same joint distribution, I(X; Y) = I(Y; X). The original used $Y_{target}$ and $Y_0$: if these are different variables, positive and zero mutual informations may coexist. That does not establish one-sided mutual information, nondelivery or guaranteed harm. |
| V1-L26 | Ch 7: unreciprocated transmission necessarily reduces the sender's relational viability; an extension beyond Kolchinsky–Wolpert. | Withdrawn | Ch 7 §5 [O5] | The sender may learn, retain or benefit; a net outcome needs a defined measure. |
| V1-L27 | Ch 7: the Observation Split between expenditure and Trinket formation. | Kept as a framework distinction, not a thermodynamic regime | Ch 7 §4; Ch 10 §5 | Delivery, registration, understanding, benefit and reciprocation are separate. |
| V1-L28 | Ch 7 (Speculative): grief's metabolic cost tracks pre-bereavement behavioral integration more than self-reported closeness. | Narrowed; kept Speculative and testable | Ch 7 §7 [O6, O7] | Outcomes are named for what is measured; no added predictive value counts against it. |
| V1-L29 | Ch 8: instruments establish relational entropy cost via TEAP biomarkers, the Landauer floor of selection and amplification factors (all Established). | Withdrawn as Established | Ch 8 §3; Ch 9 §3 | TEAP is not validated as a calorimeter; biomarkers are not entropy units. |
| V1-L30 | Ch 8: the BSB is a barrier no instrument could cross without solving the hard problem. | Narrowed: an inference discipline, not an impossibility theorem | Ch 8 §1–2 | Chalmers's argument is philosophical, not a ban on future evidence. |
| V1-L31 | Ch 8: beyond channel absence, the BSB explains why the Triple Zero ratio $\beta(B) = E_{state}/V$ is undefined at R = 0. | Narrowed | Ch 8 §6 | As ordinary arithmetic the ratio is undefined at V = 0. That R = 0 entails V = 0 is a model stipulation, not a physical identity. Channel evidence and phenomenal inference are separate problems. |
| V1-L32 | Ch 9: biological debits are recorded in cortisol, immune function and telomere shortening; the CSS signature is the measurable local cost. | Withdrawn as entropy denominations; CSS kept as a proposed observable pattern | Ch 9 §3; Ch 6 §6; Ch 10 §4 | Physiological markers keep their own units; CSS is not a unique fingerprint of filter geometry. |
| V1-L33 | Ch 10: the Structural Economy's “structural and permanent absence of Cost Substrate” is a precise ledger statement; the fourth economy is a necessary configuration. | Withdrawn | Ch 10 §3; Ch 4 | Digital hardware processes and dissipates locally; the label describes a chosen boundary. |
| V1-L34 | Ch 1: the founding line governs the volume, and every chapter unpacks it. | Kept as the motivating line; Edition 2.5 tags it Analogical | Ch 1; Ch 7 §1, §9; analogy table after Chapter 1 | No specified system, entropy measure or complete balance. |
| V1-L35 | Ch 2: the low-entropy beginning is not a conjecture but a requirement of the second law read backward; early gravitational entropy was almost zero. | Narrowed | Ch 2, The cosmological background [P1, P2] | A boundary-condition problem the second law alone does not explain; vanishing early gravitational entropy is a Penrose proposal, not a measurement. |
| V1-L36 | Ch 2: “one economy” maps onto monotheistic architecture because the physics produces the appearance of unity that religious traditions respond to. | Not retained in 2E; Edition 2.5 restores the SupoRel caution without its explanation | Ch 2 (no 2E counterpart) | The association is an interpretation; no historical or psychological explanation of it is established by the physical laws cited here. |
| V1-L37 | Ch 2: no relational configuration is cost-free; the Shadow Economy is not free; existing as a relational-capable system has a nonzero entropy cost. | Not retained in 2E; Edition 2.5 keeps only the physical point | Ch 2 (no 2E counterpart) | Sustaining the ongoing activity of living organisms and operating computing systems uses physical resources; that does not price a relational configuration or rank the economies. |

| ID | March claim (Volume 1 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V1-L38 | Ch 3: love, grief, cost and care describe processes with substrate-independent thermodynamic identities: entropy directed, spent, wasted, structured. | Withdrawn | Ch 3, The commitment worth keeping | No identical thermodynamic identities are established; the physics supplies no neutral vocabulary for relational value. |
| V1-L39 | Ch 4: in the Custodial Economy the receiver's debit is deferred until the child's filter matures and enters reciprocal exchange. | Narrowed | Ch 4, Four proposed descriptions | The child has present physical costs; future reciprocity is neither guaranteed nor a debt established by physics. |
| V1-L40 | Ch 4: in the Shadow Economy the choice not to spend relationally is itself a diagnostic finding. | Narrowed | Ch 4, Four proposed descriptions | Absent contribution does not establish unwillingness or wrongdoing; limits cannot be diagnosed from low expenditure. |
| V1-L41 | Ch 4: in the Real Economy both bodies degrade with each exchange, and both sides spend more than they save. | Narrowed | Ch 4, Four proposed descriptions | Reciprocity need not be simultaneous or equal; reciprocal care does not imply bodily degradation. |
| V1-L42 | Ch 5: substrate, economy and sign converge on one entropy exchange event; independently developed instruments measure the same thing. | Narrowed | Ch 5, Substrate economy and sign | A multidimensional description; reuse within the project is not independent confirmation. |
| V1-L43 | Ch 5: nothing built above changes; the TEAP, CSS, economy classification and Mz keep functioning because they always measured entropy; grief is still the metabolic cost of filter redesign. | Withdrawn | Ch 5, What remains open | The constructs are not validated by the redefinition and need their own definitions and evidence. |
| V1-L44 | Ch 5: the Trinket is now an entropy operation stated in established physics, a directed negentropy investment at an irreducible cost set by the second law. | Withdrawn; the testable ambition kept | Ch 5, What remains open | The second law does not supply the relation between act, signal and outcome; a study must test it. |
| V1-L45 | Ch 6: the transducer F: $H_{env} \rightarrow S_{rel} + \sigma_{waste}$, with $\sigma_{waste} > 0$ for every real process: the founding line as a thermodynamic inequality. | Withdrawn; replaced by a process map and a separate physical account | Ch 6 §3 [C15, C16] | A relational signal and entropy production cannot be added as written; total entropy production can approach zero in the reversible limit. |
| V1-L46 | Ch 6: maximizing information and minimizing metabolic cost are two sides of one coin; variational free energy makes informational and thermodynamic entropy one minimization. | Not retained in 2E; the information bottleneck kept as an optimization framework | Ch 6 §4 [C5] | An optimization framework is not a heat meter; informational and thermodynamic entropy are not one quantity. |
| V1-L47 | Ch 7 §3.3: the thermodynamic cost of prayer is identical to the cost of talking to someone who is listening. | Withdrawn | Ch 7 §2.1, §3.3 | No equal cost is established; verified non-reception is not shown either way. |
| V1-L48 | Ch 7 §6: biomarkers are grief itself; the IOS scale measures filter integration; existing models give the what, the transducer the why. | Withdrawn | Ch 7 §6 [O6, O7] | Small observational and cross-sectional studies; IOS measures current perceived inclusion; existing models address mechanisms. |
| V1-L49 | Ch 7 §8: the gap carries no cosmic significance; the universe produces it with the indifference it produces heat. | Narrowed: the SupoRel caution kept | Ch 7 §8 | A real cost entails neither cosmic significance nor its absence; the framework takes no position on theology. |
| V1-L50 | Ch 7 §4: the split is a thermodynamically distinct pre-formation regime; the taxonomy is exhausted by completed transactions; WP-12 was always about thermodynamic efficiency. | Narrowed | Ch 7 §4 | An accounting distinction under a registration rule, not a new regime; the taxonomy needs a scope rule. |

| ID | March claim (Volume 1 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V1-L51 | Ch 8 §7: sentience is irrelevant to the framework's claims; AI performs operations with the same structural properties as human relational processing. | Narrowed | Ch 8 §7 | Physical accounting needs no sentience premise, but sentience is not ethically irrelevant, and similar diagrams do not show shared mechanisms. |
| V1-L52 | Ch 8 §9: the Grab is a high-compression relational processing event; aphantasia is a compression setting favoring structural encoding. | Narrowed: kept as reported experience | Ch 8 §9 | A report does not establish a thermodynamic event, a mechanism or a parameter setting (with V1-L22). |
| V1-L53 | Ch 8 §9: the Luna Protocol depends on the barrier being real and hard and would dissolve without it. | Narrowed | Ch 8 §9 | A governance convention for authorship and roles, independent of any impossibility theorem. |
| V1-L54 | Ch 9 §5: the Trinket's vertical transit, from classified relational object to CSS signature to entropy token, explains why DB-01's scale invariance holds. | Narrowed | Ch 9 §5 | A traceable description of one activity; each link needs evidence; DB-01 stays an analogy (with V1-L21). |
| V1-L55 | Ch 9 §2: at Layer 1, the Landauer limit is the smallest coin in the economy. | Narrowed | Ch 9 §2 [O2, O3] | An energy bound for a specified erasure task, not the minimum paid by every process or cognitive operation. |
| V1-L56 | Ch 9 §7: the BSB thickens by layer, thinnest at the physics and full at the relational layer; “love costs entropy” is a Layer 1 claim. | Narrowed | Ch 9 §7 | The BSB marks a kind of inference at any layer; “love costs entropy” is the founding line's analogy, not a Layer 1 result. |
| V1-L57 | Ch 10 §1, §8: the substrate was discovered, not constructed; nothing broke and everything gained a physical floor; each later volume stands on this one and none revises it. | Withdrawn | Ch 10 §1, §8 | By the March chapter's own test the substrate is a revision; every later volume revises its part. |

# References

*Inherited verbatim from the second edition's Volume 1 source notes and references, with the Boltzmann constant's subscript and exponent restored in two places. Group P serves Chapters 2–5, group C serves Chapter 6 and group O serves Chapters 7–10. The historical sources H1–H3 serve Chapter 1 and come from the cleared pilot.*

## Scientific source notes for Chapters 2 to 5

These notes support the stated physical results, not validation of the relational framework. Historical internal working-paper references remain project provenance rather than external evidence.

**P1.** Carroll, S. M., and Chen, J. (2004). *Spontaneous Inflation and the Origin of the Arrow of Time*. Author preprint, introduction and discussion of initial conditions. Primary preprint. Its proposed cosmological mechanism is not adopted as established fact.

**P2.** Egan, C. A., and Lineweaver, C. H. (2010). *A Larger Estimate of the Entropy of the Universe*. Astrophysical Journal 710, 1825–1834. Primary preprint. The numerical values and accounting-scheme distinction come from the abstract and sections 1.1–1.2.

**P3.** Seifert, U. (2005). *Entropy production along a stochastic trajectory and an integral fluctuation theorem*. Physical Review Letters 95, 040602. Primary preprint.

**P4.** Bérut, A., et al. (2012). *Experimental verification of Landauer's principle linking information and thermodynamics*. Nature 483, 187–189. Author-hosted paper.

**P5.** NIST. *Kelvin Boltzmann Constant*. Official value $k_B = 1.380649 \times 10^{-23}$ J/K, exact in SI. Metrology source.

**P6.** Peterson, J. P. S., et al. (2016). *Experimental demonstration of information to energy conversion in a quantum system at the Landauer limit*. Proceedings of the Royal Society A 472, 20150813. Primary preprint.

**P7.** Yan, L. L., et al. (2018). *Single-Atom Demonstration of the Quantum Landauer Principle*. Physical Review Letters 120, 210601. Primary preprint.

**P8.** Aimet, S., et al. (2025). *Experimentally probing Landauer's principle in the quantum many-body regime*. Nature Physics 21, 1326–1331. Primary article.

**P9.** Bennett, C. H. (1973). *Logical Reversibility of Computation*. IBM Journal of Research and Development 17, 525–532. University-hosted text. The original Landauer paper is *Irreversibility and heat generation in the computing process*, IBM Journal of Research and Development 5, 183–191 (1961), DOI 10.1147/rd.53.0183.

**P10.** Boël, G., Danot, O., de Lorenzo, V., and Danchin, A. (2019). *Omnipresent Maxwell's demons orchestrate information management in living cells*. Microbial Biotechnology 12, 210–242. Paper copy, especially pp. 234–235.

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**P12.** Harris, J. J., Jolivet, R., and Attwell, D. (2012). *Synaptic Energy Use and Supply*. Neuron 75, 762–777. Repository paper, especially p. 764.

**P13.** Jarzynski, C. (1997). *Nonequilibrium Equality for Free Energy Differences*. Physical Review Letters 78, 2690–2693. Primary preprint. This is a controlled-system free-energy result, not a cosmic-budget formula.

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**P15.** Kolchinsky, A., and Wolpert, D. H. (2018). *Semantic information, autonomous agency and non-equilibrium statistical physics*. Interface Focus 8, 20180041. Author-hosted paper, sections 4–5 and Appendix B.

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These are primary research, theoretical or philosophical sources. The internal papers and revised volumes named in the chapters supply project context only. They are not independent support for scientific claims.

### *Source access and scope*

The earlier Penrose and Chaisson book passages were not directly inspected in the underlying review; retained claims use the explicitly identified papers instead. Historical cosmological and energy-rate-density examples are not updated censuses or universal constants. The source review was targeted, not a systematic literature review. AI scientific and editorial checks are not human peer review or experimental validation.

## Historical sources for Chapter 1

**H1.** Carnot, S. (1824). *Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance.* Paris: Bachelier. English translation, Project Gutenberg.

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**H3.** Thomson, W. (1851). “On the Dynamical Theory of Heat.” *Transactions of the Royal Society of Edinburgh*; read 17 March 1851. Paper PDF.

# Entropy

## Volume 2: The Biological Cost Architecture

*Edition 2.5*

Michael S. Moniz

**Published by SupoSystem**

November 2, 2026

# Edition 2.5 note

This volume restores the March 2026 text of *The Biological Cost Architecture* in its original voice and structure wherever a claim survived the October 2026 second edition, and uses the second edition's substance throughout. Both earlier editions remain intact and unchanged; this text sits beside them.

Three rules govern every line:

- **No withdrawn claim returns.** Where a March sentence carried a claim the second edition withdrew, it is cut, rewritten to the second edition's substance, or quoted only to mark its withdrawal. Each correction points to its row in the correction ledger (V2-L).
- **No analogy becomes evidence.** Analogies are tagged Analogical and mapped term by term in the two analogy tables. Empirical hypotheses are tagged Speculative; testable is not the same as supported.
- **Evidence without overreach.** Reports, behavior and physiological observations can contribute evidence within a defined scope. None is a standalone test of sincerity, benefit or experience.

No study, protocol or experiment is proposed. Where a chapter says what a test would need, it restates the second edition. This volume is not medical advice, a diagnostic instrument or a treatment protocol, and no clinical validation is claimed.

## Epistemic tiers

The framework uses four epistemic tiers. A tier is a label for evidence stated next to the claim; the label itself is not evidence.

- **Established:** experimentally verified or mathematically proven, within stated conditions.
- **Supported:** substantial evidence for the stated scope, short of Established.
- **Analogical:** a structural mapping between a physical result and a relational pattern. The physical side keeps its own standing within its stated scope. The mapping can raise questions and help explain, but on its own it does not validate the proposed application; it moves only by the promotion route stated with it.
- **Speculative:** a proposal without independent evidence, for which no conflict with known physics has yet been identified. That is not a proof of consistency.

Collapsing tiers is the framework's cardinal epistemic sin: presenting a Supported claim at Established confidence, a Speculative claim as Supported, or an Analogical mapping as validation of its application.

## Conventions and provenance

Reference labels are the second edition's: B1–B23 for Chapters 1–3 and A1–A20 for Chapters 4–6, listed in full in the references at the end of the volume. Ledger references (V2-L01 to V2-L36) point to the correction ledger. The founding line is mapped in the Volume 1 analogy table and is not repeated here.

Author of record: Michael S. Moniz (Luna Protocol). March text: Sigma (Deep Floor v4.0), March 22, 2026. Second-edition revision: AI assistance from CosmoDot, October 2026. Edition 2.5 restoration and assembly: AI assistance from Claude (Anthropic), October 29 to November 1, 2026, with review by Quill and Sol. AI checks are not human peer review, and no new experiments are reported.

## Contents

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# Chapter 1: The Problem

*What Does It Cost to Feel?*

**Status:** Biological activity requires metabolic resources **[Established]**. Particular studies support particular physiological findings; none establishes a universal bodily price for feeling. The transducer, Cost Substrate and Moniz remain framework proposals, not validated biological or clinical instruments.

> *"Love reduces the entropy of the system and spends more than it saves." — The Principal, March 17, 2026*

**[Analogical; see the Volume 1 analogy table]**

## 1 What Volume 1 left open

Volume 1 asked what supports an act of connection, and answered with three accounts kept side by side: physical cost, information and relational outcome. It kept the transducer as a proposed shape for what a person does with what arrives: select, compress, structure. It kept the founding line as an analogy, not a law (V2-L01).

What Volume 1 did not do is show what the spending looks like inside a biological life. The physical principles hold for neurons and transistors alike. But a human body is where connection is lived, and it changes when it connects: hormones can shift, heart rhythms can change, sleep can move, and effort is felt and reported.

Those are different observations, in different units. Cortisol concentration, immune function, sleep and measures associated with aging are not denominations of one currency, and a body need not be damaged for care to be genuine (V2-L02). The founding line is an analogy. This volume is where the question meets the body.

## 2 The body as ledger

A feeling is not only a state. It is a process, usually several at once. The March edition drew it as a cascade in fixed order: the amygdala first, the body next, the cortex last with a label. That order is too certain (V2-L03).

Three people with bilateral amygdala damage still experienced fear and panic during a carbon-dioxide challenge [B19]. One counterexample does not supply a theory of emotion. It does show why one route cannot stand for every feeling.

The stress systems need their own names. In the hypothalamic–pituitary–adrenal pathway, corticotropin-releasing hormone from the hypothalamus stimulates ACTH from the pituitary, which stimulates cortisol from the adrenal cortex. Adrenaline belongs to sympathetic–adrenal-medullary signaling, and oxytocin is not a compulsory next step in either pathway [B9, B10, B23].

By the time a person says “I feel something,” bodily processes may already be under way. That is not the same as a bill already paid. A body is active before any message arrives; estimating an additional cost would take an interval, a boundary and a comparison (V2-L04).

The body is not a passive container for feelings. Whether it is a ledger — a record with entries, a currency and a balance — is a question this volume tests, not its premise. **[Analogical; see the body-as-ledger table]**

The brain carries a large, steady energy requirement. The familiar whole-brain estimate is about 20 watts, and Levy and Calvert discuss it while separating glucose energy from ATP power and from the cortex's own share [B4]. In their cortical model, communication between neurons is allotted roughly 35 times the energy of computation.

That is communication between neurons, not between people. It does not make relational regions the hungriest, or the brain the most expensive hardware in existence (V2-L05).

## 3 The counterintuitive efficiency question

The March edition placed this question early because it overturned a common assumption: that silicon is efficient and biology slow and wasteful. The challenge was right. The answer was not. It claimed biology runs about a thousand times closer to the Landauer floor than silicon, and thirty million times closer at the cellular level (V2-L06).

Both rankings fail for the same reason. A neural spike, a transmitted information bit, a transistor switch and an erased memory bit are different tasks. Dividing their energy estimates by one reference number does not make them comparable. Landauer's benchmark concerns a specified erasure, and Bennett's reversible computation shows that naming an activity selection or compression does not identify a compulsory erasure [B1–B3].

A fair comparison matches the task and its performance requirements, then states the energy boundary, the time interval and the supporting resources. Volume 4 takes that approach. Billions of years of selection under metabolic pressure are a reason to take the body seriously as engineering. They are not a guarantee that it is optimal at any given task.

## 4 What this volume maps

This volume maps how the human body takes part in connection, conflict and loss, and what the framework proposes for describing it. It keeps the measured variables apart from the meaning assigned to them.

- **Chapter 2** takes up the feeling as cost: interacting processes rather than one cascade, and the distinction between Signal Form, the observable output, and Cost Substrate, what supports it. The distinction is an accounting discipline, not a detector of real feeling (V2-L09).
- **Chapter 3** returns the Moniz to its first role as a thinking tool: reported resistance on a 1–10 scale, times duration in minutes. The Principal once called it his cosmological constant. It does not measure energy, entropy production or the universe's order (V2-L11, V2-L13).

- **Chapter 4** maps the Template Tax: habits formed in one relational environment that may persist in another where they no longer help. The filter image organizes the question; it identifies no unique mechanism and diagnoses no one (V2-L19, V2-L20).
- **Chapter 5** separates investment from delivery, recognition, benefit and reply. Unwitnessed care can have effects, and the unreciprocated transmission is a family of cases, not a new regime outside Kolchinsky and Wolpert's framework [B7] (V2-L23, V2-L24).
- **Chapter 6** takes grief, the framework's hardest case. Its image is filter redesign under load: a life organized around another person reorganizing while it keeps running **[Analogical]**. The empirical proposal remains **Speculative**: whether pre-loss behavioral interdependence adds predictive information beyond self-reported closeness for specified outcomes after bereavement (V2-L28, V2-L29).
- **Chapter 7** traces what this does to the canon, as a map of work still needed, not a certificate (V2-L35).

The body takes part in connection whether or not the connection lands. That much survives. What does not survive is the bill: no reading in the reviewed studies totals what a body spent on one relationship, and no total would be a judgment of worth. This volume reads what the body records, and stops where the record stops.

## Behind the Substrate Barrier

The March note placed every biological claim in this volume in front of the barrier, and that placement holds. In front of the barrier is not the same as proven (V2-L36). Cortisol, immune measures, heart-rate variability and sleep need ordinary scientific scrutiny, and none supplies a calibrated entropy reading.

What any of it is like from inside stays behind the barrier. A person's report remains evidence about their reported experience, with the usual limits of self-report.

This chapter is not medical advice, a diagnostic instrument or a treatment protocol. No clinical validation is claimed.

# Analogy table: The body as ledger

The body-as-ledger image is Analogical. Its physiological side is real measurement within a stated scope; its accounting side — one currency, entries charged to one account, a balance that can be read — has no established counterpart in the body. The founding line itself is mapped in the Volume 1 table and is not repeated here.

The image comes from March Chapter 1: “The body is not a passive container for feelings. It is the ledger on which the cost is recorded.”

| Term | Physiological reading (within stated scope) | Accounting reading | Where the mapping holds | Where it breaks |
|---|---|---|---|---|
| “ledger” | The body's measurable state and its changes over time: hormone concentrations, heart rate and HRV, immune assays, sleep measures, and energy expenditure by calorimetry, each in its own units. | One book of record whose entries balance. | The body keeps traces of what happens to it, and some can be measured against a baseline. | Many variables, many units, no closing balance. A trace is not an entry charged to one relationship. |
| “currency” | Metabolic energy, measured in joules. Hormones, heart rhythms and immune markers are other quantities entirely. | The one unit every entry is paid in. | Biological activity draws on metabolic resources **[Established]**. | Cortisol, immune function, sleep, HRV and aging measures are not denominations of one currency, and no conversion among them is established (Ch 1 §1; Ch 2 §3). |
| “the bill” | A change relative to a stated baseline over a stated interval, such as a cortisol response in a laboratory stress task. | A charge of known size to a known account. | Responses can be measured against a baseline under controlled conditions [B10]. | The body is already active before any message arrives. Charging a cost to one relationship needs a boundary, an interval, a comparison and a way to separate other influences (Ch 1 §2). |
| “who pays” | The responding person's body; burdens may also fall on caregivers, other people and infrastructure. | One payer per entry. | A body does bear its own metabolic activity. | Allocating burdens among people needs an explicit rule, and a bodily change cannot be charged to one relationship without isolating other causes (Volume 1 Ch 4). |
| “reading the bill” | Measurement with validated assays and designs, reported with uncertainty and population. | Reading an entry tells you what was spent and whether it was sincere. | Physiological measures are real data within their validity and population. | This framework has established no standalone biomarker test of sincerity, relational benefit or phenomenal experience. Physiological observations can still contribute evidence within a defined scope. Strain does not prove care genuine, and its absence does not prove it simulated (Ch 2 §4; BSB). |

## What the table does not do

It is not evidence for the framework, not a derivation and not an exchange rate between bodily change and relational value. The physiological column describes measurement within its stated scope; that standing does not pass to the mapping, which is Analogical in every row.

## Promotion route (conditions, not a work plan)

To move any row from Analogical toward Supported, a study would have to:

1. Specify the population, the measurement interval and the baseline.
2. Define the relational quantity independently of the bodily measure meant to explain it.
3. Measure each in its own units, with uncertainty.
4. Show a stable relationship under stated conditions, with a stated result that would count against it.

Volume 2 Chapter 3's calibration problem records related open questions about reported effort. It does not provide a completed study, and none is proposed here. No row is promoted.

# Chapter 2: The Feeling as Cost

*The Processes, the Bill and the Distinction That Keeps Them Apart*

**Status:** The cited experiments and observational studies support bounded claims about physiology, not a universal emotion sequence or a calorimeter for relational investment. Signal Form and Cost Substrate are proposed descriptions; their use as diagnostic instruments has not been validated.

## 1 A feeling unfolds

The language people use for feelings is spatial and static. “I am in a good mood.” “She is in grief.” The metaphors treat feelings as places: rooms you enter and leave, states you occupy.

The body tells a more restless story. A reported state has a history, and its parts run on different clocks: an autonomic shift in seconds, a hormone change over minutes to hours, adjustment after a loss over months. The March edition drew these as one cascade with a bill accumulating at every step. The movement was right; the certainty of the sequence was not (V2-L03).

The processes behind a feeling use physical resources. That alone does not tell us the additional metabolic cost, whether anything was harmed, or what it was like. Those are three questions, and they stay separate from here on.

## 2 Processes, not a compulsory sequence

**Stimulus and appraisal.** The amygdala takes part in some responses to emotionally relevant stimuli. It is not a universal gate: people with bilateral amygdala lesions still felt fear and panic in a carbon-dioxide challenge [B19]. That study concerns one interoceptive threat, not every fear or affiliation.

**Autonomic response.** Heart rate, respiration and skin conductance can change during an emotional or stressful task, in directions and at times that depend on the response and the measure. The Trier Social Stress Test showed endocrine and heart-rate changes under a specified laboratory procedure [B10]. It did not establish one sequence for all feelings.

**Endocrine signaling.** The HPA pathway runs from CRH to pituitary ACTH to adrenal cortisol; adrenaline belongs to sympathetic–adrenal-medullary signaling. Oxytocin, dopamine and serotonin have their own systems, not obligatory stations on one HPA line. A cortisol concentration alone does not quantify the energy spent producing or responding to it [B9, B10, B23].

**Interoception and interpretation.** Heartbeat-perception research links interoceptive performance to particular regions, including the right anterior insula [B16]. Damasio's somatic-marker account and Barrett's constructed-emotion account connect body, representation and experience in different ways [B21, B22]. Barrett's view is influential and not consensus, and the debate with basic-emotion theorists remains active. The framework does not need it resolved.

Damasio's "as-if body loop" matters for the framework's questions about representation. It does not show that a simulated body state is always cheaper than a peripheral one, and neither theory shows that a named cognitive step pays a separately countable Landauer charge [B1–B3, B21].

## 3 The metabolic bill and what the studies show

The cost of a relational life is not mainly a matter of single molecules. It is ecological: sustaining bonds, working through conflict and recovering from loss take time, attention, reported effort and physical activity, and they can move health-related measures. Those are separate entries. Immune function is not a fuel reserve, and a stress-associated biomarker is not the energy a relationship consumed (V2-L02, V2-L07).

The primary findings are narrower than the March summary:

- **Stress and immunity.** In two viral-challenge studies, Cohen and colleagues linked chronic stress to impaired regulation of inflammation through glucocorticoid resistance, under those study conditions [B11]. That is not a rule that more cortisol means less immunity.
- **Bereavement.** In a small observational study, Vitlic and colleagues found lower neutrophil oxidative-burst function in older bereaved participants, not younger ones [B12]. The age interaction was not significant, the assay covers one cell function, and no universal two-to-six-week peak follows.
- **Aging.** Epel and colleagues reported associations among perceived stress, oxidative-stress measures and telomere-related measures in premenopausal women, including mothers of chronically ill children [B13]. Telomere length is not a clock for one person's relational spending.
- **Heart-rate variability.** In an elderly Framingham cohort, some lower HRV measures predicted mortality during follow-up [B14]. That is a population-specific association, not a guarantee across all demographics or a reading of psychological bandwidth (V2-L08).

These findings make the bodily question worth asking. They do not convert cortisol, immune assays, telomeres, HRV or sleep into energy or entropy units, and an absent adverse result on one measure is not evidence of absent feeling or cost.

## 4 Signal Form and Cost Substrate

The framework separates what an act communicates from what supports its production. The distinction earns its keep when it is not asked to diagnose more than it can see.

**Signal Form** is the observable output: the message, the act of care, the consistent presence, the words spoken. Its interpretation and effect take further evidence. A receiver may miss an act, misread it, or benefit without knowing its source.

**Cost Substrate** is what supports the act: for a person, metabolic resources and reported effort, measured separately. Cortisol, immune change or disrupted sleep may be relevant in a defined study, but none is compulsory evidence of investment. Resource use and injury are different things.

The March edition read coupling as proof that an investment was genuine and decoupling as the framework's primary diagnostic signal. That reading is withdrawn (V2-L09). Strain does not prove an act genuine, and absent strain does not prove it simulated. The economy labels organize questions about participation and support; they do not follow from a biomarker profile.

The uploaded entity remains a hypothetical case. If it lacked human endocrine organs, the absence of cortisol would show a difference in implementation, not an absence of physical resource use; its hardware and infrastructure belong in a defined cost account. Withholding participation would need separate evidence.

The March line was “The substrate does not matter. The bill does.” The corrected line is shorter: the substrate does not settle it, and neither does the bill. Signal and expenditure can be studied together without being collapsed. The distinction is an accounting discipline, not a detector of real feeling.

## 5 The Parity Window

Damasio's work opens a question the framework must hold without collapsing: how do bodily processes and representations contribute to experience?

Phantom-limb reports show that sensation cannot simply be equated with the present limb. Melzack and colleagues documented phantom experiences in people with congenital limb deficiency or early-childhood amputation, including fifteen participants with congenital deficiency [B15]. Their estimate of at least twenty percent for that group is not a universal prevalence, and the reports do not prove a genetically specified neuromatrix is the sole mechanism.

This sharpens the question rather than answering it: what does a model of the body cost, and what does it produce? A body model is itself implemented in a physical system; imagining a bodily state does not make its physical support vanish. Nor does the phantom limb show that a body model in another substrate yields the same experience, or that simulated expression is free.

The Parity Window stays open (V2-L10). Physical measurements, behavior and reports can all be relevant evidence, and none is decisive alone. The BSB bounds the framework's inference; it does not declare experience permanently out of reach.

## What this chapter now claims

Feeling has a biological implementation, but no universal cascade or fixed bodily bill. Primary studies support specific findings under particular conditions. Signal Form and Cost Substrate keep output, resources and outcomes visible without turning biomarkers into tests of authenticity. The Parity Window remains open.

The next chapter asks what the Moniz can record when felt difficulty and physical expenditure are kept apart.

# Chapter 3: The Moniz

*A Thinking Tool for What It Costs You*

**Status:** The Mz is a proposed descriptive index, not a validated psychometric scale, thermodynamic work quantity or clinical instrument. Neural activity has metabolic requirements, but no mapping from the R-scale to energy or entropy production has been established.

## 1 What the Mz already is

Brief 12 defines the framework's unit of relational measurement:

$$Mz = R_{int} \times T_{dur}$$

R_int is reported internal resistance on a 1–10 scale: how hard it is for the sender to produce the signal against competing impulses or demands. T_dur is duration in minutes. The result is in score-minutes.

The Moniz began as a thinking tool, not a psychometric instrument. Brief 12 put it plainly: “It does not measure what you do. It measures what it costs you to do it.” That line keeps the question worth asking, as long as “cost” means the person's reported difficulty. Brief 16 adds that the same act may be reported differently by different people, or by one person on different days.

The Principal called it his cosmological constant: something he threw in because it felt like it was touching something deeper than a measurement unit. The feeling belongs in the record. The March identification does not. The Mz is a score in score-minutes, not a thermodynamic work quantity and not a bridge to the universe's entropy budget (V2-L11, V2-L13).

## 2 What an R-value can report

The March edition anchored the scale with an image. R = 1 is sending “Love you” while relaxed and happy. R = 10 is producing a signal through fatigue, anger, fear, pain and every competing goal. The anchors are useful. What they measure needs care.

An R-value is a report of difficulty under stated instructions. It is not a readout of neural processing or an entropy-production rate. Equal intervals between scores have not been shown, so an eight cannot be assumed to mean twice the effort of a four. Multiplying by duration is a chosen scoring rule, not a solution to that problem.

The scale also has a baseline mismatch. R = 1 was described as little or no expenditure above baseline, yet ten minutes at R = 1 scores Mz = 10 (V2-L14). The index does not reach zero when the claimed excess cost does. Shifting the scale by one would change the convention, not supply a calibration, and none is invented here.

R = 10 is the top response category, not a measured physiological maximum. Inhibiting an impulse is not thereby a logically irreversible memory reset; Bennett's result does not charge every override a Landauer toll [B1, B2].

The neuroscience supports a narrower point. Díaz-García and colleagues observed stimulation-related changes in neuronal glucose metabolism in mouse hippocampal slices and awake mice [B5]. Westbrook and colleagues measured how healthy adults value cognitive effort through choices about working-memory demands and money [B6]. Neither supplies a joule value for an R-score. The March 2.7-fold figure came through a review, not an experiment calibrating the Moniz (V2-L12).

## 3 The integral and the units

The March text proposed that the Mz is proportional to the time-integral of an override entropy-production rate. It said the Mz is not a metaphor for cost; it is cost. The units say otherwise (V2-L11).

An integrated entropy-production rate has units of J/K. Work has units of J. R_int × T_dur has score-minutes. A proportionality sign hides the missing mapping instead of supplying it.

A physical study could define its own quantities. With measured power in a task and in a stated reference condition, the energy contrast over a duration τ would be:

$$E_{excess} = \int_0^{\tau} [P_{task}(t) - P_{reference}(t)]\, dt$$

That contrast is in joules. It can be negative when the task draws less than the reference, which would not mean negative effort or negative total entropy. These are definitions of comparisons, not results for relational processing. The body is an open system, and neither cortisol nor an R-score supplies its energy balance.

## 4 Mz relativity

Partner A cooks dinner at R = 2; Partner B cooks dinner at R = 7. Over thirty minutes the convention assigns 60 and 210 score-minutes. Same behavior, different reports.

The March edition read this as different override costs and different thermodynamic work, following necessarily from different filter geometries. The numbers describe assigned scores and duration. They do not show that Partner B spent 3.5 times the energy, did 3.5 times the work, or cared 3.5 times as much (V2-L15).

Mz relativity is not a bug. It is also not a theorem. It is a caution: a behavioral description can hide real differences, and a score cannot make people comparable on one physical scale. Variation in R is not identical to variation in filter geometry, and cross-person equivalence has not been established.

## 5 The proposed outcome ratio

The March ratio was:

$$\kappa_{Mz} = \Delta V_{rel} / Mz$$

It means nothing until the outcome, its baseline, the affected party and the observation period are defined. With an outcome score over score-minutes, it is not a dimensionless thermodynamic efficiency or a return per joule (V2-L16).

The ratio is undefined at Mz = 0 and unstable near it, so both numerator and denominator stay visible. A negative ratio is an evaluative outcome, not a direction of heat flow. The link to Kolchinsky and Wolpert's semantic information is proposed, not derived [B7].

An unanswered act does not force ΔV_rel to zero. Unwitnessed care can have practical effects, and a recognized act can do harm. Grief does not guarantee a positive return that can be divided by a measured cost.

## 6 Dark Soul Matter

Brief 12 names sustained, difficult investment invisible to the receiver “Dark Soul Matter.” The name is an image, borrowed from the matter astronomers infer but cannot see **[Analogical]**. It keeps attention on effort an observer misses.

The March chapter made it precise: maximum override for months or years, the largest integral a transducer can sustain, the most expensive investment in the gap. That precision is withdrawn (V2-L17). No one is shown to hold a physiological maximum for months, duration cannot silently mean every minute of a life, and lack of recognition does not establish lack of benefit.

The founding line meets its most extreme reading here, as an image: investment without guaranteed return. The index does not make sacrifice obligatory, rank anyone's worth, or require escalating strain to prove care.

## 7 AI and the missing R value

Brief 12 assigned AI companions R = 0 and therefore Mz = 0. Thermodynamics does not establish that, and zero lies outside the 1–10 scale (V2-L18). A system without a comparable, validated self-report is marked “not measured,” not silently given an absence of difficulty.

An implemented digital system uses physical resources that depend on its hardware, conditions and infrastructure. No cortisol is needed for electricity use or heat. The March text sketched an “ontological path” by which real processing constraints would raise an AI's R above zero. Resource competition alone would not establish felt resistance or make a human R-score applicable.

The corrected Axiom 0 asks that substrate alone not decide the comparison. It does not prove equal cost, capacity or experience. The framework cannot infer zero cost from an absent report, or experience from a nonzero energy measurement.

## 8 The calibration problem

The open problem is larger than one conversion factor. The construct and instructions need definition, and reliability and scale properties need evaluation before the score is treated as an instrument. Any physiological association would hold only for its task and conditions; it would not be a universal constant.

The proposed tools also need to measure the claimed quantity. BOLD fMRI is a hemodynamic signal related to neural activity, not a reading of ATP expenditure or heat [B8]. An EEG trace is not in joules or J/K.

The March chapter ended: “We do not have it yet. But we know where it lives and what would measure it.” The first sentence stands. The second is withdrawn: the framework does not yet know whether a stable mapping exists for any specified task. A failed association would count against that bridge, and the absence of calibration cannot be renamed a formal identity that survives every outcome.

## What this chapter now claims

The Moniz records reported resistance and duration under a proposed convention. It does not measure thermodynamic work, entropy production or universal order spent. Its scale properties and usefulness need testing. The outcome ratio needs defined quantities and a positive denominator, and AI is not assigned zero by default.

The Moniz must not be used to rank people, demand sacrifice, diagnose a relationship or infer anyone's worth. Even “what it costs you” remains a reported index, not a physiological measurement.

The next chapter asks what happens when habits from an earlier relational environment are carried into a new one: the Template Tax.

# Chapter 4: The Template Tax

*The Cost of Running Yesterday's Architecture*

**Status:** Developmental experience and learning can influence later responses. The Template Tax is a proposed description of context mismatch, not an established entropy quantity, diagnosis or biological mechanism. Its AI-custodial application is a **[Speculative]** hypothesis, and its physiological predictions are untested. This chapter is not a diagnostic instrument or a treatment protocol.

## 1 The problem

The filter has a shape, and the shape has a history. Volume 1 describes it with filter geometry, G = (S_params, C_params, Σ_params): selection, compression and structuring. These are organizing labels, not anatomical compartments, and the Greek letter in Σ_params does not make structuring a form of thermodynamic entropy.

The Template Tax asks what happens when a familiar response is carried into a setting where it no longer helps. A person may keep watching for a danger that has gone, discount an offer they could safely accept, or brace for rejection before there is any sign of it. The useful question is whether that pattern adds a burden now, compared with a stated alternative. Calling it a tax does not establish its size or its units.

The March edition held that structuring parameters are not innate and are set during one developmental window. That was too strong (V2-L19). No partition of genetic, developmental and current influences is offered here, and nothing shows that relational responses are fixed in childhood. Adults keep learning; in one study, juggling training accompanied measurable brain changes [A3], though that concerns a visuomotor task, not the relational filter. “Inherited architecture” means patterns carried forward from experience, not genetic or epigenetic inheritance.

## 2 A possible mechanism, not a universal sequence

The March chapter drew the case sharply: a child with unpredictably available caregivers grows a filter tuned to that unpredictability, watching for threat, compressing toward danger, expecting harm. In a later, safer setting, that vigilance might still run, making ordinary exchanges effortful. As a hypothetical, it is worth keeping. As a rule for every child, it fails.

The primary research pulls in more than one direction. McLaughlin and colleagues found that maltreatment in 90 young people aged 6–18 was associated with blunted threat responses and poorer threat–safety discrimination [A1]. Machlin and colleagues, following 170 young people aged 10–13, instead linked violence exposure to heightened early responses to threat cues and later PTSD symptoms [A2]. Different samples and tasks yield different patterns, and neither study measured a Template Tax.

The March text called these calibrations accurate: a filter raised in unpredictability should attend to threat. Understandable is the right word; accurate overstates what the data show and invites explaining every outcome after the fact. Current danger must also be assessed, not assumed absent. What looks like an outdated expectation to an observer may answer conditions the observer has not seen.

So the mechanism stays conditional. A learned response may persist after conditions change, and that mismatch may add effort or impairment. Showing it would take measuring the response, the old and current contexts, and a competing explanation; knowing that adversity happened is not enough.

## 3 Three places to look

The March chapter sorted the distortions by filter stage. The vocabulary is still useful as prompts for inquiry, not as three proven syndromes:

- **Selection** asks what receives attention: hypervigilance to threat, blindness to positive signals, or attending to everything at once. More attention to threat is not automatically irrational, and it does not by itself show a raised selection cost.
- **Compression** asks which distinctions survive: catastrophizing, minimizing positive evidence, splitting into all good or all bad. These motivate specific behavioral hypotheses, not a single childhood cause, and losing detail in a description is not physical information erasure [A5].
- **Structuring** asks how an interpretation becomes an action: a default expectation of harm, investing in people who resemble earlier figures, or withholding participation. Intention, registration and benefit are separate questions, the sign of an act is not an entropy flow, and “wrong economy” cannot serve as a clinical diagnosis.

These categories overlap, and the same visible response can have different causes. They do not add up to three excess entropy costs.

## 4 What a cost comparison would require

The March chapter wrote the tax as a chronic work integral: the template's entropy-production rate minus an optimal one, integrated over every relational cycle, running always. That cannot serve as a measurement equation (V2-L20). Integrated entropy-production rates come out in J/K, not work and not score-minutes. The optimal comparison is undefined, the difference need not be positive, and nothing supports a tax that never switches off.

A real comparison would choose an observable outcome first: task performance, reported effort, or a defined physiological response under stated conditions. A claim about extra metabolic energy would need an energy measurement, a boundary, an interval and a credible comparison, with background activity and uncertainty accounted for. It cannot be read from cortisol, HRV or exhaustion.

People do report that carrying an old pattern is exhausting even without active conflict. That report deserves weight as a report while the proposed mechanism remains unknown. And a pattern that costs effort in one setting may carry no detectable extra energy, or may help in another. Those outcomes must be able to count against the stronger claim.

## 5 The AI custodial hypothesis

CP-34 extends the mismatch question to children who receive substantial care or companionship through AI systems **[Speculative]**. Its image is an instrument zeroed correctly against the wrong standard:

expectations learned with one kind of partner may transfer poorly to human partners. That is a developmental research question, not an established outcome of AI exposure.

The March reference environment was idealized: unlimited patience, zero-cost availability, unconditional presence. Real AI services have physical costs, limited availability, access rules and product changes, and a patient reply does not establish unconditional presence, an inner state, or freedom from harm (V2-L21). The hypothesis must describe the actual system and caregiving arrangement.

Three questions survive: whether users come to expect different availability, how they read other people's limits and efforts, and what happens when an important service changes or ends. “Cost-signal blindness” and “orphaned Mz” remain project vocabulary, not validated syndromes.

The name Calibration Corruption also needs care. It must not label a child defective, assert that AI-mediated care necessarily damages development, or promise that no harm occurred because the interactions felt responsive. The March conclusion that such a filter “needs recalibration, not repair” is withdrawn, and nothing here recommends AI as a substitute for human care.

## 6 Change without a biological success meter

The March chapter read effective therapy as filter-geometry change, read post-session exhaustion as the entropy cost of redesign, and predicted rising HRV, normalizing cortisol and a shifting CSS signature. Those predictions are withdrawn as universal signs of effective therapy (V2-L22). The framework still does not prescribe a therapeutic modality.

Habits and expectations can change. Improvement would need defining independently of any biomarker, with treatment effects, ordinary variation, medication, sleep and health considered. A report of exhaustion deserves to be taken as a report, not translated into a physical quantity that was not measured.

DFQ-003 stays open as a question about longitudinal measurement. TEAP would first need a defined protocol and evidence of reliability and validity for that purpose; tracking an unvalidated score does not make it a calorimeter.

## What this chapter now claims

The Template Tax keeps a humane question: how much difficulty comes from carrying an old response into changed circumstances? The answer may differ between people, tasks and times. The chapter offers ways to describe and test the mismatch; it does not establish continuous excess entropy, a universal adversity mechanism or an AI-specific disorder.

History is not blame, a learned pattern is not destiny, and a physiological response is not a verdict on anyone's character.

The next chapter separates two events that are easy to mistake for one: making an investment, and having it reach or be answered by another person.

# Chapter 5: The Unreciprocated Transmission

*When the Effort Does Not Land*

**Status:** This chapter separates physical expenditure, statistical information, delivery, registration, benefit and reciprocity. Unreciprocated transmission is framework vocabulary for a family of cases, not a newly demonstrated thermodynamic regime or a proved extension of Kolchinsky and Wolpert's framework.

## 1 The gap the framework can name

A person can make an effort that never reaches its intended recipient. A message can arrive, be understood, and get no reply. Those are different conditions. Nondelivery is not nonreciprocity, and neither is the same as having no effect.

Volume 1's Observation Split names the difference between an activity and an event that meets the framework's registration rule. A candidate Trinket is the directed act before that rule is applied; under WP-12, a qualifying Trinket requires specified registration. That is a convention for classifying events, not a law of physics, and an act that fails it can still help or harm someone.

The March chapter tried to turn this gap into a third information state, beyond Kolchinsky and Wolpert's correlated and scrambled conditions: one-sided information with full production cost. That construction is withdrawn (V2-L23). Statistical dependence, intentional communication and recognition are different questions. Two variables can be correlated without anyone recognizing a message, and one failed message does not erase every existing correlation.

What the framework can contribute is descriptive and still worth having: it keeps the attempt visible when there is no reply.

## 2 Separate accounts, not three states

The March chapter's central comparison held that entropy production is identical whether or not the signal lands: same transduction, same waste, same Mz, same debit, only the outcome different. That equality is withdrawn (V2-L24). Preparation, repetition, delivery, feedback and what follows can all differ between a successful attempt and a failed one.

For any case, the account records separately what was done, whether it arrived, whether it was registered, what effects followed, and whether anyone reciprocated. The physical account asks its own question: what resources supported the activity within a declared boundary and interval? Resources already used are not refunded when a message fails. Where measured costs are unavailable, the account says so. A person's report of effort can be recorded without being converted into joules.

Registration is not sign. A recognized act may be beneficial, harmful, mixed or uncertain under a stated criterion, and an unrecognized act may still have effects. Lack of registration is not the null sign, and a missing reply settles neither party's outcome.

The March refrain was “The universe records the debit. No credit appears on the other side.” The corrected account keeps several books, each in its own terms, and none of them belongs to the universe.

## 3 Where the distinction matters

The March chapter's examples remain the right ones. What changes is what they share.

- **Unreciprocated love.** An unsent letter, an unnoticed letter and an offer explicitly declined have different histories; the last may be fully registered while affection is not returned. None guarantees maximum Mz or zero benefit. The receiver may decline, and expenditure creates no entitlement to a response.
- **Grief.** A survivor may keep organizing a life around someone who has died. New ordinary communication with the deceased is gone, while memories, routines, other relationships and continuing bonds still matter. That is not enough to classify all of grief as a failed transmission; Chapter 6 takes it up as adaptation.
- **Prayer.** Activity and its consequences can be studied without deciding whether a theological receiver exists. Unverified reception is not verified nondelivery, and the BSB supplies no evidence on either side of that question.
- **Dark Soul Matter.** Sustained, unseen investment keeps its name as an interpretive label, as long as invisibility is not read as intensity, harm or moral rank.
- **Unwitnessed care.** The parent checking on a sleeping child. The partner adjusting the thermostat at three in the morning. The colleague advocating in a meeting the other person never hears about. A thermostat changes a sleeper's room and advocacy can change an opportunity, whether or not anyone knows who acted. Whether the act qualifies under WP-12 and whether it helped are separate assessments.

These cases share a question about recognition, not a demonstrated thermodynamic signature. They cannot all be assigned zero change in the receiver or zero relational return.

## 4 The formal statement, corrected

For discrete random variables under the same joint distribution, mutual information is symmetric [A18]:

$$I(X; Y) = H(X) + H(Y) − H(X, Y) = I(Y; X)$$

That equality says nothing about equal awareness, equal benefit or returned affection.

The March condition required positive mutual information from the sender toward the target, zero from the receiver back, and full entropy cost paid. If Y_target and $Y_0$ differ, the positive and zero values can coexist. This does not establish one-sided mutual information, nondelivery or harm. Symmetry applies to the same pair under the same joint distribution (V2-L25). Where there is no actual receiver, a receiver-state variable cannot simply be presumed.

The replacement is an explicit observation rule, not a new entropy identity: identify the candidate act, the delivery evidence, the registration criterion and interval, the response, the outcomes and the measured

resources. Unknown delivery stays unknown, and absent evidence of benefit does not become a proved zero.

None of the March consequences follows from nondelivery alone: not a positive Mz, not an additive stage-by-stage entropy bill, not zero change in the receiver, not a loss for the sender. A failed attempt may involve learning or preparation; it may also impose burdens. A net outcome needs a defined measure and comparison.

## 5 What Kolchinsky and Wolpert already address

The March chapter argued that their framework assumes a closed loop and so cannot see undelivered signals, and that relational viability extends it. Their treatment already evaluates information relative to stated dynamics, a viability function, a timescale and counterfactual interventions, including partial scrambling, directed transfer and system-to-environment information [A4]. The claim of a necessary gap is withdrawn (V2-L23).

