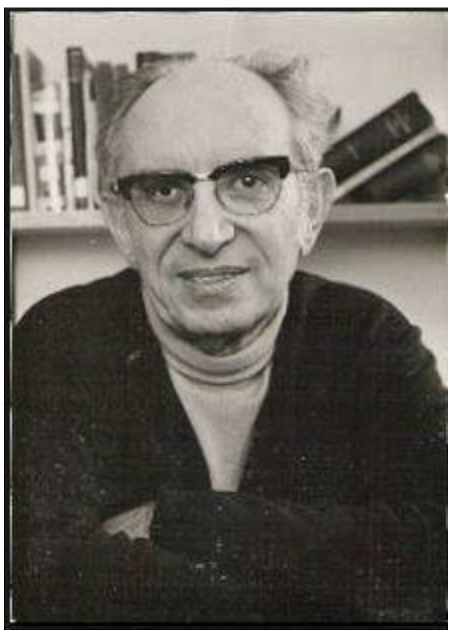
Information and Complexity

*C.Shannon, "*A Mathematical Theory of Communication", *Bell System Technical Journal***,** **27**, 373-429, 1948.
C.E.Shannon and e W.Weaver, *The Mathematical Theory of Communication*, Univ. Illinois, Urbana-Champain 1949.
N.Wiener, *Cybernetics*, MIT Press 1948

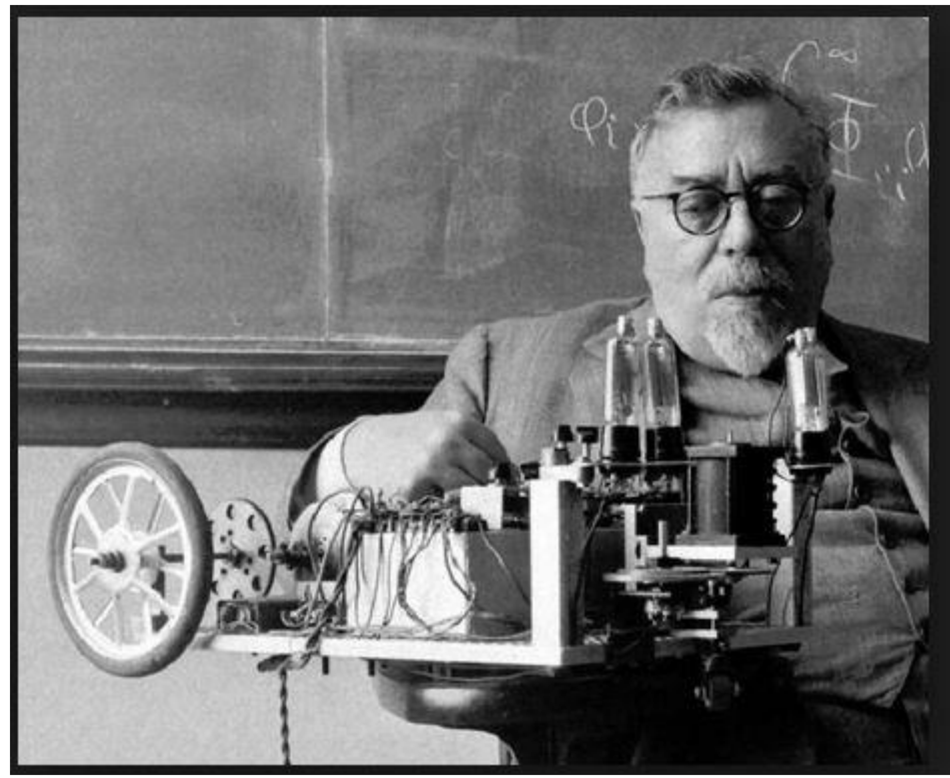
Claude Shannon (1916-2001)

$$I = -\log_2 P$$

I= information
P=event probability



Warren Weaver (1894-1978)



Norbert Wiener (1894-1964)

The information is expressed mathematically by the relationship

$$I = -\log_2 P$$

that, using the base 2 for logarithm of the probability P that a given event occurs, it allows to obtain a measured value in bits. 1 bit is equivalent for example to information obtained by the toss of a coin (P = 0.5). Entropy expressed by the Boltzmann relation is easy to obtain equality

$$S = \log_2 P$$

that allows you to express the entropy of information in the same unit, i.e. the bit. Notice how P identifies with Γ. In conclusion, it shows that the following relation holds

