JOURNEY INTO COMPLEXITY

E-Book

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Journey into complexity

First English Edition 2010

Translation of the updated version of the Italian book
Viaggio nella complessità
Edited by Marsilio Editori® s.p.a. in Venezia
First Edition 2007

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Front cover image: Gianluca Biotto
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ISBN: 978-1-4452-6078-5

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To the travellers
who are always ready to embark on the journey

PROLOGUE
FREE VARIATION ABOUT ULYSSES' TRAVEL

I cannot rest from travel: I will drink life to the lees. For always roaming with a hungry heart, much have I seen and known: cities of men and manners, climates, councils, governments. Myself, not least.

I cannot rest from travel: how silly is to have a rest, to stop going, to rust unburnished, not to shine in use! There lies the port; the vessel puffs her sails: there gloom the dark broad seas. It may be that the gulfs will wash us down, it may be that we shall touch the Happy Isles and we see the great Achilles. Always strong in will to strive, to seek, to find, and not to yield[1].

I cannot rest from travel: I want to learn things by experience, approach their meaning and come close to their mystery. It is a vane hope, maybe, but the goal is not really important, as the goal is never the same and each arrival is a new departure.

Reader, trust a merchant of dreams: it is not too late to get involved. Let us set off, old ideas are waning and I want to sail beyond the sunset, beyond the places which are already familiar to you, towards complexity.

Let us set off: we shall come across bifurcations, odd fractal shapes, circles of causes and effects, multiple

[1] Excerpts from A.L. Tennyson, *Ulysses*, 1842.

interconnections. We shall explore the Library of Babel, follow the flights of birds, and drive through the traffic.

Let us set off: like the old emigrants from Friuli, who left Italy for faraway lands, let us take some baggage and let us make an effort to be always strong in our will to search and find things, and never give up. Anin varin fortune[2] *... (Let us go, we shall be lucky…).*

[2] Language here is "Friulano", spoken by people from Friuli, region in the North-East of Italy.

PART ONE
JOURNEY INTO
THE COMPLEXITY THEORY

I.

REMARKS ABOUT COMPLEXITY

> I leave to the various futures
> (not to all) my garden of
> forking paths…
>
> JORGE LUIS BORGES (1941)

FROM DANTE TO SANTA FE

The journey starts off from a feeling, from the awareness of knowing very little about the phenomena around us. We feel bewildered and we are eager to have a more accurate understanding of reality.

This feeling of bewilderment is expressed by Dante in a sublime manner in the first lines of the *Divine Comedy*: "Midway upon the journey of our life, I found myself within a forest dark, for the straightforward pathway had been lost".

According to the scholars of the complexity theory, it is a real challenge from the Middle Age. Just when we are midway upon the journey of our life, we get lost. Just when we are piling up knowledge, we must come to terms with an abyss of ignorance. And, inevitably, we get lost into the forest dark, which reflects the complexity of the world around us, to which we belong. The forest dark is complexity.

Thanks to a space-time acrobatics, we suddenly happen to be in a big American company. The manager of one of the biggest enterprises of the world describes the feeling of bewilderment before complexity: "It is as if I were sitting in front of a camp fire, late in the night, while cinders are burning away. I can hear the noise beyond the light, just

outside my visual field, though I do know neither its origin, nor its meaning".

Challenges come both from the Middle Age and the 21st Century. Our feeling of bewilderment before complexity may be compared to that of S. Augustine for time. We live through time; we are aware of its existence, though we can neither define it nor understand it. The same applies to complexity.

The multi-disciplinary progress made by science in the 20th Century has enabled to partially quench our thirst for knowledge (which had not been totally appeased by the Newtonian science), thus giving rise to a coherent system of knowledge called "complexity theory".

1984, New Mexico, US: A group of young scientists with pigtails gathered in a deconsecrated monastery, with the clear and insane ambition of revolutionizing science, by bringing it closer to reality and its extraordinary complexity. The Santa Fe Institute is created; it becomes the temple of these studies. No more abstract theorems then but a plunge into reality, though with rigorous tools: this slogan explains the complexity theory.

Instability, non-equilibrium, irreversibility, chaos and disorder are some of the keywords of this new science.

Complex systems are the objects of complexity; they feature a number of qualitatively different elements and a lot of non-linear connections between elements. As a result, slight changes in the behaviour of those elements may trigger unconceivable effects. It is known as the butterfly effect: a flat of a butterfly's wings in China may produce a typhoon in the United States. It feels like being in a huge spider-web full of interconnections.

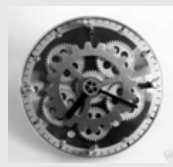
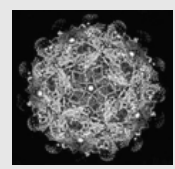
Each one of us is a complex system, made up of many different elements which are interconnected. Even the company where we work and the clubs that we usually attend are complex systems. The Internet is a complex

system. And so are cells, organisms, the brain, economics, chemical reactions, and fluids. And so on.

COMPLEX, NOT COMPLICATED

Each one of us is a mix of experience, relations, stories, individual and collective experience. Multiple interconnections and causes are intertwined with their effects: life means complexity. Sometimes life may be complicated, but it is complex, in essence. Complex does not mean complicated and therefore complexity requires a different approach.

The difference lies in the etymology itself. Complicated comes from the Latin term *cum plicum*, where *plicum* means "paper crease". Complex comes from the Latin term cum *plexum*, where *plexum* means "knot, weave". Complicated refers to the linear *plicum*, while complex refers to the interwoven *plexum*.

	COMPLICATED	COMPLEX
ETYMOLOGY	cum plicum	cum plexum
APPROACH	analytic	synthetic (systemic)
SOLUTION	considered as unfolded creases	considered as a whole
EXAMPLE	 mechanism	 organism

The analytic approach should be adopted to solve complicated problems; indeed, it enables to find the right solution by "unfolding" the problem in its "creases". It corresponds to the classical example of a mathematical system with *n* linear equations in *n* unknowns.

The various parts must be therefore considered and each of them must be explained. Although very hard, it is always possible to find a solution through this procedure. The mechanism, which can be disassembled, is a typical example of this approach. Once disassembled, the mechanism is reassembled and the problem is solved.

Complex problems require a totally different approach, i.e. a synthetic, or systemic, approach. The whole structure cannot be understood by analysing its single parts, but by thinking in terms of synthesis, or system. If you split up the fabric weave in its threads or basic components, you obtain a group of threads whose analysis does not help recreate the original system, of the original fabric.

We must give up the idea of analytically reducing a phenomenon in its creases or its threads; on the contrary, we must try and understand the whole system, which must be considered as something indivisible. From a methodological perspective, we must shift from the analytic level, where the problem lies, to the synthetic level, where the solution lies, by looking at the problem from above.

The solution lies in understanding complex problems as a whole. In this respect, the organism is very representative, as it cannot be disassembled; it must be understood by using a synthetic logic, which allows grasping its complexity. Our mind cannot be understood by analysing neurons.

While something complicated can be reduced to an equation, something complex can be only narrated. For this reason, although science, which has been strongly

idealized, is fundamental for human development, it does not enable to consider how beautiful and surprising nature may be. At least, it is not sufficient. Hence, a feeling of bewilderment was generated and it lasted until a group of young scholars with pigtails gathered in a deconsecrated monastery in Santa Fe three centuries after Newton's death.

BRIEF JOURNEY INTO COMPLEXITY WITH THE GIANT THINKERS

28th April, 1686: This was one of the greatest days in human history. On that day, Newton presented his *Principia* to the Royal Society, in London. The great synthesis of the Newtonian mechanics crowned in a triumphal manner the results achieved by those who were at the forefront of the so-called scientific revolution, like Copernicus, Galileo, Descartes, Bacon, just to quote a few prominent scientists.

The benefits of this knowledge revolution are countless and they are not limited to the scientific field. Also technicians, manufacturers and dealers benefited from this revolution. The 17th Century scientific revolution taught to technicians to take "care of the detail", i.e. to analyse problems by breaking them down into their constituent elements which can be observed more easily than the problem considered as a whole (Pacey 1975).

Still, the world of classical science is a clock-world, "a metaphor suggestive of God the Watchmaker, the rational master of a robot-like nature" (Prigogine, Stengers 1979). God sits at the remote borders of the universe, and watches its regular flow without interfering.

The underlying objective of this new scientific approach is to simplify things and make phenomena widely predictable. If something cannot be controlled, it is

solely due to human limits. Science aims at becoming certain and infallible knowledge, or *episteme* in Greek. For almost three centuries, science has actually corresponded to *episteme* in the Western world. In these few pages we shall make a journey through these centuries, escorted by the giant thinkers who animated these centuries with their thought.

We suddenly meet William Blake, the great mystic poet and painter from the English Romanticism who was the first fierce opponent of Newton's mechanistic paradigm. His criticism is clearly stated in the following lines: "May God keep us from single vision and Newton sleep". The Tate Britain in London hosts a famous painting by Blake which is also critical of Newton's attitude; indeed, Newton is depicted while he is trying to solve a problem, leaned over a piece of paper and not aware of having his back turned on the real world.

At the same time, Goethe wonderfully describes the contrast between the perspective of classical science and the Romantic vision of nature through the following lines: "All theory, dear friend, is grey, but the golden tree of life springs ever green".

At around the same time, at the dawn of the 19th Century, thermodynamics is introduced in the scientific world, thanks to the advancement of the technology for thermal machines, which were used to convert heat into work. Two principles are set out and the main relations describing the potential transformations of fluids are identified.

The advent of thermodynamics, which represents a fundamental advancement towards the understanding of natural phenomena, marks the beginning of the end of the hegemony of classical science in the knowledge world.

Thermodynamics enabled to understand that Newtonian laws cannot thoroughly describe some phenomena. Unless we wish to make an implausible inference, we cannot explain the propagation of heat between two bodies with a different temperature through the dynamic interactions between the two close masses. In his work on heat transmission in solids, which dates back to 1811, Fourier states with elegant simplicity that the heat flow between two bodies is proportional to the thermal gradient between them. Like Newtonian laws, it is a general law which describes a phenomenon which is as universal as gravitation.

1865: Clausius, the German physicist and mathematician introduced the concept of entropy, i.e. the second principle of thermodynamics, which resulted from a simple observation: in every macroscopic mechanic process, some or all the energy is dispersed and turned into heat. Closed systems display an irreversible movement towards a state of maximum entropy or disorder.

1877: According to the Austrian Ludwig Boltzmann, entropy can be also statistically defined as a measure of the degree of disorder in a system. Indeed, there exists a precise relationship between entropy and probability, which corresponds to the following formula: $S = K_B \ln P$. S stands for the entropy in a system, K_B is the Boltzmann constant and P stands for the thermodynamic probability of a system to reach a given state, i.e. the number of probable configurations which give rise to the same thermodynamic state. An increase in entropy occurring in an isolated system which reaches a state of equilibrium may be considered as an effect of the tendency of all systems to evolve from a less probable to a more probable state.

The deterministic approach is somewhat turned into a probabilistic approach. Boltzmann assumed that while it is impossible to know all trajectories of gas molecules, it is possible to know the average behaviour of these trajectories.

Boltzmann was the first to introduce a probabilistic concept and, for this reason, he was fiercely opposed by the scientific community. The famous scientist Mach leaded such protest. The effects of the conflict were tragic for Boltzmann who could not bear the pressure of being isolated from the scientific community and therefore decided to take his own life. As a tribute to Boltzmann, the formula $S = K_B \ln P$ was inscribed on his grave, in the Central Cemetery in Vienna.

Hence, the second principle of thermodynamics: starting from the assumption that the universe is an isolated system, the entropy of the world tends to a maximum. Subsequently, disorder increases. It is the end of the order, stability, and reversibility of classical science. “Disorder burst into the physical universe” (Morin 1990).

Disorder, instability, irreversibility become established as a source of complexity.

In the early 20th Century, we meet another giant thinker on our way, who leads us towards complexity; his name is Albert Einstein. With the advent of relativistic mechanics, some application limits are introduced in classical mechanics; indeed, classical mechanics is no longer valid when velocities are very high.

However, the theory of relativity is kept within the bounds of determinism. As a matter of fact, the values of parameters considered at a certain time determine the future behaviour of the whole universe. The following phrase by Einstein is very evocative and proves that determinism takes a great part in the scientist's research: "What really interests me is whether God had any choice in the creation of the world". According to Einstein, world determinism cannot be challenged. Everything is determined. Only God, maybe, had a choice at the time of creation. Maybe…

Then around 1925 quantum mechanics appears, together with its fundamental pillars, hence the Heisenberg's uncertainty principle and the De Broglie's wave theory. Like relativity, classical mechanics is not considered to be wrong, but simply insufficient; actually, it can be no longer applied to extremely small bodies but only to standard-sized bodies.

Newton's mechanics has a limited scope and cannot therefore be applied to those objects which travel almost at the speed of light and whose size becomes microscopic. The time seems ripe for science to take a new direction; as a result, in the aftermath of the Second World War a rebirth takes place in the knowledge field.

On the occasion of the Macy Conferences, which started in 1946, in March, the most brilliant intelligentsia of the time gathered in New York. They had a common

ground, as their discussions were mainly focused on knowledge models, biological computations, systemic thought, and experimental epistemology. At that time, such topics were part of one big and undifferentiated group. The Macy Conferences, which went on for more than ten years, were undoubtedly marked by the style, personality and different opinions of John Von Neumann and Norbert Wiener.

These two giant thinkers introduced cybernetics, or the control and communication in the animal and the machine. Positive and negative retroaction, feedback, loop, circularity, and organization will later give rise to complexity and some scientific concepts which will mark the 20th Century.

At the end of the 1940s, in the Bell Telephone Laboratories, US, the Information Theory is introduced by Norbert Wiener and Claude Shannon in the field of cybernetics; the Theory mainly deals with the reception of a message, encoded as a signal, through a "noisy channel". Norbert Wiener also maintains that an encoded message is, in essence, an organizational scheme. Then he identifies a similarity between communication schemes and organizational schemes in the organisms, which will later lead to think of living systems in terms of organizational schemes or organized schemes.

Complexity takes its first steps within the rising system theory, which was introduced at the end of the first half of the 20th Century, especially thanks to the research made by the Austrian biologist Ludwig von Bertalanffy. The philosophy of science of our century was deeply affected by this theory, which was given different names, such as system theory, system dynamics, system analysis, systemic analysis, structural analysis, and functional analysis.

In the introduction to his great book called *General System Theory* (1968), Ludwig Von Bertalanffy writes as follows: "Systems thinking plays a dominant role in a wide range of fields from industrial enterprise and armaments to esoteric topics of pure science."

We owe to the system theory the great achievement of shifting attention from the single elements (parts) to the system as a whole. A thorough and specific understanding of the different system parts does not automatically imply an adequate understanding of the whole of it. Hence, a shift occurs from an analytic approach to a systemic or synthetic approach, which implies a change in perspective.

A distinction is made between closed and open systems. While a closed system is generally meant to be a system in which matter and energy cannot be exchanged with the external environment, an open system envisages interaction and exchange of matter and energy with the external environment.

Especially, the studies on non-equilibrium irreversible thermodynamic phenomena carried out by the Nobel Laureate Ilya Prigogine (1917 – 2003), who is considered by many as the founding father of complexity, build upon the concept of open system. Through the exchange of matter and energy with the external environment, open systems do not evolve towards a regular and irreversible increase in entropy (unlike closed systems, see second law of thermodynamics); on the contrary, they can evolve towards a state of bigger order. Hence, continuity and discontinuity, order and disorder, complexity.

In the shift towards discontinuity, new points of order are reached. Meteorology, which later spawned the chaos theory, contributed to defining this evolution in physical, biological and social systems. To simplify matters, chaos corresponds to the *butterfly effect*, which implies non-linearity and the unpredictable effects produced by small

variations in the initial conditions. The slight change produced today in the atmosphere by the flapping of a butterfly's wings affects the potential and actual atmosphere behaviour of tomorrow. As a result, in a month time, the tornado which was supposed to devastate the Indonesian Coast does not appear or instead, if it was not supposed to happen, it actually happens.

