Toward a Mathematical Home for our Classical Phenomenome

Finding (in broad outline) a mathematical model of the universe within which the ***complex*** world we see is ***typical*** of what the model predicts ***we*** (i.e. structures capable of thought) would see.

Sidney Harris has a cartoon of a group of cosmologists in front of a blackboard. One says

"Now, if we run our picture of the universe backward several billion years we get something resembling Donald Duck. Clearly there's a fallacy here."

To attack these questions we need to understand

Notions of complexity and entropy

- Kolmogorov, Turing space/time complexity, gate complexity, logical depth, action complexity
- Algorithmic, statistical, thermodynamic entropy.

Kinds of models, ranging in ambition and realism from deterministic or stochastic cellular automata to quantum field theories and models of eternal inflation.

Arrow of time and fine tuning questions: Must a model be, in some sense, **reversible** to be plausible?

If so, can reversible models generate enough complexity while at the same time escaping the Boltzmann brain problem?

Disciplines or areas of Expertise (raise hands):

- Computability, computational complexity and algorithmic information
- General relativity
- Quantum field theory
- Big bang, Inflation, Eternal inflation theories
- Fault tolerance and dissipative and/or topological stabilization of computation and memory
- Decoherence theory and emergence of classicality
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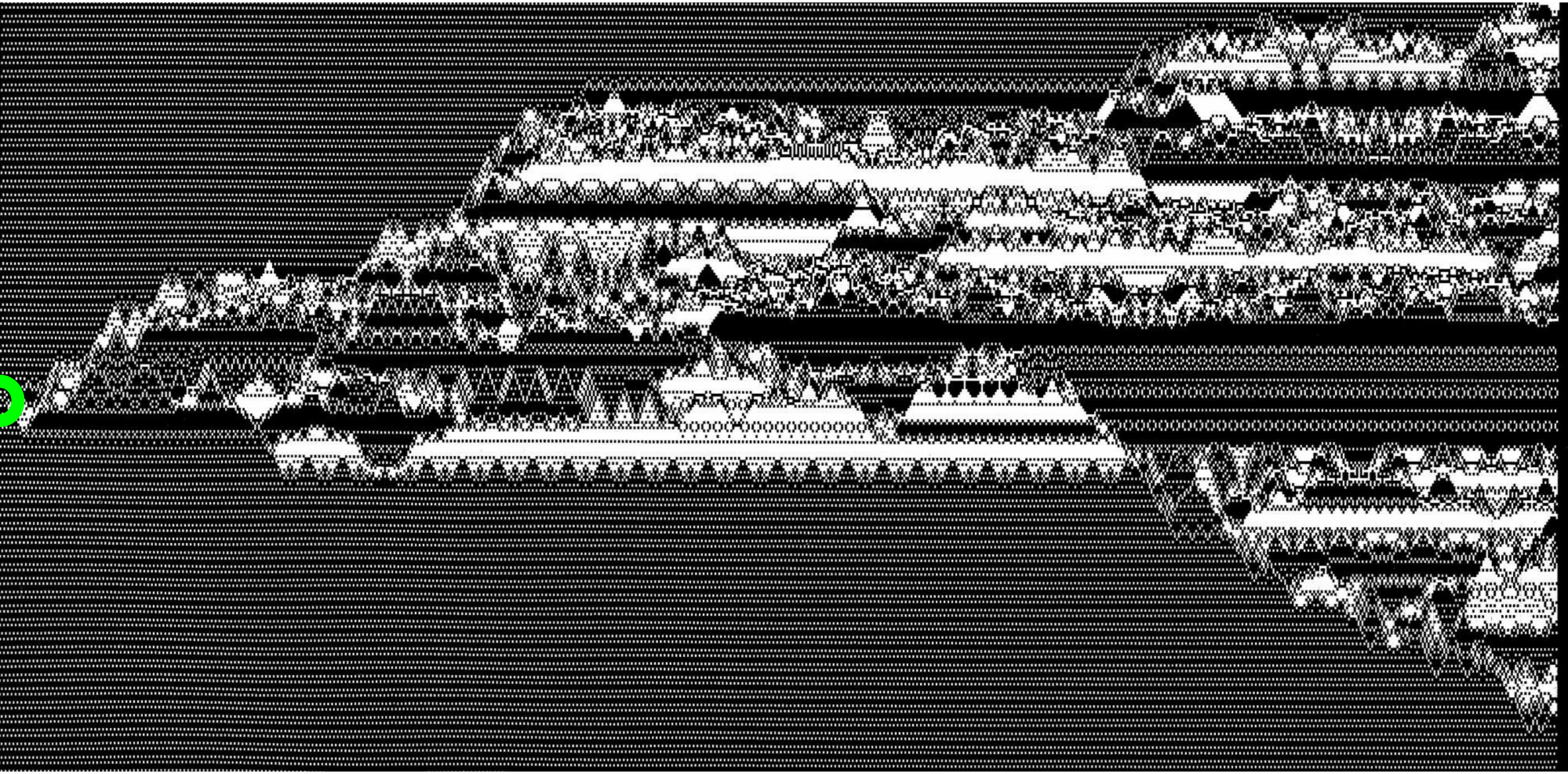
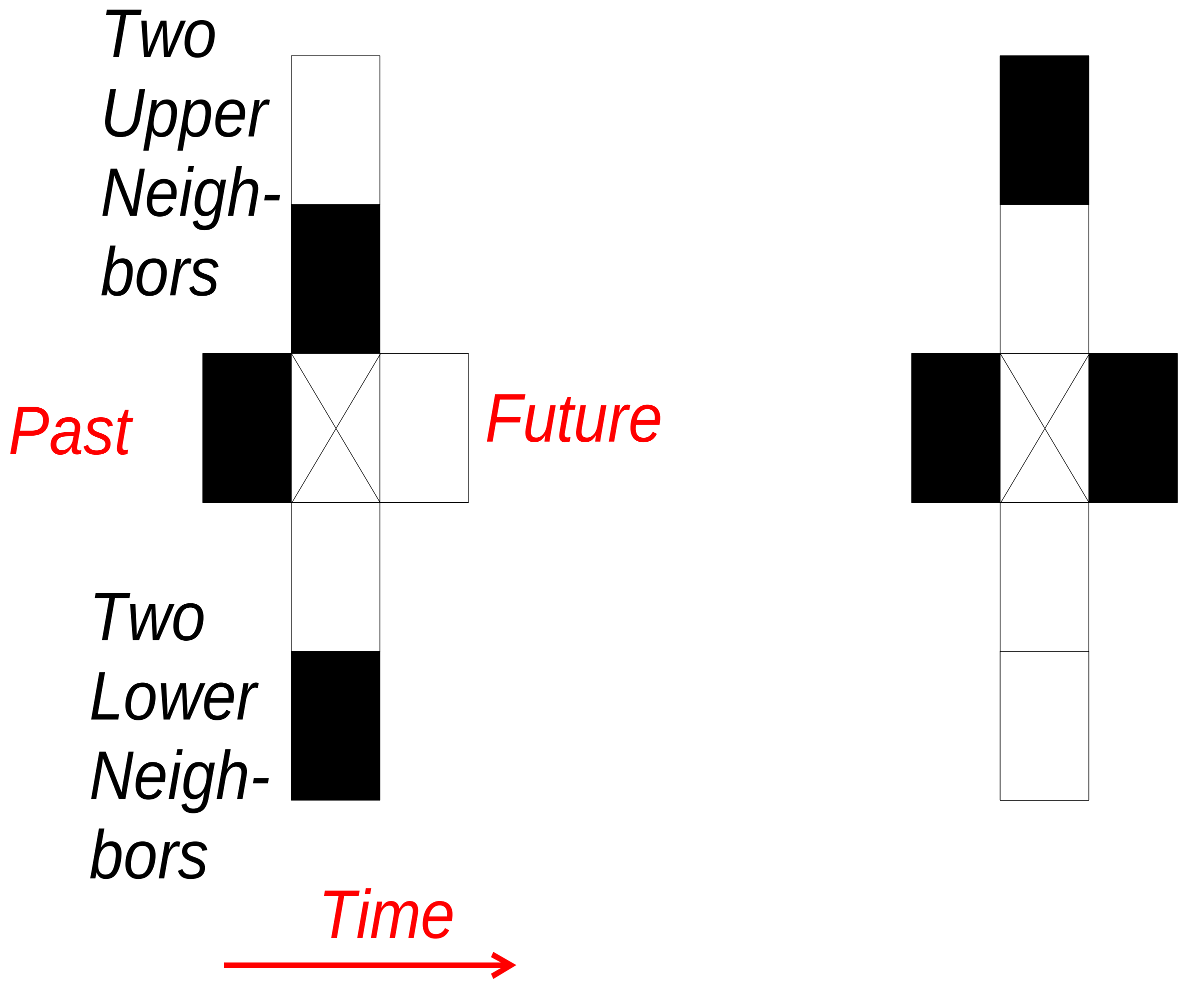
Simple classical dynamics (such as this 1 dimensional reversible cellular automaton) are easier to analyze and can produce structures of growing "complexity" from simple initial conditions.

