Since the days of the British physicist and mathematician, Isaac Newton, and until about a hundred years ago classical scientists perceived the world as deterministic. They tried to understand Nature by breaking it down into its most minute parts, assuming that once you understand the parts, it is easier to understand the whole.

But reality behaves in a nonlinear way. It consists of parts, interconnected to the point that one cannot separate them and thus one has to deal with them as a whole.

The book presents the main ideas of Complex Systems, Chaos and Networks theories. It was written mainly for managers, who need to function in a rapidly changing reality.

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Real Life is not Linear

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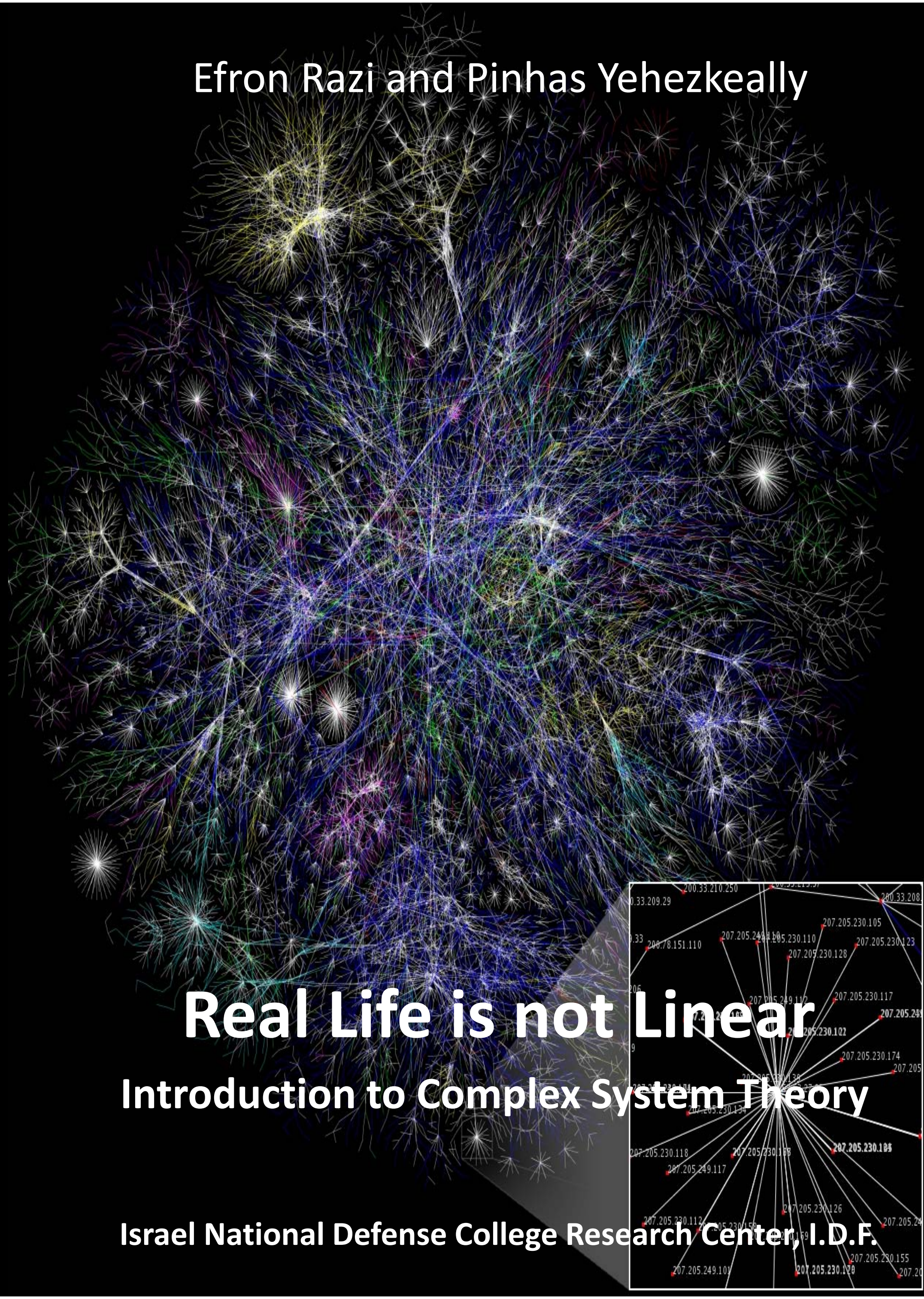

Real Life is not Linear

Introduction to Complex System Theory

Israel National Defense College Research Center, I.D.F.

Efron Razi and Pinhas Yehezkeally

Real Life is not Liniar –
Introduction to Complex System Theory

Real Life is *Not* Linear
Introduction to Complex System Theory

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Introduction

Since the days of the British physicist and mathematician, Isaac Newton, and until about a hundred years ago, classical scientists perceived the world as deterministic. They tried to understand Nature by breaking it down into its most minute parts, assuming that once you understand the parts, it is easier to understand it as a whole.

One example that typifies the spirit of those days was provided by the author Jules Verne in the second half of the 19th century. The protagonist of Verne’s book, *Around the World in Eighty Days*, Phileas Fogg, wagered twenty thousand pounds sterling (at the value of those days) against his fellow club members. He claimed that he would be able to circumnavigate the world and return to their club in London within eighty days, by calculating the timetable with true mathematical precision, jumping from steamers to trains and from trains to steamers. When one of his friends exclaimed that he could lose his wager *"by a single accidental delay"*, Fogg replied with his pivotal maxim: “*The unforeseen does not exist…*” (Verne, 1993, ch. 3, p. 21).

The perception of dynamic reality in our rapidly changing times differs radically, of course, from the reality depicted in Jules Verne’s book.

This book attempts to introduce readers to the principles of 'Complex Systems Theory', 'Chaos Theory' and 'Networks Theory'. It is intended mainly for managers who need a better understanding of the new, rapidly evolving reality in which organizations must operate. Furthermore, this theory provides tools enabling the development of the latest breakthrough modes of thinking and the development of innovative management tools.

The book was also written for those who are not management professionals, but who may find the subject of interest. For this reason, we provided numerous examples from diverse fields for the sake of illustration, and constructed the various chapters of the book so that they would be self-containing, even though this meant that some of the material would have to be repeated.

Complex systems theory, whose origins and images, including the metaphors and analogies on which it relies, is essentially technoscientific. On the other hand, managers in public systems usually have backgrounds in social sciences (while business managers have a more technoscientific background). Therefore, when writing this book, we decided to resist our natural tendency to use imagery familiar to the target audience from the field of social sciences and to base our imagery on original examples. The use of fresh imagery unfamiliar to most managers will facilitate the adoption of nonlinear thought patterns – thinking 'outside of the box'.

In today's reality, it has become extremely difficult to foresee developments. The business perspective has become very shortsighted and changes occur at an accelerated frequency, while conflicts between various positions have intensified. Theoretically, the importance of the human factor should have diminished in this rapidly evolving technological era, since machines now perform many functions previously done by humans. However, the complete opposite has occurred. The developing technologies have very much increased the extent of human interaction. The more it has increased, the more significant the role of the human factor became in systems.

In order to contend with this new reality, organizations must adopt more dynamic characteristics. Organizations that procrastinated in doing so paid dearly for their inflexibility. This, for example, happened to IBM, which allowed it to stagnate during the 1980s while small companies invaded its spheres of activity, and to HP, which in missing the mark in its predictions about the demand for personal computers, refrained from penetrating the market and suffered accordingly.

Although today's reality is comprised mainly of nonlinear phenomena, this fact is not recognized as being obvious. Most of us are clinging to linear thinking; i.e., to thought patterns that still link *cause* directly to *effect*. As long as we continue to give a linear solution to any problem that appears to be linear, the solution may seem adequate – like, for example, putting on sunglasses in dazzling sunlight. However, in reality, most problems are complex and cannot be resolved so simply. The solution of sunglasses created a new problem for those needing prescription eyeglasses: having to carry around two pairs of eyeglasses all the time. For this, a more complex solution may be proposed, like, for example, photochromic lenses.

An example of complexity of a different type is the story of the Hula Valley cranes in northern Israel. Ever since the cranes began arriving at the lake in 1992, farmers in the vicinity have been incurring substantial damages. These large birds found an abundance of food in the nearby fields, which were planted in early winter. By 1999, the crops had suffered damages to the tune of 1.2 million shekels, in addition to the farmers’ expenditure of some 600 thousand shekels per annum on futile attempts to drive off the birds. The farmers tried the entire gamut of linear tactics in their war against the cranes, like shooting in the air in an attempt to scare them off. When the damages only increased, a concern arose that desperate farmers might harm the cranes. The relatively-simple solution found was to feed the cranes regularly. However, due to inherit complexities in the environment, this solution generated a new problem. The readily available food led to a constant growth in the crane population, while the sources of financing are limited, and concerns are that the project will eventually collapse (Israeli Society of Agronomy Site, no date).

The origins of Complex Systems Theory are rooted mainly in two theories that preceded it and influenced each other: 'Cybernetics Theory' and 'General Systems Theory'. The research on these theories focused on the principles common to all autonomous entities (e.g., organizations) and on the models describing them. While the principles of 'Complex Systems Theory' and 'General Systems Theory' focused on structure, 'Cybernetics Theory' focused on function.

The foundation for 'Complex Systems Theory' was laid by the integration of these theories with the science of 'Chaos'. This science is a new field that strives to identify consistent underlying patterns in nonlinear phenomena, and to understand how these theories influence each other, alongside the evolution of sciences and technologies, mainly the development of computerization and holistic thinking.

It is interesting to note that the salient points of 'Complex Systems Theory' may already be found in the 17th century, elucidated by the French mathematician and philosopher Rene Descartes, considered one of the fathers of the new philosophy. Descartes was among the first to discern the transition between 'Chaos' and 'Order'. He wrote about the laws of nature and about man's advantage over a machine. In his book, *Discourse on Method* (Descartes, no date, ch. 5), Descartes asserts that God helped nature emerge from a state of “nothingness and disorder” (in the original “chaos,” although these two expressions are not necessarily synonymous) into the world as we know it today. He did that by applying merely a few laws (in the original, “certain laws”), that “*things purely material might, in the course of time, have become such as we observe them at present*”. Descartes describes at length the structure of vascular circulation and pulmonary circulation, which are complex holistic systems. He compares them with the pendulum clock, whose capabilities cannot be compared with human capabilities, since it does only what it was programmed to do (ibid).

We believe that the term “Complex Systems” was initially used in professional literature in Ross Ashby's book *Introduction to Cybernetics* (Ashby, 1957, p. 4). According to Ashby, one of the properties offered by cybernetics is a scientific methodology for “treating” the system, in which “*complexity is outstanding and too important to be ignored*” (*ibid*, p. 5). Such systems are prevalent in the biological world, in which systems' various components have adapted in many diverse ways. Nature, which has sustained itself for billions of years, harmonizes all these pieces with beauty and precision, in a way that still poses a mystery to scientists.

For the sake of illustration, it is fitting to read how the French philosopher-physicist-mathematician, Henri Bergson, described a complex system such as the eye:

> *Two points are equally striking in an organ like the eye: the complexity of its structure and the simplicity of its function ... the slightest negligence on the part of Nature in the building of the infinitely complex machine would have made vision impossible.*
>
> (Bergson, 1911, ch. 1)

This description is found in Chapter 1: *The Evolution of Life – Mechanism and Teleology,* from 1911 (!). He illustrates the nature of complex systems: *a very complex and complicated structure, which leads, through precise timing, to extreme simplicity of function* (ibid). If we attempt to apply this definition to the world of management, an organization with a complex structure can achieve the objectives it sets for itself by relatively simple functioning.

In Gershenson and Heylighen's article "How Can We Think the Complex?" (2003), they claim that the ability to break down nature to its most minute parts does not mean that it can be reassembled in the same manner. Today, we know more about the minutest particles in nature, thanks to physics and related sciences, but this does not mean that we will also succeed in reassembling those same particles to re-create the whole. It turns out that reassembly of all the parts is far more complicated than scientists thought it would be, and is sometimes simply impossible.

Can this conclusion also be extrapolated in relation to organizations? Apparently, it can, since, if we segment an organization, we will lose the interactions between its various parts, which are an integral part of the organization's essence. Therefore, organizations are complex systems, similar to bodies in nature and dissimilar to mechanical systems.

Increasingly nowadays, science is recognizing the fact that we are living in a world in which most of the events and phenomena in nature do not occur independently, but rather, are interconnected in a complex universal puzzle. The biologist Stuart Kauffman (1997) for example, claimed already back in the 1960s that natural selection alone is insufficient to explain evolution. There are other inevitable laws to explain the complex phenomena in nature.[1]

The mindset of thinkers from Descartes to Kauffman is still not sufficiently prevalent in the world of management. Many are clinging to the concept of a linear world in which planning, execution and control in all spheres of life (political, civil and corporate) seemingly adapt themselves to the "organizational needs" and not to the reality in which they are operating. Planning was always centralistic and long term; execution was relied on chains of command; control was also centralistic and relied on measurement tools; the main movement in an organization was top-down; the organizational hierarchy was expressed in paper-intensive, multi-stage bureaucratic processes

---

[1] An abstract of Kaufmann's doctrine in this context can be perused in three brief articles written by Brian Coffman in "*Journal of Transition Management*," July 23, 1997 (Coffman, 1977a; Coffman, 1997b; Coffman, 1977c).

requiring a plethora of approvals; the organization was perceived as a kind of machine that generates output directly proportionate to input.