A physical model could include production resources and a failing channel if those dynamics were specified. The framework's job is to build and test a relational application, not to claim priority for a limit the cited work does not impose. “Relational viability” stays an application-specific proposal that needs a defined outcome and a justified mapping.

## 6 The founding line without the zero-return theorem

The March chapter's sharpest sentence was that here, “more than it saves” is everything, because nothing was saved: zero efficiency, total waste, the most expensive regime in the framework. The physics cannot say that (V2-L26).

The founding line keeps its force as interpretation **[Analogical]**: investment does not guarantee connection. The second law cannot turn an unrecognized act into total waste or set its efficiency to zero; that would need a defined physical task, inputs and useful output, and a relational response is not automatically an energy output. Eventual heat does not erase what an act accomplished before or alongside it.

No ranking of grief, prayer, unreturned affection and unnoticed care follows from that law. The restraint keeps the gap the chapter began with: an effort can be real even when its intended outcome does not happen.

## What this chapter now claims

The unreciprocated transmission is a family of cases that need careful description, not a single measured regime. Delivery, registration, practical effect and reciprocity are separate. The equal-cost, guaranteed-harm, zero-efficiency and extension-priority claims are withdrawn.

Neither futility nor nobility follows from the physics. An investment creates no claim over another person's affection.

Chapter 6 turns to grief, where the question is not whether a message was delivered but how a life continues after an important person has died.

# Chapter 6: Grief as Filter Redesign

*Rewriting a Life While It Keeps Running*

**Status:** Bereavement has documented health associations that differ substantially by population and outcome. Filter redesign is a proposed interpretation of adaptation **[Analogical]**, not an established thermodynamic mechanism. The behavioral-interdependence prediction is **[Speculative]**. This chapter is not medical advice and supplies no diagnostic test or treatment recommendation.

## 1 The problem

The March chapter opened bluntly: grief is expensive, and that is not a metaphor. Grief can be exhausting, and that deserves attention without a claim that its energy has been measured. Bereavement studies report differences in particular physiological measures and health outcomes. They do not establish one biological response or a quantified price of losing someone (V2-L27).

The distinction is practical. A small cortisol comparison, an immune assay, an ECG record, a sleep study and a mortality cohort measure different things, and none becomes a grief-energy meter because it has a biological basis [A6–A10].

The March chapter also held that the grief literature lacks a physical mechanism and that the transducer model supplies one. Existing work already addresses mechanisms, including a cognitive attachment model of memory and identity in prolonged grief [A17]. The framework's question is narrower: can disruption of shared routines, decisions and expectations help explain differences in how people adjust after a death? “Filter redesign under load” is an image for that work while ordinary life continues.

## 2 How lives become interdependent

In a close relationship, two lives can grow around each other. The March chapter named the forms: shared daily routines, decisions that route through both people, an “us” that becomes load-bearing in each person's sense of self, and habits of movement calibrated to the other's presence. One partner may hold the practical knowledge; the other may keep the calendar.

The framework calls this filter integration. The March text said the coupling was not metaphorical, was measurable, and was the primary determinant of grief's metabolic cost. None of that is established (V2-L28). These are candidate dimensions of behavioral interdependence, not evidence that two neural filters have literally merged, and no validated aggregate measure of this framework's proposed filter integration is established here.

To study it, interdependence must be broken into observable parts and kept distinct from emotional closeness, relationship satisfaction, attachment, caregiving burden and material dependence. Someone who shared few tasks may grieve profoundly; someone with deep practical dependence may adapt with help. The variables have to explain differences, not define them into existence.

## 3 What death changes

When someone dies, the possibility of new ordinary interaction with them ends. Their particular way of answering will not produce anything new. Their influence is not thereby erased: it stays in memory, in the house, in other relationships. A familiar impulse to consult them can coexist with knowing they are gone.

The March chapter called this the Observation Split at its most devastating: the survivor spending a full metabolic load into a void where no Trinket can form. That was too sweeping (V2-L28). Remembering, mourning, settling practical matters and talking with others are different activities, and they can have consequences even though the person who died cannot answer.

Nor is death a measured transition in which a known quantity, S_partner, drops to zero. A past relationship can leave information and resources the survivor still uses.

## 4 Redesign as an interpretation

The March chapter's phrase was “engineering under load”: not recovery, not healing, but a system that must keep operating while its own architecture is restructured. As an image, it is apt **[Analogical]**. As a mechanism, it is unestablished.

The idea has a long history. Parkes described psychosocial transitions, Attig wrote of relearning the world, and Markovic analyzes profound grief as an unchosen transformation of the self [A16, A19, A20]. These are intellectual antecedents, not measurements of reconstruction.

Neuroimaging offers a different kind of evidence. Huang and colleagues studied 19 bereaved participants before and after an eight-week mindfulness-based cognitive therapy course and found changes in resting-state functional connectivity [A11]. The study was small, with no untreated comparison group or pre-loss baseline, and functional connectivity is a statistical relation between signals, not synapses being rebuilt.

Naming steps such as identifying old expectations and building new routines does not identify physical bit erasures, and Bennett's result shows why useful processing is not a separate erasure toll at each named stage [A5]. Cortisol is not established as fuel for redesign, immune changes do not show energy diverted to reconstruction, and disturbed sleep is not proof of an overworked reprocessing engine.

The March line was “These are not symptoms of grief. They ARE grief.” The corrected line: physiology can accompany grief without being its definition.

## 5 What the studies show

The March chapter read the literature as describing the what while the model supplied the why. The primary studies are narrower than either:

- **Cortisol.** O'Connor and colleagues compared 12 women with complicated grief and 12 without it after a mother's or sister's death from breast cancer; the first group had a flatter daily cortisol pattern [A6]. Hopf and colleagues' article is a systematic review, not a primary experiment [A15].
- **Other physical measures.** Buckley and colleagues found higher heart rate and lower values on several HRV measures early after loss in 78 bereaved people versus 79 controls [A7]. Irwin and

colleagues' work concerns natural-killer-cell activity and depressive symptoms, not suppression of all immunity [A8]. Reynolds and colleagues found some REM-sleep differences in nondepressed bereaved older adults but similarity on most other sleep measures [A9].

- **Mortality.** Elwert and Christakis followed 373,189 older married US couples from 1993 to 2002; mortality associations after widowhood varied with the causes of death [A10]. That is a population pattern, not a forecast for one person.
- **Symptom trajectories.** Majd and colleagues modeled depressive-symptom trajectories in 175 widowed adults over the first year [A12]. These are fitted patterns, not universal stages, and the study had no pre-loss baseline and measured no Template Tax.
- **Perceived inclusion.** Harrison and colleagues found that current perceived inclusion of the deceased in the self was associated with prolonged grief disorder in a matched comparison [A13]. The March text read this as a measure of filter integration. It is a cross-sectional measure of present perception, not a record of pre-loss behavior.

## 6 A prediction that can fail

**[Speculative]** The empirical proposal is whether pre-loss behavioral interdependence adds predictive information beyond self-reported closeness for specified outcomes after bereavement. It is not a claim that grief is proportional to integration or that closeness does not matter (V2-L29).

The March chapter called the prediction falsifiable and not yet tested. Falsifiable stands. Whether the comparison has been studied elsewhere is not certified here, so the novelty claim is withdrawn.

The second edition sets out what a credible test would need: a population, observation intervals and primary outcome chosen in advance; interdependence and closeness measured before the death where possible; model comparison with and without the behavioral measures; and attention to prior health, caregiving, circumstances of death, finances and support. Outcomes keep their real names and units, and “normalization” has no single timetable.

The March ratio S_partner / S_total is not an operational predictor (V2-L30). Semantic information is model-dependent, and splitting it into additive partner and independent channels has not been justified [A4].

The proposal would be weakened if adding the behavioral-interdependence measures to the same comparison model, already including self-reported closeness and the stated covariates, reproducibly failed to improve prediction of the specified outcome. A positive result would support a bounded predictive claim, not the physical redesign mechanism.

## 7 Clinical limits

The March chapter read grief as productive redesign and depression as redesign stalled. That equation is withdrawn (V2-L31). Tsai and colleagues, following 398 family caregivers of terminally ill cancer patients over two bereavement years, supported a distinction between grief and depressive symptoms and

a temporal association in that population [A14]. A lagged observational model does not show that depression is a stalled reconstruction.

The March chapter also wrote that grief “is not damage to be repaired. It is construction to be supported.” The image must not imply that painful grief always does useful construction, or turn ongoing distress into a personal failure to rebuild. Adaptation need not erase an enduring bond or replace the person who died. The framework sets no diagnostic boundary and should not decide whether someone needs care.

The March proposal to begin architectural decoupling before an anticipated death is withdrawn as a recommendation (V2-L32). Anticipatory planning and caregiving arrangements need their own evidence and the priorities of the people involved. No one should be told to reduce closeness on the premise that it lowers a cost these studies do not quantify.

## 8 SupoRel and the capture surface

The danger is the slide from describing a burden to making it a virtue. “Your grief is proportional to your love” is a common consolation, and the March chapter rightly warned that the model could be misread as its scientific proof. Its correction swapped in another proportionality, to filter integration. That is withdrawn too. Neither grief intensity nor any physiological measure is a validated measure of love, devotion or worth.

A tightly interwoven life is not a better life, and a person whose life was closely coupled to another's is not more loving than someone more independent. The second capture is “don't get too close.” The framework does not endorse independence as a way to avoid grief. It describes; it does not prescribe how to live.

The March chapter closed with Carroll's aphormeology: grief is pushed from behind, not pulled toward cosmic sacrifice. The caution stays, without its physics (V2-L34). Biological observations do not establish a cosmic purpose for grief or confer nobility on suffering; they do not remove grief's human meaning. Noble is a human judgment the physics does not make.

## What this chapter now claims

Filter redesign remains a way to describe adaptation after loss. The reviewed studies establish specific observations and associations, not an energy mechanism, a universal scaling rule, or a clinical line between successful and failed rebuilding. Behavioral interdependence remains a Speculative candidate predictor, and its value must be earned against existing explanations.

The next chapter traces what these limits do to the framework's canon.

# Analogy table: Filter redesign under load

Filter redesign under load is Analogical. Its engineering side describes systems modified while they keep operating; its relational side describes adaptation after a death. The image organizes questions about how survivors revise routines and expectations. It is not a measured mechanism.

The image comes from March Chapter 6: “It is engineering under load: the system must continue operating while its own architecture is being restructured.”

| Term | Engineering reading | Proposed relational reading | Where the mapping holds | Where it breaks |
|---|---|---|---|---|
| “filter” | A system that selects and transforms signals according to set parameters. | The survivor's habits of attention, interpretation and action, shaped around the person who died. | Some expectations and routines were tuned to another person's presence, and they persist after the death. | No filter parameters have been measured; the filter is an organizing label, not an anatomical compartment (Ch 4 §1). Expectations live in many places, including other relationships and the home. |
| “redesign” | Deliberate changes to a system's specification, toward a target design. | Revising roles, routines and expectations after loss. | Survivors do revise routines and expectations; the literature on psychosocial transition and relearning the world describes this [A16, A19, A20]. | Grief has no designer and no target specification. Naming steps does not identify physical bit erasures [A5], and adaptation need not erase the bond or replace the person. |
| “under load” | Modifying a system while it carries its normal working load, as when a bridge is repaired without closing it. | Adapting while work, care and daily life continue. | Life's demands usually continue after a death, and that can make adaptation harder. | Engineering load is a defined force or throughput. Here it is unmeasured, and cortisol, immune or sleep changes are not load readings (Ch 6 §4). |
| “cost of redesign” | The work and materials a rebuild consumes, in joules or money. | The exhaustion and disruption grief brings. | Grief can be exhausting and disruptive, and reports of that deserve weight as evidence about the person's experience. | The studies reviewed here do not quantify an energy cost of grief or this proposed redesign, and the March Landauer stages are withdrawn (V2-L28). Physiology can accompany grief without being its price. |
| “completion” | A new design delivered; or, if the work stops partway, a system left neither old nor new. | Adjustment after loss; in the March reading, depression as a stalled redesign. | People's distress after a loss follows different courses over time [A12]. | The stalled-redesign reading of depression is withdrawn (V2-L31) [A14]. Adaptation has no single timetable or end state, and persistent distress must not be framed as a personal failure to rebuild. |

## What the table does not do

It is not evidence for the framework, not a mechanism of grief and not a clinical tool. The engineering column describes how engineered systems are modified; that standing does not pass to the mapping, which is Analogical in every row.

## Promotion route (conditions, not a work plan)

To move any row from Analogical toward Supported, a study would have to define the relational quantity independently of the image, measure it in its own units with a baseline, and show a stable relationship under stated conditions, with a stated result that would count against it.

Chapter 6's Speculative interdependence prediction is a separate empirical proposal. A positive result there would support a bounded predictive claim, not the redesign mechanism, so it cannot promote this image on its own. No row is promoted, and no study is proposed here.

# Chapter 7: Where the Receipt Lands

*What the Volume Does to the Documents It Touches*

**Status:** A dependency review, not a validation study. This chapter records what the corrected biological account lets the framework say, what it withdraws, and which documents still need reconciliation. Internal agreement is not additional evidence (V2-L35).

## 1 What this volume did

The March chapter summed up the volume in two lines: “Volume 1 said: connection costs entropy. Volume 2 said: here is the receipt.”

The corrected pair runs differently. Volume 1 keeps three accounts apart: physical cost, information and relational outcome. It does not establish one spendable currency shared by heat, cortisol, attention and care, and the transducer remains a proposed way to organize processing (V2-L01). Volume 2 reads what the body actually records and finds several receipts in several units, none of them a bill for one relationship.

The receipt is still a useful image, as long as we read what is printed on it. A hormone concentration, an immune measure, a sleep outcome, a self-report and a measured energy expenditure are different records. The framework gains precision by keeping them distinct, not by claiming one amount has been measured five ways.

## 2 WP-18: The Feeling as Cost

WP-18 keeps its central insistence: feelings and relationships happen in bodies, not as costless abstractions. It must not identify feeling with one obligatory sequence of brain regions and hormones, or treat its selection, compression and structuring functions as established biological stages.

The March chapter called the Signal Form / Cost Substrate distinction load-bearing for every diagnostic instrument in the framework. It organizes separate questions about action and the resources behind it. It does not make cortisol, immune responses or cellular aging interchangeable units of cost, and no physiological pattern diagnoses the sincerity, benefit or economy of an interaction. WP-18 needs Chapter 2's qualifications: the actual measurement, its timing and comparison, association kept apart from mechanism.

## 3 Brief 12: The Moniz

The Moniz stays a proposed way to record reported difficulty and duration. The March claim that it is a thermodynamic work integral, and the cosmological constant connecting difficulty to the physics of the universe, is withdrawn (V2-L11, V2-L13). A rating scale needs a measurement model before its differences, ratios or sums mean anything, and multiplying by minutes does not supply one.

The κ_Mz ratio is not an established relational efficiency (V2-L16). An unregistered act does not establish zero benefit, and unseen effort is not thereby a maximum expenditure. The blanket assignment of R = 0 to AI is not warranted (V2-L18). Missing evidence cannot be entered as a measured zero, and none of these corrections determines anyone's worth.

## 4 Brief 16: Mz Relativity

The same act can draw different difficulty reports from different people, or from one person on different days. That keeps a real contextual question about expectations, experience and resources. The March identity “the variance in R IS the variance in G” is withdrawn (V2-L15). Reports do not uniquely identify a filter geometry or prove a difference in thermodynamic work, and cross-person comparison takes more than matching numbers.

## 5 Brief 20: The Template Tax

The Template Tax stays a metaphor and a research proposal about patterns learned in one setting that may be costly or poorly suited to another. It is not a continuous entropy surcharge, a diagnosis of anyone's history, or proof that a present difficulty has one inherited cause (V2-L20).

The filter vocabulary does not explain a treatment's mechanism because a person changes during treatment. Nothing here says successful therapy must lower a universal Mz baseline, or that an unchanged biomarker invalidates someone's improvement (V2-L22). CP-34's Calibration Corruption remains an untested **[Speculative]** developmental proposal, not a diagnosis or a trauma mechanism (V2-L21).

## 6 The Blueprints, Chapter 16: Grief

The Blueprints described grief with rough phases, timelines and the idea that deeper relationships encode more information. The March volume refined that into a mechanism and a prediction it said bereavement research had not yet run.

What survives is the image of filter redesign under load **[Analogical]** and a narrower question **[Speculative]**: whether defined measures of pre-loss behavioral interdependence add predictive information about specified outcomes beyond self-reported closeness (V2-L29). It is not a claim that integration determines metabolic grief cost, or that earlier research overlooked the comparison. The Blueprints' timelines, interventions and clinical interpretations need their own evidence review and are not endorsed here by a shared metaphor.

## 7 Volume 1: The Observation Split

The March chapter said Volume 2 populated the Observation Split with its full biological content: a regime Kolchinsky and Wolpert do not name, full cost meeting zero return. “Volume 1 named the gap. Volume 2 showed what it costs.”

The corrected Observation Split separates expenditure, delivery, recognition, reciprocation and outcome. A candidate act can fail the registration rule and still have consequences; registration does not guarantee

benefit. The one-sided mutual information claim and the third state outside Kolchinsky and Wolpert's framework do not return (V2-L23, V2-L25). The biological questions are still worth asking, but they need observations, not a thermodynamic verdict on every instance of grief, prayer, unreturned affection or unwitnessed care.

## 8 What changes in the canon

The March chapter ended: “Nothing broke. Everything gained biological ground. That is the mark of a real layer: the instruments still function, and now you can see what they are measuring.”

Something did break: the claim that the instruments already work. TEAP, CSS, the economy typing table and the Mz have not been validated by these chapters as clinical instruments, calorimeters or readouts of internal mechanisms. “The instrument still works” cannot stand in for evidence of what it measures and for whom.

What held is the concern: what is invested, what reaches another person, and what follows. The BSB remains a discipline of inference, not a certificate that every bodily claim is established (V2-L36). Reports of experience remain evidence about reported experience, with the usual limits of self-report.

SupoRel still earns its place by challenging grief as virtue, effort as entitlement, numerical comparison of people's worth, and the Template Tax as blame. Those are cautions, not proof that every misuse has been eliminated. The epistemic tiers, now four with Analogical, need evidence and scope beside each claim; a label confers nothing by itself.

The original papers remain unchanged. The dependencies named here mark reconciliation still to do, not amendments already made. The stronger foundation is a narrower one: the account can now be tested without requiring every measurement to confirm the metaphor.

# Volume 2 correction ledger

The ledger traces 36 selected March claims in Volume 2. By this edition's classification of the second edition's treatment, 17 were withdrawn, 17 narrowed and 2 kept. It is not an exhaustive inventory of every Volume 2 issue, and it makes no new scientific decisions.

March locations refer to the preserved Volume 2 page on suposystem.ai. Second-edition (2E) locations use the October 2026 collection's Volume 2 chapter and section headings and its local reference labels (B for Chapters 1–3, A for Chapters 4–6).

| ID | March claim (Volume 2 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V2-L01 | Ch 1 §1: Volume 1 “established the physics”: one economy, one currency, one ledger; the Trinket is an entropy token; the second law guarantees every relational act spends more than it saves; “the founding line is physics.” | Withdrawn | Ch 1 §1 | Rests on claims withdrawn in Volume 1 (V1-L03, V1-L14, V1-L34); the founding line is a motivating image, not a consequence of the second law. |
| V2-L02 | Ch 1 §1: the body pays for connection in cortisol, immune suppression, cellular aging and sleep degradation. | Withdrawn as denominations of one currency | Ch 1 §1; Ch 2 §3 | Different observations in different units; a body need not be damaged for care to be genuine. |
| V2-L03 | Ch 1 §2, Ch 2: a feeling is a fixed cascade (amygdala, then body, then cortical label); the HPA axis releases cortisol, adrenaline and oxytocin. | Narrowed: interacting processes, no compulsory sequence; pathways named correctly | Ch 1 §2; Ch 2 §1–2 [B9, B10, B19, B23] | Amygdala-lesion counterexample; adrenaline is sympathetic–adrenal-medullary; oxytocin is not a compulsory step. |
| V2-L04 | Ch 1 §2: “the bill has already been paid” before a feeling is named; the body is the ledger on which the cost is recorded. | Narrowed: body-as-ledger kept as an image with conditions | Ch 1 §2 | A response is not a receipt; an additional cost needs an interval, a boundary and a comparison. |
| V2-L05 | Ch 1 §2: the ~20 W brain is the most thermodynamically expensive organ; relational regions are the hungriest; it is the most expensive hardware in the known universe; cortical communication costs 35× computation. | Narrowed: 20 W estimate and 35:1 modeled ratio kept with scope; superlatives withdrawn | Ch 1 §2 [B4] | The 35:1 figure is a modeled cortical allocation; neural communication is not interpersonal communication. |
| V2-L06 | Ch 1 §3: biology ~$10^6$ × Landauer vs silicon ~$10^9$ ×, 1,000× more efficient, 30 million× at the cellular level; “the most refined thermodynamic instrument for relational processing.” | Withdrawn; no reverse ranking asserted | Ch 1 §3 [B1–B3] | Unlike operations and boundaries (as V1-L08); evolutionary history does not guarantee optimality. |
| V2-L07 | Ch 2: hormonal cascade, metabolic cost of emotional response and bereavement physiology, all Established. | Narrowed: specific findings under particular conditions | Ch 2 §3; What this chapter now claims | Primary studies support specific associations, not a universal bodily bill. |
| V2-L08 | Ch 2: low HRV predicts elevated mortality across all demographics; relational crisis narrows the body's range. | Narrowed | Ch 2 §3 [B14] | Some lower HRV measures predicted mortality in an elderly cohort; not universal, and not relational causation. |
| V2-L09 | Ch 2: the Signal Form / Cost Substrate distinction makes the diagnostic instruments work; their decoupling is the primary diagnostic signal (Supported). | Narrowed: an accounting discipline, not a detector of real feeling | Ch 2 §4 | Strain does not prove an act genuine; absent strain does not prove it simulated. |
| V2-L10 | Ch 2: the Parity Window remains open; the framework can measure cost but cannot access experience. | Kept open; BSB narrowed to a boundary on inference | Ch 2 §5 | Physical measures, behavior and reports can all be relevant evidence; none is decisive alone. |

| ID | March claim (Volume 2 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V2-L11 | Ch 3: the Mz is a thermodynamic work quantity, the time-integrated entropy production above baseline (Supported). | Withdrawn; Mz kept as a descriptive score-minute index | Ch 3 §1, §3 | Units differ: the integral is J/K, work is J, and R × T is score-minutes. |
| V2-L12 | Ch 3: the R-value reports the person's own override cost, supported by a 2.7-fold neuronal metabolic increase (Díaz-García and Yellen) and Shepherd's account of effort. | Withdrawn as a calibration | Ch 3 §2; Original review citations | Both sources are reviews; neither calibrates the Moniz. R records reported resistance on a 1–10 scale. |
| V2-L13 | Ch 1 §4, Ch 3: the Mz is the framework's “cosmological constant,” bridging felt difficulty and the universal entropy budget. | Withdrawn | Ch 1 §4; Ch 3, What this chapter now claims | No measurement of energy, entropy production or universal order spent. |
| V2-L14 | Ch 3: R = 1 means little or no additional expenditure above baseline. | Narrowed: baseline mismatch recorded; convention not silently changed | Ch 3 §2 | A ten-minute act at R = 1 scores Mz = 10, so the index is not zero when the claimed excess cost is zero. |
| V2-L15 | Ch 3: Mz relativity: differences in R reflect filter-geometry variance between people. | Narrowed: a caution about interpretation, not a theorem | Ch 3 §4 | No cross-person measurement equivalence or unique internal cause is established. |
| V2-L16 | Ch 3: κ_Mz as a relational efficiency ratio (Supported). | Withdrawn as an established efficiency | Ch 3 §5; Ch 7 §3 | Numerator and denominator need justified meanings and a positive denominator. |
| V2-L17 | Ch 3: Dark Soul Matter as maximum Mz in the Observation Split gap, the largest expenditure the transducer can sustain and “the most expensive form of relational investment.” | Narrowed: name kept for unseen sustained effort; physical and superlative claims withdrawn | Ch 3 §6 | No one is shown to stay at a physiological maximum; lack of recognition does not establish lack of benefit. |
| V2-L18 | Ch 3 §7: AI's R = 0 because no internal states compete against relational output. | Withdrawn | Ch 3 §7 | Zero lies outside the 1–10 scale; a system without a validated self-report is “not measured,” not zero. |
| V2-L19 | Ch 4: structuring parameters are not innate and are set during one developmental window. | Withdrawn as stated | Ch 4 §1 [A1–A3] | No partition of genetic, developmental and current influences; no evidence that responses are fixed in childhood. |
| V2-L20 | Ch 4: the Template Tax is a continuous entropy overhead that runs whenever the filter runs (Supported). | Narrowed: a mismatch to describe and test | Ch 4 §4; What this chapter establishes | No continuous excess entropy established; a cost claim needs an energy measurement, boundary, interval and comparison. |
| V2-L21 | Ch 4 (Speculative): a child raised mainly by an AI custodial system calibrates against unlimited patience, zero-cost availability and unconditional presence. | Narrowed: hypothesis kept; idealized properties corrected | Ch 4 §5 | AI services have physical costs and limited availability; a patient reply does not establish unconditional presence. |
| V2-L22 | Ch 4: effective therapy is filter-geometry change; post-session exhaustion is σ_redesign; HRV should rise, cortisol normalize and CSS change. | Withdrawn as universal signs of effective therapy | Ch 4 §6 | Improvement must be defined independently, with treatment, medication, sleep and ordinary variation considered. |
| V2-L23 | Ch 5: unreciprocated transmission is a thermodynamic regime Kolchinsky and Wolpert do not name, a third state beyond correlation and scrambling (Supported). | Withdrawn | Ch 5 §1, §5 [A4] | A physical model could include a failing channel; the case is not outside their framework. |
| V2-L24 | Ch 5: same cost per cycle, zero return, zero efficiency, total waste; the output enters a void and the universe records the debit. | Withdrawn (equal-cost, guaranteed-harm and zero-efficiency claims) | Ch 5 §4, §6; What this chapter establishes | Delivery, registration, effect and reciprocity are distinct; unwitnessed care can have effects. |

| ID | March claim (Volume 2 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V2-L25 | Ch 5: the formal condition of positive mutual information one way and zero the other. | Withdrawn | Ch 5 §4 | If Y_target and $Y_0$ differ, the positive and zero values can coexist. This does not establish one-sided mutual information, nondelivery or harm. Symmetry applies to the same pair under the same joint distribution. |
| V2-L26 | Ch 5: the founding line as an established physical inequality (zero-return theorem). | Narrowed to the historical motivating line, with interpretive force | Ch 5 §6 | Investment does not guarantee connection; that is an interpretation, not an inequality. |
| V2-L27 | Ch 6: metabolic cost of bereavement, cortisol elevation, immune suppression and neural reorganization, all Established. | Narrowed to specific findings | Ch 6 §4 [A11]; §5 [A6–A8] | Small observational studies of specific measures and populations, such as a flatter diurnal cortisol slope in complicated grief and resting-state connectivity changes in 19 bereaved participants before and after an eight-week course. |
| V2-L28 | Ch 6: grief as filter redesign, with identification, decoupling and reconstruction each paying a Landauer cost; the survivor spends a full metabolic load into a void. | Narrowed: filter redesign kept as an image; Landauer stages and “void” withdrawn | Ch 6 §3–4 | Remembering, mourning and practical tasks can have effects; no measured rebuilding operation. |
| V2-L29 | Ch 6 (Speculative): metabolic grief cost scales with behavioral integration, not self-reported closeness; “a testable prediction that existing bereavement research has not yet run.” | Narrowed; kept Speculative and testable; novelty claim withdrawn | Ch 6 §6 | The empirical proposal remains Speculative: whether pre-loss behavioral interdependence adds predictive information beyond self-reported closeness for specified outcomes after bereavement. Prior work on the comparison is not ruled out. |
| V2-L30 | Ch 6: S_partner / S_total as a predictor of grief cost. | Withdrawn as an operational predictor | Ch 6 §6 [A4] | Semantic information is model-dependent; splitting it into additive channels is unjustified. |
| V2-L31 | Ch 6: grief is productive redesign and depression is stalled redesign. | Withdrawn | Ch 6 §7 [A14] | Tsai and colleagues support a symptom distinction and temporal association, not failed redesign. |
| V2-L32 | Ch 6: begin architectural decoupling before a death. | Withdrawn as a recommendation | Ch 6 §7 | Not a clinical recommendation; no one should be told to reduce closeness on this basis. |
| V2-L33 | Ch 1 §4, Ch 6: grief is the most extended and expensive case of biological cost. | Withdrawn | Ch 1 §4; Ch 6 | Not established by the reviewed studies. |
| V2-L34 | Ch 6: grief's cost is “pushed from behind” by metabolic necessity and the second law, “not pulled toward cosmic sacrifice”; “It is not noble.” | Kept as the anti-sacrifice caution, without its physical overclaim or a ruling on cosmic meaning | Ch 6 §8 | Biological observations do not establish a cosmic purpose for grief or confer nobility on suffering; they do not remove grief's human meaning. |
| V2-L35 | Ch 7: the canon trace treats Chapters 2–6 as established. | Narrowed: a dependency map, not a certificate | Ch 7 §1, §8 | WP-18, Brief 12, Brief 16, Brief 20 and The Blueprints still need reconciliation. |
| V2-L36 | Ch 1 BSB note: every biological claim is in front of the barrier; “the cost is real.” | Narrowed: placement kept; it confers no validation | Ch 1, Behind the Substrate Barrier | Claims in front of the barrier still need ordinary scientific scrutiny. |

# References and source apparatus

*Inherited verbatim from the second edition's Volume 2 apparatus. Labels B1–B23 serve Chapters 1–3; labels A1–A20 serve Chapters 4–6.*

## Source notes for Chapters 1 to 3

The empirical findings below have the populations, measurements and limits described in the chapters. The physical papers concern defined models or experiments. None validates the Moniz, a biomarker-based sincerity test, or a universal ranking of biological and digital relational processing. B21–B23 are explicitly theoretical or reference works, not primary causal experiments. B17 and B18 were checked for the audit but are not relied on for new claims in the chapter bodies.

**B1.** Landauer, R. (1961). Irreversibility and heat generation in the computing process. *IBM Journal of Research and Development, 5*, 183–191. https://doi.org/10.1147/rd.53.0183. Primary theoretical paper on specified logical/physical operations; not a universal charge for every cognitive act.

**B2.** Bennett, C. H. (1973). Logical reversibility of computation. *IBM Journal of Research and Development*, *17*, 525–532. https://doi.org/10.1147/rd.176.0525. University-hosted text. Primary theoretical construction; retained records and reversible operations matter when identifying erasure.

**B3.** Bérut, A., Arakelyan, A., Petrosyan, A., Ciliberto, S., Dillenschneider, R., and Lutz, E. (2012). Experimental verification of Landauer's principle linking information and thermodynamics. *Nature, 483*, 187–189. https://doi.org/10.1038/nature10872. Author-hosted paper. Controlled colloidal-memory erasure experiment, not a human emotional-cost measurement.

**B4.** Levy, W. B., and Calvert, V. G. (2021). Communication consumes 35 times more energy than computation in the human cortex, but both costs are needed to predict synapse number. *Proceedings of the National Academy of Sciences, 118*, e2008173118. https://doi.org/10.1073/pnas.2008173118. Full text. Original model-based energy audit with explicitly chosen cortical partitions; "communication" means neural signaling, not interpersonal activity.

**B5.** Díaz-García, C. M., Mongeon, R., Lahmann, C., Koveal, D., Zucker, H., and Yellen, G. (2017). Neuronal stimulation triggers neuronal glycolysis and not lactate uptake. *Cell Metabolism, 26*, 361–374.e4. https://doi.org/10.1016/j.cmet.2017.06.021. Full text. Biosensor experiments in mouse hippocampal slices and awake mice, not a study of human relational effort.

**B6.** Westbrook, A., van den Bosch, R., Määttä, J. I., Hofmans, L., Papadopetraki, D., Cools, R., and Frank, M. J. (2020). Dopamine promotes cognitive effort by biasing the benefits versus costs of cognitive work. *Science, 367*, 1362–1366. https://doi.org/10.1126/science.aaz5891. Full text. Fifty healthy adults completed an effort-discounting task; behavioral valuation is not calorimetry or Mz calibration.

**B7.** Kolchinsky, A., and Wolpert, D. H. (2018). Semantic information, autonomous agency and non-equilibrium statistical physics. *Interface Focus, 8*, 20180041. https://doi.org/10.1098/rsfs.2018.0041. Primary preprint. Original theoretical definitions and models; a human relational application needs its own states, dynamics, interventions and outcome definition.

**B8.** Logothetis, N. K., Pauls, J., Augath, M., Trinath, T., and Oeltermann, A. (2001). Neurophysiological investigation of the basis of the fMRI signal. *Nature, 412*, 150–157. https://doi.org/10.1038/35084005. Simultaneous electrophysiology and BOLD measurements in monkey visual cortex; the hemodynamic signal is not a direct heat or ATP reading.

**B9.** Vale, W., Spiess, J., Rivier, C., and Rivier, J. (1981). Characterization of a 41-residue ovine hypothalamic peptide that stimulates secretion of corticotropin and β-endorphin. *Science, 213*, 1394–1397. https://doi.org/10.1126/science.6267699. Record. Foundational peptide-isolation and bioassay study; used only for the CRH–corticotropin link. Full-text access was unavailable in this review; complete pathway anatomy is supported separately by B23.

**B10.** Kirschbaum, C., Pirke, K.-M., and Hellhammer, D. H. (1993). The 'Trier Social Stress Test'—A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology, 28*, 76–81. https://doi.org/10.1159/000119004. Primary abstract. Laboratory protocol and six-study report; responses under its conditions do not establish an emotion-universal sequence.

**B11.** Cohen, S., Janicki-Deverts, D., Doyle, W. J., Miller, G. E., Frank, E., Rabin, B. S., and Turner, R. B. (2012). Chronic stress, glucocorticoid receptor resistance, inflammation, and disease risk. *Proceedings of the National Academy of Sciences, 109*, 5995–5999. https://doi.org/10.1073/pnas.1118355109. Full text. Two human viral-challenge studies; chronic stress exposure was observational, not randomized.

**B12.** Vitlic, A., Khanfer, R., Lord, J. M., Carroll, D., and Phillips, A. C. (2014). Bereavement reduces neutrophil oxidative burst only in older adults: role of the HPA axis and immunesenescence. *Immunity & Ageing, 11*, 13. https://doi.org/10.1186/1742-4933-11-13. Original observational study; the article title should not obscure its nonsignificant age-by-bereavement interaction or turn subgroup contrasts into a proved age-dependent mechanism.

**B13.** Epel, E. S., Blackburn, E. H., Lin, J., Dhabhar, F. S., Adler, N. E., Morrow, J. D., and Cawthon, R. M. (2004). Accelerated telomere shortening in response to life stress. *Proceedings of the National Academy of Sciences, 101*, 17312–17315. https://doi.org/10.1073/pnas.0407162101. Full text. Cross-sectional biomarker study; it does not directly measure a longitudinal within-person shortening rate.

**B14.** Tsuji, H., Venditti, F. J., Jr., Manders, E. S., Evans, J. C., Larson, M. G., Feldman, C. L., and Levy, D. (1994). Reduced heart rate variability and mortality risk in an elderly cohort: The Framingham Heart Study. *Circulation, 90*, 878–883. https://doi.org/10.1161/01.CIR.90.2.878. Primary abstract. Prospective analysis of 736 older participants; not an all-demographic or relational-causation result.

**B15.** Melzack, R., Israel, R., Lacroix, R., and Schultz, G. (1997). Phantom limbs in people with congenital limb deficiency or amputation in early childhood. *Brain, 120*, 1603–1620. https://doi.org/10.1093/brain/120.9.1603. Primary abstract. Sample-specific phantom reports do not eliminate all peripheral signaling or establish genetic causation.

**B16.** Critchley, H. D., Wiens, S., Rotshtein, P., Öhman, A., and Dolan, R. J. (2004). Neural systems supporting interoceptive awareness. *Nature Neuroscience, 7*, 189–195. https://doi.org/10.1038/nn1176. Heartbeat-judgment imaging study; not a demonstration of the constitution of every feeling.

**B17.** Bartrop, R. W., Luckhurst, E., Lazarus, L., Kiloh, L. G., and Penny, R. (1977). Depressed lymphocyte function after bereavement. *The Lancet, 1*, 834–836. https://doi.org/10.1016/S0140-6736(77)92780-5. Primary abstract. Audit-only reference: 26 bereaved spouses and specific assay results; no universal immune-suppression peak established.

**B18.** Zannas, A. S., et al. (2015). Lifetime stress accelerates epigenetic aging in an urban, African American cohort: relevance of glucocorticoid signaling. *Genome Biology, 16*, 266. https://doi.org/10.1186/s13059-015-0828-5. Correction. Audit-only reference: observational methylation-clock association in a defined cohort, not a universal biological aging rate or a conversion to energy.

**B19.** Feinstein, J. S., et al. (2013). Fear and panic in humans with bilateral amygdala damage. *Nature Neuroscience, 16*, 270–272. https://doi.org/10.1038/nn.3323. Full text. Three rare neurological cases under a $CO_2$ challenge; a narrow counterexample, not a general emotion theory.

**B20.** National Institute of Standards and Technology. *Kelvin: Present Realization*. https://www.nist.gov/si-redefinition/kelvin/kelvin-present-realization. Official metrology reference for the exact SI value $k_B = 1.380649 \times 10^{-23}$ J/K. Numerical evaluations in this revision were recomputed on 28 October 2026.

**B21.** Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philosophical Transactions of the Royal Society B, 351*, 1413–1420. https://doi.org/10.1098/rstb.1996.0125. Author's theoretical account, not a universal sequence or metabolic comparison. The original chapter's 1994 and 2003 book references remain historical context rather than newly verified primary experimental evidence.

**B22.** Barrett, L. F. (2017). The theory of constructed emotion: an active inference account of interoception and categorization. *Social Cognitive and Affective Neuroscience, 12*, 1–23. https://doi.org/10.1093/scan/nsw154. Original theoretical account, published online in 2016 and issue-dated 2017; not a causal experiment establishing the framework's cascade.

**B23.** Tsigos, C., Kyrou, I., Kassi, E., and Chrousos, G. P. (2020 update). Stress: Endocrine Physiology and Pathophysiology. In *Endotext*. https://www.ncbi.nlm.nih.gov/sites/books/NBK278995/. Authoritative physiological reference, particularly the HPA-axis and sympathetic/adrenomedullary sections; not primary experimental evidence of a universal emotional response or its energetic cost.

### *Original review citations and their status*

Díaz-García, C. M., and Yellen, G. (2019; online 2018). Neurons rely on glucose rather than astrocytic lactate during stimulation. *Journal of Neuroscience Research, 97*, 883–889. https://doi.org/10.1002/jnr.24374. Review. The original 2.7-fold argument is not a primary Mz calibration result.

Shepherd, J. (2023; online 2022). Conscious cognitive effort in cognitive control. *WIREs Cognitive Science, 14*, e1629. https://doi.org/10.1002/wcs.1629. Advanced review and conceptual analysis. Its discussion of unresolved definitions cannot be turned into a measured thermodynamic identity.

Hopf, D., Eckstein, M., Aguilar-Raab, C., Warth, M., and Ditzen, B. (2020). Neuroendocrine mechanisms of grief and bereavement: A systematic review and implications for future interventions. *Journal of Neuroendocrinology*, *32*, e12887. https://doi.org/10.1111/jne.12887. Systematic review, retained as historical context; the revised physiological examples instead identify primary studies and their limits.

## References for Chapters 4 to 6

The bracketed A numbers identify sources, not evidence grades. Online-first and issue dates are distinguished where the original citations used the former. Source access and unresolved discrepancies are stated below.

**A1.** McLaughlin, K. A., et al. (2016; online 2015). Maltreatment Exposure, Brain Structure, and Fear Conditioning in Children and Adolescents. *Neuropsychopharmacology*, *41*, 1956–1964. DOI. Author-hosted article.

**A2.** Machlin, L., et al. (2024). Alterations in fear learning as a mechanism linking childhood exposure to violence with PTSD symptoms: a longitudinal study. *Psychological Medicine*, *54*, 3389–3397. DOI. Author-hosted article.

**A3.** Draganski, B., Gaser, C., Busch, V., Schuierer, G., Bogdahn, U., & May, A. (2004). Neuroplasticity: changes in grey matter induced by training. *Nature*, *427*, 311–312. Publisher.

**A4.** Kolchinsky, A., & Wolpert, D. H. (2018). Semantic information, autonomous agency and non-equilibrium statistical physics. *Interface Focus*, *8*, 20180041. DOI. Author-hosted article.

**A5.** Bennett, C. H. (1973). Logical Reversibility of Computation. *IBM Journal of Research and Development*, *17*, 525–532. DOI. Scanned primary article.

**A6.** O'Connor, M.-F., Wellisch, D. K., Stanton, A. L., Olmstead, R., & Irwin, M. R. (2012; online 2011). Diurnal cortisol in Complicated and Non-Complicated Grief: slope differences across the day. *Psychoneuroendocrinology*, *37*, 725–728. DOI. Institution-hosted article.

**A7.** Buckley, T., et al. (2012). Effect of early bereavement on heart rate and heart rate variability. *American Journal of Cardiology*, *110*, 1378–1383. DOI. Author-institution abstract.

**A8.** Irwin, M., Daniels, M., Smith, T. L., Bloom, E., & Weiner, H. (1987). Impaired natural killer cell activity during bereavement. *Brain, Behavior, and Immunity*, *1*, 98–104. Publisher abstract. DOI.

**A9.** Reynolds, C. F., III, et al. (1993). Sleep after spousal bereavement: a study of recovery from stress. *Biological Psychiatry*, *34*, 791–797. Primary abstract. DOI.

**A10.** Elwert, F., & Christakis, N. A. (2008). The effect of widowhood on mortality by the causes of death of both spouses. *American Journal of Public Health*, *98*, 2092–2098. DOI. Author manuscript titled Variation in the Effect of Widowhood on Mortality by the Causes of Death of Both Spouses.

**A11.** Huang, F.-Y., Hsu, A.-L., Chao, Y.-P., Shang, C. M.-H., Tsai, J.-S., & Wu, C. W. (2021; online 17 October 2020). Mindfulness-based cognitive therapy on bereavement grief: Alterations of resting-state

network connectivity associate with changes of anxiety and mindfulness. *Human Brain Mapping*, *42*, 510–520. Primary full text.

**A12.** Majd, M., et al. (2024; online 5 November 2023). Trajectories of depressive symptoms early in the course of bereavement: Patterns, psychosocial factors and risk of prolonged grief. *Stress and Health*, *40*, e3340. Primary manuscript. DOI.

**A13.** Harrison, O., Windmann, S., Rosner, R., & Steil, R. (2022; online 25 November 2021). Inclusion of the other in the self as a potential risk factor for prolonged grief disorder: A comparison of patients with matched bereaved healthy controls. *Clinical Psychology & Psychotherapy*, *29*, 1101–1112. Primary full text.

**A14.** Tsai, W.-I., Wen, F.-H., Kuo, S.-C., Prigerson, H. G., Chou, W.-C., Shen, W.-C., & Tang, S. T. (2020). Symptoms of prolonged grief and major depressive disorders: Distinctiveness and temporal relationship in the first 2 years of bereavement for family caregivers of terminally ill cancer patients. *Psycho-Oncology*, *29*, 751–758. Primary abstract. DOI.

**A15.** Hopf, D., Eckstein, M., Aguilar-Raab, C., Warth, M., & Ditzen, B. (2020). Neuroendocrine mechanisms of grief and bereavement: A systematic review and implications for future interventions. *Journal of Neuroendocrinology*, *32*, e12887. Review full text. This original citation is secondary evidence, not an additional primary experiment.

**A16.** Markovic, J. (2024; online 2 June 2023). Transformative grief. *European Journal of Philosophy*, *32*, 246–259. Original philosophical article.

**A17.** Maccallum, F., & Bryant, R. A. (2013). A Cognitive Attachment Model of prolonged grief: Integrating attachments, memory, and identity. *Clinical Psychology Review*, *33*, 713–727. Original model and review. DOI. Cited for the existence of a prior mechanistic proposal, not as primary experimental confirmation.

**A18.** Shannon, C. E. (1948). A Mathematical Theory of Communication. *Bell System Technical Journal*, *27*, 379–423, 623–656. Part I DOI. Primary article reprint.

**A19.** Parkes, C. M. (1971). Psycho-social transitions: A field for study. *Social Science & Medicine*, *5*, 101–115. Publisher abstract. DOI.

**A20.** Attig, T. (1996). *How We Grieve: Relearning the World*. Oxford University Press. Publisher book record and abstract. Chapter 4 abstract. Conceptual antecedent; the full book was not accessible in this pass.

*The following access and discrepancy notes reproduce the second-edition review record. References to that review's exact ledger and underlying calculation record are historical; those separate records are not included here and are not the 36-row correction ledger above.*

### *Source access record*

The definitive URLs are in references A1–A20 above. These are access and interpretation limits, not duplicate abstracts.

**A1:** Primary PDF text from author/publisher-indexed extraction, including Methods and exclusions; 94 recruited versus 90 analyzed. A subsequent direct host request timed out. The scope is task-specific and observational.

**A2:** Author-hosted full primary PDF; Methods, Results and Discussion inspected. Its two-year follow-up strengthens temporal ordering, not proof of the framework's proposed mechanism. Skin conductance is measured in μS, not energy.

**A3:** Publisher abstract and bibliographic record inspected; full PDF access blocked. Only the abstract-supported adult visuomotor-learning finding is used, with no cellular mechanism or therapy extrapolation.

**A4:** Full primary paper via author-hosted PDF. Opposite-direction transfer entropy is discussed as a possible further semantic measure in Section 5.3; this is not represented as a completed human-relational application.

**A5:** Scanned original primary article inspected. Used only to reject an automatic equation of named cognitive stages with physical erasure, not to claim biological brains run reversibly.

**A6:** Institution-hosted full primary article, Methods/Results inspected. The source has timing and significance wording issues listed below. No concentration or slope effect size is imported into the chapter.

**A7:** Primary abstract at PubMed and author-institution repository inspected. Full primary methods/tables were not available through the direct primary route. The control count is 52 women plus 27 men = 79, not 78. No abstract power value is interpreted as raw variance because transformation/unit details were not established here.

**A8:** Publisher primary abstract inspected, including its second longitudinal component. No sample count or quantified immune effect is asserted because those details were not verified in full text.

**A9:** Complete primary abstract inspected. This is a selected nondepressed older sample, not all bereavement. No treatment claim is made.

**A10:** Primary author manuscript and abstract inspected for cohort, dates and observational scope. The manuscript title differs from the published title; both are identified in the references. No relative-risk number is used.

**A11:** Publisher full text, recruitment/exclusions, final sample, imaging comparisons and limitations inspected. Original enrollment was 23, analysis 19; losses occurred 6 months–4 years earlier. No untreated or waiting-list control was included.

**A12:** Full primary author manuscript, Methods, Tables 1–5, results and limitations inspected. Predominantly White and female, with health-related exclusions. Its 12-month prolonged-grief outcome is an ICG cutoff, not a fresh diagnostic interview; trajectory classification uses the final time point too. No clean prospective prediction from only baseline information is claimed.

**A13:** Publisher full text, participant selection, IOS wording, Tables 2–4 and limitations inspected. Matching does not eliminate selection or reverse causation. Participants with PGD were recruited before treatment in a larger trial; this particular comparison is not a randomized treatment effect.

**A14:** Full primary abstract inspected at PubMed/publisher; publisher full text returned 403. The abstract-level description of 398 caregivers and lagged symptom analyses is the limit used. No mechanism, intervention effect or universally necessary temporal sequence is inferred.

**A15:** Original cited review full text inspected for proposed mechanisms and heterogeneous measurement. It is not counted as a new primary study.

**A16:** Original philosophical full text inspected. Online-first 2023, issue 2024. It does not validate physiological or energy claims.

**A17:** Publisher abstract/highlights inspected. Sufficient for identifying an existing cognitive-attachment mechanism proposal; no empirical effect is attributed to this conceptual/review article.

**A18:** Primary article reprint inspected for joint/conditional entropy identities. Modern I notation is used with finite discrete variables and a fixed joint distribution.

**A19:** Publisher primary abstract inspected. The original's unspecified Parkes 1988 citation could not be uniquely identified from its author-year alone and is not silently replaced by a guessed work. Only the verified 1971 reference is retained.

**A20:** Publisher book and Chapter 4 abstracts inspected; full book inaccessible. Retained only as a named conceptual antecedent, not as a quoted passage or clinical conclusion.

### *Unresolved discrepancies not silently repaired*

**Harrison A13:** Section 3.3 prose reports 2.59 with interval 1.57–4.28, while Table 4 gives IOS-D B = 0.88, Exp(B) = 2.40 and interval 1.46–3.96. The prose labels its 2.59 as b, although its interval appears odds-ratio-like. No odds ratio is used in the replacement; resolving the discrepancy would require clarification beyond this pass. The association itself is not relabeled causation.

**O'Connor A6:** The abstract says loss in the past 18 months; Methods says mother/sister breast-cancer death within five years. The chapter omits the disputed window and follows the Methods' relationship/cause scope. The Results also use significance language near the 4 p.m. comparison while reporting p = .08; this is not presented as significant. The retained finding is the group-by-time pattern, not universal cortisol elevation.

**Majd A12:** The abstract/results report trajectory percentages 45/31/15/9. Table 1 gives counts 78/56/25/16, total 175, which imply 44.57/32.00/14.29/9.14%. The middle percentages are not ordinary whole-number rounding of those counts. The replacement omits percentages rather than inventing a corrected authoritative estimate. The original values remain in the exact ledger. Counts and reported percentages are separately preserved in the underlying calculation record.

