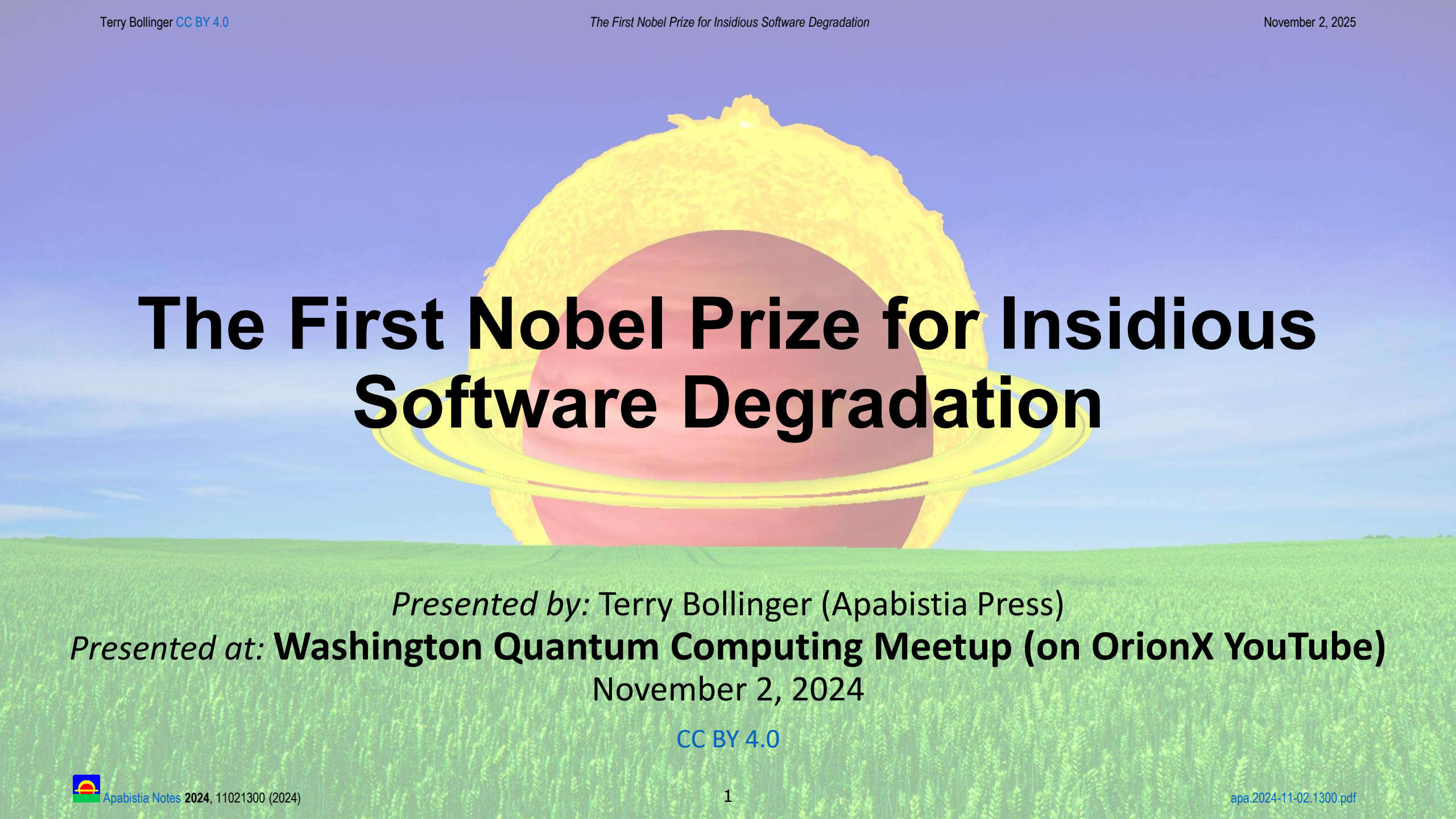


The First Nobel Prize for Insidious Software Degradation

Presented by: Terry Bollinger (Apabistia Press)

Presented at: **Washington Quantum Computing Meetup (on OrionX YouTube)**

November 2, 2024

Have you experienced anything like this?

Me: "Are schools open today, October 14, 2024?"

AI: "No, there were no classes on October 3, 2023."