When everything is clear, the ability to think wanes and planning and control atrophy. This is what caused the Russian empire to collapse, and so too, the unique kibbutz community, which failed to understand the trends evolving around it. Amateur management and a failure to contend with changes in the economic and political environment are what caused their revenues to plummet in the 1980s and led to a major crisis in the banking system. The crisis was accompanied by many *kibbutz* members abandoning ship and by social tensions that rose against the backdrop of their economic distress.

Those organizations that did contend with the new corporate-social environment, but failed in finding ways to remove the bureaucratic barriers, tried to resolve the problem by way of creating "bypasses." And thus, steering committees, coordination teams, working groups, partnerships between organizations, mergers, etc. were developed. However, the more these inventions multiplied, the more constricted became the "bottleneck." This situation led to the moral corruption of the bureaucratic systems and to the development of phenomena such as the "movers and shakers" industry of influential people, who reaped personal gains from opening bottlenecks.
Flattening of the organizational hierarchy became possible, to a certain extent, only once information systems and communications capabilities became technologically sophisticated. The growth of the computer and computerization industry during the second half of the

twentieth century looked like a way out of the bureaucratic mess, but it was not.

The internet and the mega-sized information software programs did indeed provide a great deal of information, but the centralistic management perspective that had been used at the beginning of the twentieth century no longer related to reality. In the High-Tech Era, organizations are flatter and more flexible than in the past. This rigid mindset still constitutes a barrier to a free flow of information, and is unsuccessful in responding to needs in business management or in public administration.

The need for a change in our thought patterns, in world perspectives and management methodologies has also seeped into the awareness of some leaders. The former U.S. Secretary of Defense, Donald Rumsfeld, said one day before the twin-tower catastrophe, during a lecture to hundreds of officials heading organizations involved in national security: "*we must change, because the world has*". He underscored that when a person thinks that he knows all the answers; i.e., the answers for past successes, and when, in theory, there are scenarios for everything, he ceases to ask questions and stops thinking. Rumsfeld stated that "*the future will require new ways of thinking and the development of powers and capabilities for rapid adaptation to unforeseen challenges and situations*" (Sanders, 2002). This statement is very different from the routine responses of security personnel, who usually spout the problematic slogan: "*We are prepared for every possible scenario …*"

The development of the sciences of 'Chaos' and 'Complex Systems' parallel to the development in different areas of computing has restored nonlinear thinking to center stage. In these two interconnected disciplines, creative solutions were needed for a diverse variety of possible scenarios.

This book is intended to be another layer in the debate that is still underway about fundamentals, and the need for nonlinear thinking relative to those of linear thinking. This debate has immediate implications on the development of new management tools in the fields of strategy, planning and control.

For this purpose, the book will introduce the origins of 'Complex Systems Theory'. It begins with an explanation of systems and will proceed to relate the history of the formation of 'Complex Systems Theory'. The book focuses on describing concepts and content relevant to 'Chaos Theory', to 'Complex Systems Theory' and to 'Networks Theory'. All these theories, coupled with the computerization revolution of recent years, enable us to generate more and more the benefit from 'Complex Systems Theory'. These three theories are interconnected and affect each other intimately.

The final chapters of the book formulate conclusions from the facts hereby presented, and underscore the significance of the studies done so far, as a basis for checking into the possibility of the existence of a new management perspective.

Chapter One
Systems – What are they?

The term 'system' constitutes the foundation for understanding complex systems and has many definitions deriving from various content worlds. For our purposes, we will choose Forrester's definition, whereby "*A system is a group of components operating in unison to achieve a common objective*" (Forrester, 1968, p. 11). The emphasis is on the interconnection between the system's components, because a group of parts that do not interconnect is not considered a system. It is a heap of unrelated parts (O'Connor and McDermott, 1997, p. 1).

Similar definitions describe a combination of different components having defined properties, when various additional forms of connection between them generate new and different properties (Duriel, 1996, pp. 26-27); or "*a set of elements in dynamic interaction for the sake of achieving a common goal*" (Hecht, 1999, p. 25). Another definition is "*a set of elements performing mutual interactions between them*" (Naveh, 1998, p. 6; Von Bertalanffy, 1975, p. 32).

Main properties of systems

Objective

A system is a tool whose objective is to serve a particular purpose. Therefore *the system's objective* is common to all of its elements or to all of the parts comprising it. The objective constitutes a framework for the mutual interaction between the various elements and defines the path through which the system will interact with its environment (Naveh, 1998, p. 6; Kuhn, 1971, p. 76). In an electrical lighting system, for example, there is a power source, an electrical conductor and a light bulb. Each distinct element has its own properties, but light is generated only if they are all connected correctly.

Boundaries

The boundaries of a system are defined by the set of its interacting components operating in unison to achieve a common objective in the organizational environment in which the system operates, and they are not fixed. Parts are added (examples from human organizations are, for example, acquisitions of companies, the addition of departments, etc.), or eliminated (the sale of product lines, privatization of particular segments, etc.). These flexible boundaries affect the system's functioning and are an integral part of the system's definition.

Hierarchy

A hierarchy may be created when defining systems. Any system may be comprised of a number of subsystems, and a number of systems may comprise a supersystem. Nonetheless, a system may be viewed as a single unit, while disregarding the subunits comprising it.
One example of a system is the ecosystem, the fundamental ecological supersystem. This is the relationship between the atmosphere (the layer of gases enveloping stars), the biosphere (that portion of the earth that sustains life), the lithosphere (the earth’s crust and top layer of mantle), and the hydrosphere (the aqueous layer of the planet) (see diagram no. 1). The Earth lives on the basis of the interaction between these four components.

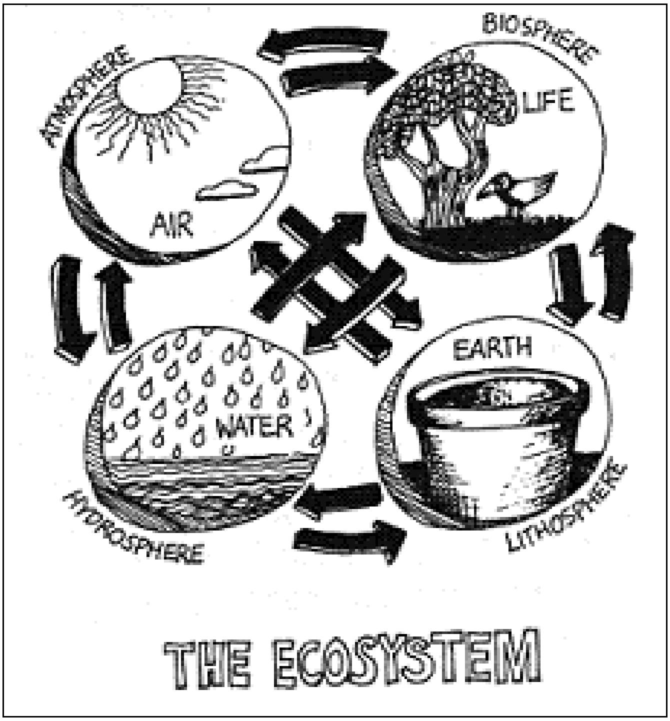
Interconnectivity

A system usually includes a few subsystems having independent structures that are not necessarily identical. There is interconnectivity between these subsystems and within each individual subsystem. The systems affect each other, are affected by each other and are dependent upon each other. These interactions are usually dynamic, but may also be controlled.

Diagram no. 1

Example of a Supersystem – the Ecosystem

(From: de Rosnay, 1979, ch. 1)



Process

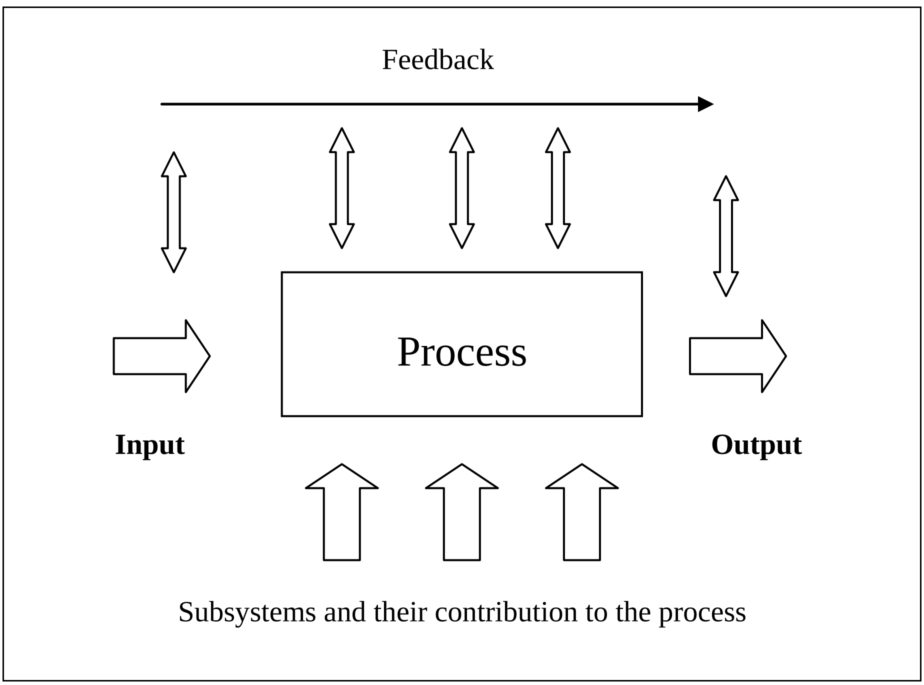
A "process" is an operation being performed in a system which transforms input into output. A system performs many processes sequentially or simultaneously. It receives input from the environment and releases output to it. Every system receives various types of input and generates various types of output. The organizational environment is the destination of the output and the source of the input (see diagram no. 2).

Control mechanisms

A system has mechanisms to control the mutual interactions between the units. These mechanisms are based on feedback (see diagram no. 2).

Diagram no. 2

How a System Works



Types of systems

A system may be defined as needed in any one of the spheres of life. It can be a conceptual system, such as the national defense system, which constitutes the supersystem for the system of concepts comprising it, such as: military might, economic strength, social cohesion, etc. (Lanir, 2004). It can also be an organizational system, comprised of a number of organizations operating in the same task environment; for example: the law enforcement system, which is comprised of the police, the advocacy, the prison service and additional entities.

A number of types of systems may be differentiated, according to various criteria, such as:

- *Closed systems versus open systems*: von Bertalanffy defines two types of systems: closed systems and open systems, which are more relevant to our discussion.

  An open system is defined as "*a system in a state of exchanging matter with its environment, including import, export, construction and destruction of its material components*." On the other hand, closed systems may be considered as being isolated from their environment (Naveh, 2001, p. 25; von Bertalanffy, 1975, pp. 38, 149). An interrelationship within systems comprising the open system may create 'polarities of wholeness'[1].

---

[1] "*Polarities of Wholeness*" (or "unity of opposites"): the term was originally used as a component of the materialistic dialectics of Marx and Engels. Opposites define each other, and also penetrate and affect each other. Thus, they assembly a new, higher essence, encompassing the opposites. For example: daytime is the opposite of nighttime. *Prima facie*,

On the one hand, each system has its own uniqueness, and, on the other hand, it is open to the other systems and is affected by them. These relationships are what enable their slow evolution or their rapid development. There are other theories that state that the relationships inside organizations, and *inter se*, are based on power. The purpose of dominant organizations is to impose their wishes on other organizations and take control over them (Lanir, 2004).

- *Systems operated from outside opposite initiator systems*: among systems operating from outside are most of the electromechanical systems used by man. Systems of the latter type are smart systems that initiate their own operations, because their attributes enable them to adapt to circumstances. In this group are all living systems in which the biological programming (the DNA) is fixed. Another example of systems of the latter type is man-made automation systems. Man programmed the order of operations to serve the purpose for which the system was planned, as well as the preset response to an event affecting it (Duriel, 1996, p. 27). Computerized systems that learn and adapt are another example. Since systems cannot be planned for all possible circumstances, computerized systems have been developed recently that are

at issue are two complete opposites, but jointly, day and night create something new – a unit of 24 hours – one day. In order to define this process, dialectics uses terms such as thesis, antithesis, and synthesis. Thesis is the opposite of antithesis and is alienated from it only at one phase, during one-dimensional perspective. Every opposite, every thesis and antithesis create a new, superior thesis. Synthesis is the product of the mutual impact of the "overturned" theses" (Shamir, 1947, pp. 224-239).

capable of learning, adapting and responding according to the conditions in the field.

- *Simple systems versus complex systems*: a simple system is a fixed and defined framework, like an automobile engine, which is a fixed and routine system. On the other hand, a complex system is a dynamic framework, deriving from the existence of interconnectivity, and which develops in order to perform tasks. These interactions have a direct impact on the efficacy of their activity. Thus, for example, the link between the automobile engine and the driver operating it is a complex system, because the interaction between the driver and the engine enables the system to respond and change depending upon the environment. The problems that a complex system faces fall within the spectrum of interactions impacting a large number of variables existing in various fields, such as: politics, economics, industry, trade, the military and more (Naveh, 2001, p. 24).

The dilemma in understanding systems

Systems are an integral part of our lives. We live and work in social systems; our scientific studies reveal the structure of systems in nature, and our technology creates complex physical systems. Nonetheless, the perspective and principles governing the functioning of systems are not sufficiently lucid to us and are not clearly elucidated in professional literature.

