# CHAOS: BACK TO "PARADISE LOST": PREDICTABILITY. THE CENTURY OF THE EMERGENCE OF SYSTEMIC THOUGHT AND CHAOS THEORY

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## Contents





## Summary

The chapter starts with the main concepts of Chaos Theory, Non-linearization, General Systems Theory, Living Systems Theory, Mechanicist Thought, Predictability, Phase spaces, Ordinary Attractors, etc.

An Introduction comes next, where the author describes his doubts on the potential double approach: on the one hand, a direct approach (a) and, on the other, the possibility of introducing chaos into the Systems Thought framework and this in turn into the context of its parallel evolution to Mechanicist Thought (b); in fact, this is the reason why the second approach is chosen.

In line with the above, Section 2 thoroughly develops the co-existence of Mechanicist Thought and Systems Thought, and the emergence of Chaos by analyzing the 20th century decades. In the analysis, the socio-economic scenario is described first, followed by the scientific development of each decade.

Section 3 presents the chapter structure and clarifies the title metaphor: disorder can 'conceal' order (chaos). How are we to tackle this? Chaos is <u>everywhere:</u> biology, linguistics, law, economics, chemistry, psychology, meteorology, galaxies… This requires us to have some knowledge on Systems Theory, qualitatively and

quantitatively speaking (recurring dynamic systems), linear and non-linear differential equation systems, fractals, periodic attractors, strange attractors, Lyapunov's Exponent, Grassberger- Procaccia methods, Whitney's reconstruction method, Poincaré's application, power spectrum, etc.).

In the methods, two relevant cases have to be distinguished in order to detect chaos dynamics:

a) recurring or continuous mathematic models as a starting point.
b) time series as a starting point.

Next, auxiliary theories are cited which appear as intermediate links in a methodological chain starting in the problem's formulation (detection of chaos dynamics in a given speciality) and finishing in the result. Initially, such theories are:

- Kauffman's models – Self-organised Critical Systems Theory – Prigogine's Theory on dissipative structures – Time-Space Chaos – Hopfield's neuronal models – Games Theory -Neurodynamics -Biodiversity (macro-evolution – Red Queen).

Section 4 describes something important: a seven-stage methodological process in which all the previous knowledge is chronologically interrelated and with the essential feedback. The reader so acquires a key instrument for the detection of chaos dynamics.

Sections 5 and 6 introduce some historically important dynamic systems: the Logistic System, the Lorenz System, the Rössler System, and Duffing's System.

Finally, conclusions are drawn in Section 7 which invite readers to delve into the fascinating world of Chaos.

## 1. Introduction

There are should be serious doubts about the approach of this chapter: what to say about chaos. There are two possibilities:

a) a 'radical' one: direct introduction of the subject.
b) A 'mild' one: introduction of chaos emergence within the context of the emergence of Systemic Thought (ST). At the same time, the emergence of ST could be addressed directly as opposed to the evolution of Mechanicist Thought, and so the evolution of both thoughts could be dealt with within the social, cultural and political context of the tremendous –in all senses- 20$^{th}$ century.

Finally opted out for the second approach will be adopted. It was indeed the coherent thing to do, a consequence of the mental structure of systemic professionals; whether we like it or not, we will always see 'realities' as systems that evolve, systems that disturb in and are disturbed by their environment.

Systemic thought is starting to take ground from mechanicist thought. People realize problems are global, and they need global solutions; the specialist is unprotected in front of the real world and needs an added value capable of overcoming the lack of protection, of providing the necessary peace to easily get to have a global vision for him/her to understand and then transform reality.

Systems are complex, they evolve; the determinism dogma - a predictability provider- is falling apart. After Heisenberg everything changed; the undetermination postulate gave us no comfort, whereas the opposite applied to predictability. Lorentz came next and made us realize that a small change in the initial conditions produces a tremendous change in the trajectories.

This is a paradoxical situation. For a while, during the "predictability time", we are still able to determine where and when; a stone –thrown in a particular way- (Newton's laws) will fall on a <u>given</u> spot at a <u>given</u> time. But when that time goes, we are prey to uncertainty; "predictability's lost paradise". From "order" to "disorder". A difficult and dramatic situation. But there the miracle lies.

Not always but sometimes we partially recover predictability. We will not recover the full knowledge of order: <u>where</u> and <u>when</u> will the stone fall? But we shall know that it will fall on a specific <u>place</u> <u>at some stage</u>. This partial recuperation of lost paradise - Milton's manes!- should be defined as chaotic dynamics. Chaos will no longer have highly pejorative connotations: disaster, confusion, kaleidoscope... On the other hand, it will be something desirable, interesting, comforting... Furthermore, chaos brings "order" back in addition to being useful as a system that has been disturbed –an environmental disaster, a financial earthquake, a pathological heart. To survive, it needs to adapt quickly and, paradoxically, the presence of chaotic dynamics in such systems facilitates adaptability.