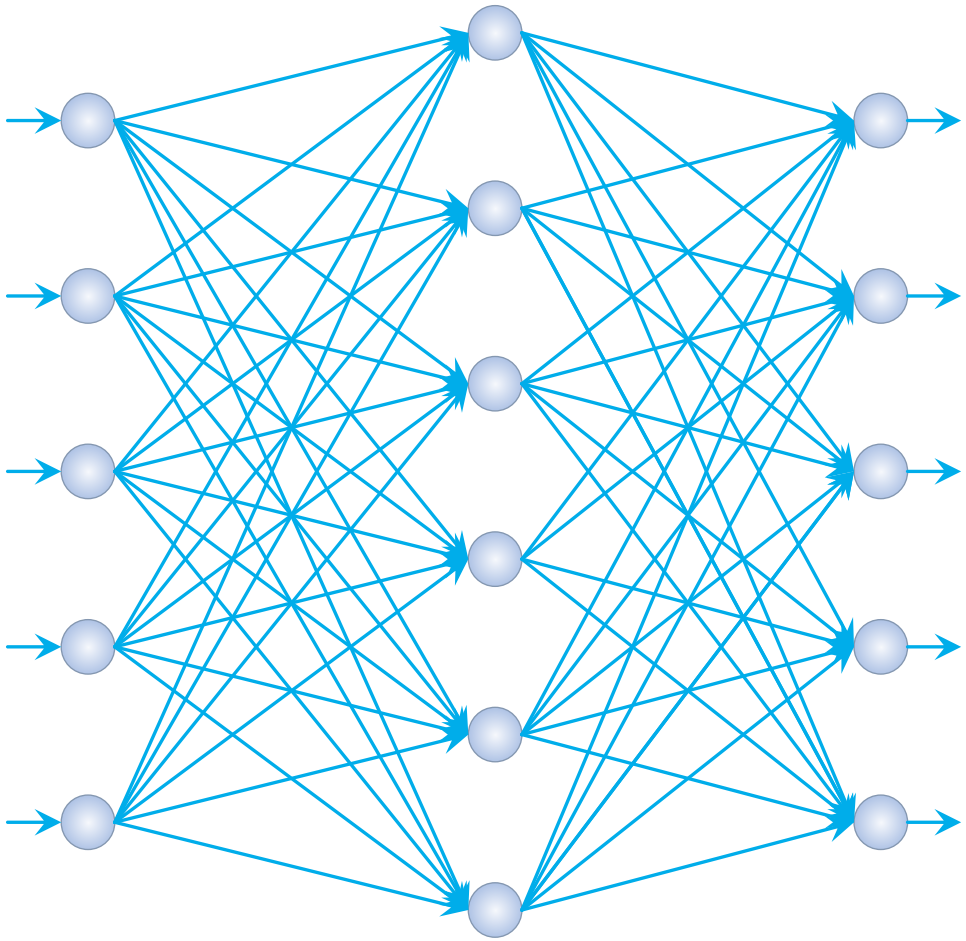
Why does this happen so often, and to so many people?

- Large Language Model (LLM) AIs follow a "what word sounds best next" path… and that's *all*. They are entirely mindless.
- LLMs achieve this goal by storing lots of human data in very clever, high-cost, but also lossy (noise-adding) data format.

Question: Why did the Swedish Academy of Sciences award its 2024 Physics Prize for massive, global over-deployment of a mindless, error-prone data compression algorithm?

Hopfield's Hope: Mistaking Data Formatting for Emergence

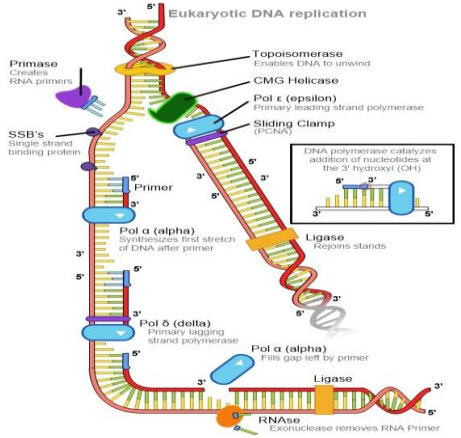
Data Organization in Neural Nets & LLMs



= High-Dimensional Holographic Data

***The Microscope**, Walter Spierings, 1984. Screen capture from "How Are Holograms Possible?," 3Blue1Brown, Oct 5, 2024, https://youtu.be/EmKQsSDIaa4?t=0m48s*

≠ Hopfield's "Improbable Emergences"



***Eukaryotic DNA Replication**, Wikimedia LadyofHats, Public domain, https://commons.wikimedia.org/wiki/File:Eukaryotic_DNA_replication.svg*

Hopfield's Clever Pseudo-Orthogonality Algorithm

The information storage algorithm

Suppose we wish to store the set of states V^s, $s = 1 \ldots n$. We use the storage prescription

$$T_{ij} = \sum_s (2V_i^s - 1)(2V_j^s - 1) \qquad [2]$$

but with $T_{ii} = 0$. From this definition

$$\sum_j T_{ij} V_j^{s'} = \sum_s (2V_i^s - 1) \left[\sum_j \left(2V_j^{s'} - 1 \right) \right] \equiv H_j^{s'} . \qquad [3]$$

