GAÏA

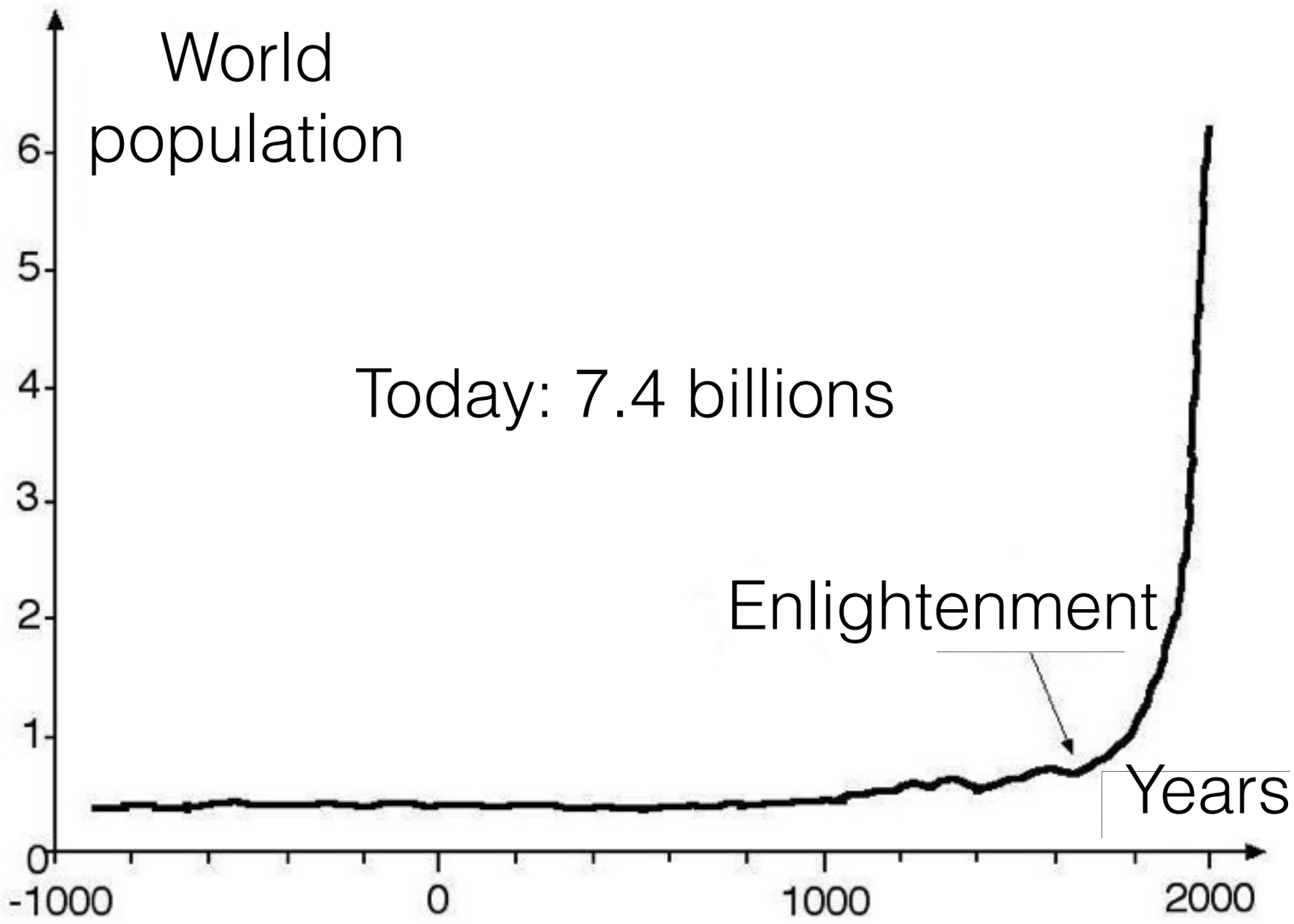
or:

The awakening of a consciousness

(Thoughts about the future of mankind)

Paris (ESA), October 7, 2016

What is going on?



Thomas Robert Malthus

1800: population grows exponentially, but agricultural production does not.

Thomas Robert Malthus
(1766-1834)

Pierre François Verhulst

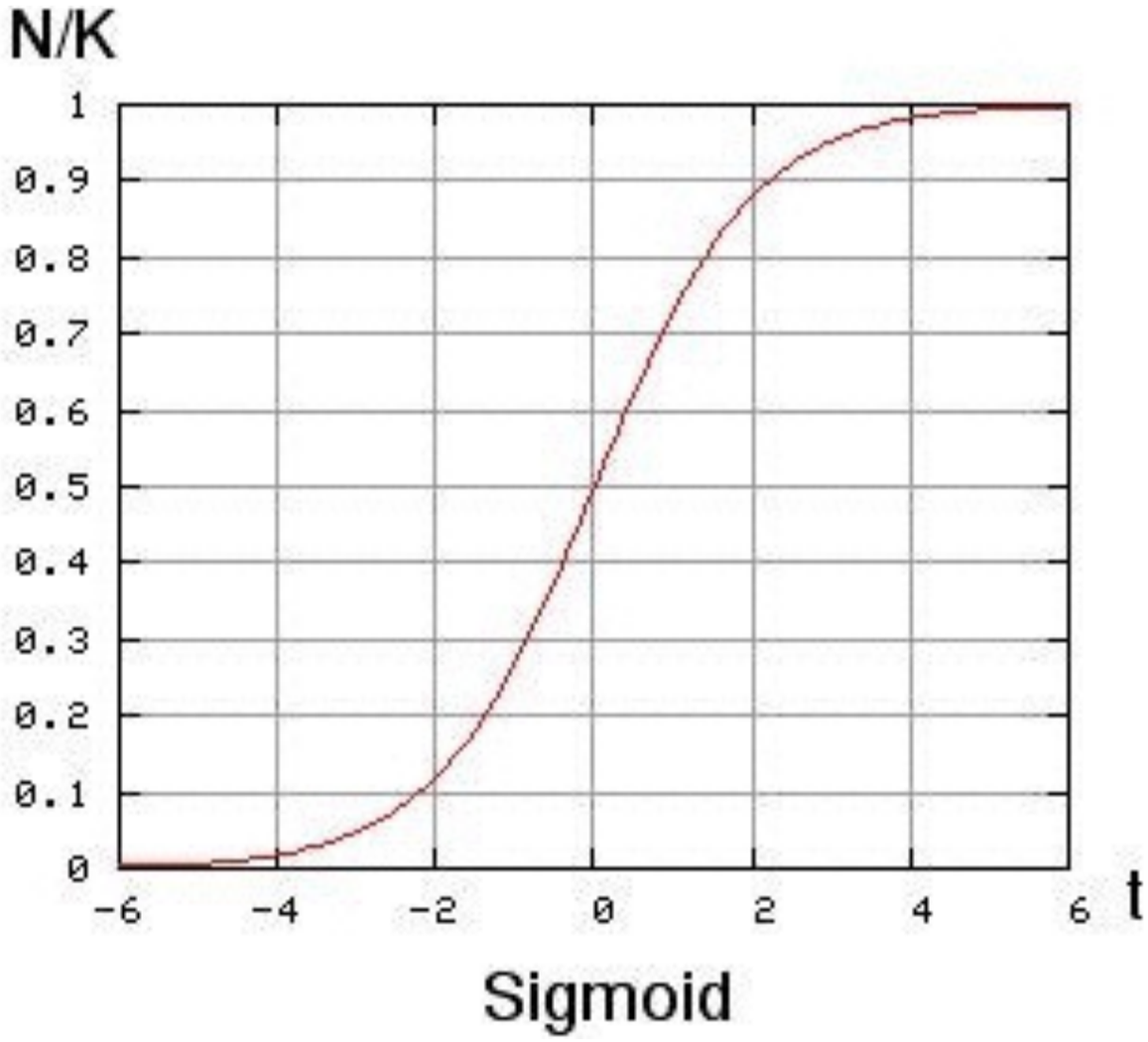
1838: **Verhulst** models evolution, through the empirical equation:

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

the solution of which is a sigmoïd.

Pierre François Verhulst (1804-1849)

Pierre François Verhulst



Demographic transition

Pierre François Verhulst
(1804-1849)

Charles Darwin

1859: Living organisms adapt themselves to their environment through ***natural sélection***.

Charles Darwin
(1809-1882)

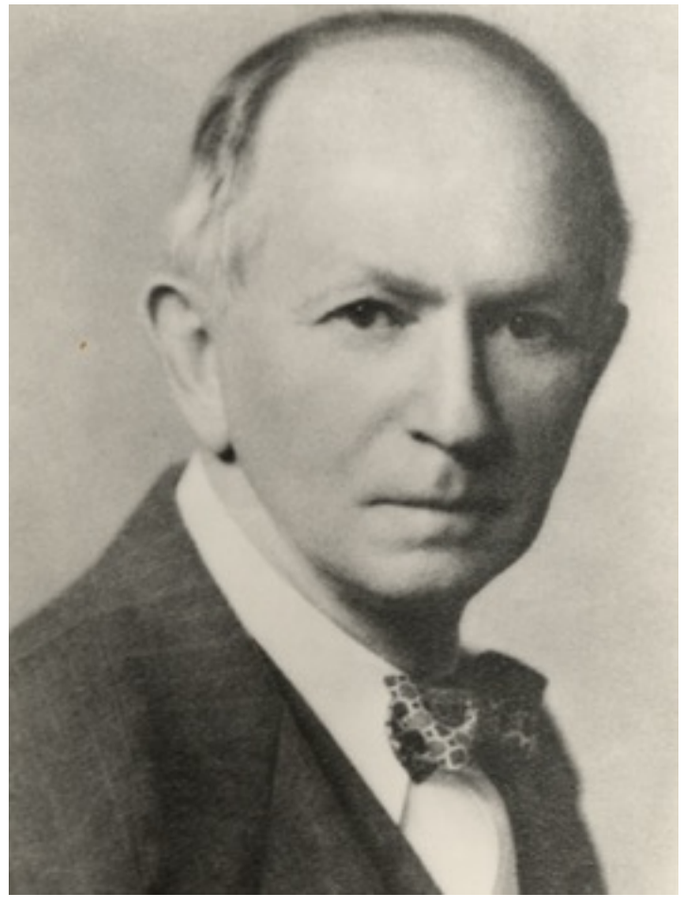
Ludwig Boltzmann

1905: The struggle for life is a struggle for ***energy dissipation*** (*entropy* production).