Four basic explanations may be given for this (Forrester, 1968, pp. 1-1, 1-2):

- In primitive societies, man did not need to understand the nature of systems. The principal systems were those created by Nature, and were accepted by man as phenomena beyond his comprehension and control. They were phenomena to which he had to try to adapt as best he could. The social systems were created as a result of natural evolution and not necessarily due to planning. People got accustomed to them without feeling a need to understand them.
- Man was unaware of the fact that there is a single theory controlling systems and dictating their operations.
- The system's principles were so nebulous that it was impossible to comprehend the nature of the system or even define it.
- Systems became complex and their behavior was perceived as so confusing that it appeared that a general theory capable of explaining and defining them was an impossibility.

* * *

This chapter provides a conceptual infrastructure for such questions as: what is a system, what are its properties and what differentiations can be made between various types of systems. It addresses the question of why the principles motivating systems are insufficiently clear to us.

This understanding will be helpful to us later, when we examine how the properties outlined here are applied in the specific case of complex systems, the main topic of this book.

Chapter Two

The Development of Complex Systems Theory – Historical Review

In the first chapter, we stressed that complex systems theory is multi-disciplinary. Therefore, this historical review of the theory's development presents examples from very diverse content worlds. The chapter also integrates theory and practice, presents both the theoreticians that grasped, at least partially, the complexity of the systems they were dealing with, and practitioners, who did not engage in theories, but still correctly coped with this complexity, sometimes merely through keen intuition.

Henri Bergson's description of the eye – *a structure of infinite complexity, which leads, through precise timing, to extreme simplicity of function* – was applied to the field of industrial management at the beginning of the 20th century (during Bergson's era). It was applied by Henry Ford, one of the pioneers of industry in the United States, who designed a complicated structure of an automated production line that functioned as simple as could be.

These two phenomena could not have been foreseen. Ford's invention was surprising, due to the speed at which it generated radical changes. Thus, Ford became a key figure in the industrial revolution, which, within mere one hundred years, underwent an organizational and social transformation. These transformations developed immeasurably faster than the biological adaptation over millions of years, such as the development of the eye. From a historical perspective, it could not have been foreseen that the eye would identify electromagnetic waves at this or that frequency, just like today it is unpredictable what the development of the eye will be in the future.

Bergson, the theoretician, and Ford, the industrialist, were only two of the pioneers of complex systems theory. A pioneer from another field was the agriculturalist, Sir Ronald Fisher, whose experiments back in the 1920s had succeeded in discerning the existence of complex systems:

> "*Not until his [Fisher's – ER/PY] work in the '20s, with experiments conducted on agricultural soils, did it become clearly recognized that there are complex systems that just do not allow the varying of only one factor at a time – they are so dynamic and interconnected that the alteration of one factor immediately acts as cause to evoke alterations in others, perhaps in a great many others.*"
>
> (Ashby, 1957, p. 5)

To the practitioners in the field of complex systems one may add, for example, Alfred Sloan, the legendary director of General Motors during the 1930s. In his book, *My Years in General Motors*, Sloan describes modern management methodologies that he developed in the company. These methodologies overcame problems of control and coordination between the various divisions that comprised a major system like General Motors, and the 'super system,'' and created working relations between them (Sloan, 1963). By doing so, Sloan was a decade ahead of the founders of cybernetics theory that was defined at the beginning of the 1940s by Norbert Wiener. Wiener defined cybernetics in his book, *The Human Use of Human Beings – Cybernetics and Society*, as "*a science of control and communication among* ***animals*** *and* ***machines*** *alike*" (Wiener, 1964; de Rosnay, 1979, ch. 2).

Wiener's successors, the theoreticians Claude Shannon and Ross Ashby (Ashby, 1954), were active during the 1940s and were considered the fathers of complex systems theory.
Shannon, the mathematician, is considered the father of the 'Information Theory', due to his article "A Mathematical Theory of Communication" (Shannon, 1948). Information theory became very significant as the industrialization spread, and particularly when the communications industry was in its infancy, an industry closely related to complex systems (de Rosnay, 1979, ch. 2.

It was Ashby, a physicist and mathematician, who initially coined the term "Complex Systems" as a unique property offering a methodology for the scientific handling of systems whose complexity cannot be ignored (one must differentiate between "complex" and "complicated" – the difference between complex systems and complicated systems will be explained later). These systems were first defined in the biological sciences. However, today, we are aware that they exist in every field, including social organizations (Ashby, 1957, p. 4).

Ashby relied, inter alia, on Sir Ronald Fisher's work. In his book, *Design for a Brain* (Ashby, 1954), he drafted a rule relating to the requisite variety of possibilities in a system. This rule had a tremendous impact on organizational planning, performance and control, as we shall see later in this book.

Ashby referred to the terms "object" or "thing" as items in daily use having degrees of freedom. "Degrees of freedom" are any object's possibilities of movement in space, which enable it to perform various operations. Such an object is, for example, a chair, which, being free in space, has six degrees of freedom: left, right, backwards, forwards, up and down (Ashby, 1957, p. 131). Objects may be used to simulate reality. This simulation is done through defining the constraints of the object in space, expanding or limiting them.
People are also objects. When they are functioning within the framework of an organization, the rules and procedures of the organization constitute the constraints on their freedom of movement and their behavior. The fine-tuning of these constraints enables revisions to be programmed into the system with the aim of improving organizational effectiveness and/or efficiency. Elimination of any of the organization's standard operating procedures will create chaos in the organization (chaos and its characteristics are discussed in a separate chapter in this book). Later, these terms came into use in computer programming as an "object-oriented" methodology.

One of the founders of cybernetics theory, Stafford Beer, was the first to see a factory as a "living company," similarly to a human organism. He gives an in-depth description of a hypothetical factory in his article

"Towards the Cybernetic Factory," which was published back in 1962. He outlines three properties of a cybernetic system:

- Significant complexity;
- Each path in the system has similar probability;
- Self-organization into the organization current structure.

According to him, this system (the factory that he described) cannot be controlled by defining external rules (to differentiate from external influences), but only through internal control (Beer, 1962, pp. 25, 27).

One example of a "factory" would be the disengagement from the Gaza Strip and from northern Samaria during the summer of 2005 (an example we will be referring to again to illustrate other concepts in this book). The disengagement is a complex factory integrating many objects: the forces in play, the population of settlers, the leaders of the settlers, the Israeli public, the local media, the foreign media, the Palestinian population and leadership, the terrorist organizations, and more.

When the security forces were planning their mission, they had a number of possible modes of action. Theoretically, each of them had a similar probability as to the actual outcome, until one mode of action was preferred over the others.

In addition to the high-echelon planning, the forces in the field were allowed a great deal of freedom of action, which enabled them to redeploy (self-organize) depending upon the various developments in the field. The internal control by the operative forces themselves led to changes in the action plan, according to external influences. Thus, for example, the forces could have completed their mission other than according to plan, but far more rapidly than had been planned.

From the 1950s until the end of the 1990s, Professor Herbert A. Simon, researcher and developer in the fields of social sciences and Nobel Prize winner in economics, made a substantial contribution in topics relating to artificial intelligence, cognitive psychology, complex systems and management sciences (Simon, 1962). Simon's research was based on the characterization of natural and artificial systems that he constructed himself. He also studied the impact of communications networks on organizations and on the performance of task groups (Guetzkow and Simon, 1955).

Another theoretician is the biologist, Stuart Kauffman, who, in the 1960s, supplemented the theory of evolution formulated by Charles Darwin during the 18th century. Kauffman asserted that systems develop not only by evolution, but also through a phenomenon of more rapid internal development (Kauffman, 1997). This accelerated development exists in various types of organizations, but despite this, considerable time passed until organization managers reached this conclusion.

Another biologist, Ludwig von Bertalanffy, coined the term "*Systems Theory*" (de Rosnay, 1979, ch. 2). According to his understanding, this was only a general conceptualization to cover his focus on closed systems and open systems (von Bertalanffy, 1975, p. 90).

Systems theory is defined in Wikipedia as "*the transdisciplinary study of systems in general*." A similar but broader definition is seen in systems theory:

> "*The transdisciplinary study of the abstract organization of phenomena, independent of their substance, type, or spatial or temporal scale of existence. It investigates both the general principles common to all complex entities; and the (usually mathematical) models which can be used to describe them.*"
>
> (Heylighen and Joslyn, 2005)

Von Bertalanffy introduced the concept of *"General Systems theory*" in 1938, based on his recognition of the existence of open systems (von Bertalanffy, 1975, p. 90; de Rosnay, 1979, ch. 2). According to this theory, a system as a whole has properties that differ from the properties of its components, and that the system as a whole is worth more than its component parts. Von Bertalanffy was the first to develop a mathematical approach to understanding the synergies in biochemical systems, and defining parameters for the behavior of a hypothetical general system. Bertalanffy's theory was a generic theory,[1] applicable to diverse fields, from natural sciences and social sciences to the fields of management, business, education and military management (von Bertalanffy, 1975). De Rosnay presents detailed illustrations of this theory in the fields of cybernetics, ecology, economics, biology, communications, society and urbanization (de Rosnay, 1979, ch. 2).

Ashby and von Bertalanffy can be considered the proponents of a new paradigm, mainly, due to the backdrop of the growing skepticism between the 1940s and the 1960s about the ability of analytical-

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1 **"Generic"** – general, common to a large variety of fields (*Oxford Dictionary*, 1993, p. 321).

mechanistic approaches for adequately coping with the challenges posed by the tremendous complexities of society and modern technology.

One of the applications of the *"General Systems Theory"* was recorded in the field of engineering. The engineer, Jay Forrester, developed a theory called "Systems Dynamics." Forrester, one of the developers of the first simulators for the American Navy, took his initial steps in the study of servo-mechanisms within the academic framework of the Massachusetts Institute of Technology. He wanted to describe the general behavior of systems and the changes occurring in them in a tangible way, while placing special emphasis on the feedback between system components (Forrester, 1968; de Rosnay, 1979, ch. 2).

Later in his career, Forrester turned to the fields of management and society and tried to apply his achievements in the social framework as well. Following a chance meeting with the mayor of Boston, he analyzed urban problems and found that the results of the simulations he conducted were, *prima facie*, counter-intuitive policies. The most well-known example related to the construction of low-income housing, which had become a poverty trap for the tenants. Despite all the major investments in the construction of inexpensive housing projects and in the upgrading of vocational training in the deteriorating inner cities, by the 1970s, the situation in those cities only deteriorated.

Forrester published his second acclaimed book, *Urban Dynamics*, following his interaction with the mayor of Boston (Forrester, 1969).

Subsequently, Forrester proceeded in two opposite directions simultaneously:

The first – global macro-economic models [see his third book, *World Dynamics* (Forrester, 1971)];

The second – adolescent education. From this field, a concept developed that, with the passage of time, came in common use in the management arena – "System Thinking." Due to the anticipated enormous popularity of this concept, it would be appropriate to note how Forrester himself perceived it. Forrester considered System Thinking to be of secondary importance to system's dynamics (Richmond, 1994, p. 3).

In 1975, predating the substantial developments in computerized systems, a French biologist called Joel de Rosnay published a book entitled *The Macroscope – A New World Scientific System*. De Rosnay defined the objective of the book as "*a new methodology that makes possible the collection and organization of accumulated knowledge in order to increase the efficiency of our actions.*" He described a new methodology, which he called a "Systemic Approach," which relies on cybernetics and systems theory (see also Heylighen, 1998, under the title 'Systems Approach'). This methodology investigates the workings of systems, from the ecological supersystem (the Eco System, see diagram no. 1) down to a human cell, and underscores their similarities, integration and interdependence. Thus, for example, there are cooperation and interdependence between two subsystems of the Eco System, the atmosphere and the biosphere, which were already mentioned in the previous chapter: The oxygen comes from the atmosphere feeds human cells, the smallest subsystem in the biosphere. The hemoglobin in human blood carries the oxygen to cells, and returns carbon dioxide to the lungs. The carbon dioxide is exhaled from the body to the other system, the atmosphere, and through a process of photosynthesis, is reconverted into oxygen (de Rosnay, 1979, chs. 1 and 2).