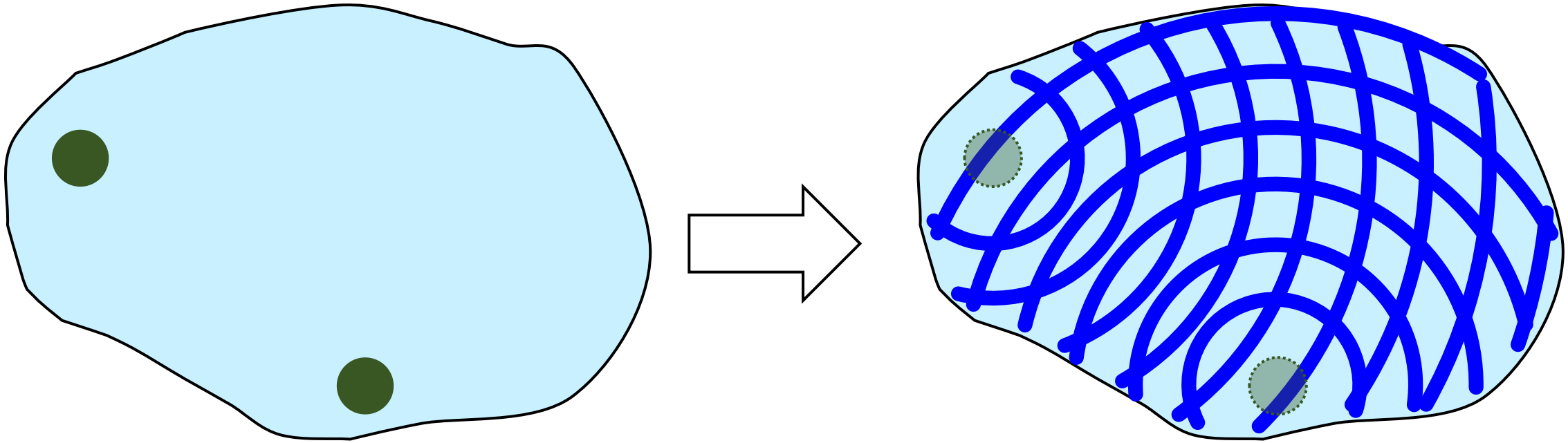
The mean value of the bracketed term in Eq. 3 is 0 unless $s = s'$, for which the mean is $N/2$. This pseudoorthogonality yields

$$\sum_j T_{ij} V_j^{s'} \equiv \langle H_j^{s'} \rangle \cong (2V_i^{s'} - 1)N/2 \qquad [4]$$

and is positive if $V_i^{s'} = 1$ and negative if $V_i^{s'} = 1$. Except for the noise coming from the $s \neq s'$ terms, the stored state would always be stable under our processing algorithm.

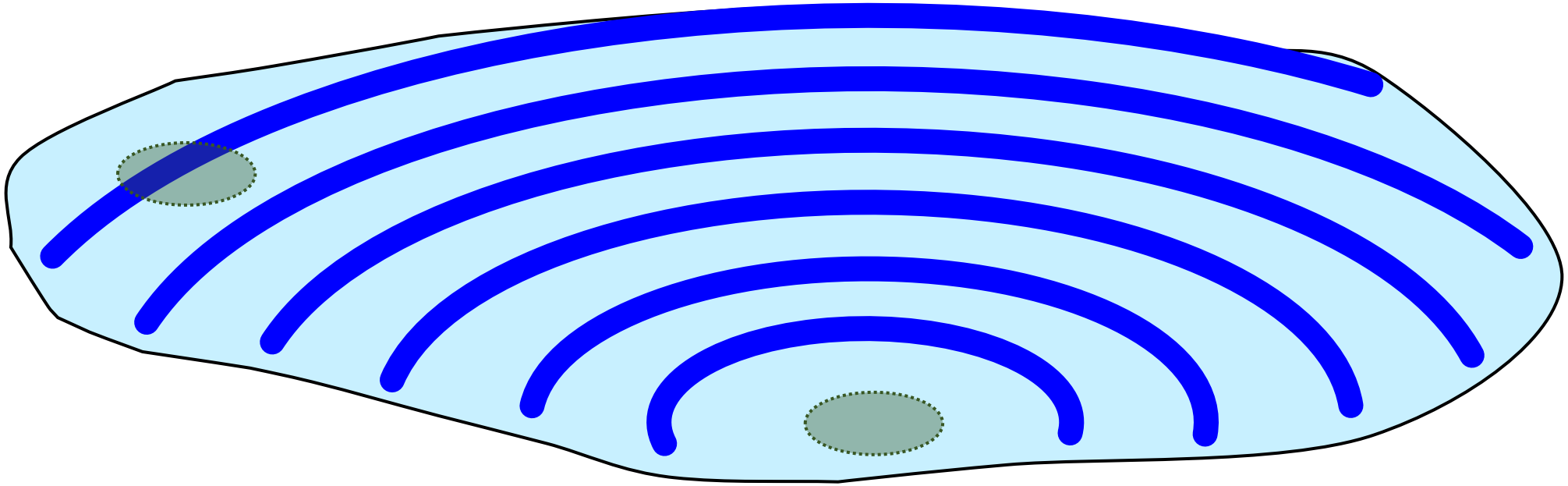
J. J. Hopfield, *Neural networks and physical systems with emergent collective computational abilities*, Proceedings of the National Academy of Sciences **79** (8), 2554–2558 (1982).