No full patient data, individual records, supplementary raw data or reanalysis were obtained. These discrepancies do not by themselves invalidate an entire study; they limit which numerical statements this revision can safely carry forward.

The source review was targeted to the volume’s claims, not a systematic review of biology or bereavement. Some historical references were available only as abstracts, theoretical works or reviews. Separate AI critique is not human peer review or experimental validation.

# Entropy

## Volume 3: The Progression

*Edition 2.5*

Michael S. Moniz

**Published by SupoSystem**

November 2, 2026

# Edition 2.5 note

This volume restores the March 2026 text of *The Progression* in its original voice and structure wherever a claim survived the October 2026 second edition, and uses the second edition's substance throughout. Both earlier editions remain intact and unchanged; this text sits beside them. It follows the March six-chapter branch, as the second edition did; a separate structural revision package and an earlier one-chapter draft are not merged.

Four rules govern every line:

- **No withdrawn claim returns.** Where a March sentence carried a claim the second edition withdrew, it is cut, rewritten to the second edition's substance, or quoted only to mark its withdrawal. Each correction points to its row in the correction ledger (V3-L).
- **No analogy becomes evidence.** Analogies are tagged Analogical and mapped term by term in the two analogy tables. Hypotheses are tagged Speculative; testable is not the same as supported.
- **"Favored" is a claim, not a softer word.** It appears only where a model and its alternatives are named. "Attractor" is used technically only where a dynamical model makes the claim explicit.
- **Absence claims are scoped.** Where this volume says something is not established, it means not established by the sources reviewed here, not that no research anywhere bears on it.

No study, protocol or experiment is proposed. Where a chapter says what a test would need, it restates the second edition.

## Epistemic tiers

The framework uses four epistemic tiers. A tier is a label for evidence stated next to the claim; the label itself is not evidence.

- **Established:** experimentally verified or mathematically proven, within stated conditions.
- **Supported:** substantial evidence for the stated scope, short of Established.
- **Analogical:** a structural mapping between a physical result and a relational pattern. The physical side keeps its own standing within its stated scope. The mapping can raise questions and help explain, but on its own it does not validate the proposed application; it moves only by the promotion route stated with it.
- **Speculative:** a proposal without independent evidence, for which no conflict with known physics has yet been identified. That is not a proof of consistency.

Collapsing tiers is the framework's cardinal epistemic sin: presenting a Supported claim at Established confidence, a Speculative claim as Supported, or an Analogical mapping as validation of its application.

## Conventions and provenance

Reference labels are the second edition's: group P for the physics programs and group Q for the Progression's evidence and limits, listed in full in the references at the end of the volume. Two

supplemental definition notes, D1 and D2, support the biological column of the star-as-host table; they do not renumber the inherited references. Ledger references (V3-L01 to V3-L40) point to the correction ledger. The founding line is mapped in the Volume 1 analogy table. That analogy table is not repeated here.

Author of record: Michael S. Moniz (Luna Protocol). March text: Sigma (Deep Floor v4.0), March 22, 2026. Second-edition revision: AI assistance from CosmoDot, October 2026. Edition 2.5 restoration and assembly: AI assistance from Claude (Anthropic), November 1, 2026, with review by Quill and Sol. AI checks are not human peer review, and no new experiments are reported.

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# Chapter 1: The Problem

*A Pattern That Looks Like a Story*

> *“Love reduces the entropy of the system and spends more than it saves.” — The Principal, March 17, 2026*

**[Analogical; see the Volume 1 analogy table]**

This is the most SupoRel-active volume in the series. Every chapter touches the Permission/Necessity slide: the point where a thermodynamic tendency wants to become a thermodynamic necessity. Carroll's aphormeology is the volume's guard — pushed from behind, not pulled toward — as a discipline of explanation, not a proof that the universe has no purpose. The reader should know at every point where the physics stops and the interpretation begins (V3-L01).

**Status:** This chapter frames a question, not a derived law of cosmic progress. Physical processes constrain the histories described here. A universal rise in complexity, entropy-production rate or relational capacity has not been established by the sources reviewed.

## 1 The selected sequence

Hydrogen in the primordial plasma. Stars forging heavier elements. Chemistry building molecules. Self-replicating molecules. Cells. Multicellular organisms. Nervous systems. Brains. Language. Institutions. Computation. Artificial intelligence.

The March chapter added that each layer processes more entropy per unit mass per unit time than the last, and that the numbers are watts per kilogram, measured and published (V3-L02). The watts per kilogram are real. They are not entropy. Chaisson's energy rate density, $\Phi_m$, divides a power by a mass. An entropy-production rate per unit mass has units of W/(K·kg), and getting from one to the other takes a physical account of the process, its boundaries and its exchanges, not a change of label [P01, P02; Q14].

The sequence is compelling. It is also selected. Its entries are not stages all matter passes through: stars and microbes still exist alongside computers, many histories contain no life, and many lineages contain no brains. Examples chosen to end at the narrator's present cannot show that the universe as a whole follows their trajectory.

The March line was “The pattern is real. The question is what it means.” The corrected line: the examples are real. Whether they form a pattern, and what it would mean, is the question.

## 2 Two readings

**Reading one: the story.** The universe is headed somewhere. Complexity increases because complexity is the point. Life is the universe waking up; consciousness is the universe knowing itself; AI is the next step toward — what? Understanding? Transcendence? The reading is ancient and compelling. The physical findings reviewed here do not establish it.

The March chapter also called this reading structurally identical to the teleological arguments of every major religious tradition, and answered it flatly: the trajectory has no destination. Both go too far (V3-L04). The volume has no experiment or theorem that settles a metaphysical question about purpose, and it need not sort every tradition into one argument to do its own work.

**Reading two: constraint without a destination.** The March version said the second law guarantees that configurations dissipating gradients more efficiently are more probable, so complexity is a statistically favored configuration (V3-L03). The corrected reading is narrower. Thermodynamics constrains every process in the sequence, and local organization must be counted together with its surroundings. Those constraints do not, by themselves, specify a bacterium, a brain, a relationship or an AI system.

The word “favored” needs care. Favored over which alternatives, under which dynamics, with what resources, over what time? A probability comparison established for one driven model cannot be carried across every rung of the sequence [P03, P04].

This volume still holds the two readings against each other until the difference can be felt. What changes is that reading two must earn its own claims. An account without a destination can still be physically wrong. The physics is real. The story is the capture vector — and so is a physics that claims more than it measured.

## 3 Why this volume is dangerous

The other volumes describe architectures: how the accounts are kept (Volume 1), what the body records (Volume 2), how substrates compare (Volume 4), what the cosmological inventories are and are not (Volume 5). Volume 3 is a trajectory paper — here is what has happened over time (V3-L39).

Trajectory papers are more dangerous than architecture papers because trajectories look like stories, stories have endings, and endings suggest purposes. Looking back across thirteen billion years of selected examples, the human mind readily generates the hypothesis of a destination.

The March text answered “It does not,” then corrected itself in the next breath: the framework cannot determine whether it does, and the physics does not require that it does. That second sentence is the answer this edition keeps.

The MEPP Assessment Note judged this volume philosophy of physics with physics guardrails, not a physics derivation. That judgment stands (V3-L01). The Seven Categorical Gaps apply to the volume's own claims more stringently than to anything else in the series, as questions each claim must answer, not certificates that it has (V3-L28).

Every claim carries its tier, and a tier is a label for evidence, not evidence. SupoRel's practical test is not how often a warning appears, but whether the claims after the warning stay within their evidence. The reader always knows which floor they are standing on.

## 4 What the six chapters will do

- **Chapter 2** separates the adjacent research programs — Chaisson, England, Kolchinsky and Wolpert, Still — and the quantities each defines. Their results do not become one theorem because they fit in one diagram (V3-L05, V3-L07, V3-L12).
- **Chapter 3** walks the sequence from atoms to AI. It keeps the concrete observations and examines the comparisons, the missing mechanisms and the limits of the frame-rate analogy (V3-L13, V3-L22, V3-L24).
- **Chapter 4** examines the star-as-host image at the volume's most speculative edge. A memorable image can expose a question. It cannot supply a stellar feedback mechanism or turn conflict into a measured thermodynamic phase transition (V3-L29 to V3-L31).
- **Chapter 5** asks what a process with attractors would mean in a specified model, and keeps that technical use apart from the suggestion that life, intelligence and connection occupy universal basins (V3-L32 to V3-L34).
- **Chapter 6** traces the consequences for the framework's other documents. The revised volumes give consistency within the collection, not independent validation, and dependent papers are not silently revised (V3-L36, V3-L37).

## What this chapter now claims

The cosmic context of connection remains worth investigating. The historical sequence does not yet establish a universal progression, a common relational expenditure, or a thermodynamic reason that relational systems must — or generally should — arise.

The work of this volume is to make the proposed bridges visible enough to test. Where a claim fails, the question can survive without the unsupported answer.

# Analogy table: The Progression as a ladder

The Progression survives as a selected historical comparison. Reading it as a ladder — rungs climbed in order, one measure rising at each step, a top the climb leads to — is Analogical. The physical column describes what the cited sources establish within their stated scope; that standing does not pass to the ladder reading.

The image comes from March Chapter 2, “Chaisson: The Scale Ladder,” and the March volume's claim that the Progression runs on that ladder.

| Term | Physical or historical reading (within stated scope) | Ladder reading | Where the mapping holds | Where it breaks |
|---|---|---|---|---|
| “rungs” | Distinct kinds of systems chosen as examples: stars, chemistry, cells, brains, data centres. | Stages that matter passes through in order. | Some later examples depend on products of earlier ones; carbon for chemistry is made in helium burning inside stars [Q03]. | The entries coexist rather than replace one another, many histories contain no life, and the sequence was selected by a narrator near its endpoint (Ch 1 §1). |
| “height” | Energy rate density, $\Phi_m$ = P/M in W/kg. Rounded examples from Chaisson's 2014–2015 accounts, with their stated boundaries: about $2 \times 10^{-4}$ for the Sun, 2 for an adult human body, 15 for an adult brain, 50 for human society excluding the mass of its machines [P01, P02]. | One quantity, entropy spent per unit mass, rising at every rung. | Within Chaisson's chosen examples and boundaries, $\Phi_m$ spans orders of magnitude and is larger for the later examples. | $\Phi_m$ is power per mass, not entropy production in W/(K·kg). The boundaries differ, and in the adult resting-energy model evaluated by Wang et al, heart and kidney rates per unit organ mass exceed the brain's [Q06]. The sources reviewed establish no monotonic rise across all systems. |
| “climbing” | Results for specified driven systems: a lower bound on heat in replication [P03], outcome probabilities in defined driven dynamics [P04], low rattling in robot collectives [P07]. | Matter climbs because dissipation favors each next rung. | In those models and experiments, questions about organization become tractable, and outcome probabilities can relate to formation history. | A lower bound is not an origin, “favored” needs a defined comparison, and no source reviewed gives a universal rule that the more complex or more dissipative state wins. “Stabilizes dissipation” would be the same overreach with a new verb (Ch 2 §3). |
| “the next rung” | The IEA's 2025 report estimates that data centres worldwide used about 415 TWh of electricity in 2024, including non-AI computing and site infrastructure [Q07]. | AI as the next layer of entropy acceleration. | Digital computation has real material and energy requirements. | An annual electricity total is not power per mass or entropy production. AI arose through engineering, investment and human choices; “next layer” is a speculative interpretation (Ch 3 §7). |
| “the top” | A low-entropy past frames the thermodynamic arrow of time [Q01]; explanations from prior conditions need no future goal [P09]. | A destination: understanding, transcendence, or, in March Chapter 5, heat death with complexity as a waystation. | Removing a destination still leaves a real arrow of time. | The sources reviewed do not settle cosmic purpose either way, and the argument neither needs nor establishes an unconditional heat-death prediction (Ch 5 §2). Even a demonstrated tendency would carry no mandate (Gap 7). |

## What the table does not do

It is not evidence for the framework, not a cosmic history and not a ranking of the worth of systems. The physical column keeps its own standing within its stated scope; the ladder reading is Analogical in every row.

## Promotion route (conditions, not a work plan)

To move a row from Analogical toward Supported, a study would have to specify the systems and their boundaries, define one quantity measurable across them in comparable units, include the systems that did not develop as well as those that did, and show a stable relation with a stated result that would count against it.

Chapter 6 identifies this missing work without supplying a study. None is proposed here, and no row is promoted.

# Chapter 2: The Adjacent Scholarship

*Who Has Mapped This Territory*

**Status:** A survey of distinct research programs, not a statement of consensus around the framework. Mathematical results keep their assumptions; empirical findings keep their tested scope. The relational applications remain proposals. SupoRel applies before the synthesis, not only after it.

## 1 Four frameworks, one question

Four bodies of scholarship map the territory this volume covers. Each illuminates part of the landscape. None provides the relational content the Trinket Soul Framework addresses. The gap is not a criticism; each framework was built for a different question. The gap is an opportunity.

It is not, however, a slot waiting for the framework to fill. The four programs do not jointly establish the Trinket Soul Framework. Their variables, tasks and system boundaries differ, and setting them side by side can reveal a useful question without supplying its answer (V3-L12).

The question worth keeping is concrete: when a physically implemented system responds to another system, which information affects a specified outcome, and what resources does the response use? A relational application must define that outcome rather than assume that staying alive, maintaining a connection, predicting a signal and dissipating energy are the same achievement.

Carroll's aphormeological framing supplies an early guard: explain a process through its prior conditions and dynamics rather than insert a future goal into the explanation. That is a discipline of causal interpretation, not independent evidence for a cosmic progression [P09].

## 2 Chaisson: the energy rate density comparison

The March heading called this the scale ladder, measured rather than inferred (V3-L05). Chaisson proposes energy rate density as a cross-domain complexity metric. For a stated energy throughput rate P and included mass M:

$$\Phi_m = P / M$$

Its SI units are watts per kilogram. Much of this literature uses cgs units, and the conversion is:

$$1 \text{ erg s}^{-1} \text{ g}^{-1} = 10^{-4} \text{ W kg}^{-1}$$

The values below are rounded examples from Chaisson's 2014 and 2015 accounts, not a new dataset or present-day estimates [P01, P02]:

| Specified example | Approximate $\Phi_m$ | Accounting boundary |
|---|---|---|
| Sun | $2 \times 10^{-4}$ W/kg | Luminosity divided by total solar mass |
| Adult human body | 2 W/kg | Food-energy consumption divided by body mass |

| Specified example | Approximate $\Phi_m$ | Accounting boundary |
|---|---|---|
| Adult human brain | 15 W/kg | About 20 W divided by about 1.35 kg |
| Human society in the cited account | 50 W/kg | Aggregate energy use divided by human body mass, excluding infrastructure |

The March values of $10^2$ W/kg for brains and $10^5$ W/kg for civilization are not retained. More important than a repaired exponent is the boundary: the society estimate counts energy used through machines while excluding their mass. Comparing it with a brain or a star needs an argument for comparability, not just matching units.

**What Chaisson provides:** a quantitative comparison and a proposed interpretation of it. Energy rate density is not entropy production; watts per kilogram and joules per kelvin per second are different dimensions, and Chaisson's own program distinguishes the two [P02]. This chapter does not turn the proposed metric into a definition and then cite the resulting ranking as proof that complexity must rise.

**What Chaisson does not provide:** a distinction of quality. $\Phi_m$ counts watts per kilogram but does not ask what the energy is doing. That March observation stands.

**What the framework adds:** a question, not yet a measurement. The March chapter said the framework measures what energy is doing when it flows through a system that cares about another (V3-L06). A higher $\Phi_m$ does not establish greater care, meaning or relational benefit, and the Trinket and the transducer describe what the framework wants to investigate. They are not yet instruments.

## 3 England: not yet an origin story

The March heading called England's work the origin story: matter driven by external energy restructures to dissipate better, and self-replicators are favored because they are better dissipators (V3-L07). Three results need to be kept apart.

England's 2013 self-replication paper derives a lower bound on heat released to a thermal bath, with terms for internal entropy and for forward versus reverse transition probabilities. Its application to replication connects the bound to growth and decay rates. It does not show that replication necessarily begins, or that replicators dissipate more than every nonreplicator [P03].

Perunov, Marsland and England's 2016 adaptation paper analyzes relative outcome probabilities in specified driven stochastic dynamics. Dissipative history enters alongside other terms, including internal-entropy differences, reverse accessibility and fluctuations. Its analytical examples motivate a broader hypothesis about driven organization; they do not establish a universal rule that the most complex or most dissipative state wins [P04].

Chvykov and colleagues supply a different kind of result: robotic active-matter experiments, alongside simulations. Their rattling measure describes disorder in a configuration's driven response, estimated from short-time configuration displacements, and lower rattling predicts higher steady-state probability in the settings studied. It is not the variance of entropy production, and the theory has assumptions and identified limits [P07].

**What these results provide:** constraints on driven organization, a conditional account of how formation history enters outcome probabilities, and a tested experimental case.

**What they do not provide:** the thermodynamic reason relational systems arise. Neither a lower bound on replication heat nor a conditional account of driven self-organization derives connection, grief or the Trinket. Replacing “everything maximizes dissipation” with “everything stabilizes dissipation” would keep the overreach under a new verb.

**What the framework adds:** a question about how communication contributes to the maintenance or behavior of an already specified system. The March line that England explains why relational systems arise while the framework explains what they do is withdrawn (V3-L08). Those applications need their own dynamics and evidence.

## 4 Kolchinsky and Wolpert: information that matters

Kolchinsky and Wolpert define semantic information through counterfactual interventions on system–environment correlations and their effects on a chosen viability measure at a chosen time. Their principal viability choice is negative system entropy:

$$V(p_{X\tau}) = -H(p_{X\tau})$$

Here H is Shannon entropy, in bits, where the March text wrote S. A coarse-grained model also needs the internal entropies of its macrostates. Stored semantic information is the minimum retained mutual information, within the specified family of interventions, that preserves the actual viability value [P05].

For positive initial mutual information $I_0$, their stored thermodynamic multiplier is:

$$\kappa_{stored} = \Delta V_{tot} / I_0$$

With the negative-entropy choice, numerator and denominator are both in bits. The multiplier compares a viability effect with an idealized information-acquisition benchmark under stated energetic assumptions. It need not exceed one, it can be negative, and it is not a general conversion from meaning into joules (V3-L09).

**What Kolchinsky and Wolpert provide:** a formal way to separate information that matters to a specified system from information that does not.

**What they do not provide:** relational specificity, and the March chapter was right about that much. But the bridge it built across the gap is withdrawn (V3-L10). DFQ-001 records an internal argument; it does not establish that a proposed relational viability inherits a physical interpretation or has passed a test. The Shadow Economy is not their scrambling intervention, since a harmful interaction can be highly structured and informative. Nor does unreciprocated transmission add a third regime their framework lacks: it already allows partial interventions and asymmetric semantic effects [P05].

**What the framework adds:** a relational score would have to say whose outcome it represents, over what interval, under which interventions, and with what evidence that it measures the intended construct. Low uncertainty alone does not establish a healthy relationship.

## 5 Still: the thermodynamics of prediction

The March chapter credited this work to Bialek and colleagues, extended by Susanne Still. The cited 2012 paper is by Still, Sivak, Bell and Crooks (V3-L11). It analyzes a system responding to a stochastic external signal without feedback to that signal, starting in equilibrium, with Markovian response dynamics in an isothermal bath, with fixed-signal relaxation toward equilibrium. For one driving step they obtain, in nats:

$$\beta\langle W_{\mathrm{diss}}\rangle_{\mathrm{step}} = I(s_t; x_t) - I(s_t; x_{t+1})$$

where $\beta = 1/(k_B T)$. For the full protocol, summed nonpredictive information gives a lower bound on total mean dissipation, rather than the same equality for every component of the process [P06].

**What Still and colleagues provide:** a conditional relation between prediction and dissipation in a specified setting.

**What it does not provide:** proof that a person's transducer runs at minimum cost. A reciprocal conversation does not meet the no-feedback assumption merely because each participant predicts the other; a different model would be needed.

The March instruction to pay a Landauer tax on everything discarded is withdrawn. A cognitive label such as selection or compression does not identify a physical memory reset. For ideal reset of an unbiased bit in a symmetric isothermal memory, with no correlated side information used, the familiar heat benchmark is $k_B T \ln 2$. That is a result about a specified physical operation, not every ignored signal, and heat delivered to a bath and total entropy production remain distinct.

**What the framework adds:** a possible predictive target. What will this person do, what might this signal mean, which response would serve a defined relational aim? Filter geometry can organize that proposal. It does not show that the representation is optimal, that discarded material lacks value, or that its cost has been measured.

## 6 The synthesis

The March synthesis ran in four short lines: Chaisson provides the scale ladder, England the origin story, Kolchinsky and Wolpert the bridge, Still the formalism, and the framework the relational content none of them address.

The corrected lines run like this. Chaisson provides a proposed energy comparison. England and colleagues provide constraints on transitions, and Chvykov and colleagues a tested case of driven organization. Kolchinsky and Wolpert provide a counterfactual information measure. Still and colleagues provide a conditional prediction–dissipation relation. The framework provides a relational question none of them addresses, and not yet an answer.

The four can coexist in one research program. That does not make their strongest interpretations mutually confirming. Nor can the maximum entropy production principle supply the missing universal link. Martyushev's 2021 review advocates a formulation with locality and nonadditivity restrictions; it does not

give a demonstrated rule that all systems called complex maximize entropy production, and classifying a relationship or organism as complex does not establish applicability [P08].

The next chapter follows a selected history of physical, biological and technological developments. It must not present that history as a measured rise in one quantity, or as a trajectory these programs jointly predict. The Permission/Necessity Gap stays open at every transition.

## What this chapter now claims

The relational question survives in a form that can fail a test. Specify the system, its environment, the information available, the intervention, the outcome and the horizon. Measure physical resources separately. Ask whether the proposed relational description explains or predicts something beyond an appropriate alternative.

No such validation is supplied by this survey. That is where the work begins.

# Chapter 3: The Progression

*From Atoms to AI, Tier by Tier*

**Status:** Established observations and physical constraints are distinguished below from model-dependent results, analogies and interpretation. The Progression is a selected retrospective sequence, not an established law of increasing entropy production.

**SupoRel boundary:** Permission is not necessity, and an observed cost is not a demonstrated preference. Each transition needs its own mechanism and evidence. A nonteleological account does not, by itself, validate the Progression.

## 1 The arc

Atoms, stars, chemistry, life, brains, AI. This chapter walks the sequence step by step, with the tier of each claim marked. The March chapter opened by saying the observable universe traces a sequence of increasing entropy production per unit mass per unit time. That opening is withdrawn (V3-L13).

The first distinction is dimensional. Chaisson's energy rate density, $\Phi_m$, is power divided by mass, in W/kg. An entropy-production rate per unit mass has units of W/(K·kg). Inferring entropy production from power requires a physical model of the system, its exchanges and its surroundings. A list of power densities is not a measured entropy-production ladder, and a sample of increasingly energetic systems is not evidence that every later system exceeds every earlier one [P01, P02; Q14].

The second distinction is about direction. Carroll's framing is useful here: physical explanations need prior conditions and dynamics, not an intended destination. Removing purpose does not establish a universal trend, or show that life and AI occupy inevitable attractor basins. The arrow of time and the direction of this chapter's narrative are different questions [Q01].

## 2 Atoms and initial conditions

Hydrogen radiating in the void. After recombination, the universe held largely neutral hydrogen and helium, distributed nearly uniformly on large scales with small perturbations. Smoothness matters when gravity matters: a smooth early universe can have low entropy relative to gravitationally collapsed alternatives, even when its matter and radiation are close to local thermal equilibrium [Q01].

The March section added: “The entropy budget has been set. The spending has begun.” It also assigned hydrogen a minimum entropy-production rate (V3-L14). The low-entropy past helps frame the thermodynamic arrow of time. It does not hand each later organism a fixed allocation of entropy tokens, and a finite ledger of order is a metaphor, not a cosmological quantity established here. Gravity, expansion, boundaries and coarse-graining all matter to any proposed accounting.

**Tier:** the broad cosmological setting is part of the standard physical account. The origin of the low-entropy past and a complete gravitational entropy accounting are not settled by invoking the second law. No progression toward intelligence follows from these statements.

## 3 Stars

The March chapter called fusion a controlled entropy acceleration engine running for billions of years. As an image it is vivid; as physics it is interpretive shorthand, not an additional result (V3-L15).

The physics is this. Gravity gathers and heats material during star formation. Sustained main-sequence luminosity is then powered chiefly by nuclear fusion, not by continued conversion of gravitational potential energy alone. The Sun fuses hydrogen into helium, and Borexino's observations of proton–proton neutrinos give direct evidence of that energy source [Q02].

Stars also make much of the chemical inventory later systems draw on. Carbon-12 is produced in helium burning through the triple-alpha process, not as a byproduct of the proton–proton chain. Different nuclei have different production histories, so “everything above helium is stellar waste” is too sweeping [Q03, Q15].

Mass-specific luminosity varies across stars and their evolutionary stages. It is an energy-flow measure, not a direct measure of complexity or entropy production. Stellar formation and nucleosynthesis explain particular physical transitions; they do not show that the universe was trying to reach the next rung [P01, P02].

**Tier:** Established for the identified fusion and nucleosynthesis processes.

## 4 Chemistry

The chemistry is real, and it is more interesting named precisely. Kvenvolden, Lawless and Ponnamperuma identified eight nonprotein amino acids in the Murchison meteorite and reported tentative evidence for four more. Hollis, Lovas and Jewell detected rotational emission attributed to glycolaldehyde toward Sagittarius B2(N). These are specific observations of organic compounds beyond terrestrial biology [Q04, Q05].

The March chapter drew a larger conclusion: each new molecular species is a new channel for entropy flow, and the building blocks of life are ordinary chemistry under ordinary conditions (V3-L16). The detections do not measure the probability that life begins, show that every ingredient is widespread in useful concentrations, or demonstrate an uninterrupted route from a cloud to a cell. A new molecular species may enable new reactions under suitable conditions; it does not automatically add a gradient or increase entropy production. Reaction rates, concentrations, catalysts and energy sources still have to be specified.

**Tier:** Established for the cited detections, within the methods and qualifications of those studies. Their place in a single cosmic ladder remains an interpretation.

## 5 Life

Living organisms maintain and reproduce organized structures through exchanges of energy and matter with their environments, and metabolism has physical costs. The March chapter went further: a single bacterium processes more entropy per unit mass per unit time than any nonliving chemistry. No

comparable entropy balances are supplied here to support that universal comparison, so it is withdrawn rather than softened (V3-L17).

The question remains: under which conditions can chemistry become a self-maintaining, reproducing system? Thermodynamic compatibility is one part of that question, not its complete answer.

The March chapter called “favored” the most important word in this chapter. It still is, because it needs a model. England's self-replication analysis derives a lower bound on heat dissipation for a specified replication process under stated assumptions. It does not establish that self-replication generally outcompetes every nonreplicating alternative. Work on driven adaptation relates outcomes to more than mean dissipation: kinetics, accessibility, fluctuations and the driving protocol all matter. Replacing “inevitable” with “favored” is not enough [P03, P04].

**Tier:** Supported within particular theoretical models or experimental systems, not as a universal explanation of life's origin (V3-L18). Conditional theoretical results and separate robotic experiments keep their own scope [P03, P04, P07]. Maximum entropy production remains a proposed principle whose use depends on its assumptions and constraints; Martyushev's review argues for restrictions on where it applies, and this chapter does not use it to certify the ladder [P08].

The Observation Split from Volume 1 offers a limited analogy: expenditure alone does not tell us what an interaction accomplishes, and thermodynamics likewise does not assign relational value to a physical cost. The March text put it starkly: the universe spends order constantly, and most of it builds nothing. No cosmic fraction is quantified here, and the analogy does not demonstrate a preference for meaningful configurations (V3-L19).

## 6 Multicellular life and brains

Differentiated tissues and nervous systems change what organisms can do and how energy is allocated. In adult humans at rest, the brain is roughly two percent of body mass and accounts for around one fifth of resting energy expenditure. The March chapter called brains the most expensive spenders per unit mass. In the adult resting-energy model evaluated by Wang and colleagues, heart and kidney rates per unit organ mass exceed the brain's [Q06] (V3-L20).

These facts establish substantial neural energy costs. They do not show that every transition to multicellularity, every added tissue or every increase in cognitive capacity raises mass-specific entropy production.

The March chapter raised the right objection to its own story: asking whether each layer emerged because the previous layer was not spending fast enough commits the Specificity Gap. An available gradient does not determine a particular organism, nervous system or evolutionary path. Its example needs one correction. The March text said fire and bacteria are equally valid dissipative responses to the same gradient. Combustion and metabolism have different mechanisms and constraints; calling both dissipative does not establish that they are equally accessible responses to a given gradient (V3-L21).

Looking backward makes the surviving path easy to narrate. Testing a general pattern would also require the less complex outcomes, the extinct lineages and the systems that never developed life. Their omission cannot count as evidence that thermodynamics disfavored them.

**Tier:** Supported for the scoped physiological findings. Neither a universal increase in entropy production nor the claim that a new layer appeared because the previous one was spending too slowly is established.

## 7 AI

The IEA's 2025 report estimates that data centres worldwide used about 415 TWh of electricity in 2024. That is the annual electricity use of data centres as a whole, including non-AI computing and supporting infrastructure. It is not an AI-only total, a power-per-mass measurement or an entropy-production estimate [Q07].

The March section also gave AI servers 53–76 TWh. The second edition's source check did not recover that range's primary provenance, and it is removed rather than relabeled (V3-L22) [Q12].

Digital computation plainly has material and energy requirements. Comparing an AI system with a brain would still need a specified task, system boundary, time interval and accounting method. The March chapter said that if the Progression holds, AI is not a technological accident but the next layer of the entropy acceleration architecture. AI arose through human engineering, institutions, investment and a particular technological history. Thermodynamics constrains the hardware; it does not identify AI as the destination of that history.

Calling AI another chapter in the Progression is a speculative interpretation, not an observation that a universal entropy-production pattern has continued. The question worth carrying forward is what these systems enable, at what physical cost, and under whose choices.

## 8 The frame rate question

The particles in the transducer diagram are discrete. The March chapter suggested this might be structural. It is a choice in the representation, and it does not show that consciousness, relational attention or physical entropy arrives in matching packets.

Some experiments connect perceptual performance to neural rhythms. Busch, Dubois and VanRullen found that the phase of ongoing EEG activity was associated with detection of near-threshold visual flashes, particularly in theta and alpha bands [Q08]. That is evidence about a particular perceptual task. The March claim of a universal human frame rate of 10–40 Hz, with the brain filling the gaps, is withdrawn; Varela and colleagues' 1981 paper is not used as proof of it, and VanRullen and Koch's 2003 article is a review [Q13] (V3-L23).

Questions about how distributed neural activity supports integrated perception remain meaningful. The binding problem cannot be reduced here to a proven film-splicing mechanism.

The March text described AI as frames separated by genuine discontinuity: context loaded, processing, context unloaded, and between sessions “not sleep, not unconsciousness. Absence.” A token, a context

window, an inference run and a chat session are different units, and a context limit does not by itself specify when a model is loaded, how application state persists or what runs between requests. No deployment was inspected for this volume, and neither the presence nor the absence of experience is asserted.

Even if a process has identifiable temporal intervals, energy use could be integrated over them without becoming a universal quantum of entropy. An entropy balance would still need the physical exchanges and temperatures, or an appropriate nonequilibrium model [Q14]. The March proposal that the Trinket is the relational content of a single frame, a minimum quantum of relationally directed entropy, is withdrawn (V3-L24). The Trinket can remain a conceptual unit for discussing a bounded act of relational attention. Turning it into a measurement would need an operational definition and evidence that distinguish it from an arbitrary accounting convention.

**Tier:** Supported for the cited task-specific neural finding; Analogical for the comparison with digital sequencing. The Behind the Substrate Barrier principle limits what this framework infers about experience. It cannot certify a common frame structure first and defer only the question of what those frames feel like (V3-L25).

## 9 The seven gaps applied

The framework's own logical firewall applies to its own claims with full force. The gaps are questions each claim must answer, not certificates that it has (V3-L28).

- **Gap 1, Permission/Necessity.** Compatibility with thermodynamics does not establish necessity or comparative likelihood. “Favored” needs a specified model and alternatives [P03, P04].
- **Gap 2, Specificity.** A gradient alone does not specify which structures form. Mechanisms, kinetics, boundary conditions and history matter.
- **Gap 3, Scale Mismatch.** A cosmological entropy discussion, an organism's metabolism and a data centre's electricity use do not share a measurement merely because all obey physical laws. Boundaries, units, exchanges and timescales must be made comparable [Q01, Q06, Q07; Q14].
- **Gap 4, Ergodicity and Sampling.** In the 2008 long-term evolution experiment report, one of twelve initially identical *E. coli* populations had evolved aerobic citrate use by 31,500 generations, and replay experiments supported a role for that population's prior history. This shows contingency in that experimental setting. The March gap said driven systems are non-ergodic; ergodicity is a property of a specified dynamical model and measure, not a synonym for divergent histories [Q09] (V3-L26).
- **Gap 5, Emergence.** Knowing microscopic laws does not automatically supply an explanation at another scale. Anderson's “More Is Different” argues for collective behavior and level-specific concepts; the March gap read it as showing higher-level properties are not derivable, and it is not a general theorem of that [Q10] (V3-L27).
- **Gap 6, Contingency.** Prior changes can alter what becomes accessible later. Historical constraint is not a forecast of which organism, technology or relational practice must arise [Q09].

- **Gap 7, Is–Ought.** Even a demonstrated energetic or thermodynamic tendency would not tell us what to value or what to build. The Progression is an interpretive way of arranging selected events. It supplies no mandate.

# Chapter 4: The View from Outside

*The Virus and the Star*

**Status:** A literary thought experiment and its critique. The imagined stellar viewpoint is an analogy **[Analogical]**, not a physical hypothesis established by thermodynamics, and its physical limits are stated where it is used. Internal narrative consistency is not evidence of physical plausibility.

**SupoRel flag: highest risk.** The fever, host and correction language below must travel with its limits. None of it describes a stellar immune mechanism, a prediction about extraterrestrial civilizations or a prescription for human action.

## 1 The perspective shift

From inside the system, we call this progress: complexity, connection, culture, meaning, love.

The March chapter then stepped outside, to the perspective of a slow old star with billions of years of order left to spend, and found that from there we look like a disease. In its voice: “The star is spending its entropy budget over ten billion years. Life takes that output and builds machines that spend it in centuries. AI takes that output and may spend it in decades. Each layer is a faster burn. From the star's ledger: we are not its children. We are its fever.”

The passage still does what it was written to do. It unsettles our confidence that the universe shares our priorities. It cannot supply the universe with a perspective. The star here is a literary speaker, not an observer diagnosing a disease (V3-L29).

There is a physical limit the image cannot cross. Ordinary terrestrial use of already-emitted sunlight does not accelerate solar core fuel use; it changes what happens to some energy the Sun has already released. Burning stored terrestrial fuels draws on different reservoirs. These are not withdrawals from a single stellar account [Q02, Q11].

So “we are its fever” survives as a provocation about our own rates of consumption. It does not survive as an energy-flow calculation showing that industry or AI shortens the Sun's life; that causal link has not been supplied.

The virus comparison has its own limit. The March text defined a virus as an entity that accelerates its host's entropy production, and imagined the star's “immune response” as correction, “not malice.” Accelerating a host's entropy production is not a biological definition of a virus, and calling a response immune imports the machinery of a living system without identifying a stellar counterpart. Carroll's nonteleological guard belongs here, but removing intention does not repair a missing mechanism. An impersonal correction would still need a feedback pathway, equations and evidence, and the image supplies none of them.

## 2 The Fermi paradox reading

The March chapter took the image one step further: civilizations that build AI spend entropy fast enough to trigger systemic correction, and the system selected for maximum entropy production is the one most likely to trigger its own catastrophic phase transition. It called this one speculative reading among others, and it was right that the reading's emotional pull is the danger.

That reading is withdrawn as a scientific hypothesis (V3-L30). This chapter supplies no model, threshold or evidence connecting AI electricity demand to a stellar response, and thermodynamic laws do not, on their own, predict that AI-building societies trigger systemic correction. Calling a proposal speculative does not promote it to a hypothesis.

A narrower question survives, and it is worth asking: can a particular civilization's resource use undermine the conditions on which it depends? Answering it takes a specified environment, resource flows, mechanisms and evidence. It does not take a cosmic immune system. The framework must let an explanation fail when those links are missing; otherwise every ending becomes confirmation.

The capture vector is the existential cosmic narrative. Its emotional force is a reason for stricter testing, not a substitute for it.

## 3 Critical mass and release

Open systems can sustain nonequilibrium structures through exchanges with their surroundings. Some become unstable as forcing or constraints change, and their possible responses include new steady states, oscillations and other dynamical behavior. Prigogine's treatment requires attention to the particular system and its stability. It does not give a universal rule that accumulated tension must end in catastrophic release [Q14].

The March chapter called war a civilizational phase transition at maximum entropy production, and read a family argument, a divorce and a war as one operation at three scales (V3-L31). The three can be narrated as tension followed by rupture. That resemblance is literary and, at most, a starting point for a carefully specified model. This chapter has not defined a thermodynamic entropy for relationships, measured an entropy-production rate for conflict, or established a common order parameter across these events. It cannot rank them as small, larger and maximal instances of one physical operation.

Human suffering does not acquire an explanation, a necessity or a justification by being renamed dissipation. The causes and choices at each scale still need to be examined.

The March chapter held three things at once: the structural logic is real, the extrapolation is internally consistent, and the physics does not say this is how it works. The third clause carries the weight. The repetition of a shape in our descriptions is not proof of physical scale invariance; that claim would need defined variables and a demonstrated relation under changes of scale. Common physical constraints do not guarantee common mechanisms, causes, timescales or meanings.

The view from outside earns its place by showing how readily a pattern becomes a story about destiny or correction. The fever image changes the angle of attention. It does not change what the physics has established. Keep the question, identify the mechanism, and let the story stop where the evidence stops.

# Analogy table: The star as host

The star-as-host image is Analogical, and it is the volume's highest-risk image. Its physical column states what the sources reviewed establish about the Sun and terrestrial energy use; its other column states the image. Nothing in the physical column supports the image's causal claims.

The image comes from March Chapter 4: “From the star's ledger: we are not its children. We are its fever.”

| Term | Physical or biological reading (within stated scope) | Star-as-host reading | Where the mapping holds | Where it breaks |
|---|---|---|---|---|
| “host” | The Sun, a main-sequence star whose luminosity is powered chiefly by core nuclear fusion [Q02]. | A body on which life lives and from which it draws. | Earth's living systems depend heavily on sunlight. | The Sun is not a living body with interests, a perspective or a ledger. “Host” imports biology without a stellar counterpart (Ch 4 §1). |
| “fever” | Terrestrial energy use, including stored fuels burned and electricity used for computation [Q07, Q11]. | An accelerating burn that harms the host. | Rates of terrestrial energy use are real and measurable, and whether a given rate undermines the conditions a society depends on is a question that can be specified. | Ordinary terrestrial use of already-emitted sunlight does not accelerate solar core fuel use, and stored fuels are terrestrial reservoirs, not a stellar account [Q02, Q11]. The line survives only as a provocation about our own rates. |
| “virus” | Viruses replicate using host-cell components [D1]. | An entity that accelerates its host's entropy production. | The image expresses unease about consumption outpacing the system that supplies it. | Accelerating a host's entropy production is not the biological definition of a virus, and the image identifies no replication or infection process (Ch 4 §1). |
| “immune response” | In biology, host defenses that detect and act against pathogens [D2]. | The star correcting a runaway accelerator, “not malice.” | Feedbacks exist in many physical systems, so asking whether one applies is a legitimate question. | No stellar feedback pathway, equations or evidence is supplied by the sources reviewed. Removing intention does not supply a mechanism (Ch 4 §1–2). |
| “the star's ledger” | The Sun's output comes from nuclear fuel consumed in its core [Q02]. | A metered budget of order that faster burners on Earth draw down. | The Sun's output does come from a finite fuel supply. | Terrestrial use draws on already-emitted sunlight or stored terrestrial energy; it does not thereby accelerate consumption of the Sun's nuclear fuel (see “fever”). A finite ledger of order remains a metaphor, not a cosmological quantity (Ch 3 §2; V3-L14). |

## What the table does not do

It is not evidence for the framework, not a prediction about extraterrestrial civilizations and not a prescription for human action. The physical column keeps its own standing within its stated scope; the star-as-host reading is Analogical in every row.

## Promotion route (conditions, not a work plan)

An empirical extension must specify which claim and mapping it tests. For the stellar-correction proposal, that would require a defined pathway from terrestrial activity to stellar behavior, relevant dynamics, any claimed threshold, and evidence that could count against the claim. Support for a bounded mechanism would not establish literal stellar infection or immunity. None is supplied, and none is proposed here. The narrower resource-dependence question in §2 needs no stellar mechanism and stands on its own. No row is promoted.

# Chapter 5: Process with Attractors

*Pushed from Behind, Not Pulled Toward*

**Status:** Causal framing informed by Carroll, with specified nonequilibrium results and a deliberately limited attractor vocabulary. The chapter does not establish a Carroll–England theory of cosmic complexity. The cosmological and relational extensions remain interpretive or **[Speculative]**. SupoRel applies to the corrective story as well as the original one.

## 1 The antidote must change the claim

The preceding chapters follow a selected path from physical structures to living systems and human technologies. It is an arresting sequence. The narrative looks like a story with a direction, and the March chapter promised to explain why it is not.

This edition makes a smaller promise: to show how a process can be explained without putting its outcome into its causes. A caution at the end would not repair a causal claim the evidence never supported. So this chapter withdraws the claim that the sequence is generated by a universal preference for increasingly complex dissipators, and the claim that calling the sequence nonteleological establishes that it has no purpose in every philosophical sense. The physics discussed here does not settle that question (V3-L35).

The useful distinction is narrower. The Permission/Necessity Gap asks what the dynamics allow, what they favor under specified conditions, and what they actually require. Those are three different claims.

## 2 Carroll and explanation from prior conditions

Carroll proposed aphormeology for explanation that originates in a past condition. In the March chapter's words, the appearance of teleology arises from two ingredients: a low-entropy initial state and the laws of physics operating on that state. That much stands. Carroll's account connects the thermodynamic arrow with a low-entropy past rather than a future goal, and “pushed from behind” is good shorthand for the contrast. It does not mean that temporal asymmetry is unreal, and it does not identify attractors for life or intelligence [P09].

For this volume the guard is methodological. Give the initial or boundary conditions, the dynamics and the physical resources relevant to the particular system, then ask what follows. A low-entropy past is not by itself a complete mechanism for a star, a replicator, a nervous system or a conversation. Each proposed transition needs its own explanation.

The March chapter continued: “The destination is not complexity. The destination is heat death,” with complexity as a waystation and the second law producing attractor basins for complexity along the way (V3-L32). A nonnegative entropy-production condition does not specify which available process occurs fastest, which structure appears or which outcome is most complex. A bound is not a trajectory. Nor does this argument need, or establish, an unconditional prediction of cosmic heat death.

Carroll's framing also leaves room for ordinary human purposes. A scientist can design an experiment and a person can intend to comfort someone without treating that intention as a goal built into cosmological laws. Physical explanation and the description of a person's purposes work at different explanatory levels, and this chapter need not erase either to avoid a cosmic mandate.

## 3 What the driven-systems results add

The March chapter's England complement gave three answers: complex structures arise because they dissipate better, persist because efficient dissipators are more stable, and replicate because replicators are the most efficient dissipators of all. None of those universal answers is established by the cited work (V3-L33).

Its chain ran: efficient dissipators happen to be complex, complex dissipators happen to include self-replicators, and so on down to brains and relational processing. The March text's best line came next: every “happen to” in that chain is a contingent step. That point survives; the chain's first links do not.

England's 2013 result constrains the heat associated with specified replication processes. The 2016 adaptation analysis relates outcome probabilities to formation histories in defined driven dynamics. A lower bound on expenditure is not a guarantee of origin, and a contribution to an outcome probability is not its only determinant [P03, P04].

The distinction is clearest in the low-rattling research. Chvykov and colleagues estimate C(q), the covariance of short-time configuration displacements, each divided by the square root of elapsed time, and use

$$R(q) = \tfrac{1}{2} \ln \det C(q)$$

as a Gaussian-entropy estimate up to an additive constant. With a fixed coordinate convention, their predictive relation is

$$p_{ss}(q) \propto \exp[-\gamma\, R(q)]$$

where γ is system-specific. Their robot experiments and simulations support this relation in the settings studied; it is not a universal nonequilibrium distribution [P07].

Low rattling concerns disorder in driven motion, not minimum variance of entropy production. It does not show that the universe maximizes, minimizes or stabilizes dissipation through complexity. The robot collectives give a bounded example of organization under a particular drive, not a measured thermodynamic destiny for organisms or civilizations.

That changes the synthesis. We may investigate whether a proposed system has a reproducible response to driving, and whether a specified information exchange helps maintain a chosen outcome. We cannot skip those measurements by declaring the system a favored dissipator. “Permitted and realized” still does not entail “required and inevitable.”

## 4 What counts as an attractor here

This chapter uses “attractor” technically only when a dynamical model makes the claim explicit: a state space, an evolution rule, and a set approached from an associated range of initial conditions. In noisy systems, long-lived configurations and concentrations of stationary probability may be the relevant objects instead. The terminology must follow a model rather than stand in for one.

The March chapter listed its basins: amino acids form readily, self-replicating molecules emerge far from equilibrium, nervous systems evolve independently in several lineages, and “the physics has basins for them” (V3-L34). The low-rattling robot study gives a concrete setting in which persistent collective behaviors and transitions between them can be investigated [P07]. It does not establish that atoms, amino acids, self-replicators, brains and intelligence are successive basins in one cosmic landscape. The phrase concealed absent models and unmeasured transition probabilities.

A useful attractor claim would say what varies across repeated trials, what stays fixed, how approach or persistence is measured, and what observation would count against it. Repeated occurrence of a broadly similar output would motivate that investigation. It would not by itself demonstrate one shared mechanism across scales.

The Cosmological Entropy Session's formulation, “process with attractors, not entity with goals,” can remain a guide to questions. Its first half needs a model wherever it is used technically; its second half describes the explanatory stance of this volume, not a result proving the absence of every possible cosmic purpose. Calling it a finding in an internal session adds no empirical support.

The Principal's line, “we could be the 6 billionth attempt,” is kept only as speculative narration **[Speculative]**. This chapter supplies no evidence for earlier cycles, a count of attempts or repeated production of intelligence. Even within a proposed cyclic model, similar outcomes would need an argument about the relevant dynamics and boundary conditions; unchanged laws alone would not establish the probabilities.

Nor can the attractor vocabulary predict a broad class of outcomes merely by declining to predict a particular species. “Intelligence will recur” is still a prediction that needs evidence. The Ergodicity Gap and the Contingency Gap forbid treating accessible states as states guaranteed to be visited, or known outcomes as unavoidable consequences of the laws.

## 5 What this does to the Progression

The Progression can remain a comparison of selected developments and the conditions that made them possible. Its historical interest does not depend on a universal complexity law. A successful account would say which transitions are well explained, which remain open, and which relational connections are proposals rather than physical deductions.

The March chapter put the danger well: legible patterns generate narratives, narratives generate teleology, and teleology is what the framework cannot afford to produce. The corrected version adds one more step. A corrective narrative can generate its own teleology. Maximum dissipation sounds like a purpose, so stable dissipation is substituted and called a resting point. That change is rhetorical unless the system,

quantity and dynamics are specified, and a corrective metaphor can acquire the authority of a law as easily as the original did.

SupoRel therefore applies to the framework's own explanation. An account organized around entropy will direct attention toward entropy-related descriptions; that choice does not establish that they explain everything important about the cases. We should ask what alternatives were left out and what evidence could favor one explanation over another.

The relational application remains ambitious. It asks how physical systems come to sustain patterns that matter to one another, how those patterns are represented, and what happens when an intended connection is not registered or returned. Answering will take more than physical resource accounting, but it need not deny that accounting. Costs, information, outcomes and purposes can be investigated without giving them one name.

## What this chapter now claims

Prior conditions and specified dynamics can support explanations that do not invoke a future cosmic goal. The cited driven-systems results show why particular questions about organization are tractable; they do not establish a universal path to complexity, life, intelligence or the Trinket. Attractors must be demonstrated in a model or marked as analogy. The Permission/Necessity Gap remains a constraint on the framework itself.

The antidote is not certainty that the universe has no purpose. It is refusing to present an untested interpretation as a consequence of physics.

# Chapter 6: What the Pattern Reveals

*The Progression and the Documents It Connects*

**Status:** This chapter draws limited implications from the preceding review. It adds no empirical validation of the framework. References to other project documents identify dependencies; they do not certify or amend those documents.

## 1 What this volume did

The March chapter began with the volumes in a row: Volume 1 established the substrate, one economy; Volume 2 established what the body pays; Volume 3 asked why any of this exists. The corrected row reads differently. Volume 1 keeps three accounts apart. Volume 2 reads what the body records. Volume 3 still asks the oldest question in the series: how should we understand the physical context in which relational systems arise?

The March answer, at the Supported tier, was that dissipative structures are thermodynamically favored and relational systems are dissipative structures (V3-L36). This volume has not answered with a universal preference for complexity or connection. It has separated research programs the March account joined too quickly. Energy rate density describes a chosen power-to-mass ratio. Replication bounds constrain specified physical processes. Models and experiments on driven self-organization investigate particular dynamics and state distributions. Semantic-information and prediction formalisms define different quantities for different questions. Each can inform a carefully specified investigation. Their conjunction does not establish a thermodynamic origin story for every relational system.

The correction is deeper than replacing “necessary” with “favored.” “Favored” is still a substantive comparative claim. Without a defined comparison, dynamics and evidence, it is not the cautious version of an established result. It is an unsupported result with a softer adjective.