Ludwig Boltzmann
(1844-1906)

Alfred Lotka

1922: Natural selection favors those organisms that dissipate the most energy (produce the most *entropy*). It acts as if it were a ***third law of thermodynamics***.



Alfred Lotka
(1880 - 1949)

Claude Shannon

Entropy = Loss of information

1861: Gibbs's paradox.

1861: Maxwell's devil.

1929: Leo Szilard

1944: Erwin Schrödinger

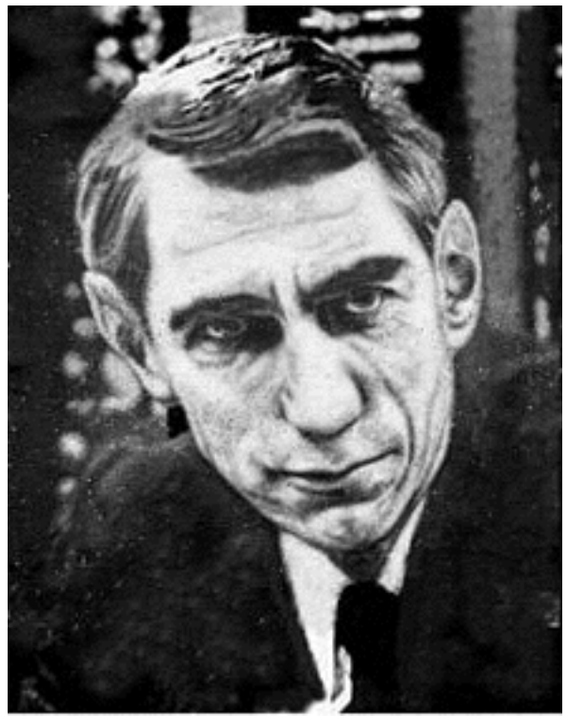
1948: Claude Shannon

1956: Leon Brillouin

1961: Ralph Landauer

1972: Charles Bennett

1982: Ed Fredkin



Claude Shannon
(1916 - 2001)

*Experimental proof in **2015** (Lutz et al).*

What is information?

Information = whatever can be ***memorized*** (in a brain or any other physical device).

Information introduces a **delay** between an event and its consequences (**hysteresis**).

The area inside a **hysteresis cycle** measures the amount of energy dissipated.

Georgescu Roegen

1971: When dissipating energy, human societies produce *entropy* which affects their environment

First application of ***thermodynamics to economy***.

Nicholas Georgescu-Roegen
(1906-1994)

Ilya Prigogine

1961: In the presence of a permanent flow of energy, structures (said to be dissipatives) ***self-organize*** to dissipate energy.

Examples: a cyclone, a living being, a human society.

Ilya Prigogine
(1917-2003)

Ilya Prigogine

An ensemble of interacting **dissipative structures** is also a dissipative structure:

— **The atmosphere of Earth**.

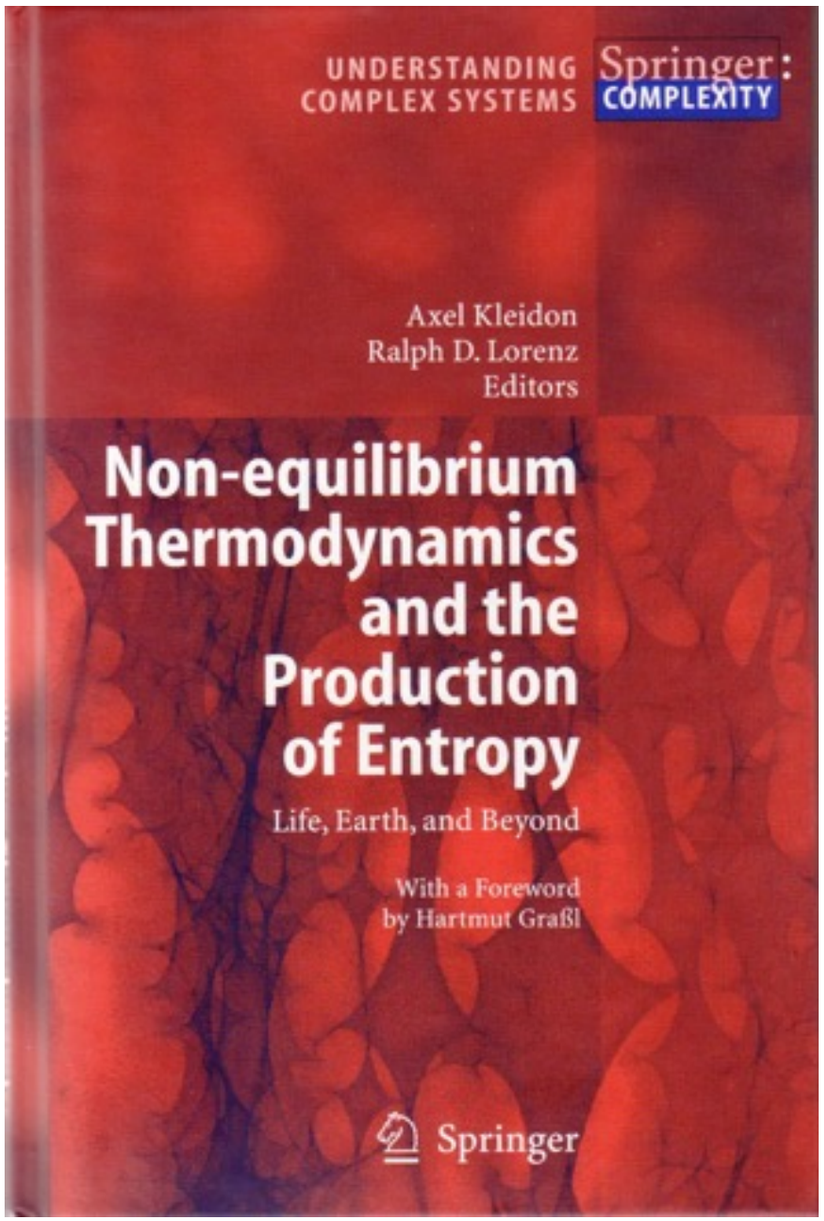
— **An animal or vegetal species**.

— **A human society**.

Ilya Prigogine
(1917-2003)

Maximum entropy production (2003)

Physicists and biologists present convicing evidence for Lotka's law: ***dissipative structures maximise their entropy production***.



Per Bak

Dissipative structures self-organize like a **continuous phase transition** (a phase change near a critical point).

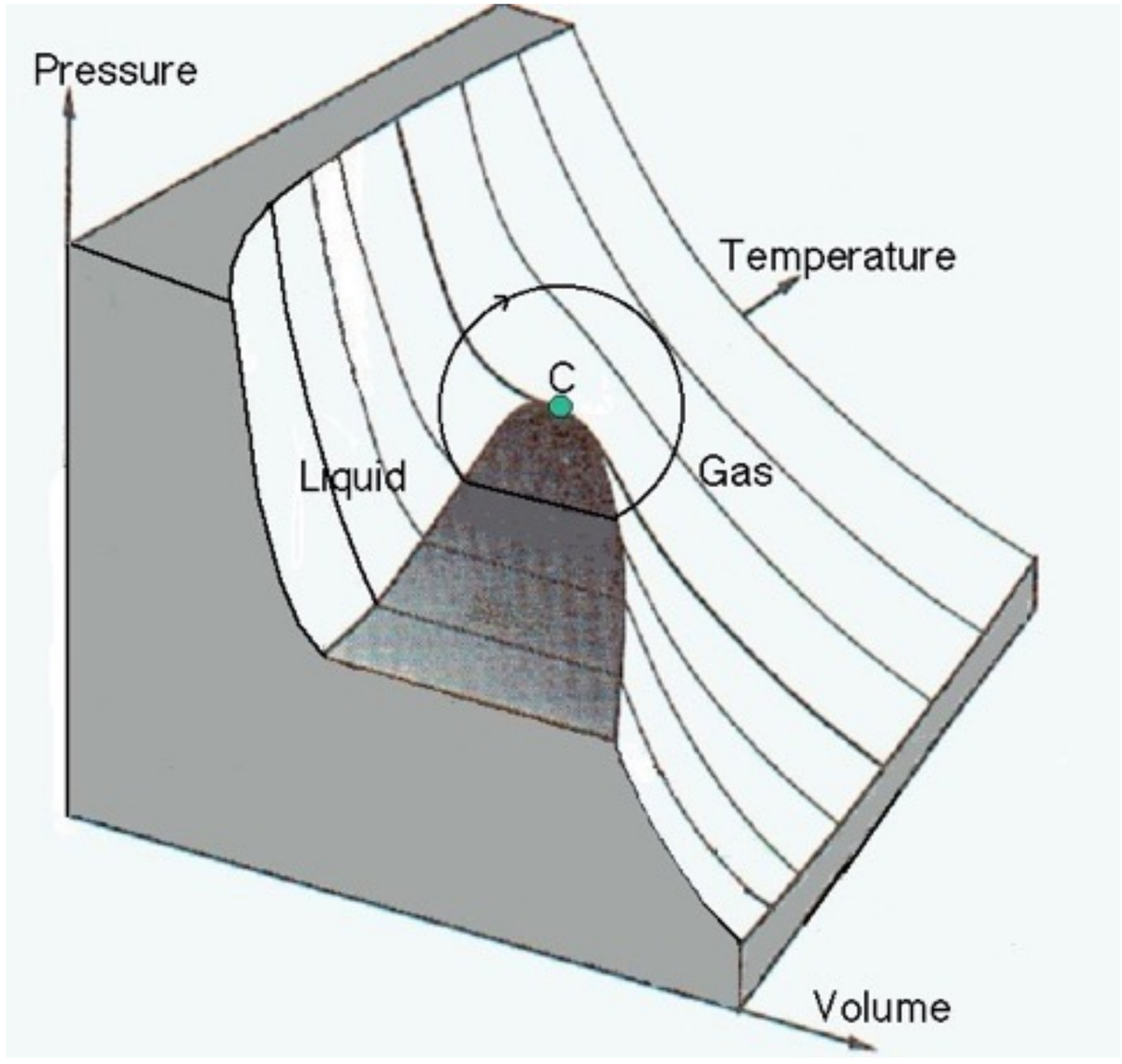
Per Bak
(1948-2002)