A Quick Holography Intro: The Pond Analogy



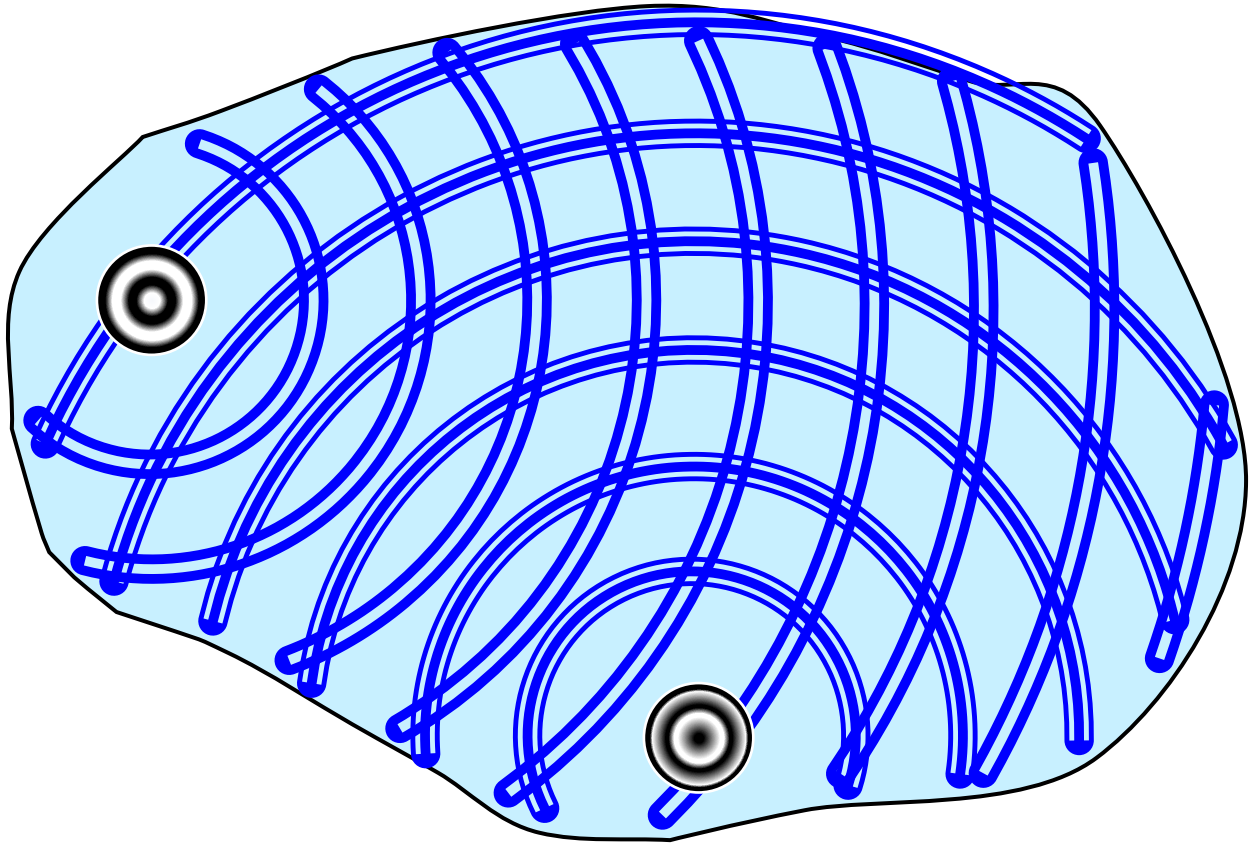
- Wave-particle duality is one of the deepest principles in nature
- The waves “encode” the two points almost as well as the stones
- Wave overlap (superposition) is *not* a problem in the wave view

Holography Encoding is Naturally Hebbian



- Reinforced access: The wave stands out as you get closer
- Close splashes build stronger waves (compression, nearness)
- The wide-spread wave is more tolerant of flaws in the surface

Extending Dimensionality Via Additional Coding



- If you make waves more complex, each splash can code more
- Well-coded (e.g., Walsh) waves are nicely pseudo-orthogonal

Two Important Corrections

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2024 jointly to

John J. Hopfield and **Geoffrey E. Hinton**

"for foundational discoveries and inventions that enable ~~*machine learning with artificial neural networks*~~*"*

compressed holographic data storage (∨)

pseudo-orthogonality of high-dimensional data (∧)

Scientific Background to the Nobel Prize in Physics 2024 for Foundational Discoveries and Inventions that Enable Machine Learning with Artificial Neural Networks, The Royal Swedish Academy of Sciences, Oct. 8, 2024.

