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A View on Some Laws and Principles in Computer Science: Are They Really Laws?

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A Recap on Scientific Laws

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Laws as Regularities

It is a mistake to assume that law-like behavior is caused by anything. *(David Hume's Opinion)*

- Fail to distinguish between accidental and law-like regularity
- Fail to identify the direction of causal dependency
- Suffer from exceptionlessness: most of the claims that are taken to be scientific laws do not qualify
- Not able to vindicate the validity of a law beyond the experimental domain

A Recap on Scientific Laws

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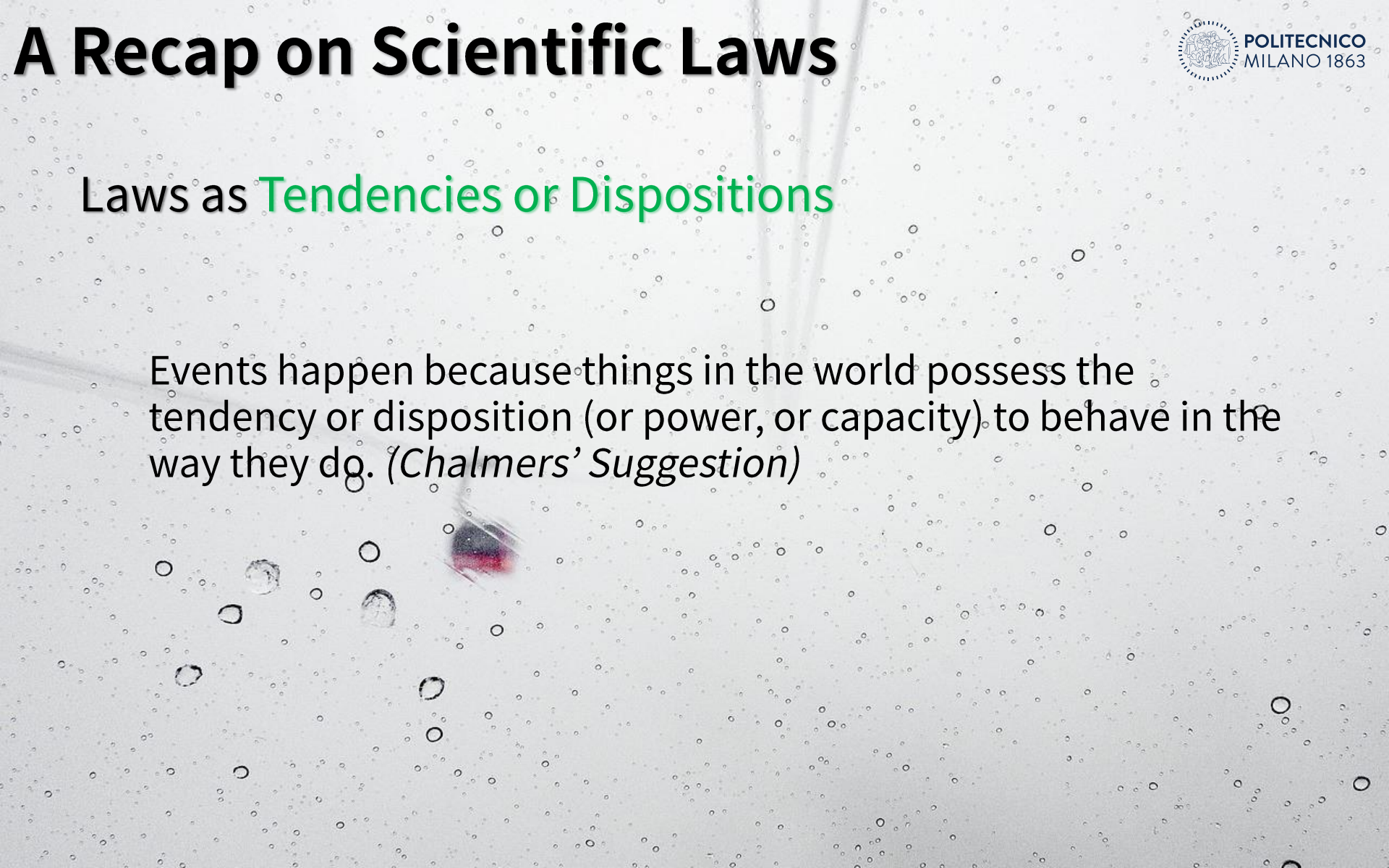
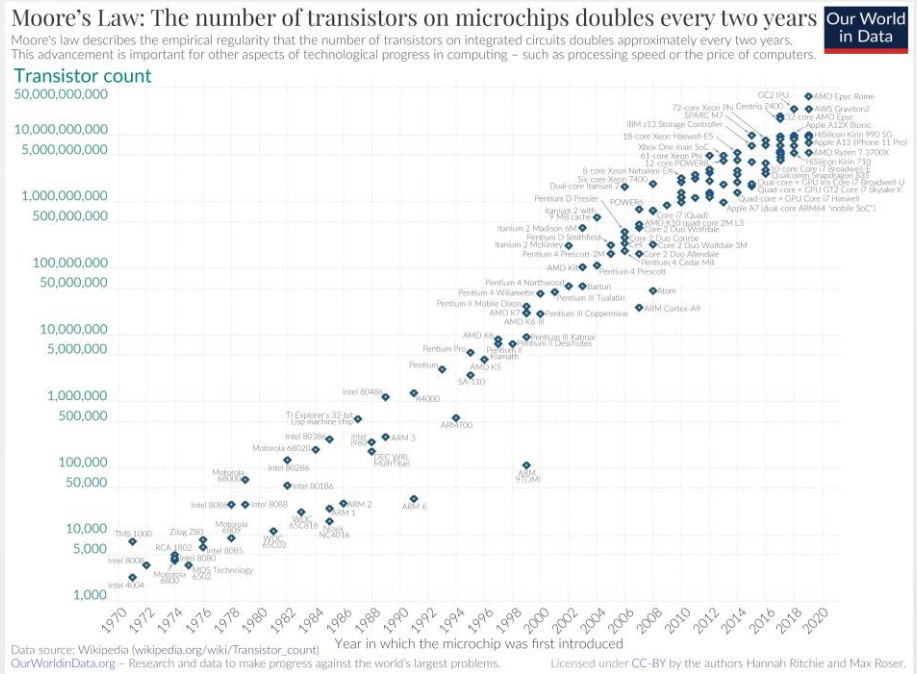
Laws as Tendencies or Dispositions