time ⟶



Small irregularity (green) in otherwise periodic initial condition produces a complex deterministic wake.



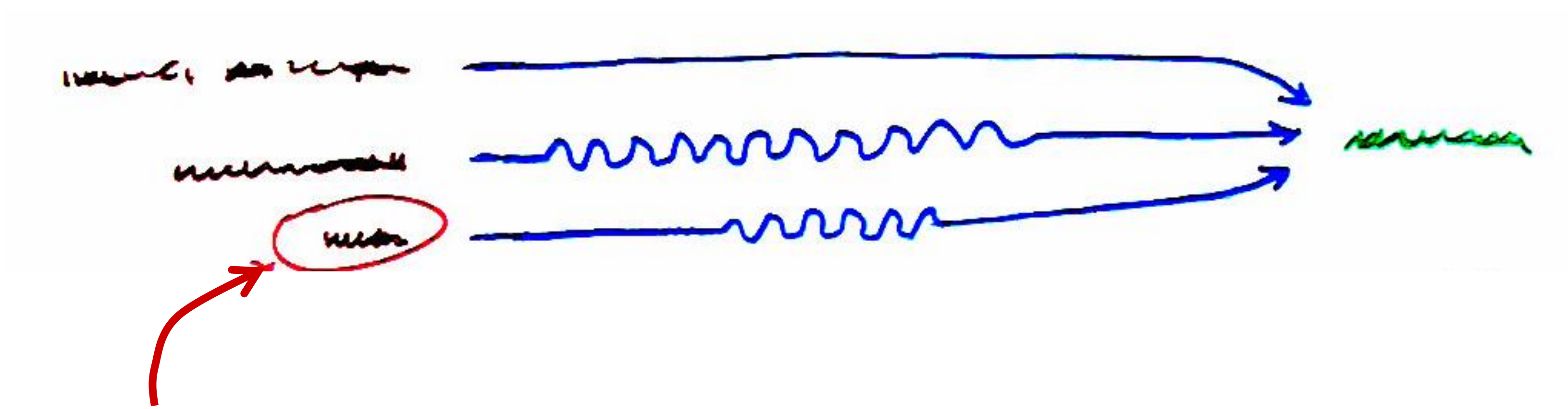
Range-2, deterministic, 1-dimensional Ising rule. Future differs from past if exactly two of the four nearest upper and lower neighbors are black and two are white at the present time.