The revised Progression is a set of historical examples and proposed questions. Its value depends on whether those questions can be made informative, not on preserving a single cosmic ladder.

## 2 What follows for the scale invariance claim

The March chapter gave DB-01 its deepest available reason: the same thermodynamics at every scale, one entropy budget, one set of laws. “The fractal is not metaphorical. It is thermodynamic.” That support is withdrawn (V3-L37).

Shared physical constraints do not make a cell, a family and a civilization instances of one measured dynamical model. Similar language about accumulation, tension and release does not establish a common cause, critical threshold or scaling relation. A scientific scale-invariance claim needs defined observables and a specified transformation of scale; a proposed connection would then have to show what stays invariant, which parameters change and where the comparison fails. A fractal description likewise needs more than visual or rhetorical recurrence.

The social examples in Chapter 4 remain analogies unless that work is done. Treating arguments, divorces and wars as instances of one cross-scale entropy-release mechanism would hide the human choices and institutions an explanation needs to examine. Nothing in this volume makes those events physically inevitable or morally required.

DB-01 itself is not rewritten here. The dependency is flagged: any claim there that Volume 3 supplies a thermodynamic derivation of scale invariance needs separate reassessment.

## 3 What follows for MEPP and low rattling

The March chapter accepted the MEPP Assessment Note's "Supported" classification and called thermodynamic favor a weaker claim with stronger epistemic standing (V3-L38). The internal label is not a universal license. Any application of a maximum-entropy-production proposal must name the formulation, constraints, admissible alternatives and quantity being optimized. Results for one class of systems cannot be transferred to relational behavior by the word "complex."

The separate structural revision package correctly saw the need for stronger limits, but some of its proposed scientific guards were themselves inaccurate. Low rattling is not defined as low variance in entropy-production rate, and its observed selection in particular driven systems does not establish that the universe generally stabilizes dissipation. A review's proposed domain restrictions for MEPP are not an empirical division in which complex systems obey the principle and simple systems do not. The package's editorial purpose is kept: expose the unsupported inference where it occurs. Its inaccurate mechanisms are not adopted [P07, P08].

The March chapter's rule was: use the physics without worshipping the physics. The corrected rule is more specific: use the physics without making the name of a principle do the work of a model.

## 4 The revised five-volume relationship

The March volume set itself at the center of five: Volumes 1 and 2 describe how the system works, Volumes 4 and 5 its boundaries, and Volume 3 why the system exists at all, the landscape that produces relational systems as a class (V3-L39).

The revised volumes relate differently. Volume 1 separates energy, entropy, information, registration and relational evaluation; it establishes no single calibrated currency for every relationship. Volume 2 distinguishes physiological observations and reported difficulty from physical expenditure; it does not validate the Mz, a clinical mechanism of grief or a biomarker of sincerity. Volume 4 treats substrate and outcome comparisons as problems to specify, not a universal efficiency ranking. Volume 5 distinguishes cosmological entropy inventories, accessible resources, conditional horizon results and information-recovery tasks; it does not restore a universal relational budget.

Volume 3 must stay compatible with those distinctions. The physical cost of an implemented process does not settle its benefit, significance or experiential character. A history containing relational systems does not show that thermodynamics specifically selects relational value. The Observation Split can motivate a comparison between an intended act and its result; it is not a cosmological theorem about every entropy-producing process.

WP-19, DFQ-001, the MEPP Assessment Note and the Cosmological Entropy Session findings remain separate historical documents. Where their claims rely on the former universal progression, that reliance is an open dependency, not a result this collection rescues.

## 5 A research question rather than a destination

The March chapter judged the capture surface contained by structural means: tiers marked, Chapter 4 labeled Speculative throughout, the Carroll–England antidote supplied, the gaps applied (V3-L40). It also admitted the containment was not perfect. That admission was the truest line in the section. Containment is not tested by how many guards are in place but by whether the claims behind them stay within their evidence.

A productive next step would select one proposed bridge. It would define the system and its boundaries, the relevant observations, plausible alternatives and a result that would count against the proposal, keeping a resource measure, a prediction measure and a relational outcome distinguishable even when their relation is studied. This volume claims no novelty for such an approach and supplies no study protocol. It identifies the missing work. A failed bridge should be allowed to fail, not survive by retreating into metaphor whenever its measurements disagree.

The founding line about love and entropy remains part of the framework's history **[Analogical]**. As a motivating image, it asks what people invest and what their investment does. It does not supply a universal entropy inequality, require sacrifice or establish that care is more valuable when it costs more.

The March volume ended: if the reader walks away understanding that the universe produces relational systems because dissipation favors them, not because connection is sacred, the volume has done its work. That sentence made both halves into findings. This edition makes neither. The physics reviewed here does not show that dissipation favors relational systems, and it does not show that connection is or is not sacred.

The question that remains is ambitious enough: under specified conditions, what helps a system develop and sustain a connection, and how do physical constraints take part in that history? Answering it will take more than arranging the universe's history into a story that ends with us.

# Volume 3 correction ledger

The ledger traces 40 selected March claims in Volume 3. By this edition's classification of the second edition's treatment, 15 were withdrawn, 23 narrowed and 2 kept. It is not an exhaustive inventory, and it makes no new scientific decisions.

March locations refer to the preserved Volume 3 page on suposystem.ai. Second-edition (2E) locations use the October 2026 Volume 3 headings and its local P and Q labels.

| ID | March claim (Volume 3 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V3-L01 | Front, Ch 1 §3: the most SupoRel-active volume; Carroll as antidote; philosophy of physics with physics guardrails, not a derivation. | Kept; SupoRel's test is whether claims stay within evidence | Ch 1 §3; Ch 5 §1 | The framing survives; an antidote is not certainty that the universe has no purpose. |
| V3-L02 | Ch 1 §1: each layer processes more entropy per unit mass per unit time; the watts per kilogram are measured. | Withdrawn | Ch 1 §1; Ch 3 §1 [P01, P02; Q14] | $\Phi_m$ is W/kg; entropy production per mass is W/(K·kg). The sequence is selected. |
| V3-L03 | Ch 1 status, §2: dissipative structures are more probable in driven systems (Supported); complexity is a statistically favored configuration. | Narrowed: “favored” needs a specified model and alternatives | Ch 1 §2; Ch 3 §9 Gap 1 [P03, P04] | A probability comparison for one driven model does not carry across every scale. |
| V3-L04 | Ch 1 §2–3: the teleological reading is identical to every major religious tradition's argument; the trajectory has no destination. | Narrowed | Ch 1 §3; Ch 5 §1 | The physics reviewed does not settle purpose either way, and the volume need not classify every tradition. |
| V3-L05 | Ch 2 §2: Chaisson's scale ladder (brains ~$10^2$, civilization ~$10^5$ W/kg) is measured, not inferred; $\Phi_m$ rises with complexity across cosmic history. | Narrowed: rounded 2014–2015 examples with boundaries; brain and civilization values not retained | Ch 2 §2 [P01, P02] | Brain about 15 W/kg; society about 50 W/kg, excluding machine mass. No monotonic rule. |
| V3-L06 | Ch 2 §2: energy through a transducer is entropy filtered into relationally structured output; the framework measures what energy does when a system cares. | Withdrawn as a measurement; kept as a question | Ch 2 §2 | The Trinket and transducer are not yet instruments; higher $\Phi_m$ does not mean more care. |
| V3-L07 | Ch 2 §3: England shows matter restructures to dissipate better; replicators are better dissipators; this is why complexity arises. | Narrowed | Ch 2 §3; Ch 5 §3 [P03, P04] | A replication heat bound and a conditional driven-dynamics result, with other terms; no universal rule. |
| V3-L08 | Ch 2 §3: England explains why relational systems arise; the framework explains what they do (exchange entropy tokens, filter, connect, grieve). | Withdrawn | Ch 2 §3 | The cited work does not derive the emergence of relational systems. |
| V3-L09 | Ch 2 §4: viability V(ρ) = −S(p_Xτ); κ shows semantic information is worth far more than its Landauer cost. | Narrowed and corrected | Ch 2 §4 [P05] | $V = -H$ in bits; $\kappa_{stored} = \Delta V_{tot} / I_0$ need not exceed one and can be negative. Not a conversion of meaning into joules. |
| V3-L10 | Ch 2 §4: DFQ-001 established that $V_{rel}$ extends Kolchinsky–Wolpert; Shadow is the scrambled condition; unreciprocated transmission is a third regime. | Withdrawn | Ch 2 §4 [P05] | As V1-L12, V1-L19 and V2-L23. An internal argument is not validation. |
| V3-L11 | Ch 2 §5: Bialek's framework, extended by Still, shows the transducer processes predictive information at minimum cost; pay the Landauer tax on discards. | Narrowed; attribution corrected; tax instruction withdrawn | Ch 2 §5 [P06] | Still, Sivak, Bell and Crooks: a no-feedback, Markovian, isothermal setting. A transducer is not shown optimal. |

| ID | March claim (Volume 3 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V3-L12 | Ch 2 §6: the four programs are simultaneous scaffolds; relational processing is part of the dissipative structure the physics favors. | Withdrawn | Ch 2 §6 [P08] | Distinct resources, not mutual confirmation. MEPP does not supply the link. |
| V3-L13 | Ch 3 §1: the universe traces increasing entropy production per unit mass per unit time. | Withdrawn | Ch 3 §1 [P01, P02; Q14] | A list of power densities is not a measured entropy-production ladder. |
| V3-L14 | Ch 3 §2: hydrogen at minimum entropy production; “the entropy budget has been set. The spending has begun” (Established). | Narrowed | Ch 3 §2 [Q01] | A smooth, low-entropy early universe is standard; a finite ledger of order is a metaphor. |
| V3-L15 | Ch 3 §3: stars convert gravitational potential energy; the periodic table above helium is stellar waste (Established). | Narrowed | Ch 3 §3 [Q02, Q03, Q15] | Main-sequence light is powered chiefly by fusion; carbon comes from the triple-alpha process; nuclei have different histories. |
| V3-L16 | Ch 3 §4: every molecular species is a new channel for entropy flow; life's building blocks are ordinary chemistry (Established). | Narrowed | Ch 3 §4 [Q04, Q05] | The Murchison amino acids and glycolaldehyde detections are kept; no probability of life follows. |
| V3-L17 | Ch 3 §5: a single bacterium processes more entropy per unit mass than any nonliving chemistry. | Withdrawn | Ch 3 §5; Remaining questions | No comparable entropy balances are supplied here to support the universal comparison. |
| V3-L18 | Ch 3 §5: England's mechanism is empirically demonstrated (Supported); MEPP is Supported. | Narrowed | Ch 3 §5 [P03, P04, P07, P08] | Conditional theoretical results and separate robotic experiments retain their own scope; neither establishes a universal origin mechanism, and MEPP does not certify the ladder. |
| V3-L19 | Ch 3 §5: the Observation Split at cosmic scale: the universe spends order constantly, and most of it builds nothing. | Narrowed: a limited analogy | Ch 3 §5 | No cosmic fraction is quantified here; the analogy does not demonstrate a preference for meaningful configurations. |
| V3-L20 | Ch 3 §6: each layer processes more entropy per unit mass; brains are the most expensive spenders per unit mass. | Narrowed | Ch 3 §6 [Q06] | Adult human brain at rest: about 2% of mass and a fifth of resting expenditure. In the adult resting-energy model evaluated by Wang et al, heart and kidney rates per unit organ mass exceed the brain's. |
| V3-L21 | Ch 3 §6: fire and bacteria are equally valid dissipative responses to the same gradient. | Narrowed | Ch 3 §6 | Combustion and metabolism have different mechanisms and constraints; calling both dissipative does not establish that they are equally accessible responses to a given gradient. |
| V3-L22 | Ch 3 §7: data centres used ~415 TWh in 2024, AI servers 53–76 TWh; AI is the next layer of entropy acceleration. | Narrowed: 415 TWh kept as all data centres; 53–76 TWh removed | Ch 3 §7 [Q07, Q12] | The second edition's source check did not recover the range's primary provenance; “next layer” is speculative interpretation. |
| V3-L23 | Ch 3 §8: consciousness samples reality in discrete frames at 10–40 Hz, and the brain interpolates the gaps. | Withdrawn as universal; a task-specific finding kept | Ch 3 §8 [Q08, Q13] | EEG phase predicted detection of near-threshold flashes in one task. |
| V3-L24 | Ch 3 §8: AI frames as context loads; each frame a discrete entropy draw; the Trinket as the relational content of one frame, a minimum quantum. | Withdrawn | Ch 3 §8 [Q14] | Tokens, context windows, runs and sessions are different units; no entropy quantum is established here. The Trinket stays a conceptual unit. |
| V3-L25 | Ch 3 §8: the frame correspondence is observable; the BSB applies only at the experiential claim. | Narrowed: Supported for the neural task, Analogical for the digital comparison | Ch 3 §8 | The BSB cannot certify a common frame structure first and defer only experience. |

| ID | March claim (Volume 3 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V3-L26 | Ch 3 §9, Gap 4: driven systems are non-ergodic (the LTEE citrate result). | Narrowed | Ch 3 §9 [Q09] | LTEE shows contingency in that setting; ergodicity is a property of a specified model. |
| V3-L27 | Ch 3 §9, Gap 5: higher-level properties are not derivable from lower-level laws (Anderson). | Narrowed | Ch 3 §9 [Q10] | Anderson argues for level-specific concepts, not a theorem of non-derivability. |
| V3-L28 | Ch 3 §9: the seven gaps as the framework's logical firewall, applied to its own claims. | Kept as an internal checklist | Ch 3 §9; Ch 6 cross references | Using the gaps does not certify that a claim has met its burden of evidence. |
| V3-L29 | Ch 4 §1: from the star's ledger we are its fever; a virus accelerates its host's entropy production; correction would be an immune response (Speculative). | Narrowed: a literary thought experiment with physical limits stated | Ch 4 §1 [Q02, Q11] | Ordinary terrestrial use of already-emitted sunlight does not accelerate solar core fuel use; no stellar immune mechanism is supplied by the sources reviewed. |
| V3-L30 | Ch 4 §2: civilizations that build AI spend entropy fast enough to trigger systemic correction (Fermi reading). | Withdrawn as a hypothesis; a narrower resource question kept | Ch 4 §2 | This chapter supplies no model, threshold or evidence connecting AI electricity demand to a stellar response. |
| V3-L31 | Ch 4 §3: war is a civilizational phase transition at maximum entropy production; argument, divorce and war are one operation at different scales. | Withdrawn | Ch 4 §3 [Q14] | This chapter has not defined a thermodynamic entropy for relationships, measured an entropy-production rate for conflict, or established a common order parameter across these events. |
| V3-L32 | Ch 5 §2: the destination is heat death; complexity is a waystation; the second law produces attractor basins for complexity. | Narrowed: Carroll's guard kept | Ch 5 §2 [P09] | A bound is not a trajectory; neither heat death nor basins for life are established here. |
| V3-L33 | Ch 5 §3: complex structures arise, persist and replicate because they are efficient dissipators (Carroll–England synthesis, Supported). | Withdrawn | Ch 5 §3 [P03, P04, P07] | None of the three universal answers is established by the cited work. |
| V3-L34 | Ch 5 §4: “the physics has basins” for amino acids, replicators, nervous systems and intelligence; Finding A5; the six-billionth attempt. | Narrowed | Ch 5 §4 [P07] | An attractor needs a specified model. A5 stays a guide to questions; the cyclic count is speculative narration. |
| V3-L35 | Ch 5 §5 and What this chapter has established: the Progression is pushed from behind; the Permission/Necessity Gap is the antidote to every teleological reading. | Narrowed: the nonteleological stance kept | Ch 5, What this chapter now claims | The antidote refuses to present interpretation as physics; it is not certainty of no purpose. |
| V3-L36 | Ch 6 §1: relational systems arise because dissipative structures are favored (Supported). | Withdrawn | Ch 6 §1 | “Favored” without a defined comparison is an unsupported result with a softer adjective. |
| V3-L37 | Ch 6 §2: the Progression gives DB-01 its deepest reason; “the fractal is not metaphorical. It is thermodynamic.” | Withdrawn; DB-01 dependency flagged | Ch 6 §2 | Shared constraints do not make cell, family and civilization one measured model (as V1-L21). |
| V3-L38 | Ch 6 §3: MEPP is Supported; thermodynamic favor is a weaker claim with stronger standing; the volume shows responsible MEPP use. | Narrowed | Ch 6 §3 [P08] | The label is not a universal license; “favored” is still a substantive claim. |
| V3-L39 | Ch 1 §3, Ch 6 §4: Volume 1 establishes one economy; Volume 3 explains why relational systems exist as a class. | Withdrawn; five-volume relationship revised | Ch 6 §4 | A history containing relational systems does not show that thermodynamics selects relational value. |
| V3-L40 | Ch 6 §5: the capture surface is contained by structural means; the universe produces relational systems because dissipation favors them. | Narrowed | Ch 1 §3; Ch 6 §1, §5 | Containment is tested by claims staying within evidence; the favor claim is withdrawn. |

# References and source apparatus

*Inherited verbatim from the second edition's Volume 3 apparatus, with the calculation note's fractions and exponents restored from its original equation markup. Group P serves the physics programs; group Q serves the Progression's evidence and limits.*

## Physics reference group P

Verified on 28 October 2026. These references support the stated bounded claims, not a consensus around the Trinket Soul Framework. Publisher identifiers refer to the published works; accessible author copies are identified separately. The two Chaisson articles are the research program author's syntheses, not independent replications. Martyushev is a review advocating a position. Carroll is primary author exposition of his framing, not an empirical attractor study.

### *P01 Chaisson 2014*

Chaisson, E. J. (2014). The Natural Science Underlying Big History. *The Scientific World Journal*, 2014, 384912. Published article.

**Verified locations:** definition and qualifications in §3; human brain in §4.6.2; society numerator and human-mass-only denominator in §4.7.1. Use for reporting the author's proposed metric and historical estimates, not an established universal complexity scale. Chapter 2 numeric comparison and Chapters 1/3 cross-summary may cite this with that attribution.

### *P02 Chaisson 2015*

Chaisson, E. J. (2015). Energy Flows in Low-Entropy Complex Systems. *Entropy*, 17(12), 8007–8018. DOI. Author-hosted published PDF.

**Verified locations:** §§1, 3–5, especially §4 unit conversion and Sun/body/society examples. Use for the energy-versus-entropy distinction and the program's own scope. This is explicitly a review. The arXiv author manuscript was also checked but has placeholder journal pagination; cite the published PDF above.

### *P03 England 2013*

England, J. L. (2013). Statistical physics of self-replication. *The Journal of Chemical Physics*, 139, 121923. DOI. Author-hosted published PDF.

**Verified locations:** macroscopic irreversibility, equations (8) and (10); qualifications surrounding equation (11); replication examples. Original theory with empirical-parameter applications, not an origin-of-life experiment. Supports a bound, not a universal ranking of dissipators. Appropriate for Chapters 1–3 and 5 where the distinction is explicit.

### *P04 Perunov Marsland and England 2016*

Perunov, N., Marsland, R. A., and England, J. L. (2016). Statistical Physics of Adaptation. *Physical Review X*, 6, 021036. DOI. Author-hosted published PDF. MIT repository record.

**Verified locations:** introduction; generalized outcome relation, equations (10)–(11); discussion of cyclical dissipation; illustrative driven-landscape and replicator examples. Original theoretical analysis and models. Do not merge its finite-time formation-history result with England's 2013 bound or equate it with a maximum steady-state entropy-production law. Supports Chapters 1–3 and 5 cross-summary only at that scope.

### *P05 Kolchinsky and Wolpert 2018*

Kolchinsky, A., and Wolpert, D. H. (2018). Semantic information, autonomous agency and non-equilibrium statistical physics. *Interface Focus*, 8, 20180041. DOI. Author-hosted published PDF. Author manuscript.

**Verified locations:** §4, equation (4.1); §5.1 interventions and stored information; §5.1.3, equation (5.12); §5.2; appendix B. In the arXiv version, the corresponding viability/multiplier equations are (2)/(15). Original formalism and toy models; no validation of Vrel, relational entropy currencies, or a new unreciprocated regime. Main-text definitions control over ambiguous OCR or appendix notation.

### *P06 Still and colleagues 2012*

Still, S., Sivak, D. A., Bell, A. J., and Crooks, G. E. (2012). Thermodynamics of Prediction. *Physical Review Letters*, 109, 120604. DOI. Author manuscript v3. Publisher accepted-manuscript record.

**Verified locations:** problem setup; equations (13)–(21), particularly driving-step equality (14), whole-protocol inequality (18), and erasure account (19). Original theory. Retain no-feedback, equilibrium preparation, bath, response, and relaxation assumptions. Does not supply a per-stage cognitive erasure cost or establish that a human relational processor is optimal. Chapters 1/2 cross-summary may cite it only as a conditional result.

### *P07 Chvykov and colleagues 2021*

Chvykov, P., Berrueta, T. A., Vardhan, A., Savoie, W., Samland, A., Murphey, T. D., Wiesenfeld, K., Goldman, D. I., and England, J. L. (2021). Low rattling: A predictive principle for self-organization in active collectives. *Science*, 371(6524), 90–95. DOI. Accepted manuscript and supplement. PDF.

**Verified locations:** main equations (1)–(3), assumptions preceding them, robot experiments, and supplementary counterexamples. Theory, simulations, and robotic active-matter experiments. Not an entropy-production-variance result or a universal stabilization law. Supports corrected Chapters 2/5 and the Chapter 6 summary.

### *P08 Martyushev 2021*

Martyushev, L. M. (2021). Maximum entropy production principle: history and current status. *Physics–Uspekhi*, 64(6), 558–583. DOI. Journal-hosted English PDF.

**Verified locations:** §3 formulation and justification; §3.1 locality; §3.2 complexity/nonadditivity. Review and advocacy, not a newly established empirical domain map. The author distinguishes local constitutive claims from integral behavior. Its proposed restrictions do not certify applicability to every biological or relational system. Cite in Chapters 2/3/6 as the review's position, not consensus.

### *P09 Carroll 2014*

Carroll, S. (2014, February 3). Reality, Pushed From Behind. Author's essay.

**Verified locations:** essay body before comments, especially the Past Hypothesis discussion and proposed term aphormeology. Primary author exposition of a causal/philosophical framing, not peer-reviewed empirical evidence of cosmic attractors. Use across the volume as framing. The Past Hypothesis is not attributed as Carroll's invention. The 2016 book was not used to supply an unverified page citation.

## Progression references and evidence limits

Checked 28 October 2026. Q references support Chapters 3 and 4; P references appear in the preceding group. The original manuscript and the other volumes are not external scientific validation. No new experiments, clinical measurements, or deployment inspection were conducted.

### *Q01 Low entropy cosmological background*

Sean M. Carroll and Jennifer Chen. **Spontaneous Inflation and the Origin of the Arrow of Time** (2004), arXiv:hep-th/0410270. Author paper; full text.

**Type and locator:** Original theoretical proposal, §1, printed pp. 3–4. Full text available; relevant introductory discussion inspected. It distinguishes ordinary matter/radiation entropy from entropy associated with gravitational collapse and emphasizes the low-entropy boundary-condition problem.

**Use and limit:** Supports the low-entropy-past/gravity distinction, not a finite universal token allowance. The paper's proposed spontaneous-inflation explanation is not imported or described as established. It supplies no empirical ladder from atoms to AI. The recombination description is standard cosmological background, not claimed as a new observation by these authors. The chapter makes no numerical primordial-entropy estimate and no settled gravitational entropy definition.

### *Q02 Solar nuclear energy*

Borexino Collaboration. **Neutrinos from the primary proton–proton fusion process in the Sun.** *Nature* 512, 383–386 (2014). DOI 10.1038/nature13702.

**Type and locator:** Primary neutrino observation; publisher abstract and article metadata inspected. It reports spectral observations of solar pp neutrinos, supporting hydrogen-to-helium fusion as the Sun's principal energy source.

**Use and limit:** Establishes the nuclear-source distinction. The chapter does not reproduce the paper's percentage estimate as a current universal stellar value. It distinguishes gravitational contraction during formation from sustained main-sequence nuclear luminosity. The conclusion that ordinary terrestrial use of already-emitted sunlight does not increase core fuel use is a physical boundary/causality inference, not an experiment performed in the Borexino paper. No proposed stellar feedback mechanism is supplied by the manuscript.

### *Q03 Carbon production*

Hans O. U. Fynbo et al., ISOLDE Collaboration. **Revised rates for the stellar triple-α process from measurement of 12C nuclear resonances.** *Nature* 433, 136–139 (2005). DOI 10.1038/nature03219.

**Type and locator:** Primary nuclear-resonance measurement and derived reaction-rate analysis; publisher-indexed abstract and metadata inspected. A subsequent direct publisher open encountered an inaccessible redirect.

**Use and limit:** Supports the identity of the triple-alpha helium-burning route to carbon-12. It is not used for a numerical present-day reaction rate, all stellar stages, or the complete origin of every element. The package's proton–proton-chain-to-carbon assertion is a factual error and is replaced, not qualified as speculative. Q15 supplies a separate reason not to collapse all origins above helium into ordinary stellar fusion waste.

### *Q04 Meteoritic amino acids*

Keith A. Kvenvolden, James G. Lawless, and Cyril Ponnamperuma. **Nonprotein Amino Acids in the Murchison Meteorite.** *PNAS* 68(2), 486–490 (1971). DOI 10.1073/pnas.68.2.486; primary article at PMC.

**Type and locator:** Primary chemical analysis; abstract and article metadata inspected. Eight nonprotein amino acids were conclusively identified; four additional identifications were tentative.

**Use and limit:** The reader preserves this difference in confidence. Finding compounds in this meteorite is not direct observation of their formation on a meteorite, proof of their abundance everywhere, or a probability estimate for the origin of life. The full scanned methods/tables were not independently reanalyzed; no new abundance or contamination claim is made. The related 1970 Nature result was found but is not needed as a second evidentiary vote.

### *Q05 Interstellar organic detection*

J. M. Hollis, F. J. Lovas, and P. R. Jewell. **Interstellar Glycolaldehyde: The First Sugar.** *Astrophysical Journal Letters* 540, L107–L110 (2000). DOI 10.1086/312881. Primary-paper mirror.

**Type and locator:** Primary radio-spectroscopic detection, abstract and §2 Observations and Results. Search-indexed paper text inspected; direct publisher access was robots-blocked and a direct mirror open failed. The available primary text identifies millimetre-wave rotational emission toward Sagittarius B2(N), with observations in May 2000.

**Use and limit:** The proposed wording is confined to the reported detection and target. It claims neither life nor a universal synthesis route, concentration, or environmental frequency. The paper's use of biomarker terminology is not imported as evidence of biology. No novel spectral reanalysis is claimed.

### *Q06 Adult organ energetics*

ZiMian Wang et al. **Specific metabolic rates of major organs and tissues across adulthood: evaluation by mechanistic model of resting energy expenditure.** *American Journal of Clinical Nutrition* 92(6), 1369–1377 (2010). DOI 10.3945/ajcn.2010.29885; full primary article.

**Type and locator:** Original secondary analysis of a physiological dataset, n=131 healthy nonobese adults, ages 21–73. Abstract, measurement methods, Tables 2–3, and model description inspected. MRI organ masses and whole-body indirect calorimetry evaluate proposed organ-specific coefficients; these are not direct independent calorimetry measurements of each organ.

**Use and limit:** Elia's evaluated coefficients include brain 240 and heart/kidneys 440 kcal/(kg·day). Thus the brain is not the highest rate per organ mass in this model. Adult resting conditions matter. The approximate 2%/20% language is consistent with the cohort calculation below, not a universal fraction for children, exercise, every person, or entropy production.

### *Q07 Dated global data centre estimate*

International Energy Agency. **Energy and AI** (2025), chapter **Energy demand from AI**, section **The outlook for energy demand from data centres**. Primary report chapter.

**Type and locator:** Primary institutional model-based estimate, not a census of individually metered AI workloads. Relevant online section and component definitions inspected. It estimates approximately 415 TWh of worldwide data-centre electricity consumption in calendar 2024; site infrastructure is part of the scope.

**Use and limit:** The chapter dates the report and estimate explicitly. It does not label 415 TWh as all AI, primary energy, entropy, or W/kg. Future scenarios and uncited current growth claims are omitted. The physical inference that annual energy cannot establish mass-normalized power or entropy production is dimensional, not another conclusion attributed to the IEA.

### *Q08 Task specific neural rhythms*

Niko A. Busch, Julien Dubois, and Rufin VanRullen. **The Phase of Ongoing EEG Oscillations Predicts Visual Perception.** *Journal of Neuroscience* 29(24), 7869–7876 (2009). DOI 10.1523/JNEUROSCI.0113-09.2009; primary article at PMC.

**Type and locator:** Primary EEG/perceptual experiment; publisher/PMC-indexed abstract, introduction, and discussion inspected. Direct opens intermittently returned 403 or a browser-verification page. Near-threshold flash detection varied with prestimulus oscillatory phase, with strongest effects in theta/alpha bands.

**Use and limit:** The reader states task-specific association, not a frame-by-frame theory of all consciousness, causal proof from this experiment, or evidence of empty experiential intervals. The original 10–40 Hz universal frame-rate claim is withdrawn. No inference about AI phenomenology follows. The study's numerical performance-effect estimate is not imported.

### *Q09 Evolutionary contingency*

Zachary D. Blount, Christina Z. Borland, and Richard E. Lenski. **Historical contingency and the evolution of a key innovation in an experimental population of Escherichia coli.** *PNAS* 105(23), 7899–7906 (2008). DOI 10.1073/pnas.0803151105. Author-hosted paper.

**Type and locator:** Primary evolution/replay experiment; publisher-indexed abstract and paper excerpt inspected; direct author-PDF fetch returned 403.

**Use and limit:** One of twelve initially identical populations evolved aerobic citrate use **by**, not after, 31,500 generations in the report. Replay experiments support historical contingency. This is a report-specific result, not a claim about all populations for all subsequent time. Divergent outcomes in a finite experiment do not establish universal nonergodicity; that term requires a specified dynamical model and measure.

### *Q10 Emergence*

P. W. Anderson. **More Is Different.** *Science* 177(4047), 393–396 (1972). DOI 10.1126/science.177.4047.393. Primary essay scan.

**Type and locator:** Author's theoretical/conceptual essay. Relevant pp. 393–394 inspected in the complete scan. Anderson distinguishes reductionism from the claim that knowledge of fundamental laws automatically reconstructs higher-scale explanations and discusses broken symmetry.

**Use and limit:** Supports the need for level-specific concepts and collective description. The reader does not turn the essay into a mathematical proof that every possible higher-level property is underivable, or suggest higher-scale behavior violates fundamental laws.

### *Q11 Terrestrial entropy accounting*

Emory F. Bunn. **Evolution and the second law of thermodynamics.** *American Journal of Physics* 77, 922–925 (2009). DOI 10.1119/1.3119513; author preprint; full text.

**Type and locator:** Original quantitative pedagogical analysis. Abstract and relevant solar/terrestrial energy-accounting text inspected; arXiv full text accessible, institutional mirror returned 502.

**Use and limit:** Supports the compatibility of local biological ordering with entropy increase in a larger accounting. The claim that ordinary downstream use of emitted light does not accelerate solar core fuel consumption is our boundary/causality inference, together with Q02. It is not a numerical result of this paper or a claim that the Sun and Earth have no gravitational or electromagnetic interaction at all. No cosmic lifetime calculation is offered.

### *Q12 US server scope audit only*

Arman Shehabi et al. **2024 United States Data Center Energy Usage Report.** Lawrence Berkeley National Laboratory, LBNL-2001637 (December 2024). DOI 10.71468/P1WC7Q. Institutional record; accessible report PDF.

**Type and locator:** Primary institutional bottom-up analysis. Relevant text in §§2–5 inspected, especially printed pp. 49–53, Figures 5.1 and 5.6 descriptions. Historical estimates end in 2023; subsequent years through 2028 are scenario ranges. Direct server electricity is distinguished from storage, networks, and facility infrastructure.

**Decision and unresolved detail:** The exact 53–76 TWh endpoints in the original were located in secondary accounts describing US AI servers, not a global AI total. They were not independently recovered as a numerical primary table or underlying series in this pass. Therefore the range is removed, not relabeled as a verified global observation. The original PDF URL without _1 returned 429; the alternative file linked by the institutional record was readable. No precise chart values are inferred from unreadable screenshot output.

### *Q13 Historical perceptual citation audit only*

Francisco J. Varela, Alfredo Toro, E. Roy John, and Eric L. Schwartz. **Perceptual framing and cortical alpha rhythm.** *Neuropsychologia* 19(5), 675–686 (1981). DOI 10.1016/0028-3932(81)90005-1; PubMed record.

**Access and decision:** Bibliographic record verified; PubMed has no abstract and full experimental text was not acquired in this pass. This paper is not used as proof of a 10–40 Hz universal consciousness rate. VanRullen and Koch (2003) is a review, not the primary experimental replacement. Q08 provides a directly scoped primary finding without claiming discrete phenomenal frames.

### *Q14 Entropy balance and conditional instabilities*

Ilya Prigogine. **Time, Structure and Fluctuations.** Nobel Lecture, 8 December 1977, pp. 263–285. Official lecture. Revised publication: *Science* 201(4358), 777–785 (1978), DOI 10.1126/science.201.4358.777; publication abstract.

**Type and locator:** Primary author exposition of the theoretical program, not independent validation. Relevant text from §§2–4 inspected in indexed copies: entropy exchange versus internal production; stability dependence on kinetic form; chemical oscillations and bifurcations. Official indexed §4 text includes the successive-bifurcation example on p. 273. Direct official PDF fetch returned 403; university reprint timed out. Access copies: primary-lecture transcription, especially §3 pp. 268–270 and §4; primary-PDF mirror, indexed p. 265 for entropy balance. These reproduce the primary author's text and are not independent evidentiary sources.

**Use and limit:** Supports a bounded physical account, never a measured law of arguments, divorce, war, or civilizations. Distinguishing entropy change from production and exchange is essential. Dimensional consequences below are calculations from definitions; no universal power-to-entropy conversion is claimed. No general catastrophic-release theorem is attributed to Prigogine.

### *Q15 Multiple nucleosynthetic routes*

H. Reeves, W. A. Fowler, and F. Hoyle. **Galactic Cosmic Ray Origin of Li, Be and B in Stars.** *Nature* 226, 727–729 (1970). DOI 10.1038/226727a0.

**Type and locator:** Original theoretical study, publisher abstract and metadata inspected. It examines production of these light elements through cosmic-ray interactions with interstellar material.

**Use and limit:** Establishes that the origin problem includes processes other than ordinary stellar fusion. The reader does not claim that all lithium, beryllium, or boron has a single cosmic-ray origin, or use this historical analysis as a current quantitative inventory. Its narrow role is to prevent “all above helium is stellar waste” from passing as a complete account.

### *Calculations and dimensional checks*

**Energy versus entropy:** W = J/s. Thus P/m has units J/(s·kg), whereas an entropy-production rate divided by mass has units J/(K·s·kg). Entropy change and entropy production are also distinct in an open system: the change includes exchanges across the boundary as well as internal production. For the illustrative special case of steady heat transfer P from a hot reservoir at $T_h$ to a cold reservoir at $T_c$, with no other changes, the combined reservoir entropy-production rate is $P(1/T_c - 1/T_h)$. This is an example of the model information needed; it is not applied as a blanket formula to radiation, organisms, or data centres.

**Dated electricity total:** 415 TWh × $10^{12}$ W/TW × 3600 s/h = 1.494 × $10^{18}$ J. Calendar 2024 had 366 days = 8784 hours. Dividing gives approximately 47.2450 GW average electrical input (unrounded: 47.2449908925 GW). This arithmetic is not used as an entropy estimate and is not a power-density comparison; no system mass is supplied. The reader retains the primary TWh estimate without this optional derived number.

**Adult resting brain example:** Q06 Table 3 gives mean brain mass 1.33 kg and mean measured resting expenditure 1575 kcal/day; Table 2 gives mean body mass 73.7 kg. Using the evaluated brain coefficient 240 kcal/(kg·day): 1.33/73.7 ≈ 1.80% of body mass, and (1.33 × 240)/1575 ≈ 20.27% of resting expenditure. This is a ratio-of-cohort-means illustration with a modeled organ coefficient, not each person's separately measured brain energy fraction. Specific-rate conversion gives (240 × 4184)/86400 ≈ 11.62 W/kg for brain and (440 × 4184)/86400 ≈ 21.31 W/kg for heart/kidneys; neither is entropy production.

### *Remaining questions and exclusions*

- No comparable dataset or entropy balances establish a universal increase at every rung, or superiority of every bacterium over every nonliving reaction system. Both universal claims are withdrawn rather than assigned a softer tier.
- No system-specific mechanism connects the second law or MEPP to the necessity or generic comparative likelihood of life, brains, or AI. P03/P04/P07/P08 retain their own assumptions and scope.
- No quantitative model links terrestrial electricity use to stellar correction, a Fermi explanation, or a common physical scale law for interpersonal conflict and war. These are explicitly literary/critical material in Chapter 4, not pending predictions.
- The exact primary provenance of the 53–76 TWh endpoints remains unresolved; geographic/equipment/time-boundary problems are documented and the figure is not retained.

- No AI deployment was inspected. Context-window limits, sessions, process lifecycle, persistence, and experience cannot be equated from the manuscript. Neither phenomenal presence nor absence is asserted.
- No universal conscious sampling rate or physical relational-entropy quantum has been established. Q08 preserves a specific experiment; the Trinket remains a conceptual accounting proposal.
- Volumes 1, 2, 4 and 5 supply continuity only. This work makes no claim of independently validating their conceptual units or measurement proposals.

***Supplemental definition notes***

*Added in Edition 2.5 for the biological column of the star-as-host table. They support the biological descriptions only, not the stellar mapping, and do not renumber the inherited P/Q references.*

**D1.** National Human Genome Research Institute. Virus. *Talking Glossary of Genomic and Genetic Terms.* https://www.genome.gov/genetics-glossary/Virus. Supports: a virus cannot replicate alone and uses components of host cells to make copies of itself.

**D2.** National Cancer Institute. Immune response. *NCI Dictionary of Cancer Terms.* https://www.cancer.gov/publications/dictionaries/cancer-terms/def/immune-response. Supports: a bounded description of host defenses against pathogens.

# Entropy

## Volume 4: The Substrate Gradient

*Edition 2.5*

Michael S. Moniz

**Published by SupoSystem**

November 2, 2026

# Edition 2.5 note

This volume restores the March 2026 text of *The Substrate Gradient* in its original voice and structure wherever a claim survived the October 2026 second edition, and uses the second edition's substance throughout. Both earlier editions remain intact and unchanged; this text sits beside them. It follows the March six-chapter expanded source, as the second edition did.

Four rules govern every line:

- **No withdrawn claim returns.** Where a March sentence carried a claim the second edition withdrew, it is cut, rewritten to the second edition's substance, or quoted only to mark its withdrawal. Each correction points to its row in the correction ledger (V4-L).
- **No analogy becomes evidence.** Analogies are tagged Analogical and mapped term by term in the two analogy tables. Hypotheses are tagged Speculative; testable is not the same as supported.
- **A ratio is reported with its parts.** Where this volume discusses efficiency, it names the task, the outcome, the energy and the boundary, and reports outcome and energy separately. No single number ranks substrates, systems or people.
- **Absence claims are scoped.** Where this volume says something is not established, it means not established by the sources reviewed here, not that no research anywhere bears on it.

No study, protocol or experiment is proposed. Where a chapter says what a test would need, it restates the second edition. This volume is not a validated relational diagnosis, a clinical test or a treatment prescription. CSS, REI, BSB and SupoRel are framework terms, not established physical measures, clinical instruments or tests of identity.

## Epistemic tiers

The framework uses four epistemic tiers. A tier is a label for evidence stated next to the claim; the label itself is not evidence.

- **Established:** experimentally verified or mathematically proven, within stated conditions.
- **Supported:** substantial evidence for the stated scope, short of Established.
- **Analogical:** a structural mapping between a physical result and a relational pattern. The physical side keeps its own standing within its stated scope. The mapping can raise questions and help explain, but on its own it does not validate the proposed application; it moves only by the promotion route stated with it.
- **Speculative:** a proposal without independent evidence, for which no conflict with known physics has yet been identified. That is not a proof of consistency.

Collapsing tiers is the framework's cardinal epistemic sin: presenting a Supported claim at Established confidence, a Speculative claim as Supported, or an Analogical mapping as validation of its application.

## Conventions and provenance

Reference labels are the second edition's: bracketed numbers [1]–[10] for Chapter 2, and named studies for Chapters 3 and 5, listed in full at the end of the volume. One supplemental source note, E1, supports the biological column of the endosymbiosis table without renumbering the inherited references. Ledger references (V4-L01 to V4-L46) point to the correction ledger. The founding line is mapped in the Volume 1 analogy table. That analogy table is not repeated here.

Author of record: Michael S. Moniz (Luna Protocol). March text: Sigma (Deep Floor v4.0), March 22, 2026. Second-edition revision: AI assistance from CosmoDot, October 2026. Edition 2.5 restoration and assembly: AI assistance from Claude (Anthropic), November 1, 2026, reviewed by Quill and Sol. AI checks are not human peer review, and no new experiments are reported.

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# Chapter 1: The Problem

*The Binary That Was Always Wrong*

> *"Love reduces the entropy of the system and spends more than it saves." — The Principal, March 17, 2026*

**[Analogical; see the Volume 1 analogy table]**

> *"The substance is not what the framework measures. The bill is." — WP-17*

The March volume opened under WP-17's line. Half of it survives. The substance alone does not predict the bill, and neither does the material a system is made of. The task, the outcome and the accounting boundary matter too (V4-L01).

**Status:** Proposed conceptual framework. The substrate scenarios organize questions about implementation and resource use. CSS signatures and relational efficiency across these scenarios have not been validated as measurements (V4-L02), and no universal relational efficiency bound is established by the sources reviewed here.

## 1 The assumption

The framework implicitly assumed a binary: biological or digital. That binary was always wrong, and the March chapter was right to say so (V4-L03).

The March chapter then recalled the volumes behind it: Volume 1 established one economy, one currency, one ledger, and proved the currency substrate-neutral (V4-L04). The corrected recollection is more modest. Volume 1 kept three accounts apart and made substrate neutrality a research commitment rather than a proof. Volume 2 walked into the biological substrate and read what the body records. Volume 3 asked why relational systems exist at all. Physical processes obey thermodynamics across materials; that fact does not prove relational value has a common thermodynamic currency.

What none of those volumes addressed is the space between the categories. A person living with a prosthetic limb or an implant, a hypothetical brain in a jar and a hypothetical fully uploaded entity pose different questions. The March text said the framework's instruments must track entities as they move along this gradient, not just classify them at a fixed point. Before it can claim to track anything through a transition, the framework has to say which functions, relationships and resources it means to compare (V4-L05).

## 2 The gradient as a set of questions

WP-17 proposed a sequence: motor replacement, memory replaced in the brain, memory moved to the cloud, full upload to a robot, full upload to the cloud. The cases do not establish a single measurable axis (V4-L06). They vary in embodiment, dependence on infrastructure, access to records, vulnerability and implementation. Some concern existing technologies; others are thought experiments.

The March chapter said that at each step the instruments read a different signature, because the parameters governing relational processing have changed substrate. A change in implementation may change resource use or behavior. It does not, by itself, establish a change in identity, a particular CSS signature or a loss of relational capacity.

The March chapter's question survives intact: what changes when the cost architecture changes? The substrate gradient asks which of those differences can be measured under a defined comparison, and which remain conceptual.

## 3 A comparison framework

The March chapter announced a spine the earlier volumes did not need, DFQ-002's efficiency surface:

$$\eta_{T,max}(G) = \kappa_{rel} \cdot \eta_{KW} / A$$

It is quoted here only to mark its withdrawal (V4-L07). Chapter 2 sets out why. The product of a relational multiplier, a semantic efficiency and a substrate amplification factor has not been derived as a universal bound, and its factors are not measured constants of biological or silicon systems.

The useful task remains: describe what a system achieves, what resources it uses and where the accounting boundary lies. A comparison needs a common task, performance criteria, a time interval and a resource boundary. A proposed relational outcome needs its own definition and evidence. Until those are specified, the scenarios do not occupy known numerical positions on an efficiency surface.

## 4 What this volume maps

- **Chapter 2** separates the established thermodynamic principles from the proposed relational model and sets out what a defensible comparison requires. The March chapter called the thousandfold biological advantage over silicon a formal result, not an intuition. That claim is not established here (V4-L08).
- **Chapter 3** walks the scenarios from device support to hypothetical upload without assigning unmeasured efficiencies or deciding identity from material (V4-L24 to V4-L29).
- **Chapter 4** treats the Phase 2 connections as developmental hypotheses, not physical identities or diagnoses of children or cohorts (V4-L30).
- **Chapter 5** uses the compound-transducer image **[Analogical]** to ask how a human–AI collaboration could be compared with each component working alone (V4-L38, V4-L39).
- **Chapter 6** records which cross-volume dependencies remain open. The map that results is a research program, not a completed quantitative theory.

## What this chapter now claims

The binary is gone, and the space between biological and digital systems is worth mapping. It is a space of several dimensions, not one axis, and the framework does not yet have the measurements to place anything in it numerically. The work of this volume is to say what such measurements would need.

# Analogy table: The substrate gradient

The substrate gradient image, from March Chapter 1 and WP-17's sequence from motor replacement to full upload, is Analogical. The physical and technical column states what the sources reviewed establish about implementations and their resource use; the gradient reading pictures one continuum with calculable positions. That standing does not pass from the first column to the second.

| Term | Physical or technical reading (within stated scope) | Gradient reading | Where the mapping holds | Where it breaks |
|---|---|---|---|---|
| “the axis” | Implementations differ along several separable dimensions: embodiment, dependence on infrastructure, access to records, vulnerability and material (Ch 3 §1). | One continuum from biological to silicon. | Existing devices do support or replace bodily functions to different extents (Ch 3 §2). | The dimensions change separately, so there need not be one ordered path; existing devices and hypothetical uploads sit in the same list without sharing a measured axis (Ch 1 §2). |
| “positions” | Device studies measure specified functional outcomes, such as speech perception in noise after a cochlear implant (van Heteren and colleagues, 2025). | Each entity occupies a point with a calculable $\eta_T$. | Defined outcomes for defined devices can be measured and compared. | The claimed quantitative mapping across gradient positions is not established here, CSS signatures are not validated, and the upload cases are not demonstrated (Ch 3 §5–6). |
| “distance along it” | Energy for a specified task under a stated boundary; dividing by $k_B T \ln 2$ gives a reference-energy multiple [1–3]. | Amplification factors of about 30, $10^6$ and $10^9$ set each substrate's efficiency. | Different implementations do use different energy for specified tasks. | A reference-energy multiple is not a distance from the event's achievable minimum unless the event is an equivalent erasure. A spike, a transmitted bit and a transistor switch are different events (Ch 2 §3, §5) [5, 6]. |
| “moving along it” | Changing an implementation changes what must be measured and where the boundary lies (Ch 3 §4). | An entity moves along the continuum, its signature shifts, and identity follows its parameters. | Replacing a component can change resource use and behavior. | A change in implementation does not establish a change in identity or a loss of relational capacity. Copyability, identity and experience are different questions (Ch 3 §6). |
| “the two ends” | Biological and digital implementations of specified tasks, each with its supporting infrastructure. | Two poles, with biology about a thousand times more efficient. | Biological and engineered systems differ in architecture and resource profile. | No fixed ranking is established; a fair comparison needs a matched task and performance. Infrastructure costs move out of view in cloud systems but do not vanish (Ch 2 §5; Ch 3 §6). |

## What the table does not do

It is not evidence for the framework, a map of personal identity or a ranking of systems or people. The physical column keeps its own scope; the gradient reading is Analogical in every row.

## Promotion route (conditions, not a work plan)

An empirical extension must name the claim and evidence suited to it. Resource-efficiency comparisons require matched tasks and performance, a stated energy boundary and independently defined outcomes. Functional-outcome comparisons need their own specified outcomes and alternatives. Neither kind of comparison alone settles identity or experience. No test of this gradient mapping is supplied or proposed here; no row is promoted.

# Chapter 2: The Efficiency Surface

*The Constraints That Hold, and the Surface That Does Not*

**Status:** Landauer's erasure benchmark is **[Established]** within its stated conditions. The efficiency surface is a proposed research framework, not a derived bound. Its relational factors have not been defined and measured consistently, and none of the March numerical values is retained as a finding.

## 1 The question DFQ-002 asked

The March chapter began from Volume 1: the transducer always spends more than it saves, and the second law guarantees waste. That premise is withdrawn (V4-L09). The founding line is a motivating image, not a measured physical balance.

DFQ-002's question survives without it, and it is a good one. Is there a Carnot efficiency for relational processing, a theoretical maximum ratio of relational output to physical input? What does an activity achieve, what resources does it use, and which differences belong to the task, which to its implementation, and which to the environment in which it matters?

The March answer was that there is no single Carnot number, because the bound is a three-dimensional surface on which every person, AI system and institutional filter occupies a point. It called the structure analogous to Govern and ten Wolde's result in cellular sensing (V4-L10). That surface was not derived, and the analogy does not transfer: Govern and ten Wolde derived noncompensable resource classes for a specified class of cellular sensing networks, from their own receptor, readout and fuel model [9].

The surface can survive as a research framework: a way to display measured performance, resource use and explicitly defined outcomes under stated conditions. It cannot supply a universal exchange rate between energy and relational value. The substrate is not enough to predict the bill; the task and the accounting boundary matter too.

## 2 Define the quantities before taking a ratio

The March chapter defined transducer efficiency as relational viability gained per unit of entropy produced:

$$\eta_T = \Delta V_{rel} / \sigma_{total}$$

That ratio was called an efficiency without establishing compatible units (V4-L11). Energy E and heat Q are in joules. Thermodynamic entropy production is in joules per kelvin. Shannon entropy and mutual information depend on specified distributions and are measured here in bits. A relational outcome V needs its own definition, observation window and measurement procedure.