Events happen because things in the world possess the tendency or disposition (or power, or capacity) to behave in the way they do. *(Chalmers' Suggestion)*



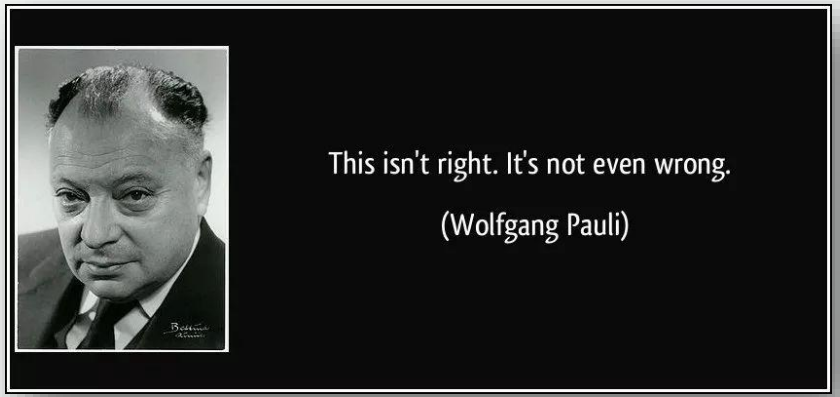
Moore’s Law

Moore's law is the observation that the number of transistors in an integrated circuit (IC) doubles about every two years.



Moore’s Law

- Moore's law is a product of inductivism.
- It has guided the development of IC Industry for quite a long time. Nevertheless, it’s not a scientific law.
- Though not even wrong, there is no causal dependency between Moore’s Law and the development of IC Industry.



Shannon Information Theory

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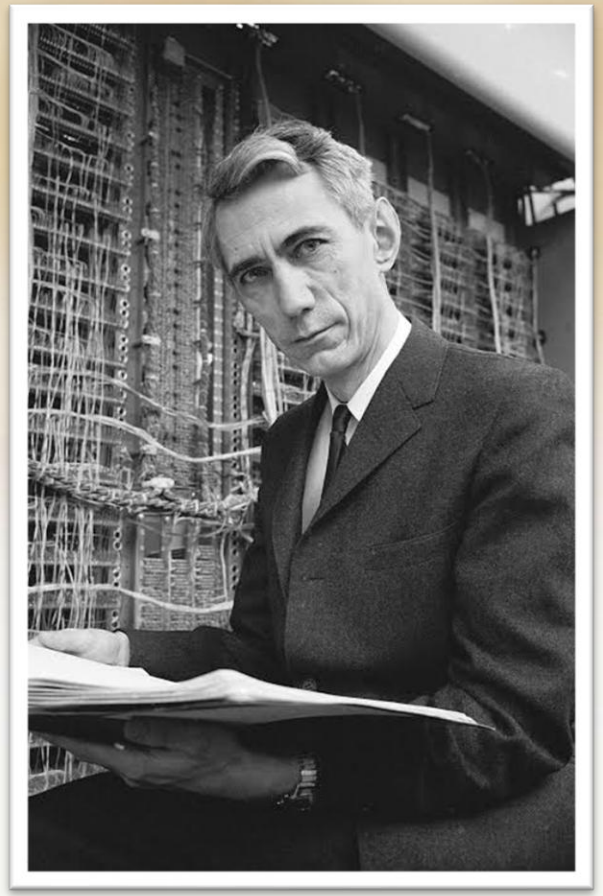
- Information theory is the mathematical study of the quantification, storage, and communication of information.
- The field was established and put on a firm footing by Claude Shannon in the 1940s.
- It is at the intersection of electronic engineering, mathematics, statistics, computer science, neurobiology, physics, and electrical engineering.