By the way, this is no news to anybody. By now, everybody is aware of the unpredictability of the future, though magicians and fortune-tellers are paid handsomely for selling the illusion of predictability. Small causes may have significant effects; Blaise Pascal's following remark was not accidental: "Had Cleopatra's nose been shorter, the whole face of the world would have changed". It is quite new though that, in some systems, slight variations of the initial conditions often leads to totally different effects so that every attempt of predicting them seems actually vain.

Chaos appears as a science in the Information Age; some of the elegant mathematic concepts used to model chaos have relevant applications in a number of fields. Today many scientists apply non-linear dynamics to model a large number of phenomena, from fluid dynamics to chemical and biochemical processes, from genetics to heartbeats, from people dynamics to the evolution theories, and economics.

Starting from the 20th Century scientific discoveries, the complexity theory developed in a turbulent, disordered and multidisciplinary manner. Physicists, mathematicians, computer scientists, biologists, philosophers, men of letters, economists, management scholars and many others contributed to complexity. The contributions available in literature are numerous, scattered, heterogeneous and very inspiring. The main objective is to understand the behaviour of complex systems, which are made up of a

number of different elements and a number of non-linear connections.

Hence, the Santa Fe Institute was created in 1984. The famous temple, in which the scientists with pigtails gathered, was especially devoted to the study of CAS (*complex adaptive systems*), i.e. complex living systems with evolution abilities.

Three centuries after Newton, we have come to a new harbour, escorted by the giant thinkers. Goodbye to order abstraction, linearity, predictability, determinism. Welcome human beings, groups, people, organizations, vitality and change. With a real thirst for knowledge, oriented at solving heterogeneous problems, the complexity theory will be soon confronted with a number of different topics, such as the behaviour of a flight of birds, traffic jam dynamics, stock market fluctuations, the behaviours of cooperation and competition among companies, global warming and Aids, just to quote a few examples.

A complex adaptive system can be defined as an unstable collection of elements and connections which are self-organized to ensure adaptation. Such a system is shaped consistently through time; it is adaptive and self-organized and is not managed or controlled by any single entity. The fundamental objective of adaptation is achieved through the regular redefinition of the relationship between the complex system and the external environment.

According to Kauffman, an American biologist, complex adaptive systems move on fitness landscapes and are distorted by the systems themselves, by other systems and exogenous elements. Everything is interconnected, we are part of the whole and we all actively contribute to shaping the big web of life through our actions (Capra 1996).

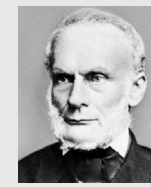
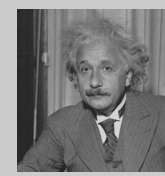
Starting from the experience made by the scientists with their hair in pigtails working at the Santa Fe Institute, several research centres about complexity were created, such as the Necsi (New England Complex Systems Institute) and Exystence (The Complex Systems Network of Excellence), to name but a few.

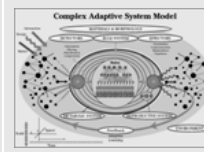
Hereafter follows a table with the various stages of our journey together with the above quoted giant thinkers. It is a sort of travel map.

Knowledge is gained all along the journey, not just at the final destination. The destination is out of reach and cannot be reached, since it shifts forward as we get closer to it. However, the thirst for knowledge and the search for the meaning of things will always push human beings to set off again.

From where shall we start, three centuries after Newton's death?

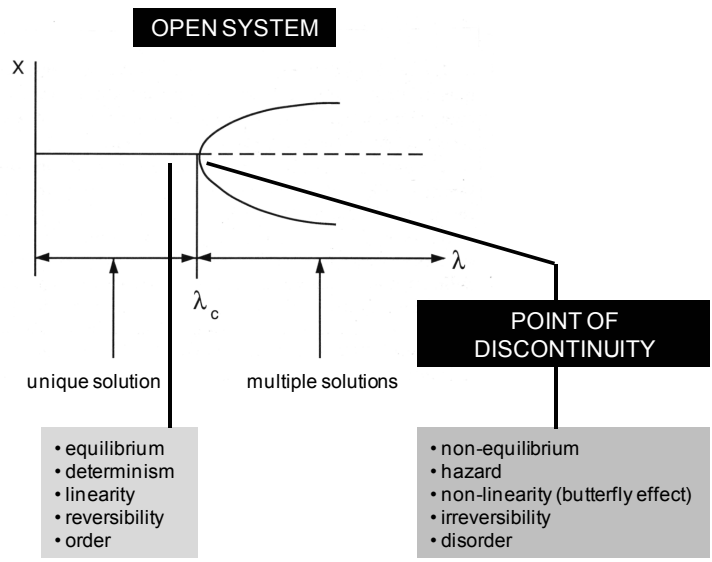
By now, we are becoming more aware that nothing happens in isolation and nothing can be understood in isolation. Phenomena and events are connected to a huge number of other phenomena and events. A revolution is taking place, in which scientists of all disciplines are realizing that complexity has its own architecture and the evolution of many physical, biological and social phenomena follows a common trend. The evolutionary trend is forked; hence it is continuous and discontinuous at the same time, as the founding father of the complexity theory, Ilya Prigogine, wonderfully explained. May this giant thinker lead the way throughout the next paragraph.

1686	**Newton** presents his Principia to the Royal Society of London. His work, which includes the fundamental laws of motion, introduces a new approach to science and a new vision of the world	
1865	**Clausius** presents the second principle of thermodynamics, hence the concept of entropy: disorder and irreversibility become scientific objects	
Early 20th Century	The theory of relativity and quantum mechanics set some application limits for classical science (which cannot be applied in case of extreme size or velocity)	
1946	During the Macy Conferences, the two mathematicians **Von Neumann** and **Wiener** introduce cybernetics, or the science of control and communication in the animal and the machine	
1950	**Von Bertalanffy** introduces the system theory in the scientific world. His major work, General System Theory, dates back to 1968	

1961	At the MIT, the meteorologist **Lorentz** discovers that a tiny change in the initial conditions of a system produces unexpected effects (butterfly effect): the chaos theory is introduced	
1977	**Prigogine** is awarded with the Nobel Prize "for his contribution to non-equilibrium thermodynamics, especially for the theory of dissipative structures"	
1984	The Santa Fe Institute is founded. It is a research institute dedicated to the study of complex systems	
2000	The NECSI (Boston), New England Complex Systems Institute, is founded	
2002	The Complex Systems Network of Excellence, Exystence, is founded	

PRAISE TO CONTINUITY AND DISCONTINUITY

Dissipative structures, analysed by Prigogine, are open systems that keep the order and may even evolve towards a qualitatively different state thanks to the steady exchange of matter and energy with the external environment. Like the majority of complex systems, dissipative structures evolve through bifurcations and the alternation of continuity and discontinuity.



Although complex systems are subject to the exchanges with the external environment and the fluctuations resulting from such exchanges, they can temporarily keep within the organized borders of continuity. However, when the thermodynamic force acting on the system reaches high values and the system forcedly quits the linear region, some fluctuations may grow until they

occupy the whole system and finally lead it to evolve to a new state which may be qualitatively different from stationary states. At the point of discontinuity, the system evolves towards a new state which cannot be predicted a priori (hazard plays a role in science!).

The results obtained by Prigogine in the field of thermodynamics can be valid for life as well, which implies the alternation and coexistence of necessity and hazard, continuity and discontinuity, order and disorder. Life is based on the coexistence of opposites. According to the French philosopher Edgar Morin (1990), one of the major representatives of complex thought, "in a universe of perfect order, innovation, creation and evolution would not be possible. Living and human beings could not exist. Similarly, any form of existence could not thrive in a state of sheer disorder, as the lack of stability would prevent the development of any organization".

We praise continuity as "repetition, steadfastness, invariance, and all that is under the aegis of a highly probable relationship, all that can be framed in a law". Hence, we praise simplification, reduction, certainty, rule, honest living.

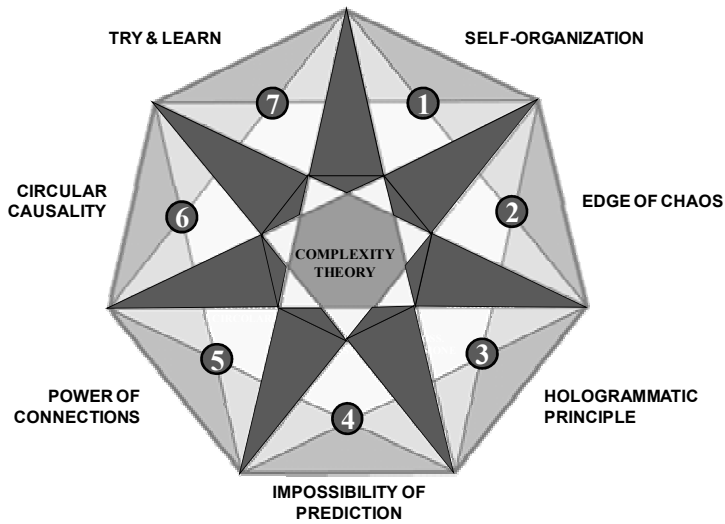
But we also praise discontinuity, which is "irregularity, deviation from a given structure, risk, unpredictability". Hence, we praise change, novelty, the unexpected, risk, freedom, dream and action.

Finally, complexity is the vital coexistence of continuity and discontinuity. We are aware of this fact and we experience it day by day. Forrest Gump describes it as follows: "I don't know if we each have a destiny, or if we're all just floating around accidentally, like on a breeze. But I think that maybe it's both, maybe both happening at the same time".

II.

THE SEVEN PRINCIPLES OF THE COMPLEXITY THEORY

It's all equilibrium above madness
VASCO ROSSI (1996)



The complexity theory is a system made of multidisciplinary knowledge, encompassing physics, biology, philosophy, economics, management, etc. All disciplines can contribute to the theme of complexity, because complexity is everywhere. The need to rationalize these heterogeneous contributions led us to identify seven principles for the complexity theory. Seven is a magical

number, according to the biblical tradition. This number was not decided *ex ante* but was an *ex post* result.

PRINCIPLE 1. SELF-ORGANIZATION

Self-organization can be defined as the spontaneous creation of order, new structures and new forms of behaviour in systems that are thermodynamically open but organisationally closed and far from equilibrium.

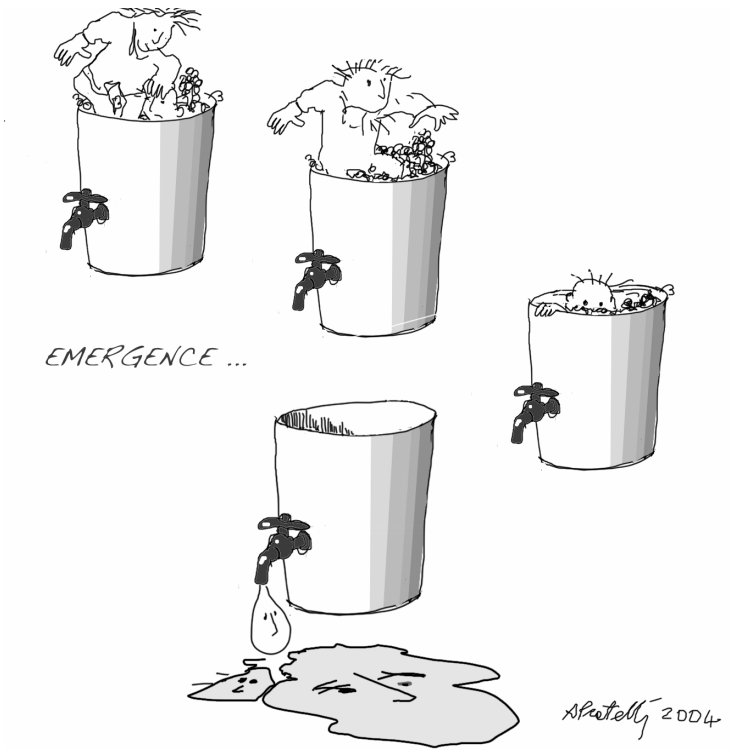
The flights of birds migrating to the south in autumn show fluidity in their movements, as if they were following a predefined and organized choreography. Though, there is neither a leader nor a project guiding the flights. They move harmoniously because every single bird follows a set of basic rules, according to which the bird imitates the behaviour of the neighbours which are flying next to it. The final result is a coherent behaviour.

Aunts and cars in a traffic jam behave similarly. Again, the result is a coherent behaviour.

The emergence of new bottom-up structures and forms of behaviour, which do not follow any predefined scheme from the external environment, is one of the most fascinating aspects of complex systems. Local interactions are determined by a few simple rules and can give rise to complex and amazing global behaviours.

Self-organization accounts for the tendency of an open system to give rise to new structures and forms starting from internal dynamics, from the cooperative and competitive interactions within the system. The complexity theory studies open systems from the thermodynamic perspective, which are the opposite of closed systems envisaged by the second principle of thermodynamics. In such open systems, we find a tendency to organisation (neghentropy) which is opposite

to the tendency to degradation (entropy). Open systems are defined as "thermodynamically open but organisationally closed" due to their independence from any external scheme.



All living beings are self-organized in millions of plant and animal species, ranging from very simple species to complex ones. In the universe, elementary particles give rise to atoms, molecules, elements and compounds. On a cosmic scale, gaseous clouds condense to form stars, which, in turn, form galaxies and groups of galaxies, etc.

The human brain is another brilliant example of self-organization: indeed, the property of conscience results from neuronal interactions.

The flights of birds migrating to the south in autumn do not have a leader, nor a project and yet, their behaviour is coherent. According to Philip Anderson, Nobel Laureate in Physics (1972), this is "the most fascinating mystery of science".

PRINCIPLE 2. EDGE OF CHAOS

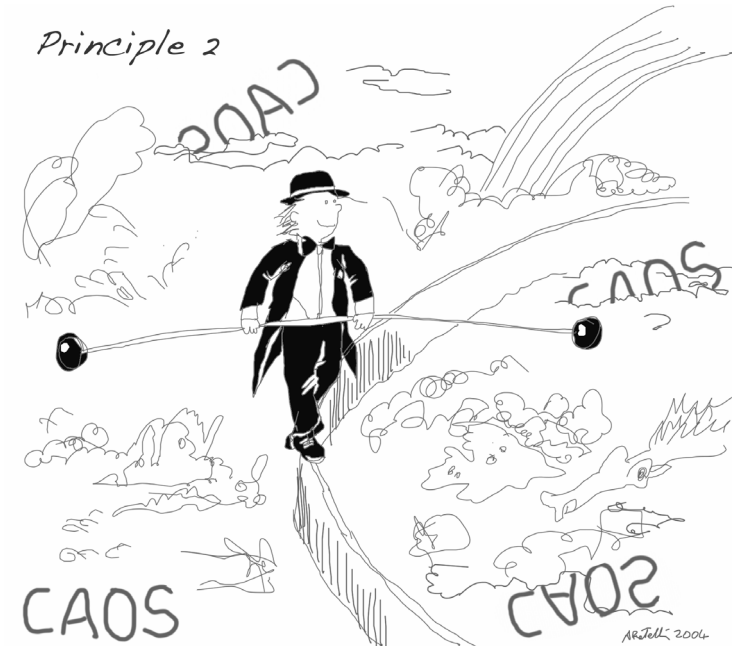
Complex systems evolve towards the edge of chaos, which is an ever changing vital state of dynamic equilibrium between order and disorder.

Let us consider our existence, again. If we search for order only, we learn to always stick to rules, we get used to normality, and we are doomed to become fossil-like. On the other hand, the relentless search for novelty, rule-breaking and fast living may lead us to disintegration. Many studies have shown that complex systems move in an area of dynamic equilibrium between order and disorder, which is called edge of chaos. Michael Crichton, the famous novelist who wrote *Jurassic Park*, defined it as "a zone of conflict and upheaval, where the old and the new are constantly at war".

The edge of chaos is the alternation and coexistence of continuity and discontinuity in the bifurcation; it is the place where life is stable enough to flourish and creative enough to deserve the name of life. Therefore, it is the place of steady changes and innovation.

The Danish physicist, Per Bak, resorted to a *power law* distribution to explain the phenomena happening at the edge of chaos. According to Bak, the average frequency of a given size of avalanche is inversely proportional to some

power of its size. As a result, big avalanches are rare, small ones are frequent. This is the law of change.



The power law distribution is very common in nature. It was observed in the solar activity, in the light emitted from galaxies, in the power flow through a resistor, and finally in the water flow in a river. In 1956, Beno Gutenberg and Charles Richter discovered that the law also applies to telluric movements.