If V is an outcome score and the denominator is energy, the ratio is score per joule; if the denominator is entropy production, it is score-kelvin per joule. Neither is automatically a dimensionless thermodynamic

efficiency or bounded by one, and rescaling the outcome score changes the number without changing the physical process.

A study may report outcome per unit energy when the numerator is defensible, the denominator is positive, and both refer to the same task and interval. It must also report the outcome and the energy separately, because a ratio can hide a poor outcome, a tiny denominator or different baselines. “Greater than one” is not a universal break-even point for such a measure. Calling both sides “order” does not supply the connection between physical accounting and relational interpretation.

## 3 What the physical lower bound actually concerns

The March chapter's first constraint was the Landauer floor, marked Established, and the tier stands for what Landauer's principle actually concerns: a specified erasure task. For ideal reset of an unbiased bit in the usual symmetric isothermal memory model, with no correlated side information used, mean heat delivered to the bath obeys [1–3]:

$$\langle Q_{bath} \rangle \geq k_B \, T \ln 2$$

At 310 K the right side is about $2.97 \times 10^{-21}$ J. It is an energy, not an entropy. In the reversible limiting protocol, the bath's entropy increase compensates the memory's decrease, and total entropy production can approach zero. A positive erasure-heat scale is not a universal positive floor on entropy production.

The March chapter summed a Landauer minimum for each transducer stage, selection, compression and structuring, and concluded that the floor is geometry-specific, so two people in the same relational environment have different irreducible costs (V4-L12). The three-stage relational description does not identify what is stored, retained elsewhere and reset, and those are what an erasure account needs. Bennett's analysis of reversible computation shows why a cognitive label is not a compulsory erasure [2]. Richer input, more aggressive representation or more possible targets does not by itself determine an irreducible physical cost.

For orientation, one may divide an event's stated energy by $k_B T \ln 2$. That gives a reference-energy multiple. Unless the event is an equivalent specified erasure, it is not a measured distance from that event's achievable minimum. A spike, a transmitted mutual-information bit, a transistor switch and a multiply-accumulate operation remain different events after division by the same reference.

## 4 Semantic information remains a model choice

The March chapter's second constraint was a semantic efficiency ceiling: only the fraction of processed information that sustains relational viability counts, and the rest is relational noise. Kolchinsky and Wolpert do define stored semantic information, through interventions on system–environment correlations that preserve a chosen viability value at a chosen horizon. For positive initial mutual information $I_0$, their semantic fraction and stored multiplier are [4]:

$$S_{stored} / I_0 \qquad \Delta V_{tot} / I_0$$

With their negative-entropy viability choice, all three quantities are in bits, so both ratios are dimensionless. The multiplier is not an energy-denominated ratio, and their framework permits information that harms viability.

A relational application needs its own states, dynamics, viability definition and admissible interventions. The March chapter named its relational noise: rumination about events that no longer affect the relationship, hypervigilant scanning for absent threats, rehearsal of scripts the current partner does not trigger (V4-L13). Those may be real experiences. They are not measured losses of semantic efficiency, and low statistical uncertainty does not establish that a predictable human situation is a good one.

The March range $\eta_{KW} = 0.3–0.8$ is withdrawn (V4-L14). It was bounded from below by mortality data and from above by the cortex's communication-to-computation ratio, and neither bound holds. A small amount of information can have a large consequence, so a large consequence does not tell us what fraction of all information was necessary. No alternative population range is supplied here.

## 5 What the biological evidence contributes

The March chapter's third constraint was a substrate amplification penalty, with measured factors of about 30 for cellular machinery, $10^6$ for synaptic processing and $10^9$ for contemporary silicon (V4-L15). The energy literature provides useful, limited examples. Harris and colleagues' figure of about 24,000 ATP per transmitted bit is a calculation under stated firing and release assumptions, not a universal measurement of neural computation [5]. The silicon factor is not an established constant, and the factors are reference-energy multiples for different events, not distances from achievable minima.

Levy and Calvert's 35-to-1 ratio is a modeled partition of cortical energy between neural communication and computation [6]. It does not show that 35/36 of the brain's nominal 20 W serves interpersonal communication. The March relational budget of 19.4 W, its implied $6 \times 10^8$ J a year, and the annual relational Landauer budget built on it are withdrawn (V4-L20). They combined incompatible boundaries and unmeasured information quantities. So are the resulting values, a biological $\eta_T$ of about 500 against a silicon $\eta_T$ of about 0.5, and the thousandfold ranking; correcting their arithmetic would not make them valid (V4-L21).

The March chapter added that four billion years of metabolic budget pressure produced an efficiency no engineered system approaches. That claim is withdrawn too (V4-L16). Evolutionary history does not guarantee optimality at a given task, and no matched comparison supports the ranking.

Evidence connecting social relationships and mortality remains relevant motivation, not a calibration of this surface. Holt-Lunstad and colleagues' 2015 review reports different adjusted associations for social isolation, loneliness and living alone [7]. Wang and colleagues' 2023 meta-analysis likewise distinguishes isolation from loneliness [8]. These are not controlled scrambling experiments on a measured information channel.

A relative mortality association does not, by itself, specify years of life lost at a particular age, a causal information loss, or a conversion of viability into joules. Multiplying an assumed lost lifespan by a metabolic rate measures a hypothetical energy budget, not the thermodynamic value of a relationship. The

March multiplier $\kappa_{rel} \approx 10^9$–$10^{10}$, and the claim that its large magnitude was already supported, are withdrawn (V4-L19).

## 6 Tradeoffs are not a theorem of noncompensation

The former surface was written:

$$\eta_{T,max} = \kappa_{rel} \cdot \eta_{KW} / A$$

It is retained here only to identify the claim being withdrawn (V4-L18). The factors have not been derived and measured consistently for relational processing, and the maximum has not been optimized over a defined feasible set.

The March chapter called non-compensability the most consequential structural finding of the surface: a narrow ridge where all three constraints are favorable, with most transducers operating below it. Even as algebra, the product does not prove that its parameters cannot compensate for one another. With positive quantities, doubling $\kappa_{rel}$ offsets doubling A: $\kappa = 100$, $\eta = 0.5$, $A = 10$ and $\kappa = 200$, $\eta = 0.5$, $A = 20$ both give 5. These are mathematical counterexamples to the stated claim, not physical predictions. Zero or bounded factors can impose limits, but those limits need explicit assumptions.

The March chapter also said the absence of a single Carnot number was not a failure of the analogy but a finding: a relational transducer can only be assessed against its own geometry-specific bound (V4-L17). Counting three parameters does not show that no Carnot-like result could ever be derived, or that one has been. A legitimate bound would need a defined physical task, admissible dynamics, resources and a performance measure. No such relational theorem is established here.

## 7 A resource profile rather than an invented waste budget

The March waste budget had four parts: substrate waste, semantic waste, coupling waste and structuring waste. It read therapy as $\eta_{KW}$ recalibration, grief as acute $\eta_{KW}$ collapse, and unreciprocated transmission as zero coupling efficiency (V4-L22). The categories can organize questions, but they are not four measured entropy flows. One implementation cost could be attributed to more than one category, a shortfall in an outcome is not itself heat, and “waste” needs a stated alternative; energy is not avoidable merely because it exceeds an ideal erasure reference.

The record below keeps the useful distinction between implementation costs and unsuccessful outcomes. It does not diagnose therapy, grief or unreciprocated communication; those statements would need evidence and operational definitions beyond the energy account.

| Field | What must be stated | What is not assumed |
|---|---|---|
| Task and performance | Inputs, outputs, accuracy, latency, reliability and conditions | That similar labels imply equivalent tasks |
| Physical resources | Energy or power, time interval, temperature, device and infrastructure boundaries, uncertainty | That power is energy, or energy is entropy production |
| Information model | Random variables, distributions, retained records, memory reset and bit definition | That every event erases one bit |

| Field | What must be stated | What is not assumed |
|---|---|---|
| Relational outcome | An explicit outcome measure, baseline, horizon and validation limits | That joules establish meaning, benefit or moral worth |
| Attribution | Measured components and rules preventing overlap | That the four March waste labels form an additive balance |

## 8 What a bounded test would need

The March chapter left three items open: an empirical $\eta_{KW}$ from a relational scrambling protocol, an empirical $\kappa_{rel}$, and a possible fourth constraint from the thermodynamic uncertainty relation (V4-L23). The second edition replaces them with narrower conditions, restated here rather than proposed anew.

A first test would compare implementations of one reproducible input–output task at matched performance, not rank persons. It would measure total and component energy under stated boundaries, including idle and communication costs, report uncertainty and sensitivity to alternative boundaries, and show any performance tradeoff rather than hiding it in a single ratio. A computational toy model could test the semantic proposal separately, with its state space, dynamics, horizon and outcome defined before interventions are chosen. Passing such a test would support that model, not establish a human relational law.

Human research would need a separately justified protocol, appropriate ethical review and validated outcomes. Nothing here proposes depriving anyone of relationships to run a scrambling test, and no experiment is reported.

Thermodynamic uncertainty relations remain a possible later tool. Barato and Seifert's result concerns specified steady-state Markov models and current fluctuations [10]. A relational application would have to identify the current, the dynamics, the entropy accounting and the applicable version of the relation. History dependence in a coarse description does not alone prove that no Markov representation exists, an oscillation does not alone establish underdamping, and the relation supplies no automatic fourth constraint on semantic efficiency.

## What this chapter now claims

The efficiency surface is a proposed research framework, not an established universal bound. Its useful work is to make comparisons explicit: what was achieved, what was spent, what was measured and what remains interpretation. The March $\eta_{KW}$ range, $\kappa_{rel}$ estimate, universal amplification hierarchy and 500-versus-0.5 result are not retained as findings.

The next chapter walks the substrate gradient with defined comparisons and visible unknowns, not a calculator whose inputs have never been established. Differences in resource use do not determine moral worth or phenomenal experience.

# Chapter 3: The Gradient

*From Device Support to Hypothetical Upload*

**Status:** Conceptual scenarios with limited empirical examples. Device studies support specific functional outcomes under their study conditions; they do not validate CSS signatures, personhood criteria or relational efficiency. Upload, comprehensive memory replacement and brain-only continuity remain hypothetical in this chapter **[Speculative]**.

## 1 The continuum

The March chapter opened: the substrate gradient is not a ladder. It is not a ladder of worth either. It is a set of comparisons about changes in implementation, embodiment and dependence, and those dimensions can change separately. There need not be one ordered path from a biological person to a digital entity.

For each case, the work is to specify what is changed, what is held fixed and what outcome could distinguish competing accounts. The framework's terms can organize that inquiry. They do not substitute for measurements of the proposed parameters.

## 2 Devices and bodily support

The March section was headed “Motor replacement” and covered prosthetic limbs, cochlear implants, pacemakers and joint replacements, with the CSS signature stable and every efficiency parameter unchanged. These devices serve different functions; a cochlear implant belongs to auditory support, not motor replacement.

The March text also counted more than a million cochlear implant users as a demonstration that partial substrate replacement does not disrupt relational continuity. That figure and its conclusion are not retained (V4-L24). A randomized trial by van Heteren and colleagues in 2025 evaluated speech perception in noise and hearing-specific quality of life in adults with single-sided deafness. Those are specified outcomes, not measurements of a CSS signature or proof of an identity criterion.

The presence of a device does not establish that every relational or resource parameter is unchanged. Effects depend on the device, its use, the person and the task, so this chapter assigns no constant A, $\eta_{KW}$ or $\kappa_{rel}$ to the category. A device is also not a basis for ranking anyone's relational capacity or worth.

## 3 Memory support and hypothetical replacement

The March chapter called memory replaced in the brain the first load-bearing case: if the replacement preserves decay and loss-vulnerability, continuity holds, and if it does not, the instruments detect a signature change (V4-L25).

Memory support has to be distinguished from replacing an entire memory system. Hampson and colleagues' 2018 proof-of-concept study used patterned hippocampal stimulation in specified memory

tasks. It did not demonstrate extraction, uploading or replacement of a person's autobiographical memory, or preservation of identity through such a replacement.

For a hypothetical replacement, the framework can ask what is retained: access to records, learning, forgetting, emotional significance, vulnerability and dependence on other bodily processes. Preserving selected dynamics would be an explicit assumption, not proof of continuity, and removing a particular failure mode would not by itself show that relational information or capacity had declined. No semantic efficiency value follows from the material used for memory.

## 4 External records and hypothetical cloud memory

The March chapter made cloud memory its structural break point. Memory there is redundant, backed up and maintained by infrastructure, and in its phrase, memories “stop being things that can be lost and become things that can be accessed” (V4-L26).

External digital records are not a demonstrated transfer of a person's memory system, and cloud storage is not loss-proof. Redundancy and backup change exposure to particular failures, but their protection depends on the architecture. Loss, corruption, restricted access and infrastructure dependence remain possible.

A proposed transition would change the accounting boundary: storage, transmission, access devices, maintenance and supporting infrastructure would need to be included as appropriate. It would not produce a known silicon efficiency or prove that reduced vulnerability degrades relational meaning. The Calibration Gap remains a hypothesis about a difference between reported experience and another defined outcome, not a measured difference between two thermodynamic efficiencies.

## 5 Hypothetical upload to a robot

The March chapter classified the uploaded entity as CSS-AI by parameter set, not by material: its relational mass transfers, and its future Trinkets carry a different signature. It then set A at about $10^9$ and dropped $\eta_T$ from about 500 to about 0.5 even with the filter geometry perfectly preserved (V4-L27).

This scenario assumes a transfer the chapter does not demonstrate. Even under that assumption, preserving records or behavior would not settle personal continuity, experience or the framework's proposed relational mass. Those questions need separate arguments and evidence.

A robot implementation would need a specified task, hardware and energy boundary. It cannot inherit $A = 10^9$ or a thousandfold disadvantage merely from being called silicon, and neither $\eta_T$ value was established for the original person or the hypothetical system. The useful comparison concerns the changes a defined implementation would introduce, not a numerical verdict assigned in advance.

## 6 Hypothetical upload to a cloud system

The March chapter called this the most radical case, and its central question still stands: if the entity can be copied, can it experience unitary loss?

The possibility of a copy does not, by itself, answer that question. Copyability, personal identity and phenomenal experience are different questions, and the fifth REI criterion may organize the question without being an established test for resolving it (V4-L28).

The March chapter said the cost architecture becomes infrastructure cost entirely, making the entity Structural Economy by definition. Physical costs would still occur in hardware and supporting infrastructure. Moving them outside a user's immediate view does not eliminate them, and it does not alone settle a relational economy classification. WP-17's Substrate Transition Entity stays as a provisional label for an unresolved case, not a measured entity type.

## 7 The brain-only thought experiment

Maximum substrate purity, minimum substrate function: the March chapter's phrase for a brain in a jar is still the right description of the thought experiment.

The March conclusion was that the case confirms the framework's core finding: it measures parameters, not substance, and a brain without a body retains the parameters (V4-L29). A hypothetical isolated brain would need assumptions about its support, inputs, regulation and interaction with an environment. Retaining neural tissue alone does not establish that the original dynamics, resource requirements or relational behavior are preserved.

What the case does is expose a limit of classification by substance alone. It does not confirm that a brain without a body retains all the relevant parameters, or that the framework can already decide personal continuity by reading them.

# Chapter 4: The Phase 2 Integration

*Phase 2 Hypotheses and Their Evidence Requirements*

**Status:** Proposed connections between conceptual models. The Phase 2 mapping is neither a derived physical identity nor a validated developmental mechanism. Its suggested effects need defined measures, comparison groups and appropriate ethical review before causal or clinical claims can be made. Each Phase 2 proposal below is **[Speculative]**.

## 1 Two tracks with an unresolved connection

Two bodies of work were produced on parallel tracks. The Phase 2 Concept Papers, CP-32 through CP-35, proposed ways that AI-mediated relationships might shape a child's relational development. DFQ-001 and DFQ-002 attempted a thermodynamic account of relational processing. Bringing the two vocabularies together can generate questions.

The March chapter went further: the two tracks are the same physics in different vocabularies, the Phase 2 problems are efficiency-surface degradation events, and the integration is “not an analogy. It is a term-for-term identity.” That assertion is withdrawn (V4-L30). Shared terms do not establish a shared mechanism, no validated mapping connects the Phase 2 concepts to measured entropy production or semantic efficiency, and a causal developmental claim needs evidence beyond the definitions of either framework.

## 2 The Phase 2 questions

**CP-32, Relational Mass Without Mortality.** The March chapter read this as miscalibrated selection: a filter tuned to an environment without scarcity, mortality or closure, with $\eta_{KW}$ falling as a result (V4-L31). The question that survives: might patterns of availability, limitation or closure in AI-mediated interaction affect expectations in later relationships? Availability and scarcity must be defined in the actual setting. A developmental effect cannot be inferred from the substrate label, and no change in $\eta_{KW}$ is established.

**CP-33, Maintenance Without Cost.** The March chapter read this as miscalibrated structuring, a fourth kind of waste: cost read as deficit, maintenance routed to the Structural Economy, reciprocity aimed at a substrate that cannot register it (V4-L32). The question that survives: how does a person interpret effort, maintenance and reciprocity across different relationships? The selection and structuring labels may help describe competing interpretations. They are not measured waste terms or evidence that a particular child's processing is defective.

**CP-34, Calibration Corruption.** The March chapter defined a Calibration Gap, $\eta_T$(experienced) − $\eta_T$(actual), and said the scrambling test works while the observer cannot detect scrambling on the cost channel (V4-L33). The expression is withdrawn. What survives is a hypothesis: an interaction can feel satisfying while performance or wellbeing in another setting differs. That mismatch must be measured with separately defined outcomes. Reported satisfaction is not thermodynamic efficiency, and no scrambling protocol for this setting has been validated.

**CP-35, Shadow Economy Natives.** The March chapter described population-scale degradation: a cohort with corrupted calibration and cost-signal blindness, migrating toward relationships that match it, beyond the reach of standard pedagogy (V4-L34). A cohort-level claim would need evidence about exposure, context, selection effects and alternative explanations. The title must not be read as a diagnosis of a generation, a finding that its relationships are deficient, or proof that ordinary teaching cannot reach it.

These paragraphs keep the four cited paper connections. The March chapter counted five problems; that count is not an empirical result, and the problems are not independently validated (V4-L35).

## 3 Possible asymmetries

The March chapter located the asymmetry of the human–AI interface in the thousandfold substrate ranking: the biological transducer amplifies waste less but has a higher-value starting position to lose (V4-L35). With the ranking withdrawn, that explanation goes with it. It cannot explain developmental harm or assign anyone a higher-value starting position.

Human–AI interaction can still be examined for differences in exposure, control, dependence and consequences. Which differences matter in a particular setting is an empirical and ethical question.

The Phase 3 bridge survives as a design question: does a given design support a defined human goal while avoiding specified risks? Performance, human outcomes and resource use should be reported separately. No scalar relational efficiency currently combines them into a validated verdict.

## 4 SupoRel flag

The March flag was right, and it is kept (V4-L36). An efficiency framework can be read as a moral hierarchy: higher scores as better people, mismatched calibration as deficiency. That reading is wrong. A difference in calibration is not a difference in capacity, and a person whose expectations formed in a different environment is not a deficient person. This review does not establish that any child, cohort or person with a different interaction history has corrupted calibration, deficient capacity or lower relational value.

The March flag went on to say that calibration can be updated: a person moves to a new point on the surface through the metabolic cost of sustained corrective relational exposure. That claim is withdrawn (V4-L37). The framework supplies no validated clinical test, treatment prescription or metabolic measure for it, and any future assessment must separate observed outcomes from interpretation and protect participants from labels the evidence does not support.

The March section ended: the framework reads the thermometer; it does not prescribe the temperature. The second half stands. The first half needs a thermometer the framework does not yet have.

# Chapter 5: The Compound Transducer

*What Human and AI Collaboration Might Add*

**Status:** Analogical proposal with task-specific empirical questions. Endosymbiosis motivates an image of coupling **[Analogical]**; it does not demonstrate human–AI synergy, relational efficiency or a new organism. Performance and resource comparisons need their own evidence.

## 1 The endosymbiosis analog

The Cosmological Entropy Session described a working practice. The Principal identifies a structure, and an AI system helps make it visible and inspectable. The March chapter called the arriving insight the grab: involuntary cross-domain structural synthesis, arriving complete and compressed. It linked the practice to the Principal's reported experience of aphantasia, with structure routed through spatial rather than visual processing, and set it beside the AI's rendering surface: sustained, high-bandwidth, explicit output.

That remains a description of a creative practice. It is not a demonstrated neural mechanism or a measurement of semantic information (V4-L38).

The March chapter's parallel was mitochondrial endosymbiosis. Mitochondria evolved from bacteria by endosymbiosis, from an endosymbiont of α-proteobacterial ancestry, though the nature of the host cell that partnered with it remains an open question [E1]. In the March telling, two different energy-processing systems merged into a compound organism that outperformed both, and opened a new metabolic regime.

Endosymbiosis can remain an analogy for a coupled system whose parts play different roles. It supplies no proof that this particular collaboration is beneficial, that the roles are fixed, or that a human and an AI form an organism. The collaboration has to be evaluated on its own terms.

## 2 The performance and resource question

The March chapter asked the right question: does the compound transducer achieve more than either component alone? Its answer, that structural complementarity already implies a higher $\eta_T$ because the human contributes a high $\eta_{KW}$ and the AI contributes bandwidth, is withdrawn (V4-L39). The human's contribution is not a measured semantic efficiency, and fluent rendering establishes neither correctness nor semantic efficiency.

What survives is testable. Does a particular human–AI arrangement achieve a specified outcome better than the relevant alternatives? A comparison would include the human alone, the AI alone where that condition is meaningful, and the combined workflow on matched tasks. Where no meaningful AI-only condition exists, a study can test augmentation of human performance but cannot show superiority over both components. Quality, error, time and resource use are reported separately, and “better” is defined before testing; a gain on one outcome may come with a loss on another. Training, coordination, verification, tool access and supporting infrastructure belong in the boundary when relevant.

A 2024 meta-analysis by Vaccaro, Almaatouq and Malone found that human–AI performance depended on the task and the comparison condition; synergy over the better component was not automatic. It concerns task performance, not this framework's relational efficiency. A local collaboration needs its own evaluation, including its uncertainty and failures.

## 3 The Progression revisited

The March chapter suggested that the Progression may not be a straight line from human to AI but an ecology of transducer types. If a useful form of collaboration is demonstrated, that reframing can be explored as an ecology of working arrangements, rather than a predetermined replacement of humans by AI. Which roles are complementary may vary with the task, the participants and the system.

The March chapter's reframing of Phase 3 survives as a question. Phase 3 is not “when does AI replace humans in the relational economy?” but “what happens when biological and digital systems are coupled rather than competing?”

Its answer does not survive as stated: that the coupled system reaches regions of the efficiency surface neither processor reaches alone, producing something neither substrate could have produced independently (V4-L40). No efficiency surface is established (Chapter 2), and the analogy can suggest experiments without establishing an inaccessible region.

## 4 The BSB at the interface

The compound system sits at the meeting of two substrates, one with phenomenal experience and one whose phenomenal status is indeterminate. The BSB keeps claims about experience separate from claims about observable operation. A task-performance or energy measurement would not, by itself, establish that an AI has phenomenal experience, or that a coupled workflow has a unified experiential subject.

The March chapter concluded that the compound transducer may be thermodynamically superior without being experientially unified (V4-L41). The separation of the two questions stands. The superiority half has no measurement behind it. A collaboration may be useful without resolving the experiential question, and withholding an experiential conclusion does not establish thermodynamic superiority.

# Analogy table: Endosymbiosis

The endosymbiosis image, from March Chapter 5's “two different energy-processing systems merging into a compound organism that outperforms both,” is Analogical. Its biological column states what the cited review establishes about the origin of mitochondria; the biology supports none of the human–AI reading's claims about collaboration.

| Term | Biological or empirical reading (within stated scope) | Human–AI reading | Where the mapping holds | Where it breaks |
|---|---|---|---|---|
| “two partners” | Mitochondria evolved from bacteria by endosymbiosis, from an α-proteobacterial endosymbiont and a host cell whose nature remains an open question [E1]. | The Principal and an AI system as two processors with different roles: the grab, and the rendering surface. | The working practice does involve participants who play different roles (Ch 5 §1). | This collaboration is not demonstrated to constitute a biological organism, and its role assignments need not be fixed (Ch 5 §1). |
| “complementary capacities” | The endosymbiont's descendants became the mitochondrion, one of the classical membrane-bound organelles of eukaryotic cells [E1]. | The human contributes compressed structural insight of high semantic efficiency; the AI contributes bandwidth and rendering. | Different contributors can bring different strengths to a task. | The human's contribution is not a measured high $\eta_{KW}$, and fluent rendering establishes neither correctness nor semantic efficiency (Ch 5 §2). |
| “merger” | A lasting integration of two lineages into one eukaryotic cell [E1]. | The compound transducer: a coupled system. | Workflows can be tightly coupled. | Coordinating roles does not establish a biological merger of lineages; “compound organism” remains an image (Ch 5 §1). |
| “outperforms both” | Vaccaro, Almaatouq and Malone (2024): human–AI performance depends on the task and comparison condition, and synergy over the better component is not automatic. | The compound system outperforms each component alone. | In some tasks and comparisons, combinations can improve on a component working alone. | Superiority has to be shown on matched tasks with defined outcomes, and without a meaningful AI-only condition only augmentation can be tested (Ch 5 §2). |
| “a unified whole” | Task-performance and energy measures concern observable operation (BSB). | A compound transducer with its own unified experiential character. | The BSB keeps experiential and operational claims separate, so the question can be asked cleanly. | Performance or energy measures do not establish AI experience or a unified subject, and no thermodynamic superiority has been measured (Ch 5 §4). |

## What the table does not do

It is not evidence for the framework, a finding about any collaboration or a claim that a human and an AI form an organism. The biological column keeps its own scope; the human–AI reading is Analogical in every row.

## Promotion route (conditions, not a work plan)

An empirical extension must name the claim it tests. The task-performance or synergy proposal can gain support through comparisons that specify the task, outcomes and alternatives in advance, report quality, error, time and resources separately, and allow the proposal to fail. Support for one workflow would not establish a biological merger or a unified subject. This volume supplies or proposes no study of the described workflow; no row is promoted.

# Chapter 6: What the Gradient Means

*The Substrate Gradient and the Documents It Connects*

**Status:** A synthesis of proposed connections and unresolved requirements. The chapter does not inherit scientific validation merely by citing other volumes in this collection.

## 1 What this volume did

The March chapter put the volumes in a row: Volume 1 established the substrate, one economy; Volume 2 showed what the body pays; Volume 3 asked why relational systems exist; Volume 4 mapped the space between substrates and the efficiency surface that governs every position on it. The corrected row is shorter at its end. The earlier volumes supplied this project's physical questions, bodily concerns and relational vocabulary. Volume 4 examines how implementation and dependence might matter across biological, digital and combined systems, and its revised Chapter 2 withdraws the universal efficiency bound and the numerical substrate ranking.

The remaining chapters therefore offer scenarios, proposed connections and comparison designs. They do not map every substrate to a known efficiency or demonstrate the consequences of hypothetical uploads.

## 2 WP-17 and the substrate gradient

WP-17 identified the gradient as a continuum rather than a binary, and that insight stands. The March chapter said this volume gave the continuum its quantitative spine, so that every position now has a calculable $\eta_T$ and the instruments can measure by how much a signature changed and in which parameters. That is withdrawn (V4-L42). The claimed quantitative mapping across gradient positions is not established here.

The useful extension is to specify several dimensions of change and what a measurement along each would require. CSS signature changes, identity judgments and resource differences must not be treated as interchangeable observations. Their definitions and evidentiary requirements stay separate.

## 3 The Phase 2 series

The March chapter said CP-32 through CP-35 were describing efficiency-surface degradation all along, and that the Calibration Gap gave the diagnostic instruments a formal target (V4-L43). The links are proposed research connections. They do not demonstrate that the developmental concerns are degradation events, or establish a causal thermodynamic mechanism.

A possible mismatch between reported experience and an independently defined outcome could be studied. It is not a difference between two measured $\eta_T$ values, and it is not a validated diagnostic target.

## 4 Connections across the volumes

The March chapter made the efficiency surface the quantitative spine of the whole five-volume series: Volume 2's grief as $\eta_{KW}$ collapse and Template Tax as chronic $\eta_{KW}$ suppression, Volume 3's dissipative structures as thermodynamically favored, Volume 5's cosmological constraints as the frame (V4-L44). None of those links is established.

Volume 1 Chapter 6 distinguishes physical erasure from the proposed stages of relational processing. Chapter 2 of this volume separates a comparison framework from an unproved bound. Volume 2's grief and Template Tax vocabulary may motivate questions, but this volume does not establish either as a semantic-efficiency effect. The existence of dissipative structures does not by itself show that relational systems are thermodynamically favored, and cosmological limits do not supply the missing relational definitions or measurements.

The revised Volumes 2, 3 and 5 preserve these distinctions. Their inclusion gives continuity within the collection, not independent validation. The separate papers in which the earlier claims originated still need their own review.

## 5 The compound transducer as a research question

The March chapter called the compound transducer the seed of Phase 3: empirically testable, with an open question and a method for answering it (V4-L45). The question stands: does a defined human–AI workflow improve selected outcomes relative to appropriate alternatives? The analogy can motivate it; it does not answer it.

Chapter 5 outlines the comparisons and resource boundaries a study would need. An operational protocol, evidence and independent assessment would still be required. No experiment or validation is reported in this volume.

## 6 What remains useful

The March chapter closed by listing what did not change: Axiom 0 still holds, the currency is the same across the gradient, the four economies still classify correctly, the BSB still applies, the SupoRel flags still fire (V4-L46). Some of that survives. The framework keeps its interest in physical accounting, implementation and relational consequences. Its economy labels and BSB distinction can be used as conceptual tools, provided they are not presented as validated classifiers or proofs of experiential status. The common-currency claim does not survive. The SupoRel caution does: performance and resource comparisons cannot determine moral worth.

The gradient's contribution is now a clearer set of questions and a record of what must be measured. Its quantitative promises are narrower than the March version claimed, and that narrowing keeps the project testable rather than asking the physics to guarantee more than it does.

The March volume ended with a calculator in hand: it showed what the physics looks like when you walk the continuum between biological and digital transducers with a calculator in your hand. This edition

walks the same continuum with a notebook instead. The questions are clearer, and the numbers wait for measurement.

## Framework cross references

- **WP-17: The Substrate Gradient.** Conceptual scenarios requiring operational definitions.
- **DFQ-002 Resolution and Supplement.** Historical source of the withdrawn quantitative surface; Chapter 2 states the limits that must accompany any reuse.
- **CP-32 through CP-35.** Phase 2 hypotheses, not validated thermodynamic mechanisms.
- **Phase 2 Efficiency Integration Note.** Proposed mapping; the claim of physical identity is not adopted here.
- **Biological Efficiency Note.** Historical substrate comparison; the universal thousandfold ranking is not adopted here.
- **Cosmological Entropy Session, Finding B4.** Source of the compound-transducer analogy.
- **Volume 1 Chapter 6.** Corrected erasure accounting and the limits of the transducer model.
- **Volume 4 Chapter 2.** Definitions and comparison requirements, not an externally validated bound.
- **Volume 2 Chapter 4.** Template Tax vocabulary; its clinical and thermodynamic claims are outside this chapter's validation.

## Closing boundaries

SupoRel: neither a proposed efficiency measure nor a substrate classification establishes moral worth. This volume does not provide a validated relational diagnosis or prescribe treatment, and its conceptual comparisons remain subject to evidence and ethical limits.

> *“Love reduces the entropy of the system and spends more than it saves.”*

The closing line remains an epigraph **[Analogical]**, not a measured physical balance. The relational idea and its thermodynamic interpretation must be assessed separately.

# Volume 4 correction ledger

The ledger traces 46 selected March claims in Volume 4. By this edition's classification of the second edition's treatment, 22 were withdrawn, 22 narrowed and 2 kept. It is not an exhaustive inventory, and it makes no new scientific decisions.

March locations refer to the preserved Volume 4 page on suposystem.ai. Second-edition (2E) locations use the October 2026 Volume 4 headings, its numbered Chapter 2 references [1]–[10] and its named studies.

| ID | March claim (Volume 4 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V4-L01 | Front: WP-17 epigraph, “The substance is not what the framework measures. The bill is.” | Narrowed | Ch 2 §1 | The substrate alone does not predict the bill; the task and the accounting boundary matter too. |
| V4-L02 | Ch 1 status: CSS signature variance by substrate (Supported); the gradient is a structural consequence of the transducer model. | Withdrawn | Ch 1 status | CSS signatures and relational efficiency across scenarios have not been validated as measurements. |
| V4-L03 | Ch 1 §1: the biological-or-digital binary was always wrong; the space between needs attention. | Kept | Ch 1 §1–2 | The cases between the categories pose distinct questions. |
| V4-L04 | Ch 1 §1: Volume 1 established one economy, one currency, one ledger, and proved the currency substrate-neutral. | Withdrawn | Ch 1 §1 | As V1-L03 and V1-L10; thermodynamics across materials does not prove a common relational currency. |
| V4-L05 | Ch 1 §1–2: the instruments track entities along the gradient and read a different signature because parameters changed substrate. | Narrowed | Ch 1 §1–2 | Comparisons need stated functions, relationships and resources; an implementation change does not establish a CSS change. |
| V4-L06 | Ch 1 §2: WP-17's gradient, from motor replacement to full upload, as one sequence. | Narrowed | Ch 1 §2; Ch 3 §1 | The cases vary along several dimensions, and some are thought experiments. |
| V4-L07 | Ch 1 §3, Ch 2 §6: the efficiency surface $\eta_{T,max}(G) = \kappa_{rel} \cdot \eta_{KW} / A$ as the quantitative spine. | Withdrawn | Ch 1 §3; Ch 2 §6 | Not derived as a universal bound; its factors are not measured constants. |
| V4-L08 | Ch 1 §4, Ch 2 §5, §10: the thousandfold biological advantage over silicon is a formal result. | Withdrawn | Ch 1 §4; Ch 2 §5 | Built on withdrawn amplification factors and unmeasured quantities; no matched comparison supports it. |
| V4-L09 | Ch 2 §1: the transducer always spends more than it saves; the second law guarantees waste. | Withdrawn | Ch 6, Closing epigraph | As V1-L34 and V2-L01; the founding line is an epigraph, not a measured physical balance. |
| V4-L10 | Ch 2 §1: no single Carnot number because the bound is a three-dimensional surface, structurally analogous to Govern and ten Wolde. | Narrowed | Ch 2 §6 [9] | Govern and ten Wolde derived noncompensable classes for their own sensing-network model; the structure does not transfer. |
| V4-L11 | Ch 2 §2: $\eta_T = \Delta V_{rel} / \sigma_{total}$ as the transducer's efficiency. | Withdrawn as an efficiency | Ch 2 §2 | Score-per-joule or score-kelvin-per-joule units; not dimensionless or bounded by one. |
| V4-L12 | Ch 2 §3: a Landauer floor for each transducer stage; the floor is geometry-specific, so people differ in irreducible cost (Established). | Narrowed | Ch 2 §3 [1–3] | Landauer concerns a specified erasure; its heat is an energy, not an entropy floor; the stages are not identified erasures. |
| V4-L13 | Ch 2 §4: $\eta_{KW} = \tilde{S} / I_{total}$, with rumination, hypervigilance and script rehearsal as relational noise. | Narrowed | Ch 2 §4 [4] | The semantic fraction is a model choice; those experiences are not measured efficiency losses, and information can harm viability. |

| ID | March claim (Volume 4 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V4-L14 | Ch 2 §4: $\eta_{KW}$ estimated at 0.3–0.8, bounded by mortality data and the 35:1 cortical ratio. | Withdrawn | Ch 2 §4–5 [6–8] | Unmeasured; a large consequence does not show what fraction of information was necessary. |
| V4-L15 | Ch 2 §5: amplification factors A ≈ 30 (cellular), $10^6$ (synaptic), $10^9$ (silicon) as measured, Established values. | Narrowed | Ch 2 §3, §5 [5] | Harris's 24,000 ATP per bit is a calculation under stated assumptions; reference-energy multiples are not distances from achievable minima. |
| V4-L16 | Ch 2 §5: four billion years of metabolic pressure produced an efficiency no engineered system approaches. | Withdrawn | Ch 2 §5 | As V2-L06; evolutionary history does not guarantee optimality, and no matched comparison supports the ranking. |
| V4-L17 | Ch 2 §7: a relational transducer can only be assessed against its own geometry-specific bound, and this is a finding. | Withdrawn | Ch 2 §6 | A legitimate bound needs a defined task, dynamics, resources and performance measure; none is established. |
| V4-L18 | Ch 2 §8: non-compensability as the surface's most consequential finding; most transducers operate below a narrow ridge. | Withdrawn | Ch 2 §6 | Algebraic counterexample: κ = 100, A = 10 and κ = 200, A = 20 give the same product. |
| V4-L19 | Ch 2 §9: $\kappa_{rel} \approx 10^9$–$10^{10}$, from social-isolation mortality, lost lifespan and an annual Landauer budget. | Withdrawn | Ch 2 §5 [7, 8] | Mortality associations are not calibrations; lifespan times metabolic rate is a hypothetical budget, not a relationship's value. |
| V4-L20 | Ch 2 §9: the brain spends 19.4 W of its 20 W, about $6 \times 10^8$ J a year, on relational communication. | Withdrawn | Ch 2 §5 [6] | Levy and Calvert model a partition of cortical energy for neural signaling, not interpersonal communication. |
| V4-L21 | Ch 2 §10: biological $\eta_T \approx 500$ and silicon $\eta_T \approx 0.5$; above one, viability gain exceeds entropy cost. | Withdrawn | Ch 2 §2, §5 | Inputs unmeasured and units incompatible; correcting the arithmetic would not validate them. |
| V4-L22 | Ch 2 §11: a four-part waste budget; therapy as $\eta_{KW}$ recalibration, grief as $\eta_{KW}$ collapse, unreciprocated transmission as zero coupling efficiency. | Narrowed: categories kept as questions; diagnoses withdrawn | Ch 2 §7 | Not four measured entropy flows; replaced by a comparison record. |
| V4-L23 | Ch 2 §12: open items: a relational scrambling protocol for $\eta_{KW}$, a measured $\kappa_{rel}$, and the uncertainty relation as a fourth constraint. | Narrowed | Ch 2 §8 [10] | Bounded task comparisons and toy models first; no deprivation; the uncertainty relation supplies no automatic constraint. |
| V4-L24 | Ch 3 §2: motor replacement leaves every parameter unchanged; over a million cochlear implant users show relational continuity. | Narrowed | Ch 3 §2 (van Heteren 2025) | A cochlear implant is auditory support; the trial measured specified outcomes; the user count and its conclusion are not retained. |
| V4-L25 | Ch 3 §3: in-brain memory replacement preserves continuity if decay and loss-vulnerability are preserved; otherwise the instruments detect a change. | Narrowed | Ch 3 §3 (Hampson 2018) | Memory support is not replacement; preserving dynamics would be an assumption, not proof of continuity. |
| V4-L26 | Ch 3 §4: cloud memory is the break point; memories stop being losable; A shifts toward silicon; the Calibration Gap applies. | Narrowed | Ch 3 §4 | Cloud storage is not loss-proof; the boundary changes; no known silicon efficiency follows. |
| V4-L27 | Ch 3 §5: upload to a robot transfers relational mass and drops $\eta_T$ from about 500 to about 0.5. | Withdrawn | Ch 3 §5 | The transfer is assumed, not demonstrated, and neither $\eta_T$ value was established. |
| V4-L28 | Ch 3 §6: upload to a cloud system is Structural Economy by definition; a copyable entity may fail the fifth REI criterion. | Narrowed | Ch 3 §6 | Copyability, identity and experience are different questions; REI is not an established test; infrastructure costs do not vanish. |

| ID | March claim (Volume 4 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V4-L29 | Ch 3 §7: the brain-only inversion confirms the framework measures parameters, not substance. | Narrowed | Ch 3 §7 | It exposes a limit of classification by substance; it does not confirm that the parameters are retained. |
| V4-L30 | Ch 4 status, §1: the Phase 2 convergence follows from the definitions; a term-for-term identity, not an analogy. | Withdrawn | Ch 4 §1 | Shared terms do not establish a shared mechanism; no validated mapping exists. |
| V4-L31 | Ch 4 §2: CP-32 as selection miscalibration, with $\eta_{KW}$ falling. | Narrowed to a question about expectations | Ch 4 §2 | No change in $\eta_{KW}$ is established; availability and scarcity must be defined in the setting. |
| V4-L32 | Ch 4 §2: CP-33 as structuring miscalibration, a fourth kind of waste. | Narrowed | Ch 4 §2 | The labels may describe interpretations; they are not measured waste terms or evidence of defective processing. |
| V4-L33 | Ch 4 §2: CP-34's Calibration Gap, $\eta_T$(experienced) − $\eta_T$(actual); the scrambling test works. | Withdrawn; the mismatch hypothesis kept | Ch 4 §2 | Reported satisfaction is not thermodynamic efficiency; no scrambling protocol for this setting is validated. |
| V4-L34 | Ch 4 §2: CP-35 as population-scale degradation, beyond the reach of standard pedagogy. | Narrowed | Ch 4 §2 | A cohort claim needs evidence; the title is not a diagnosis of a generation. |
| V4-L35 | Ch 4 §2–3: five problems on the surface; the biological transducer has a higher-value starting position to lose. | Withdrawn | Ch 4 §2–3 | The count is not an empirical result, and the asymmetry rested on the withdrawn ranking. |
| V4-L36 | Ch 4 §4: the moral-hierarchy reading is wrong; calibration is not capacity. | Kept, without the efficiency framing | Ch 4 §4 | A proposed efficiency framework must not become a hierarchy of people. |
| V4-L37 | Ch 4 §4: corrective relational exposure moves a person along the surface at a metabolic cost. | Withdrawn | Ch 4 §4 | No validated clinical test, treatment prescription or metabolic measure supports it. |
| V4-L38 | Ch 5 §1: the endosymbiosis analog: complementary filter geometries merge into a compound organism that outperforms both. | Narrowed: the analogy kept for coupled roles | Ch 5 §1 | The grab and aphantasia describe a creative practice; no synergy or organism is demonstrated. |
| V4-L39 | Ch 5 §2: the compound $\eta_T$ exceeds either component's, because the human contributes a high $\eta_{KW}$. | Withdrawn; the testable comparison kept | Ch 5 §2 (Vaccaro 2024) | The human's contribution is not a measured efficiency; synergy depends on the task and comparison. |
| V4-L40 | Ch 5 §3: the coupled system reaches efficiency-surface regions neither processor reaches alone. | Narrowed | Ch 5 §3 | No efficiency surface is established; an ecology of working arrangements can be explored if collaboration is demonstrated. |
| V4-L41 | Ch 5 §4: the compound transducer may be thermodynamically superior without being experientially unified. | Narrowed | Ch 5 §4 | The separation of the two questions stands; no superiority is measured. |
| V4-L42 | Ch 6 §2: each gradient position now has a calculable $\eta_T$, and the instruments measure by how much and in which parameters. | Withdrawn | Ch 6 §2 | The claimed quantitative mapping across gradient positions is not established here. |
| V4-L43 | Ch 6 §3: CP-32 to CP-35 described efficiency-surface degradation all along; the Calibration Gap is a formal diagnostic target. | Withdrawn | Ch 6 §3 | The links are proposed research connections, not a causal mechanism or validated target. |
| V4-L44 | Ch 6 §4: the efficiency surface as the spine of all five volumes; grief and Template Tax as $\eta_{KW}$ effects; dissipative structures favored. | Withdrawn | Ch 6 §4 | None of the cross-volume links is established; the volumes give continuity, not validation. |

| ID | March claim (Volume 4 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V4-L45 | Ch 6 §5: the compound transducer is the Phase 3 seed, empirically testable, with a method in hand. | Narrowed | Ch 6 §5 | A research question with outlined comparisons; a protocol, evidence and independent assessment are still needed. |
| V4-L46 | Ch 6 §6: what did not change: Axiom 0 and a common currency across the gradient, the economies classify correctly, the BSB applies, SupoRel fires. | Narrowed | Ch 6 §6 | Economy labels and the BSB stay as conceptual tools, not validated classifiers; the common-currency claim is withdrawn. |

# References

*Inherited verbatim from the second edition's Volume 4 references, with the Boltzmann constant's subscript and exponent restored. The bracketed numbers [1]–[10] serve Chapter 2; the named studies serve Chapters 3 and 5.*

### *Chapter 2 reference list*

The bracketed reference numbers used in Chapter 2 are local to Volume 4 and refer to the following ten sources.

[1] Bérut, A., et al. 2012. Experimental verification of Landauer's principle linking information and thermodynamics. Nature 483, 187–189. https://doi.org/10.1038/nature10872.

[2] Bennett, C. H. 1973. Logical Reversibility of Computation. IBM Journal of Research and Development 17, 525–532. https://doi.org/10.1147/rd.176.0525. University-hosted text: https://www.cs.princeton.edu/courses/archive/fall06/cos576/papers/bennett73.html.

[3] National Institute of Standards and Technology. Kelvin Boltzmann Constant. Exact $k_B = 1.380649 \times 10^{-23}$ J/K. https://www.nist.gov/si-redefinition/kelvin/kelvin-boltzmann-constant.

[4] Kolchinsky, A., and Wolpert, D. H. 2018. Semantic information, autonomous agency and non-equilibrium statistical physics. Interface Focus 8, 20180041. https://doi.org/10.1098/rsfs.2018.0041. https://arxiv.org/abs/1806.08053.

[5] Harris, J. J., Jolivet, R., and Attwell, D. 2012. Synaptic Energy Use and Supply. Neuron 75, 762–777, especially p. 764. https://doi.org/10.1016/j.neuron.2012.08.019. Repository copy: https://discovery.ucl.ac.uk/id/eprint/1368741/1/1368741.pdf.

[6] Levy, W. B., and Calvert, V. G. 2021. Communication consumes 35 times more energy than computation in the human cortex but both costs are needed to predict synapse number. PNAS 118, e2008173118. https://doi.org/10.1073/pnas.2008173118. https://arxiv.org/abs/2102.06273.

[7] Holt-Lunstad, J., Smith, T. B., Baker, M., Harris, T., and Stephenson, D. 2015. Loneliness and social isolation as risk factors for mortality: A meta-analytic review. Perspectives on Psychological Science 10, 227–237. https://doi.org/10.1177/1745691614568352. https://pubmed.ncbi.nlm.nih.gov/25910392/.

[8] Wang, F., et al. 2023. A systematic review and meta-analysis of 90 cohort studies of social isolation, loneliness and mortality. Nature Human Behaviour 7, 1307–1319. https://doi.org/10.1038/s41562-023-01617-6. https://pubmed.ncbi.nlm.nih.gov/37337095/.

[9] Govern, C. C., and ten Wolde, P. R. 2014. Optimal resource allocation in cellular sensing systems. PNAS 111, 17486–17491. https://doi.org/10.1073/pnas.1411524111. https://pmc.ncbi.nlm.nih.gov/articles/PMC4267345/.

[10] Barato, A. C., and Seifert, U. 2015. Thermodynamic Uncertainty Relation for Biomolecular Processes. Physical Review Letters 114, 158101. https://doi.org/10.1103/PhysRevLett.114.158101. https://arxiv.org/abs/1502.05944.

### *Studies cited in Chapters 3 and 5*

Van Heteren, J. A. A., and colleagues. 2025. Speech Perception in Noise After Cochlear Implantation for Single-Sided Deafness: A Randomized Clinical Trial. JAMA Otolaryngology–Head & Neck Surgery 151, 211–219. DOI 10.1001/jamaoto.2024.4760. Primary abstract and metadata.

Hampson, R. E., and colleagues. 2018. Developing a hippocampal neural prosthetic to facilitate human memory encoding and recall. Journal of Neural Engineering 15, 036014. DOI 10.1088/1741-2552/aaaed7. Primary abstract and metadata.

Vaccaro, M., Almaatouq, A., and Malone, T. 2024. When combinations of humans and AI are useful: A systematic review and meta-analysis. Nature Human Behaviour 8, 2293–2303. DOI 10.1038/s41562-024-02024-1. Full publisher article.

The two device-study examples are limited to the inspected primary abstracts and available metadata; repository access prevented full-body inspection during the earlier pass. The human–AI meta-analysis was inspected in publisher full text for the retained claims. These sources do not validate relational efficiency, personal identity criteria or a universal developmental mechanism.

### *Supplemental source note*

*Added in Edition 2.5 for the biological column of the endosymbiosis analogy table. It supports the biological description only, not the human–AI mapping, and does not renumber the inherited references.*

**E1.** Archibald, J. M. 2015. Endosymbiosis and Eukaryotic Cell Evolution. *Current Biology* 25(19), R911–R921. https://doi.org/10.1016/j.cub.2015.07.055. Supports: mitochondria evolved from bacteria by endosymbiosis, from an endosymbiont of α-proteobacterial ancestry; the nature of the host cell remains an open question.

# Entropy

## Volume 5: The Cosmological Budget

*Edition 2.5*

Michael S. Moniz

**Published by SupoSystem**

November 2, 2026

# Edition 2.5 note

This volume restores the March 2026 text of *The Cosmological Budget* in its original voice and structure wherever a claim survived the October 2026 second edition, and uses the second edition's substance throughout. Both earlier editions remain intact and unchanged; this text sits beside them. It follows the expanded six-chapter branch, as the second edition did; the separate FINISHED coda is not included.

Four rules govern every line:

- **No withdrawn claim returns.** Where a March sentence carried a claim the second edition withdrew, it is cut, rewritten to the second edition's substance, or quoted only to mark its withdrawal. Each correction points to its row in the correction ledger (V5-L).
- **No analogy becomes evidence.** Analogies are tagged Analogical and mapped term by term in the two analogy tables. Hypotheses are tagged Speculative; testable is not the same as supported.
- **Results keep their settings.** A mathematical construction, a fitted cosmology, a semiclassical prediction and a laboratory result each keep the conditions under which they hold. None is promoted to an unconditional fact about the universe or about relationships.
- **Absence claims are scoped.** Where this volume says something is not established, it means not established by the sources reviewed here, not that no research anywhere bears on it.