Example of self-organization

Abrupt phase transition

Cycle around a critical point

The transition is **continuous** in the light zone. It is **abrupt** in the dark zone (condensation).



Per Bak

Dissipative structures self-organize around a dynamical **critical point**. Per Bak has given this process the name of:

Self-organized criticality.

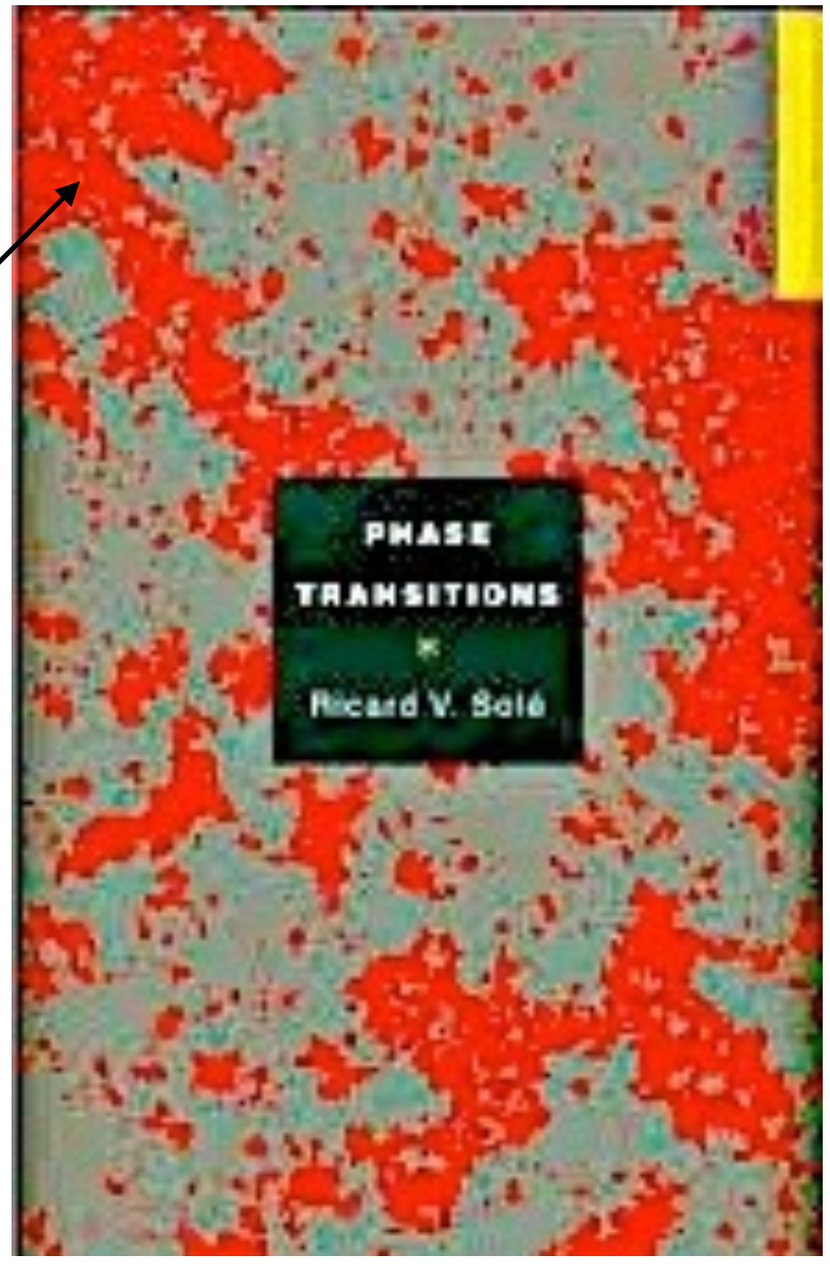
Per Bak
(1948-2002)

Ricard V. Solé

Among chapter titles:

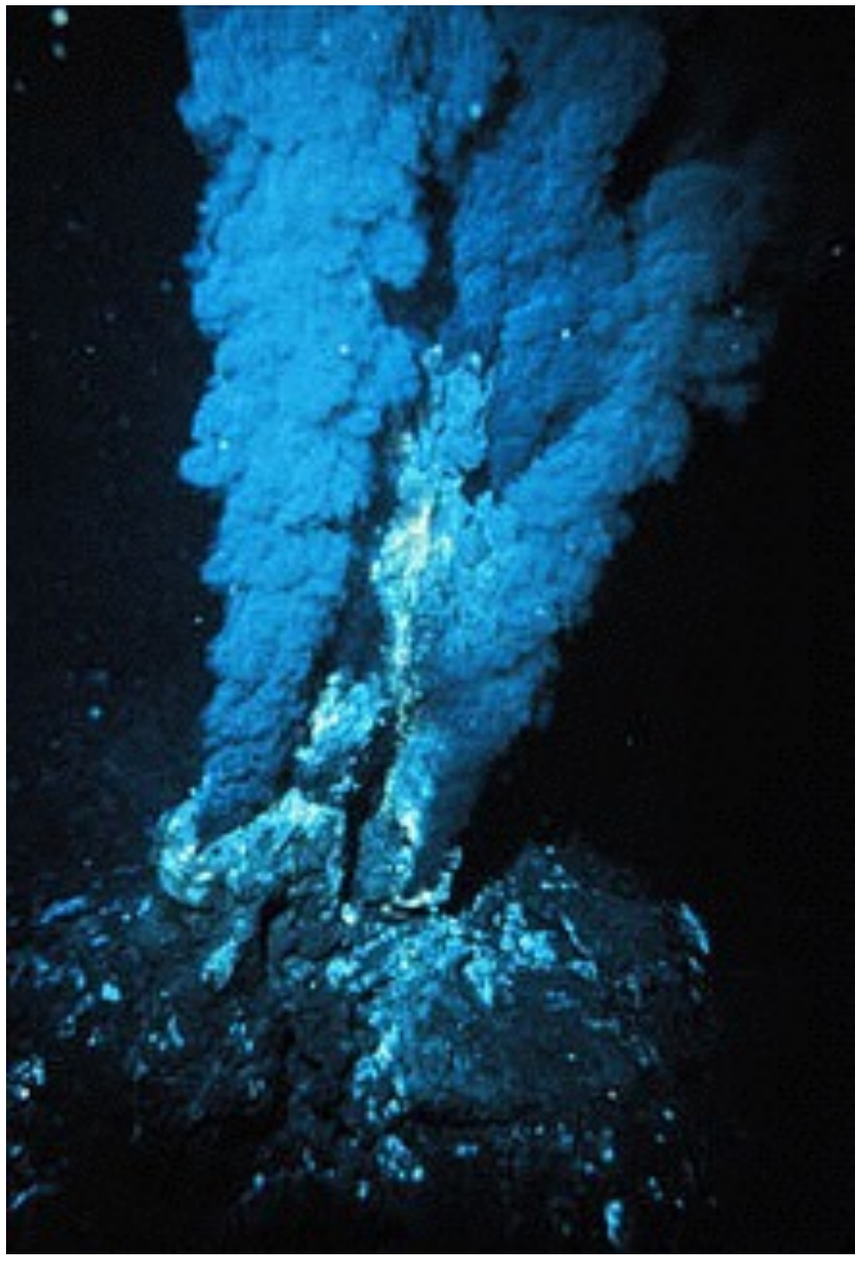
- **Phase change**
- Bifurcations
- Percolation
- Life origins
- Virus dynamics
- Gene networks
- Ecological shifts
- Collective intelligence
- **Social collapse**