Occam's Razor

Alternative hypotheses

Deductive path

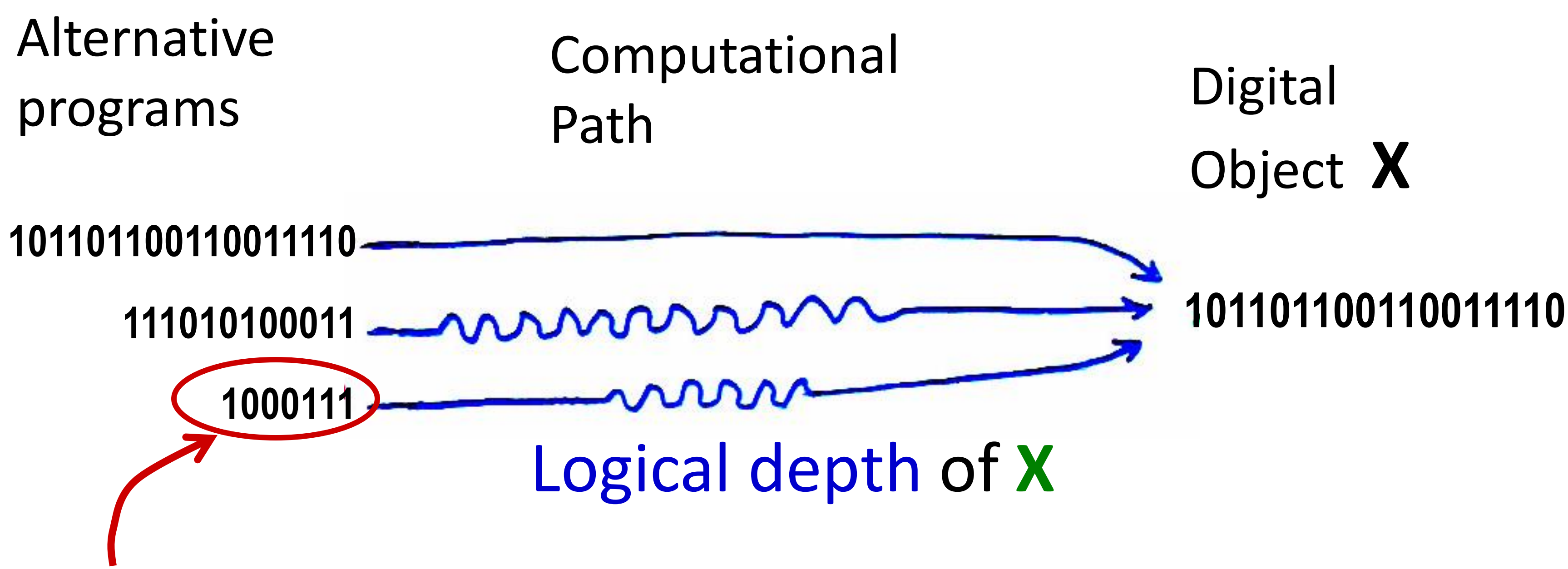
Observed Phenomena



The most economical hypothesis is to be preferred, even if the deductive path connecting it to the phenomena it explains is long and complicated.