There is also an Israeli contribution to the development of complex systems theory. Professor Aharon Katzir was a renowned scientist in the fields of chemistry and brain research, who engaged, inter alia, in the application of principles of complex systems theory in natural sciences. He was far ahead of many of his generations in this field, and, already back in 1972, had convened a group of experts at the prestigious Massachusetts Institute of Technology in the United States to present his research on the subject of applying principles of "thermodynamic networks" in order to advance our understanding of complex systems in nature. (On May 30, 1972, upon returning from the conference, Katzir was murdered during the terrorist attack at Ben-Gurion International Airport, and his academic research was cut short). In 2001, Dr. Jesaiah Ben-Aharon wrote an article entitled "Introduction to the Development of Consciousness in History." In this article, Ben Aharon describes Katzir's brain research as follows:

> "*How and where does the transition occur in the brain from the mechanical to the biological, from the biological to the cognitive and psychological, and from the cognitive to the spiritually creative? In order for these transitions to be applicable, it is essential that the brain be organized in a way enabling* ***"phase transitions*** *" and "* ***high-***

> ***quality leaps**"* [emphases added – ER/PY] *from state to state, from one level of organization and activity to another ... these transitions occur ... in situations far from equilibrium, open to the environment, which actively exchange material and energy and develop, through self-organization, to more complex levels of order."*
>
> (Ben-Aharon, 2001)

Katzir's popular book, *In the Crucible of the Scientific Revolution*, addresses the link between science and society and presents many aspects of complex systems theory as we understand it today (Katzir, 1972). In his book, Katzir writes as follows:

> "*The common meaning of causality, which presents the links between phenomena as a one-dimensional sequence leading from cause to consequence in an infinite chain of linear interactions, is erroneous. A deeper perception assumes a general reciprocal link between natural phenomena, and leads to a concept of comprehensive interaction between all parts, which constitute the integral proof of the global system.*"
>
> (Katzir, 1972, p. 54)

In 1974, Paul Watzlawick, John Weakland and Richard Fisch, attempted to "break" the linear approach in behavioral sciences in their book, *Change – Principles of Problem Formation and Problem Resolution* According to their approach to problem resolution, they differentiated between two types of problems – "*problems of the first order*" and "*problems of the second order*" (*Watzlawick et al*, 1974):

- *"Problems of the first order*" – there is a direct (linear) link between problems and their solution. This is the phenomenon of 'Negative Feedback' i.e., in the problem's opposite direction. The system restores its internal equilibrium while it does not change. For example, in the winter, we wear warm clothing and heat the house, while in summer, we wear light clothing and cool the house.
- *"Problems of the second order*" – a direct, linear link is not apparent between the problem and the correct solution. In such instances, the structure of the system itself must undergo change. A second-order change is imposed on the system from outside. Here, a change takes place in the fundamental assumptions governing the entire system. For example, a car will go faster by pressing on the gas pedal, but also with the right combination of gears; educational reform will be achieved not only through increasing budgets, adding classroom hours, and the like, but also through a combined course of action to *truly* raise (and not merely a declaration of intentions) the standards of education in Israel, etc.

Another Israeli who contributed considerably to 'Complex Systems Theory' is Professor David Harel – a mathematician and computer expert from Weizmann Institute, to whom we will again refer later in this book. Harel was awarded an Israel prize, inter alia, for his development of the field of visualization in complex systems (Israel Prizes, 2005). This visualization enables the development of decision-support computer programs today, which can help managers/programmers greatly in contending with future planning and with problem resolution (this issue will also be addressed later in this book).

A secondary branch of complex systems theory is the concept of 'System Thinking' (also known as 'Systems Thinking' or 'System*ic* Thinking'), which was already referred to in this book in relation to Forrester. The catalyst for its development was the popular book by Peter Senge, which was published in 1994 – *The Fifth Discipline* – a practical book that also contains a number of conceptual aspects. Senge adopted some of Forrester's system dynamics theory (Senge, 1990). Senge describes five disciplines, with the fifth, the core of the book, being the concept of "System Thinking" (Senge, 1990, p. 89). This concept had only been a marginal topic in Forrester's theory.

Dr. Barry G. Richmond wrote an article addressing the degree of importance that Forrester had attributed to the concept of 'System Thinking':

"I will define as 'System Thinking' that is quite unique, quite powerful, and quite broadly useful as a way of thinking and learning…
... The purpose was to think more productively about how to improve the way a system worked."

(Richmond, 1994, pp. 3, 4).

Senge defined System Thinking as nonlinear thinking, which engages in seeing the whole. He explained that 'System Thinking' is necessary nowadays more than in the past, *"because we are becoming overwhelmed by complexity"* (Senge, 1994, p. 54):

> *All around us are examples of "systemic breakdowns"—problems such as global warming, ozone depletion, the international drug trade, and the U.S. trade and budget deficits — problems that have no simple local cause. Similarly, organizations breakdown, despite individual brilliance and innovative products, because they are unable to pull their diverse functions and talents into a productive whole.*
>
> (Senge, 1994, p. 54)

The concept 'System Thinking' gained wide circulation through researchers, organizations and authors, some of whom wrote "instant prescriptions" for successful organizations.[2]

Thus, a minor, supplementary topic in Forrester's *Systems Dynamics* became a central focus of social scientists in this field, thanks to the popularity that Senge attracted. The experts in this field did not adhere to the levels of precision that Forrester had intended, similarly to what he had recognized in servo electromechanical mechanisms. Most of them lacked the aspect, and mainly the essential application of a dynamic system that includes feedback, control, "payment for failures" and reward for measured achievements. Furthermore, they made almost no use of the tools and potential of complex systems theory and of network's theory (see later in this book).

Since the concept 'System Thinking' is widely studied in Israel, the following are illustrations of a variety of salient points made by Israeli authors:

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[2] One such basic book is, for example: O'Connor and McDermott (1997).

According to Lanir (1988, pp. 4-5), 'System Thinking' is always context-dependent; i.e., a process of defining concepts in a particular *context.* Frank (2001) asserts that System Thinking encompasses the ability to discern reciprocal effects of the various components on the entire system. This is lateral and not in-depth thinking, in contrast to the trend of pinpointed, deep specialization traditionally being conducted within the academic community. Yehezkeally (2004a) defined it as "*An approach that copes with problems from diverse fields in a manner that is either inter-dimensional and multidimensional or interdisciplinary and multidisciplinary or a combination of the two.*" Klein (2004) views it as "*perception of the whole… being larger than all of its components*." Lanir (2004), Naveh (2001) and Frank (2001) all support Senge's assertion (1998) that it is "*nonlinear thinking*" and Naveh (1998, pp. 181-183) calls the reverse approach to "linearism" – "*simultaneity*."[3]

Lanir emphasizes that 'System Thinking' facilitates rethinking of problems from various fields and encourages thinking without redefining how the problem should be analyzed. This process requires a considerable degree of dynamic and associative thinking of the part of the thinker (Lanir, 1988, p. 2). It requires the adoption of multidimensional coping techniques that facilitate contending with complex problems. Therefore, a process of 'System Thinking' will always is also a process of knowledge development that evolves from

[3] **'Simultaneity'** is defined in the dictionary, inter alia, as "concurrent; existing or occurring at the same time, simultaneously" (*Pines et Pines*, 2000-2001, p. 470).

the convergence of context and the creation of new concepts (Lanir, 2004).

Topics like multidimensional techniques and knowledge development have not yet actually matured. Therefore, 'System Thinking' is perhaps useful as an educational factor, but in fact, has not been proven as a substantive applications tool. Some applications have been launched in Israel for 'System Thinking', such as: the application produced by Praxis, headed by Dr. Zvi Lanir;[4] the Reut Institute, which was founded in order to provide decision-support to policy-makers[5] and makes use of Lanir's methodology; or the Israel Defense Forces Operational Theory Research Institute founded by Brigadier General Dr. Shimon Naveh. Naveh identified a theoretical gap in the military doctrine between the tactical level and the strategic level, and developed a " theory"[6] (Naveh, 2001) [it should be noted that the term "System Thinking" does not appear in Naveh's book, " *Art"* (Naveh, 2001); he uses the term "Systemic Logic"].

Various aspects of 'System Thinking' were documented in the public administration arena, when a number of well-known professionals authored documentaries and instruction manuals, primarily within the spheres of their personal experience. These books referred to interoffice coordination and proposed interorganizational solutions. Among these, we mention, for example: Dr. Yehuda Ben-Meir, who

4 See the Praxis website: http://www.praxis.co.il.

5 See the Reut website: http://www.reut-institute.org.

6 Naveh (1998) uses the word "systemic" both in the sense of "system" and in the sense of "operation," as in military operations. The use of the term "systemic logic" refers to the first meaning: "system."

focused on decision-making and coordination (or the lack thereof) among the various government ministries (Ben-Meir, 1987); Professor Yehezkel Dror, who, at the end of the 1960s, focused on what was then called “Administrative Coordination”) (Dror, 1966); and Yehezkeally (1991) and Yehezkeally et Shalev (1993), who scrutinized the administrative coordination between the Israel Police and organizations in its organizational environment, and called this “Systemic Work.” All these materials provided a local solution for specific problems, but, usually were not based on an accepted, broad theoretical foundation, and certainly were not based on complex systems theory.

To complete our review, we point out that the fact that the separate development of disciplines, such as systems dynamics and cybernetics, caused a lack of uniformity in definitions between the discipline's *inter se* and between them and other disciplines, due to academic and practical considerations. Each discipline 'pulls' its theory in different directions and ascribed various definitions to concepts such as: stability, feedback, information and more (Joslyn, 2002).

In recent years, we have been seeing an attempt to integrate the theories of system dynamics and cybernetics. The integration of the intellectual and application tools of both theories will enable the creation of models and simulations that might help us to understand management better processes in organizations, as well as social processes (Schwaninger *et al*, 2004).

At the beginning of the 2000s, applications of 'Complex Systems Theory' began to be introduced into practical spheres of our lives. For example, the organizational consultants, Avi Altman, Miki Rosenstein and Kalmi Pressburger have applied complex systems theory in executive training programs. They describe how, using simple concepts of complex systems theory. A theoretic framework may be incorporated into the senior training processes in organizations (Altman *et al*, 2004).

In recent years, the academic arena constitutes the spearhead in the development of advanced, practical tools and thought processes, which integrate the study of complex systems theory with chaos theory, and, recently, also networks theory (which we shall discuss in this book's key chapters). We will merely list a few fields at the forefront of this development: "Practical Geometry" as a unique visual expression of system behavior; creative software tools relying on parallel computerization capabilities through which nearly any thought can be transformed into a computerized tool; and a relatively new field called "Free Agents," which are mini softwares capable of learning and adaptation. These are in addition to three categories of software: "Cellular Automata," "Neural Networks" and "Fuzzy Logic." These programs encompass a field being applied only partially in business and social systems.

The inability to cope with problems using the tools that complex systems theory began to provide, led to the collapse of such mega organizations as AT&T, which failed to identify, in time, that analog transmission have been replaced by digital.

The switch from analog to digital transmission in time. A completely different example is the Soviet Empire, which collapsed because it had based itself on long-term planning in a dynamic, rapidly changing reality and on centralized control methodologies. These tools could not provide a suitable solution, since they were not dynamic and were incapable of adaptation and spontaneity. Companies like Enron – the energy giant in the United States, with the help of Andersen, one of the worlds largest consulting and accounting groups – had tried, during the 1990s, to cover up a failure to adapt to the changing environmental conditions using accounting tricks, which resulted in the dismissal, arrest and prosecution of its executives.

The collapse of these corporate giants demonstrated the need for the adoption of other approaches, relying on programming tools and hardware. They will develop and maintain flexible, creative systems that rapidly adapt to changing market conditions, and to the accelerating speed environment and ecology change; it demonstrated the need for managers, which understand the new political, social, economic and business environment that has evolved. The last decade is replete with examples: The astounding growth of Singapore; The skyrocketing of such companies as: Visa, E-Bay, Google, Amazon and more – giants who sprouted and captured center stage in the global economy at speeds never before encountered.

* * *

This chapter presented the origins of complex systems theory, which are cybernetics theory and general systems theory. The chapter reviewed the evolution of the theory and its various historical applications. Special emphasis was placed on the fact that the theory developed and was applied concurrently in vastly diverse content worlds, such as: biology, cybernetics, engineering, mathematics, agriculture and, of course, in management theory, which is the focus of our discussion in this book. We elaborated on Forrester's "systems dynamics" from which the concept of "System Thinking" evolved.

During the last two decades of the 20^{th} century, which still coped with the repercussions of the world wars, particularly World War II, life on the planet changed dramatically. Competition gave birth to new technologies in all the familiar scientific disciplines, while certain technologies allowed the emergence of the information revolution – the end of the industrial age and the beginning of the information age. Organizations and companies began switching from manufacturing to marketing, and later, also to services; from a provincial environment to the global village; and from operations struggling with limited information to freely accessible information systems. This evolution changed the character of our lives again and led to the end of three hundred years of linear thinking in the western world. However, this change occurred before most of the functionaries in the political, social and economic systems were ready to contend with this way of thinking, which vastly differed from the mindset they had grown up with: freedom, access to information, limited hierarchies and more.

We discussed here the enormous potential of the amassed knowledge in the academic world, in the direct, and mainly indirect, context of complex systems. Only in recent years have substantive attempts been made to convert this knowledge into practical applications for running business and public companies.

Chapter Three

Chaos, Order and In Between

Chaos

It is difficult to understand the 'Complex Systems Theory' without at least a rudimentary understanding of chaos theory. Therefore, this chapter is presented at the beginning of the book; even though some of the origins of 'Complex Systems Theory' had been formulated before chaos theory had evolved into any real discipline.

An extreme image of chaos is described in the book of *Genesis*. According to the biblical description, the Lord transformed a state of chaos and disorder into a state of order by creating an entire world in seven days. Is man also capable of functioning from within a state of chaos and achieving order;[1] i.e., arriving at an optimal solution, or is he merely survives in a state of order?

Chaos is a term taken from the Greek, and its first meaning was the “primordial abyss.” The dictionary definition of the Hebrew word, in its biblical context, is “disorder,” while, semantically expanded, it is synonymous with “havoc” – the absence of a planned form, a state of disorder and randomness. The term “chaos” was adopted by a new

[1] The terms **'order'** and **'chaos'** are not necessarily opposites, since certains states of order may be found in chaos.

scientific field that strives to identify ordered patterns in nonlinear phenomena (see elaboration: Gleick, 1991, p. 4).
Apparently, the first philosopher who used the term 'Chaos', was Rene Descartes (no date, ch. 5). Nonetheless, the awareness of this phenomenon arose only in the 1970s, when physicists discerned erratic phenomena in various fields. Classic science did not have an answer for such phenomena as: the oscillations of the heart and brain; the turbulence of waterfalls or whirlpools at sea, with their instantaneous unpredictable changes; fluctuations in the rates of growth and waning of human and other populations; fluctuation in product and stock prices lacking any logical explanation, and more.