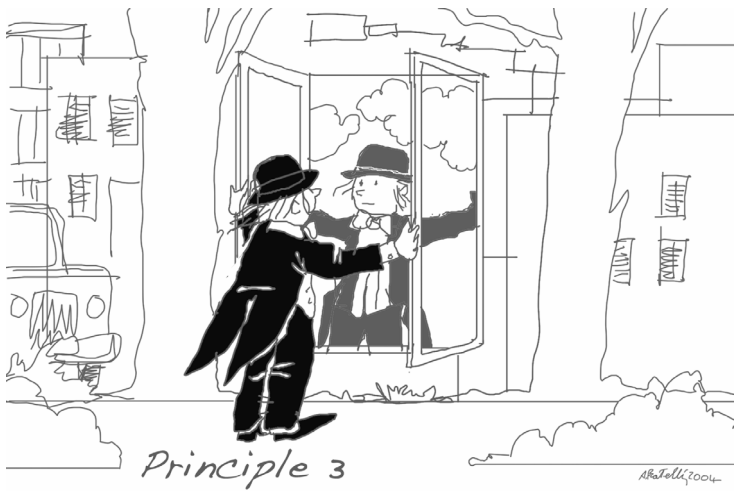
Some historical events are also seen as a direct effect of dynamic order. The fall of Communism in Europe reminds of the stability and upheaval at the edge of chaos. The Cold War can be seen as a long stable period of time, with many insignificant upheavals which did not lead to big

avalanches. Then, a revolutionary avalanche came with its amount of destruction and creation: the fall of the Berlin wall, the visible point of discontinuity.

The principle of the edge of chaos suggests that we accept the coexistence of the opposites and shift from an *or* approach to an *and* approach. Indeed, things do not rule out or cancel out each other; on the contrary, they come together, coexist, integrate and complement each other. As Heraclitus wrote in the *Fragments*, we should "[unite] things whole and things not whole, that which tends to unite and that which tends to separate, the harmonious and the discordant".

PRINCIPLE 3. HOLOGRAMMATIC PRINCIPLE

The part is in the whole. The whole is in the part.

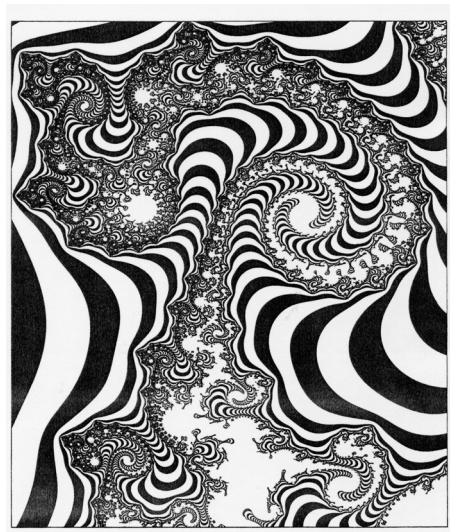


Perfect circles, triangles, regular surfaces have been the common features of Euclidean geometry for thousands of

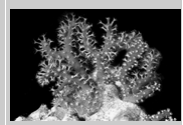
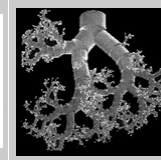
years. Several artists found an ideal beauty in these features and Ptolemaic astronomers posited a theory of the universe based on the Euclidean geometry. However, today a new geometry appears; it mirrors a universe which is irregular, not rounded, scabrous, and not smooth. It is the geometry of the pitted, the pocked, and broken up, the twisted, the tangled, and intertwined. It is called fractal geometry and was introduced by Benoit Mandelbrot, a Polish mathematician.

Fractals are irregular forms. Sometimes they are awkward, sometimes they are slender. They are often tangled and twined around each other. They are computer-created, self-organized forms resulting from a few simple basic rules. The *sea horse valley*, also called the *elephant (trunk) valley*, is shown hereunder. It results from the iteration of the formula:

$$Z\ (\text{future}) = Z^2\ (\text{present}) + C$$



Above all, these forms can be found in nature. The complex forms of the Dolomites, recently declared a Unesco World Heritage Site, can be expressed through a fractal number. The same applies to the jagged coastlines and to many other examples.

	FRACTAL IMAGES		
NATURAL WORLD	 snow flake	 lightning	 coastline
VEGETABLE WORLD	 cauliflower romanesco	 spiral cactus	 fern
ANIMAL WORLD	 coral	 nautilus shell	 bronchus

These forms are regulated by the hologrammatic principle. The term “hologram”, which was coined by the Hungarian scientist, Dennis Gábor, in 1947, combines the Greek words *holos* (whole) and *gramma* (transfer) suggesting that the whole is transferred to its parts. As a

result, in a hologram the information about the whole object can be found in the smallest point of the image.

If we take a family picture and cut it in two parts, the grandfather, grandmother and one half of the father will happen to be in one part, while the mother, the two children and the other half of the father will be visible in the other part. On the contrary, if we cut a hologram, each portion will show the whole image.

According to the hologrammatic principle, in complex systems the part is in the whole and the whole is in the part. For instance, stem cells are the parts included within the whole (the body) but they contain information about the whole body.

There is a close relationship of mutual dependence and influence between a complex system and its external environment. Our view of the world is based on such relationship. According to the Santiago Theory, elaborated by the Chilean scientists Maturana and Varela, we bring forth a world which is a representation of reality based on our personal experience. In other words, the whole (environment) fits into the part (us) through our mental schemes.

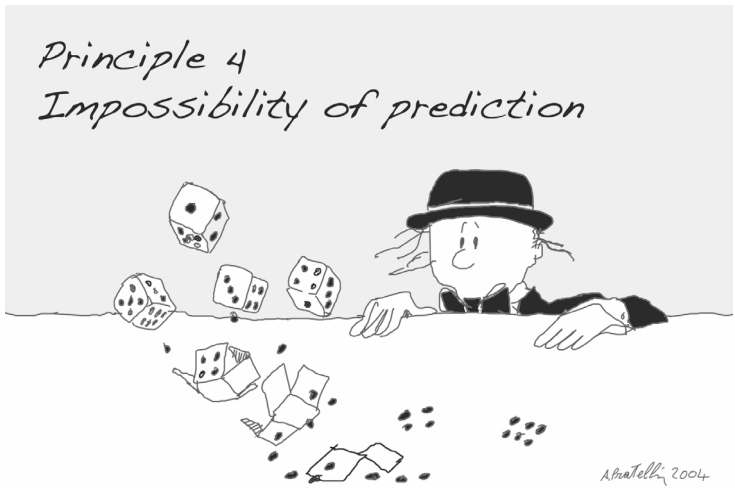
PRINCIPLE 4. IMPOSSIBILITY OF PREDICTION

Complex systems are in a state between predictability and unpredictability, where everything is possible but not everything is actually fulfilled.

May the big heavy doors open so that I can finally enter the Library of Babel with its countless planes, shelves and dusty books. There lay all the books written in the past, all the books that will be written in the future, and finally all those that won't ever be written, although they are among those which could be possibly written. There lie terribly

boring books, where you can just read letter A, or even books whose sheets are all blank. There lies my autobiography in its indefinite versions, stories about battles of the past, wars of the future or wars which won't ever take place. There lie dissertations about the theory of relativity or just something that looks like it, and about theories which will be discovered only in 10000 A.C.

Everything is possible but maybe nothing is actually fulfilled. The Library stands for the infinite number of possibilities. Only some of these possibilities are actualized.



Complexity is the space of possibility. It is impossible to predict with certainty the future state of a complex system, although it is possible to predict its possible states (structure) as a general rule. As regards the weather, its specific state is not predictable, while its structure, i.e. its possible states, is not unpredictable. Indeed, climate,

meant as a structure which limits the possible weather states, can be predicted to a great extent.

In 1991 Giovanni Comboni, an Italian economist, writes about the transition from "Necessary to Possible" and states that "thanks to its indefiniteness and infinity, Possible becomes the driving force of complexity".

Complexity is possibility. It is the mother of freedom and change. It is a garden of forking paths, the alternation of continuity and discontinuity, the place where everything is destroyed and recreated around us, the place where we are the first active creators of the reality.

Complexity requires the acceptance of the possibility, the surprise and the novelty. According to the Italian philosopher Gianluca Bocchi (1985), "nature is so amazingly complex and rich that almost everything can happen. Those who are in search of clear, resolute and global answers to life's problems cannot find them in nature".

It is impossible to predict the future, everything is possible and not everything will be actualized. To say it through the words of the French Michael Serres (1990), "What is future? I don't know. I am interested in it because it is strongly, highly and gloriously unpredictable, inventive".

PRINCIPLE 5. POWER OF CONNECTIONS

Everything is connected to everything else, often in a very sensitive manner. In certain circumstances the least uncertainty can grow to such an extent that the future of the system becomes totally unpredictable. Connections are numerous and powerful.

The human brain is the most complex organization in the universe. It is made up of several billions of neurons,

which are connected to many others (say thousands of neurons on average), and which altogether form a huge neuronal network. The human brain is slightly over one kilo in weight, and yet it hosts around 10^{13} connections, which ensure its functions.

Human intelligence is entirely based on connections and works through neuronal connections. Neurons are binary, either they fire or they do not, while intelligence is represented in the brain as incoming connections between neurons (synaptic connections).

According to one of the most popular slogans related to the complexity theory, the whole is greater than the sum of its parts and connections are the added value. Brain is something more than the sum of its neurons. It is an incoming property, or the result of many billions of neurons acting in compliance with the biological laws of the living cell. It is a self-organization.

Connections in complex systems are numerous and powerful. Also, as they are often non-linear, they give rise to the above quoted butterfly effect (a flat of a butterfly's wings in China may produce a typhoon in the United States).

Connections and networks are everywhere. Pietro Quattrocchi, an Italian philosopher, states that "[according to the complexity theory], the scientific object is not the thing itself, but the network of relations beyond the one thing, visible from the perspective of complexity".

Connections and networks are everywhere. Organisms are made up of cells which are independent and yet closely connected to each other. Populations are networks of individual organisms belonging to the same species. Ecosystems are groups of organisms, either unicellular or multi-cellular, belonging to a number of different species.

Principle 5

Power of connections

All the things and the individuals in the world belong to a wide non-linear web of incentives, constraints and connections (the web of life). The Information and Communication technologies have recently given a boost to the process. Still, the American Indians had realized it a long time ago: "We know this. We know that everything is connected to everything else, like family members are united by blood…".

PRINCIPLE 6. CIRCULAR CAUSALITY

In complex systems causes produce effects which are retroactive and therefore give rise to a self-feeding circular relationship.

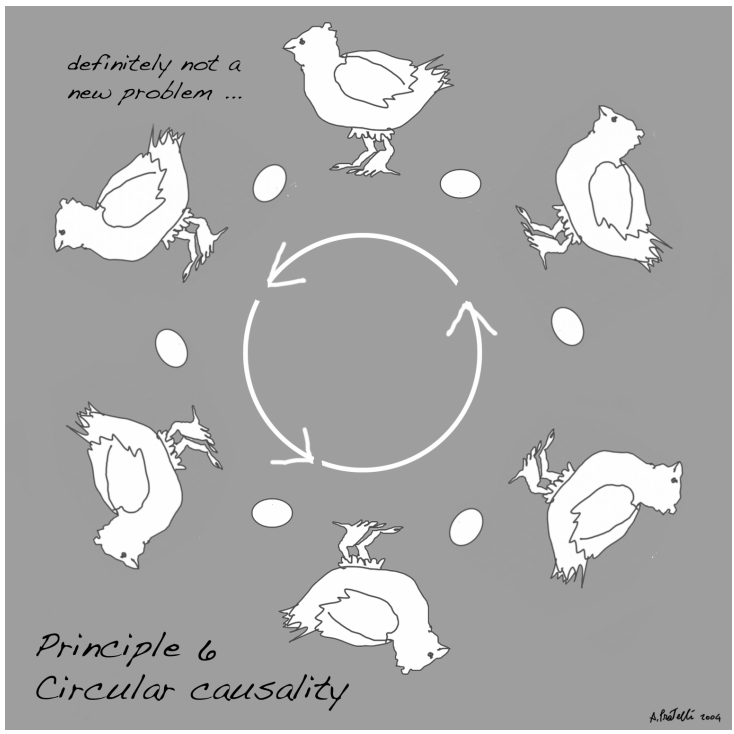
In physics and philosophy, the cause-effect relationship has always been central. In the language of machinery, a cause corresponds to an "input", while in psychology a cause is defined as a "stimulus". In each field of study, a particular term has been coined to express this concept.

However, in each field of study the hope is to deduce effects from causes; indeed, up to now our culture has supported the following hypothesis: we may and ought to think according to processes modelled by cause-effect relationships. The input sets the machine in motion and what comes out of the machine is called "output". If we were dealing with physiology or experimental psychology, we would speak of "response". Hence, the cause/effect, input/output, stimulus/response schemes are outlined.

However, as always (fortunately) happens, reality is a little more complex than its definitions. The various causes and the various effects are often intertwined or exchanged; they are retroactive and can diverge or converge. Reality is made up of a number of different interconnections; if you try and find short-term linear relations, you frame reality

into schemes which, of course, may be necessary for scientific purposes but not quench our thirst for knowledge.

The discovery of non-linear causality, with its numerous interconnections that are not fixed and sometimes indefinitely stretched through time, is an achievement of the 20th Century. This principle, introduced in cybernetics, is applied in the complexity theory.



The term suggests the circular action from the response to the relevant stimulus and from the effect back to the

relevant cause, as in a loop. Circular causality affects the functions of the systems studied in cybernetics; indeed, it leads to the typical processes of self-balancing and self-strengthening circles underlying the system structure and the self-organisational ability. Reality is made up of different elements which are interconnected in self-strengthening (virtuous or vicious) circles which move away from equilibrium and self-balancing circles which tend to move back to equilibrium.

Swimming into the sea of complexity requires the development of a new way of thinking. It calls for a systemic vision of the world and an attempt to understand its essential interconnections and circles. Everything is interconnected. Causes are connected to their effects and effects retroact upon their causes.

PRINCIPLE 7. TRY & LEARN

At a high level of complexity, in a situation between necessity and hazard, the only way to learn is to try (try & learn).

Living beings are the outcome of history. Each one of us derives from a number of casual, individual and unexpected bounds, laws and elements. According to Italian scientific journalist, Pietro Greco (1999), "we, human beings, turn up at the reception of the Universe Grand Hotel without having made any special reservation. We are not unwelcome. Though, we are not even expected". Evolution is not necessity, but history instead: catastrophes, hazard and contingency.

Theoretically, you cannot find two identical flakes among all the billiards of trilliards of flakes which have fallen down to the Earth. All flakes are either hexagonal or triangular, and symmetrical, and yet we can tell the

difference between them at a glance. This is history, hence a combination of an overall determinism, which sets the global features, and a specific randomness, which sets the local features.

The shift from the Darwinian view to a more complex view of evolution has marked a change of perspective vis-à-vis the learning theme. As a matter of fact, evolution and learning are closely linked. Learning generates evolution which, in turn, generates new learning.

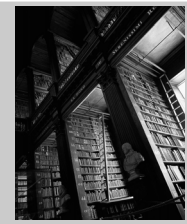
According to Italian economist Enzo Rullani (2002), learning in complex systems "takes away […] free complexity from the environment, takes it into the system structures, thus turning it into rule-governed complexity". Learning means being able to manage the complexity of the external environment.

According to John Holland, a scholar from the Santa Fe Institute, learning is divided into two types. Learning through exploitation means refining what we have already achieved. On the contrary, the second type of learning is more radical; indeed, it implies a complete change in the network connections, as some old connections are taken away and new connections are introduced. Learning through exploration means taking the risk related to high stakes to enjoy the opportunity of big gains. Exploring means trying and learning from trials.

Gregory Bateson (1990), cyberneticist, maintains that complex system learning is more efficient if the trial and error approach (*try&learn*) is applied. It is not only the result of widespread case studies, but it comes from our everyday personal experience of the ever changing fitness landscapes.

Exploring, trying, acting, learning: these are the new keywords for learning.