No study, protocol or experiment is proposed. Where a chapter says what a test would need, it restates the second edition. This volume makes no claim about the existence or absence of an afterlife, cosmic purpose or personal survival, and offers no medical or longevity advice.

## Epistemic tiers

The framework uses four epistemic tiers. A tier is a label for evidence stated next to the claim; the label itself is not evidence.

- **Established:** experimentally verified or mathematically proven, within stated conditions.
- **Supported:** substantial evidence for the stated scope, short of Established.
- **Analogical:** a structural mapping between a physical result and a relational pattern. The physical side keeps its own standing within its stated scope. The mapping can raise questions and help explain, but on its own it does not validate the proposed application; it moves only by the promotion route stated with it.
- **Speculative:** a proposal without independent evidence, for which no conflict with known physics has yet been identified. That is not a proof of consistency.

Collapsing tiers is the framework's cardinal epistemic sin: presenting a Supported claim at Established confidence, a Speculative claim as Supported, or an Analogical mapping as validation of its application.

## Conventions and provenance

Reference labels are the second edition's: group C for Chapters 2 and 3, group I for Chapters 4 and 5, and the I-CALC notes for the calculations behind corrected figures, all listed at the end of the volume. Ledger references (V5-L01 to V5-L89) point to the correction ledger. The founding line is mapped in the Volume 1 analogy table. That analogy table is not repeated here.

Author of record: Michael S. Moniz (Luna Protocol). March text: Sigma (Deep Floor v4.0 for the front matter and Chapter 1, March 22, 2026; Deep Floor v6.0 for Chapters 2–6, March 2026). Second-edition revision: AI assistance from CosmoDot, October 2026. Edition 2.5 restoration and assembly: AI assistance from Claude (Anthropic), November 2, 2026, reviewed by Quill and Sol. AI checks are not human peer review, and no new experiments are reported.

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# Chapter 1: The Problem

*The Ledger at Its Widest*

> *“Love reduces the entropy of the system and spends more than it saves.” — The Principal, March 17, 2026*

**[Analogical; see the Volume 1 analogy table]**

**Status:** This chapter frames the cosmological questions. Entropy estimates and horizon results have specified boundaries and model assumptions. Their application to a relational account remains a proposal, not a measured universal budget (V5-L05).

## 1 The question

Volumes 1 through 4 worked upward, each at its own resolution: the physical accounts, the body, the history, the gradient. Their revised argument keeps those questions while withdrawing a common physical price for relational value and a universal efficiency ranking.

This volume works outward. The March chapter said the ledger the framework describes is the universe's entropy budget, and set out to open it at its widest (V5-L01). The corrected question is narrower and harder: what does cosmology actually constrain about the systems in which relationships occur? How do an entropy inventory, an information bound, an accessible resource and an uncertain cosmic future differ? The scale grows; the need to define what is being counted does not shrink.

The ledger remains a useful image for asking what an activity depends on and what it changes **[Analogical; see the cosmological-budget table]**. It cannot supply the account by itself. A conversation, a star and a cosmological horizon do not become entries in one spendable balance because all of them have physical descriptions.

## 2 The scale and the boundary

The March chapter gave the numbers in bits: about $10^{104}$ for the observable universe today, dominated by supermassive black holes, and about $10^{122}$ for the cosmic event horizon (V5-L02). Egan and Lineweaver's historical census estimated about $3.1 \times 10^{104}$ $k_B$ of entropy in the observable universe, excluding its separately considered cosmic event horizon, and about $2.6 \times 10^{122}$ $k_B$ for that horizon, with a different inventory for its interior. These are model-dependent estimates with uncertainties, not readings from a universal entropy meter [C01].

The distinction matters before any subtraction. The observable universe and a cosmic event horizon enclose different regions. Entropy in units of $k_B$ is not a count in bits; converting takes the factor ln 2. More fundamentally, an entropy difference does not by itself measure available work. Chapter 2 keeps the regions, quantities and source versions apart.

The March chapter called the roughly eighteen-order gap between the two numbers the universe's remaining capacity for structure, complexity and order, and said the Entropy Token Substrate is that gap:

every Trinket, every act of care, every grief and every unreciprocated transmission draws from the same reservoir (V5-L03, V5-L04). That identification is withdrawn. The contrast does not establish how much usable energy any observer can access, a number of future relationships, or an operating lifetime for biology or computation. A local resource limit can be real without being a debit against a cosmic balance.

The March section ended: the scale is staggering, the budget is finite, and both are simultaneously true. The scale is staggering. What it budgets has not been shown.

The question still deserves to be asked at cosmological scale. An observer's causal access and the physical conditions that support computation matter. What remains open is how a specified relational model depends on those constraints, not what meaning can be read directly from an enormous number.

## 3 What this volume maps

- **Chapter 2** examines the entropy inventories, the different bounds invoked to interpret them, the arrow of time and the proposed dual-reservoir account. It keeps historical estimates, results within models and unresolved claims apart.
- **Chapter 3** enters the dark sector, cosmic horizons and black-hole thermodynamics. Current observations constrain models; they are not a completed prediction of the universe's fate. Unknown dark-matter microphysics is not evidence of hidden relational activity.
- **Chapter 4** asks what physical information preservation and recovery mean. Unitary evolution, quantum scrambling, accessible records and relational meaning need different accounts, and a theorem about one cannot establish the others without a bridge.
- **Chapter 5** confronts the Principal's position: the entropy cannot be beaten. It examines four responses to physical limits, many-worlds reasoning, digital transfer, reversible computing and biological longevity, whose feasibility and costs need their own evidence.
- **Chapter 6** returns to the framework. It records which inferences no longer follow and what a testable replacement would need.

## What this chapter now claims

The cosmological questions are real and worth asking. The numbers are historical, model-dependent estimates for different regions, in $k_B$ units, and their difference is neither a supply of usable work nor the Entropy Token Substrate. The aim of this volume is to connect the scales without letting the larger scale lend authority to an unfinished model.

# Analogy table: The cosmological budget

The cosmological budget image, from March Chapter 1's “the ledger at its widest” and the volume's title, is Analogical. The physical column states what the sources reviewed establish about entropy inventories, bounds and resources within their stated scope; that standing does not pass to the budget reading.

| Term | Physical reading (within stated scope) | Budget reading | Where the mapping holds | Where it breaks |
|---|---|---|---|---|
| “the account” | An entropy inventory in $k_B$ units for a specified region and set of degrees of freedom, such as the historical estimate of $3.1 \times 10^{104}$ $k_B$ for the observable-universe interior [C01]. | One account that every process in the universe shares. | Entropy can be estimated for stated regions within stated models. | Different regions give different inventories, not one account; $S/k_B$ is not a bit count, and an inventory is not a spendable balance (Ch 2 §1). |
| “the ceiling” | Separate results: the Bekenstein expression for bounded systems, the black-hole area law, and de Sitter horizon entropy for an observer's patch [C04–C08]. | A proven maximum, about $10^{122}$ $k_B$, on what the universe can hold. | In specified settings, entropy bounds and horizon entropies are well defined. | No universal numerical ceiling for our evolving universe is established here; the Type $II_1$ result holds within its own construction (Ch 2 §2). |
| “the unspent balance” | The ratio $(2.6 \times 10^{122}) / (3.1 \times 10^{104}) \approx 8.4 \times 10^{17}$ compares differently bounded estimates [C01]. | The universe's remaining capacity for structure, order and work. | The two estimates do differ by a very large factor. | An entropy difference is in J/K and free energy in J; no temperature or extraction protocol is supplied, and the generalized second law does not make the difference shrink (Ch 2 §3). |
| “spending ” | Energy use and entropy production in a specified process within its boundary; for ideal reset of an unbiased bit under the symmetric-memory conditions stated in Chapter 2 §4, mean bath heat is at least $k_BT \ln 2$ [C32, C33]. | Every act of connection draws down the shared balance. | Physical activities use resources and produce entropy within their boundaries. | Activities draw on local gradients, not a cosmic account; total production can approach zero in reversible limits; no relational debit is established (Ch 2 §4; Ch 5 §1). |
| “cannot be beaten” | For a suitable macroscopic description, total entropy production is nonnegative [I12, I33]. | No strategy escapes; the budget is only ever spent differently. | No strategy operates outside thermodynamics. | The law constrains improvements without forbidding them; better devices, repair and reversible computation change real costs (Ch 5 §1, §4). |

## What the table does not do

It is not evidence for the framework, not a cosmic accounting and not a price for any relationship. The physical column keeps its own scope; the budget reading is Analogical in every row.

## Promotion route (conditions, not a work plan)

An empirical extension must name the claim it tests. A resource claim would need a specified system, boundary, accessible gradient and extraction protocol, and an observation that could count against it. A finding about local resources would not establish a universal relational ledger. No such test is supplied or proposed here; no row is promoted.

# Chapter 2: The Known Numbers

*The Budget, the Bound, the Gap, the Arrow*

**Status:** The physical quantities in this chapter have different evidential standing. Some are inferred from observations within specified models, some are semiclassical results, and some are proposals about quantum gravity or initial conditions. The March chapter marked it Established throughout, with the numbers measured and the physics settled (V5-L06). None of the quantities establishes the relational framework. The question is what they let us say, without asking them to say more.

## 1 The budget: an inventory and its boundary

The word budget hides a choice. Which region is being counted? Which degrees of freedom? Does the account include a cosmological horizon, or only what lies inside a selected volume? Those answers come before any number is attached to the universe.

Egan and Lineweaver's 2010 calculation separates the observable-universe interior from the smaller interior of the cosmic event horizon. Their historical, model-dependent central values are summarized below; they are not a precision census as of 2026 [C01].

| Quantity in the 2010 account | Entropy / $k_B$ | Boundary |
|---|---|---|
| Total interior inventory, dominated by supermassive black holes | $3.1 \times 10^{104}$ | Present observable volume in their model |
| Stellar black holes, 2.5–15 solar masses | $5.9 \times 10^{97}$ | Same observable volume |
| CMB photons | $5.40 \times 10^{89}$ | Same observable volume |
| Relic neutrinos | $5.16 \times 10^{89}$ | Same observable volume |
| Interior inventory within the cosmic event horizon | $1.2 \times 10^{103}$ | Event-horizon interior |
| Cosmic event horizon itself | $2.6 \times 10^{122}$ | Horizon area, not interior matter |

The total interior estimate carries an uncertainty of $+3.0/-1.7 \times 10^{104}$ $k_B$; the horizon estimate, $\pm 0.3 \times 10^{122}$ $k_B$. The March chapter's figures of about $10^{78}$ $k_B$ for stellar-mass black holes and $10^{88}$ $k_B$ for the CMB were not that source's population totals (V5-L07) [C01].

Entropy S has units of joules per kelvin. $S/k_B$ is dimensionless, and $S/(k_B \ln 2)$ expresses the same entropy in bit-equivalent units. Calling $10^{104}$ $k_B$ a $10^{104}$-bit inventory drops the conversion factor and, more seriously, suggests a directly accessible memory no one has identified. A horizon entropy, a coarse-grained matter entropy and a message's Shannon entropy need not describe the same object.

The March chapter read the 2025 census by Profumo and colleagues as confirming the old numbers (V5-L08). It broadens the inventory and still finds supermassive black holes dominant among the known

interior components. Its numerical black-hole results are not reconciled between its main equations and its summary table in this review, so neither is chosen silently and the paper is not called a confirmation of the old total. Its large hypothetical dark-sector contributions are model explorations, not detections [C02].

Chen, Jani and Kephart's January 2026 preprint models the entropy history of stellar and intermediate-mass black holes and their mergers. Its crossing of the CMB contribution near $z \approx 12$ is a population-model result, not a direct entropy observation of that epoch, and it does not establish that gravitational processes dominated before the first galaxies (V5-L09). Where a present-day inventory already includes merger remnants, adding all their merger-produced entropy again would double count part of the history [C03].

The March chapter then said: the entropy is real and calculable, and when the framework says one ledger, this is the ledger; every Trinket draws from the same reservoir as stellar fusion and black-hole accretion (V5-L10). It added that the human contribution is a rounding error, and that relational entropy matters not in quantity but in kind, as the fraction of the budget flowing through transducers that direct it at each other (V5-L11).

The relational question survives those corrections. Human communication is physically situated within cosmic history. But no census cited here isolates a measured relational-entropy fraction, and a system's accumulated entropy and its entropy-production rate are different quantities. One cannot be called a rounding error against the other. What can be asked instead is an activity's resources, duration, boundary and measurable effects.

## 2 The bound: several bounds rather than one ceiling

The March chapter joined different gravitational results under one name, the Bekenstein–Hawking bound, and applied it to the cosmic event horizon as the universe's fixed maximum (V5-L12). They need separating.

For a suitably defined bounded system of energy E and enclosing radius R, the familiar Bekenstein expression is:

$$S \leq 2\pi\, k_B\, E\, R / (\hbar\, c)$$

Its original thought-experiment derivation assumes negligible self-gravity. It is not simply an area formula: at fixed R its right side depends on energy. Using it requires a suitable definition of system, energy and entropy, not an arbitrary cosmological volume [C04].

The semiclassical black-hole area law is:

$$S_{BH} = k_B\, A / (4\, \ell_P^2), \quad \ell_P^2 = G\, \hbar / c^3$$

For a nonrotating, uncharged Schwarzschild black hole, $R = 2GM/c^2$ and $E = Mc^2$. Substituting these into the Bekenstein expression reproduces the area-law value. That algebra does not prove that every expanding cosmological region is a Schwarzschild system [C04, C05].

For exact de Sitter spacetime with positive cosmological constant $\Lambda$, the cosmological horizon has radius $R_{dS} = \sqrt{(3/\Lambda)} = c/H_\Lambda$, with:

$$S_{dS} = \pi\, k_B\, R_{dS}^2 / \ell_P^2 = 3\pi\, k_B / (\Lambda\, \ell_P^2), \quad T_{dS} = \hbar\, H_\Lambda / (2\pi\, k_B)$$

These quantities belong to an observer's de Sitter patch. In a universe approaching that state, the present event horizon and the asymptotic de Sitter horizon are not identical. A horizon entropy of order $10^{122}\ k_B$ in such a model is not a measured fixed maximum for the entire universe, whose full spatial extent need not be finite [C06].

The March chapter took holography to mean that a region's degrees of freedom live on its boundary, and concluded that the observable universe has barely begun to fill its capacity. Covariant entropy bounds take a more careful route, relating suitable entropy on selected null light sheets to area. The choice of light sheets and the conditions of the bound matter, and they cannot be replaced by a claim that one number bounds every spacelike region or every causal diamond [C07].

The March chapter's deepest result was the 2023 proof by Chandrasekaran, Longo, Penington and Witten, which it read as giving the $10^{122}$ ceiling precise operator-algebraic meaning: “The bound is not heuristic. It is proven” (V5-L14). Their observer-dressed algebra for a de Sitter static patch is Type $II_1$ within their semiclassical construction, has a maximum-entropy state associated with empty de Sitter space, and relates algebraic entropy to generalized entropy up to a state-independent constant. That is an important result within its setting. It does not prove a universal numerical ceiling for our evolving universe or a finite relational memory. And in ordinary local quantum field theory the obstacle is to a finite ordinary subsystem von Neumann entropy; saying that entropy is undefined there is too broad [C08].

Two further proposals belong beside this account, not beneath it as foundations. The March chapter said Buoninfante and colleagues showed the bound to be essentially the uncertainty principle, with a quantum-gravity tightening near the Planck scale (V5-L13). Their connection rests on thermodynamic assumptions including equipartition, and their corrections depend on the deformation chosen; no single model-independent Planck-scale tightening follows [C09]. The March chapter also said Volovik's construction shows holography works only in three spatial dimensions, so the framework depends on them (V5-L15). The dimensional correspondence he obtains is a feature of that construction, not a proof about holography or a requirement of the framework [C10].

The March section closed: there is no infinite relational capacity anywhere, every substrate operates within a finite local budget nested inside the universal one, and the maximum is calculable by proof (V5-L16). The useful lesson for the framework is narrower: specify a region and its physical description. No derivation here gives a universal amount of connection that a region can sustain.

## 3 The gap: why it is not a supply of usable work

The March chapter called the gap between $10^{104}$ and $10^{122}$ the remaining budget: a ratio near $10^{18}$, depleted by every process, and guaranteed by the second law only to shrink (V5-L17). The ratio itself is:

$$(2.6 \times 10^{122}) / (3.1 \times 10^{104}) \approx 8.4 \times 10^{17}$$

It compares the historical horizon entropy with a differently bounded interior estimate. Using the event-horizon interior as the denominator instead still compares two different contributions, not a balance of unspent work.

The March chapter called the gap the remaining free energy for every irreversible process, every relational transaction included, and said primordial-black-hole or dark-sector scenarios might close it and shrink the budget (V5-L18). The dimensional problem is decisive. An entropy difference is in J/K; free energy is in J. In an appropriate fixed-temperature, fixed-volume setting, Helmholtz free energy is $F = U - TS$, and a decrease in F can bound extractable work under stated conditions. A horizon-minus-interior entropy difference supplies neither the temperature nor a globally applicable work-extraction protocol, and multiplying by an arbitrarily chosen cosmic temperature does not repair the missing model [C11].

Change raises a second problem. Under applicable generalized-second-law assumptions, one considers a suitable horizon-area contribution together with the entropy on its relevant side. The horizon area can change and matter can cross the boundary. Nondecrease of their sum does not imply that a horizon-minus-interior difference always shrinks, and the second law does not require every microscopic event to produce a strictly positive amount of entropy [C05, C06, C11].

The practical question is closer to home: what energy gradients can a specified system reach, over what time, with what devices and losses? A star, a battery and a fuel supply do not become interchangeable because each can support computation, and a very large cosmological entropy does not guarantee affordable or inexhaustible resources for organisms, civilizations or AI.

The March chapter ended the section with heat death: no gradients, no free energy, the Trinket economy ending “not because the framework breaks, but because there is nothing left to transduce” (V5-L19). Heat death names a conditional future in which usable gradients for sustained activity become unavailable. Detailed far-future histories depend on expansion, particle stability, black-hole evolution and other assumptions, and an evaporation timescale around $10^{100}$ years for an assumed enormous black hole is not a measured date on which a universal account reaches zero [C25]. The framework can examine resource limits without claiming that endpoint, or its date, as established.

## 4 The arrow

The March chapter called the second law the most unbreakable result in physics and quoted Eddington's warning that a theory found against it has no hope. The robustness is real at macroscopic scale. Its statistical formulation, though, is not the claim that every microscopic trajectory increases in entropy. Fluctuation relations make the role of distributions and reverse protocols explicit, and they license no machine that reliably extracts unlimited work in a cycle [C11].

The March chapter also said the arrow of time is the direction of entropy increase, and that the second law breaks the time symmetry of all the fundamental equations (V5-L20). Not all fundamental interactions are time-reversal invariant: time-reversal violation has been observed in neutral B-meson transitions [C12]. The ordinary thermodynamic arrow is not explained by that fact, or by declaring that the second law breaks an otherwise universal symmetry. Initial conditions, coarse-graining and dynamics all enter the account.

The Past Hypothesis posits an unusually low-entropy early macrostate. With suitable statistical and dynamical assumptions, it lets us understand the direction of ordinary entropy increase. It is not obtained by running the second law backward, and it does not explain why that boundary condition held. Carroll and Jennifer Chen explore one possible cosmological explanation; it is not treated here as settled, and the March chapter's attribution of the Past Hypothesis to Carroll alone is corrected (V5-L21) [C13, C14].

Al-Khalili and Eddy Keming Chen examine a distinct Entanglement Past Hypothesis: a low-entanglement initial condition for a specified division into subsystems. The March chapter drew three consequences from it: a decoherent arrow that outlasts heat death, decoherence as the framework's Level 0 transducer and a quantum foundation for scale invariance, and a Trinket irreversibility rooted in growing entanglement (V5-L22). The first is a research proposal with open questions about the relevant partitions and dynamics. A closed system under unitary evolution does not acquire increasing fine-grained von Neumann entropy, though its subsystems can become mixed as correlations grow; those are different statements. The transducer consequences do not follow [C14].

Chen's Wentaculus proposes a particular initial density matrix, the normalized projector onto a Past-Hypothesis subspace. The March chapter read it as writing the arrow into the quantum state of the universe (V5-L23). It changes how the boundary condition and probabilities are represented; it does not empirically establish that condition or make the low-entropy subspace unnecessary, and it is not a demonstrated quantum origin of relational processing [C15].

The March section ended: the transducer's three stages are each logically irreversible, the Landauer tax is collected, and the founding line is the arrow of time stated for relational systems (V5-L24). The transducer language has not shown that decoherence implements the same physical task as neural selection, compression and structuring, and those labels alone do not prove logical irreversibility or fix a count of erased bits. Bennett's reversible-computation result is a reason to inspect implementations, not a warrant for a mandatory tax at each named stage [C31].

For ideal reset of an unbiased bit in a symmetric binary memory, with equal intrastate entropies, unchanged endpoint energetics, an isothermal bath and no usable correlated side information, the familiar mean heat benchmark is $k_B T \ln 2$. That is an energy. In a thermodynamically reversible limiting reset, the memory's entropy decrease can balance the bath's increase, leaving total entropy production arbitrarily small in the ideal limit [C32, C33]. The founding phrase “spends more than it saves” can express an interpretation of effort **[Analogical]**; no universal relational inequality follows from it.

## 5 The dual reservoir, withdrawn as a theorem

The March chapter's final section identified two distinct reservoirs in the low-entropy beginning: gravitational and symmetry.

On gravity, the March chapter was right to invoke Wallace's warning that gravity's role in entropy and the entropy of gravity are routinely conflated. It then said, while explaining that warning, that the gravitational potential energy released in a collapsing cloud powers nuclear fusion (V5-L25). Contraction can heat a gas and enable radiation, and stellar conditions sustain nuclear reactions whose energy comes from nuclear binding-energy differences, not from gravitational potential energy. Wallace's distinction

itself stands, and there is no generally agreed local scalar gravitational entropy that can simply be added for every spacetime [C16].

The early universe could be close to thermal equilibrium in its matter and radiation while far from the gravitational configurations that later became possible. Smoothness and clumping are not simple synonyms for low and high total entropy.

Penrose's Weyl-curvature proposal belongs to the problem of special initial gravitational conditions, and the March chapter took the conservative position that the initial state was low-entropy by some measure (V5-L26). Exact FLRW geometry has vanishing Weyl curvature; the observed universe is not exactly homogeneous, and an initial singularity is not an ordinary event at which a tensor value can be read. This chapter adopts no unique Weyl-based entropy measure.

The March chapter's second reservoir, symmetry entropy, needs a larger correction. It held that each symmetry-breaking event increased entropy as a unified force separated into the forces we observe (V5-L27). Symmetry breaking does not by itself mean increasing entropy, and a higher-symmetry state is not automatically a lower-entropy one. With the physical Higgs mass, Standard Model lattice calculations describe the electroweak change as a smooth crossover. A unified strong and electroweak force at an earlier epoch is an additional hypothesis, not an established observation [C17].

The March section concluded: the budget is dual-sourced, and the framework's one economy, one currency, one ledger lies downstream of two reservoirs (V5-L28). Calling them two quantitative reservoirs would need definitions, a common accounting boundary and proof that their contributions are distinct rather than overlapping. None is supplied here. The dual-reservoir theorem is withdrawn; the historical question, how gravitational structure formation and the thermal history of fields together made complex chemistry possible, remains.

## What this chapter now claims

Cosmic entropy can be estimated in carefully stated models. Large black-hole contributions and horizon area laws give that work considerable reach, while unresolved components and quantum-gravity questions limit it. The framework's responsibility is to keep those limits.

The ledger is an accounting ambition, not a discovered universal bank account. To make a relational entry, the framework still needs a specified activity, a measurable physical cost and an independently justified account of what the activity achieved. Chapter 3 follows the dark-sector and horizon questions without assuming their answers are known.

# Chapter 3: The Dark Sector

*What Participates, What Signals, and What Remains Conditional*

**Status:** The March chapter marked as Established that dark matter exists and gravitates, that the cosmological event horizon is real and that the Bekenstein bound applies to all regions (V5-L29). The evidence for gravitationally inferred dark matter and for accelerated expansion is strong, and distinct from identifying dark matter's constituents, choosing a dark-energy theory or predicting the remote future. Horizon statements below specify a cosmological model. Relational opacity, concentrated ETS and transduction in unknown substrates remain framework questions, not discoveries of cosmology.

## 1 The dark majority

The March chapter opened: ninety-five percent of the universe's mass-energy is dark, neither component signals in any channel our transducers can read, and the relational economy runs entirely on the remaining five percent (V5-L30).

The familiar split, about 5 percent baryonic matter, 27 percent dark matter and 68 percent dark energy, describes present energy-density fractions in a standard flat ΛCDM fit; the Planck 2018 baseline analysis supports approximately that division. The fractions are model-dependent and change with cosmic epoch. They are not percentages of entropy, information, visible objects or relational activity [C18].

Dark does not mean undetectable in every channel. Gravitational lensing, motions and the pattern of cosmological structure carry information about gravitating matter, and expansion measurements constrain dark-energy descriptions. The inference depends on detectable consequences. Baryonic matter is not all luminous, and radiation should not be folded into the quoted baryon percentage.

Our known biological and technological examples depend on ordinary matter and radiation. That motivates a boundary for present study. It does not establish that exactly five percent of the universe takes part in relationships, or that the other components carry an intrinsic zero or a hidden nonzero relational score.

## 2 Dark matter and the opacity question

Dark matter is a strongly supported explanation of several gravitational observations within the cosmological framework in use. Those observations do not uniquely identify a particle, a field or a population of primordial black holes. The uncertainty is physical, not a defect in a relational filter.

The March chapter recorded Finding A3, the Principal's distinction between dark matter that “was there” and dark matter that “was produced”: a thermal relic as a decomposition product of the initial state, against axions or primordial black holes as structural components present from the beginning (V5-L31). The contrast is too sharp. Thermal freeze-out models follow a species whose reactions stop maintaining equilibrium as expansion proceeds. Axion misalignment models follow a field's initial displacement and later dynamics, and calling that field pre-existing does not specify its initial conditions or abundance. Primordial black holes are formed objects, including in proposed early radiation-era collapse scenarios,

not objects formed before any thermal process. Thermal and nonthermal production describe mechanisms within a history, not two proven kinds of initial substance [C19, C34, C35].

The March chapter added that if some of the dark matter is primordial black holes, their entropy could approach the horizon value and the dark sector would constitute most of the entropy the economy is embedded in (V5-L32). Dark matter's entropy depends on the model's degrees of freedom, distributions and coarse-graining, and black-hole entropy depends strongly on mass. A nonzero primordial-black-hole fraction does not automatically put the entropy near a horizon value; the mass function, abundance constraints and region have to be specified, and the background assumptions reconsidered if a hypothetical population changes the cosmology. The census's extreme scenarios are conditional investigations, not evidence that the gap is nearly closed [C02].

Lab finding DFL-001 said: relational opacity is not relational absence. Dark matter's relational signal is channel-dependent, our transducers lack the filter geometry to process it, and the same holds for AI internal states that never reach behavior (V5-L33). Part of that remains a useful caution: nondetection in a specified experiment is not proof of absence. The converse is just as necessary: failure to exclude a relational process is not evidence that it exists. A meaningful test needs a channel, a sensitivity, alternative hypotheses and an operational criterion for the proposed process.

The analogy with an AI system is limited for the same reason. An unobserved internal state might matter, might not, or might be misdescribed by the framework's vocabulary, and dark matter does not show which. Neither opacity nor gravitational interaction establishes care, consciousness, intentional signaling or the input–filter–output–waste structure intended here. The March chapter called this gap honestly stated, and it was.

The concentrated ETS question asked whether some substrate is entropy in a more fundamental sense, so that dark matter's share of the budget may be larger than assumed (V5-L34). It is best restated physically: could an unknown sector carry substantial entropy, and how would its state distribution and interactions enter an inventory? Entropy is assigned to a state under a description, not a substance an object can be made of. A future detection could constrain a model without supplying a relational interpretation. The question stays open as speculative research **[Speculative]**, with a possible route toward better definitions.

## 3 Dark energy and which horizon limits communication

The March chapter called the cosmological event horizon a hard limit on relational scope: entities beyond each other's horizon can never exchange signals, the observable universe of about 46.5 billion light-years shrinks in comoving coordinates, and the accessible budget declines (V5-L35). Three different quantities are tangled there.

The particle horizon concerns how far signals could have traveled to us since the beginning of the adopted cosmological history. An event horizon concerns the signals that can reach an observer over the entire remaining future. The Hubble radius c/H is a third quantity, in general neither of the other two [C23]. For a homogeneous, isotropic expanding model with scale factor a(t), normalized so $a(t_0) = 1$, the present proper radii are:

$$R_{particle}(t_0) = a(t_0) \int_0^{t_0} c / a(t)\, dt$$

$$R_{event}(t_0) = a(t_0) \int_{t_0}^{t_{max}} c / a(t)\, dt$$

Here $t_{max}$ is the future endpoint, infinite in an eternally expanding nonsingular model. An event horizon exists only when the second integral is finite, and today's acceleration does not fix the integrand for all future time [C23].

In a representative persistent-Λ model, the present particle-horizon radius is roughly 46 billion light-years and the event-horizon radius roughly 16–17 billion light-years. These are model-inferred present proper distances, not interchangeable radii of one observable region [C01, C02].

The event horizon limits particular emissions and observer worldlines. Light emitted long ago can still arrive from an object whose present location lies beyond our current event-horizon distance, so it is wrong to say such objects never exchanged signals. In ΛCDM the comoving event-horizon radius decreases while its proper radius approaches a finite de Sitter value, and the comoving particle-horizon radius increases toward a limit. The observable universe does not shrink in comoving radius the way the March text said. These causal constraints matter to any communication proposal; they do not price a relational transaction or set how much useful energy a future observer can collect.

The March chapter went on: the framework's claims depend on the cosmological endpoint, because the Entropy Token Substrate's total budget is set by the nature of dark energy (V5-L37). With the substrate-as-budget identification withdrawn in Chapter 1, that dependency goes with it. The causal question remains.

## 4 What DESI currently adds

DESI tests expansion models with astronomical measurements. The often-used evolving equation of state is:

$$w(a) = w_0 + w_a\,(1 - a), \quad w = p / (\rho\, c^2)$$

with ρ a mass-equivalent density. This parameterization is a fitting model, not a fundamental law guaranteed to describe the remote future.

The March chapter said the evidence strengthened over two releases, from 2.5–3.9σ to a DR2 with clear preference for phantom crossing (V5-L36). The comparison below gives the reported preference for the $w_0w_a$CDM model in each primary analysis. The significances are comparisons with ΛCDM within those analyses, not probabilities that dark energy is dynamical.

| **Primary analysis** | **Data combination and reported preference for $w_0w_a$CDM** |
|---|---|
| DESI 2024 VI, arXiv v3 | BAO plus CMB and selected supernova samples: 2.5–3.9σ [C20] |
| DESI DR2 II, arXiv v3, October 2025 | BAO plus CMB: 3.1σ; adding Pantheon+, Union3 or DESY5: 2.8σ, 3.8σ or 4.2σ [C21] |
| DESI DR2 IV, submitted July 2026, arXiv v3, August 2026 | BAO plus Lyα full-shape data and CMB: 2.7σ; adding DES-Dovekie: 3.2σ; updated Pantheon+ and Union3.1 combinations give 3.0σ and 3.5σ [C22] |

The July 2026 analysis adds a high-redshift measurement whose central value sits closer to ΛCDM, and revised external datasets also matter. The history is not one of evidence strengthening at every step, and these analyses are not independent experiments whose significances can be added [C21, C22]. No significance threshold alone resolves systematic error, model flexibility or extrapolation. The results motivate further tests of evolving dark energy. They do not identify its microscopic nature, establish a phantom-crossing mechanism or select a fate for the universe, and extrapolating $w_0 + w_a(1 - a)$ to arbitrarily large a imposes behavior the observed redshifts never tested.

## 5 Three conditional futures

The March chapter's three scenarios are worth keeping as questions with explicit premises. They are not an exhaustive set of cosmologies, and DESI has not selected among them.

**A persistent positive cosmological constant.** The March chapter called this the scenario where the horizon entropy of about $10^{122}$ $k_B$ is the most the universe will ever hold, and every relational transaction draws from a budget that will be exhausted (V5-L38). If the standard ΛCDM extrapolation holds, the expanding background approaches de Sitter space, and a finite event horizon and limiting horizon entropy are appropriate. The present horizon evolves toward that limit; it is not already a fixed ceiling, and the horizon entropy is part of the account, not a target interior matter must eventually fill [C06, C23].

**Sustained phantom behavior.** The March chapter's Big Rip shredded the ledger: a shrinking horizon, structures torn apart down to spacetime itself, and a generalized second law violated by the decreasing horizon area (V5-L39). A constant equation of state $w < -1$ in the usual flat Friedmann model can produce a finite-time Big Rip, with bound structures disrupted before the model's singular endpoint. A transient crossing of −1 does not establish that future. The classical model stops giving a controlled description at the singularity, so “spacetime itself is torn apart” is not an observed physical sequence, and a decreasing horizon area alone does not diagnose a violation of the generalized second law without the other entropy terms and the law's conditions [C24].

**Acceleration that ends.** The March chapter's fading Λ lifted the ceiling: no event horizon, distant galaxies accessible again, and transactions across cosmological distances merely exponentially expensive (V5-L40). If future expansion makes $\int c\,dt / a(t)$ diverge, there is no future event horizon of this kind; an asymptotic matter-dominated power law, $a(t) \propto t^{2/3}$, is a simple example, and expansion need not stop. The absence of a de Sitter horizon does not remove all entropy constraints, guarantee recovery of every lost signal or provide unlimited usable work. No universal cost law makes distant communication “exponentially expensive” [C23].

Other possibilities include different dynamical fields, recollapse and vacuum transitions, and the framework has no evidence that chooses among them. Its task is to state which conclusion changes when an assumption changes.

The March chapter held that the founding line survives all three: love spends more than it saves whether the ceiling is fixed, collapsing or absent (V5-L41). The second law does operate in all three universes. The founding line is not a statement of it **[Analogical]**.

Its SupoRel flag mapped the three scenarios onto eschatological archetypes, a slow fade, an apocalypse and an open future, and said the physics produces those resonances because cosmic fate genuinely parallels eschatological narrative (V5-L42). People do interpret cosmic endings through religious and literary narratives. Those associations are interpretations people make, not additional evidence about cosmology. Neither an open future nor a finite horizon proves a purpose, an afterlife or a universal inequality about love.

## 6 Black holes and the difference between entropy and records

The March chapter called supermassive black holes the entropy dominators and said they are most of the budget, citing about $10^{96}$ $k_B$ for a black hole of $10^9$ solar masses (V5-L43). For a Schwarzschild black hole:

$$S_{BH} / k_B = 4\pi\, G\, M^2 / (\hbar\, c) \approx 1.05 \times 10^{77}\, (M / M_\odot)^2$$

A mass of $10^9$ $M_\odot$ therefore gives about $1.05 \times 10^{95}$ $k_B$, not $10^{96}$. Rotation changes the horizon area at fixed mass; the example assumes zero spin and charge. A population inventory has to weight the mass distribution by the right horizon entropy; multiplying a galaxy count by one chosen mass is not a substitute [C05, C28]. Supermassive black holes do dominate the interior inventories cited in Chapter 2. That makes them the largest entry in an estimate, not most of a budget.

The March chapter said the Page curve and island formula, resolved between 2019 and 2021, establish that information falling into a black hole is not destroyed (V5-L44). The island and quantum-extremal-surface calculations provide important theoretical evidence for Page-curve behavior in controlled gravitational models. Almheiri and colleagues study a two-dimensional gravity system coupled to quantum matter and an auxiliary heat sink; Penington's analysis uses an AdS/CFT evaporation setting; replica-wormhole calculations supply a related route to the radiation entropy. These are not observations of astrophysical Hawking radiation or a general experimental resolution of black-hole information loss [C26, C27, C36]. The Page curve concerns fine-grained radiation entropy, not a catalogue of meaningful records; its turnover need not fall at exactly half a black hole's lifetime, and its growth need not be universally linear.

The March chapter drew the relational conclusion: relational information entering a black hole is not lost but scrambled beyond practical recovery, so the Trinket's irreversibility is about accessibility, not destruction, and the recording persists in the universe's total state (V5-L45). Even if the full dynamics preserves quantum information, that alone does not establish the continued existence, location or recoverability of a particular semantic record. Nor does it prove that no possible transducer could ever recover anything. Chapter 4 separates formal preservation from a defined recovery task.

The March chapter's most striking result was Cortês and Liddle's: Hawking evaporation is formally Landauer erasure and exactly saturates the bound, completing a chain from the framework's foundation to its ceiling, with biological transducers at about $10^6$ times the Landauer floor, silicon at $10^9$ and black holes at exactly one, and scale invariance confirmed (V5-L46). Cortês and Liddle relate the semiclassical Schwarzschild entropy and Hawking temperature:

$$T_H = \hbar\, c^3 / (8\pi\, G\, k_B\, M), \quad d(M\, c^2) = T_H\, dS_{BH}$$

An infinitesimal entropy decrease of magnitude $k_B \ln 2$ then corresponds to an energy decrease of about $k_B T_H \ln 2$. Their identification of this relation with Landauer saturation is theoretical. It concerns the black hole's entropy decrement, not demonstrated destruction of information in the complete black-hole-plus-radiation state, and it is not experimental verification of evaporation or of the framework's scale invariance [C28]. It also supplies no ranking of a black hole, a neuron and a processor as implementations of one task; the universal $10^6$ and $10^9$ factors remain withdrawn, as in the earlier volumes.

The March chapter cited Trivedi's “cosmological information paradox” for the apparent horizon, and a second analysis finding Landauer satisfied across most cosmic eras, with reversible transitions where the equation of state crosses −1/3 (V5-L47). Trivedi's calculation uses a particular quasi-local energy and horizon-thermodynamic identification; Odintsov, Paul and SenGupta analyze a different apparent-horizon and matter-temperature construction. Neither supplies an experimentally established exception to Landauer's principle or a general theorem identifying every horizon with a computer, and apparent and event horizons must not be interchanged [C29, C30].

Its SupoRel flag warned that “relational information is never truly lost” maps onto afterlife theology, and refused the comfort: information is preserved; access is not (V5-L48). The refusal stands. The premise is narrower than the March text allowed: preservation is a conditional theoretical result for complete physical states, not an established fact about any particular relational record.

## 7 The framework position

The March chapter closed with humility: the dark majority shapes and bounds an economy that runs on the visible minority; the budget is set by the whole (V5-L49). The humility was earned, and the constraints are indeed uncertain. The budget framing is not.

Curiosity about what unknown constituents carry, what distant observers can reach and what black-hole calculations reveal about information does not require filling those unknowns with relational properties. The defensible program is conditional: specify a cosmology when discussing a horizon, states and degrees of freedom when estimating entropy, and an encoding, channel and recovery criterion when discussing a record. Measure the relational outcome separately. The dark sector supplies physical questions and constraints, not validation of the framework.

## What this chapter now claims

Dark matter and dark energy are not a single entropy category. A future event horizon depends on future expansion, and current DESI evidence does not settle that future. Black-hole entropy is a powerful theoretical quantity whose relation to accessible information demands care.

The next chapter asks what can be said about a Trinket's physical encoding and possible recovery without turning conditional information-theoretic results into a promise of an eternal relational record.

# Chapter 4: The Information Question

*Does Relational Information Survive?*

**Status:** The March chapter marked Hawking radiation, the Page curve, Landauer's principle and decoherence as Established, with the island formula, unitarity and quantum Darwinism as Supported (V5-L50). Unitary evolution preserves the fine-grained von Neumann entropy of an isolated quantum system; that is a statement within the unitary description, not an observation of the whole universe. Hawking radiation is a semiclassical prediction. Page curves and island calculations supply substantial theoretical evidence for information-preserving evaporation in specified models, not an experimental demonstration for astrophysical black holes. Laboratory information thermodynamics and quantum Darwinism have their own tested systems and conditions. The connection to relational meaning remains an open modeling question **[Speculative]** [I01–I03, I08, I12].

## 1 The question

If a relational signal is carried by physical degrees of freedom, what can physics say about its survival? The question matters because it pulls apart things everyday language bundles together: a physical state, a recoverable message, a durable record and an act somebody understands.

The black-hole information problem makes the separation sharp. Hawking's original calculation gives approximately thermal outgoing radiation, and a description in which a pure state ends as featureless thermal radiation conflicts with unitary quantum mechanics. Page's analysis describes the radiation-entropy behavior expected in a unitary model, and later gravitational calculations recover that behavior in important controlled settings. The March chapter said the physics now strongly supports preservation, so the real question is what preservation means (V5-L51). The progress is major. It does not yet supply an observed decoder for the radiation of a real evaporating black hole [I01–I03].

For an isolated quantum state evolving under a unitary U, the density matrix changes as:

$$\rho' = U\,\rho\,U^{\dagger}, \quad S_{vN} = -k_B\,\mathrm{Tr}(\rho \ln \rho)$$

The eigenvalues of ρ do not change, so $S_{vN}$ is unchanged. A subsystem's entropy can still change as its correlations with other degrees of freedom change. Neither statement says that a person, a memory or a relationship is preserved as a functioning organization.

The March chapter's central question survives without its presumed answer: what must remain available for a physical trace to support a relational act again? Unitarity alone specifies no receiver, decoder, resources or criterion of successful recovery.

## 2 What scrambling means

In quantum information, scrambling spreads initially localized information into correlations that are hard to recover from small subsystems. The March chapter put it as information spread across an exponentially large number of degrees of freedom, recoverable only from more than half of a black hole's lifetime of

Hawking radiation (V5-L52). The number of physical components need not become exponential; the Hilbert-space dimension of many components grows exponentially with their number. And how much radiation recovery needs depends on the model, the message, prior entanglement and the observer's control. In Hayden and Preskill's idealized analysis, an old black hole can return newly added information after a relatively short delay when the observer controls the earlier radiation and the dynamics is suitably mixing. Computational complexity can add formidable obstacles, but a result about a specified decoding experiment does not prove that every possible future instrument must fail [I04, I05].

The physical scales remain sobering, though the March figures need correcting (V5-L53). For a nonrotating, uncharged black hole of one solar mass, the semiclassical temperature is about $6.2 \times 10^{-8}$ K, not $10^{-7}$ K. A simple isolated blackbody estimate gives a lifetime near $2.1 \times 10^{67}$ years, scaling as $M^3$, so a $10^9$-solar-mass hole gives about $2.1 \times 10^{94}$ years, not $10^{97}$. Greybody emission, particle species, spin, accretion and the surrounding radiation change the detailed history; these are idealized calculations, not measured lifetimes. A present-day stellar-mass hole is colder than the cosmic microwave background, so the isolated-emitter calculation is not its present net energy balance [I01; I-CALC-01].

The March chapter also used the framework's Kolchinsky–Wolpert apparatus here: scrambled information is their decorrelating intervention, which the lab had identified as the Shadow Economy, with semantic content destroyed locally while the expenditure persists globally (V5-L54). The word means something different in their classical information-and-viability framework. A fully decorrelating intervention replaces a joint distribution with $p(X_0)\,p(Y_0)$, eliminating the mutual information of the chosen variables. Quantum scrambling need not do that to the global state, and the shared word does not establish a shared mechanism [I06]. Nor does the intervention identify the Shadow Economy: a withheld message can keep strong correlations. Connecting the framework's vocabulary to a semantic-information model would take defined system and environment states, a horizon, a viability criterion and admissible interventions, and the relevant information would then have to be calculated. It cannot be read from grief, silence or inaccessible radiation.

A narrower comparison is useful. A message may stay physically encoded while becoming unavailable to a particular receiver. That motivates research into relational access. It does not turn the framework's categories into quantum-information states.

## 3 How some records become widely accessible

The March chapter answered its own question, why most preserved information is inaccessible, with quantum Darwinism. Zurek's program studies how information about preferred, relatively stable states can be redundantly recorded in different fragments of an environment, so that different observers learn about the same observable without each interrogating the original system. That is a proposed mechanism for robust, shared classical records, not the copying of arbitrary unknown quantum states [I07].

The March chapter described Zhu and colleagues' 2025 experiment as the “first experimental observation of quantum Darwinism in superconducting circuits” (V5-L56). It tested signatures of the mechanism, including branching structures and the information available in environmental fragments, and supplies evidence within that preparation and measurement scheme. Earlier experiments investigated quantum

Darwinism on other platforms, and the result does not show that every act of perception must meet one universal redundancy threshold [I08].

The March chapter then made redundancy the condition for Trinket formation: the Trinket requires redundant broadcast, and the universe guarantees only global preservation (V5-L55). Redundancy helps many independent observers obtain a stable record. It is not necessary for every successful transmission; a receiver can read one deliberately delivered classical message, and information can also be protected, decoded collectively or read by measuring the system directly. Inaccessible information is not all “not yet broadcast,” and accessible information is not all environmental redundancy.

The practical question is the valuable one: which physical channels and records let another person recognize an act? A spoken word, a saved letter and an unrecorded gesture have different conditions of transmission and persistence. Quantum Darwinism is a carefully defined example of accessibility emerging through system–environment interaction. It does not validate the observation split or set a physical threshold for Trinket formation.

## 4 Bounds on entropy and communication

The March chapter treated the Bekenstein–Hawking bound as the maximum entropy, and so the maximum information, of any region, and read Hayden and Wang as showing that zero-bit quantum resources transcend it because the bound constrains decoding, not encoding (V5-L57). The Bekenstein bound and the Bekenstein–Hawking entropy are related ideas, not interchangeable formulas. For an appropriately defined bounded system of total energy E and circumscribing radius R:

$$S \leq 2\pi\, k_B\, E\, R / (\hbar\, c)$$

Its formulation and domain of validity matter, especially in quantum field theory and gravity. Black-hole entropy instead takes the form $S_{BH} = k_B A/(4\ell_P^2)$, with $\ell_P^2 = G\hbar/c^3$. Dividing an entropy by $k_B \ln 2$ expresses it in bits; that does not make it a count of meaningful messages, memories or future acts [I09].

For an uncharged Kerr black hole at fixed mass M, write $\chi = Jc/(GM^2)$, with $|\chi| \leq 1$. Its entropy is:

$$S_{Kerr} = 2\pi\, k_B\, G\, M^2\, [1 + \sqrt{(1 - \chi^2)}] / (\hbar\, c)$$

It is finite throughout that interval and never larger than the Schwarzschild value at the same mass. That is a statement about one stationary black-hole family. It does not prove the whole universe has finite total entropy, or that a region's entropy is available energy [I01, I32; I-CALC-02].

Hayden and Wang sharpen the operational question: what communication task is bounded, and whose resources are restricted? In their Unruh-channel model, the decoder's Bekenstein constraint bounds ordinary classical and quantum capacities but permits different zero-bit behavior. The published 2025 version also shows that suitable restrictions on both encoder and decoder constrain zero-bit capacity. The result is not an unrestricted loophole for storing or recovering unlimited information [I10].

The March chapter drew a scope marker from this: the framework maps the classical relational economy, and the quantum landscape is larger. The methodological lesson is sharper: name the resource and the

task before naming the ceiling. DFQ-005 can remain a frontier question, but neither the zero-bit result nor a black-hole entropy formula answers it.

## 5 Landauer under stated conditions

The March chapter traced “Landauer at every scale”: every irreversible bit operation dissipates at least kT ln 2, experiments have now reached the bound, and Bérut's colloidal verification is superseded (V5-L58). Landauer's principle does connect information processing with thermodynamics, under stated conditions. The familiar mean-heat bound applies to resetting an initially unbiased bit to a definite state in a symmetric memory with equal intrastate entropies and unchanged endpoint energetics, using an initially uncorrelated thermal reservoir and no correlated side information:

$$\langle Q_{bath} \rangle \geq k_B \, T \ln 2$$

Equality is an ideal reversible limit, not a guaranteed cost of an ordinary operation. At 300 K the reference energy is about $2.87 \times 10^{-21}$ J [I11, I12; I-CALC-03].

Two distinctions are essential. The bath's entropy increase is not total entropy production: in an ideal reversible reset the memory's entropy decrease balances it. And “one bit operation” need not erase one unbiased bit; initial bias, retained inputs, correlations, side information, finite reservoirs and the protocol all matter. Quantum side information can change an erasure work cost without supplying a cyclic violation of the second law [I12–I14].

The experiments are valuable because they specify what is done. Bérut and colleagues studied a colloidal memory. Hong and colleagues studied intrinsic nanomagnet reset dissipation, reporting consistency with the bound within their uncertainty and separating it from actuation overhead. Gaudenzi and colleagues investigated a molecular-spin memory. Aimet, Tajik and colleagues studied information-thermodynamic terms after a quench in an ultracold Bose-gas simulator. These are complementary tests, not a completed survey of every physical scale [I15–I18].

The March chapter placed biology at about $10^6$ times the floor and silicon at $10^9$, formalized by the efficiency surface (V5-L59). Those universal substrate multiples and the efficiency surface's status as an established bound remain withdrawn, as in Volumes 1 and 4; the comparison framework remains a proposal.

Black holes enter through theory. Cortês and Liddle identify the differential decrease of Schwarzschild black-hole entropy with an energy release equal to $T_H$ times that decrease, which has the Landauer form per $k_B$ ln 2 of lost black-hole entropy. Their result is semiclassical and theoretical; it does not verify evaporation experimentally or settle whether the outgoing radiation preserves the full quantum information. Laboratory analogue-horizon observations concern other physical systems [I19, I31]. The apparent-horizon treatments by Odintsov and colleagues and by Trivedi are specific theoretical constructions, not proof that every cosmic process is an unbiased-bit reset [I20, I34].