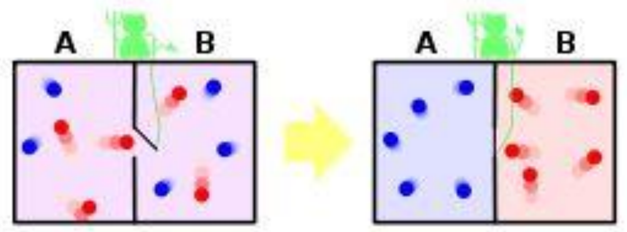
$$I = -S$$

which can be stated as "to an increase in entropy corresponds to a loss of information on a given system, and vice versa"

"The choice of a logarithmic base corresponds to the choice of a unit for measuring information. If the base 2 is used the resulting units may be called binary digits, or more briefly *bits*, *a word suggested by* J. W. Tukey. A device with two stable positions, such as a relay or a flip-flop circuit, can store one bit of information" (Shannon, 1948)

Delicate relationship between Information, Energy and Entropy

After Shannon, the investigation was significantly advanced by Landauer, following indications by Brillouin, which concluded that energy is used in the reset process, not in the computing process. This was further developed and applied by Bennet to many different examples. Feynman verified the accuracy of the basic mechanism and provided illustrations. However, in none of these works is information defined, except occasional reference is made to a bit being a "1" or "0" and sometimes relating this to bipolar states such as spin where spin (up) is a "1" and spin (down) is a "0". Currently, the negative information state has not been defined or applied to information theory although negative entropy exists and, by analogy, negative information should also exist.



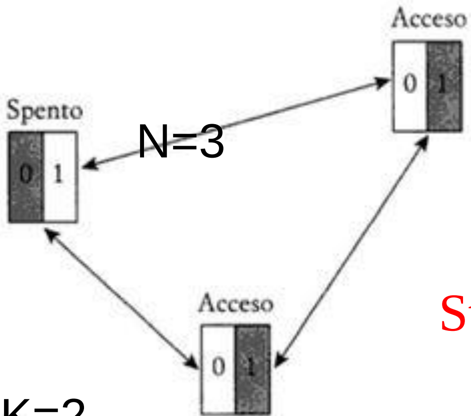
- Maxwell demon

(erasing information; measuring the minimum energy dissipated by deleting information was experimentally measured by Eric Lutz *et al.* in 2012, following suggestions by Landauer, 1961)

Cfr Alpert, 2010

Landauer (1961) investigated the question of the bawhat are the physical limitations on building a device to implement a computation. At the time he wrote, an influential body of work had been developed, by Brillouin (1951, 1956), Gabor (1964) and Rothstein (1951), arguing that the acquisition of information through a measurement required a dissipation of at least $kT \ln 2$ energy for each bit of information gathered.

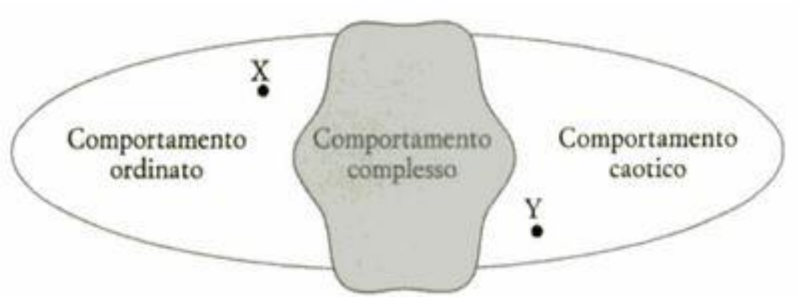
von Neumann (1949) had also suggested on sis of Szilard's work, that every act of information processing was necessarily accompanied by this level of energy dissipation.