From the above fact –applicable at present- to the convenience of generating "prostheses" or inserting 'artificial' chaotic systems into disturbed systems, there is only a step to be taken.

Where do these things occur? They have always happened, but right on the very first night. Poincaré –brilliant- advanced something in 1900. After that, we slept. Some daring researchers have "seen" chaos: the butterfly of Lorenz the meteorologist, May, the biologist, Yorke the mathematician, Feigenbauen the physicist. They have all played a part in an exciting novel, in a scientific psychological thriller. And they were on the winning side.

Nowadays, chaos is studied in chemistry -kinetic chemistry- vegetal biology, genetics, quantum mechanics, psychology, cardiology, population biology, economics, linguistics, sociology, satellite signal detection, education, political science...

Is it difficult to understand it or use it? Not from a conceptual point of view, but the Cartesian and reductionist barriers must be overcome; one must get into systemic thought with an open mind, provoke an interdisciplinary discourse, an interdepartmental dialogue, and delve into new concepts *Phase spaces, trajectories, bifurcations, fractals, strange attractors, chaos*.

The different specialists must make an effort to learn some uncomplicated mathematical methods, guided by qualified pedagogues. It is only a small toll to be paid if compared to the immensity and beauty of the scenario they have been deprived of.

Actually, it was them who deprived themselves of it. Can a lecturer, a professional researcher afford to be unaware of such a transcendental thing, not from the philosophical point of view but from a pragmatic one? The author honestly does not think so. That is why the author has written this chapter.

A chapter with a simple sometimes colloquial sometimes rigorous language to explain the why, what for, how, who for of chaotic thought. A chapter for lecturers, university researchers, graduates doing their PhDs in any specialization for them to be able to tackle complex problems –with no 'hang-ups'-that is, as users. Moreover, its is addressed to any people with a degree or even to curious self-learning individuals interested in the scientific thought adventure and willing to be up-to-date. There are thousands of them.

Let us realize that, beyond the meaning of chaos from the point of view of its discovery and its pragmatic repercussion, we face chaos as a generic phenomenon that brutally affects our philosophical conformism: not only in front of Laplace's arrogance when he tells Napoleon he does need God to get to know the future. Future lies within the predictability stemming from the determinism of (his) differential equations, but also in front of the resignation resulting from Heisenberg's uncertainty.

We can draw order from disorder, disorder from order, etc. The future in the shape of Russian boxes, black boxes, a big one inside a small one and so on. Can intellectuals keep on living in their happy and confident town?

Chaos Theory analysis should be developed by considering it an isolated whole. However, this would be poor an analysis which, to start with, would refer to the interrelations with the rest of knowledge. This is why we have chosen a different avenue where Chaos Theory is considered a whole and at the same time a part in another whole: systems thought (Systems Theory).

Together with Mechanicist Thought, Systems Thought defines a new whole finally included in the evolution of cultural processes (political, social, military processes). Of course, this new approach requires big efforts and so the chapter focuses on the 20$^{th}$ century. As would be expected, the final decades in the century will be further explained.

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**Biographical Sketch**

**Lorenzo Ferrer Figueras** born in Barcelona in 1920.

* Teacher for *Generalitat de Catalunya* (Catalonia's autonomous government) in 1938 (during the Civil War).

* Teaching degree completed in 1941.

* BSc in Mathematics in 1943.

* PhD in Mathematics in 1951.

* BSc in Architecture in 1956.

* Industrial engineering degree, last year not completed.

* *Torres Quevedo* Award, *Consejo Superior de Investigación Científica de España* (Spanish Council for Scientific Research), on two occasions, 1953 and 1955.

* Associated lecturer in the college of Mathematics, in the College of Industrial Engineering, and the University School of Quantity Surveyors, Barcelona from 1947 to 1959.

* Professor of Theoretical Mechanics, Universitat de València (1959-1987).

* Professor of Differential Equations, Polytechnic of Valencia (1965-1975).

* Emeritus Professor, Universitat de València from 1987 to date.

* Founder and Head of the School of Operations Research, Universitat de València (1965-1991).

* President of the Valencian Systems Group (1981-1992)

* President of the Spanish Society of General Systems from 1994 to date.

* Has defended 15 Theses on Systems Theory.

* Has published the book "Del Paradigma Mecanicista al Paradigma Sistémico" (*From the Mechanicist Paradigm to the Systemic Paradigm*) (Universitat de València, 1997).

- At present, he leads a research team developing the project "Chaos Theory and its applications to evolution, self-organisation, prediction and control of Natural Complex Systems and Social Complex Systems". The project encompasses 15 teams from 22 University departments (from 1998 to date)

- In 2000, he would have been lecturing for 53 years. He has delivered hundreds of courses in the colleges of Chemistry, Physics, Mathematics, Economics, Agricultural Engineering, Civil Engineering, Architecture, and at the Operations Research School in Valencia, and at the colleges of Chemistry, Mathematics, and Industrial Engineering in Barcelona.