Shannon Information Theory

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- A key measure in information theory is entropy, which measures the level of disorder in the probability distribution of a system.
- The more uniform the probabilities, the higher the uncertainty and the greater the entropy.
- The formula of the entropy is:

$$H = -\sum_i P(x_i) log P(x_i)$$

where $P(x_i)$ is the probability of event x_i.

Shannon Information Theory

Tenet by Christopher Nolan, a sci-fi about entropy in Thermodynamics.

There is also entropy in Thermodynamics, which describes the degree of disorder in a system and the probability distribution of its thermodynamic states. It is defined as follows:

$$S = k_B ln\Omega$$

where k_B represents Boltzmann constant, and Ω is the number of microstates in the system, which represents the possible microscopic arrangements corresponding to a given macroscopic state.

Shannon Information Theory

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- Information entropy can be seen as a generalized definition of entropy.
- Thermodynamic entropy can be considered a specific application of information entropy in physical systems, describing the degree of disorder in the probability distribution of microscopic states.
- Thermodynamic entropy S can be expressed in the form of information entropy as follows:

$$S = -k_B \sum_i P_i ln P_i$$

where P_i is the probability distribution of the system's microscopic states.

Shannon Information Theory

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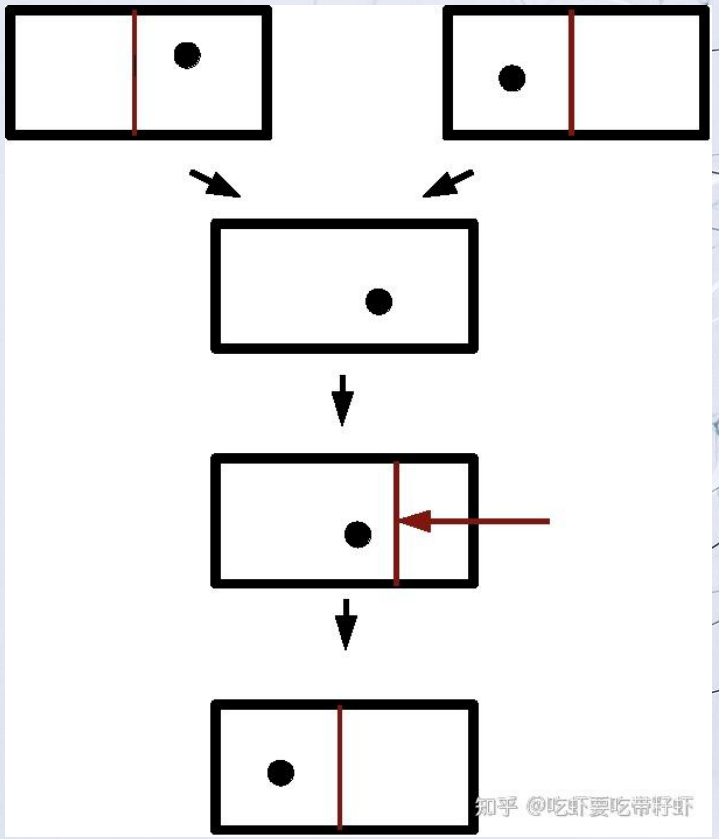
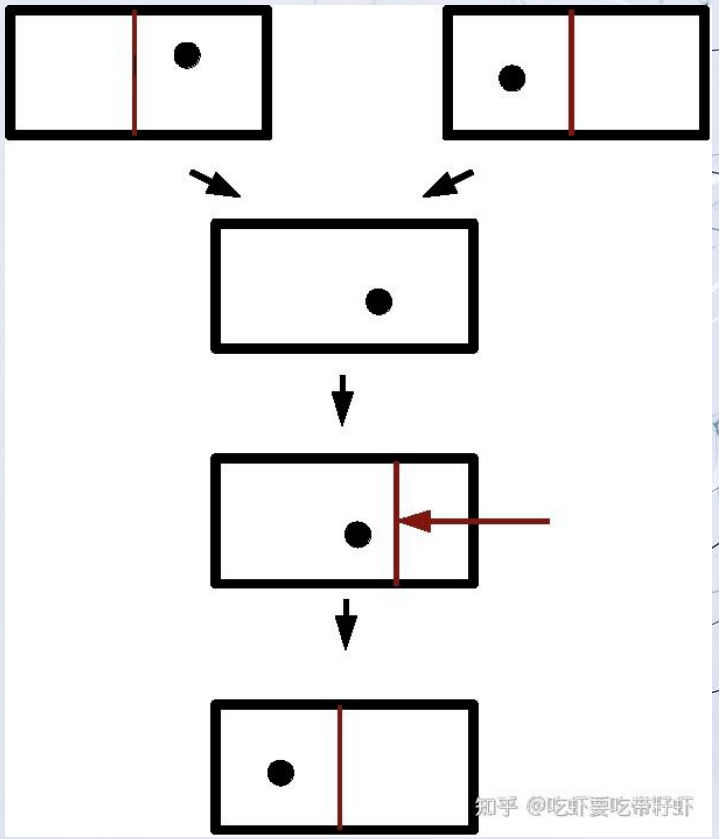
- Shannon Information Theory is a scientific law, for it describes the tendencies of every aspect of information.
- Both information entropy and thermodynamic entropy are describing the disorder and uncertainty of a system, quantifying some kind of dispositions in their own fields.
- There are indeed some direct connections between information and energy, which we'll see next.