COMPLEXITY METAPHORS IN THE UNIVERSAL LITERATURE

The Library of Babel (Borges, 1941) "An infinite library, containing all the books ever written but also all texts which could possibly ever be written…"	
The Garden of Forking Paths (Borges, 1941) "I leave to the various futures (not to all) my garden of forking paths…"	
The Castle of Crossed Destinies (Calvino, 1973) "In the midst of a thick forest, there was a castle that gave shelter to all travellers overtaken by night on their journey: lords and ladies, royalty and their retinue, humble wayfarers…"	
Wayfarer (Machado, 1917) "Wayfarer, the only way Is your footsteps, there is no other. Wayfarer, there is no way, You make the way as you go. As you go, you make the way And stopping to look behind, You see the path That your feet will never travel again. Wayfarer, there is no way, Only foam trails in the sea."	

III.

REMARKS ABOUT ORGANIZATIONS AND COMPLEXITY

> If we want everything to remain as it is, it will be necessary for everything to change
>
> GIUSEPPE TOMASI DI LAMPEDUSA (1958)

THE BEST DOES NOT ALWAYS WIN!

The ongoing changes in the scientific world lead us to adopt a new approach vis-à-vis people and organizations: the ability to manage complexity has become central. Although Adam Smith's economy, Fordism and traditional models are not outdated yet, they must be integrated by something in order to take into account the complexity of their operational environment.

The market is a dynamic system, and not a static system. It is not balanced, but unstable, moody, lively and not always able to select the best technologies, as suggested by the neoclassical theory. There are countless examples of this kind of situations, when a lower technology or, say, a standard technology finally establishes itself into the market. Actually, the market is made up of multiple interconnections, convergent and divergent circles, causes and effects.

Let us consider, for instance, the QWERTY keyboard, which is used for almost all typewriters and computers in the Western world. The name QWERTY actually corresponds to the first six letters of the first line on the

keyboard. Is QWERTY the most functional way to arrange the keyboard letters? Not at all!

In 1873, the engineer Christopher Scholes designed the QWERTY keyboard with the aim of slowing down the typists: indeed, when the typists worked quickly, the hammers linked to the single keys tended to jam.

The Remington Sewing Machine Company started a mass production of the QWERTY typewriters so that many typists became familiar with this machine. Subsequently, other companies began to produce these typewriters; so, many more typists became familiar with the system which therefore entered current usage.

Later on, thanks to the progress made in the technical field, the problem was solved and a more efficient keyboard was designed. In 1932 a new keyboard was introduced: it was twice faster and 95% less fatiguing.

However, the QWERTY keyboards were strongly supported by millions of typists, teachers, and typewriter and computer manufacturers; therefore any evolution towards a higher level of efficiency was prevented in the last sixty years. As a result, low technology prevailed over high technology thanks to a vicious circle.

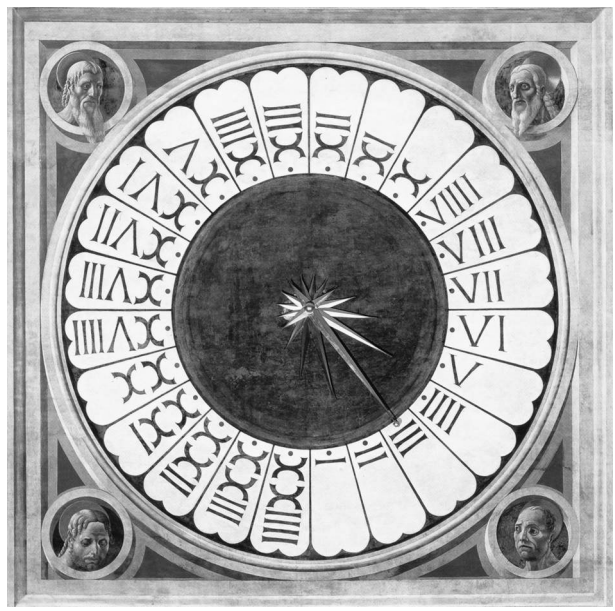
Let us consider now the competition between the Beta and the VHS video recording systems in the Mid-Seventies. Already in 1979, it was obvious that the VHS would finally dominate the market, although a number of experts argued that its technology was lower than Beta's.

Why did the VHS become so popular? The VHS system was launched shortly before the Beta system, so the VHS producers initially gained a larger market share which gave them a considerable advantage despite the lower VHS technology. The demand for VHS was slightly higher and sellers could not afford the expense of both the formats. As a result, video recorder producers were encouraged to align to the prevailing standard and the VHS system finally

achieved an ever greater market share, thus widening the gap between the two recording systems. This is another example of vicious circles.

If you own an airline and you decide to buy a Boeing aircraft, you will purchase a certain number of aircrafts to make things easier for pilots. Similarly, the head clerk will possibly purchase the same computer model for all employees, so that they all share the same software. These examples show that high technologies tend to be focused on a small number of models, from IBM-Compatible and Apple PCs to Boeing, McDonnell and Lockheed aircrafts; they are representative of the above quoted vicious circles.

In some cases, habits and deeply rooted conventions have prevented people from looking for a new solution. Suffice it to think of a clock: Why do the hands on a clock turn clockwise? Could they turn counter-clockwise, as shown in the following figure?



The clock owes its clockwise motion to the Earth's motion around the Sun. Indeed, once people used to read the time by observing the shadow cast by the sun onto the sundial, which moved in a clockwise direction. When sundials were finally replaced by clocks, the latter could have been planned to move in a counter-clockwise direction or featured twenty-four hours instead of just twelve. Apparently, such hypothesis was taken into account in the past, but was finally left aside.

The clock in the Cathedral of Santa Maria del Fiore in Florence (shown in the figure above), which was planned by Paolo Uccello in 1443, features a counter-clockwise motion and twenty-four hours. Again, a vicious circle of old habits and deeply rooted conventions prevented a new solution from becoming established.

FROM MACHINE ORGANIZATION TO COMPLEX SYSTEM ORGANIZATION

When life was flowing as slowly as a river, complexity existed but was not really perceived. Nowadays, everybody feels complexity like a second skin, since life is flowing at a fast pace and looks like a rushing stream.

When complexity was not really perceived, organizations were considered and managed as *simple systems in simple environments*. The famous statement about the Ford Model T, which suggested that this car could be painted any colour as long as it was black, says a lot about the ability of the industrial model of the time to cope with the external and internal complexity. The so-called Taylorism-Fordism model trusted rationality and ultimately believed in the opportunities offered by technology. The organization was conceived as a system able to regulate a huge mechanism in which people operated mechanically and predictably, workers could be

replaced by anyone else and finally design and manual activities were completely detached.

This conception was developed under the influence of the Newtonian science and Adam Smith's economy. Organization is decided from the top, as if it were a machine. The different machine components simply have to carry out the tasks for which they have been designed. Predefined rules, formalized controls and hierarchical structures aim at simplifying the operational process of the organization and obtaining clear and simple answers.

The objective of a machine organization is stability. Since balance is central in a stability-oriented approach, all resources must be devoted to ensuring predictability (error-free world).

However, today life's rhythm is as fast as a rushing stream. Trying to be stable on board would be pointless. On the contrary, we must necessarily learn how to manage the stream rapids, consciously adapt to its unexpected movements and try to anticipate them, whenever possible. A new orientation appears, according to which we must focus our energies on flexibility, i.e. the ability to keep open one's own options (error-aware world). In this context, the underlying hypothesis is that the future is unpredictable rather than predictable.

In the last decades a change of paradigm occurred. Nowadays, several authors consider organizations as complex adaptive systems and therefore tend to apply one or more principles of the complexity theory. Organizations are *complex systems in complex environments*. The instruments and concepts belonging to the complexity theory and other incoming disciplines may provide people and organizations with new guidelines.

Managers and entrepreneurs are called to confront themselves with the unpredictability of the future, the non-linearity of the answers, the need for significant

discontinuities, the importance of the evolution through learning and self-organization, the absolute strength of internal sharing and external networking, according to the logic of reciprocity between actions and reactions.

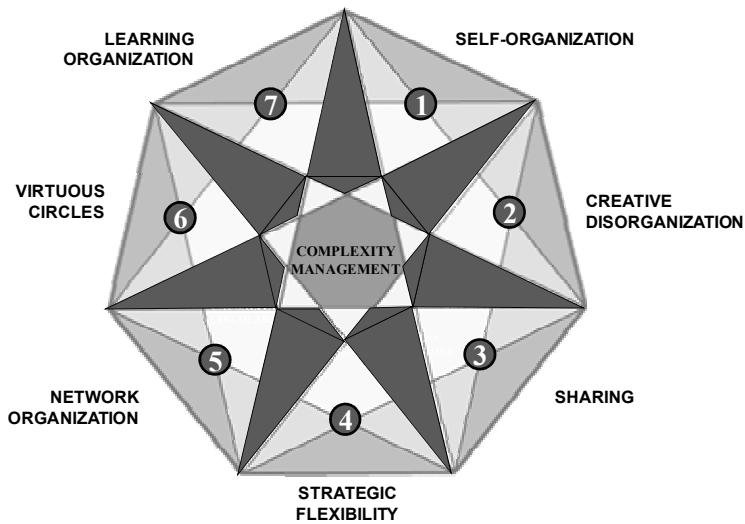
Of course, complexity is complex. It is like a spider-web, in which companies may be either the spider, i.e. the main character who turns the web to its advantage, or the sacrificial victims, i.e. the preys which get trapped into the web.

IV.

THE SEVEN PRINCIPLES OF COMPLEXITY MANAGEMENT

Logic will get you from A to B. Imagination will take you everywhere

ALBERT EINSTEIN (1955)



The seven principles of the complexity theory are matched by the seven principles of complexity management, which suggest an innovative approach to the world and the organizations. In order to translate the complexity management principles into effective managerial actions, you first have to understand its underlying criteria, mechanisms and logic; only then, you

will be able to creatively apply them to the contingent situation of each organization.

PRINCIPLE 1. SELF-ORGANIZATION

Organizations self-organize and support the development of internal and external networks, with the aim of promoting the emergence of shared intelligence.

The flights of birds migrating to the South in autumn follow a few basic rules and show a coherent behaviour, although they are not guided by an outside leader. Like the flights of birds, organizations can have a self-organizing behaviour.

Self-organization does not imply a lack of leadership, though. Self-organization implies a new complex leadership: entrepreneurs and managers are called to take into account the strengths emerging from the bottom, ranging from their collaborators, their personnel, to external actors such as suppliers, customers, users, etc.

It is not about a small change: the shift is from the traditional *top-down* logic to the *bottom-up* logic. Provided that some basic rules are observed, the leadership's focus should be delegating, which would enable the emergence within the organizations of shared intelligence, i.e. the network of (intellectual, operational, innovative, emotional) skills of human beings.

Self-organization implies an internal network, made up of knots, corresponding to the individuals' intelligence, and connections, corresponding to the interactions, even informal, among the individuals. It also implies an external network involving all potentially relevant actors; the Italian districts are representative of this phenomenon.

The district is a self-organized system without any subject, predefined plan, *top-down* setting, or power

pretending to overtake the organizer's role. Despite the lack of a predefined plan and an active leadership able to channel the events towards the desired direction, the combination of all interactions does not lead to a chaotic and ungovernable process.

In fact, a spontaneous order and an effective coordination emerge, though their underlying structure is not visible at first glance. The decisions made by the different actors are not visibly connected and sometimes seem to be made randomly. The contrary is true, though. The decisions are connected in a network which controls and channels them towards a definite order, which is a source of great competitiveness for the system at a local and global level.

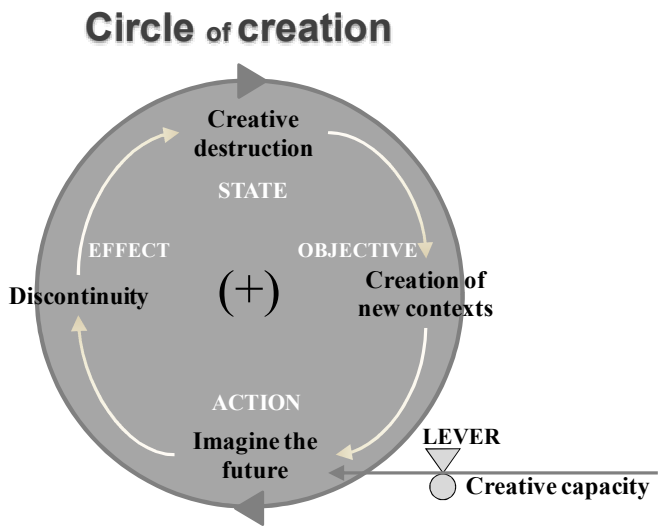
The statement made by Philip Anderson, the Nobel Laureate for Physics (1972), "emergence is the most amazing mystery of science" could be actually restated by saying that emergence from the bottom is the most amazing future for the organizations.

PRINCIPLE 2. CREATIVE DISORGANIZATION

Creative disorganization accounts for the visible discontinuity which organizations pursue by feeding the creation circle.

The praise of discontinuity at the edge of chaos means steady change to stay as we are and disequilibrium because static equilibrium resides just in dead things. Hence, destruction and creation. Accordingly, Joseph Schumpeter, Austrian economist, defines capitalism through the following words: it can never be static and it is basically fuelled by the new consumption goods, production or transport methods, the markets and forms of industrial organization.

In the organizations, the creation process features a self-strengthening circularity.



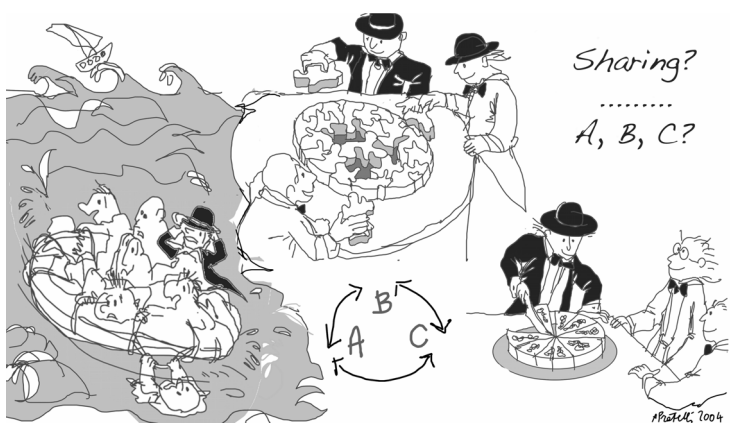
It is about a virtuous circle resulting from the introduction of a certain amount of creative capacity into the company. The creative capacity is what the actors (entrepreneurs and managers) are called to act upon. And the resulting action is the ability to imagine. The effect of

imagination is discontinuity, the creation of a new reality. The state of creative destruction is finally achieved. The ultimate objective is to create new contexts, which in turn enable to strengthen the ability to imagine new scenarios, thus fuelling the creation circle.

As Italian poet Giacomo Leopardi wrote: "Imagination is the first source of human happiness". Today, imagination has also become the added value of successful organizations. Dream is the driving force for creation and change. "Nothing happens unless first a dream", said Carl Sandburg, who considered dreams as the driving force for life. Imagination and creativity enable to win the challenge of complexity: the future belongs to those who can imagine it.

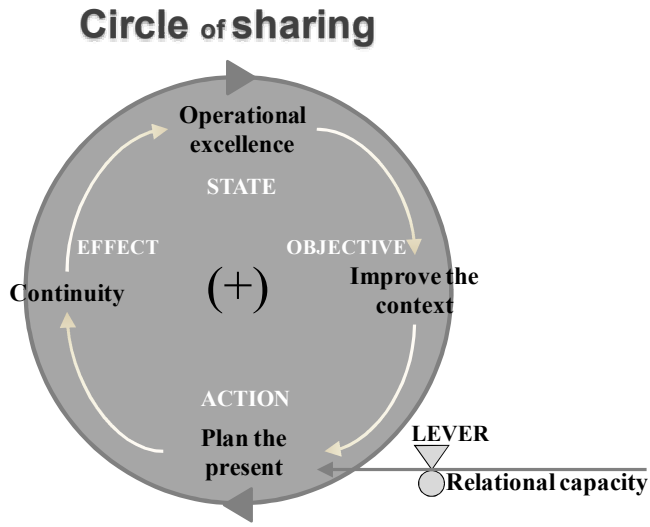
PRINCIPLE 3. SHARING

Sharing accounts for the visible continuity which organizations pursue to constantly improve towards operational excellence.