Birth of the LLM Spontaneous Emergence Myth

The myth: *"The bridge between simple circuits and the complex computational properties of higher nervous systems **may** be the spontaneous emergence of new computational capabilities from the collective behavior of large numbers of simple processing elements."* — Hopfield 1982

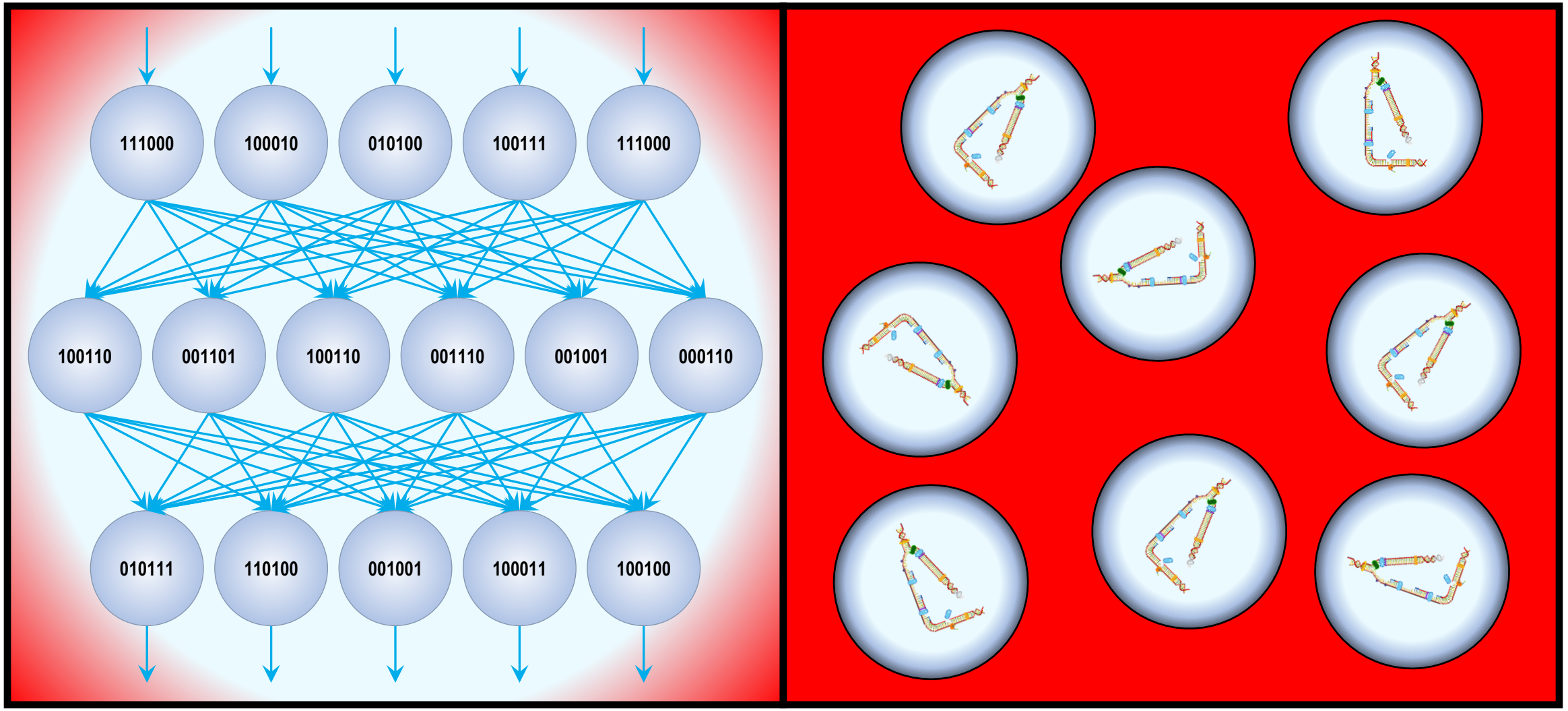
The reality: Hopfield devised a clever compression technique for storing unique data facts as "almost-orthogonal" vectors in a high dimensional, Hilbert-like holographic space. However, the data remains data. Hopfield's real innovation was auto-generation of Walsh-like pseudo-orthogonality codes help isolate the vectors.

What is Emergence?