Landauer’s Principle



- Landauer's principle is a physical principle pertaining to the lower theoretical limit of energy consumption of computation.
- It holds that an irreversible change in information stored in a computer, such as merging two computational paths, dissipates a minimum amount of heat to its surroundings.

Landauer's Principle

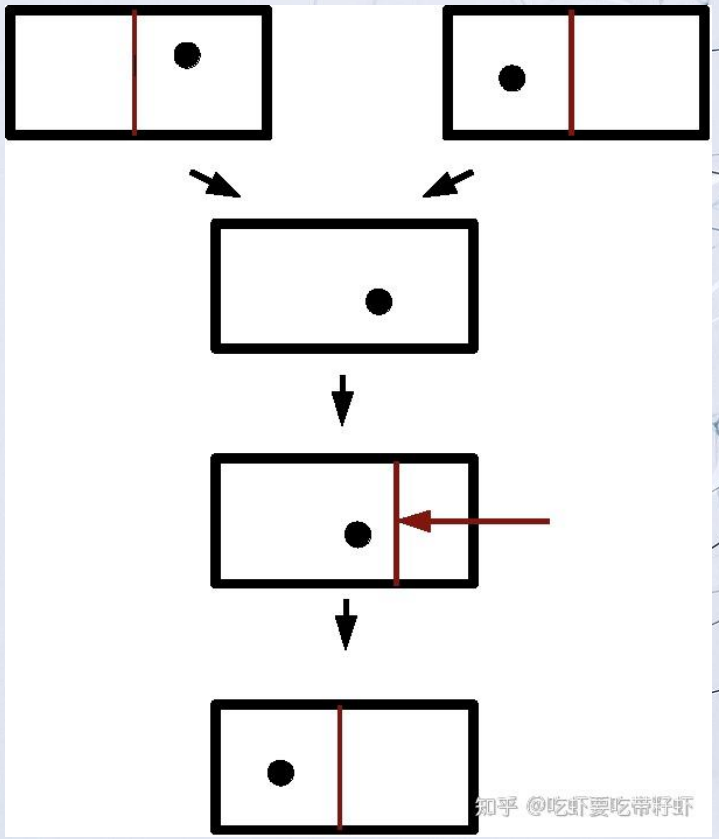


- Landauer's principle states that the minimum energy needed to erase one bit of information is proportional to the temperature at which the system is operating.
- Specifically, the minimum energy needed for this computational task is given by:

$$E = k_B T ln2$$

where T represents the temperature in Kelvins of the operating environment.

Landauer’s Principle



- Landauer's principle establishes a direct connection between information entropy and thermodynamic entropy.
- It is derived from the laws of thermodynamics, thus is a scientific law.
- Recent research in 2018 has extended the validity of the principle to quantum realm, demonstrating its correctness.
- This scientific law is a description of a kind of tendency.


Thank You