The praise of continuity implies the tendency to steady improvement, the search for routine and efficiency, and the fact of doing the same things over and over again, and always better. The part is in the whole, the whole is in the part: sharing values and objectives is the fundamental prerequisite to progress along the path of steady improvement towards operational excellence.

In the organizations, the sharing process features a self-strengthening circularity.



The operational excellence, i.e. the state of maximum efficiency in the execution of the organization's operations, is achieved by developing some process routines which ensure repetitiveness and continuity in the business operations. To develop such organizational routines, which encompass both the internal and external operational processes, the convergence of all the parts in

the organization is required, together with a great relational capacity by the management. The relational capacity is what the managers are called to act upon. The resulting action is the capacity to organize the present. Therefore, the organizational action has an effect, which is continuity; moreover, it leads to a state of operational excellence and its ultimate objective is sharing as a way to improve the context and therefore fuel the sharing circle.

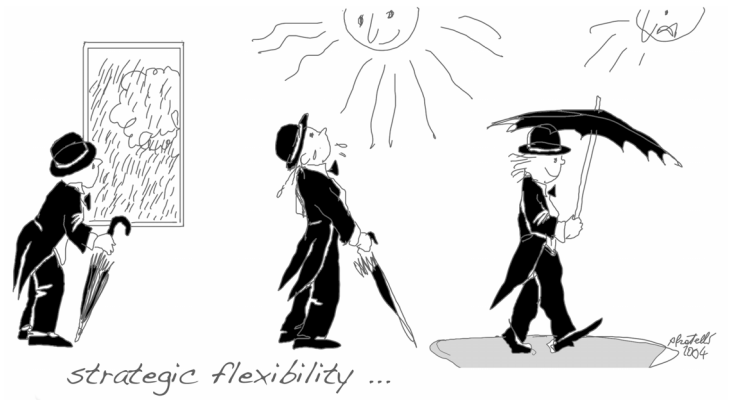
The creation of a shared spirit, the fact of believing and fighting together are all crucial for the organization's success. It is just like in a sport team, where the trainer is also called to create a sense of belonging in the team. In the film *Any Given Sunday*, Al Pacino, who plays the role of a football trainer, tells his men what follows: "In this team, we fight for that inch. In this team, we tear ourselves and everyone else around us to pieces for that inch. We claw with our fingernails for that inch. Because we know that when we add up all those inches, that's gonna make the difference between winning and losing, between living and dying!".

PRINCIPLE 4. STRATEGIC FLEXIBILITY

Organizations try to achieve strategic flexibility by carefully considering weak signals and pursuing explorative strategies which must be open to change.

Organizations such as nuclear power stations, air traffic control centres, emergency units in hospitals, hostage negotiation teams are supposed to be always ready to face unexpected situations. When the unexpected reveals itself through weak signals, there is a widespread tendency to give a weak response. Though, the above quoted organizations are called to give strong responses to weak

signals. This counterintuitive act is key to managing the unexpected.



Now that life flows as fast as a rushing stream, now that it is impossible to predict the future and now that we are confronted to a number of indefinite possibilities, the ability to promptly receive signals, even weak, and change our direction can make the difference.

To effectively detect weak signals, our attention should be focused not only on upstream and downstream markets but also on secondary markets. It is just on the periphery, which refers not only to the sector's borders but also to the small enterprises outside the big business, that tiny but great innovations can occur and possibly bring about a change in global competitiveness.

Weak signals (on the periphery, too) can be detected through a monitoring system and a relational network which helps identify potentially innovative actors.

Once weak signals are promptly received, just like complex systems, which steadily change either to adapt to or to shape the external environment, organizations must

seize the moment and must be therefore flexible to this end. Explorative strategies, which are open to change, are more reliable than long-term forecasts in ensuring development in complex and changing environments. There is little room for rigorous and hardly changing elements in nature.

Strategic flexibility means accepting that one's direction becomes clear only when the adequate conditions are in place. You make the way as you go. It is not true that you just predefine your desired destination and then you must comply with this predefined plan. On the contrary, you should be in a position where you can seize the so called *creative moment*.

This approach gives a competitive advantage to the organizations and also fulfils the wish to live a true life, shared by men and women alike. In the film *Dead Poets Society*, Robin Williams tries to convey this concept to his young students through the following words: "Gather ye rosebuds while ye may, old time is still a-flying; and the same flower that smiles today, tomorrow will be dying".

PRINCIPLE 5. NETWORK ORGANIZATION

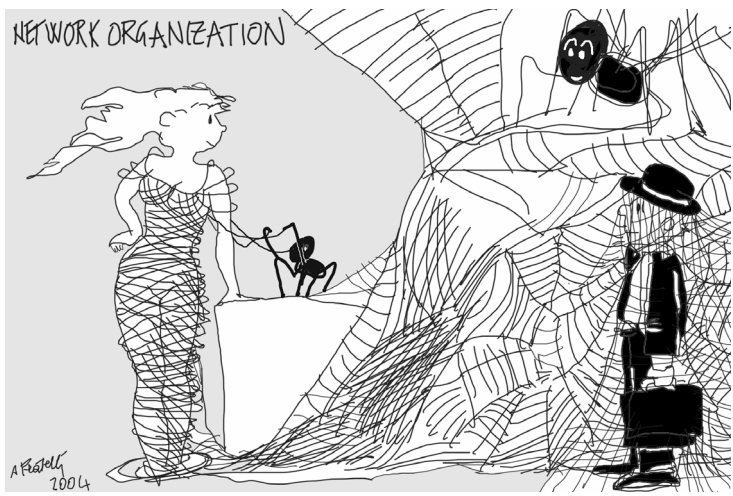
The network organization, which is typically open to external relations, reflects the situation occurring in nature at the organizational level.

The castle is a magical and fabulous place. Though, since always, it also means power, detachment from reality, and control over the subjects, as suggested by Franz Kafka in his unequalled descriptions. We could intentionally exaggerate and draw a parallel between the above quoted concept of castle and the traditional organization which was scientifically described by Weber,

entrepreneurially developed by Ford and planned in detail by Taylor and Fayol.

Still, in the 20th Century people have realized that the network, with its numerous and powerful connections, is the general organizational model available in nature. The castle is an artificial structure.

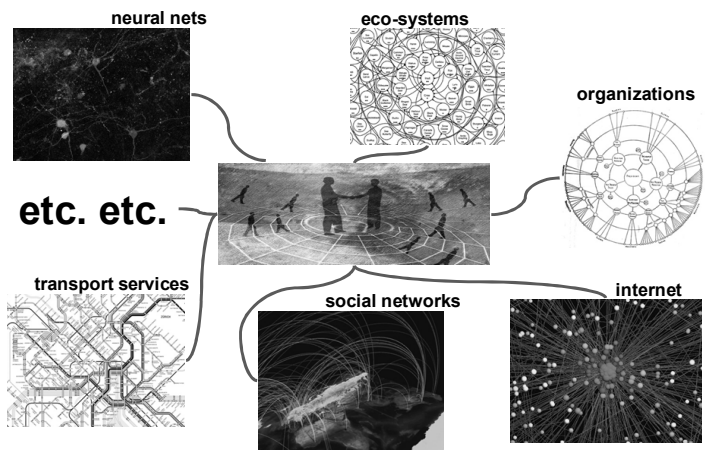
From the beginning of the century to the present day, the organization's structure has experienced a profound change; the Fordist idea of an all inclusive enterprise, which was developed internally in essence, has been gradually replaced by less integrated forms of enterprise, in which also the hierarchical structure of the decision-making process has been gradually weakened.



A shift from the castle to the network (network organization) has occurred. The spread of the outsourcing and the establishment of network structures to monitor the value chain have led to a shift from a culture of possession to a culture of monitoring. Accordingly, activities, once

built in one single vertical enterprise, have been gradually repositioned within a network of relations. A shift occurred from mainly formal coordination mechanisms to mainly informal coordination mechanisms.

According to the technologist Kevin Kelly (1998), "networks, enhanced and multiplied by technology, penetrate our lives so deeply that "network" has become the central metaphor around which our thinking and our economy are organized". Networks are everywhere.



The network organization is a flexible and creative answer to complexity. Like the dissipative structures analysed by Prigogine (1979), the organization opens up to the external environment to allow exchanges of matter, energy and information, which lead to new self-organized states. This process involves all potentially relevant actors, such as suppliers, customers, other companies, professional communities, credit and financial systems, research institutions and academies, the public

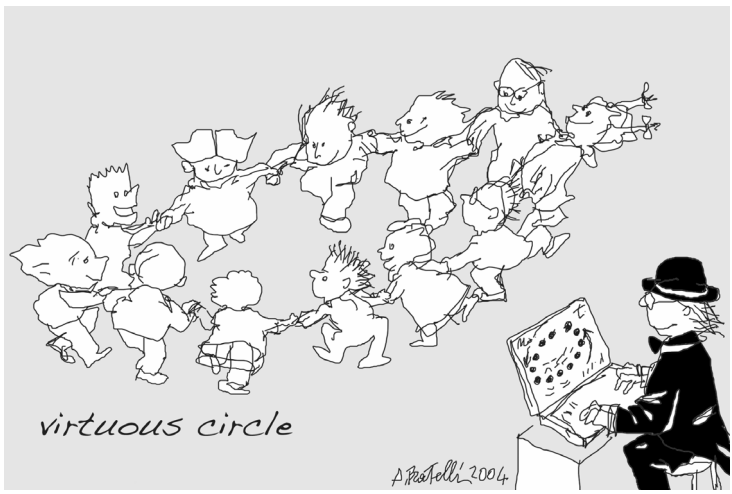
administration, professional and trade unions, socio-cultural institutions, other bodies, etc.

Hence, people are becoming more and more aware of the importance of gathering scattered knowledge resources in a single network.

PRINCIPLE 6. VIRTUOUS CIRCLES

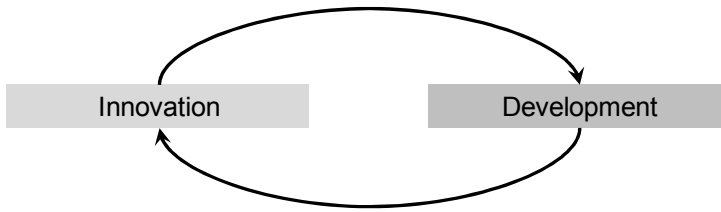
Organizations pursue self-feeding virtuous circles through a systemic approach oriented to the identification of their structural connections.

It is all about multiple interconnections, convergent or divergent circles, causes and effects. As suggested before, a flat of a butterfly's wings in China may produce a typhoon in the United States. Small, very small actions may diverge and lead to unexpected effects.



It is a great threat and, at the same time, a great opportunity for the organizations that are encouraged to adopt a systemic approach which enables them to have a comprehensive view of the phenomena and their interconnections. It is often hard to identify all the relationships within the circles. Only experience enables to model complex situations and feed virtuous circles rather than vicious circles.

According to the philosopher Hegel, the world is made up of circles and philosophy is the circle of circles. This definition is strongly evocative of one of the most important circles for organizations, i.e. innovation and development.



Being innovation-oriented is becoming increasingly important for those organizations that wish to compete in a complex environment. Innovation is the recurring challenge and the complexity theory suggests that creativity, novelty and diversity lie at the edge of chaos. Innovation triggers development and, in turn, development generates the resources to invest in innovation. It is just this fundamental virtuous circle that organizations are inevitably called to create.

Development is not just an entrepreneurial objective, though a value, first of all. Organizations are not stable in essence; they are either developing or declining. The value of development can be found in successful enterprises. The path of growth is clear, priorities are outlined later

though they can undergo some changes, and people are encouraged to look for career opportunities or for economical advancement within the organization itself. The definition of a path of constant development gives people confidence and strength to face challenges.

The systemic approach enables to identify and therefore feed other possible virtuous circles.

PRINCIPLE 7. LEARNING ORGANIZATION

The learning organization helps to get rid of outdated mental schemes and promotes an error-tolerant approach, thus encouraging action which is a source of learning.

Imagine an iceberg. Its tip, emerging from water, is far smaller than the part underwater, say around one fifth or one eighth. Knowledge within an organization can be compared to an iceberg: the emerging tip corresponds to rational and explicit knowledge, while the part underwater corresponds to the implicit knowledge which is not evident because it is part of our behaviour.

The part underwater concerns our individual and collective experience, our stories, our particular knowledge, the experience and visions of single individuals, as well as our collective imagination. It is impossible to fully explore all this.

Organizations become learning systems (*learning organizations*) when they succeed in converting implicit knowledge into explicit knowledge and, especially, when they manage to get rid of outdated mental schemes and encourage people's initiatives.

Mental schemes are a simplification of reality; they help to map complexity, though they can be dangerous if they are static and changeless. They often derive from successful behaviours of the past which tend to settle.

Questioning such behaviours promotes action and learning through action.

Therefore a learning organization is also an *unlearning organization*, in that it unlearns and forgets classical, old-fashioned models and searches for new ones. Unlearning is an intentional process which enables to get rid of old-fashioned and misleading knowledge.

The culture promoting learning, unlearning, initiative, exploration and action is a culture prone to tolerance and critical assessment of error.

The fundamental issue is that every experience, every success or failure can be seen as an opportunity to learn something. Learning is a path and cannot be therefore error-free. Errors suggest the progress made in the learning process.

You learn from your mistakes. It is not just a saying, though a scientific truth. A recent study coordinated by the Harvard Medical School revealed that a specific area in the human brain is involved in assessing mistakes and devising ad hoc strategies which prevent people from making them again.

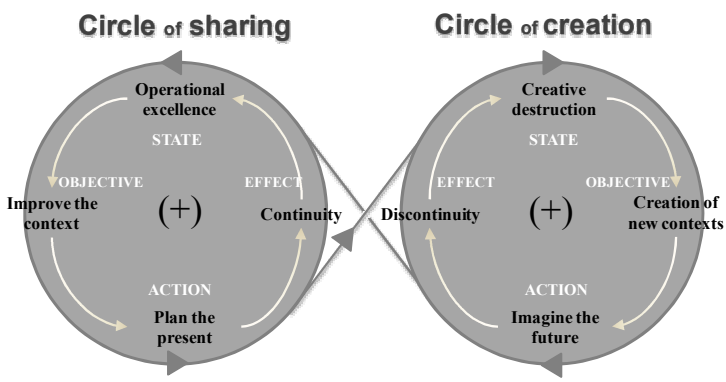
V.

GUIDELINES
FOR COMPLEX ORGANIZATIONS

> Two dangers constantly threaten the world: order and disorder
>
> PAUL VALERY (1943)

SHARED CREATION AT THE EDGE OF CHAOS

Complexity, or the vital coexistence of continuity and discontinuity, can be no longer procrastinated in the light of the present political and socio-economical situation. To the organizations, this means praising both continuity, i.e. network sharing towards excellence, and discontinuity, i.e. creation towards new self-organized states.

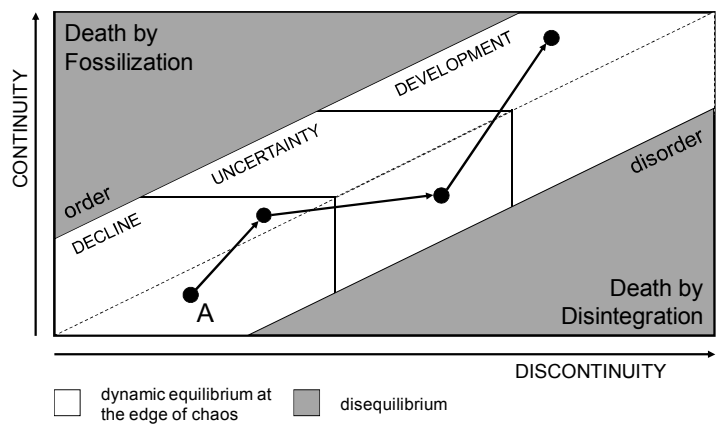


The creation and sharing circles depicted above are interconnected to the patterns of continuity and discontinuity. These interconnections give rise to the circle of shared creation at the edge of chaos, which, in our opinion, synthesises the results achieved in the complexity theory applied to the management.

The creation and sharing circles lead organizations to the edge of chaos. Both circles are fundamental. The creation circle pushes organizations towards disorder, while the sharing circle pushes them back towards order, thus enabling them to achieve the dynamic equilibrium which is fundamental for life.