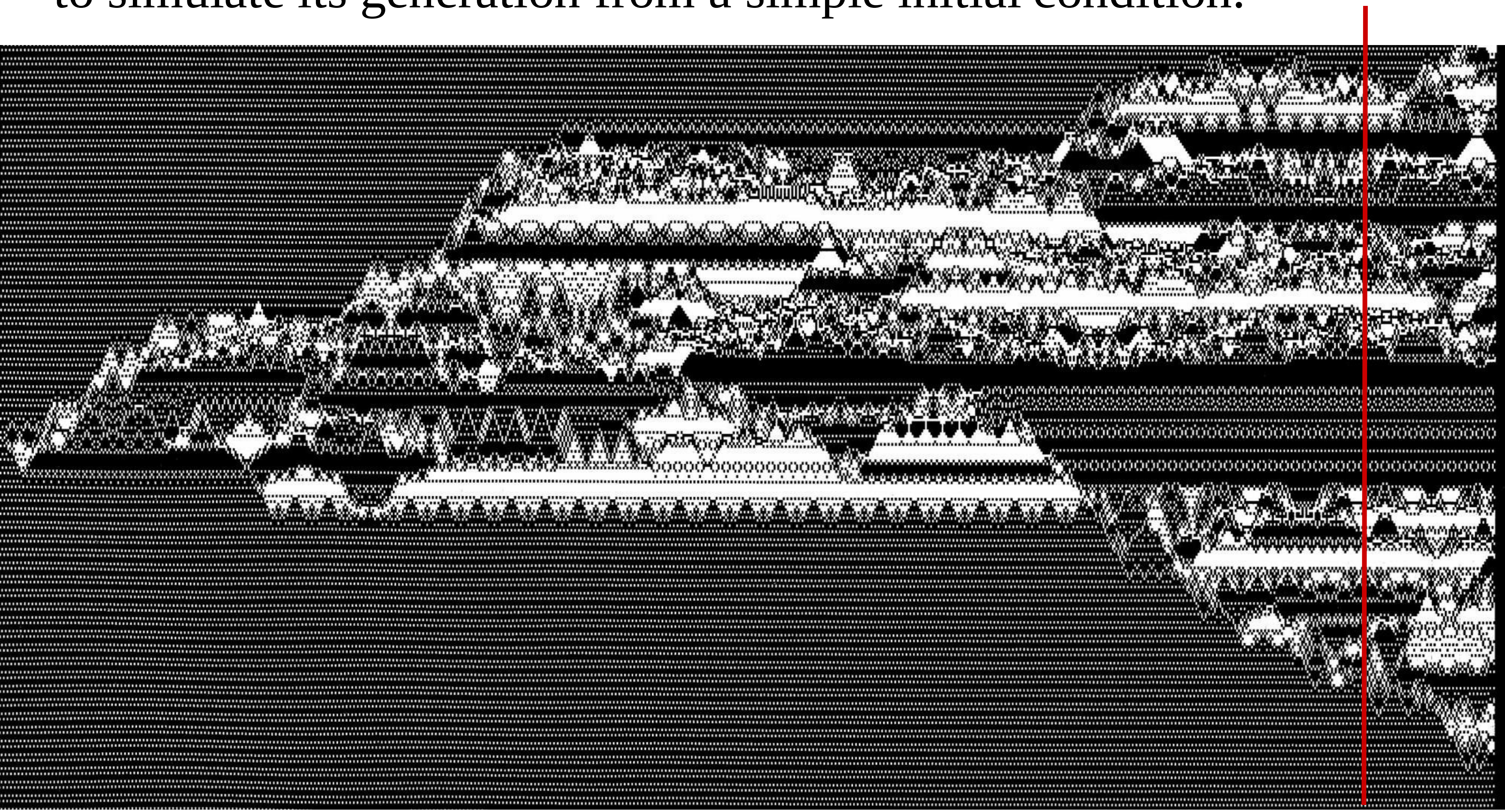
But how does one compare economy of hypotheses in a disinterested way?

In a computerized version of Occam's Razor, the hypotheses are replaced by alternative programs for a standard universal computer to compute a particular digital (or digitized) object **X**.