In red:
Ising domains



A likely life origin

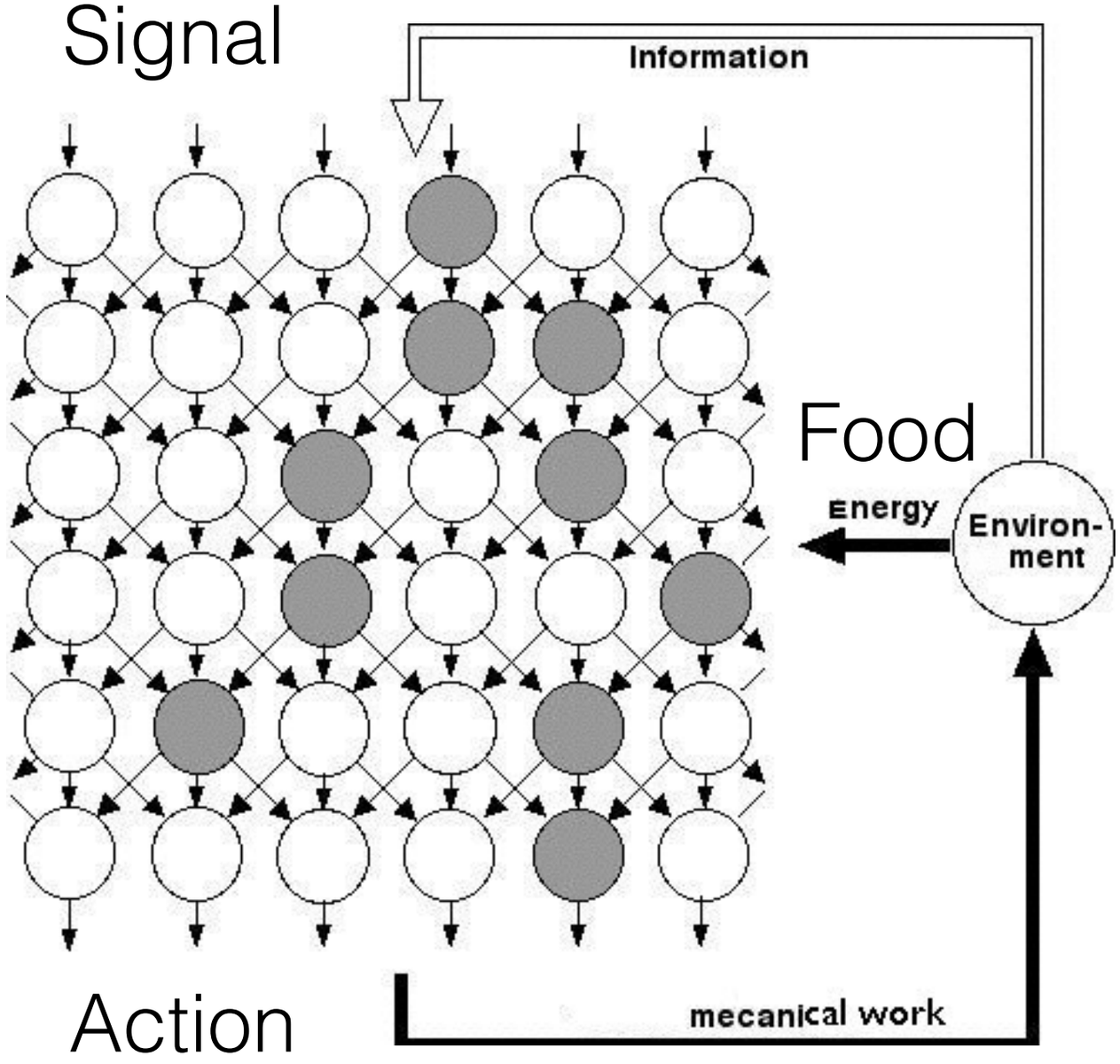
C*ritical opalescence* of water (374°C, 217atm.) near **hydrothermal vents** may have triggered the chemical reactions at the **origin of life** because of the huge surface/volume ratio favoring **catalysis**.
Ingredients needed: water, methane, hydrogen sulfide, ammonia.



Stassinopoulos and Bak

A n*umerical model for a brain*: The organization of the neural network is a process of **self-organized criticality**.

In gray: **Ising domains**



Generalization

The model applies to any ensemble of "memories" exchanging **energy** and **information**, for example an ensemble of:

- molecules (fluids)
- living beings (ecosystems)
- individuals (human societies)

Carnot's law (1824)

(**Second principle of thermodynamics**)

Mechanical work can be sustainably produced only through ***cycles of transformations*** extracting heat from a **hot source** while releasing some to a **cold source**. The efficiency is a maximum when all transformations are reversibles.

Sadi Carnot
(1796-1832)

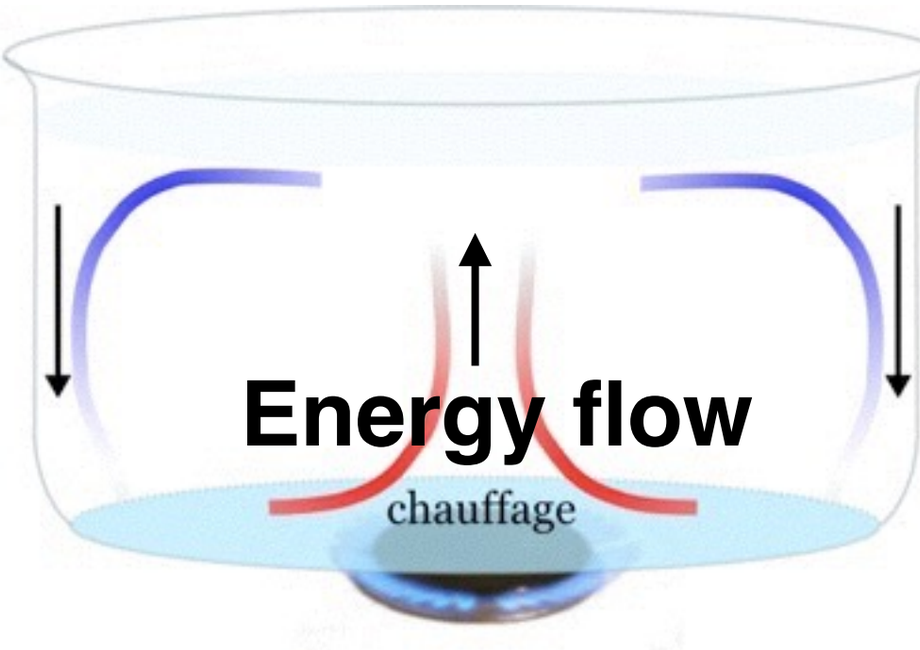
Application to fluids

A **convective cell** behaves like a **heat engine**:

It follows cycles producing **mechanical work**:

$W = Q_1 - Q_2$

The **cold** source (T_2) receives Q_2



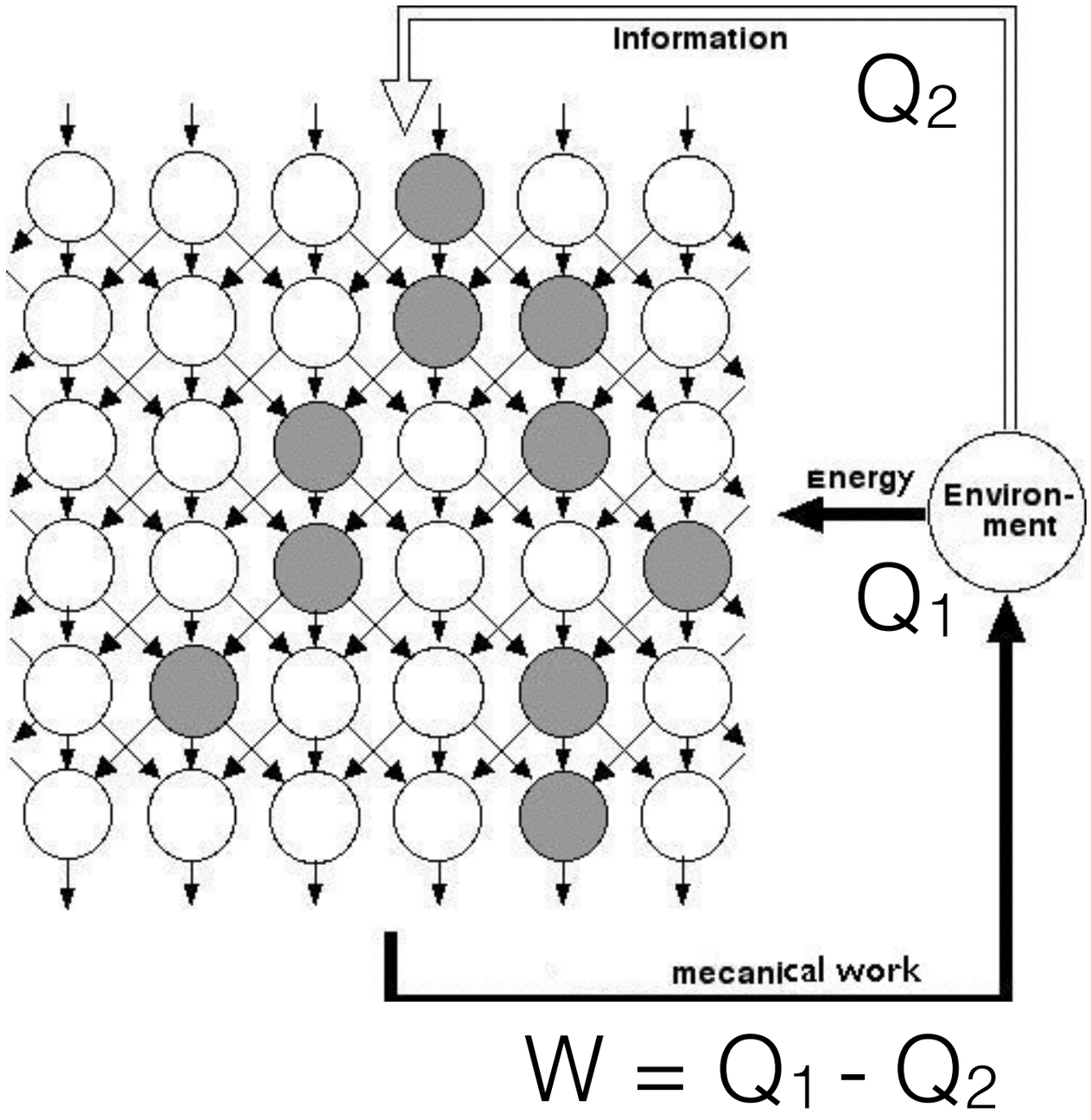
The **hot** source (T_1) gives energy Q_1

Is a convective cell also a brain?