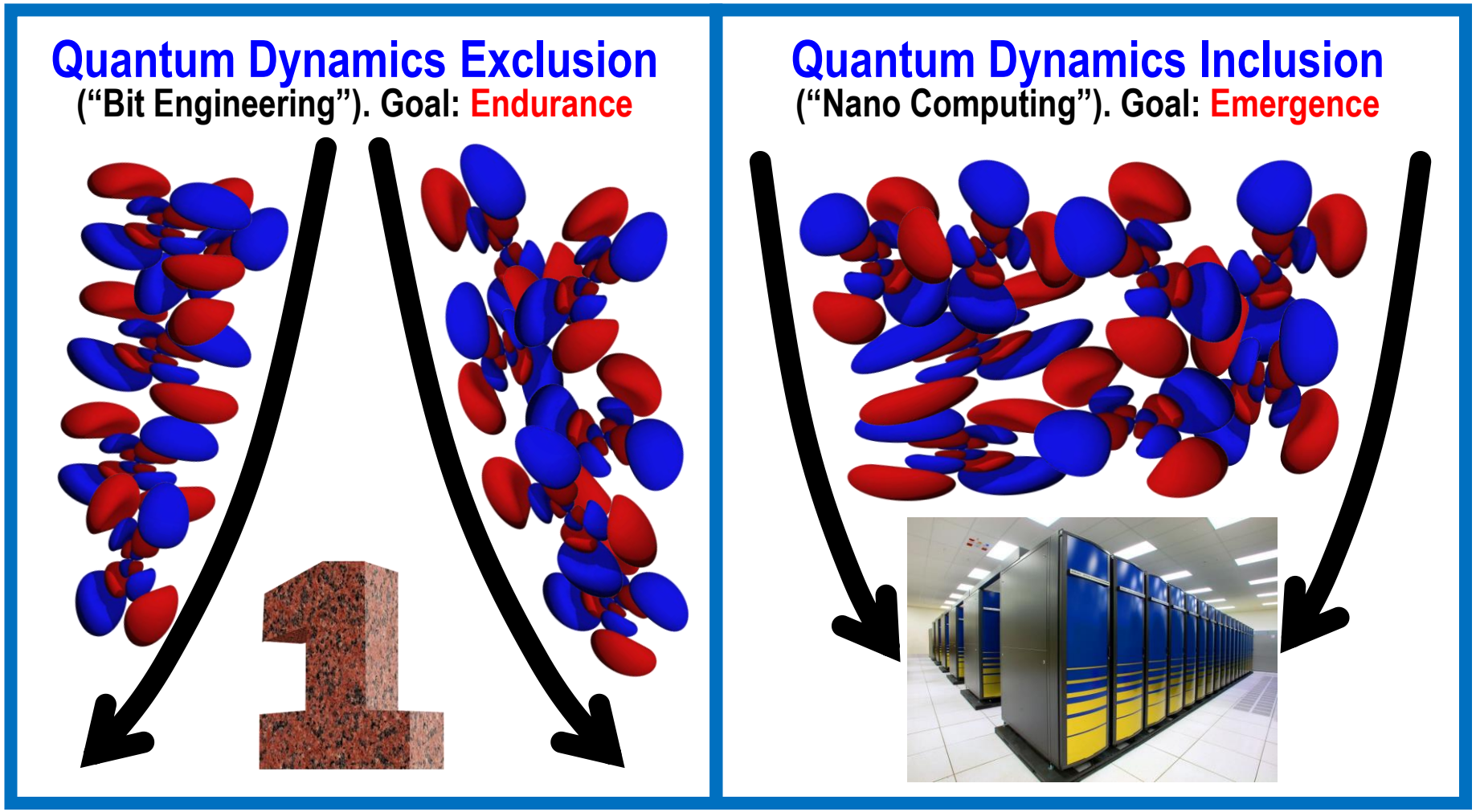
Folks call two very different phenomena “emergence.”

- Simplifying emergence discards & reduces complexity
  - Temperature is the classic example: Enormous numbers of extremely complicated molecular motions “average out” to the vastly simpler (but useful) concept of temperature.
- Implausible emergence beats impossible odds
  - Cellular metabolism is a vast collection of implausible *quantum-level* emergences (e.g., electron transfers) from thermally chaotic mixes of molecules (Hopfield 1974).

Classical Networking vs Quantum-Bio Emergence



A Quantum Emergence Surprise: Bits *Hate* Quantum



Hopfield's "Spontaneous Emergence"

When Hopfield said "spontaneous emergence" in 1982, what kind of emergence did he mean?

- His 1974 work firmly identified *implausible emergences*
- His 1982 "new computational capabilities" remarks suggests he believed he had found a new implausible emergence

The reality:

- By his own equations, the total complexity of the *data* stored in his clever networks is always lossy to varying degrees
- His "new" capabilities arise from his clever classical encoding

A Confusion of Causes

Hopfield in 1982: *"Additional emergent collective properties include some capacity for generalization, familiarity recognition, categorization, error correction, and time sequence retention."*

More accurately: *"Additional* ~~*emergent collective properties*~~ ***holographically distributed data properties*** *include some capacity for generalization, familiarity recognition, categorization, error correction, and time sequence retention."*

