**Challenge #2**

**J. P. Crutchfield, W. L. Ditto, and S. Sinha, “Introduction to Focus Issue: Intrinsic and Designed Computation: Information Processing in Dynamical Systems—Beyond the Digital Hegemony,” *Chaos: An Interdisciplinary Journal of Nonlinear Science*, vol. 20, no. 3, p. 037101, Sep. 2010, doi:** [**10.1063/1.3492712**](https://doi.org/10.1063/1.3492712)**.**

This paper introduces a collection of scholarly articles centered around a critical and timely theme: how dynamical systems store, transmit, and process information, and how this understanding can redefine computation beyond the limitations of digital technology.

The authors begin by highlighting an impending problem—the 2020 digital roadblock, referring to the stagnation of Moore’s Law. As scaling in silicon electronics hits physical limits, alternative computational paradigms rooted in dynamical systems emerge as potential game changers.

Key Themes Explored:

1. Intrinsic vs Designed Computation:
   * *Intrinsic computation* refers to the natural way systems store and process information, without reference to external utility (e.g., neurons firing, cells signalling).
   * *Designed computation* is purposeful, like classical computing machines built for solving problems.
   * The authors explore how intrinsic computation can inform and enhance designed systems, potentially leading to new computing paradigms.
2. Historical Foundations:
   * They revisit foundational work by Kolmogorov, Shannon, Chaitin, Wiener, and others who tried to quantify unpredictability, entropy, and complexity in both natural and artificial systems.
   * Notably, the cybernetics vision of Norbert Wiener is positioned as an underutilized framework that could inform future computational models.
3. Philosophical & Scientific Implications:
   * Questions such as “What is intelligence?” and “Can physical systems be inherently intelligent?” are posed.
   * The authors challenge the AI community’s digital-centric view by advocating for non-symbolic, physically grounded models of intelligence.
4. The Ubiquity of Computation:
   * Nature is inherently computational—whether in the brain, a weather system, or molecular networks.
   * This paper proposes methods to detect, measure, and leverage this computational behaviour across disciplines.
5. Contributions in the Focus Issue:
   * The paper previews a set of interdisciplinary contributions, including:
     + Chaogates: Logic gates built using chaotic systems.
     + Stochastic gene regulation in yeast as a model of noisy computation.
     + Rotor-router systems: Discrete models for analog-like computation.
     + Bayesian inference by neural architectures, and quantum dynamical systems as intrinsic computers.

This paper does more than introduce a collection of articles, it sets an intellectual agenda.

Strengths:

* Interdisciplinarity: It spans physics, biology, computer science, and philosophy—an essential step in redefining computation.
* Philosophical Depth: By probing what “computation” really means, it opens the door to redefining intelligence and information processing.
* Historical Grounding: It thoughtfully traces the lineage of ideas back to pioneers like Shannon, Kolmogorov, and Wiener, reinforcing the long-standing yet evolving nature of these inquiries.

What I Learned:

* Intrinsic Computation as a Quantifiable Property: The idea that natural systems *compute* even when not designed to do so—and that this computation can be quantified—is powerful and non-obvious.
* Computation ≠ Digital: The paper powerfully argues that computation need not be digital, symbolic, or even designed. This disrupts the typical view held in CS and AI.
* The Semiotic Gap: The distinction between meaningful, useful computation (as designed by humans) and natural computation (which may not have purpose but is rich in structure) is a subtle yet important philosophical leap.
* Physical Intelligence: Intelligence does not necessarily need to be symbolic or digital—it could be a property of a well-organized physical system.

For anyone working in computational neuroscience, bio-inspired computing, or unconventional computing (like Bhavana with spiking neurons and ASICs), this paper is a goldmine. It validates the idea that computing systems can be:

* Non-digital
* Dynamical and continuous
* Embedded in nature
* Designed with chaotic or probabilistic elements

It is especially useful when designing new architectures that do not rely on von Neumann or Turing-style computing but rather on information-rich dynamical behaviours like spiking neural arrays or quantum substrates.

I also tried connecting dots between this *Chaos journal focus issue* paper and the Johns Hopkins paper on *“Designing Silicon Brains using LLMs”* and modeling spiking neurons (e.g., RLU, Hodgkin-Huxley) with possible ASIC implementation via OpenLane.

1. From Designed to Intrinsic Computation

The Johns Hopkins paper talks about leveraging LLMs (like ChatGPT) to describe spiking neuron arrays. That fits squarely in the “designed computation” realm— intentionally using natural language tools to program silicon that mimics biology.

But the *Chaos* paper argues for something deeper: rather than *designing* systems that imitate brain-like behaviour, why not directly harness the intrinsic computation that exists in nature, such as:

* The way a neuron integrates signals (biophysical dynamics)
* The chaotic but stable firing of spiking neural networks
* The way a protein network evolves its state over time

The exploration of neuron models like Hodgkin-Huxley is literally an attempt to understand the *natural computation* done by ion channels and membranes. That is intrinsic computation in action.

2. Physical Substrates as Intelligent Systems

The Chaos paper asks: *Can intelligence be non-biological and physical?* The answer to that question is turning neurons into circuits. By building an ASIC-based spiking network, we are embedding intelligence into a physical substrate—exactly what the paper envisions.

The RLU neuron, for example, might be seen as a building block of “physical intelligence.” Same with silicon implementations of Hodgkin-Huxley dynamics. We are creating hardware that does not just process binary logic but also mimics rich, nonlinear, dynamic behaviour of real brains.

3. Chaogates and Chaotic Logic vs. Neuromorphic Design

The paper talks about *chaogates*—logic gates derived from chaotic systems that can morph into different gates on demand. That is not far from the goal: in neuromorphic design, we are encoding flexible behaviour using biologically-inspired nonlinear elements.