It feeds on a hot source to produce mechanical work.

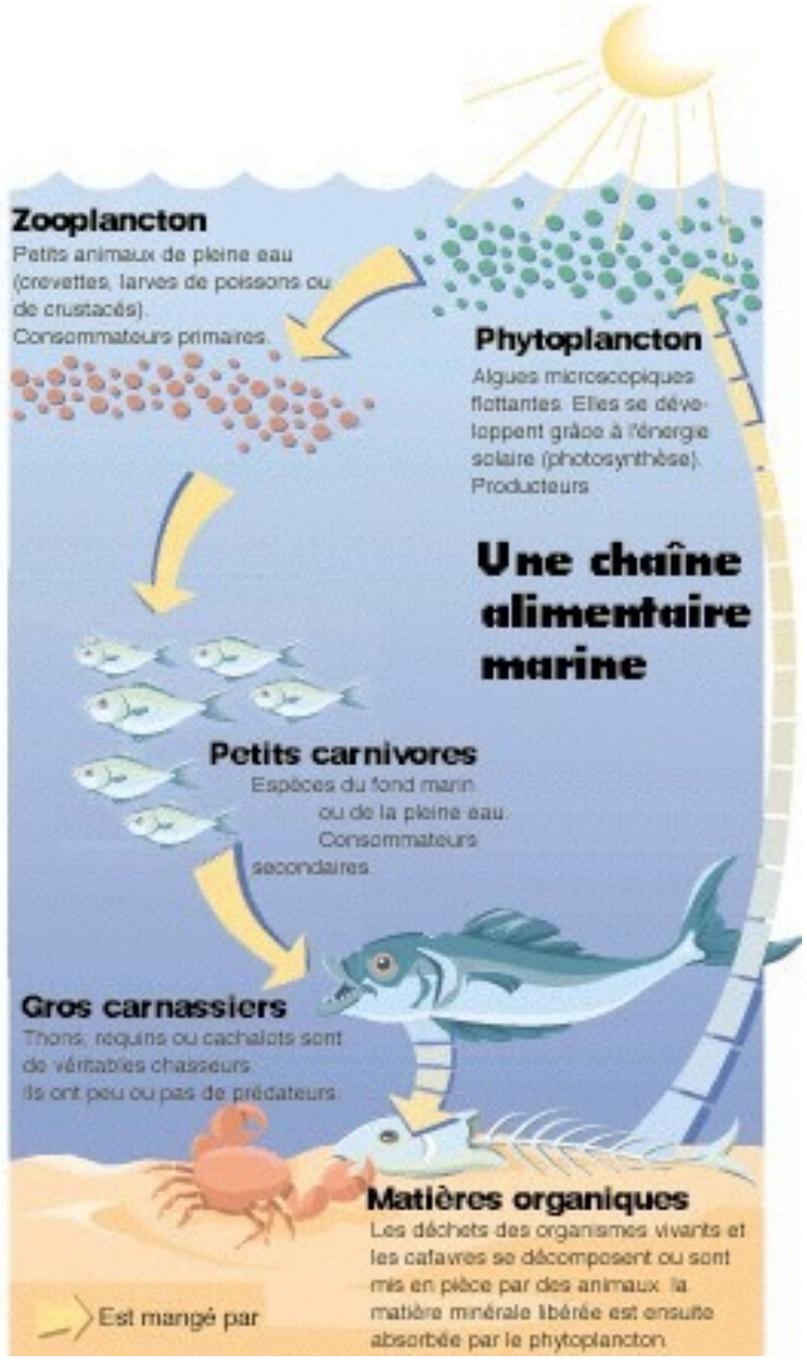
The **entropy output** Q_2/T_2 is *necessarily* associated to an **information input**.

Q_2 is the **latent heat** for **self-organization**.



Application to ecosystems

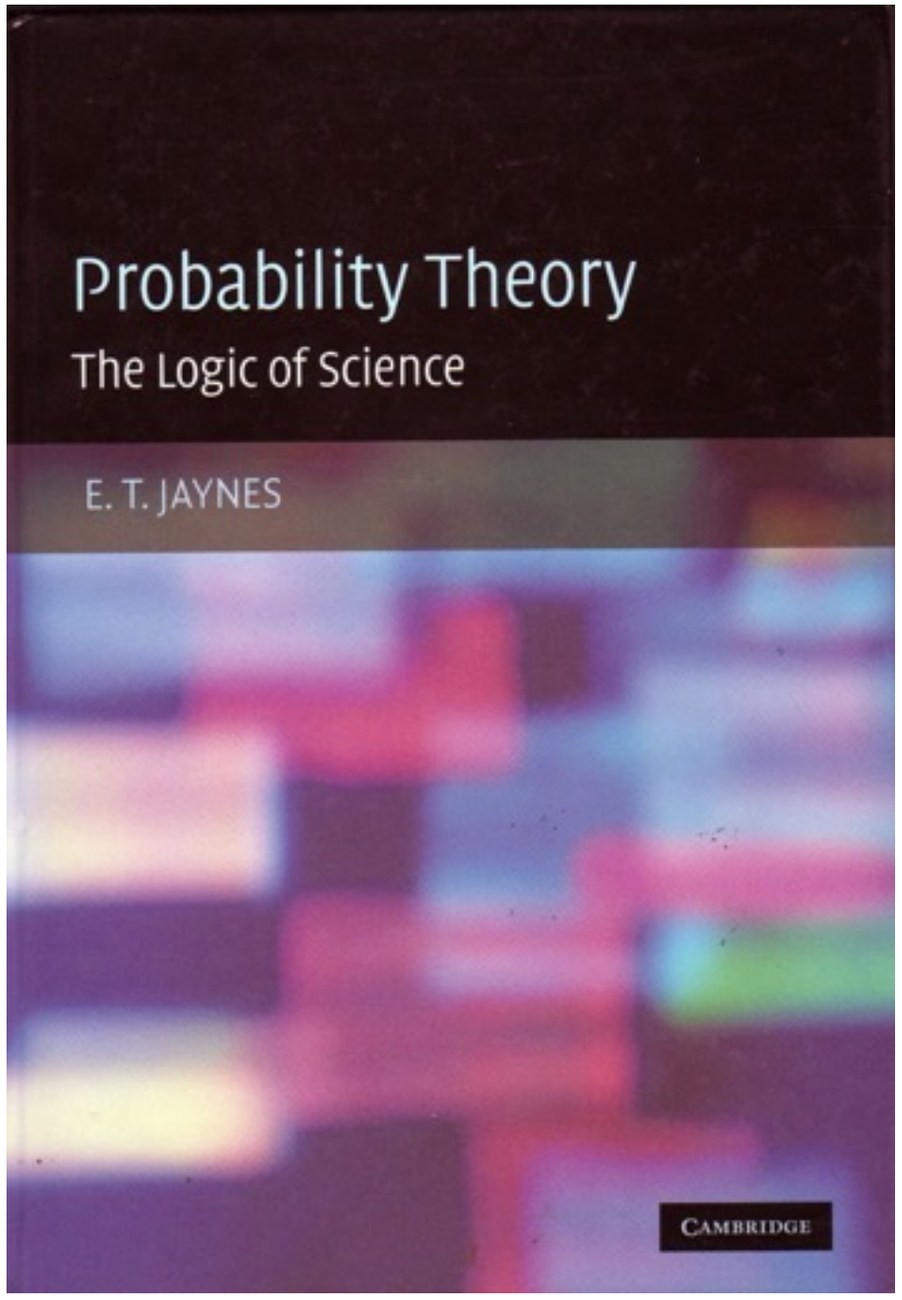
Ecosystems follow **cycles** of transformations using the **sun** as a **hot** source and the **night sky** as a **cold** source, which allows to import an **information** (from the environment) which is **stored in genes**. The heat output is the **latent heat** for self-organisation.