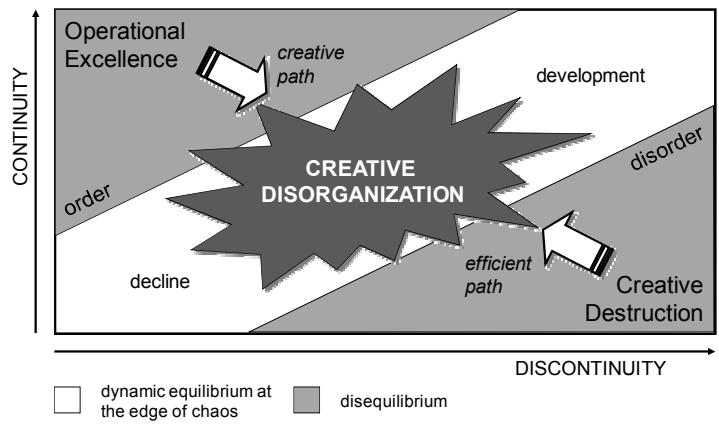
Too much discontinuity leads to death by disintegration: if the organization focuses solely on innovation and the creation of new products without carefully considering the management of the processes for operational excellence, it is doomed to disintegrate.

On the contrary, too much continuity leads to death by fossilization: if the organization is able to perfectly manage its processes but is not able to be creative, it is doomed to become fossilized.



The dynamic equilibrium between continuity and discontinuity keeps the organization alive: however, while a short amount of continuity and discontinuity leads to involution and decline, a big amount of continuity and discontinuity ensures evolution, hence development. It is necessary to travel the virtuous path towards the development area.

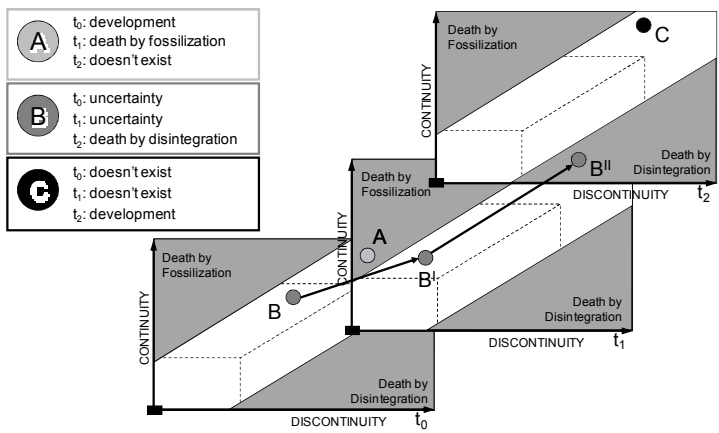
To achieve the state of life, evolution, development and creative disorganization, organizations can follow either the efficient path or the creative path. The organizations which are too much oriented to operational excellence should admit some discontinuity and capitalize on innovation; in other words, they should follow the *creative path*. Conversely, the organizations which are too much oriented to creative destruction should admit some continuity and capitalize on excellence; in other words, they should follow the *efficient path*.



Both paths must take into account the evolution of the competitive system. The organizations are called to move

through fitness landscapes which are steadily distorted by economic, political and social changes, etc. Being flexible and ready to seize the moment is fundamental to adapt to such distortions and possibly create or anticipate them. Predefined, static strategies do not successfully apply to the complexity field.

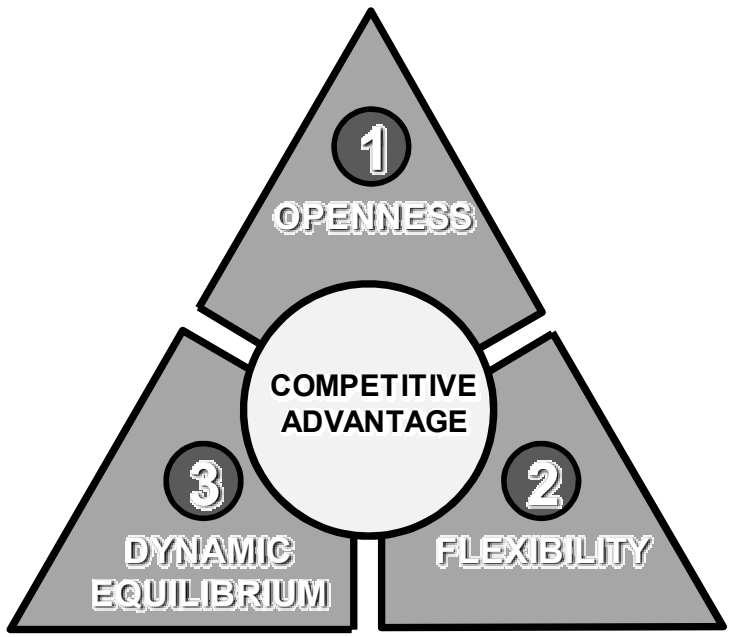
In the figure below, company A is in the development area in the t_0 moment and decides not to move, which leads it to fossilization in the t_1 moment. Company B tries to move towards the development area, though it is still in the uncertainty area in the t_1 moment (same position as in the t_0 moment). Then, the company heads to the development area and yet death by disintegration awaits it in the t_2 moment. The situation is favourable to company C, which was born from the ashes of company A and B and is located in the development area in the t_2 moment.



Briefly, continuity and discontinuity mark the shift from an *"or" culture* to an *"and" culture*. Pier Luigi Amietta (1991), communication expert, defines this shift

as “the end of “black or white”, “you are either with me or against me”, “I am right, you are wrong”, “angel or devil”, “blessed or damned”, “generalist or specialist”, “education or training””. To use Borges’s own words, “When you come to a fork in the road, take it!”.

THE THREE LAWS OF COMPLEX ORGANIZATIONS



After describing the seven principles of the complexity theory applied to the management, we now try to identify the laws which enable to turn the above quoted principles into some useful guidelines for the managers of complex organizations.

Principles serve as the foundation of a doctrine or a science; in this respect, the seven complexity principles are the theoretical basis of complexity management. The laws presented herein are simple guidelines and do not have any deterministic or prescriptive purpose. Indeed, there are no golden remedies to manage complexity.

a. The law of openness

All complex systems are open, in that they exchange matter, energy and information with the external environment. Organizations should be "open", in order to co-evolve in the environment around them. Organizations open up to the external environment by exchanging information: information can be either disseminated externally (advertising, press releases, *investor relations*, etc.) or gathered internally (market researches, benchmarking, *competitive intelligence*, etc.). Just like the open systems initially analysed by the Russian scientist Prigogine (1979), openness helps organizations gather some information, which can be considered as a useful energy push towards new self-organized states, contributing to growth.

First law of complex organizations
LAW OF OPENNESS

Given two competing organizations in an environment-system (competitive environment), there is a direct relationship between the larger amount of resources (R) invested by one of the organizations in a certain time range (T) with the aim of encouraging openness and the increase in the competitive advantage (V); such relationship is expressed through the ε coefficient which shows the investment quality

$$\frac{\Delta R_{openness}}{\Delta T_{openness}} \varepsilon_{openness} = \Delta V_{openness}$$

b. The law of flexibility

Complex adaptive systems show a great ability; indeed, they can recover from the unexpected discontinuities by reorienting themselves. Forecasts and plans are useful only if possibilities are turned into probabilities and real events reflect the plans. Though, in certain circumstances what is possible becomes improbable and the unexpected comes into play. In these situations, organizations must be ready to seize the moment, react to the unexpected and keep the situation under control. Events such as September 11th or the strong growth of Asian economies demand a flexible approach, a reorientation which implies, for instance, the creation of alternative scenarios, *contingency plans*, etc.

Second law of complex organizations
LAW OF FLEXIBILITY

Given two competing organizations in an environment-system (competitive environment), there is a direct relationship between the larger amount of resources (R) invested by one of the organizations in a certain time range (T) with the aim of encouraging flexibility and the increase in the competitive advantage (V); such relationship is expressed through the ε coefficient which shows the investment quality

$$\frac{\Delta R_{flexibility}}{\Delta T_{flexibility}} \varepsilon_{flexibility} = \Delta V_{flexibility}$$

c. The law of dynamic equilibrium

Complex systems live on the edge of chaos between order, which leads to fossilization, and disorder, which leads to disintegration. Also complex organizations pursue the vital coexistence of continuity and discontinuity. Continuity is achieved through the creation of a relational network within all the actors involved in the operational excellence. Organizations are called to generate the improbable through radical innovations. They must boost discontinuity by investing in research and development and showing tolerance towards limited inefficiencies aimed at increasing creativity, etc. Investments are repaid through the gains obtained with the radical innovations of products, services, processes and organizational management models.

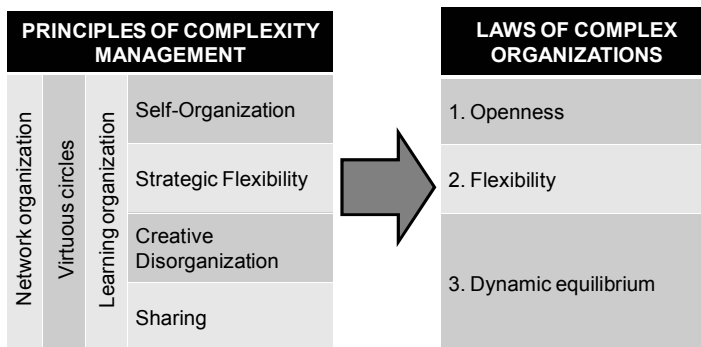
Third law of complex organizations
LAW OF DYNAMIC EQUILIBRIUM

Given two competing organizations in an environment-system (competitive environment), there is a direct relationship between the larger amount of resources (R) invested by one of the organizations in a certain time range (T) with the aim of encouraging dynamic equilibrium between continuity and discontinuity and the increase in the competitive advantage (V); such relationship is expressed through the ε coefficient which shows the investment quality coefficient

$$\frac{\Delta R_{\substack{dynamic\\equilibrium}}}{\Delta T_{\substack{dynamic\\equilibrium}}} \varepsilon_{\substack{dynamic\\equilibrium}} = \Delta V_{\substack{dynamic\\equilibrium}}$$

FROM PRINCIPLES TO LAWS

There is a relationship between the laws of complex organizations and the principles of complexity management. The laws, which serve as guidelines for the managers of complex organizations, have been elaborated starting from the theoretical basis concerning the application of the complexity theory to the management science.



The first law of complex organizations, i.e. the law of openness, has been elaborated starting from the principle of self-organization. According to this principle, solely open systems self-organize and therefore co-evolve towards more organized states. By virtue of this principle, it is possible to affirm that complex organizations capitalize on openness to receive new ideas, incentives, products, services, processes and organizational management models from the external environment.

The second law results from the principle of strategic flexibility. The complexity theory has revealed that there is little room for rigorous and hardly changing elements in

a world where predicting is impossible. Exogenous discontinuities require prompt reactions; as a result, it is possible to affirm that complex organizations capitalize on flexibility to be able to react more promptly to the unexpected.

The third law derives directly from the creative disorganization and sharing principles. The principle of creative disorganization states that organizations should pursue creativity, novelty, discontinuity. The sharing principle states that organizations should also pursue continuity: beside radical innovations, organizations should focus on the constant improvement of products, services and processes; in other words, they should tend to operational excellence and organize the present. The law of dynamic equilibrium is based on the combination of these two principles: the investments made by complex organizations aim at ensuring both regular improvements and a creative destruction, with an eye on the present and a look into the future.

Also the other principles of the complexity theory contribute to providing the three laws with a sound theoretical basis.

Complex organizations are *network organizations*, in that they create a network of relations with all relevant actors; hence, the importance of being open to connections and incentives, to adapt to the situational changes related to unexpected events and to finally keep the delicate equilibrium between a state of creative destruction and the objective of operational excellence.

The circularity of even minor events, which can grow and become extremely positive or negative events, leads organizations to open up to the external environment in order to grasp all incoming signals, to adapt to the positive or negative growth and to finally achieve an equilibrium

between the management of the present (sharing circle) and the imagination of the future (creation circle).

Finally, the same applies to complex organizations, such as *learning organizations*. Learning implies different things. Firstly, it requires openness to new tendencies. Secondly, it entails flexibility to forget outdated mental schemes and replace them with modern ones, and thirdly, it suggests the coexistence of continuity and discontinuity to improve the management of the present and explore new paths.

BREAK
BEFORE SETTING OFF AGAIN

The journey is long and moves us away from certainty. Reader, we shall stop now because it is getting dark, we have gone a long way and we have seen much. In this night full of stars, our mind goes to the lands that we have seen.

We recall the bifurcations, the vital coexistence of continuity and discontinuity, the flights of birds that self-organize without following any leader or predefined plan. The behaviour of the flights, traffic jams and anthills results from the sheer interaction dynamics between the single elements and cannot therefore be predicted on the basis of the single parts, no matter how accurately you know them.

We think again about the edge of chaos, the dynamic equilibrium between order and disorder, and the steady change, necessary for life. There is no life far from the edge of chaos. Life and all that stems from it is far from equilibrium, in a continuous search for the new and the improbable; this is the only way to survive.

We slip into irregular, convoluted and tangled fractals which look like multiple interconnections, like convergent or divergent circles, like causes and effects alike. We read again the books of the Library of Babel; we have already read many versions of the page that we are reading again

now. We linger on the call to action in the field of complexity, which is the only source of learning. Complexity is the mother of freedom and calls us to change within the space of possibility.

Reader, we shall forget deterministic rules. Complexity does not allow the extrapolation of the past as a way to find future paths. We shall forget equilibrium, as it means death.

Suddenly, we set off again.

PART TWO
JOURNEY THROUGH
THE COMPLEXITY OF REALITY

VI.

HOW THE CHINESE THOUGHT TACKLES COMPLEXITY

> There is no road to happiness. Happiness is the road
>
> CONFUCIUS (5th Century B.C.)

FROM THE SCIENTIFIC APPROACH TO THE PHILOSOPHICAL APPROACH

Three laws, three guidelines for complex organizations are the legacy of our journey through the complexity theory. Now, in the second part of the journey, we plunge into the complexity of reality, behind theories, behind the Santa Fe scientists with pigtails. Because complexity is in real things, everywhere; its principles and assumptions are part of our everyday life.

We shall just touch upon the Chinese thought, which is not influenced by classical science but, on the contrary, is steeped in complexity. Hence, people and organizations can find some hints at the end of this journey. We shall travel a different path which leads to similar conclusions. We shall no longer adopt a scientific approach, as in the complexity theory; conversely, we shall adopt a philosophical approach that gives us an insight into the Chinese thought and its way through the complexity of reality, which, being different, can help us corroborate our conclusions at the end of the journey.

In this chapter, we shall therefore adopt a philosophical approach. Though, it must be added that there is not just

one Western thought and one Eastern thought. They are not clearly opposed. To simplify matters, it is possible to affirm the following: on the one hand, the evolution of the Western thought marked the triumph of the analytical approach, typical of the European classical science, which tends to reduce and simplify things, while, on the other hand, the evolution of the Eastern thought marked the triumph of the Chinese systemic approach, which goes hand in hand with complexity. By contrasting the two thoughts, we actually mean to synthesize them and highlight their respective strengths.

Up to the 14th Century, Europe and China experienced a similar technological evolution; starting from the development of classical science, their paths began to diverge. Europe began to invest in the idea of model and, especially, in the mathematical model, which is the model par excellence. Of course, there is a fully fledged Chinese mathematics which includes algorithmically developed transformational procedures, but Chinese people have never thought of a world written "in the language of mathematics, and its characters are triangles, circles, and other geometrical figures" (Galileo, *Il Saggiatore*, 1623, *The Assayer*, English transl.). The Chinese civilization developed autonomously; therefore, it was poorly influenced by classical science, while it shows many similarities to the complexity theory.

Reality is made up of relations and the coexistence of opposites; its complexity is mirrored in the language. In Chinese, "thing" is meant to be the "East-West": we use one single term, the Latin *res,* while the Chinese term for "thing" suggests a relation, an interaction, which implies an antithesis. The Chinese term for "landscape" is "mountain and water", which includes what is high, still and shaped as well as what is low, dynamic and unshaped.

It is all about relations and the coexistence of the opposites[1].