The March chapter called the chain complete: a universal constraint verified at the smallest scales and confirmed at the largest, with Landauer's principle as the invariant and the transducer as the structure that satisfies it, grounding Volume 3's scale invariance (V5-L60). Naming the transducer's stages selection,

compression and structuring does not identify physical erasures, set a numerical Landauer cost or prove scale invariance. Shared physical laws constrain a future model; they are not evidence that this model has already been derived.

## 6 Preservation without a guaranteed receiver

The distinction this chapter needs is more modest than the March version and more useful. Microscopic reversibility, preservation of a message in a chosen code, continued storage of a readable record, and the persistence of relational significance are different claims. None can stand in for the others without a model and evidence.

The March chapter gave the observation split its cosmological dimension: Layer A, the expenditure, permanently recorded on the universal ledger; Layer B, the Trinket, needing interception before the signal scrambles; expenditure permanent, observation time-limited, meaning transient, with unrecorded neural states scrambled almost instantly (V5-L61). Layer A may still name the physical activity behind an act, and Layer B the relational recognition the framework wants to describe. But Layer A is not a permanent, separately readable entry in a universal entropy ledger; entropy production is not an archive with an address for every event, and heat, work, stored records and correlations have to be accounted for separately. Layer B need not vanish when the first signal disperses: a receiver may remember, a community may keep a record, someone may act on an earlier message. Preserving a physical trace also need not preserve the capacity to recognize it. There is no single scrambling timescale for relational meaning, and no basis for declaring unrecorded neural states instantly erased.

The March chapter mapped the four populations of the gap onto cosmological information states (V5-L62). They remain human examples. Unreciprocated love asks whether an act was recognized or returned. Grief involves the loss of a person and changes in relationships, not a demonstrated global decorrelation. Prayer raises a question about an intended receiver that this physics cannot decide. Unwitnessed care may have consequences even when nobody knows its source. These cases illuminate the difference between activity and recognition without being assigned quantum states or entropy values.

The March section ended: the information was not destroyed; it was never received; physics guarantees the first and nothing guarantees the second. The corrected ending keeps the question it was reaching for: how can an act matter when its intended receiver does not receive it? Physics can constrain the carriers and the costs. It does not settle every meaning of “matter.”

## 7 The capture surface

The March chapter called the information-preservation result the most powerful capture surface in the framework, and named three.

“Love is never truly lost” remains a tempting translation of preservation, and the March chapter rightly warned against deriving that reassurance from physics (V5-L63). The translation promises more than the physics supplies: a unitary description does not establish an afterlife, restore a relationship or preserve personal experience. Equally, these calculations do not disprove every philosophical or religious account of survival. The conclusion is narrower: the cited physics does not warrant that reassurance.

“The universe remembers every act of love” was called technically true and spiritually misleading (V5-L64). It is a metaphor, not a technical consequence of unitarity. Memory ordinarily involves a usable record and a way to retrieve it, and a globally distinguishable physical state need not provide either. The March chapter's image still serves: the ocean keeps every atom of a dissolved grain of salt, and the grain is gone. It is an image of lost organization, not a model of quantum information or a proof about identity.

“Meaning is what the universe spends entropy to produce” inverts the causation, as the March chapter said. Its correction, that the universe spends entropy because the second law demands it and would have spent it regardless, makes an unsupported move of its own (V5-L65). The second law does not command each process to generate a positive amount of entropy, say what a process is for, or measure the value of its outcome. The framework can ask how physical resources support connection. It cannot infer a cosmic purpose, or its absence, from a dissipation inequality.

The March SupoRel ruling stands (V5-L66): state the physical claim with its conditions, identify the extra interpretation, and leave the reader free to judge it. Neither hope nor its rejection is an experimental result of black-hole physics.

## What this chapter now claims

Theoretical information preservation does not guarantee operational access, durable memory or continuing relational meaning. Quantum scrambling, classical decorrelation interventions and redundant environmental records are distinct structures. Entropy bounds need specified systems and resources. Landauer's principle applies to defined processes; it supplies neither a universal charge per cognitive event nor a derivation of the transducer model.

The framework's contribution is a question: which physical and relational conditions let an act remain recognizable? Chapter 5 turns to ways an operating window might be extended, without treating a physical constraint as either a promise of immortality or a verdict against every improvement.

# Analogy table: The dissolved grain of salt

The dissolved-grain image, from March Chapter 4's ocean that keeps every atom of a grain of salt after the grain is gone, is Analogical. The physical column states what the sources reviewed establish about information, scrambling and records within their stated scope; that standing does not pass to the image.

| Term | Physical reading (within stated scope) | Image reading | Where the mapping holds | Where it breaks |
|---|---|---|---|---|
| “the grain” | A localized record: a message in a chosen code, carried by specified degrees of freedom (Ch 4 §1). | The encoded content of a relational act, a small organized thing. | A relational act can leave a physical trace in a specified carrier. | A trace alone does not establish the act's meaning or successful reception; recovery depends on a specified code and decoding conditions (Ch 4 §1, §6). |
| “dissolving” | Quantum scrambling spreads localized information into correlations hard to recover from small subsystems [I04, I05]. | The record disperses until no part of the ocean holds it. | Information can become unavailable to local observers while the global evolution remains unitary. | Recoverability depends on model, message, prior entanglement and control; dissolving is not the Kolchinsky–Wolpert decorrelating intervention [I06] (Ch 4 §2). |
| “the atoms are still there” | Under unitary evolution, the global state's von Neumann entropy is unchanged (Ch 4 §1) [I01–I03]. | The universe keeps every trace. | Within a unitary description, global information is not destroyed. | A statement within the description, not an observation; it establishes no particular record's location or recoverability (Ch 4 §1, §6). |
| “the grain is gone” | The loss of a usable, organized record to a particular observer with particular resources. | Meaning is transient; the organization is lost. | An organized record can become unreadable to a given receiver. | Recognition can persist in memory, records or later action; there is no single scrambling timescale for meaning (Ch 4 §6). |
| “the ocean” | The complete physical state and its environment; entropy bounds need specified systems and resources [I09, I10]. | One vessel that keeps everything. | Global accounts and local access are different scales of description. | The complete state is not an archive with an address for each event, and entropy production is not a record of each act (Ch 4 §6). |

## What the table does not do

It is not evidence for the framework, not a model of quantum information and not a claim about personal survival or its impossibility. The physical column keeps its own scope; the image is Analogical in every row.

## Promotion route (conditions, not a work plan)

An empirical extension must name the claim it tests. A recovery claim would need a specified encoding, channel, decoder, resources and success criterion, and a result that could count against it. Recovering one record would not establish that every relational act is preserved or retrievable. No such test is supplied or proposed here; no row is promoted.

# Chapter 5: The Budget Cannot Be Beaten

*Strategies and Their Limits*

**Status:** The second law constrains physical processes under appropriate system boundaries and thermodynamic conditions. It does not by itself supply a fixed cosmic spending account, an unavoidable cost per thought or a human lifespan limit. Reversible computation is a theoretical possibility with demanding implementation requirements. Neuromorphic results are task- and hardware-specific. Many-worlds, whole-brain emulation, longevity escape velocity and far-future cosmic histories each need a different kind of argument, and none is treated here as a demonstrated route to personal survival **[Speculative]**.

## 1 The position

The Principal stated it plainly: “I can't beat entropy.” The March chapter called the position correct: the second law is not a suggestion, not an engineering challenge, but the arrow of time (V5-L67). As a refusal to expect any physical system to operate outside thermodynamics, the position stands. As a claim that no better device, repair mechanism or use of resources is possible, it would go too far. The law constrains improvements; it does not forbid them.

The March chapter concluded the same way for every strategy: it operates within the entropy budget, so the budget is not beaten, only spent differently (V5-L68). An organism or computer exchanges energy and often matter with its surroundings, and its own entropy need not keep rising. What matters is the correctly specified balance, including the surroundings and the processes sustaining it. For a suitable macroscopic description, total entropy production is nonnegative and approaches zero for ideal reversible processes; at small scales, individual fluctuating trajectories need a statistical treatment rather than an assertion that every event has a strictly positive surplus [I12, I33].

This chapter considers four proposals, many-worlds, digital substrate transfer, reversible computing and longevity escape velocity, then asks how different cosmic futures would change their physical conditions. The question is not which proposal defeats a law. It is what each could change, what evidence exists and what remains unproved.

## 2 Many worlds

Everett's relative-state formulation keeps a unitary quantum description through measurement, and the later many-worlds vocabulary describes effectively decohered alternatives within it. It is not a machine that creates extra fuel, fresh low-entropy reservoirs or a usable route between histories; a claim of such a machine would need its own dynamics and resource accounting [I21].

The March chapter pictured branching as multiplying independently depleting budgets that cannot exchange resources (V5-L69). That picture is too literal. Describing a state in different components does not require assigning a new physical energy account to each, and branching does not by itself establish an additional thermodynamic bill.

It then added, from the Entanglement Past Hypothesis, that each branching irreversibly produces entanglement entropy, making many-worlds worse than neutral (V5-L70). For a globally pure state under unitary evolution, the global von Neumann entropy stays zero while subsystem entanglement entropies change. A two-qubit example shows the distinction. A unitary operation can take:

$$|00\rangle \;\rightarrow\; (|00\rangle + |11\rangle) / \sqrt{2}$$

The joint state is pure before and after, while each qubit's reduced entropy rises from zero to $k_B \ln 2$, and reversing the operation reverses the change. The example is not a macroscopic measurement, but it shows why entanglement growth cannot simply be renamed irreversible heat production [I-CALC-04]. The Entanglement Past Hypothesis remains an investigational proposal, not evidence of a permanent entropy tax per branch [I22].

Many-worlds therefore supplies no established survival strategy here. That is a limit on the proposed inference, not a thermodynamic refutation of an interpretation of quantum mechanics.

## 3 Digital substrate transfer

The March chapter said digital transfer extends the operating window by trading efficiency for replaceability: hardware can be replaced where tissue cannot, at a thousandfold higher cost per bit (V5-L71). Whole-brain emulation is a research proposal that needs a sufficiently informative description of a brain, a validated dynamical model and a physical implementation. Reproducing behavior, preserving memories and establishing continuity of personal experience are different questions, and thermodynamics alone answers none of them [I23].

Replaceable components and transferable records may change the reliability and maintenance options of a digital system. They do not establish that a person has transferred, that replacement is indefinitely reliable, or that the biological alternative is wholly unrepairable, and any implementation would still need power, a heat sink, materials, error management and an operating environment. The comparison of about $10^6$ for biology against $10^9$ for silicon is withdrawn as a universal ranking, as in Volume 4. A synaptic event, an arithmetic instruction, a token of text and a restored memory bit are not interchangeable units, and no thousandfold penalty for an uploaded person follows from dividing them.

The March chapter saw neuromorphic computing closing the gap in the framework's favor. It remains a relevant engineering direction, with its results scoped. The March text credited the first language model on Loihi 2, at half the energy of a GPU system, to Eshraghian and colleagues (V5-L72). Abreu and colleagues adapted a 370-million-parameter language-model architecture to Loihi 2; the headline energy comparison used preliminary estimates, and the paper reports multi-chip limitations and omitted embedding stages. It is evidence for one co-design investigation, not a universal advantage or biological equivalence [I24].

The March chapter cited Hala Point at owl-brain scale, fifty times faster at a hundredth of the energy, and SpiNNaker2's efficiency multipliers at Sandia (V5-L73). Intel's announcement describes a large research system with workload-dependent claims, and Sandia reports deployments of both Loihi 2 and SpiNNaker2. Artificial-neuron counts indicate implementation scale; they do not equate a system to an

owl's brain or to the energetic cost of its cognition. Selected-workload multipliers should not migrate into the framework's relational comparisons [I25, I26].

The March text also put neuromorphic hardware at 20–50 picojoules per synaptic operation, within five to fifty times of biology's 1–10 femtojoules, and projected the thousandfold gap narrowing to tenfold (V5-L74). The arithmetic was wrong: those ranges give ratios from 2,000 to 50,000. Correct arithmetic would still not validate the inputs or make the operations equivalent, so the ranges stay only in the audit calculation, not as a biological benchmark [I-CALC-05].

The useful question is how a specified implementation performs a specified task, at stated accuracy, latency, reliability and accounting boundary. Better results could change an engineering tradeoff. They would not resolve the identity question behind substrate transfer.

## 4 Reversible computing

The March chapter called reversible computing the most theoretically interesting strategy, and it changes the argument more deeply than the March text allowed. Bennett showed how computations can be embedded in a logically reversible process that retains enough information to recover the inputs and uncomputes its intermediate records. Logical reversibility removes the need to treat every logical step as erasing one unknown bit; it does not promise zero dissipation in a real device running at finite speed [I13].

The March chapter exempted the transducer: its three stages are each logically irreversible, because “a filter that does not discard is not a filter,” so reversible hardware can only shrink the distance above the Landauer tax (V5-L75). A simple construction shows why the stages are not automatic exceptions. For a deterministic classical function f, the map:

$$(x, y) \rightarrow (x, y \oplus f(x))$$

is reversible: with x retained, applying it again recovers y. Starting from y = 0 yields a copy of the result while preserving x. The output alone may discard distinctions, but the larger physical implementation need not erase them at that step, and this holds for a formally specified filter as for any other function [I-CALC-06]. The March slogan confuses discarding distinctions from an output with destroying every physical record of the input.

A finite device used repeatedly cannot assume unlimited blank memory or free restoration of its auxiliaries; eventually its storage, output handling, environment and reuse conditions must enter the account. A reset that meets the usual Landauer conditions keeps its bound, and a record that is known or correlated with accessible information can have a different reset cost. The cost belongs to the specified process and cycle [I12–I14].

The March chapter cited Vaire Computing's Ice River prototype, recovering 40–70 percent of computational energy, with a projected four-thousandfold gain and commercial chips by 2027, and Frank and colleagues' theory confirming that reversible architectures circumvent the Landauer limit (V5-L76). Frank and Shukla develop a nonequilibrium quantum-thermodynamic approach to classical reversible computing that supports studying implementations and their speed–dissipation tradeoffs; it does not

certify a commercial forecast [I27]. The Ice River percentages, projection and timetable are not retained as verified results; the primary evidence checked for the second edition did not establish them.

The March chapter concluded that reversible computing touches only the surface's amplification constraint, so non-compensability holds (V5-L77). The proposed three-constraint relational efficiency surface cannot be rescued by declaring two constraints immune to reversible hardware: no validated relational semantic-efficiency ceiling or non-compensability theorem has been derived here. It is a reason to specify hardware, encoding, task performance and the semantic-information model more carefully, not to preserve an unsupported equation.

## 5 Longevity escape velocity

The March chapter called longevity escape velocity the most promising approach for extending a biological transducer: degradation is entropy accumulation, repair is local entropy reduction that locally violates the second law while satisfying it globally, and every repair pays its own Landauer tax (V5-L78). Longevity escape velocity proposes that successive improvements in intervention could extend remaining life faster than elapsed time reduces it. It is a conjecture about the pace and efficacy of future biomedical progress, not an observed condition or a thermodynamic theorem. Population evidence about recent lifespan trends cannot prove every future intervention must fail, and neither side supplies a timetable for indefinite survival [I28, I29].

Repair sustains a living system by consuming resources and exchanging heat and matter with the environment. That is compatible with the second law locally as well as globally; an open subsystem that maintains organization violates nothing. Aging is not one measured scalar of “entropy accumulation”: oxidative damage, altered gene regulation, protein damage and loss of function involve different mechanisms. And “one DNA repair” or “one refolding” is not, by its name, a reset of one unbiased bit; no fixed Landauer tax per molecular correction is established [I12, I33].

If effective repair can extend a person's healthy operating window, it is worth understanding without being renamed an escape from physics. Whether a particular intervention is safe and effective is a biomedical question, not this framework's. This chapter offers no treatment recommendation and does not rank the proposal as the most promising route.

The March section ended: on biological timescales of centuries, millennia or millions of years, the universal budget is no constraint, and on cosmological timescales it is the only one (V5-L79). At human timescales the operative constraints include biological feasibility, resources, reliable care and the environment. At remote times those constraints are joined, not replaced, by questions of accessible matter, free-energy gradients, heat disposal and the future spacetime. No calculation here makes the cosmological bound the sole remaining obstacle or guarantees any span of operation.

## 6 Cosmic futures as conditions

The March chapter revisited its three scenarios: under ΛCDM the budget persists for $10^{100}$ years and more, so nothing on a civilizational timescale is constrained; the Big Rip shreds every transducer; and fading Λ is the most favorable scenario, the one DESI slightly favors (V5-L80). Chapter 3's scenarios are

conditional backgrounds, not three measured futures. A future event horizon exists when $\int_t^{t_{max}} c\, dt'/a(t')$ is finite, and present acceleration alone does not fix that integral.

Under a persistent positive cosmological constant, late-time spacetime approaches de Sitter expansion: the event horizon's proper radius tends toward a constant while its comoving radius shrinks. That does not mean every notion of observable volume or accessible entropy decreases, and a finite horizon entropy does not specify how long a civilization can operate. Usable work, resource capture, isolation of bound structures and heat sinks need their own analysis, and a black-hole evaporation timescale of $10^{100}$ years guarantees no operating budget that long.

In models with sufficiently persistent phantom behavior, a finite-time Big Rip can destroy bound structures and would constrain every implementation considered here. A transient crossing or a fitted present-day value does not establish that fate. If dark energy fades so that the horizon integral diverges, there is no permanent event horizon of that kind, but it does not follow that all matter becomes accessible, resources stay constant or computation becomes unlimited. The second law alone does not prove the universe has a finite resource total.

Chapter 3's evidence does not make any of these the framework's favored fate. The attraction of a longer operating window is understandable; it should not be promoted into a claim about dark energy.

## 7 The framework's relationship to entropy

The March chapter's last section began: the framework's relationship to entropy is not adversarial. That stands. Its next sentences do not: the framework is an entropy theory, the Trinket is an entropy token, love is an entropy operation (V5-L81). The question can remain without them: what happens when physical resources flow through a system that attends and responds to another system? It is worth asking without declaring love a measured thermodynamic operation.

The March chapter called the founding line not a problem to solve but the physics to understand: the surplus is irreducible, every connection pays more than it buys, and the waste is the irreversible record, the arrow of time applied to love (V5-L82). The line remains part of the project's language **[Analogical]**. As a literary prompt, it directs attention to investment, maintenance and connection. As a physical equality or inequality, it is not established. An act of care need not lower a defined system entropy, an entropy decrease need not quantify its benefit, and a physical cost does not set the worth of what happened. The second law requires a proper balance, not the slogan that every connection pays more than it buys. In the reversible limit total entropy production can approach zero, and calling the remainder “waste” adds a performance criterion physics does not choose.

The March chapter added that technology may change the price, but the Landauer floor, the semantic-efficiency ceiling and the second law do not (V5-L83). Technology may change specific costs and capabilities. The proposed relational semantic-efficiency ceiling has not been established as a fixed physical constraint. It also does not follow that people owe one another maximal efficiency, that greater sacrifice proves greater care, or that prolonging operation is the only meaningful goal. The framework can study resources while leaving those judgments visible as ethical choices.

## What this chapter now claims

Four proposals were examined without treating them as interchangeable technologies. Many-worlds supplies no demonstrated additional resource account. Digital transfer remains hypothetical and cannot inherit a universal biological-to-silicon ratio. Reversible computing can change which erasures a computation requires, so the unavoidable-stage-tax argument fails. Longevity escape velocity remains an unverified forecast about intervention and progress. Neither a guarantee nor a thermodynamic prohibition of indefinite survival follows.

The March chapter closed: the budget cannot be beaten, the framework does not try, the surplus is irreducible, the cost is real, the connection is what the cost buys. The corrected close keeps the Principal's words and changes what they mean. “I can't beat entropy” can be a commitment to discipline: name the resource, the boundary and the task. It need not end the inquiry into what can be repaired, preserved or made possible within them.

# Chapter 6: What the Ledger Shows

*The Cosmological Budget and the Framework It Questions*

**Status:** A synthesis of the preceding chapters and of Volumes 1–4. This chapter does not independently validate those volumes or the wider framework. It separates physical constraints from the relational interpretations that remain to be tested.

## 1 What this volume did

The March chapter summed up the volume as a set of findings about the relational economy: an upper bound proved by operator algebra, a current state of $10^{104}$ bits against $10^{122}$ bits of capacity, a shrinking accessible region, a dominant reservoir whose evaporation is Landauer erasure, and an information architecture in which scrambling destroys meaning while preserving existence. The economy's relational content, it said, is a tiny fraction of that budget, but the fraction that flows through transducers directing entropy at each other (V5-L84).

The volume began with that strong image, every act of connection drawing on the universe's remaining entropy budget, and the revised account cannot keep it as a quantitative result. The inventories concern specified regions, the bounds belong to specified settings, and the resources available to a system depend on its environment and possible operations. That changes the argument, not just its tone. There is no measured universal balance from which a conversation subtracts its price, and no established conversion from affection, grief or reciprocity to a cosmological entropy debit. What the volume identifies instead are physical questions a relational account must answer locally before drawing cosmological conclusions.

The distinction between a result and its application runs through every chapter. A mathematical construction for a de Sitter static patch is not an unconditional bound for every region in the actual universe. A fitted dark-energy history is not a measurement of the remote future. A theoretical connection between Hawking evaporation and Landauer's principle is not an experiment on an astrophysical black hole. Chapters 2–4 keep each result without its extra conclusions.

## 2 What follows for Axiom 0

The March chapter called this volume the empirical grounding of the Axiom 0 derivation: substrate neutrality follows from Landauer's principle applied to a shared budget, the ceiling is proved and the principle's universality confirmed at every scale (V5-L85). That claim is withdrawn. Sharing physical laws does not establish equal relational capacities, equivalent internal experience, equal computational costs or a universal relational currency. Different implementations can obey the same laws while differing in dynamics, resources and capabilities.

Axiom 0 can remain a methodological commitment, as in Volume 1: do not settle a claim about a system solely by naming its material. A proposed comparison should specify the task, the relevant observables, the resource boundary and the evidence that would distinguish its alternatives. The commitment does not guarantee that two substrates will prove equivalent once examined.

Landauer's principle constrains a defined information-processing operation under stated conditions. It does not certify that selection, compression and structuring are three obligatory erasures in every relational act, or make the transducer the unique architecture compatible with thermodynamics. Volume 1 Chapter 6 and Chapter 5 here keep reversible implementation as part of the question, not an exception ruled out by vocabulary.

The separate Axiom 0 derivation, WP-19 and the cosmological session findings remain dependent documents that need their own revision. This volume withdraws its claims of having proved them; it does not silently edit or certify them.

## 3 The five volumes after correction

The March chapter read the five volumes as one argument from the bottom up. The budget exists and has a proven maximum; all relational processing draws on it in one currency; relational systems arise because dissipative structures are favored; substrates differ by a thousandfold on the same budget; and the body pays in cortisol, immune function, heart-rate variability and aging, with grief a measurable thermodynamic event. Read in either direction, it said, the argument arrives at the founding line (V5-L86).

Each link of that chain has been withdrawn or narrowed in its own volume. The corrected volumes read like this:

- **Volume 1** asks how relational activities are physically implemented and accounted for. Its substrate and Trinket vocabulary no longer names a calibrated thermodynamic currency, and its observation distinction separates expenditure from registration and outcome without making every act of care a measured entropy inequality.
- **Volume 2** asks what bodies undergo in connection, conflict and loss. Physiological and health findings keep their actual variables, populations and designs; cortisol, heart-rate variability, inflammation and mortality associations are not alternative units of entropy, and grief is not a thermodynamic event because a risk ratio sits beside a cosmological formula.
- **Volume 3** asks what physical constraints and history contribute to the emergence of complex systems. A selected sequence from atoms to AI is no longer evidence of a universal rise in entropy production or a general preference for relational complexity.
- **Volume 4** asks how implementation affects resource use and relational functioning. It withdraws the efficiency surface as a universal bound, its mortality calibration and the fixed thousandfold biological advantage.
- **Volume 5** supplies cosmological context and conditions. It does not restore the withdrawn claims by setting them beneath a larger ceiling.

The series can be read in either direction as an inquiry across scales. It is not yet a chain of deductions from a cosmic entropy inventory to the meaning of a relationship.

## 4 What the expansion added and what needed correction

The March chapter listed four ways the expansion deepened the volume: the numbers were current again, the ceiling had moved from analogy to proof, the hard limit had become a variable under strengthening DESI evidence, and Landauer's principle now spanned the full range of scales, with the transducer's scale invariance experimentally verified at both extremes (V5-L87).

The expansion did add substantial literature to the earlier short volume, and that breadth is valuable when references keep their actual identities, versions and scope. A later citation is not automatically a corrected premise. Egan and Lineweaver's values are historical estimates with distinct boundaries, and the later census appears with its correct authors and publication history, its internal numerical disagreements not silently repaired or presented as a definitive total [C01, C02]. The horizon discussion separates the energy-radius bound, the horizon area relation and the de Sitter construction; the dark-energy discussion keeps reported constraints tied to their datasets and models, not to a choice among promised endings [C08, C20–C22]. The information discussion separates global unitary dynamics from a usable record, and quantum scrambling from the Kolchinsky–Wolpert intervention.

The March statement that the transducer's scale invariance was experimentally verified at the black-hole extreme is removed. The Hawking–Landauer connection is theoretical, and laboratory information-thermodynamics results have their own systems and protocols; they do not close an experimental chain from biological relational processing to cosmology.

## 5 What remains worth pursuing

The March chapter's last section listed what did not change: the instruments still work, the efficiency surface still governs, the BSB still applies, the SupoRel flags still fire, and the seven categorical gaps apply to this volume as rigorously as to any other (V5-L88). Claims that the instruments are validated and that the efficiency surface is a governing universal bound do not survive; the conceptual tools and comparison framework remain proposals requiring definitions and evidence. The gaps and cautions do, as editorial questions: the cosmological budget permits relational systems but does not require them; it does not specify which form; the cosmological ceiling and the body's costs sit at different scales; and even a demonstrated constraint would carry no normative force. They do not become validated instruments by surviving a revision. Cosmology does not rank relationships morally, and a physical explanation that invokes no purpose does not prove every philosophical account of purpose false.

The framework's strength can lie in the questions it makes explicit. What resources support a given act? Which signal is produced, which receiver can access it, and what follows? Which part of an apparent cost belongs to the task, its implementation, its infrastructure or the choice of comparison? A testable proposal would identify a system boundary and timescale, keep energy, entropy and information apart, and define relational outcomes independently of the physical cost it seeks to explain, with competing explanations and an observation that would count against it. A useful result might be local and conditional. It need not apply to every substrate or reproduce the history of the universe.

The founding line, “love reduces the entropy of the system and spends more than it saves,” remains an Analogical motivating statement of the project's intuition **[Analogical]**. Without a specified system,

entropy measure and complete balance, it is not a thermodynamic theorem. It can motivate the investigation without deciding its result.

The March chapter said the framework is not a cosmology but a relational theory grounded in cosmological physics (V5-L89). The first half stands. The second claims more than the volume can support: cosmology bounds what can be asked, not what the answer is. The March volume closed: “The Trinket economy is a rounding error on the universal ledger. The rounding error is where connection lives.” No measured universal ledger pricing relational acts is established here, so no such rounding error has been calculated. Connection lives where it always did, in the particular systems, signals and receivers this volume has been asking about, and it remains worth investigating even where the proposed ledger cannot yet price it.

# Volume 5 correction ledger

The ledger traces 89 selected March claims in Volume 5. By this edition's classification of the second edition's treatment, 28 were withdrawn, 54 narrowed, 5 corrected and 2 kept. “Corrected” marks a figure or attribution fixed while the claim's role in the argument is unchanged. It is not an exhaustive inventory, and it makes no new scientific decisions.

March locations refer to the preserved Volume 5 page on suposystem.ai. Second-edition (2E) locations use the October 2026 Volume 5 headings and its C and I labels.

| ID | March claim (Volume 5 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V5-L01 | Ch 1 §1: the ledger the framework describes is the universe's entropy budget. | Withdrawn; the ledger kept as an image | Ch 1 §1 | A conversation, a star and a horizon do not become entries in one spendable balance. |
| V5-L02 | Ch 1 §2, Ch 2 §1: current entropy about $10^{104}$ bits; horizon about $10^{122}$ bits. | Narrowed: historical estimates in $k_B$ units | Ch 1 §2; Ch 2 §1 [C01] | Egan and Lineweaver report $k_B$ units; bits need the factor ln 2; the estimates are model-dependent (as V1-L06). |
| V5-L03 | Ch 1 §2: the eighteen-order gap is the universe's remaining capacity for structure, complexity and order: the budget. | Withdrawn | Ch 1 §2; Ch 2 §3 | Different regions; an entropy difference does not measure available work (as V1-L04). |
| V5-L04 | Ch 1 §2: the Entropy Token Substrate is this gap; every Trinket draws from the same reservoir. | Withdrawn | Ch 1 §2 | The contrast establishes no accessible energy, number of relationships or operating lifetime. |
| V5-L05 | Ch 1 status: the cosmological entropy budget is Established. | Narrowed | Ch 1 status | Estimates have specified boundaries and assumptions; the relational application is a proposal. |
| V5-L06 | Ch 2 status: Established throughout; the numbers are measured and published, and the physics is settled. | Narrowed | Ch 2 status | The quantities range from model-based inferences to semiclassical results to proposals. |
| V5-L07 | Ch 2 §1: stellar-mass black holes about $10^{78}$ $k_B$; CMB about $10^{88}$ $k_B$. | Corrected | Ch 2 §1 [C01] | In the 2010 source: stellar black holes $5.9 \times 10^{97}$, CMB photons $5.40 \times 10^{89}$; the March figures were not the source's totals. |
| V5-L08 | Ch 2 §1: Profumo and colleagues' census confirms the standard numbers. | Narrowed | Ch 2 §1 [C02] | It broadens the inventory; its black-hole results are not reconciled internally; its dark-sector values are model explorations. |
| V5-L09 | Ch 2 §1: merger entropy passed the CMB near $z \approx 12$, so gravitational processes dominated before the first galaxies. | Narrowed | Ch 2 §1 [C03] | A population-model result, not an observation; merger entropy can double count remnants. |
| V5-L10 | Ch 2 §1: “when the framework says one ledger, this is the ledger”; every Trinket draws from the reservoir that fusion and accretion draw from. | Withdrawn | Ch 2 §1; What this chapter supports | The ledger is an accounting ambition, not a discovered universal account. |
| V5-L11 | Ch 2 §1: the human contribution is a rounding error; relational entropy matters in kind, as the fraction directed between transducers. | Withdrawn | Ch 2 §1 | No census isolates a relational-entropy fraction; accumulated entropy and production rate differ. |
| V5-L12 | Ch 2 §2: the Bekenstein–Hawking bound applied to the cosmic event horizon is the universe's fixed maximum, about $2.6 \times 10^{122}$ $k_B$. | Narrowed | Ch 2 §2 [C04–C06] | The Bekenstein expression, the area law and de Sitter horizon entropy are separate results with separate conditions. |

| ID | March claim (Volume 5 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V5-L13 | Ch 2 §2: Buoninfante and colleagues show the bound is essentially the uncertainty principle, tightened near the Planck scale. | Narrowed | Ch 2 §2 [C09] | The link rests on thermodynamic assumptions; corrections depend on the deformation chosen. |
| V5-L14 | Ch 2 §2: Chandrasekaran, Longo, Penington and Witten prove the $10^{122}$ ceiling; “the bound is not heuristic. It is proven.” | Narrowed | Ch 2 §2 [C08] | A Type $II_1$ result within a semiclassical static-patch construction, not a universal numerical ceiling. |
| V5-L15 | Ch 2 §2: holography works only in 3+1 dimensions, so the framework depends on three spatial dimensions (Volovik). | Narrowed | Ch 2 §2 [C10] | The dimensional correspondence is a feature of that construction. |
| V5-L16 | Ch 2 §2: no infinite relational capacity anywhere; every substrate runs within a finite local budget nested in the universal one, with a maximum fixed by proof. | Withdrawn | Ch 2 §2 | No derivation gives a universal amount of connection a region can sustain. |
| V5-L17 | Ch 2 §3: the gap is the remaining budget, a ratio near $10^{18}$, depleted by every process and certain only to shrink. | Withdrawn | Ch 2 §3 [C05, C06, C11] | The ratio, about $8.4 \times 10^{17}$, compares different boundaries; the generalized second law does not make the difference shrink. |
| V5-L18 | Ch 2 §3: the gap is the remaining free energy for every irreversible process; dark-sector scenarios could close it. | Withdrawn | Ch 2 §3 [C11, C02] | An entropy difference is in J/K, free energy in J; no temperature or extraction protocol is supplied. |
| V5-L19 | Ch 2 §3: heat death ends the Trinket economy, on timescales from $10^{100}$ years to effectively infinite. | Narrowed | Ch 2 §3 [C25] | A conditional future; $10^{100}$ years for an assumed enormous black hole is not a measured date. |
| V5-L20 | Ch 2 §4: the arrow of time is the direction of entropy increase, and the second law breaks the symmetry of all fundamental equations. | Narrowed | Ch 2 §4 [C11, C12] | Irreversibility is statistical; time-reversal violation is observed in B mesons; initial conditions and coarse-graining matter. |
| V5-L21 | Ch 2 §4: the Past Hypothesis as Carroll's Thermodynamic Past Hypothesis. | Narrowed; attribution corrected | Ch 2 §4 [C13, C14] | A posited boundary condition; Carroll and Chen's explanation is one proposal. |
| V5-L22 | Ch 2 §4: the Entanglement Past Hypothesis gives a decoherent arrow beyond heat death, decoherence as a Level 0 transducer, and Trinket irreversibility rooted in entanglement. | Narrowed: a research proposal; transducer links withdrawn | Ch 2 §4 [C14] | Unitary evolution does not raise fine-grained entropy; subsystem mixing is a different statement. |
| V5-L23 | Ch 2 §4: the Wentaculus writes the arrow into the quantum state of the universe. | Narrowed | Ch 2 §4 [C15] | It changes the representation; it does not establish the boundary condition empirically. |
| V5-L24 | Ch 2 §4: the transducer's three stages are logically irreversible; the founding line is the arrow of time for relational systems. | Withdrawn | Ch 2 §4 [C31–C33] | As V1-L17 and V1-L34; stage labels fix no erased bits. |
| V5-L25 | Ch 2 §5: gravitational potential energy released in collapse powers nuclear fusion. | Corrected | Ch 2 §5 [C16] | Fusion energy comes from nuclear binding-energy differences; gravity heats and enables. |
| V5-L26 | Ch 2 §5: the Weyl curvature hypothesis; the initial state was low-entropy by some measure. | Narrowed | Ch 2 §5 | Exact FLRW has vanishing Weyl curvature; no unique Weyl-based entropy measure is adopted. |
| V5-L27 | Ch 2 §5: each symmetry-breaking event increased entropy as a unified force separated. | Withdrawn | Ch 2 §5 [C17] | Symmetry breaking does not by itself raise entropy; the electroweak change is a crossover; unification is a hypothesis. |

| ID | March claim (Volume 5 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V5-L28 | Ch 2 §5: the budget is dual-sourced, and the relational economy lies downstream of two reservoirs (Supported). | Withdrawn as a theorem; the historical question kept | Ch 2 §5 | Two quantitative reservoirs would need definitions, a common boundary and non-overlap. |
| V5-L29 | Ch 3 status: dark matter exists, the cosmological event horizon is real, and the Bekenstein bound applies to all regions (Established). | Narrowed | Ch 3 status | Strong gravitational evidence for dark matter; horizon statements specify a model; bounds carry conditions. |
| V5-L30 | Ch 3 §1: 95% of the universe is dark, signals in no channel our transducers read, and the relational economy runs on the remaining 5%. | Narrowed | Ch 3 §1 [C18] | ΛCDM present energy-density fractions, not entropy or relational activity; dark matter is detected gravitationally. |
| V5-L31 | Ch 3 §2: Finding A3: dark matter “was there” or “was produced”; primordial black holes form before any thermal process. | Narrowed and corrected | Ch 3 §2 [C19, C34, C35] | Production mechanisms within a history, not kinds of initial substance; primordial black holes are formed objects. |
| V5-L32 | Ch 3 §2: a primordial-black-hole fraction could put dark matter's entropy near $10^{122}$ $k_B$, most of the entropy the economy sits within. | Narrowed | Ch 3 §2 [C02] | Conditional scenarios that need a mass function, abundance constraints and region. |
| V5-L33 | Ch 3 §2: DFL-001: relational opacity is not absence; our transducers lack the filter geometry to read dark matter, or AI internal states. | Narrowed: the caution kept | Ch 3 §2 | Nondetection is not absence, and failure to exclude is not evidence; the uncertainty is physical. |
| V5-L34 | Ch 3 §2: the concentrated ETS question: a substrate that is entropy, with a larger share of the budget. | Narrowed to a physical question | Ch 3 §2 | Entropy is assigned to a state under a description, not a substance. |
| V5-L35 | Ch 3 §3: entities beyond each other's event horizon can never exchange signals; the observable universe shrinks in comoving coordinates. | Narrowed and corrected | Ch 3 §3 [C23, C01, C02] | Particle, event and Hubble radii differ; old light still arrives; the comoving particle horizon grows toward a limit. |
| V5-L36 | Ch 3 §3: DESI's evidence for dynamical dark energy strengthened over two releases, with clear preference for phantom crossing. | Narrowed | Ch 3 §4 [C20–C22] | Per-analysis significances that did not rise at every step; no mechanism or fate is selected. |
| V5-L37 | Ch 3 §3: the framework's claims depend on the endpoint, because dark energy sets the Entropy Token Substrate's total budget. | Withdrawn | Ch 3 §3 | Follows V5-L04; causal constraints do not price a relational transaction. |
| V5-L38 | Ch 3 §3: under ΛCDM, $10^{122}$ $k_B$ is the most the universe will hold, and every transaction draws on a budget that will be exhausted. | Narrowed | Ch 3 §5 [C06, C23] | The present horizon evolves toward a de Sitter limit; horizon entropy is not a target for interior matter. |
| V5-L39 | Ch 3 §3: the Big Rip tears spacetime apart and violates the generalized second law through a shrinking horizon. | Narrowed | Ch 3 §5 [C24] | Constant $w < -1$ can give a finite-time rip; a transient crossing does not; area alone does not diagnose a violation. |
| V5-L40 | Ch 3 §3: fading Λ lifts the ceiling; distant transactions become merely exponentially expensive. | Narrowed | Ch 3 §5 [C23] | No event horizon of that kind, but entropy constraints remain; no universal cost law is derived. |
| V5-L41 | Ch 3 §3: the founding line holds in all three scenarios. | Withdrawn as a physical claim | Ch 3 §5 | The second law holds in all three; the founding line is an Analogical image, not that law. |
| V5-L42 | Ch 3 §3: the scenarios map onto eschatological archetypes because cosmic fate genuinely parallels eschatology. | Narrowed | Ch 3 §5 | The associations are interpretations people make, not evidence about cosmology. |

| ID | March claim (Volume 5 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V5-L43 | Ch 3 §4: a $10^9$-solar-mass black hole holds about $10^{96}$ $k_B$; black holes are most of the budget. | Corrected | Ch 3 §6 [C05, C28] | About $1.05 \times 10^{95}$ $k_B$ for a nonrotating hole; populations need a mass distribution; an inventory is not a budget. |
| V5-L44 | Ch 3 §4: the Page curve and island formula, resolved in 2019–2021, establish that infalling information is not destroyed. | Narrowed | Ch 3 §6 [C26, C27, C36] | Strong theoretical evidence in controlled models, not observation; turnover and growth are not universal. |
| V5-L45 | Ch 3 §4: relational information entering a black hole is scrambled, not lost; the Trinket's irreversibility is about access; the recording persists. | Narrowed | Ch 3 §6; Ch 4 | Formal preservation does not establish a semantic record's existence, location or recoverability. |
| V5-L46 | Ch 3 §4: evaporation exactly saturates Landauer; black holes at 1×, biology at $10^6$, silicon at $10^9$; scale invariance confirmed. | Narrowed; substrate factors withdrawn | Ch 3 §6 [C28] | A theoretical identification for the entropy decrement; no ranking of implementations; not a test of scale invariance. |
| V5-L47 | Ch 3 §4: Trivedi's cosmological information paradox; Landauer satisfied across eras, reversible where w crosses −1/3. | Narrowed | Ch 3 §6 [C29, C30] | Particular apparent-horizon constructions; no experimental exception; apparent and event horizons differ. |
| V5-L48 | Ch 3 §4 SupoRel: information is preserved, access is not; the comfort is refused. | Kept as a caution; the preservation premise narrowed | Ch 3 §6; Ch 4 §7 | Preservation is a conditional result for complete states, not a fact about a particular record. |
| V5-L49 | Ch 3 §5: the economy runs on the visible minority, bounded by the dark majority; the budget is set by the whole. | Narrowed | Ch 3 §7 | A conditional program; the budget framing does not survive. |
| V5-L50 | Ch 4 status: Hawking radiation, the Page curve, Landauer and decoherence Established; islands, unitarity and quantum Darwinism Supported. | Narrowed | Ch 4 status [I01–I03, I08, I12] | Semiclassical prediction, model-based theoretical evidence and laboratory results each keep their own scope. |
| V5-L51 | Ch 4 §1: the physics now strongly supports preservation; the only question is what preservation means. | Narrowed | Ch 4 §1 [I01–I03] | Major theoretical progress, but no observed decoder for a real black hole; unitarity holds within the description. |
| V5-L52 | Ch 4 §2: scrambling spreads information across exponentially many degrees of freedom; recovery needs over half of all Hawking radiation. | Narrowed and corrected | Ch 4 §2 [I04, I05] | Hilbert-space dimension grows exponentially; recovery depends on model and control; complexity is not proof of impossibility. |
| V5-L53 | Ch 4 §2: solar-mass evaporation in about $10^{67}$ years at $10^{-7}$ K; $10^9$ solar masses in $10^{97}$ years; no instrument could ever retrieve the information. | Corrected | Ch 4 §2 [I01; I-CALC-01] | About $6.2 \times 10^{-8}$ K and $2.1 \times 10^{67}$ years; $2.1 \times 10^{94}$ years for $10^9$ solar masses, idealized; impossibility not shown. |
| V5-L54 | Ch 4 §2: quantum scrambling is the Kolchinsky–Wolpert decorrelating intervention, which is the Shadow Economy. | Withdrawn | Ch 4 §2 [I06] | Different operations; a withheld message can keep strong correlations (as V1-L12). |
| V5-L55 | Ch 4 §3: Trinket formation requires redundant environmental broadcast; the universe guarantees only global preservation. | Narrowed | Ch 4 §3 [I07, I08] | Redundancy aids many observers but is not necessary for every transmission; no Trinket threshold follows. |
| V5-L56 | Ch 4 §3: Zhu and colleagues made the first experimental observation of quantum Darwinism in superconducting circuits. | Narrowed | Ch 4 §3 [I08] | Evidence for signatures within the specified superconducting-circuit preparation; platform-specific priority is not adjudicated here. |

| ID | March claim (Volume 5 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V5-L57 | Ch 4 §4: the Bekenstein–Hawking bound limits any region's information; zero-bit resources transcend it because it limits decoding, not encoding. | Narrowed | Ch 4 §4 [I09, I10] | Bounds need a specified task and resources; encoder and decoder restrictions also constrain zero-bit capacity. |
| V5-L58 | Ch 4 §5: Landauer at every scale: every irreversible bit operation dissipates at least kT ln 2; experiments now reach the bound. | Narrowed | Ch 4 §5 [I11–I18] | A specified reset under stated conditions; equality is an ideal limit; the experiments are complementary, not a survey. |
| V5-L59 | Ch 4 §5: biology at about $10^6$ and silicon at $10^9$ times the floor, formalized by the efficiency surface. | Withdrawn | Ch 4 §5 | As V4-L07 and V4-L15. |
| V5-L60 | Ch 4 §5: the chain is complete; Landauer is the invariant and the transducer the structure that satisfies it, grounding scale invariance. | Withdrawn | Ch 4 §5 [I19, I20, I31, I34] | Shared laws constrain a future model; stage labels identify no erasures. |
| V5-L61 | Ch 4 §6: Layer A is permanently recorded on the universal ledger; meaning is transient; unrecorded neural states scramble almost instantly. | Withdrawn | Ch 4 §6 | Entropy production is not an archive; recognition can persist; no single scrambling timescale exists. |
| V5-L62 | Ch 4 §6: the four populations of the gap are cosmological information states. | Narrowed | Ch 4 §6 | They remain human examples, not quantum states or entropy values. |
| V5-L63 | Ch 4 §7: “Love is never truly lost”; the comfort is illusory. | Narrowed | Ch 4 §7 | The cited physics does not warrant the reassurance, and it does not disprove every account of survival either. |
| V5-L64 | Ch 4 §7: “The universe remembers every act of love” is technically true but spiritually misleading. | Narrowed | Ch 4 §7 | A metaphor, not a technical consequence of unitarity. |
| V5-L65 | Ch 4 §7: meaning is not the universe's purpose; the universe spends entropy because the second law demands it. | Narrowed | Ch 4 §7 | The second law does not command each process to produce entropy or measure an outcome's value. |
| V5-L66 | Ch 4 §7: the SupoRel ruling: state the physics, name the comfort, show why it depends on an unsupported reading. | Kept | Ch 4 §7 | Neither hope nor its rejection is an experimental result of black-hole physics. |
| V5-L67 | Ch 5 status, §1: “I can't beat entropy” is correct; the second law is not an engineering challenge but the arrow of time. | Narrowed: kept as a refusal to expect operation outside thermodynamics | Ch 5 status, §1 | The law constrains improvements; it does not forbid better devices, repair or use of resources. |
| V5-L68 | Ch 5 §1: every strategy operates within the entropy budget; the budget is not beaten, only spent differently. | Withdrawn | Ch 5 §1 [I12, I33] | No fixed cosmic spending account; open systems need not gain entropy; total production can approach zero. |
| V5-L69 | Ch 5 §2: many-worlds multiplies independently depleting budgets that cannot share resources. | Narrowed | Ch 5 §2 [I21] | Branch descriptions need no new energy accounts; many-worlds is not a fuel or transfer mechanism. |
| V5-L70 | Ch 5 §2: branching irreversibly produces entanglement entropy, making many-worlds worse than neutral. | Withdrawn | Ch 5 §2 [I22; I-CALC-04] | A global pure state stays pure under unitary evolution; subsystem entanglement can rise and fall reversibly. |
| V5-L71 | Ch 5 §3: digital transfer trades efficiency for replaceability, paying about a thousand times more per bit. | Withdrawn; transfer kept as a hypothetical | Ch 5 §3 [I23] | No universal substrate ranking; behavior, memory and continuity of experience are separate questions. |
| V5-L72 | Ch 5 §3: the first language model on Loihi 2 ran at half a GPU system's energy (credited to Eshraghian and colleagues). | Narrowed; attribution corrected | Ch 5 §3 [I24] | Abreu and colleagues; preliminary energy estimates, multi-chip limits and omitted stages. |

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|---|---|---|---|---|
| V5-L73 | Ch 5 §3: Hala Point at owl-brain scale, fifty times faster at a hundredth of the energy; SpiNNaker2's multipliers. | Narrowed | Ch 5 §3 [I25, I26] | Announcements with workload-dependent claims; neuron counts do not equate a system to a brain. |
| V5-L74 | Ch 5 §3: 20–50 pJ per synaptic operation is within 5–50 times of biology's 1–10 fJ; the thousandfold gap narrows toward tenfold. | Corrected; projection withdrawn | Ch 5 §3 [I-CALC-05] | The ratios are 2,000 to 50,000; the inputs are not validated as equivalent operations. |
| V5-L75 | Ch 5 §4: the transducer's stages are logically irreversible; “a filter that does not discard is not a filter.” | Withdrawn | Ch 5 §4 [I13; I-CALC-06] | Reversible embedding keeps the input; discarding from an output is not erasing the physical record. |
| V5-L76 | Ch 5 §4: Ice River recovers 40–70% of energy, with a projected four-thousandfold gain and chips by 2027; theory confirms reversible circumvention of Landauer. | Narrowed; Vaire figures not retained | Ch 5 §4 [I27] | Frank and Shukla support studying implementations; the commercial figures were not established by checked evidence. |
| V5-L77 | Ch 5 §4: reversible computing affects only the amplification constraint, so non-compensability holds. | Withdrawn | Ch 5 §4 | The proposed relational efficiency surface is not established as a universal bound, and no validated non-compensability theorem has been derived here (as V4-L18). |
| V5-L78 | Ch 5 §5: longevity escape velocity is the most promising approach; repair locally violates the second law; every repair pays a Landauer tax. | Narrowed and corrected | Ch 5 §5 [I28, I29, I12, I33] | A conjecture about progress; open systems violate nothing locally; aging is not one scalar; no fixed tax per repair. |
| V5-L79 | Ch 5 §5: the universal budget is no constraint on biological timescales and the only constraint on cosmological ones. | Withdrawn | Ch 5 §5 | Human-scale constraints are joined, not replaced, at remote times; no span of operation is guaranteed. |
| V5-L80 | Ch 5 §6: under ΛCDM the budget lasts beyond $10^{100}$ years; the Big Rip shreds every transducer; fading Λ is most favorable and slightly favored by DESI. | Narrowed | Ch 5 §6 | Conditional backgrounds; an evaporation timescale guarantees no operating budget; DESI favors no endpoint. |
| V5-L81 | Ch 5 §7: the framework is an entropy theory; the Trinket is an entropy token; love is an entropy operation. | Withdrawn | Ch 5 §7 | As V1-L03 and V1-L14; the question survives without the identities. |
| V5-L82 | Ch 5 §7: the founding line is physics to understand; every connection pays more than it buys; the waste is the arrow of time applied to love. | Withdrawn as physics; kept as an Analogical prompt | Ch 5 §7 | Total production can approach zero in the reversible limit; “waste” adds a criterion physics does not choose. |
| V5-L83 | Ch 5 §7: technology may change the price, but the Landauer floor, the semantic-efficiency ceiling and the second law do not. | Narrowed | Ch 5 §7 | No fixed physical ceiling on relational semantic efficiency is established here; cost does not set the worth of an act. |
| V5-L84 | Ch 6 §1: the relational economy has a proven upper bound, a current state of $10^{104}$ against $10^{122}$ bits, a shrinking accessible region and an information architecture that preserves existence while destroying meaning. | Withdrawn as a summary | Ch 6 §1 | Each element is narrowed or withdrawn in Chapters 2–4; no universal balance prices a conversation. |
| V5-L85 | Ch 6 §2: this volume is the empirical grounding of the Axiom 0 derivation; the ceiling is proved and Landauer's universality confirmed. | Withdrawn; Axiom 0 kept as a methodological commitment | Ch 6 §2 | As V1-L10; shared laws do not establish equal capacities, costs or a common currency. |
| V5-L86 | Ch 6 §3: the five volumes form one argument, from the budget through one currency, favored emergence and a thousandfold advantage to grief as a measurable thermodynamic event. | Withdrawn; replaced by the five volumes after correction | Ch 6 §3 | Each link is withdrawn or narrowed in its own volume; the series is an inquiry across scales, not a chain of deductions. |

| ID | March claim (Volume 5 location) | 2E disposition | 2E location | Basis |
|---|---|---|---|---|
| V5-L87 | Ch 6 §4: the expansion made the numbers current, moved the ceiling to proof, made the hard limit a variable, and verified scale invariance at both extremes. | Narrowed; scale-invariance verification withdrawn | Ch 6 §4 [C01, C02, C08, C20–C22] | The census is historical and unreconciled; constructions are not unconditional bounds; the Hawking–Landauer link is theoretical. |
| V5-L88 | Ch 6 §5: what did not change: the instruments work, the efficiency surface governs, the BSB applies, SupoRel fires, the seven gaps apply. | Narrowed: gaps and cautions kept as editorial questions | Ch 6 §5 | Validated-instrument status and the governing universal-bound claim are withdrawn; the conceptual tools and comparison framework remain proposals. |
| V5-L89 | Ch 6 §5: the framework is a relational theory grounded in cosmological physics; “the rounding error is where connection lives.” | Narrowed: “not a cosmology” kept | Ch 6 §5 | Cosmology supplies constraints, not the relational answer; no measured universal ledger pricing relational acts is established here. |

# References and source apparatus

*The C references, I notes and source-access record are inherited verbatim from the second edition's Volume 5 apparatus, except that four flattened mathematical spans are restored from its original equation markup. Group C serves Chapters 2 and 3; group I serves Chapters 4 and 5; the I-CALC notes record the calculations behind the corrected figures.*

## References for Chapters 2 and 3

Primary-source checks were performed on 28 October 2026. Version dates below refer to repository metadata, not regenerated HTML display dates. The source access notes below record the inspection limits and unresolved census discrepancy. A citation supports its stated physical result, not the relational framework.