Stochastic Boolean networks

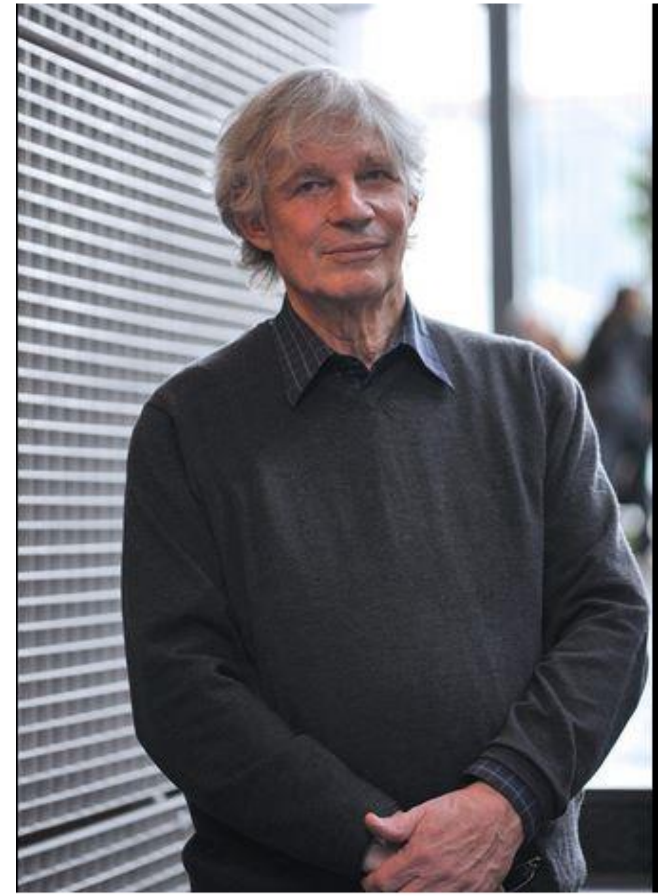
K=2

K,N = parameters



(control parameter) K →

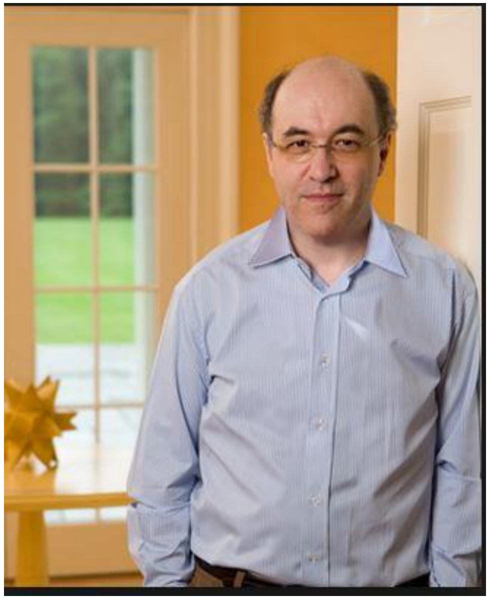
- networks that can have only two states (on/off) randomly generated. This system was used to mimic the gene regulatory networks. The hypothesis is based on the observation that all cells of an organism contain the same genes and assumes that the various cell types (organs) are stable chaotic attractors. Surprisingly it can predict, albeit with a certain approximation, the maximum number of cell types of an organism, if it is known the number of present genes.



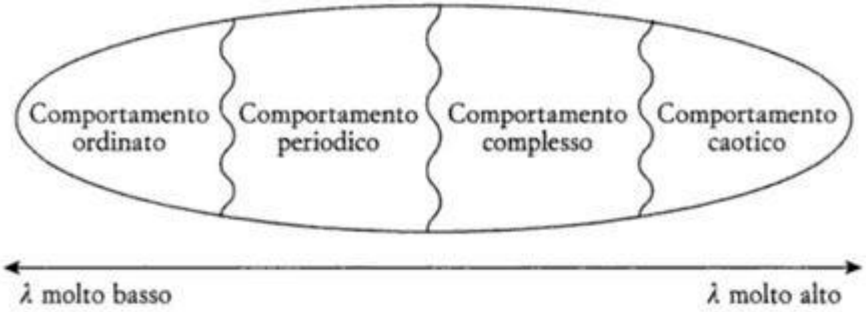
Kauffmann (1939 - …)

Cellular automata

Christopher Langton (1948/1949- …)



Stephen Wolfram (1959-…)



λ = mode by which the cells exchange information

Molecular network

● A molecular network is imprinted as a *graph* and could be considered as an ensemble of *nodes* (representing biomolecules) and part of them are connected with *links*, *edges* (representing interactions and relations of the biomolecules). In each cell, there are different kinds of molecular networks such as protein–protein physical interaction networks, protein–protein genetic interaction networks, regulatory networks, expression networks, signal transduction pathways, and metabolic networks (better characterized than the rest). All these are cross-linked and combined together constitute the cellular network.

● Scale-free network (Barabasi,1998)-- graph with following property: If we consider the relationship between the number of nodes and the number of their connections we see that its graphic is a negative exponential, and therefore invariant to scale changes. This scale-free means that comparing the number of two types of nodes, such as those with 10 connections and those with 15, the proportion between the two is