James Gleick described 'Chaos' in his book, *Chaos – Making a New Science*:

> *"Chaos breaks across the lines that separate scientific disciplines. Because it is a science of the global nature of systems, it has brought together thinkers from fields that had been widely separated ... chaos is a science of process and not of state – of emergence and not of experience.*"
>
> (Gleick, 1991, p. 5)

Chaos is a type of system behavior. Such behavior can be random and is determined by order or by a concealed pattern. Chaos can certainly be found in dynamic systems, when the parameters controlling it exceed a particular critical level.

In an organization[2], 'Chaos' and 'Order' may also be defined as two fundamental states for every process. The question is not merely what happens in both states, but also what happens *between them*.

'Chaos Theory' began to emerge during the 1920s. Jules Henri Poincaré grasped the concept of chaos well in his book, *Science and Method*, which discussed dynamic systems. He wrote as follows:

> "*A very small change, which escapes us, causes an outcome so dramatic that we cannot help but see it, and then we say that this outcome is due to chance … it may happen that slight changes in the initial conditions produce very dramatic changes in the final phenomena; a slight error in the former would make an enormous error in the latter. Prediction becomes impossible…*"
>
> (Gleick, 1991, p. 22)

Edward Lorenz was one of Poincaré's successors and researched weather at the Massachusetts Institute of Technology (MIT). In 1960, Lorenz discovered that, although he had used the same database for the weather forecast. He obtained two different results (see diagram no. 3):

Lorenz saw a sophisticated geometric structure and order impersonating randomness; i.e., phenomena that theoretically are random, but, in effect, have some order. As a mathematician, Lorenz examined repetitive systems such as: epidemics, population volumes, etc., and found that this phenomenon of different results is repeated there too.

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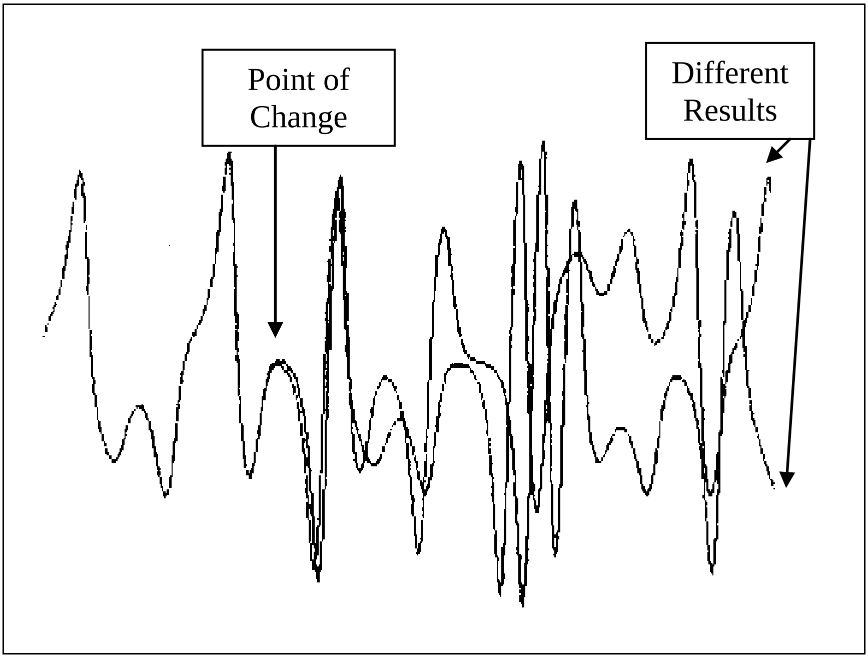
2 See footnote 1.

Diagram no. 3

Lorenz's study: a minor change in the initial conditions produces entirely different results later

(from: http://www.imho.com/grae/chaos/chaos.html)



Lorenz understood that "*there must be a link between the unwillingness of the weather to repeat itself and the inability of forecasters to predict it – a link between aperiodicity and unpredictability*" (Gleick, 1991, p. 22). Lorenz sought and found a way to generate behavior similar to a complex system and found that this system may be described by merely three equations.

The mathematical phenomenon of chaos began to attract increasing numbers of investigators, and research on the subject gained momentum. By the 1960s, investigators had developed specialized terminology and even a new form of geometry called ‘fractal geometry,’ which was considered the language that articulates the science of chaos. When a fractal geometry is used in a computerized analysis of the spectrum of possible states in a chaotic system, a unique picture for that system is obtained – a “*fractal image.*”

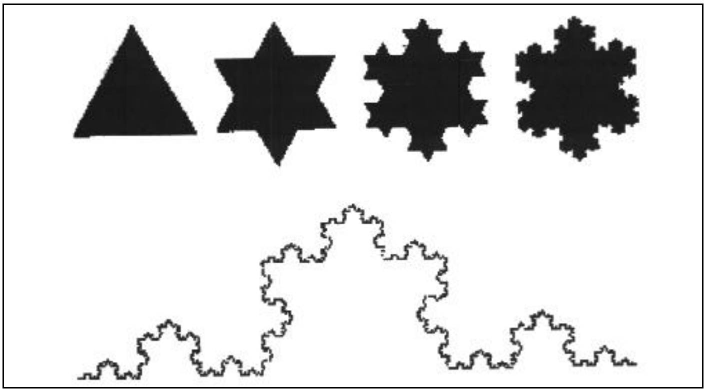
The term “fractal” was coined by Benoit Mandelbrot – a mathematician who worked in IBM and who was studying fluctuations in cotton prices during the 1960s. The origin of this term is from the Latin word “fractus,” which means “broken.” It refers to the development of a new geometry to describe irregular patterns in nature (Gleick, 1991). The computer-generated points on the chart for each of the operations described in the fractal express the holistic flow of the phenomenon being described.

Diagram no. 4 illustrates the various stages in the formation of a fractal: from a triangle to a triangle inside a triangle, and progressing to a triangle inside a triangle inside a triangle.

Diagram no. 4

Illustration of the primary structure of a fractal

(from: http://library.thinkquest.org/3120/old_htdocs.1/img-bin/koch.gif)



What are the possible uses for fractals?

Up until Mandelbrot invented fractals, descriptions of things could be visualized in three dimensions: one linear dimension, two dimensions of planes and three dimensions of volumes. The definition of fractals enabled the presentation of more dimensions and as fractions.

Although fractals are "mathematical creatures" and no physical creature in our world has real fractal properties. Physical creatures can have fractal attributes or may be approximately depicted by fractals (Shamir, 2005).

Chaotic behavior exists in nature in a variety of phenomena, such as clouds, mountains, rivers, snowflakes, etc., which may be described by fractals, and modeled with the help of fractals. Thus, for example, fractals may be used to run models of behavior of stocks on the stock market and of fluctuations in animal populations in nature, as a function of time (Shamir, 2005).

Contending with chaos

Although, *prima facie*, chaos may not be controlled, recent research studies have shown that, nevertheless, we can influence the future. The way to do it is to introduce specific "*noise*" into the system (Later, we will see that this discovery enables us to improve our planning capabilities considerably). For example, suppose, during the planning process, we have to cope with whirlwinds, which appear and behave chaotically; if we know that whirlwinds are caused by heat, then we can employ a heat-reducing technique that will minimize the formation of whirlwinds in the future.

As a rule, a system can be compartmentalized in one of four groups of behavioral patterns represented by fractals (although some sources refer to only three patterns). In complex systems terminology, these patterns are called '*attractors*'.

An attractor is defined as the set of constraints or limitations in a system (the parameters), which is used to determine how the system will function under varying environmental conditions. This is the term used to describe scenarios in which the entire system encounters a situation and is drawn from its current point to another point, due to the external influence (Zigdon et al., 2004, p. 27) and according to its internal response.

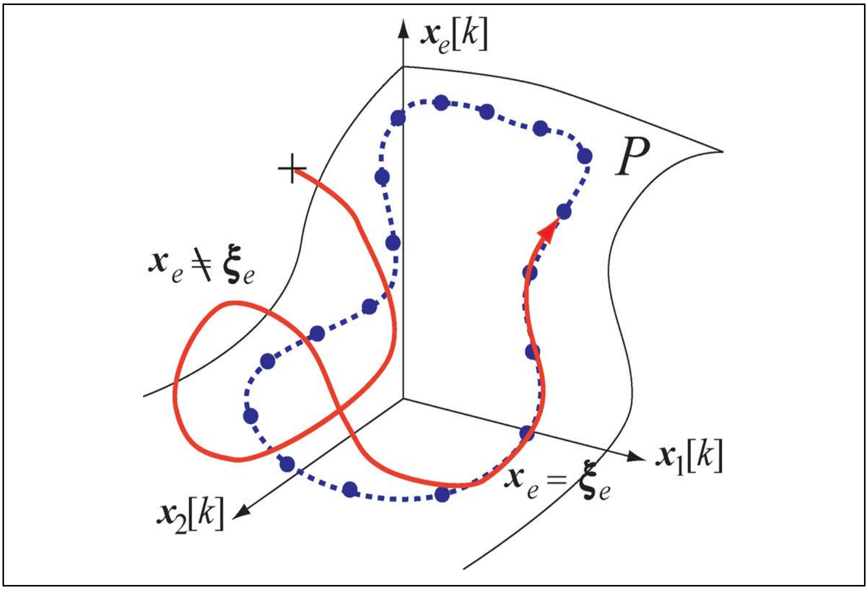
In some instances, this external influence causes “perturbation,” which affects one or more of the system parameters. A pattern of phases or states may be identified that adapt to change when receiving new values (see the example of an attractor in diagram no. 5). Each point in the vicinity of the attractor represents a state of all those parameters characterizing the system at that point in time.

Illustrating phenomena using personal examples is problematic; however, due to the complexity of this topic, we will, nonetheless, present such examples from the field of social sciences.
One example of 'perturbation' was the false information that the Russians had transmitted to the Egyptians prior to the Six-Day War at the end of April 1967. The information reported a deployment of Israeli forces, including reserves, on the Syrian-Israeli border. It was reported that Israel was planning a large-scale offensive between May 15 and May 22, 1967 (Oren, 2004, pp. 79-86). This 'perturbation' by the Russians, whose motives are unclear to this day, led to a series of interactions between the subsystems comprising the political system, the Middle East. Just like a “whirlwind” in nature’s systems, this “perturbation” caused a war, disrupted the balance of powers and changed the face of the Middle East.

Diagram no. 5:

Attractor

(from:
http://www.dynamics.mep.titech.ac.jp/japanese/theme/attractor_design/attractor.jpg)



A 'perturbation' (external and/or internal) is what causes the system to move from one attractor to another.

An example of a social attractor is a significant reduction of the deterrent capabilities of the law enforcement system in Israel, following the legislative reform of the early 1990s. The "Basic Law: Human Dignity and Liberty," coupled with other laws, and particularly the interpretations ascribed to them by the Supreme Court, prodded the law enforcement system to give excessive consideration to debtors, suspects, detainees, people under investigation and prisoners. Due to a state of anarchy associated with some of the crimes, and due to the dramatic rise in violence, we are currently seeing a shift from this attractor to a new one, with a more aggressive legal, enforcement and judicial approach.

It is the system dynamics – the shifting of the system from its current state – that determines the attractor. The new attractor changes the system's behavior, according to its *different* set of rules.The transition from one attractor to another is called a *'phase transfer'*.

An example of a 'phase transfer' from the field of social sciences is the communist regime. The communist attractor was an extremist, centralistic regime. When it was 'perturbed' by external forces, such as the dissatisfaction of various ethnic groups, coupled with the economic collapse, the framework was shattered into many nationalist subsets, and the ripples of that change have not subsided to this very day.

A different example of a phase transfer occurred in 1979, when Ted Turner announced the opening of the television channel dedicated to news, CNN, which would broadcast 24 hours a day from all over the globe. From that day on, the global population's consumption of news changed.

It is interesting to note that we also found chaos in the terminology describing the transition from attractor to attractor. This chaos is expressed by the plethora of terms describing a variety of similar phenomena, but usually stemming from different disciplines. Some sense may be made of these terms by presenting them in a common context.

In addition to the term 'phase transfer', other parallel expressions appear in professional literature, such as *'revolution'*, *'paradigm change'*, *'strategic turning point'* and '*metamorphosis':*

'***Revolution***'

We mentioned earlier the 'Constitutional Revolution' in Israel. The *Ibn-Shoshan Dictionary* (1968, vol. 2, p. 720) defines "revolution" as "*a sudden and radical reversal in a subject or particular profession.*" As examples, it mentions the mechanical loom, which introduced a revolution in the manufacture of woven fabrics, and the Einstein's theory of relativity, which caused a revolution in the science of physics.

