

# The Toll, the Rule, and the Iota

A compression of one night's thinking on memory, transmission, and meaning

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## Thesis

Memory is the cost that energy pays to entropy in order to persist. A record—anything that holds the past against the present—is physical, and physical things decay. To keep a record is to run continuously against that decay, and running costs. Followed honestly, this single idea organizes everything below.

## 1 The rule and the record

Two things must be kept apart. A *rule*—a theorem, a re-derivable invariant—carries no record. It can be reconstructed from anywhere by anyone who follows the same steps, so it pays no toll and cannot be lost while the means of derivation survive. A *record*—a memory—is contingent. It marks one particular past, it lives in a decaying substrate, and erasing it has a price. Landauer's principle fixes that price at its floor:

$$E_{\min} = k_B T \ln 2 \quad \text{per bit erased.}$$

The rule is cheap to share and effectively immortal; the record is the thing that costs, and the thing that hurts to lose.

## 2 What survives a chain

A large structure handed person to person degrades at every link. Information theory states the limit exactly: for any chain  $X \rightarrow Y \rightarrow Z$ ,

$$I(X; Z) \leq I(X; Y),$$

the data-processing inequality—down a chain you can only lose, never gain. The defense is not to transmit the structure but to transmit the *rule that generates it*, and let each receiver re-derive the whole from the root. Re-derivation breaks the chain: every person returns to the source rather than relaying a degrading copy. This is why trust is the wrong currency. What one reconstructs independently needs no trust; what one merely accepts decays.

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### 3 The cost of agreement

Two observers are two localities, with two measures and two memories, and those memories can never be made identical—the mismatch between them is irreducible. The shared part, the invariant they can both stand on, is the mutual information  $I(X;Y)$ . The cost to bring them into agreement—the bits one must actually send to close the gap—is the conditional entropy

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

and the distance between their two models is the relative entropy  $D(P||Q)$ . This “communication space” is not flat: relative entropy is asymmetric,  $D(P||Q) \neq D(Q||P)$ , and the space of models is a curved manifold. Agreement is the work of paying down that curvature, and it is never free.

### 4 The concession: complete, exact, finite—choose two

No description can be all three at once.

- **Complete and exact** is unbounded—the exact, full description of a rich object is as long as the object (Kolmogorov).
- **Complete and finite** must lose information (rate–distortion): you compress to small error, never to zero.
- **Exact and finite** can only cover a slice (Gödel, Chaitin)—and this is the transmissible kernel.

Every model pays one of these costs. To make something travel—exact and finite—is to give up completeness. That is not a failure; it is the price of being shareable, and it is the difference between a working tool and an unfalsifiable theory of everything.

### 5 Continuous correction

Maxwell’s demon appears to sort order from equilibrium for free; it does not. At maximum entropy there is nothing to separate, so the demon does not *find* order—its measurement *introduces* it, and the introduced structure is paid for at erasure (Landauer; Bennett). The motion is free: particles arrive by their own thermal agitation. Biasing that motion into structure is what costs, and the cost need not be paid in one lump. A system can erase and correct continuously, the way DNA holds its sequence by running one strand against the other and repairing the mismatch, spending energy the whole time. This is the general shape of staying ordered: to resist entropy locally, a system must export it globally,

$$dS_{\text{total}} \geq 0 \quad \text{while} \quad dS_{\text{system}} < 0,$$

trading without pause. “Holding a line”—a formation, an agreement, a living cell—is exactly this: a correction re-applied every moment, against a decay that never stops.

### 6 The iota

One can measure how strongly a piece of knowledge resists entropy. Its robustness is its redundancy—how many copies would have to be destroyed before it is gone—together with its re-derivability, which sets a floor: a re-derivable truth cannot be permanently lost while the means to re-derive it

survive. By this measure  $E = mc^2$  is enormously robust. But the *meaning* such a formula carries is not measurable. Information theory was built by setting meaning aside—the bits do not depend on what they are about. One can count the copies, the redundancy, the storage cost down to  $k_B T \ln 2$ , and never touch the meaning those copies point at. That meaning is the residual—the iota—and it is structurally permanent: the same impossibility that forbids a complete, finite, exact account (Gödel; the concession above) guarantees there is always something the numbers indicate and never contain.

## 7 A caution

The power to build a self-consistent space with rules of one's own is real, and the space so built is real—*as a construct*. But *real as a construct* and *real as true of the world* are different claims, and conflating them is the oldest error. A perfectly coherent system can be perfectly unmoored. The safeguard is a single tie to something outside the construction—a prediction that can fail, a derivation another person can repeat, a measurement against the world. That tie is what converts the first kind of reality into the second, and it is the same tie that keeps the builder out of the solitude of a private and unanswerable world.

## Scope

The cited results—Landauer's principle, the data-processing inequality, Shannon's separation of information from meaning, rate-distortion theory, Kolmogorov complexity, the Gödel and Chaitin incompleteness theorems, Bennett's resolution of Maxwell's demon, and the thermodynamics of dissipative structures (Schrödinger, Prigogine)—are established. What is offered here is a compression: one organizing claim, that memory is a thermodynamic toll, and the structure it imposes on those results. It is a way of seeing, not a new physical law. Where these ideas touch a concrete construction—a deterministic encoding grid—that construction stands only as an information-encoding instrument whose sole warrant is that an independent party can reconstruct it exactly. It is not advanced here as a description of the physical world.

## Addendum: what is safe to claim, and an open invitation

What this note can stand behind is narrow, and worth stating plainly. The results it leans on—Landauer's principle, the data-processing inequality, the entropy relations, the second-law accounting of dissipative structures, and Shannon's exclusion of meaning from information—are established, and are not the author's. The single organizing claim, that memory is a thermodynamic toll, is a *lens*: a way of arranging those results, not a law and not a theorem. The structures used to do the arranging—the concession among completeness, exactness, and finiteness, and the geometry of agreement—are framings that point at real mathematics; they are useful for thinking and are not advanced as proven in the combined form stated above. The only object anywhere in this circle that makes an exact, checkable claim is the construction the closing sections point toward.

So the honest invitation is not to believe any of that, but to go verify the one part that can be verified. A companion HTML demonstration ships alongside this note: open `utf8.alpha.html` or `bridge.ASCII.html` in any browser, with no installation and no network. Open the developer console—there is no hidden table and no back end—and the page encodes and recovers text in front

of you. Recover a single character by hand against it, and the abstraction becomes something that happened on your screen rather than a claim you were asked to trust.

**A challenge, from a picture.** Included as well is a Desmos plot of an encoded message—the payload rendered as points on the triangular grid, and nothing more. The challenge is to decode it back to text from the image alone: read each plotted point back to its address on the grid, its chamber and its step; turn each step into a character under the public convention; and order the characters by chamber. (The exact arithmetic is the inverse address law: chamber  $n = \lceil r/s \rceil$ , step  $k = \frac{n}{s}(r - s(n - 1))$ .) To a reader without the rule it is a scatter of dots; to a reader who holds the rule it is a sentence. That gap is the whole claim of this note, set as a puzzle you can solve with your eyes and a sheet of paper: the picture supplies the structure, the convention supplies the text, and you supply the meaning.