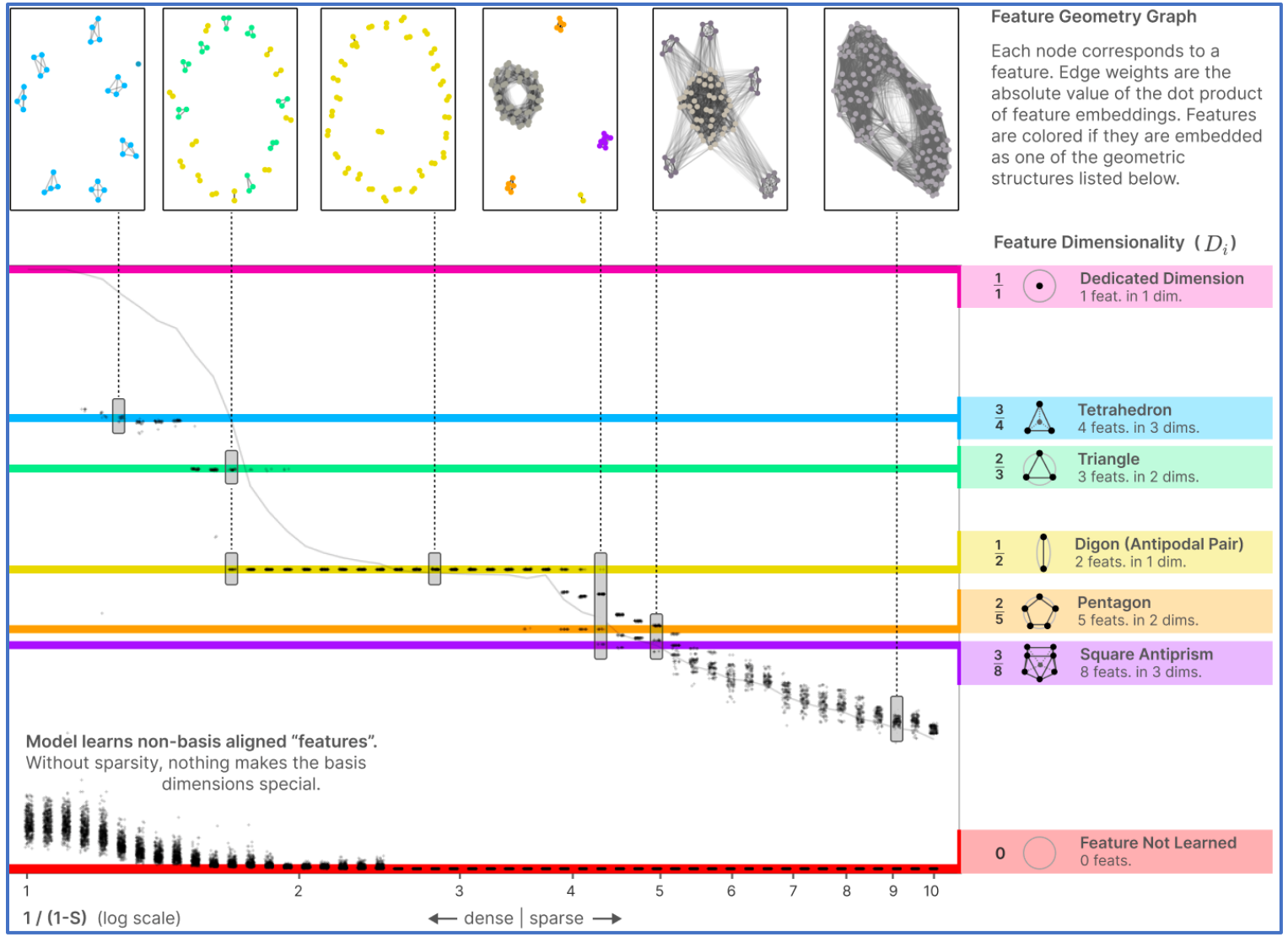
- Generalization = Near-axis access and matching to data items
- Familiarity = Access to existing data axes when new data is similar
- Categorization = Slotting of new data base on similarity to existing axes
- Error Correction = Close-match-access + resilience to localized flaws
- Time sequence recall = Similarity-based axis linkages (dot products)

2023: LLM Superposition Needs a Holographic Perspective

> *"Superposition is really annoying, really important, and terribly understood. Superposition is the phenomenon, studied most notably in Toy Models of Superposition [1], where models represent more features than they have neurons/dimensions. We consider understanding how to reverse-engineer circuits in superposition to be one of the major open problems in mechanistic interpretability."*

N. Nanda, S. Rajamanoharan, J. Kramár, and R. Shah, "Why superposition?" in *Fact Finding: Attempting to Reverse-Engineer Factual Recall on the Neuron Level*, AI Alignment Forum, Dec. 22 (2023).

LLM Geometries from a Holographic Perspective



N. Elhage et al., *Toy Models of Superposition*, Transformer Circuits Thread, Sep. 14 (2022). https://transformer-circuits.pub/2022/toy_model/index.html

Complex geometries found in LLM Toy data represent opportunities to explore holographic and code-based high dimensional vectors.

The Dangers of Cult Thinking in Science

- In most situations, Hopfield's unrealistic 1982 hope for improbable, quantum-like emergence in a "dead data" system with clever formatting would be no big deal
- However, as Feynman once noted, Cargo Cult science is always a danger. That is when beliefs bases on what superficial resemblances, such as error correction versus molecular quantum order emergence from chaos, dominate
- In this case, the Hopfield Hope cult of improbably emergence from dead data has already enabled massive, often subtle damage to domains that depend on facts, including software.
- The Nobel Physics Committee did *no one* a favor on this pick

Five Recommendations for Future LLM Research

1. **Drop Hopfield's "Spontaneous Emergence" Myth** for LLMs; transition to holographic interpretations with telecom crossovers
2. **Explore Optical Holographic Language Models** as a more efficient replacement for digital matrix multiplication
3. **Restart Molecules-as-Computers Research** as first proposed and self-abandoned by Yuri Manin in 1980
4. **Develop and Apply Improbable Emergence** to counteract persistent data holographic data degradation in ANNs and LLMs
5. **Develop Energy-&-Info Aware Formalisms** for modeling quantum dynamics; abandon naïve Hilbert space dynamics