"Landscape" in Chinese Language

MOUNTAIN	WATER
high	low
still	dynamic
shaped	unshaped

While the Eastern world thinks in terms of synchronism, the Western world adopts a deterministic cause-effect thinking model. Synchronism suggests that events are connected by a mysterious thread and cannot be explained through a cause-effect relationship. Jung deals with this topic for the first time in the preface to the German edition of the Chinese *I Ching*, or *Book of*

[1] The *tao* itself, which means "path", "road", is symbolized by a circle symmetrically divided into two halves by an S-shaped line, with one half black and the other half white. The two halves, which are called *Yin* and *Yang*, are the two poles of universal energy. Yang originally referred to the sunny southern side of a mountain, which is bright and warm, while Yin referred to the dark, cold northern side of the mountain. Everything exists in the two poles. The symbol shows a white circle in the black field, and a black circle in the white field, which suggests the coexistence of the two poles; each pole contains its opposite.

Changes. The concept of synchronism clearly refers to the traditional Chinese thought. The Western thought assumes that there is a cause-effect relationship between events, whereas the synchronic thought assumes that (subjective or objective) events are parts of a whole and can therefore be explained by considering the whole to which they belong.

We shall now move away from our dominant thought and then get back to it. We shall move away to understand how it feels when our thought is disoriented; then we shall get back to our original thought and question it on a topic which is not usually studied. In the next paragraph, the patterns of the dominant European and Chinese strains of thought are compared. By distancing ourselves from our thought and touching upon the Chinese thought, we shall come across complexity, intended as real complexity beyond theory.

LIKE A DEMIURGE SHAPING MATTER, LIKE WATER FLOWING THROUGH THE ROCKS

According to the methodology suggested by the Western thought, which underlies classical science, the model is defined first and then it is implemented (*design & implementation*). The origins of such methodology can be traced back to ancient Greece. Actually, Greek philosophers suggest the creation of an ideal shape, which is your objective and therefore must be followed by the drafting of a relevant plan. Finally, they suggest you start acting according to the plan and the objective. The classical European thought implies the interaction of two faculties, i.e. mind and will. Again, theory comes first and practice follows. Several examples show the strong influence of this thinking model on our way of perceiving reality: the revolutionary plans the model of the future

society, the soldier plans the next war, and finally the manager charts growth plans.

Classical science and philosophy have led to the establishment of modelling, the strength of Europe. Hence, the scientific method, Newton's hegemony, and Descartes's strong belief that we could become "the lords and possessors of nature" have established. Hence, the influence of classical science on our way of thinking is clearly visible in our management of organizations, which are seen as simple machines in simple environments, and in our actions of planning and control, strategy and long-term plans.

Still, the complexity of reality is something else. Reality is a little more complex and does not reflect any fixed model. Karl Phillip Gottlieb von Clausewitz, who was a Prussian military theorist, as well as the author of his military strategy treatise *On War* (*Vom Kriege*), states that war is always deviating from the plans. Suddenly something happens and plans no longer match with reality. Modelling is like walking on the ground: there are no problems on your way and each step is logically followed by the next. On the contrary, when the plan is implemented and war operations begin, it is like walking in water: friction comes from each side, resistance is put up by the circumstances, steps are unsteady and therefore you risk losing your balance. Perhaps you need to change course and explore new paths.

Now, if you read the influential Chinese works about the art of war (by Sun Tzu and Sun Bin), dating back to the 5^{th} – 4^{th} Century B.C., you realize that the European methodology (*design & implementation*) is totally absent in the Eastern world. Sun Tzu, a general who lived in China probably between the 6^{th} and 5^{th} Century B.C., is the author of *The Art of War*, one of the most influential ancient treatises on military strategy. Sun Bin, a

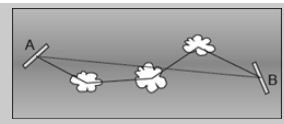
descendant of Sun Tzu, was a military theorist and wrote the treatise *Sun Bin Bing Fa.* He was recently rediscovered after being lost for almost 2000 years. The starting point is not a modelled situation but rather that upon which you can act, hence try and find out its hidden potential, as well as the right way to exploit it. Therefore, the methodology adopted by the Chinese thought is the following: first the context is evaluated and then its potential is exploited (*evaluation & exploitation*). The full understanding of reality enables to predict its evolution and take advantage of this. The title of the first chapter of *The Art Of War* is *ji*, which can be translated as "calculation", "evaluation" and is quite representative indeed: in the first place, the potential of the situation is evaluated and afterwards, it can be successfully exploited.

The two opposed methodologies do not share the same idea of model. The first defines the model *ex ante*, whereas the latter defines it *in itinere* or, at the most, schematises it *ex post*. Design and implementation is the motto of the European thought. This analytical approach, typical of classical science, is perfect to solve complicated problems, with *n* equations in *n* unknowns. Evaluation and exploitation is the motto of the Chinese thought. This systemic approach can be applied to solve complex problems, which cannot be reduced to a system of equations. The whole design cannot be understood by examining its single parts. Life cannot be reduced to an equation. Life can only be narrated. At the most, you can try and give a meaning to your life starting from your experience, ex post.

The underlying logic of the European thought is the achievement of a purpose. Making plans for the future implies the definition of an objective, which is achieved through adequate means. In the Eastern world, the objective is not defined on the basis of an ideal model;

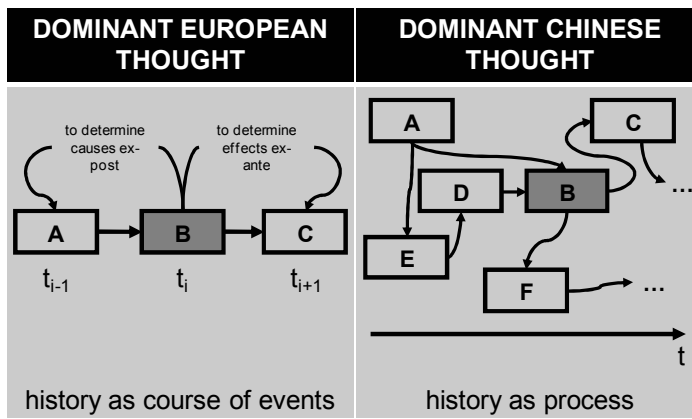
actually, the objective does not exist on its own, though it results from the interaction of changing situations. The logic of inclination replaces the logic of finality: inclinations are exploited while they are unwinding. No more means-ends, but only conditions-consequences, which means that all favourable elements are gathered upstream; they are the main factors, the conditions which must be developed and fully exploited. According to the Chinese thought, we should let effects happen without aiming at them (as suggested by the logic of finality) but just envisaging them (as a possible consequence, as suggested by the logic of inclination). In other words, we should not search for the relevant effects but just gather them.

The European thought can be compared to a journey by airplane, where a predefined route let you reach a well defined place. The Chinese thought can be compared to sailflying, where the route depends on the context (e.g. wind, updraught, etc.), not knowing in advance where it will take you.

DOMINANT EUROPEAN THOUGHT	DOMINANT CHINESE THOUGHT
  flying by airplane	  sailflying

The European thought focuses on a given event. The predefined objective is achieved after a series of single events by using the adequate means. For instance, the thought focuses on the single battles making up the war. The fall of the Berlin Wall or September, 11th are other significant examples. The event is either glorified or execrated.

However, the Chinese world is steeped in complexity: the focus is on the process and the event is just the visible discontinuity. The event is like the fruit falling off after ripening; as observed by Prigogine (1979), the event is the bifurcation or the visible state of change after invisible fluctuations. The battle, whose potential is exploited to boost the big whole, is just the point where the continuous change becomes visible.



Therefore, for the European thought history can be seen as a course of events, while for the Chinese thought the focus is on the whole process. The Chinese say that you never really become ill: the event defined as "illness" is

just the visible discontinuity in a progressive dysfunction which was not recognized as such, though whose result is suddenly assessed as an event. Confucius himself said: "I have not created anything by myself. I have just conveyed something". The Chinese word for "I think" is "I heard them say that": instead of positioning as a subject/author of the event, the Chinese tend to think of themselves as descendants, thus highlighting the process continuity. The dominant Chinese thought focuses on the process and lets the event fade away.

The objective of the dominant European thought is to achieve the heroic success through a series of events, battles, visible phenomena. The European general wins the war during the battle, when he heroically destroys the enemy. On the contrary, when the Chinese general goes to battle, he has already won, having fully exploited the potential of the situation. As a result, the objective of the dominant Chinese thought is to achieve easy success. It could not be otherwise: the great merit is to not have merits and win against the defeated enemy by exploiting the potential of the situation. The winner is designated before the battle is started; indeed, the event (battle) is nothing else than the visible discontinuity in a long process. It is like picking up the fruit after a long and peaceful ripening process. There are no events or dates to celebrate, just the continuous and peaceful process. As a matter of fact, solely the Chinese culture has not a historical epos, nor celebrations of the heroic success. Japan, India and Greece all have an epos: their literature begins with the stories of great heroic achievements of which they always want to keep the memory. Just like Ulysses and Aeneas: "I sing of arms and the man who came of old, a fated wanderer, from the coasts of Troy to Italy". China has never had an epos, nor bards, or poets; China is the land of passage, of peaceful processes.

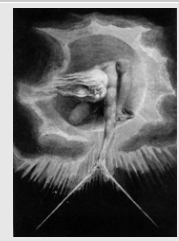
DOMINANT EUROPEAN THOUGHT	DOMINANT CHINESE THOUGHT
	
heroic success	easy success

On the one hand, we find the strong and extraordinary ability to simplify; on the other hand, we come across the marks of complexity, which is not feared, though fully experienced. Hence, the metaphor of the Demiurge is applied to the Western world, whereas the Eastern thought is associated with the image of the water flowing through the rocks.

The Demiurge is the Greek God who models reality, according to Plato. He is a divine craftsman who shapes the world according to ideas: hence, intelligence gives rise to the world, by using ideas as models and matter as an instrument. The analogy between the cosmogonic Demiurge and the artisan is easily explained: just like the craftsman, the Demiurge shapes the matter according to an ideal model, thanks to his intellectual as well as technical skills. The modelling-application scheme is applied.

Conversely, water flows relentlessly on the ground, adapting to its inclination. The effects are visible in the long-term only, when the endless flow has made rocks smooth. Accordingly, the fruit slowly ripens through time. Here is the core of the Chinese thought: wait for the fruit

to be ripe and help its ripening without forcing it. When the fruit is ripe and is about to fall off the tree, pick it up. Evaluating and exploiting the potential means therefore creating the right conditions, waiting and being able to seize the right moment.

		DOMINANT EUROPEAN THOUGHT	DOMINANT CHINESE THOUGHT
FEATURES	1. METHODOLOGY	model definition and implementation *(design & implementation)*	context evaluation and exploitation of potential *(evaluation & exploitation)*
	2. MODEL DEFINITION	*ex ante*	*in itinere*, with *ex post* schematization
	3. UNDERLYING LOGIC	finality: means-ends	inclination: conditions-consequences
	4. FOCUS	event	process
	5. OBJECTIVE	heroic success	easy success
	6. METAPHOR	 Demiurge who shapes matter	 water flowing through the rocks and adapting to their shape

VII.

OPERATIONAL IMPLICATIONS FOR THE COMPLEXITY OF REALITY

What a caterpillar calls the
end, the rest of the world
calls a butterfly
OLD CHINESE SAYING

THREE KINDS OF IMPLICATIONS FROM THE CHINESE THOUGHT

Operational implications are the guidelines which give meaning to the two strands of thought and channel action within the complexity of reality. According to our logic, laws can also be considered as rules which can help people and organizations to tackle reality. We have selected three among many. We have intentionally made things simple by comparing the two worlds, although we are aware of the incompleteness of such a comparison. In the European world the analytic thought is prevailing; it promotes action, planning and control, deliberate strategy. In the Chinese world, we find the systemic thought, hence transformation, monitoring and orientation of co-evolution, emerging strategy.

		DOMINANT EUROPEAN THOUGHT	DOMINANT CHINESE THOUGHT
OPERATIONAL IMPLICATIONS	1. ACTION CLASS	action	transformation
	2. MAJOR ACTIVITIES	planning and control	co-evolution monitoring and orientation
	3. MAJOR STRATEGY	deliberate	emerging

The first implication is the action class, which corresponds to action, according to the dominant European thought, and transformation, according to the dominant Chinese thought.

From the European perspective, once the modelling-application combination is fixed, action must necessarily occur. Planning alone does not suffice. Plans must be put in practice: practice means "to do" in Greek (*prattein*). Commitment and action are necessary to shape reality according to the ideal form. This always implies some straining. As a result, besides intellect, the will is necessary to shape the resilient and restive matter according to the form which has been planned. As the French sinologist François Jullien suggested in his *Treatise on Efficacy*, action might be defined as: 1) temporary, 2) local, as it occurs here and now, 3) explicitly referring to a subject, or a group of subjects. Action stands out from the flow of things and can become the topic of a story, just like the epos or the great heroic achievements.

On the contrary, the first operational implication for the dominant Chinese thought is transformation. The Chinese think about the world in terms of a steady and progressive transformation which is imperceptible, though its results are visible. The *I Ching*, also called *Book of Changes*, is the earliest Chinese classic text. Everything flows without any rest, night and day. The Chinese wiseman must not act to make things happen; on the contrary, he transforms things by turning the process of continuous change to his advantage. Implied transformation replaces direct action, since reality is inclined and you simply need to exploit its potential. Transforming means acting without really acting: I do not strain things, though I am an active agent, in that I follow the flow of reality. How to help plants grow? You cannot strain their growth, though you cannot even neglect them.

Transformation can be defined as: 1) systemic, as it involves the system as a whole; 2) stretching through time, progressive and continuous. It always implies a process; 3) not directly referring to a subject. It exerts a discrete influence on a broad, pregnant and pervasive basis. Transformation is not visible, whereas its results stand out. Plants grow unnoticed, though you can notice their fruit when it is about to fall off the tree. People do not see themselves as they grow older, and the river hollows out the rocks unnoticed; however, the complexity of reality results from the imperceptible course of events. It is like Prigogine's bifurcations (1979), or the coexistence of continuity and discontinuity.

1. ACTION CLASS	action	transformation
a)	temporary	systemic
b)	local (here and now)	stretching through time (process)
c)	explicitly referring to a subject	not directly referring to a subject

The second operational implication envisages the major activities of planning and control, on the one hand, and co-evolution monitoring and orientation, on the other hand.

In a given situation, where predictability is high and the *design & implementation* method allows simplification, planning and control ensure high levels of efficiency. Therefore, planning and control is the ideal option for simple organizations which operate in simple environments, and for castles where aristocracy takes control over their subjects' life.

In the complexity of reality, we find the co-evolution monitoring and orientation. The concept of relation becomes crucial and the idea of networks replaces that of castles. Networks involve all potentially relevant actors at the global level, since co-evolution implies a systemic evolution of all individuals. Therefore, the different actors influence each other and distort the fitness landscapes through their actions. The monitoring is crucial; it refers to the time when the main factor, which is promising though still imperceptible, is hardly identified as a weak signal. The potential of a given situation must be identified in its embryonic stage, before the event actually occurs. The orientation already exists, though it is not really visible. The initial stage deserves your utmost attention, as acting without acting means acting upstream, especially. That is the time when you can set the course of co-evolution.

2. MAJOR ACTIVITIES	planning and control	co-evolution monitoring and orientation
a)	stable and predictable context	unstable and unpredictable context
b)	efficiency maximization	potential exploitation

The third operational implication is the deliberate strategy, on the one hand, and the emerging strategy, on the other hand. To simplify matters again, we can assume that the real strategy actually results from the combination of the deliberate strategy and the emerging strategy.

The deliberate strategy is made up of the strategies elaborated intentionally, according to a definite plan. Finally, a model is outlined.

On the contrary, the emerging strategy results from the circumstances; it is occasional, unintentional and

unexpected. It stems from co-evolution. Emergence requires the evaluation of the potential in a given situation, the identification of weak signals and the adaptation to change. The end is not fixed according to an ideal model, but it results from the interaction of changing situations. Like a dragon, which is the course of a river reflected in the sky. It is a flexible body without any fixed shape, which ripples and bends in all directions. It shrinks and stretches, it bends and moves forward. It perfectly sticks to the clouds which bring it forward; as a result, it moves forward without making any effort by simply exploiting the potential of a given situation. In a few words, it behaves like the snake from the Chang Mountain "when you attack the snake's head, he pricks up his tail; when you attack the snake's belly, he pricks up both his head and his tail". Whether it is water, dragon or snake, according to Confucius, "the strategist shows neither inclinations nor prejudice and he is talented in that he can shift from one extreme to the other".