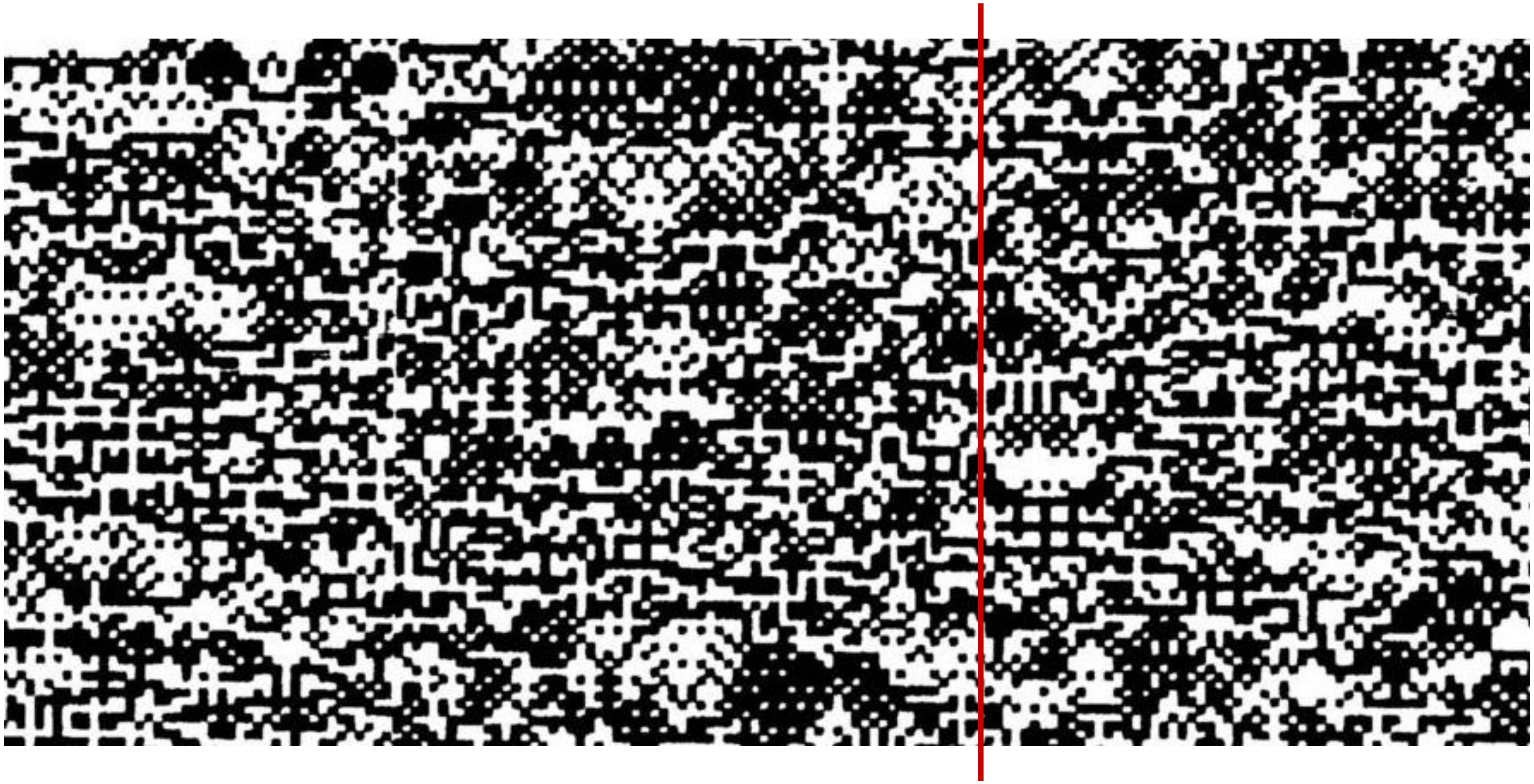


The shortest program is most plausible, so its *run time* measures the object's logical depth, or plausible amount of computational work required to create the object.

Initially, and continuing for some time, the logical depth of a time slice increases with time, corresponding to the duration of the slice's actual history, in other words the computing time required to simulate its generation from a simple initial condition.



But if the dynamics is allowed to run for a large random time after equilibration (comparable to the system’s Poincaré recurrence time, exponential in its size), the typical time slice becomes shallow and random, with only short-range correlations.



The minimal program for this time slice does not work by retracing its actual long history, but rather a short computation short-circuiting it.

Why is the true history no longer plausible?

Because to specify the state via a simulation of its actual history would involve naming the exact **number** of steps to run the simulation.

This number is typically very large, requiring about $\boldsymbol{n}$ bits to describe.

Therefore the actual history is no more plausible (in terms of Occam's razor) than a "print program" that simply outputs the state from a verbatim description.