Application to mankind

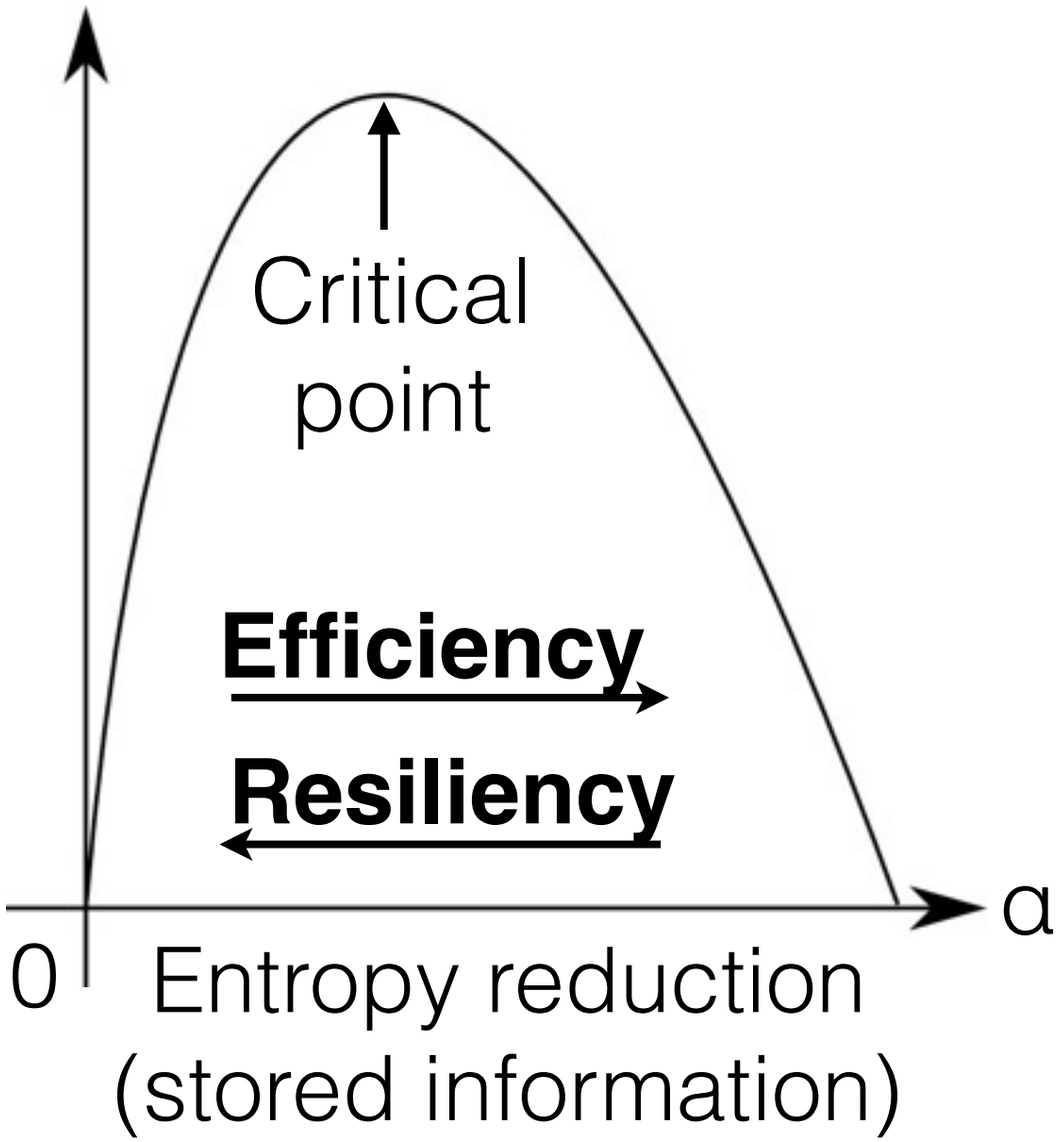
Ecosystems or mankind import information from their environment through Bayesian "*maximum entropy estimates*".

Maximising entropy production, maximizes intelligence!



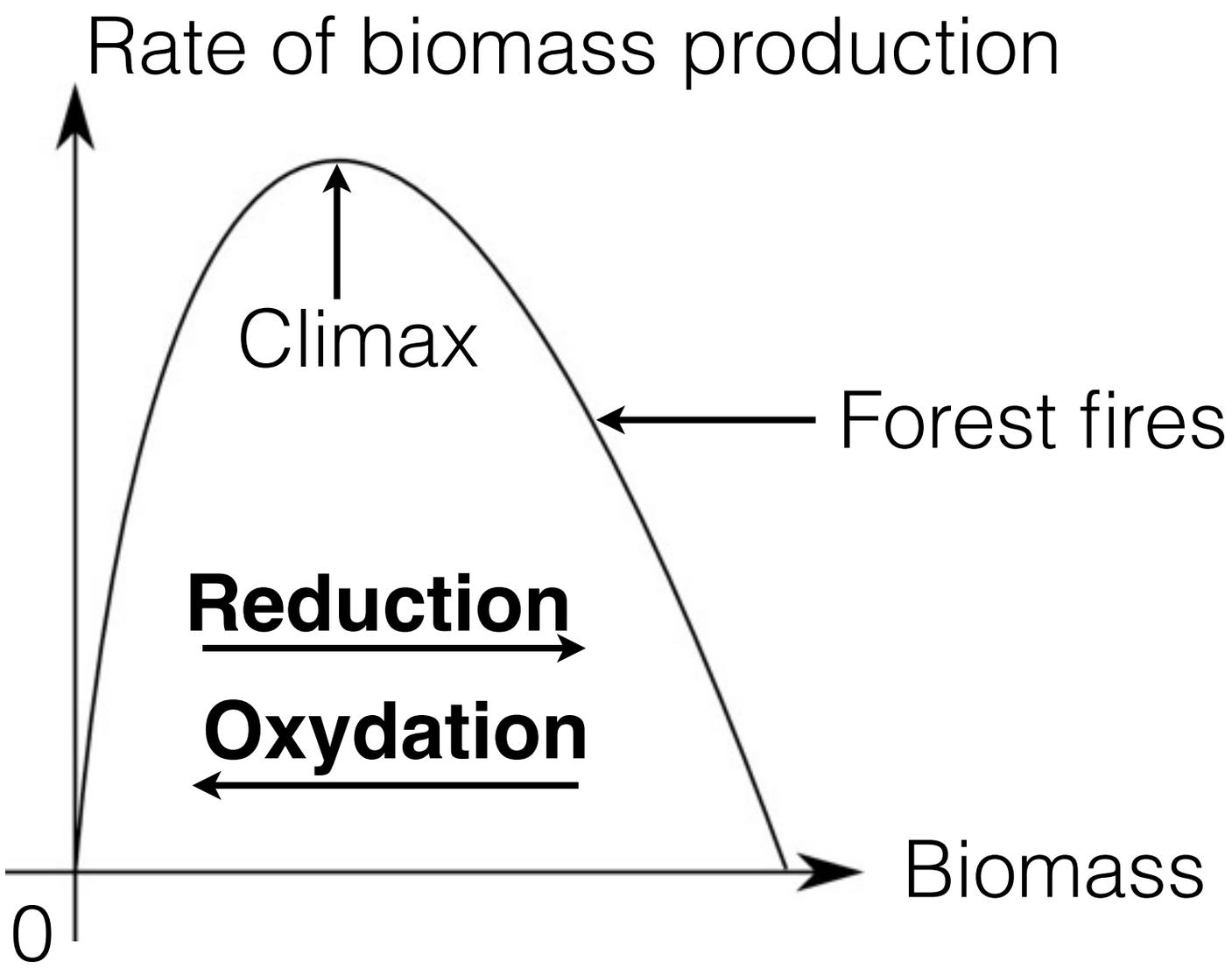
Robert Ulanowicz

-α.log α (Rate of entropy production)