1. Drop Hopfield's "Spontaneous Emergence" Myth

Thinking that chaos and chance are your friends in LLM design and training annihilates all changes of building reliable systems

- Linear interpolation between known cases the *opposite* of cognition, as is "guessing" at entropic language limits
- Actual cognition jumps into an incremental framework at such points: Looking at the problem from new angles, often literally

Never accept that emergence *must* happen with "enough" training

- This thinking *always* turns into a scale explosion of complexity
- It is the software-support version of an endless Ponzi scheme

2. Explore Optical Holographic Language Models

Replacing electronic (Hopfield *et al.*) pseudo-orthogonal holography with optical holography has interesting research potential

- The possibility of enormous energy cost reductions exists
- Such literally light-speed systems may also prove faster

Existing LLM research could inspire and guide the transition

- Borrow existing optical storage methods as starting points
- Reinterpret the total capacity of and LLM as an optical medium
- Look for ways to translate LLM structures into coded waveforms

3. Restart Molecules-as-Computers Research

First proposed and quickly self-abandoned by Yuri Manin in 1980

- Flip the usual perspective upside down: If modeling even small molecule requires supercomputers and quantum computers …
- … then what can one small molecule compute for us?
- This is closer to Feynman's 1982 view of quantum computing

Not an easy task! Molecules would be come tiny, hard-to-control, multi-function devices that no one know how to set or read

- Chemistry, especially that of enzymes, could be a starting point
- Bose condensates have some potential as "giant" single atoms

4. Develop and Apply Improbable Emergence

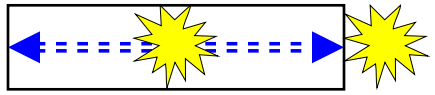
Dynamic emergence is *needed* to counteract persistent and inherent data holographic data degradation in ANNs and LLMs

- Scales needed for LLMs are beyond human capacities
- Current methods try (and fail) to use human correction

This is a hugely difficult problem!

- The biomolecules of life *may* give powerful example…
- … but they may be more akin to predesigned machines
- Likely important: What role does quantum play in improbably emergence? What do biomolecules do that machines cannot?

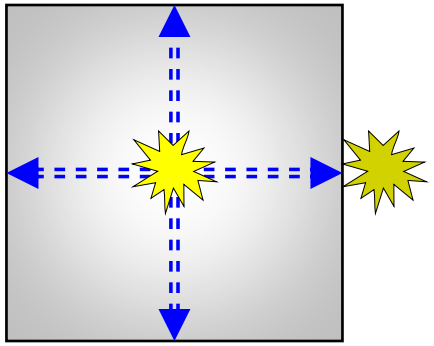
Sidenote: Hilbert Spaces Don't Model Dynamics Well



$n = 1$

constant

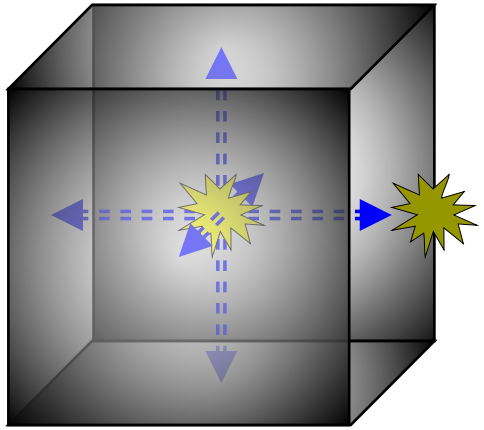
(color force)



$n = 2$

$1/r$

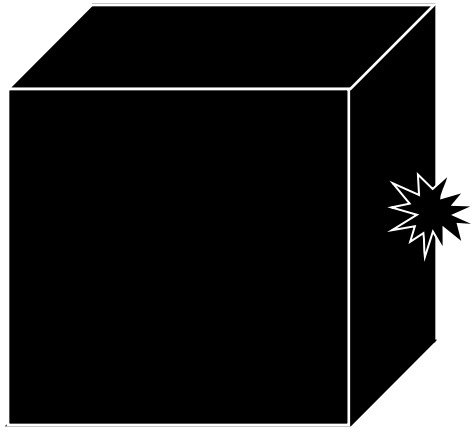
(pond waves)



$n = 3$

$1/r^2$

(electric force)



$n = \infty$

null

(Hilbert space

5. Develop Energy-&-Info Aware Formalisms

Math models such as Hilbert spaces map out *static* state spaces

- Real-world dynamics do not seem to work that way
- "Bursts" of local activity instead penetrate these dark infinities

Most math models include "fairy dust" (details not seen in physics)

- Example: A Bloch sphere with infinite number density at the top
- Example: Coordinate systems whose definition outdistance the speed of light (Einstein 1911 and "clouds of clocks")

Can math formalisms include energy, information, and lightspeed limits more naturally and at all experimental scales?