'***Paradigm Change***'

In his book, *The Structure of Scientific Revolutions*, the philosopher and scientist, Thomas S. Kuhn, defined the term 'phase transfer' in the scientific sense as a 'paradigm change'.[3] According to Kuhn, when a scientist studies a paradigm, he acquires not only theory, but also methodologies and criteria, usually in an inseparable mix. Therefore,

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[3] Kuhn (1996, ch. 2) defined 'paradigm' as a theory that meets two criteria:

a. sufficiently *unprecedented* to attract an enduring group of adherents away from competing modes of scientific activity and
b. sufficiently *open-ended* to leave all sorts of problems for the redefined group of practitioners (and their students) to resolve, i. e., research.

when paradigms change, there are significant shifts in the criteria determining the legitimacy both of problems and of proposed solutions. Paradigm changes do cause scientists to see the world of their research-engagement differently. Insofar as their only recourse to that world is through what they see and do, we may want to say that, after a revolution, scientists are responding to a different world (Kuhn, 1996, ch. 10).

“***The Strategic Turning Point***”

Andrew Grove, the President and C.E.O. of Intel, identified an attractor and a phase transfer in a practical field. In his book, *Only the Paranoid Survive*, he calls the attractor “10x” (Grove, 1997; 1996, ch. 2).and the phase transfer 'the strategic turning point'. Grove likens the attractor to “wind,” “typhoon” and “tidal wave.” A change in any component of management of the business becomes many times greater than what the business is used to. Then, all the previous forecasts lose their relevance. The business no longer responds to the company’s actions as it used to and the management loses control (Grove, 1996, pp. 38-39).

A 'Turning Point' occurs when the organization’s old strategic picture fades away and is replaced by a new one. Both opportunities and threats are present at this juncture. From this juncture, the business can soar to new heights, or plummet and become irrelevant. Grove states that “*it is hard to tell, in retrospective, exactly where a strategic inflection point occurred*” and that, “*most of the time recognition takes place in stages.*”

(Grove, 1996, pp. pp. 33, 34):

> "*At first, there is a troubling sense that something is different. Things don't work the way they used to ... Then there is a growing dissonance between what your company thinks it is doing and what is actually happening inside the bowels of the organization ... Eventually, a new framework, a new set of understandings and a new set of actions emerges. It's as if the group that was lost finds its bearings again (this could take a year – or a decade).*"
>
> (*ibid*, pp. p. 34)

According to Grove, one of the signs that the reality is changing and a "10x change" (*ibid*, ch. 2) is taking place is "*customers drifting away from their previous buying habits*" (*ibid*, p. 65). For example, the consumer shift to buying liquid soap instead of soap bars during the 1990s did not occur overnight, but rather, was a gradual trend. Manufacturers who failed to identify this change on time suddenly became irrelevant.

"*Metamorphosis*"

An alternate term for "phase transfer" – *"Metamorphosis"*, was used by Professor Yehezkel Dror (2005). The dictionary defines for "*metamorphosis*" is a transformation or a "change from one form to another" (*Pines et Pines,* 2000-2001, p. 366). As examples, Dror cites: the transition in South Africa from apartheid to a real democracy between 1990 and 1994; the collapse of the Ottoman Empire and the establishment of modern Turkey by Kemal Atatürk on October 29, 1923; the unification of Germany into a nation-state by Otto von

Bismarck, the chancellor of Prussia in 1871; the collapse of the Roman Empire, etc.

These examples also support Grove's argument, whereby the phase transfer is a process that might be extended. An example of this is the beginning of the decline of the Roman Empire in the middle of the 4th century, while the collapse occurred only in the year 410, after the Visigoth, Alaric, conquered Rome, and it ceased to be a real power.

When we identify a number of principal types of attractors, and the determinant parameter or parameters may be steered, one of the following types of behavior will occur:

1. *Convergence of the determinant parameter to a single point or value* – this is the simplest way for the system to reach equilibrium. For example: a pendulum stops at the end of its movement at the lowest point in its oscillation; a pupil who is expelled from a classroom due to poor behavior will usually be re-admitted later, etc. This group represents, most of the time, linear situations.
2. *Simple or complex cyclical movement* – the system passes through a series of results in a cyclical manner, similarly to movement in a circle. In this case, there are two dimensions offering a number of possible ways to achieve equilibrium. For example: the sleep cycle of man; the routine human schedule, comprised of eating, work, travel, recreation, etc. This group also usually represents linear situations.

3. *Random cyclical motion* – the system does not repeat itself, but the possible results are known. The movement is depicted as a three-dimensional spiral (length, width and height). The ability to forecast and maneuver in it requires unconventional means for steering it. This occurs in businesses, in multinational organizations, in government systems, in interdivisional designated task forces, in the behavior of military units on the battlefield, and more. This group represents nonlinear situations.
4. *Chaotic movement – divergence* and infinite possibilities of movement, including those that are unpredictable. For example: the location of the eye of a whirlpool. In such instance, more than three dimensions are required, and fractal geometric development becomes useful. Only by applying the methodology described in the next paragraph, one can epitomize the many 'degrees of freedom' in it. The attractors in this group have been dubbed "*strange attractors*," and the environment in which they operate is, of course, nonlinear.

We can find the 'strange attractor', which, as we said, represents a chaotic system, in "phase space" – "*one of the most powerful inventions of modern science*" (Gleick, 1991, p. 134). Phase space is a sort of multidimensional topographical map of all possible behaviors of a system. Phase space converts numbers into pictures, while abstracting every scrap of essential information (from a mechanical or liquid set of moving parts, or from a social system) and plots out a flexible roadmap to all of its possibilities. The phase space of a system changes according to the system's motion on the subsets comprising it, in a manner regulated by the attractor.

A field that can lead to the identification of future trends, or to attempts to target them, uses the new geometry – fractal geometry – which was already mentioned in this chapter. This geometry is easier to understand than mathematical tools, with the fractal expressing the parameter's motion through all types of behavior. This information enables us, inter alia, to identify those points or states in which bifurcation occurs. In other words, it allows us to identify the possibility of the existence of a number of results, including those constituting a phase transition.

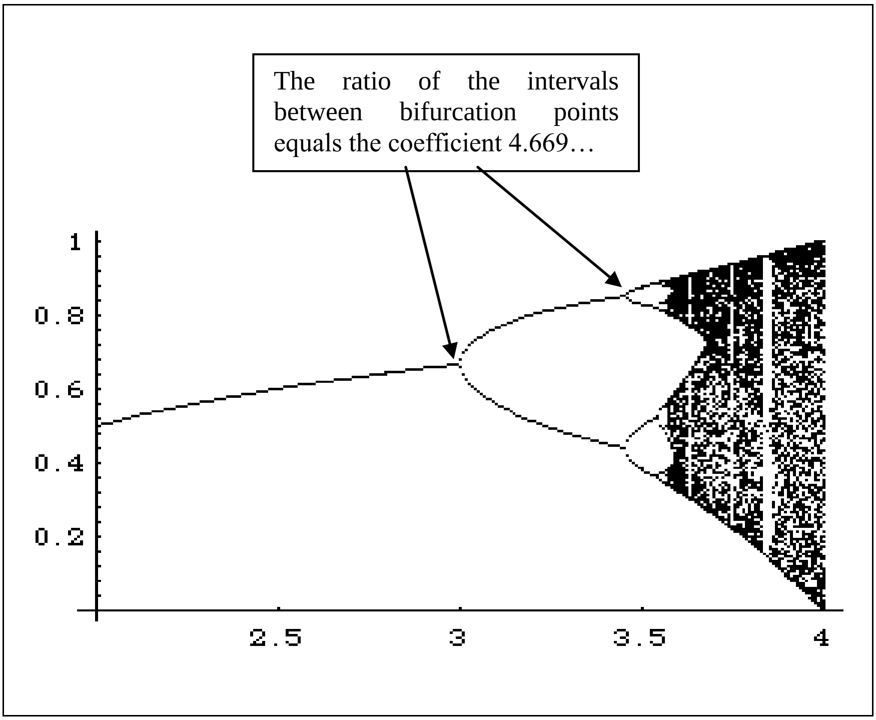
In the 1970s, the mathematician, Feigenbaum, discovered a fixed coefficient – "Feigenbaum's Constant" (constant rate of 4.669), which can be identified in the ratio between the values being measured in different processes or systems. For example: when comparing the ratio between the time that it takes for the range of possibilities to pass from two results to four, or from four results to eight, on the way to many possible results.

The scaling factor of the accelerating "pace" of the bifurcations (i.e., being a universal constant) enable the identification of trends of growth or shrinking processes in a variety of systems. The latent potential of a universal constant has not yet been realized (Gleick, 1991, p. 177). Diagram no. Six presents a well-known example of Feigenbaum's Constant in bifurcation. When we look at it, we see that it occurs at an increasingly fast pace and is measurable according to "Feigenbaum's Constant." The environment describing the range of possibilities is named after its inventor – "Feigenbaum's Delta".

Diagram no. 6

Example of Feigenbaum's Constant in bifurcation

(from: http://alumni.imsa.edu/~stendahl/chaos/chaos.html)



We encounter numerous obstacles when contending with chaos. The French astronomer, Michel Hénon, is a peer of Lorenz. Using the first computer that he could obtain, he tried to cope with an unsolved problem in dynamics: the calculation of the movement of each of the star clusters whose densities and joint movement were too complicated to compute. Hénon used a method for identifying points that star crosses in a visual space he created. The sequence of spaces on a time axis enabled a concentration of “trajectories” of star movements. Although the trajectories never repeat themselves exactly, nevertheless, it is possible to predict their next point of encounter (Gleick, 1991, p. 50). Years later, Hénon’s many successors identified that points began to appear randomly. That is to say, they observed chaotic processes in the movement of star clusters – a phenomenon that Hénon had not taken into account.

We single out this event in order to indicate the difficulty in identifying processes, and the risk when handling issues relating to governmental, business and social organizations. Forrester also had tried to identify social and global trends based on his successes with dynamic systems, which were his specialty, but without much success.

To summarize this section, we reiterate that four behavioral paths of attractor systems have been defined. The two relatively simple groups (point and cycle attractors) are found in space that appears linear, while the two groups representing more complex states are definitely found in nonlinear space.

Chaos and the problem of prediction

Chaos' academic research is trying to understand chaotic phenomena using tools like attractors, fractals, bifurcation and the like, and using a wide variety of ideas stemming from diverse fields. This research can provide a solution for characterizing complex systems through the building of models. On the other hand, the issue of prediction is still in its infancy (Shachar et Arzi, 2005, p. 9). It turns out that, although identifying future development options poses an enormous challenge – due to what is called "spontaneous eruption" – in many instances it is not identified at all. Under ordinary conditions, the prediction success rate is relatively high, but the prediction is not trivial. A classic example that we already discussed at length is the considerable work being exerted in order to predict the weather for mere few days ahead. Enormous efforts are also being exerted in predicting earthquakes, but without any significant success.

In July 2005, an interview was publicized with Lee Raymond, the president of the world's largest Gas Company, Exxon Mobile. During the interview entitled "Forecasts of the Oil Market? Completely Random," Raymond stated that Exxon Mobile had not succeeded in the task of forecasting, notwithstanding its excellent database and its major investments in models:

> "*For years we had an in-house research department whose job it was to try to forecast the behavior of the energy market. Indeed, who has better information about supply and demand in the market than Exxon? We thought it would be worthwhile to invest a few million dollars a year in retaining the services of experts, who would analyze the raw data that we furnish them and provide us with a reasonable forecast for oil prices. Such a forecast would constitute a foundation for our work plans, and could improve our business performance.*

> *In fact, we would have been better off had we paid this department three times what we paid <u>not</u> to provide us with forecasts. I must admit that I have no complaints against the employees of the research department ... I can voice a complaint only against ourselves, the senior management. We imposed an impossible task on them and therefore, <u>we received forecasts whose accuracy had been completely random</u>. Our problem was that we quickly turned the forecast into a working assumption and from it to a concept ... consequently, during the last two years, we made two mistakes in our assessments* [emphases added – ER/PY].
>
> (Zur, 2005)

If this is the case, a question arises: in the absence of any valuable forecast, how will complex systems be able to prepare for the future?

An attempt to overcome this inability to forecast the future was made by Steven Benge in his book, *El Alamein*. Benge describes the German tactical doctrine during World War II. He argues that the German army recognized the fact that the war was being waged in absolute havoc and uncontrollable chaos:

> "*Nonetheless, a control and command system must exist, even in the midst of chaos. Therefore, the German army adopted the "mission command" tactic, which was developed according to principles prescribed by the German general staff during the second half of the 19th century ... the "mission command" tactic is based on the assumption that officers must understand the mission that they are being ordered to execute, but must be given the latitude to independently decide the optimal way to execute it. "The mission"*

> *contained two elements: mission and target. During the pre-combat briefing, both were presented in simple terms by the commanding officer, without delving into particulars. Once the subordinate officers understood the objective of the immediate task they were ordered to perform, they were given the freedom to take decisions based on the actual situation on the battlefield, but always in line with their commander's intentions. Thanks to this tactic, the officers succeeded in adapting themselves to the changing circumstances in the chaos of the battlefield, and more importantly, they succeeded in exploiting unforeseen opportunities. This tactic requires initiative ... a lack of initiative is considered a crime. In order to ensure that this tactical doctrine would be well internalized, and in order to carry out joint exercises by officers in all military branches, officer training programs focused on-field exercises. Thus, the officers acquired skills of rapid response, cooperation with their fellow officers and efficient improvisation during real crises.*"
>
> (Bungay, 2005, p 47)

This example is very helpful to us, since it provides the right foundations for coping with a chaotic world. Since forecasting is worthless, chaos must be contended with in a manner allowing rapid redeployment in response to circumstances, which are also changing rapidly.