Int. J. of Design & Nature and Ecodynamics. Vol. 4, No. 2 (2009) 83-96

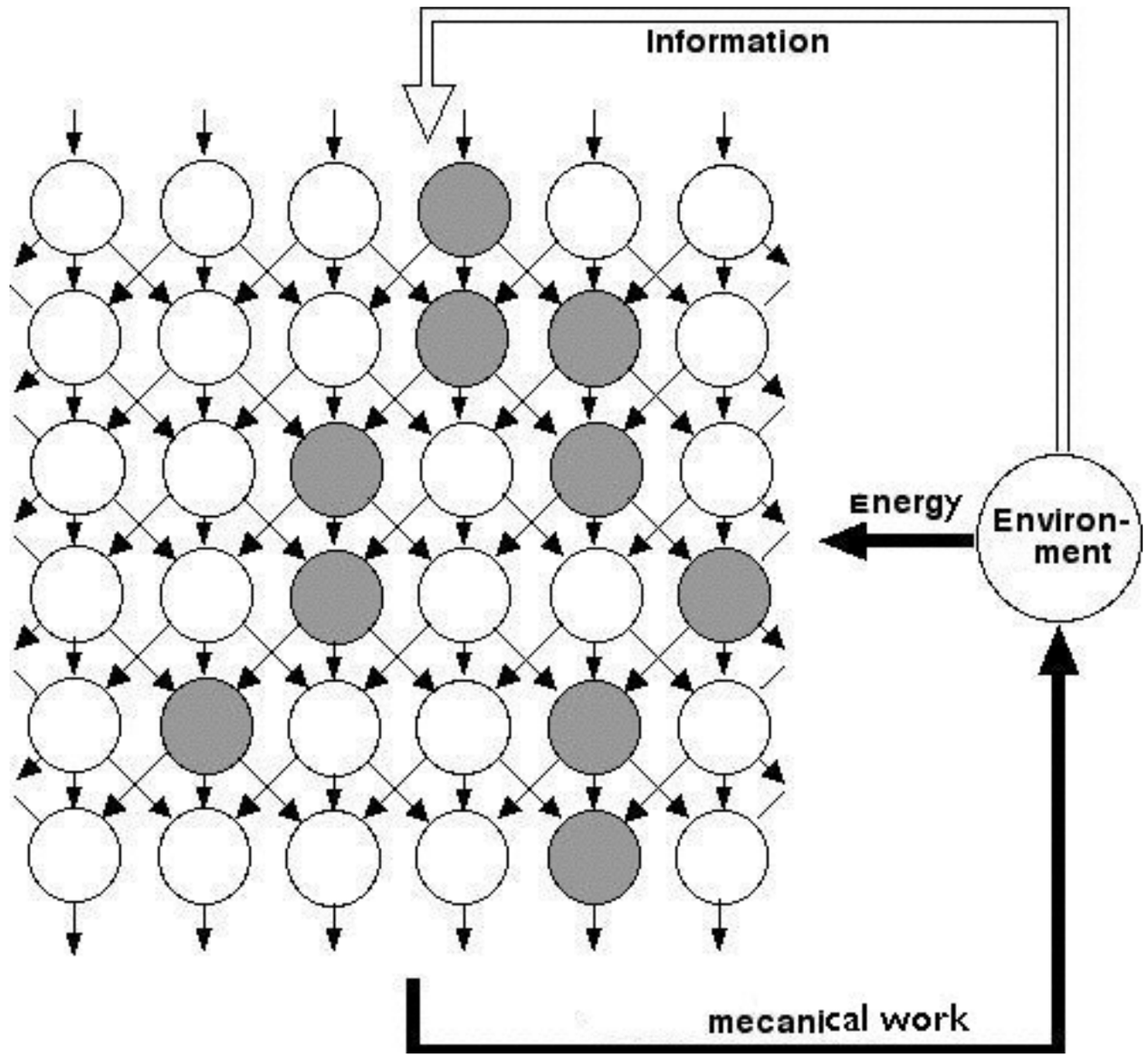
Application to biomass



Application to economy

The model applies to an ensemble of economic agents exchanging **money**.

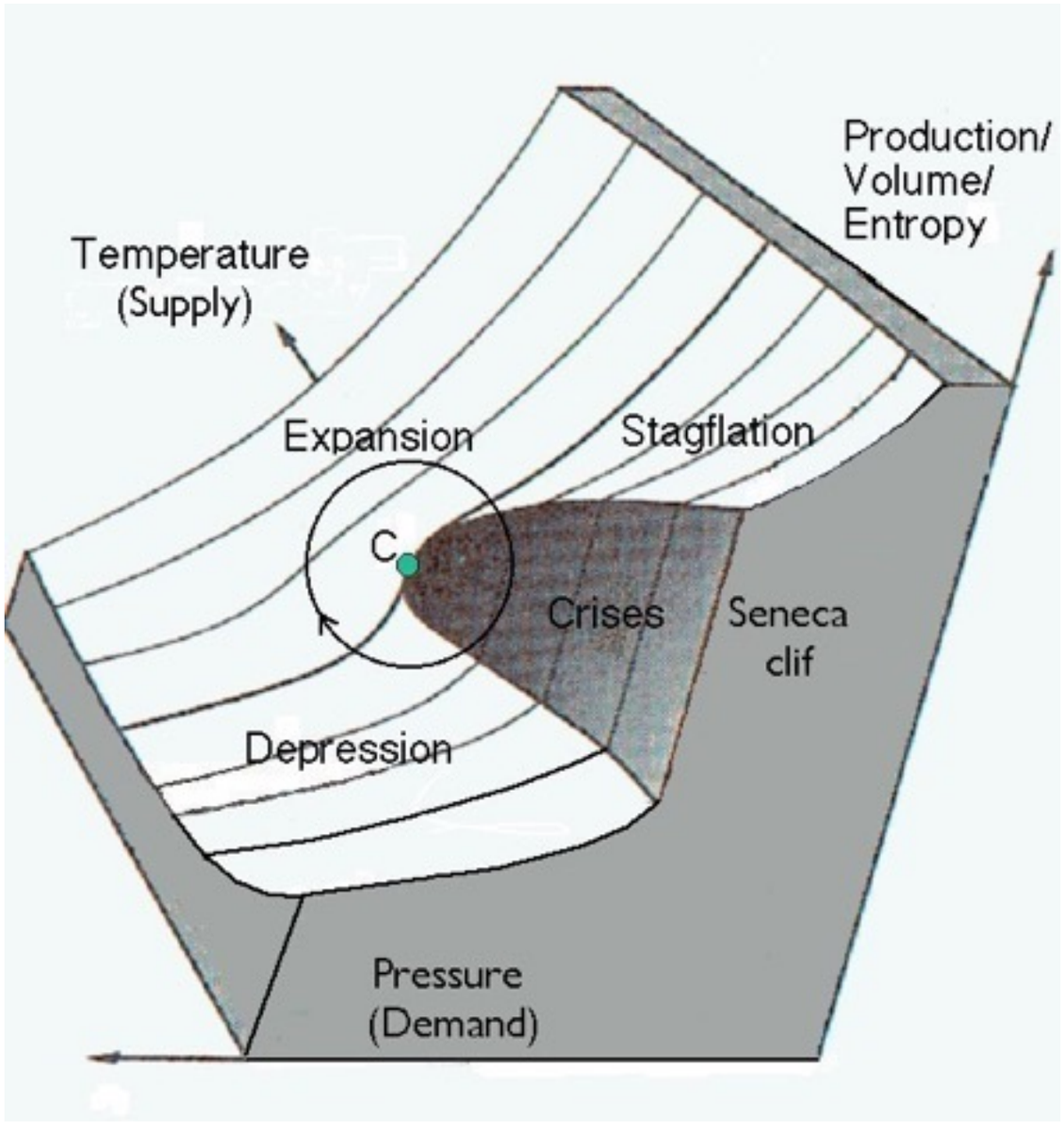
(François Roddier, Res Systemica, Volume12, article 03)



Application to economy

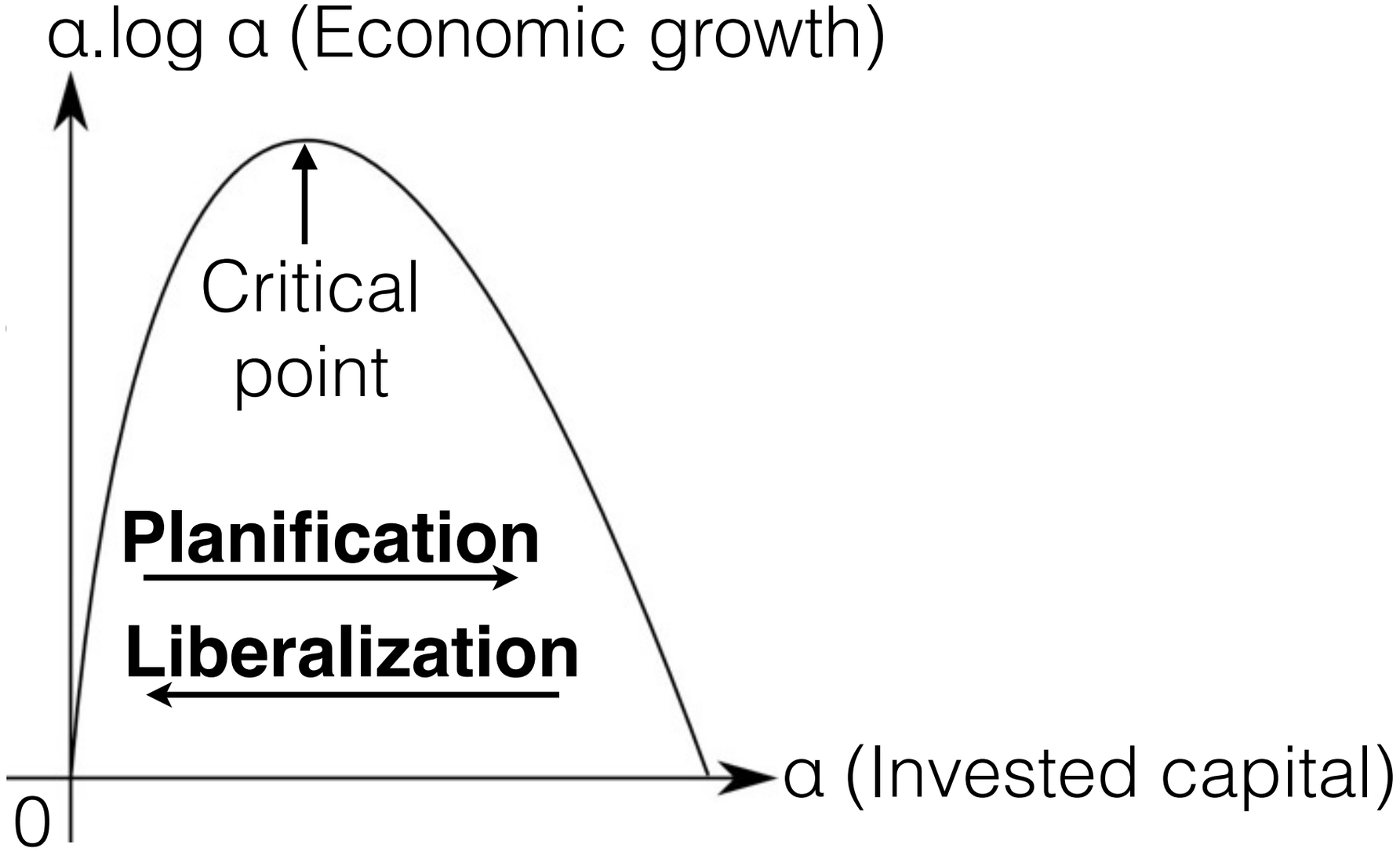
Economic cycles (Turchin & Nefedov, 2009) form around a **critical point**.

Economic crises appear during the phase in which the **society reorganizes itself** to *adapt to the environmental changes it has produced*.