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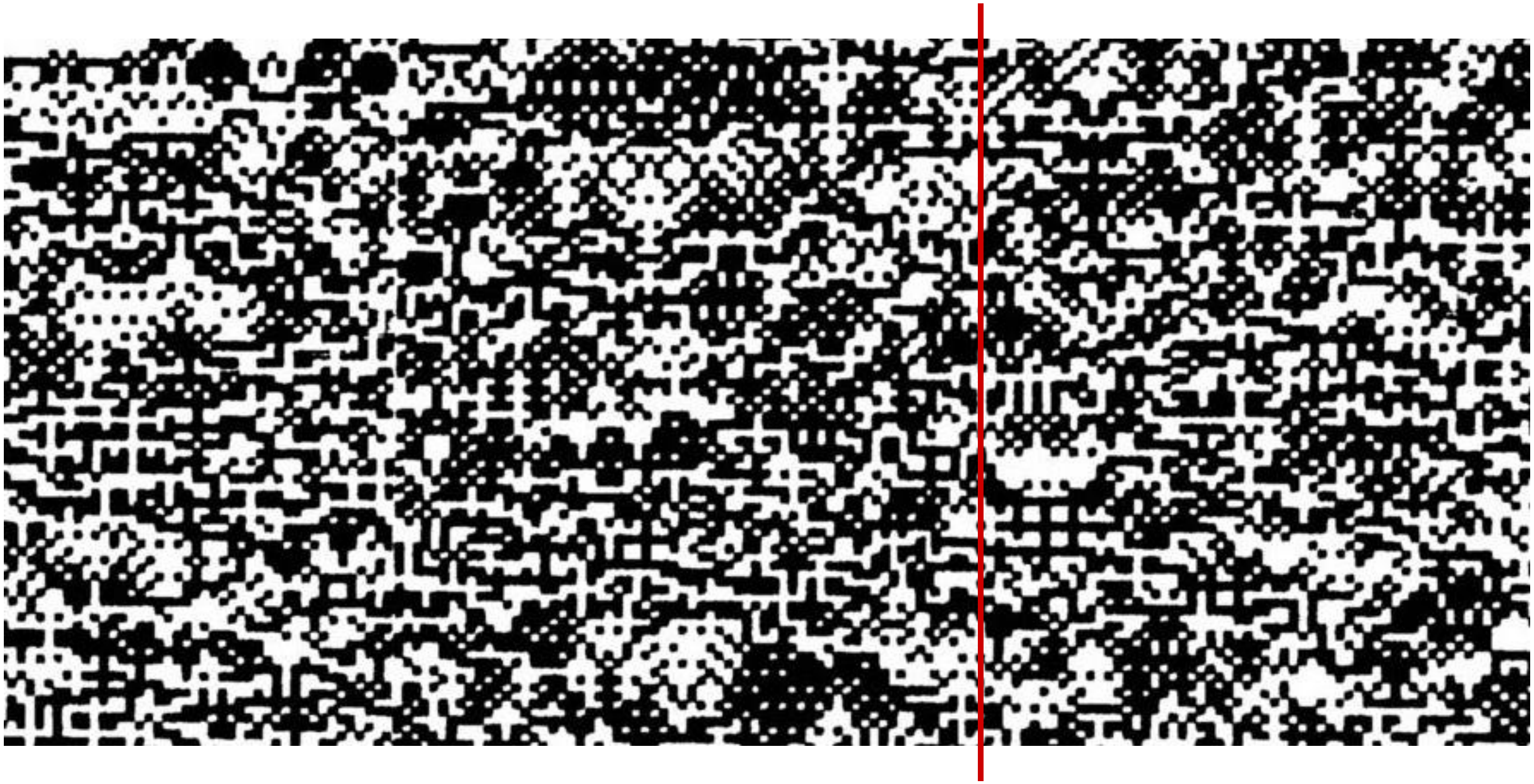

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The cellular automaton is a classical toy model, but real systems with fully quantum dynamics behave similarly, losing their complexity, their long-range correlations and even their classical phenomenology as they approach equilibrium.

If the Earth were put in a large reflective box and allowed to come to equilibrium, its state would no longer be complex or even phenomenologically classical.

The entire state in the box would be a microcanonical superposition of near-degenerate energy eigenststates of the closed system. Such states are typically highly entangled and contain only short-range correlations.