In 2002, T. Irene Sanders published an article in the *Washington Post,* "To Fight Terror, we Can't Think Straight." Sanders wrote:

> "*The challenge before us is to move from an emphasis on simple cause-and-effect relationships to a focus on more intuitive, associative forms of pattern recognition ... the science of complexity emphasizes*

the context in which a particular event takes place, and provides a broad framework for understanding what was missed and why."

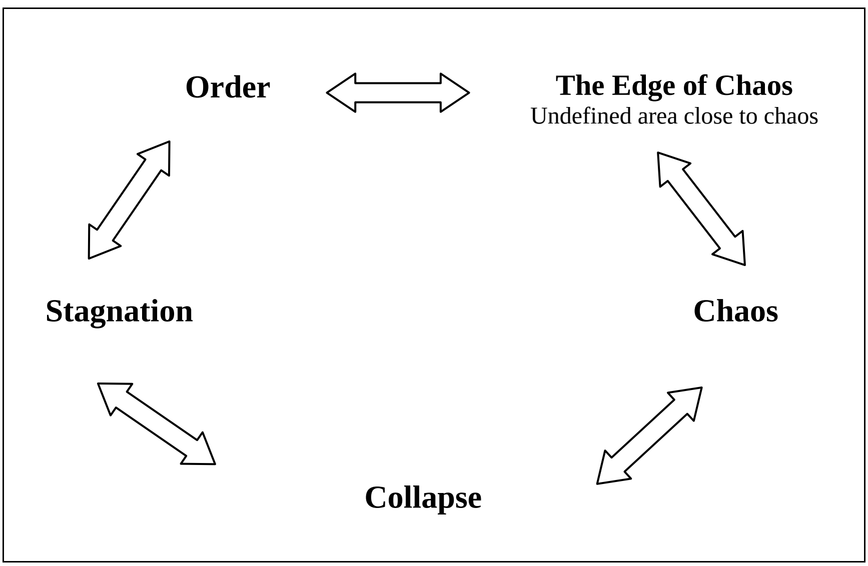
(Sanders, 2002)

Possible states of a system – between chaos and order

The series of possibilities in which a complex system can find itself (its phase space) is within the spectrum ranging from chaos to order.[4] The spectrum (see diagram no. 7) is qualitative and not quantitative, and characterizes polar states, from complete paralysis (Stagnation) to the opposite extreme, which is havoc (chaos). Note that both – chaos and stagnation – may lead to collapse.

Diagram no. 7:

Complex system - spectrum of possible states



4 This, even though "chaos" is not the opposite of "order," since "chaos" may be defined as "a different type of order."

In order to obtain an in-depth understanding of the possible states shown in the diagram no. 7, we will describe the characteristic states along the spectrum:

- ***State of Paralysis*** – no information flow; the system does not function. For example, a bureaucratic organization with too many hierarchies.

  A lack of coordination among organizations operating in the same 'environment task' and jointly constitute a complex system in itself, can lead, under certain circumstances, to paralysis. This occurs when components of the joint system fail to operate according to its objectives, and when these objectives are different from the targets of the organizations they represent. For example: the various government ministries, national security bodies, the OPEC, the NATO alliance, etc. One example of a state of paralysis is the work of civil-service committees in Israel. Paralysis persisted for years when port's workers prevented reforms; when the banks prevented reforms in the capital market; when, due to various special-interest groups, Israel has been unable to enact a modern constitution, etc.

- ***State of order*** – the system, which is in a state of imbalance, (chaos) stabilizes. For example, when an erratic heartbeat is restored to a steady beat after a pacemaker is implanted. Minor perturbations in relations between participants will not have an impact on a state of order, and the system will "adjust itself" in order to revert to its previous orderly state. We already mentioned the example of the pendulum that was jolted and returned to its original point after a number of oscillations. This is not the case when the jolts are substantial. The system will not necessarily restabilize back to its original state. It will apparently proceed to another attractor and stabilize in another position in its phase space.

Factors that propel a system towards order are: restricting the number of participants in a decision-making process; reducing the number and frequency of interconnections in a system; the screening and regulating of input; and/or adding many more rules that limit the possibilities at the level of each free agent.

- ***State of chaos*** – the system moves radically and uncontrollably from state to state. In such instance, it is advisable to make changes in the vertices and links to decelerate processes (in the direction of order). For example: in a family business, like a shop or bakery, a sudden exit by one or more family members is a chaotic state; however, order may be restored by recruiting and training new employees. In this example, the process is a short-range one, but in other instances, it can be a protracted process, like, for example, when Enron collapsed in the United States or when the communist empire crumbled.

  Factors that propel the system towards chaos: excessive decentralization by encouraging managerial autonomy in many subsystems; i.e., allowing too much leeway for decision-making in order to increase interactions among the organization’s agents; excessive encouragement of conflicts, initiatives and innovation;

encouraging the many agents in the organization to automatically regulate the impact of the necessary decision-making input so that they can take decisions faster; increasing the number of interconnections inside the organization. In an organization with a vast network of interconnections, information is relayed relatively easily among employees, however, the faster the information flows in the connections, the higher the probability that the situation will get out of control and become chaotic (sometimes too much information is a disadvantage); incessant learning, planning and periodic reiteration of assessments, while diminishing the use of forecasts and shortening their horizon to the absolute minimum.

- ***State of the edge of chaos*** – this is a field in itself, located in the spectrum between chaos and order, and not at any specific point. For a system, the edge of chaos is essential and even critical, since any small change can propel it in any direction; i.e., either towards chaotic behavior or towards 'order'. This space contains various nuances of emergent behavior, a region distancing itself from equilibrium and a state that is somewhere between paralysis (extreme order) and absolute chaos. The edge of chaos is a notional concept evoking a region in which organizational applications may develop that relate to processes motivating innovation. Imagine to yourselves that the edge of chaos is the last incline before the summit of a mountain, when all of the surrounding mountains begin to appear and offer an opportunity to choose which way to proceed from there. The edge of chaos as a concept enables theoretical discourse to develop, as well as practical tools to assist organizations under various circumstances.

Many researchers claim that a complex system will optimally cope with a dynamic and changing reality, by striving to reach the edge of chaos.

Transition between states

One phenomenon that illustrates the transition process between the system's various possible states is "*turbulence*." This phenomenon describes types of uncontrollable whirlpools, such as a river flow, according to the intensity of rainfall; heartbeats or the vascular flow also change chaotically for various reasons. An example of turbulence in a social context can be any unexpected or unintentional disruption in the workflow of an interministerial committee. An uncooperative participant disrupting any committee creates "whirlpools" and prevents the committee from converging towards resolution of the matter at hand. A change in one variable can also suffice at times to cause deterioration in the political and economic situation of a country, in the marketing position of a company, and the like.

Poincaré (to whom we referred earlier) already "*saw at the rough surface of a river that the eddies always mix with regions of smooth flow*" (Gleick, 1991, p. 123). That is to say, already back in Poincaré's time, during the 1920s, the juxtapositioning of states of disorder and states of order had been identified.

Turbulence causes a waste of energy. This phenomenon exists not only in a river, but also in chemical and other processes, including gases, liquids and solids undergoing various transitions. In other words, they undergo a phase transition or a phase transfer, and consistent with the laws of dynamics, are ubiquitous: water turns to ice or vaporizes; an isolated battle develops into a regional war; a marketing error is liable to push a company to the brink of collapse; faulty or poor political judgment may constitute a dangerous precedent for the future of the country.

In communications as well, the transition from analog to digital broadcasting opened a window of infinite opportunities for technologies and companies on the one hand; However, in a manner essentially similar to the turbulence of phase transfers, it is liable to slip into a chaotic process, on the other hand.

Using fractals to identify trends and diagnose the intensities of turbulence enables responses to be developed at optimal doses and direction. Models for adapting and organizing processes in response to change environmental conditions can serve as appropriate models for rulers, managers, the self-employed and others.

* * *

This chapter presents a description of the environment with which 'Complex Systems Theory' needs to contend. It enables us to understand what chaos is and what methodologies may help organizations to thrive in a chaotic environment. The rationale behind this chapter is that chaos is actually a new type of order, and that there are rules that propel it. A key term in this chapter is *the edge of chaos*, which relates to phasing transitions in systems. These terms will be used frequently later this book, when we address the survivability of organizations and their effective functioning in a chaotic environment.

Chapter Four
Complex Systems

Preface

In the introduction and in the historical chapter, we reviewed the work of the pioneers of cybernetics theory and general systems theory, and we presented problems that arose in business and social environments as a result of the use of linear thinking and management tools in a dynamic environment. Then we reviewed chaos theory, in order to understand the origins of those problems. All these constitute the basis on which complex systems theory was founded.

Chris Langton, one of the inventors of computerized simulations, defined complex systems as follows:

> "*A field of research in which we try to study systems that are scientifically very interesting, but, which do not yield to the usual tools of mathematical analysis. Such systems contain many autonomous participants which interact with each other, for example: human society and economy, insect colonies, cellular automata on computers, some chemical systems, and other systems in various domains, such as physics, biology and cosmology. We are trying to study the behavior of such system, and our working hypothesis is that they exhibit some common structural features, which are more relevant to such a study than the specific details of each system*".
>
> (Ben-Dov, 1995).

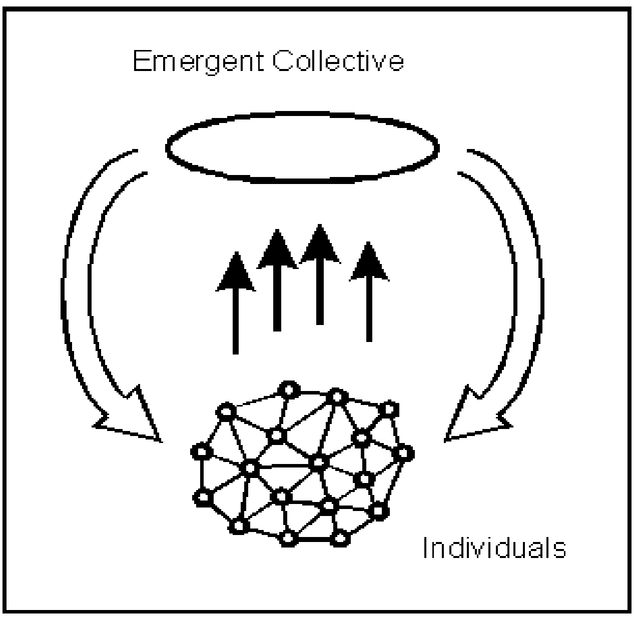
Langton describes this in diagram no. 8. According to him, many systems are constructed in the following manner:

> "… *they contain many individual agents, each one of which interacting with its neighbors. From the network of these local interactions, there are features, which emerge (up-going arrows): market forces, cultural and social trends, features of insect colonies like a well-defined ant trail, etc. These features, in their turn, define an environment which influences the rules of interaction of every single participant with its neighbors (the down-going fat arrows).*

Diagram no. 8:

Complex systems according to Chris Langton

(from: Ben-Dov, 1995, Downloaded on 19/7/11)



Traditional scientific research was concerned only with the up-going arrows – to understand a system, you try to go to a more fundamental level. But in complex systems, sometimes you have to go to the higher level of emergent collective behavior."

(Ben-Dov, 1995)

Complexity

The term "complexity" is taken from the Latin root "complexus," which means to intertwine/embrace a number of parts linked in a manner that makes it difficult to separate them.

In order to obtain complexity, the following are needed: (1) two or more distinct parts; and (2) they must be linked in a nearly inseparable manner.

Classical thinking does not allow us to understand this complexity, unless the parts are separated. However, if the parts are separated, the connection between them will be destroyed and the complexity, as we are beginning to comprehend it, will be lost, since it is found in the center, in the interconnections.

The conclusion is that an attempt to describe a complex system using the classic scientific modes of thinking will not succeed. It's components are intertwined, so that a change in one component will naturally spread through a series of interactions to the other components. These, in turn, will affect remoter components and perhaps, in the end result, even that component that began the chain reaction. In this context, Bergson wrote the following remarks:

> "*From this survival of the past, it follows that consciousness cannot go through the same state twice. The circumstances may still be the same, but they will act no longer on the same person, since they find him at a new moment of his history ... Our duration is irreversible ... Thus our personality shoots, grows and ripens without ceasing. Each of its moments is something new added to what was before. We may go further: it is not only something new, but something unforeseeable* ..."
>
> (Bergson, 1911, ch. 1)

This phenomenon makes it extremely difficult to attempt to track the global behavior of a system, in terms of the components comprising it. Typical examples of complex systems are: a cell in the human body, a society, an economy, the internet, the brain, and more. All these are comprised of an enormous quantity of components, whose interactions produce a collective behavior that cannot be reduced to the behavior of its individual components (Gershenson and Heylighen, 2003; Bar Yam, 2004).

Complexity is itself a complex concept, since we cannot make an unequivocal distinction between simple and complex systems. Many measures of complexity have been proposed for different contexts, such as computational, social, economic, biological, etc. An example of one of these measures may be found in the approach developed by Bar Yam (2004), which presents a quantitative approach to understanding the world of complex systems. This approach is based on understanding the interconnectivity between a system and how it is described. The central idea is that the complexity of a particular system may be quantitatively described according to the volume of information needed to describe it.