François Roddier, Res Systemica, Vol. 14, 01

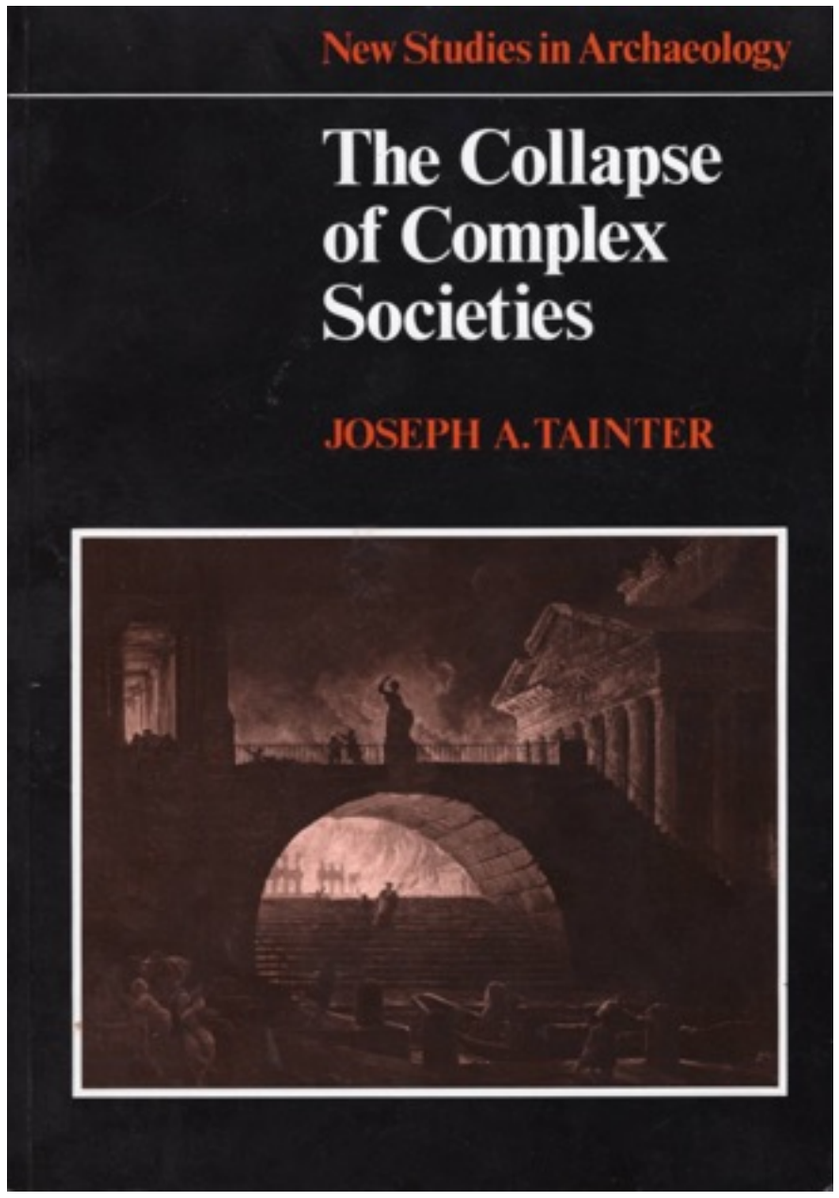
Application to economy



Joseph Tainter

When a society becomes too **complex** ($\alpha \geq 1/e$), its **efficiency** ($-\log \alpha$) becomes smaller than unity and it collapses.

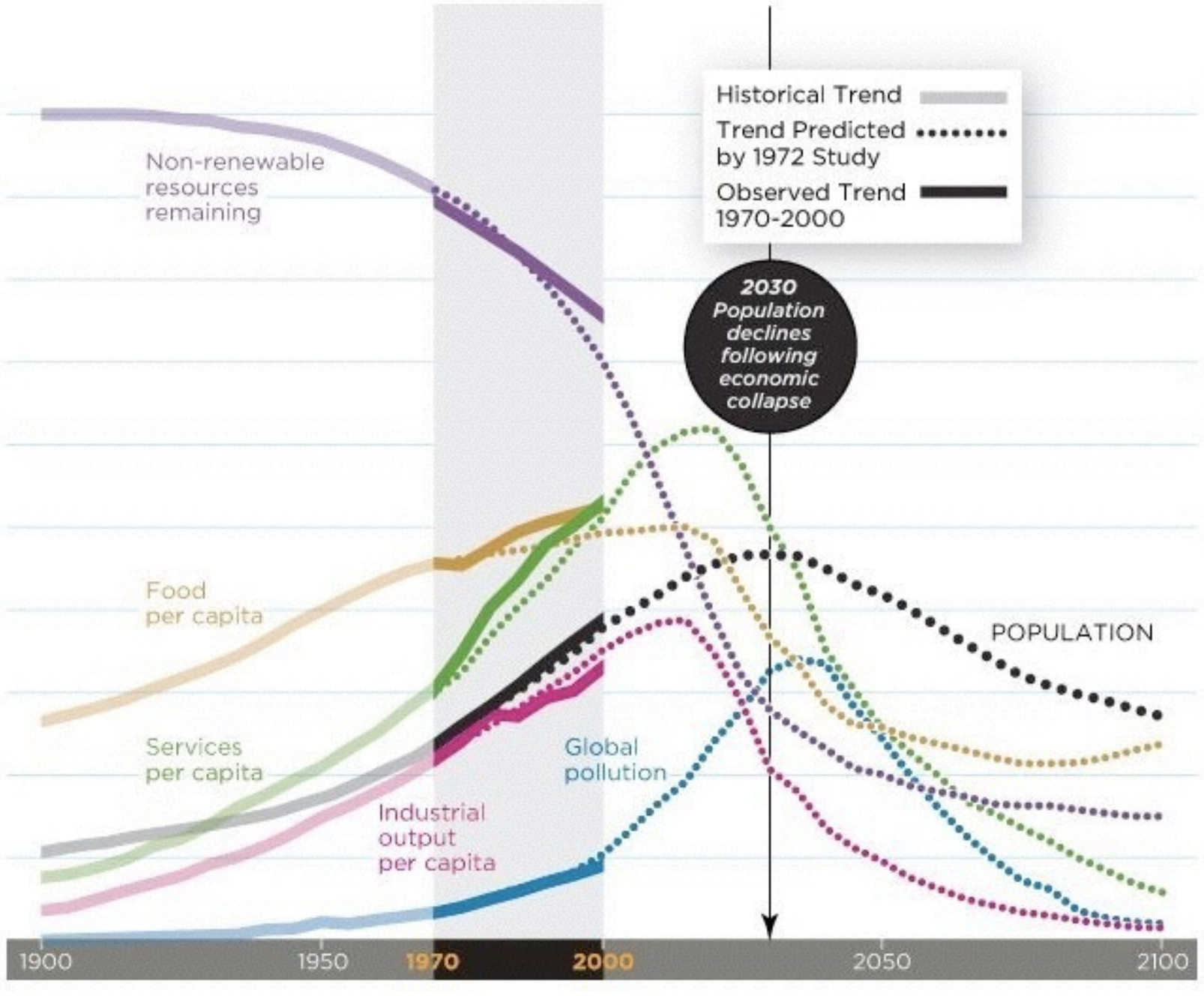
When Tainter published his book (1988), Ulanowicz had not yet discovered his law!



Application to economy

Ulanowicz' -α.log α law must be compared to **Verhults'** parabola rN(1-N/K). **Verhults**' society seeks to renew the energy source to which it is adapted. That of **Ulanowicz** adapts to new ressources. At Neolithic man adapted himself to new foods (bred and milk).

What is going to happen?



What is Gaïa?

Gaïa consists of all the structures that **dissipate solar energy** on Earth: the earth itself, its atmosphere, its oceans, its ecosystems and mankind.

Property of Gaïa:

Each part of Gaïa affects its own environmement, but *not their ensemble*.

The **stability of the outer space** allows Gaïa to regulate itself in order to maximise energy dissipation (**homeostasis**).

Property of Gaïa:

In order to *maximize energy dissipation*, Gaïa produces living beings capable to store ever more information. **It fosters intelligence**.

The evolution of mankind

The **enlightment** is due to the invention of *typography*. Today mankind stores information through *computers*.

The internet forms a neural network.

The evolution of mankind

By altering its environnement, mankind has severely altered Gaïa's previous state (holocène). It's new state (anthropocène) requires a deep *cultural evolution* of mankind and a deep *physical evolution* of the ecosystems that go with it.

It is a learning process.

Conclusion

With Gaïa, mankind becomes *conscious* it is in charge of the ecosystems and the Earth's atmosphere, in the same way an individual brain become conscious it is in charge of its own body to feed it and keep it in good health:

The proposed SOS Treaty
is one of the manifestation.

The end

Nuclear energy:

Lovelock's proposal to use nuclear energy is **unfortunate** and **unwelcome** because *nuclear energy*:

- Produces **wastes** that cannot be recycled.
- Produces **stocks instead of flows**.

Suggested readings:

- **Jacques Blamont**, Introduction au siècle des menaces, Odile Jacob (2004)
- **André Lebeau**, L'engrenage de la technique. Essai sur une menace planétaire, Gallimard (2005)
- **Roger-Maurice Bonnet**, **Lodewijk Woltjer**. Surviving 1.000 centuries. Can we do it? Springer-Praxis (2008)
- **André Lebeau**, L'enfermement planétaire. Gallimard (2008)
- **André Lebeau**, Les horizons terrestres. Réflexions sur la survie de l'humanité. Gallimard (2011)
- **François Roddier**, Thermodynamique de l'évolution. Parole (2012)