3. MAJOR STRATEGY	deliberate	emerging
a)	elaborated intentionally	results from the circumstances
b)	fixed	flexible

We have experienced another way of thinking. The dominant Chinese thought, which is steeped in complexity, has therefore the following operational implications: transformation, co-evolution monitoring and orientation, emerging strategy.

CONCLUSIONS

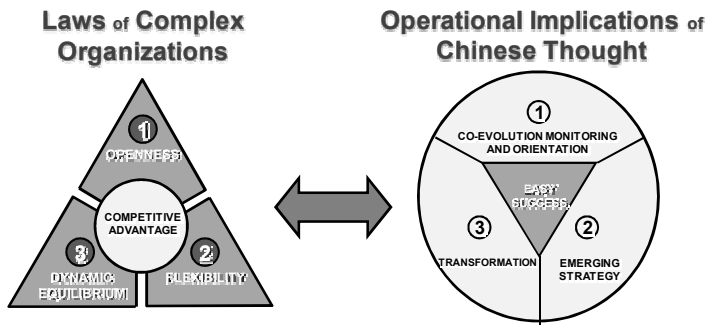
VIII.

AT THE END OF THE JOURNEY

> …unite things whole and things not whole, that which tends to unite and that which tends to separate, the harmonious and the discordant
>
> HERACLITUS (5th Century B.C.)

THE "AND" CULTURE: SCIENTIFIC APPROACH AND PHILOSOPHICAL APPROACH

In short, at the end of our journey through the complexity theory, three laws have been put forward, which are based on the complexity management principles and serve as guidelines for complex organizations. Finally, at the end of our journey through the complexity of reality, the major operational implications of the Chinese thought have been identified.



Finally, the two paths meet, thus giving rise to the "and" culture, which implies the integration of the scientific approach and the philosophical approach. A one-to-one correspondence is established between the three laws and the implications of the Chinese thought. The two paths into the complexity theory (scientific approach) and the complexity of reality (philosophical approach) are herein synthesised in some guidelines for people and organizations, although we are perfectly aware that there are no golden remedies.

The first guideline is openness, i.e. co-evolution monitoring and orientation, because exchange makes individuals alive and openness is a fundamental prerequisite for exchange. Openness to the external environment implies monitoring which helps grasp weak signals and orient co-evolution to the external environment.

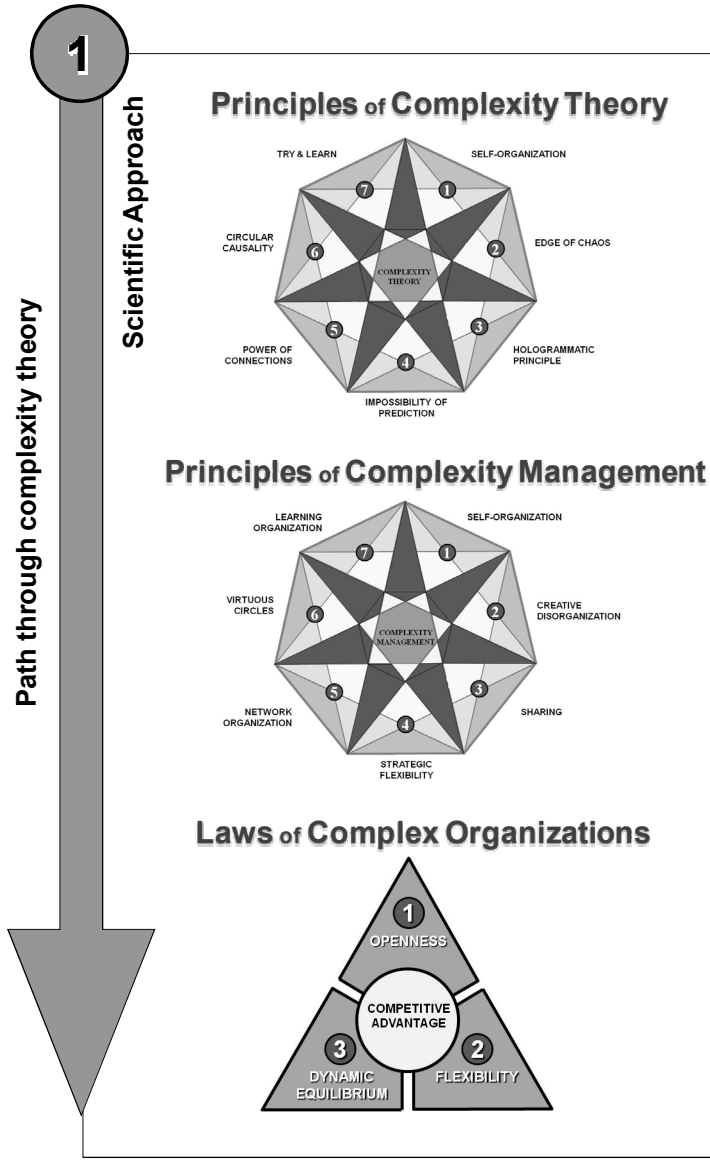
The second guideline is flexibility, i.e. strategy emergence, because nothing is rigid and unchangeable in nature and all that was believed to be unchangeable actually changes all along the path. As you are travelling the path, you need to be flexible and able to reorient your direction.

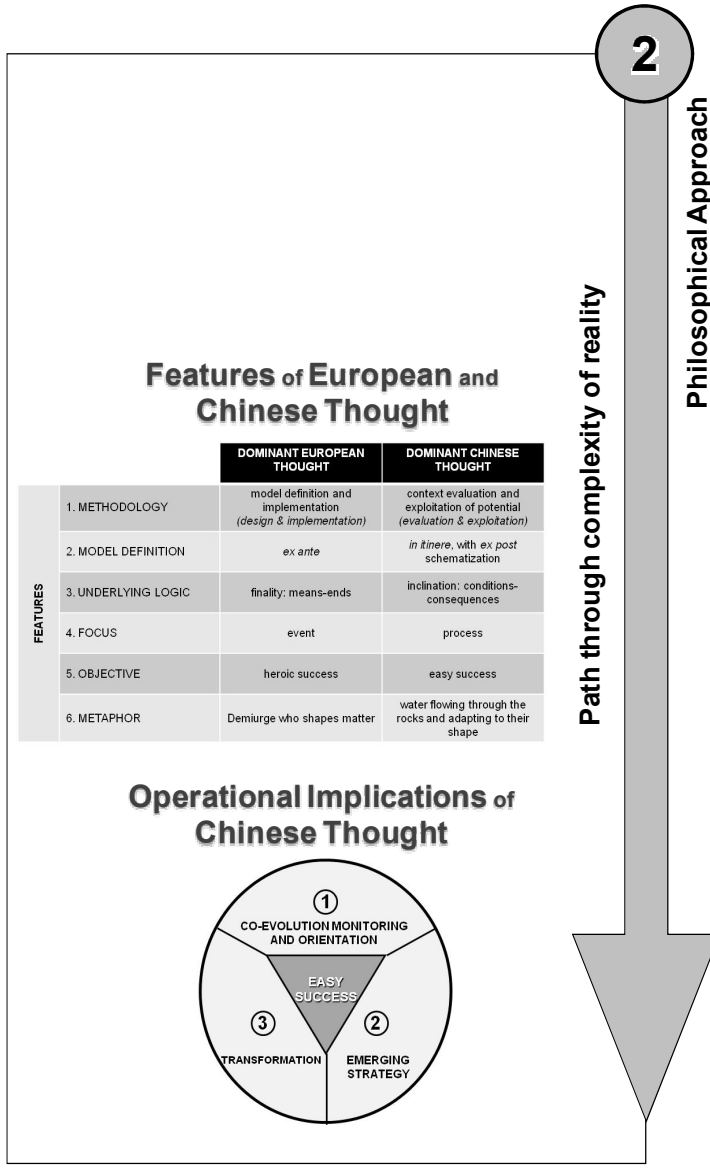
The third guideline is the dynamic equilibrium between continuity and discontinuity, i.e. transformation, because everything flows unceasingly, like a river, and it is impossible to step twice into the same river. The small number of visible discontinuities actually results from the strenuous and relentless underground activity made up of many tiny changes. Searching for the dynamic equilibrium between continuity and discontinuity, i.e. transforming, means creating, adapting to and exploiting the vital coexistence between the two extremes.

AT THE END OF THE JOURNEY, THE TRAVEL MAP

Now that our journey through complexity is coming to an end, the travel map is provided. The map is usually provided at the beginning of the journey, as it helps orient you and find the right direction. However, travelling without any map and making up your own route underway is often more exciting. Then, at the end of the journey, while checking the path that you have travelled, you might be impressed by all the steps that you have taken and the experience that you have gained. For this reason, the map is provided only now, when our journey is coming to an end.

On the map, two paths are reported: the first leads us through the complexity theory, while the latter drives us through the complexity of reality.


1
Path through complexity theory
Scientific Approach
Principles of Complexity Theory
TRY & LEARN
SELF-ORGANIZATION
CIRCULAR CAUSALITY
EDGE OF CHAOS
COMPLEXITY THEORY
POWER OF CONNECTIONS
HOLOGRAMMATIC PRINCIPLE
IMPOSSIBILITY OF PREDICTION
Principles of Complexity Management
LEARNING ORGANIZATION
SELF-ORGANIZATION
VIRTUOUS CIRCLES
CREATIVE DISORGANIZATION
COMPLEXITY MANAGEMENT
NETWORK ORGANIZATION
SHARING
STRATEGIC FLEXIBILITY
Laws of Complex Organizations
OPENNESS
COMPETITIVE ADVANTAGE
DYNAMIC EQUILIBRIUM
FLEXIBILITY


2
Philosophical Approach
Path through complexity of reality
Features of European and Chinese Thought
FEATURES
DOMINANT EUROPEAN THOUGHT
DOMINANT CHINESE THOUGHT
1. METHODOLOGY
model definition and implementation (design & implementation)
context evaluation and exploitation of potential (evaluation & exploitation)
2. MODEL DEFINITION
ex ante
in itinere, with ex post schematization
3. UNDERLYING LOGIC
finality: means-ends
inclination: conditions-consequences
4. FOCUS
event
process
5. OBJECTIVE
heroic success
easy success
6. METAPHOR
Demiurge who shapes matter
water flowing through the rocks and adapting to their shape
Operational Implications of Chinese Thought
1
CO-EVOLUTION MONITORING AND ORIENTATION
EASY SUCCESS
2
EMERGING STRATEGY
3
TRANSFORMATION

Path n° 1 brings us through the complexity theory, according to a scientific approach. First of all, the rationalization of the many and heterogeneous contributions available in literature about the complexity theory has enabled to identify seven principles for the complexity theory, i.e. self-organization, edge of chaos, hologrammatic principle, impossibility of prediction, power of connections, circular causality, *try&learn*. Afterwards, the transposition of the above quoted principles to the organizations enabled us to introduce the seven principles of complexity management, which serve as a theoretical basis for the management of complex systems in complex environments. Hence, the principles of self-organization, creative disorganization, sharing, strategic flexibility, network organization, virtuous circles, and learning organization have been presented. From the principles to the laws, three guidelines for complex organizations have been identified, hence openness, flexibility and dynamic equilibrium.

Path n° 2 leads us into the complexity of reality, according to a philosophical approach. First of all, we come across the main patterns of the Chinese thought, which is steeped in complexity and therefore it clashes with the European thought that marks the triumph of classical science; it is crucial to move away from our way of thinking and then go back to it and question what we generally take for granted. Hence, the operational implications of the Chinese thought, i.e. co-evolution monitoring and orientation, emerging strategy and transformation.

Although thousands of years and miles away from each other, both path n° 1 and path n° 2 lead to similar conclusions, to the same finishing point. We have put forward a one-to-one correspondence between the three laws of complex organizations and the operational

implications of the Chinese thought. They actually account for the "You are here" indication on the map for the journey through complexity.

IN THE NETWORK, READY TO SEIZE THE CREATIVE MOMENT

At the end of this journey, what is left for the people and the organizations? In a very few words, what is the meaning of the journey through complexity? Above all, what is the meaning of the journey through complexity that each one of us makes every day? In our opinion, taking up the challenge of complexity means above all being open to all directions, even if you may be advancing hesitantly sometimes, or you may be defining the path as you are travelling it. We are purposely provocative when we reply to the key question "Once you have come to terms with complexity, which direction should be taken by people and organizations?". Indeed, our answer is "all potential directions".

This is a powerful message to organizations, especially: by monitoring their external environment, by pursuing self-organization, by promoting innovation at the edge of chaos, by being flexible, by strengthening both the internal sharing and the external network relations, by fuelling virtuous learning circles, organizations will be highly dynamic, ready to change and seize new opportunities. The three laws of complex organizations are a synthesis of this message: although you are aware that there are no golden remedies, be open, be flexible, be in a continuous state of changing dynamic equilibrium between continuity and discontinuity. In other words, try and identify the main factors, monitor and orient co-evolution, let the strategy emerge from the context, help transformation, and finally adjust to the inclination of the inclined reality.

Once the strategy and the direction have been arranged, be aware that you make the way as you go, and your initial objectives may possibly change all along the path. Paradoxically, we decide not to take a predefined direction, though to stay open to all potential directions. Borrowing a slogan which synthesises the laws of complex organizations and the operational implications of the Chinese thought, we can say that we decide to stay *in the network, ready to seize the creative moment*. You should be aware that you cannot search for the moment, though you should seize it as a consequence of the natural inclination of things, by orienting the evolution process of the main environmental factors.

Being open to transformation and networking with as many actors as possible is one of the methods to win the challenge of complexity. It is all about shifting from the concept of *possession* to that of monitoring, from the idea of *action* to that of *transformation*, from the *or* approach to the *and* approach, and finally from the idea of *castle* to that of *network*. The most advanced organizations monitor the places where real innovation happens; the sites are often peripheral, where small companies, universities and decentralized research centres are located. Like a spider waiting for his prey to be wrapped in the threads of his web, the organization must deal with complexity by carefully monitoring the places where unexpected opportunities may arise.

EPILOGUE
THE JOURNEY NEVER ENDS

Reader, we have come to the end of our journey. Now we must take different paths. Before parting, let's wish good luck to each other and may fate be on our side. The journey is not over and one day we will meet again under the same stars.

The journey is not over yet. The journey is never over. Only travellers come to an end. And they can also live in our memory, in our memories and stories. When the traveller sat down on the sand and said "There is nothing left to see", he knew that it was not true. You have to see what you missed the first time, see again what you already saw, see in springtime what you saw in summer, in daylight what you saw at night, see the sun shining where you saw the rain falling, see the crops growing, the fruit ripen, the stone which has moved, the shadow that was not there before. You have to go back to the footsteps already taken, to go over them again or add fresh ones alongside them. You have to start the journey anew. Always. The traveller sets out once more[1].

Reader, life is complex and its course is changing. Who knows, maybe it is already written in some corner of the

[1] Excerpts from José Saramago, *Journey to Portugal: In Pursuit of Portugal's History and Culture (transl. by Amanda Hopkinson and Nick Caistor),* The Harvill Press, London, UK, 2002.

sky, or it is to be written from scratch. Maybe it is both. And the path that we have travelled together does not lead to the final destination. The destination is not important, the destination changes, and each arrival is a new departure.

Parting is sad, though let us part now: like the old Friulian emigrants who set out to faraway lands, let us make an effort to always be strong in our will to search and find things and never give up.

Suddenly, the journey starts again. Anin varin fortune…

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Human beings cannot live without travelling. Nowadays, old, outdated ideas are waning and it is time for an intellectual journey into complexity. Life and all that stems from it is far from equilibrium, in a continuous search for the new and the improbable. This book is a smooth journey into the complexity theory; especially, it is an invitation to embark on the continuous search for the creative moment, where each arrival is a new departure. Those who want to imagine their future, those who have a dream will be inspired to venture into the mysterious and charming land at the edge of chaos, being aware that their future may also depend on chance.

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