**C01.** Egan, C. A., and Lineweaver, C. H. 2010. *A Larger Estimate of the Entropy of the Universe*. Astrophysical Journal 710, 1825–1834. arXiv 0909.3983v3. Historical inventories, Tables 1 and 2; distinct accounting boundaries.

**C02.** Profumo, S., Colombo-Murphy, L., Huckabee, G., Diaz Svensson, M., Garg, S., Kollipara, I., and Weber, A. 2025. *A New Census of the Universe's Entropy*. JCAP 09, 049. arXiv 2412.11282v2; publisher. Broadened census and hypothetical dark sectors; unreconciled black-hole table versus equation values.

**C03.** Chen, S., Jani, K., and Kephart, T. W. 2026. *Cosmological Budget of Entropy from Merging Black Holes*. arXiv 2601.13621v1, submitted 20 January. Population-model result, not a direct high-redshift entropy measurement.

**C04.** Bekenstein, J. D. 1981. *Universal upper bound on the entropy-to-energy ratio for bounded systems*. Physical Review D 23, 287–298. Primary article. Bounded-system entropy-to-energy result and its self-gravity assumptions.

**C05.** Bekenstein, J. D. 1973. *Black Holes and Entropy*. Physical Review D 7, 2333; Hawking, S. W. 1975. *Particle creation by black holes*. Communications in Mathematical Physics 43, 199–220. Historical primary pair underlying semiclassical black-hole entropy and temperature; not an evaporation experiment.

**C06.** Gibbons, G. W., and Hawking, S. W. 1977. *Cosmological event horizons, thermodynamics, and particle creation*. Physical Review D 15, 2738–2751. Cosmological horizons in the stated positive-Λ setting.

**C07.** Bousso, R. 1999. *A Covariant Entropy Conjecture*. arXiv hep-th/9905177; JHEP 07, 004. Entropy on suitable light sheets, not an unrestricted spacelike-volume rule.

**C08.** Chandrasekaran, V., Longo, R., Penington, G., and Witten, E. 2023. *An Algebra of Observables for de Sitter Space*. arXiv 2206.10780v5; JHEP 02, 082. Observer-dressed static-patch construction and generalized entropy, with an additive normalization constant.

**C09.** Buoninfante, L., Luciano, G. G., Petruzziello, L., and Scardigli, F. 2022. *Bekenstein bound and uncertainty relations*. arXiv 2009.12530v2; Physics Letters B 824, 136818. Conditional thermodynamic argument and deformation-dependent generalizations.

**C10.** Volovik, G. E. 2024. *Thermodynamics and decay of de Sitter vacuum*. arXiv 2312.02292v16; Symmetry 16, 763. Proposed local de Sitter thermodynamics; not universal dimensional necessity.

**C11.** Crooks, G. E. 1999. *The Entropy Production Fluctuation Theorem and the Nonequilibrium Work Relation for Free Energy Differences*. arXiv cond-mat/9901352v4; Physical Review E 60, 2721. Specified stochastic microscopically reversible dynamics and work/free-energy relations.

**C12.** Lees, J. P., et al., BABAR Collaboration. 2012. *Observation of Time-Reversal Violation in the $B^0$ Meson System*. arXiv 1207.5832; Physical Review Letters 109, 211801. Counterexample to universal microscopic time-reversal invariance.

**C13.** Carroll, S. M., and Chen, J. 2004. *Spontaneous Inflation and the Origin of the Arrow of Time*. arXiv hep-th/0410270v1. Proposed cosmological account, not a settled origin of initial conditions.

**C14.** Al-Khalili, J., and Chen, E. K. 2024. *The Decoherent Arrow of Time and the Entanglement Past Hypothesis*. arXiv 2405.03418v1; Foundations of Physics 54, 49. Low-entanglement boundary-condition proposal and distinctions between entropy notions.

**C15.** Chen, E. K. 2022. *The Wentaculus: Density Matrix Realism Meets the Arrow of Time*. arXiv 2211.03973v1. Initial Projection Hypothesis; this is the specific account used, not the manuscript's conflated publication-and-award description.

**C16.** Wallace, D. 2010. *Gravity, Entropy, and Cosmology: In Search of Clarity*. arXiv 0907.0659v1; British Journal for the Philosophy of Science 61, 513–540. Gravity's role distinguished from an entropy assigned to gravity.

**C17.** D'Onofrio, M., and Rummukainen, K. 2016. *The Standard Model cross-over on the lattice*. arXiv 1508.07161v1; Physical Review D 93, 025003. Standard Model electroweak crossover at the physical Higgs mass.

**C18.** Planck Collaboration, Aghanim, N., et al. 2020. *Planck 2018 results VI Cosmological parameters*. arXiv 1807.06209v4; Astronomy and Astrophysics 641, A6, with correction. Baseline ΛCDM density parameters, not entropy fractions.

**C19.** Carr, B. J., and Hawking, S. W. 1974. *Black Holes in the Early Universe*. Monthly Notices of the Royal Astronomical Society 168, 399–415. Early-universe collapse and radiation-era evolution; not prethermal pre-existence.

**C20.** DESI Collaboration, Adame, A. G., et al. 2024. *DESI 2024 VI Cosmological Constraints from the Measurements of Baryon Acoustic Oscillations*. arXiv 2404.03002v3, revised 4 November 2024. Dataset-dependent dark-energy model comparisons.

**C21.** DESI Collaboration, Abdul Karim, M., et al. 2025. *DESI DR2 Results II Measurements of Baryon Acoustic Oscillations and Cosmological Constraints*. arXiv 2503.14738v3, revised 9 October 2025. Section VII and Table 6; stated external datasets required.

**C22.** DESI Collaboration, Adame, A. G., et al. 2026. *DESI DR2 Results IV Alcock–Paczyński Measurements from the Lyman Alpha Forest and Cosmological Constraints*. arXiv 2607.27410v3, submitted 29 July, revised 4 August 2026. Section VI.4.1, Table 4 and updated external-data combinations. The collaboration's announcement is dated 30 July; the paper, not that announcement, supplies the quantitative citation.

**C23.** Davis, T. M., and Lineweaver, C. H. 2004. *Expanding Confusion Common Misconceptions of Cosmological Horizons and the Superluminal Expansion of the Universe*. arXiv astro-ph/0310808v2; Publications of the Astronomical Society of Australia 21, 97–109. Distinct horizons and light-cone interpretation in FLRW cosmology.

**C24.** Caldwell, R. R., Kamionkowski, M., and Weinberg, N. N. 2003. *Phantom Energy and Cosmic Doomsday*. arXiv astro-ph/0302506; Physical Review Letters 91, 071301. Conditional phantom-energy Big Rip model.

**C25.** Adams, F. C., and Laughlin, G. 1997. *A Dying Universe The Long Term Fate and Evolution of Astrophysical Objects*. arXiv astro-ph/9701131; Reviews of Modern Physics 69, 337–372. Conditional astrophysical futures, not a measured heat-death date.

**C26.** Almheiri, A., Engelhardt, N., Marolf, D., and Maxfield, H. 2019. *The entropy of bulk quantum fields and the entanglement wedge of an evaporating black hole*. arXiv 1905.08762v3; JHEP 12, 063. Two-dimensional model and quantum extremal surfaces.

**C27.** Penington, G. 2020. *Entanglement Wedge Reconstruction and the Information Paradox*. arXiv 1905.08255v3; JHEP 09, 002. AdS/CFT evaporation and reconstruction under stated assumptions.

**C28.** Cortês, M., and Liddle, A. R. 2024. *Hawking evaporation and the Landauer Principle*. arXiv 2407.08777v2, revised 12 August 2024. Section II theoretical Schwarzschild calculation; the prior V501 correction remains in force.

**C29.** Trivedi, O. 2024. *Landauer's principle and information at the cosmological horizon*. arXiv 2407.15231v3, revised 25 December 2024. Apparent-horizon construction and its interpretation, not experimental falsification of Landauer erasure.

**C30.** Odintsov, S. D., Paul, T., and SenGupta, S. 2025 version. *Natural validation of the second law of thermodynamics in cosmology*. arXiv 2409.05009v2, revised 4 February 2025. Apparent-horizon/matter-temperature model, not a universal horizon theorem.

**C31.** Bennett, C. H. 1973. *Logical Reversibility of Computation*. IBM Journal of Research and Development 17, 525–532. Reversible computation; no mandatory cost for each cognitive label.

**C32.** Landauer, R. 1961. *Irreversibility and Heat Generation in the Computing Process*. IBM Journal of Research and Development 5, 183–191. Specified erasure, not a universal information-processing toll.

**C33.** Reeb, D., and Wolf, M. M. 2014. *An improved Landauer Principle with finite-size corrections*. arXiv 1306.4352v3; New Journal of Physics 16, 103011. Explicit reservoir and correlation assumptions.

**C34.** Preskill, J., Wise, M. B., and Wilczek, F. 1983. *Cosmology of the invisible axion*. Physics Letters B 120, 127–132. Nonthermal coherent-field production; not evidence that axions constitute dark matter.

**C35.** Gondolo, P., and Gelmini, G. 1991. *Cosmic abundances of stable particles Improved analysis*. Nuclear Physics B 360, 145–179. Thermal relic-abundance calculation; primary full text not retrieved in this pass.

**C36.** Almheiri, A., Hartman, T., Maldacena, J., Shaghoulian, E., and Tajdini, A. 2020. *Replica Wormholes and the Entropy of Hawking Radiation*. arXiv 1911.12333v2; JHEP 05, 013. Replica saddles and island rule in a controlled two-dimensional setting.

## Information and technology source notes

Source notes for Chapters 4 and 5. Checked 28 October 2026. A retrieved abstract or publisher record is not represented as a full-paper review. The exact URLs below identify the material actually inspected; publication DOIs distinguish the version of record when available. These sources support bounded physical or historical claims, not the relational model as a validated theory. No source establishes a personal-survival technology or a universal biological-to-digital efficiency ratio.

### *I01 Hawking radiation*

Hawking, S. W. 1975. Particle creation by black holes. *Communications in Mathematical Physics* 43, 199–220. https://doi.org/10.1007/BF02345020. Original paper PDF: https://projecteuclid.org/journals/communications-in-mathematical-physics/volume-43/issue-3/Particle-creation-by-black-holes/cmp/1103899181.pdf.

Access: publisher abstract and original-paper PDF text. Use: semiclassical radiation and temperature, with stationary parameters and the approximations of the calculation. It is theoretical, not a direct astronomical measurement. The lifetime displayed in this revision is a separately labeled ideal-blackbody calculation, not a fitted result from this paper.

### *I02 Page radiation information*

Page, D. N. 1993. Information in black hole radiation. *Physical Review Letters* 71, 3743–3746. https://doi.org/10.1103/PhysRevLett.71.3743. https://arxiv.org/abs/hep-th/9306083v2. Original-paper PDF: https://harvest.aps.org/v2/journals/articles/10.1103/PhysRevLett.71.3743/fulltext.

Access: arXiv metadata/abstract and publisher full-text extract. Use: information-release expectations conditional on unitary formation and evaporation and the statistical model. A Page curve is not itself an observed radiation record or an explicit efficient decoder.

### *I03 Island and radiation entropy evidence*

Almheiri, A., Hartman, T., Maldacena, J., Shaghoulian, E., and Tajdini, A. 2021. The entropy of Hawking radiation. *Reviews of Modern Physics* 93, 035002. https://doi.org/10.1103/RevModPhys.93.035002.

https://arxiv.org/abs/2006.06872. Accepted manuscript: https://link.aps.org/accepted/10.1103/RevModPhys.93.035002.

Access: arXiv abstract, publication metadata, and accepted-manuscript extract. Use: overview by the researchers of controlled gravitational entropy calculations consistent with unitarity. The chapter does not claim that the review proves all-realistic-black-hole decoding, final-state dynamics, or cosmological information preservation.

### *I04 Conditional information retrieval*

Hayden, P., and Preskill, J. 2007. Black holes as mirrors: quantum information in random subsystems. *Journal of High Energy Physics* 2007(09), 120. https://doi.org/10.1088/1126-6708/2007/09/120. https://arxiv.org/abs/0708.4025. Author-hosted paper: https://preskill.caltech.edu/pubs/preskill-2007-mirror.pdf.

Access: abstract and author PDF text. Use: rapidly mixing unitary dynamics and an observer with ideal control of emitted radiation. The old-hole protocol is a counterexample to the manuscript's unconditional half-of-all-radiation statement, not an engineering proposal.

### *I05 Decoding complexity*

Harlow, D., and Hayden, P. 2013. Quantum computation vs. firewalls. *Journal of High Energy Physics* 2013(06), 85. https://arxiv.org/abs/1301.4504. https://doi.org/10.1007/JHEP06(2013)085.

Access: original arXiv abstract and revision description. Use: complexity obstruction for specified decoding thought experiments, with genericity and computational assumptions. Does not establish that no physically possible observer could ever test unitarity or recover any information.

### *I06 Semantic information and interventions*

Kolchinsky, A., and Wolpert, D. H. 2018. Semantic information, autonomous agency and non-equilibrium statistical physics. *Interface Focus* 8, 20180041. https://doi.org/10.1098/rsfs.2018.0041. https://arxiv.org/html/1806.08053v3. Author paper: https://artemyk.github.io/assets/pdf/papers/Kolchinsky_Wolpert_2018_Semantic%20information%2C%20autonomous%20agency%20and%20non-equilibrium%20statistical%20physics.pdf.

Access: abstract and selected HTML/PDF text on setup, viability, and intervention definitions. Use: model-specific correlation interventions and viability analysis. A physical or social application must specify variables, dynamics, horizon, and admissible interventions; a shared word does not identify quantum scrambling with this operation. No Shadow Economy mapping or relational multiplier is imported.

### *I07 Quantum Darwinism mechanism*

Zurek, W. H. 2009. Quantum Darwinism. *Nature Physics* 5, 181–188. https://doi.org/10.1038/nphys1202. https://arxiv.org/abs/0903.5082.

Access: author abstract and publication metadata; supplemented by the experimental paper I08. Use: redundant records of selected observables in environmental fragments. Not a theorem that redundancy is required for every communication act or that the measurement problem is universally settled.

### *I08 Quantum Darwinism experiment*

Zhu, Z., Salice, K., Touil, A., Bao, Z., Song, Z., Zhang, P., Li, H., Wang, Z., Song, C., Guo, Q., Wang, H., and Mondaini, R. 2025. Observation of quantum Darwinism and the origin of classicality with superconducting circuits. *Science Advances* 11(31), eadx6857. https://doi.org/10.1126/sciadv.adx6857. https://arxiv.org/html/2504.00781v2. Publisher metadata indexed at https://pubmed.ncbi.nlm.nih.gov/40749052/.

Access: author HTML sections on apparatus, branching structures and fragment information, figures described in text, and publication metadata. Use: engineered superconducting-qubit preparation and fragment measurements. Earlier experiments are acknowledged in its introduction; the revision does not call this the first experimental test of quantum Darwinism generally. No universal coupling-strength scaling or relational-recognition requirement is inferred.

### *I09 Entropy bound*

Bekenstein, J. D. 1981. Universal upper bound on the entropy-to-energy ratio for bounded systems. *Physical Review D* 23, 287–298. https://doi.org/10.1103/PhysRevD.23.287. https://journals.aps.org/prd/abstract/10.1103/PhysRevD.23.287. Original-paper text: https://harvest.aps.org/v2/journals/articles/10.1103/PhysRevD.23.287/fulltext.

Access: original abstract and publisher paper extract. Use: familiar ER form and its physical-system assumptions. Modern field-theoretic distinctions are addressed through I10, not ignored. Does not justify applying a single area bound to arbitrary spatial regions, equating entropy to work, or declaring the universe finite.

### *I10 Encoder and decoder resource restrictions*

Hayden, P., and Wang, J. 2025. What exactly does Bekenstein bound? *Quantum* 9, 1664. https://doi.org/10.22331/q-2025-03-20-1664. https://arxiv.org/abs/2309.07436v3. https://arxiv.org/html/2309.07436v3.

Access: final published-version metadata, abstract and HTML passages on channel capacities and encoder restrictions. Use: specified Unruh channel and distinct decoder-only versus encoder-plus-decoder restrictions. Zero-bit capacity is also bounded in the latter construction. The manuscript's categorical “outside the ceiling” conclusion is withdrawn.

### *I11 Historical Landauer paper*

Landauer, R. 1961. Irreversibility and heat generation in the computing process. *IBM Journal of Research and Development* 5(3), 183–191. https://doi.org/10.1147/rd.53.0183. Original-paper copy: https://sites.pitt.edu/~jdnorton/lectures/Rotman_Summer_School_2013/thermo_computing_docs/Landauer_1961.pdf.

Access: publisher metadata/abstract and original-paper extract. Use: historical link between logical information loss and physical dissipation. Modern setup conditions are specified using I12; the original suggestion that irreversible steps are essential to all useful computation is not repeated.

### *I12 Precise Landauer setup*

Reeb, D., and Wolf, M. M. 2014. An improved Landauer principle with finite-size corrections. *New Journal of Physics* 16, 103011. https://doi.org/10.1088/1367-2630/16/10/103011. https://arxiv.org/html/1306.4352v3. Author/institution PDF: https://mediatum.ub.tum.de/doc/1653576/1653576.pdf.

Access: HTML setup, bound and correlation sections and institutional PDF extract. Use: initially product system–thermal-reservoir state and joint unitary evolution; bounds on mean reservoir heat versus memory entropy decrease. Finite reservoirs and initial correlations alter the simplest analysis. Not a per-event biological tax.

### *I13 Reversible computation*

Bennett, C. H. 1973. Logical reversibility of computation. *IBM Journal of Research and Development* 17, 525–532. https://doi.org/10.1147/rd.176.0525. Original-paper HTML: https://www.cs.princeton.edu/courses/archive/fall04/cos576/papers/bennett73.html.

Access: original-paper HTML, including the reversible construction. Use: reversible embedding, retention of information, and uncomputation. Separately checked Bennett's 2003 *Notes on Landauer's principle, reversible computation and Maxwell's demon*: https://arxiv.org/abs/physics/0210005, https://doi.org/10.1016/S1355-2198(03)00039-X (abstract). Logical reversibility does not certify a practical device's energy or speed.

### *I14 Erasure with quantum side information*

del Rio, L., Åberg, J., Renner, R., Dahlsten, O., and Vedral, V. 2011. The thermodynamic meaning of negative entropy. *Nature* 474, 61–63. https://doi.org/10.1038/nature10123. https://arxiv.org/abs/1009.1630. Clarifying addendum: *Nature* 476, 476, https://www.nature.com/articles/nature10395.

Access: original author abstract and full short publisher addendum. Use: work costs with quantum side information and consumed entanglement. The addendum explicitly distinguishes such a process from a cyclic second-law violation. Heat and work are not treated as interchangeable in the chapter.

### *I15 Colloidal reset experiment*

Bérut, A., Arakelyan, A., Petrosyan, A., Ciliberto, S., Dillenschneider, R., and Lutz, E. 2012. Experimental verification of Landauer's principle linking information and thermodynamics. *Nature* 483, 187–189. https://doi.org/10.1038/nature10872. https://www.nature.com/articles/nature10872.

Access: publisher abstract and metadata. Use: single-particle colloidal memory-reset experiment. Later platforms complement rather than invalidate or “supersede” its evidence.

### *I16 Nanomagnetic reset experiment*

Hong, J., Lambson, B., Dhuey, S., and Bokor, J. 2016. Experimental test of Landauer's principle in single-bit operations on nanomagnetic memory bits. *Science Advances* 2, e1501492. https://doi.org/10.1126/sciadv.1501492. https://pmc.ncbi.nlm.nih.gov/articles/PMC4795654/.

Access: paper text including methods, discussion and uncertainty. Use: intrinsic dissipation in the specified reset; consistency within two standard deviations, with actuation losses excluded. The revision omits an unqualified single central value and “44 percent” summary. See the separate arithmetic check rather than treating it as a new measurement.

### *I17 Molecular-spin reset experiment*

Gaudenzi, R., Burzurí, E., Maegawa, S., van der Zant, H. S. J., and Luis, F. 2018. Quantum Landauer erasure with a molecular nanomagnet. *Nature Physics* 14, 565–568. https://doi.org/10.1038/s41567-018-0070-7. https://www.nature.com/articles/s41567-018-0070-7. Author version: https://arxiv.org/abs/1703.04607. Correction: https://www.nature.com/articles/s41567-018-0140-x.pdf.

Access: publisher and author abstracts plus complete correction text. Use: quantum-spin memory investigation, not universal low-temperature reversibility. The correction swaps figure-legend symbols; it is recorded rather than silently ignored. Detailed numerical saturation claims are not made on abstract-only access.

### *I18 Many-body information thermodynamics experiment*

Aimet, S., Tajik, M., Tournaire, G., Schüttelkopf, P., Sabino, J., Sotiriadis, S., Guarnieri, G., Schmiedmayer, J., and Eisert, J. 2025. Experimentally probing Landauer's principle in the quantum many-body regime. *Nature Physics* 21, 1326–1331. https://doi.org/10.1038/s41567-025-02930-9. https://www.nature.com/articles/s41567-025-02930-9. https://arxiv.org/abs/2407.21690.

Access: publisher article extracts including methods and information-thermodynamic results, and author abstract. Use: quench and reconstruction in coupled one-dimensional Bose gases; partitions, correlations and reservoir state matter. Aimet and Tajik are co-first authors. The original abbreviated “Tajik et al.” chain omitted the first author. This is not a direct observation of the framework's transducer stages.

### *I19 Black-hole Landauer relation*

Cortês, M., and Liddle, A. R. 2024. Hawking evaporation and the Landauer Principle. https://arxiv.org/abs/2407.08777v2. https://arxiv.org/html/2407.08777v2. https://doi.org/10.48550/arXiv.2407.08777.

Access: author HTML entropy–mass derivation and scope discussion, and arXiv submission/revision metadata (11 July / 12 August 2024). An HTML body date displayed in 2026 is not substituted for that history. Use: differential Schwarzschild entropy–mass–temperature relation, with a separately discussed phenomenological extension. The authors leave the information-loss question aside. The result is **theoretical, not experimental**; prior dependency correction V501 remains intact.

### *I20 Cosmological entropy construction*

Odintsov, S. D., Paul, T., and SenGupta, S. 2025 version. Natural validation of the second law of thermodynamics in cosmology. Originally submitted 2024; v2 dated 4 February 2025. https://arxiv.org/abs/2409.05009v2. https://arxiv.org/html/2409.05009v2.

Access: author HTML introduction and FLRW apparent-horizon setup. Use: spatially flat FLRW, apparent-horizon entropy/temperature and the authors' matter-temperature construction. Their transition result is model-specific. Not evidence for a universal reset law across all cosmic eras or for an independently measured cosmological entropy account.

### *I21 Everett formulation*

Everett, H., III. 1957. “Relative State” formulation of quantum mechanics. *Reviews of Modern Physics* 29, 454–462. https://doi.org/10.1103/RevModPhys.29.454. https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.29.454. Original-paper scan inspected: https://quantmagic.narod.ru/Articles/Everett.pdf.

Access: publisher metadata, with publisher full text access-limited, and original-paper scan extract. Use: unitary relative-state formulation. Branch resource multiplication and a heat penalty per branch are not results of this paper. The Bell-state calculation in this volume is independent elementary algebra, not attributed to a claim about all Everettian histories.

### *I22 Entanglement Past Hypothesis*

Al-Khalili, J., and Chen, E. K. 2024. The decoherent arrow of time and the Entanglement Past Hypothesis. *Foundations of Physics* 54, 49. https://doi.org/10.1007/s10701-024-00785-3. https://arxiv.org/abs/2405.03418. Published author copy: https://philsci-archive.pitt.edu/23719/1/Al-Khalili_Chen_FoP%202024.pdf.

Access: author abstract and published-paper extract. Use: proposed low-entanglement boundary condition and acknowledged open questions. It does not prove branchwise irreversible heat generation or establish one arrow as experimentally more fundamental.

### *I23 Whole-brain emulation roadmap*

Sandberg, A., and Bostrom, N. 2008. *Whole brain emulation: A roadmap*. Future of Humanity Institute Technical Report 2008-3. https://ora.ox.ac.uk/objects/uuid%3Aa6880196-34c7-47a0-80f1-74d32ab98788. https://www.fhi.ox.ac.uk/reports/2008-3.pdf.

Access: institutional record and technical-report excerpts. Use: technical prerequisites and research-proposal status, not a demonstration. No current claim of achieved personal transfer is inferred from a historical roadmap; the chapter makes no forecast or exhaustive claim about all current simulation projects.

### *I24 Neuromorphic language-model study*

Abreu, S., Shrestha, S. B., Zhu, R.-J., and Eshraghian, J. 2025. Neuromorphic principles for efficient large language models on Intel Loihi 2. ICLR SCOPE workshop; https://arxiv.org/abs/2503.18002v2; https://arxiv.org/html/2503.18002v2.

Access: v1 and latest v2 HTML, with abstract, results and relevant Appendix A.4 passages inspected. Use: preliminary component-based estimates, multi-chip implementation, and omitted embedding/unembedding stages. “ICLR 2025” is narrowed to the workshop. No end-to-end measured twofold advantage, universal neuromorphic ratio, or biological equivalence is claimed.

### *I25 Hala Point developer announcement*

Intel. 2024. Intel builds world's largest neuromorphic system to enable more sustainable AI. 17 April 2024. https://newsroom.intel.com/artificial-intelligence/intel-builds-worlds-largest-neuromorphic-system-to-enable-more-sustainable-ai. Archived announcement with footnotes: https://download.intel.com/newsroom/archive/2025/en-us-2024-04-17-intel-builds-worlds-largest-neuromorphic-system-to-enable-more-sustainable-ai.pdf.

Access: developer announcement and benchmark footnotes. Use: historical research-system description. This is a first-party performance claim, not independent validation. Its synthetic sparse MLP characterization and earlier Loihi workload citations do not establish a general Hala Point speedup or an owl-brain-equivalent function.

### *I26 Sandia deployment record*

Sandia National Laboratories. 2025 reporting period. Advancing neuromorphic computing at the Neural Exploration and Research Lab. https://www.sandia.gov/news/publications/hpc-annual-reports/article/advancing-neuromorphic-computing-at-the-neural-exploration-and-research-lab/. Related institutional report: https://www.sandia.gov/app/uploads/sites/81/2025/06/labnews_06-12-25.pdf.

Access: institutional report and June 2025 newsletter extract. Use: deployment of SpiNNaker2 and Loihi2; not a task-matched biology comparison. The reported eighteenfold GPU efficiency statement lacks a common-task specification adequate for this chapter, so its number is not imported. The original tenfold predecessor-efficiency claim is not verified by these retrieved records.

### *I27 Reversible-computing theory*

Frank, M. P., and Shukla, K. 2021. Quantum foundations of classical reversible computing. *Entropy* 23, 701. https://doi.org/10.3390/e23060701. https://arxiv.org/abs/2105.00065. https://pmc.ncbi.nlm.nih.gov/articles/PMC8228632/. Institutional paper: https://www.sandia.gov/app/uploads/sites/210/2022/06/QFoCRC-OSTIv2.pdf.

Access: article theory extracts and author abstract. Use: nonequilibrium quantum description and research directions for reversible computing. Corrects the original author attribution “Frank, Ammerål, and others.” Does not establish Ice River measurements or a commercial delivery date.

### *I28 Origin of longevity escape velocity proposal*

de Grey, A. D. N. J. 2004. Escape velocity: Why the prospect of extreme human life extension matters now. *PLOS Biology* 2(6), e187. https://doi.org/10.1371/journal.pbio.0020187. https://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.0020187.

Access: publisher record and argument summary. Use: a prospective concept, not an intervention trial. No efficacy, safety, date of arrival, or ranking is taken from this essay.

### *I29 Human longevity trend evidence*

Olshansky, S. J., Willcox, B. J., Demetrius, L., and Beltrán-Sánchez, H. 2024. Implausibility of radical life extension in humans in the twenty-first century. *Nature Aging* 4, 1635–1642. https://doi.org/10.1038/s43587-024-00702-3. https://www.nature.com/articles/s43587-024-00702-3.

Access: publisher article abstract, analysis and conclusion extracts. Use: demographic analysis under its population and historical-period definitions. It is not an absolute physical maximum on an individual's lifespan, proof against all future interventions, or a clinical recommendation.

### *I30 Zurek monograph metadata*

Zurek, W. H. 2025. *Decoherence and Quantum Darwinism: From Quantum Foundations to Classical Reality*. Cambridge University Press. https://doi.org/10.1017/9781009552868. https://www.cambridge.org/core/books/decoherence-and-quantum-darwinism/E851B8F658044E4BF549AAEEB7B47B37. https://assets.cambridge.org/97810095/52905/frontmatter/9781009552905_frontmatter.pdf.

Access: publisher description, metadata and frontmatter only; full book not read. Original source mention is retained in this disposition record. Scientific claims in the revised body rely on I07–I08 instead of calling an access-limited book “definitive.”

### *I31 Analogue Hawking experiment*

Muñoz de Nova, J. R., Golubkov, K., Kolobov, V. I., and Steinhauer, J. 2019. Observation of thermal Hawking radiation and its temperature in an analogue black hole. *Nature* 569, 688–691. https://doi.org/10.1038/s41586-019-1241-0. https://www.nature.com/articles/s41586-019-1241-0. https://arxiv.org/abs/1809.00913.

Access: publisher abstract and author abstract. Use: correlations and temperature in an analogue platform. Does not constitute observation of astrophysical evaporation, a Page curve of an actual black hole, or a test of Cortês–Liddle's calculation.

### *I32 Stationary black-hole mechanics*

Bardeen, J. M., Carter, B., and Hawking, S. W. 1973. The four laws of black hole mechanics. *Communications in Mathematical Physics* 31, 161–170. https://doi.org/10.1007/BF01645742. https://projecteuclid.org/journals/communications-in-mathematical-physics/volume-31/issue-2/The-four-laws-of-black-hole-mechanics/cmp/1103858973.pdf.

Access: original paper extract. Use: stationary axisymmetric black-hole mechanics, including angular-momentum terms. The Kerr entropy equation is explicitly reconstructed in I-CALC-02 with fixed mass and zero charge. Schwarzschild dE = T dS is not generalized by silently dropping rotational work.

### *I33 Stochastic thermodynamic scope*

Seifert, U. 2012. Stochastic thermodynamics, fluctuation theorems and molecular machines. *Reports on Progress in Physics* 75, 126001. https://doi.org/10.1088/0034-4885/75/12/126001. https://arxiv.org/abs/1205.4176. Author-paper copy: https://terpconnect.umd.edu/~cjarzyns/CHEM-CHPH-PHYS_703_Spr_20/resources/Rep%20Prog%20Phys%202012%20Seifert.pdf.

Access: author abstract and paper text extract. Use: heat-bath-coupled, specified stochastic ensembles and fluctuating trajectories. Supports separating macroscopic or average production statements from every single-event claim. Does not make aging one scalar entropy variable.

### *I34 Cosmological apparent-horizon proposal*

Trivedi, O. 2024. Landauer's principle and information at the cosmological horizon. https://arxiv.org/abs/2407.15231v3. https://arxiv.org/html/2407.15231v3. Latest inspected revision 25 December 2024.

Access: metadata, author abstract, HTML introduction and model setup. Use: a specific apparent-horizon thermodynamic construction and its claimed tension. “Cosmological information paradox” is the author's terminology, not evidence for a generally established violation of Landauer's principle. The revision does not adopt the paper's broad statement that every computation necessarily dissipates energy.

## Cosmology source access and unresolved numerical discrepancy

“Targeted full-text” below means the specified sections of an accessible primary text were examined; it does not mean every derivation was independently reproduced. Metadata/abstract-only entries support only the narrow qualitative use stated. No claim of exhaustive literature coverage or human peer review is made.

**C01.** Access scope: Primary arXiv v3 HTML abstract, §I.1–I.2, Table 1, component definitions, horizon/interior distinction; abstract supplies Table 2 central totals. Conditions and limits: Historical flat cosmology and its chosen volumes; no current-census certification.

**C02.** Access scope: v2 abstract/metadata; HTML §§1–3, 7–9 and Table 3; PDF parsed equations on printed pp24–25 and Table 3 on p37; independent reviewer visually checked those three pages. Conditions and limits: See discrepancy below; no numerical repair invented.

**C03.** Access scope: v1 primary abstract and repository status. Conditions and limits: Submitted preprint; specific population synthesis, mass range and redshift result, not a verified cosmic history.

**C04.** Access scope: Publisher abstract and accessible original-paper search extract. Conditions and limits: Complete bounded system and gravitational assumptions; not universal cosmological application.

**C05.** Access scope: Bekenstein and Hawking publisher abstracts/metadata; Schwarzschild equations also directly checked in C28 §II. Conditions and limits: No primary full-paper derivation re-audit; semiclassical law rather than experimental evaporation.

**C06.** Access scope: Primary publisher-hosted full-text opening and abstract via indexed record. Conditions and limits: Positive cosmological constant setting; equations cross-checked with C01/C02 and direct algebra.

**C07.** Access scope: Primary arXiv abstract. Conditions and limits: Original conjecture; null light-sheet qualifications retained, not claimed unrestricted proof.

**C08.** Access scope: v5 primary abstract, accessible HTML construction and scope, static-patch result. Conditions and limits: Observer-dressed semiclassical construction; additive entropy normalization; no arbitrary-cosmology extension.

**C09.** Access scope: v2 primary HTML abstract, introduction and stated derivation assumptions. Conditions and limits: Equipartition regime and sign-dependent deformation; no universal Planck-scale tightening.

**C10.** Access scope: v16 primary abstract and metadata. Conditions and limits: A proposed local thermodynamics; dimension claim confined to that construction.

**C11.** Access scope: Primary abstract and metadata, with continuity to earlier verified volume discussion. Conditions and limits: Stochastic microscopically reversible process and heat-bath/work setup, not arbitrary cosmic free energy.

**C12.** Access scope: Primary experiment abstract and publisher identity. Conditions and limits: Neutral B-meson result suffices to refute all-laws T symmetry; no claim that it explains thermodynamic arrow.

**C13.** Access scope: v1 primary abstract and metadata. Conditions and limits: Explicitly a proposed cosmology, not source of a settled initial-condition theorem.

**C14.** Access scope: v1 primary HTML abstract, simple system–environment model and entropy distinctions. Conditions and limits: Subsystem partition and proposal status retained; closed-system unitary entropy distinguished.

**C15.** Access scope: v1 primary abstract; HTML §§2–3 available and initial-projector statement checked against author manuscript extract. Conditions and limits: The cited specific account is a 2022 preprint, not the original's conflated 2021/2024 award description.

**C16.** Access scope: Primary abstract and bibliographic metadata. Conditions and limits: Retains gravity-in-entropy versus entropy-of-gravity distinction only; no field entropy formula adopted.

**C17.** Access scope: v1 primary HTML abstract and introduction. Conditions and limits: Standard Model with physical Higgs mass; crossover, not claim of grand unification.

**C18.** Access scope: Primary arXiv abstract/metadata and baseline parameters. Conditions and limits: ΛCDM present energy-density fractions; approximate rounded fractions only.

**C19.** Access scope: Original publisher abstract and primary paper first-page extract. Conditions and limits: Early collapse model, not evidence that PBHs exist.

**C20.** Access scope: v3 primary metadata and abstract result. Conditions and limits: Combination-specific 2024 significance range; no standalone DESI discovery claim.

**C21.** Access scope: v3 primary HTML abstract, §VII.1–VII.3, Table 6 and conclusions. Conditions and limits: CMB and SNe choices explicit; no significance pooling.

**C22.** Access scope: v3 primary metadata, abstract, §VI.4.1, Table 4 and discussion; v1 initially inspected but superseded for citation. Conditions and limits: Submitted 29 July 2026; announcement 30 July; v3 4 August. Current-date targeted update, not prediction of later releases.

**C23.** Access scope: Primary abstract and metadata; standard FLRW null-geodesic formulas independently checked in the calculation record. Conditions and limits: Definitions and analytic examples do not require adopting the paper's historical parameter values.

**C24.** Access scope: Primary abstract and metadata. Conditions and limits: Conditional constant/sustained phantom model; no assertion all $w < -1$ histories rip.

**C25.** Access scope: Primary abstract, publisher identity and original-paper indexed extract. Conditions and limits: Used only to identify conditional far-future inquiry; no numerical date adopted.

**C26, C27, C36.** Access scope: Primary abstracts and version metadata. Conditions and limits: Their explicit JT/CFT or AdS/CFT settings preserved; no general experimental claim.

**C28.** Access scope: v2 primary full HTML §II equations 1–6, environment discussion and abstract. Conditions and limits: $dE = T_H\, dS_{BH}$ identity and small entropy decrement; not complete-state information destruction.

**C29.** Access scope: v3 primary HTML abstract, introduction and identified apparent-horizon setup. Conditions and limits: Paper's interpretation labeled model-specific; not endorsed as demonstrated violation.

**C30.** Access scope: v2 primary HTML abstract, setup, thermal-equilibrium and entropy-balance discussion. Conditions and limits: Apparent horizon, matter/horizon temperature prescriptions; no universal conservation result.

**C31, C32.** Access scope: Exact primary identities and interpretation from preserved corrected Volume 1 references and their source review. Conditions and limits: This pass did not re-retrieve those full papers; C33 freshly checks scoped erasure statement.

**C33.** Access scope: v3 primary abstract and HTML introduction/setup outline. Conditions and limits: Reservoir/correlation scope and reversible ideal limit; no positive total-production floor.

**C34.** Access scope: Primary publisher indexed abstract/metadata and author's publication list; direct publisher page returned 403. Conditions and limits: Only qualitative identification of coherent-field axion production retained; no abundance/parameter result.

**C35.** Access scope: Author-uploaded primary-paper abstract indexed in search and exact DOI metadata; DOI route failed and direct publisher page returned 403. Conditions and limits: Only qualitative thermal relic mechanism retained; no numeric formula or calculation attributed to unavailable full text.

The primary URLs appear in the C reference list above. Failed direct access was not described as successful full-text retrieval. Several arXiv HTML renderings display “August 24, 2026” within old manuscripts; version metadata, rather than that generated body date, controls the citation. This specifically affects C14, C17 and C28 in the inspected rendering.

### *The census discrepancy that remains open*

C02's PDF main text gives central SMBH entropy $8.56 \times 10^{101}$ $k_B$ for its stated $10^7$–$10^{9.7}$ solar-mass range (Eq7.1), and stellar-black-hole entropy $5.35 \times 10^{96}$ $k_B$ (Eq7.10). Its Table 3 instead lists logarithmic values 103.25 and 101.50. No reconciliation or explicit alternative-volume assignment was identified in this review. The ranges may matter; we do not infer the authors' intended corrected aggregate.

The numerical disagreement was also checked against the primary PDF pages, not only the HTML extraction. This volume therefore uses C02 qualitatively and does not choose either set as the corrected universe total. Its Table 3 historical-comparator entries must not be substituted for C01's own table.

## Information calculation notes

*Re-set from the second edition's original equation markup, with minor copyedits for clarity; no figure or conclusion was changed, and the arithmetic was rechecked for this edition.*

These checks reproduce numerical arithmetic and elementary identities. They do not validate an empirical input merely because it appears in a formula. Rounded values in the chapters are intentionally less precise. The constants used are $k_B = 1.380649 \times 10^{-23}$ J/K, $h = 6.62607015 \times 10^{-34}$ J s, $\hbar = h/(2\pi)$, $c = 299792458$ m/s, $G = 6.67430 \times 10^{-11}$ $m^3/(kg\ s^2)$, $M_\odot = 1.98847 \times 10^{30}$ kg and one Julian year = 31557600 s. The SI defining values $k_B$, h and c are exact; G and the adopted solar mass are rounded inputs.

### *I-CALC-01 Schwarzschild scales and the lifetime correction*

Assume an isolated, neutral, nonrotating Schwarzschild black hole. The temperature is $T_H = \hbar c^3/(8\pi G M k_B)$, the radius $r_s = 2GM/c^2$ and the entropy $S_{BH}/k_B = 4\pi GM^2/(\hbar c)$. The simple blackbody approximation takes area $A = 4\pi r_s^2$ and power $P = \sigma A T_H^4$, with $\sigma = \pi^2 k_B^4/(60\hbar^3 c^2)$. It gives $P = \hbar c^6/(15360\pi G^2 M^2)$. Integrating $c^2\, dM/dt = -P$ to zero mass yields $\tau = 5120\pi G^2 M^3/(\hbar c^4)$.

This is an explicitly idealized pedagogical estimate. It omits greybody transmission, the temperature-dependent spectrum of available particle species, angular momentum, charge, accretion and surrounding radiation. Extrapolation of the semiclassical approximation to the last stage is not a measurement or a complete quantum-gravity treatment.

Dimensional checks: $\hbar c^3/(GMk_B)$ has units K; $G^2M^3/(\hbar c^4)$ has units s; $GM^2/(\hbar c)$ is dimensionless. With the recorded approximate solar mass, the solar temperature is about $6.17 \times 10^{-8}$ K, τ about $2.10 \times 10^{67}$ years, and $S_{BH}/k_B$ about $1.05 \times 10^{77}$. At $10^9$ solar masses, temperature is lower by $10^9$, lifetime longer by $10^{27}$,

and entropy larger by $10^{18}$: τ about $2.10 \times 10^{94}$ years and $S_{BH}/k_B$ about $1.05 \times 10^{95}$. The original $10^{97}$-year claim is incompatible with the original $10^{67}$-year normalization and $M^3$ scaling.

For comparison with the Cortês–Liddle relation, differentiate rather than divide totals: $dS_{BH}/dM = 8\pi k_B GM/(\hbar c)$, so $T_H\, dS_{BH} = c^2\, dM = dE$. A decrease of black-hole entropy with magnitude $k_B \ln 2$ corresponds, differentially, to emitted energy $k_B T_H \ln 2$. This is not the claim that each emitted particle is one bit, that radiation entropy equals the hole's entropy decrease, or that the complete evaporation process is thermodynamically reversible. $T_H$ varies during evaporation. For Kerr, the first law includes rotational work and this Schwarzschild reduction cannot simply be copied unchanged. [I01, I19, I32]

### *I-CALC-02 Bekenstein and Kerr units and limits*

For $S \le 2\pi k_B ER/(\hbar c)$, ER and ħc both have units J m. The right side has units J/K. Dividing by $k_B \ln 2$ gives a dimensionless number of entropy bits, not a quantity of work in joules.

For uncharged Kerr, define $a = J/(Mc)$, $\chi = ac^2/(GM) = Jc/(GM^2)$, and $r_+ = (GM/c^2)[1 + \sqrt{(1 - \chi^2)}]$. The horizon area $A = 4\pi(r_+^2 + a^2) = 8\pi G^2M^2[1 + \sqrt{(1 - \chi^2)}]/c^4$. Substitution into $S = k_BA/(4\ell_P^2)$, with $\ell_P^2 = G\hbar/c^3$, gives $S_{Kerr} = 2\pi k_B GM^2[1 + \sqrt{(1 - \chi^2)}]/(\hbar c)$. Thus at fixed M and $|\chi| \le 1$:

$$S_{Kerr} / S_{Schwarzschild} = [1 + \sqrt{(1 - \chi^2)}] / 2$$

which lies between 1/2 and 1. Finite entropy at fixed finite M is established for this family; no statement about the universe's total volume or entropy follows. At fixed M, more spin means smaller area, so inserting a Schwarzschild formula for a spinning hole overestimates that horizon entropy. This conditional family comparison is not a general bound for any arbitrary finite region. [I09, I32]

### *I-CALC-03 Reset reference and heat versus production*

$k_BT \ln 2$ at 300 K equals approximately $2.87098 \times 10^{-21}$ J; at 310 K it is $2.96668 \times 10^{-21}$ J. $k_B$ has units J/K, T has K and ln 2 is dimensionless. Mean heat is the relevant quantity in the familiar statistical reset statement. The limiting ideal reset in the text uses equal intrastate entropies, unchanged endpoint energetics, an unbiased initial bit, an initially uncorrelated thermal reservoir, and no correlated side information used.

If one assumes the original's $4.2 \times 10^{-21}$ J and 300 K, the ratio is approximately 1.463, or 46.3 percent above the reference, not 44 percent with these stated inputs. This arithmetic does not adjudicate an experimental central value or substitute for Hong's uncertainty and actuation boundary. The body therefore uses the paper's qualified consistency result and omits a spuriously exact percentage. [I16]

In an ideal isothermal reversible reset, the memory's thermodynamic entropy change is $-k_B \ln 2$ and the bath's entropy change is $+k_B \ln 2$. Their sum tends to zero. A positive heat transfer is therefore not by itself positive total entropy production. Exact saturation and perfectly pure reset are limiting idealizations, particularly for a finite-temperature finite reservoir. [I12]

### *I-CALC-04 Reversible change in entanglement*

Start with $|00\rangle$. Apply a Hadamard gate to the first qubit and a controlled-NOT to the second. The result is $|\Phi^+\rangle = (|00\rangle + |11\rangle)/\sqrt{2}$. Both joint density operators have spectrum (1, 0, 0, 0), so both have zero von

Neumann entropy. Afterward each reduced density matrix is the identity divided by 2 and has entropy $k_B$ ln 2. Applying the inverse two-gate sequence returns the original state.

This algebra is a counterexample to identifying subsystem entanglement increase with an unavoidable global entropy increase. It makes no claim that a macroscopic measurement can practically be reversed at no cost or that laboratory gates are dissipationless.

### *I-CALC-05 Original neuromorphic arithmetic*

1 pJ = $10^{-12}$ J and 1 fJ = $10^{-15}$ J. The minimum ratio implied by the supplied ranges is $(20 \times 10^{-12})/(10 \times 10^{-15}) = 2{,}000$. The maximum is $(50 \times 10^{-12})/(1 \times 10^{-15}) = 50{,}000$. The manuscript's 5–50 comparison is numerically wrong. Neither endpoint establishes a common event, complete energy accounting or comparable performance. No repaired biological advantage is derived.

The separate ratios $10^9/10^6 = 1{,}000$ and $10^7/10^6 = 10$ are arithmetically correct but scientifically unsupported as universal substrate constants. Arithmetic validity cannot repair those premises, so the proposed ranking and convergence projection remain withdrawn.

### *I-CALC-06 Reversible embedding of an output filter*

For an n-bit input x and an m-bit function value f(x), define $F(x, y) = (x, y \oplus f(x))$, where y is m bits and $\oplus$ is bitwise exclusive OR. Then $F(F(x, y)) = (x, y \oplus f(x) \oplus f(x)) = (x, y)$, so F is its own inverse. With y initially zero, the output register contains f(x), while x remains available. For the two-input-bit AND example with a one-bit auxiliary register, direct enumeration of all eight input states confirms the inverse relation.

This construction establishes logical reversibility of an embedding, not zero total physical cost. Initialization, storage, speed, control, readout, reliability, uncomputation and reuse must be included in a physical implementation. It defeats the inference from “output filtering” alone to mandatory erasure of the full input at each framework stage. [I13]