GAÏA

or:

The awakening of a consciousness

(Thoughts about the future of mankind)

Paris (ESA), October 7, 2016
What is going on?

World population

Today: 7.4 billions

Enlightenment

Years
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)
1859: Living organisms adapt themselves to their environment through *natural sélection*.
Ludwig Boltzmann

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

Ludwig Boltzmann (1844-1906)
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.
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

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.
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.
An ensemble of interacting \textbf{dissipative structures} is also a dissipative structure:

— The atmosphere of Earth.
— An animal or vegetal species.
— A human society.
Maximum entropy production (2003)

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

**Critical opalescence** of water (374°C, 217 atm.) 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.
A numerical 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.
Ecosystems or mankind import information from their environment through Bayesian "maximum entropy estimates". Maximising entropy production, maximizes intelligence!
Robert Ulanowicz

\[-\alpha \log \alpha \text{ (Rate of entropy production)}\]

Application to biomass

Rate of biomass production

Climax

Forest fires

Reduction

Oxydation

Biomass
Application to economy

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

(François Roddier, Res Systemica, Volume 12, 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

\[ \alpha \log \alpha \text{ (Economic growth)} \]

Critical point

Planification

Liberalization

\[ \alpha \text{ (Invested capital)} \]
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' \(-\alpha \log \alpha\) 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 environment, 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 **enlightenment** 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 (anthropopocène) 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:


• André Lebeau, L’engrenage de la technique. Essai sur une menace planétaire, Gallimard (2005)


• André Lebeau, L’enfermement planétaire. Gallimard (2008)


• François Roddier, Thermodynamique de l'évolution. Parole (2012)