$$Exp[-a(N_a-N_b)]$$

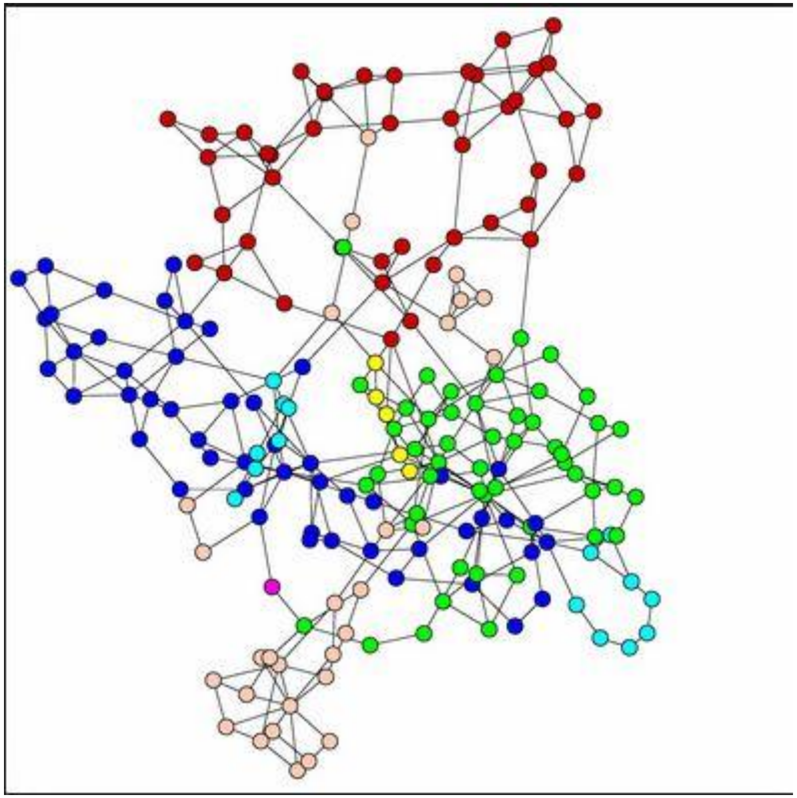
where N_a and N_b are, respectively, the number of nodes of numerator and denominator and a is a parameter of the type of network considered. This law is called the ***power law*** and *a* is the parameter relative to considered network.

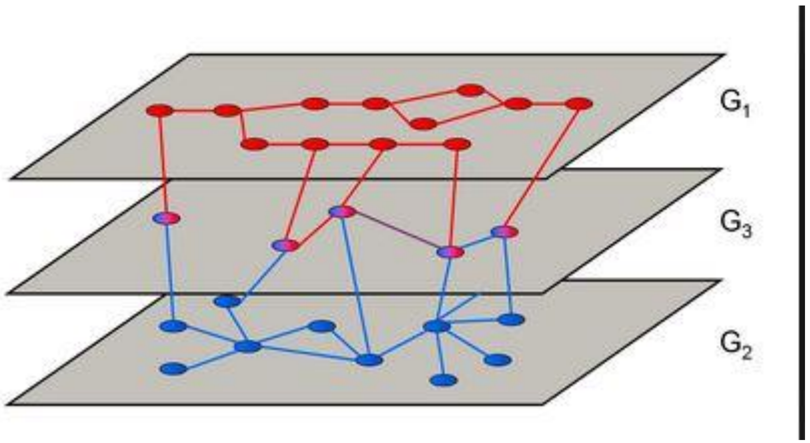
- Autopoiesis (self-creation) (Maturana, 1980; Maturana-Varela, 2004)

An autopoietic system is a system that continuously redefines itself and sustains and reproduces itself by means own interior. An autopoietic system can then be represented as a network of creation, transformation and destruction of components Processes that, by interact with each other, support and regenerate continuously the same system. Moreover, the system defines itself, in fact, i.e. the domain of existence of an autopoietic system coincides with the topological domain of its components.

Knowledge as experience is something personal and private and can not be transferred, and what you believe is transferable, i.e. objective knowledge, has to be created by the listener: the listener understands, and objective knowledge seems to be transferred only if he is prepared to understand. Thus cognition as biological function is such that the answer to the question "What is knowledge?" must arise from understanding knowledge and the knower by means the ability to learn of the Second.

Biological Networks





Biological networks can have different forms, are connected by ***edges*** (usually molecular interactions, e.g. transcription factor-DNA, protein-protein, ecc.) into ***nodes*** (proteins or genes) and are characterized by the *grade* and *grade distribution.*

Degree: the connectivity *k* for each node: it can be k_{in} and k_{out}

Degree distribution: P(k): the probability that a node (protein) has k links

Power law distribution: $P(k) \approx k^{-\gamma}$, where γ is the degree exponent (Barabasi).

Clusters: Proteins (nodes) within a network with more intersections among themselves (clusters). With Q=2m/[n(n-1)] density of connections

Ecosystem complexity, defined by connectivity C(C):C=2L/[N(N-1)] with L=actual food links