In Gershenson and Heylighen's article of 2003, they summarize the section addressing complexity as follows:

> "*While we do not really need an absolute measure of complexity, using such relative comparison may be useful to indicate when it becomes necessary to abandon our simple, classical assumptions and try to develop a more sophisticated model. Shifting from classical to "complex" thinking brings both gains and losses*" [when describing the characteristics of complex systems].
>
> (Gershenson and Heylighen, 2003, p. 3)

How is the complexity of the whole related to the complexity of the elements comprising it? The answer to this question is that there does not have to be a connection between the complexity of the elements and the complexity of the whole. According to this approach, it is certainly possible that systems can have complex collective behavior even though the elements comprising it are simpler (Bar-Yam, 2004).

Complex systems are open systems; i.e., there is always a transfer of material and energy between them and the environment, and they exist and develop when they are far from equilibrium. This situation is the opposite of closed systems, which strive to reach equilibrium. We tend to relate to social systems as closed systems and to handle them accordingly. However, in reality, these systems are not closed.

Therefore, the applications' tools built for them are usually not the right ones.

What differentiates complex systems from complicated systems? This question may be tackled by various angles. We chose to focus on the following four main differences between “complicated” and “complex” (Roli, 2005):

- While a complex system may only be understood by analyzing all the intertwined elements comprising it, in a complicated system, each of the elements may be understood in and of itself.
- In a complex system, the interactions between its components are of essential importance. This is the source of its logic and possible options. On the other hand, in a complicated system, there is no interaction between the components, and the complexity focuses on problems in the way the components are assembled.

  One example of this could be an air-conditioner: as long as we have not yet assembled it, the dismantled air-conditioner is a complicated system. There is no interaction between its parts, and the complexity derives from its various elements and the problems in assembling them; on the other hand, as soon as the air-conditioner is assembled, the interaction between its elements enables operations to be performed that were unavailable to us until then: raising or lowering the heat intensity, etc. If we dismantle the air-conditioner, these capabilities disappear. Therefore, an assembled air-conditioner is a complex system.

An example relating to social systems could be an interministerial committee, in which each participant has distinct characteristics that differ from those of the other participants. As long as the committee has not begun working, its participants may be considered a complicated system – everyone possessing his own unique attributes that may be distinctly explained. As soon as the committee begins to function, it may be viewed as a complex system. The interaction and the communication between the committee members become the main factor, through which the process of the committee's work and the results it achieved may be explained.

- A complex system is characterized by a holistic approach, while a complicated system is characterized by an individualized approach. For example, a military system is a complex system, while a military unit is a complicated system.
- The elements comprising a complex system are "interwoven," and, once they have become a system, their individual unique properties disappear. An example of such a complex system is a chemical compound – once we have diluted its ingredients, we obtain a new substance. It has different properties than the molecular properties at the beginning of the process, which usually are unidentifiable at the end of the process.

  On the other hand, the elements comprising a complicated system are "folded together." These elements may easily be isolated at any time, similarly to a mixture, whose constituent parts retain their own properties and may be separated out.

> It is difficult to find an example of a complicated social system, since every social system comprised of two or more people is based on the interaction between its constituent parts; i.e., is a complex system.

Characteristics of complex systems

Presence of objects and entities in the system

In every system at least a number of interacting elements must be operating. In organizations, for example, these will be people, who interact among themselves within subsystems such as departments, divisions, etc.; or other types of systems, such as airline companies, together with aircrafts, hangars and landing strips. Complex systems theory calls these elements *free agents*. In professional literature, one can find differentiations between at least three types of agents: *a single agent* – for example, one person or robot having *no* degree of freedom of choice or action; *a free agent* – for example, one person or robot that *does have* degrees of freedom of choice or action; *a set of multiagents* – for example, an organization comprised of a number of free agents [for more information about multiagent systems, see one of the well-known researchers in this field, Katia Sycara (Sycara, 1998)].

An important group of free agents is software programs: programs that "talk" among themselves, those with "learning" capabilities and recently, also software that "evolve." A real revolution has taken place in recent years thanks to the independence of these agents, from a

remote use of credit cards, control over combat aircraft, intervention in human stem cells and even intervention in optical mechanisms.
The unique identity created between the physical and human elements and the programmed elements, like the "*object-oriented*" programming methodology, is what led to the development of a variety of innovative software. Among other things, these programs enabled computerized simulations of complex systems in a way that had not previously been possible.

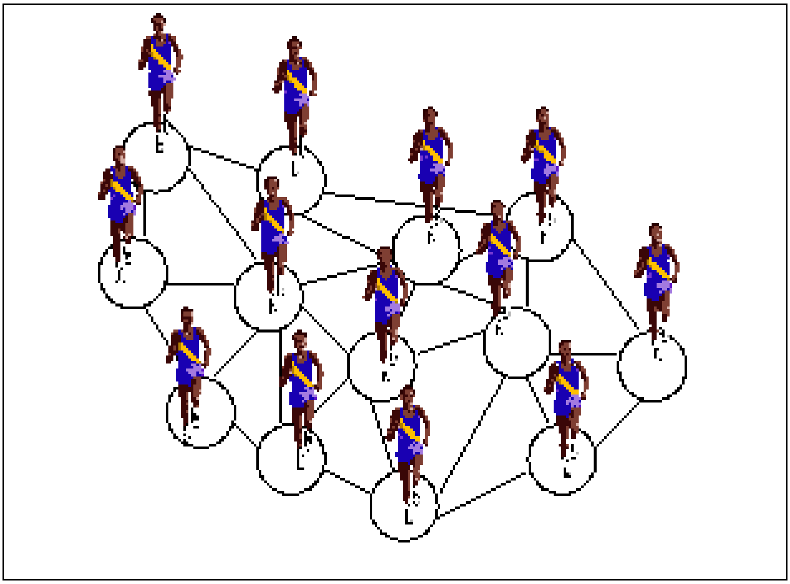
Emergence of interaction among free agents in the system

The various formal and informal interactions among the free agents affect the system's mode of functioning. Since interconnectivity constitutes the most essential key in the emergence and organization of complex systems, it also became necessary to deal with the interconnections. These interconnections are expressed in the form of a network (see the separate chapter below addressing networks theory).

In recent years, this branch has developed tremendously, the objective being to develop new management tools that enable visualization of a number of parameters, for the viewer's convenience. For the sake of illustration, diagram no. 9 depicts a number of people at stations and the interconnections between these stations alone.

Diagram no. 9

Interconnectivity through a single parameter



With a slight addition, the diagram could show a few types of interconnections, like in the following diagram. Diagram no. 10 originally appeared in a variety of colors, showing a number of parameters simultaneously: aircraft, airline companies, flight routes, number of flights by airport, etc. All these are based on the interconnectivity between those free agents, while there is great significance to the strength of the connection and other nuances, including this or that connection or lack thereof.

The subject of networks as a management tool will be discussed later in this book.

Diagram no. 10:

Interconnectivity representing multiple parameters

(From: http://www.nordregio.se/filer/bsr/fig03-14.jpg,

downloaded on 20/8/11)

Since free agents have degrees of freedom of decision and action, they have a number of possible modes of action. Therefore, the results obtained from these actions are not necessarily linear. It would be more reasonable to assume that they would *not* be linear; i.e., the dialogues between them may develop in a variety of directions.

The degrees of freedom of decision and action that free agents have derived from the interconnectivity and communications between them. In recent years, this field has developed considerably: the “quantum leap” in the field of communications, coupled with the emergence of hardware and software capabilities, has enabled nearly unlimited dissemination of information. These changes have propelled organizations through two-phase transfers simultaneously, in a manner enabling them to better cope with the new business environment.

One phase transfer is a technical one, and derives from the colossal developments in computerized capabilities in recent years.

The second is conceptual – a change in the modes of thinking and in the perception of events and phenomena: new markets for products; accelerated processes between countries and/or populations; different forms of government and the impact of the global village that influences them; personal relationships between leaders, like, for example, the special relationship that had developed in the 1980s between two leaders at that time, Anwar Sadat, the Egyptian president, and Ezer Weizman, the Israeli minister of defense, during the peace negotiations with Israel. This relationship helped to resolve many conflicts that arose during the course of the negotiations.

The system's ability to develop in different directions

The best way to explain the ability of a complex system to develop in different and unpredictable directions is by presenting illustrations from various spheres of life:

- The emergence of a new nerve cell during the reproduction and/or rejuvenation process of human or plant cells may or is liable to be affected by a genetic variation. The development could be positive or negative and in different intermediate directions.
- Although the human system of organs and muscles is comprised of a known number of muscles and bones, they enable man nearly infinite degrees of freedom of movement. This trait is what enables the human species to adapt to even extreme situations.
- The network of aviation routes can change in each of the analyzable parameters affecting it, such as: the frequency of flights of the various airline companies; take-off and landing schedule; flight duration; flight's destinations, etc.

The ability to develop in different directions depends upon the number of factors and the degrees of freedom they have. Since a system cannot develop beyond a limited number of possibilities, it is bound by "*constraints*." It was Ashby who argued that:

> "*Constraints are of high importance in cybernetics ... because, when a constraint exists, advantage can usually be taken of it ... it follows that every law of nature is a constraint.*"
>
> (Ashby, 1957, p. 130)

For example, policy teams can develop scenarios for different courses of action, if they have not been dictated in advance. Any constraint that is imposed on them will significantly detract from their ability to arrive at all possible outcomes.

The fields of communications, computerization and electronics have had the greatest impact on humanity in recent years. The dynamics in the technologies of products and services is developing beyond what was imaginable even a decade ago. A number of technologies that were developed in small companies occasionally caused a very material shift in our lives (a phase transfer), such as Mirabilis. This Israeli company created a direct communication standard on the internet (the ICQ direct messaging program) – a developmental direction that had not been foreseen even a year earlier.

The ability to evolve in nature, like in society, is extremely extensive. However, in the final analysis, it is limited. On the one hand, impeding factors may be identified, such as the widening gap between the rich and the poor; the widening gap between rich and poor countries; the gap in earnings between the various population groups and more.

On the other hand, there are factors that encourage a further "quantum leap," such as the forgiving of the poor countries' debts, which may help boost them into the groups of consumer countries. *Prima facie*, at issue are opposing forces. However, from a holistic perspective, we are again encountering a phenomenon of "Polarities of Wholeness" or "*The Unity of Opposites*", which we discussed earlier in this book. The opposites (thesis and antithesis) assemble a newer, higher essence (synthesis), which is the outcome of the mutual interactions of these "opposite" theses and which encompasses them (Shamir, 1947, pp. 224-239).

Complexity is possible by a few laws

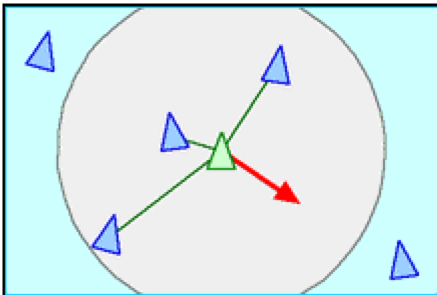
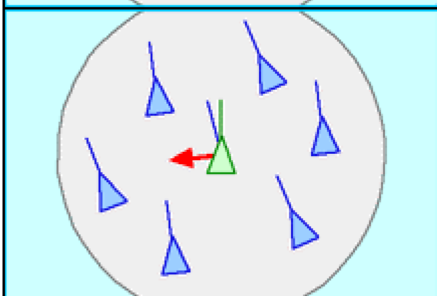
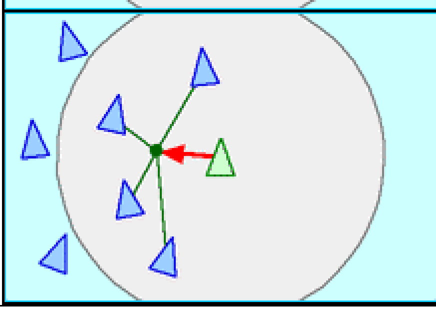
For many years ornithologists have been tracking the phenomenon of bird migration in an attempt to understand the laws' regulating migration. Birds fly for hours and days to climatic geographical regions that most had never visited before. There is no fixed leadership during their flight (!), with the leading bird being replaced from time to time. The majority of the birds take off and arrive together. Their behavior in feeding zones is orderly; i.e., flocks finish eating and vacate the area for other birds, etc.
In the 1980s, Craig Reynolds designed a computerized model called "Boids" that simulates the flocking behavior of birds. For the purposes of the algorithm, Reynolds conducted a study and found that, using *only* three rules – separation, alignment and cohesion – it was possible to create a visualization of birds in flight (see diagram no. 11). For the sake of amusement, while playing the simulation on the computer, the model enables the number of birds to be selected, as well as fluctuations in their flight speed (Reynolds, 1995).

The flock of birds navigating its way to its destination is very similar to a system comprised of free agents, which is supposed to maneuver until it achieves its objective. The three rules by which the birds succeed in their journey can be translated into a few rules by which

Diagram no. 11:

Three simple rules representing the phenomenon of bird migration

(from: http://www.red3d.com/cwr/boids, downloaded on 12/8/11)

	***Separation:*** steer to avoid crowding local flockmates
	**Alignment**: steer towards the average heading of local flockmates
	**Cohesion**: steer to move toward the average position of local flockmates

subsystems are supposed to operate in order to achieve their objectives.

This attribute of complex systems – their ability to operate and achieve their objectives by setting a limited number of rules – can provide insight to managers about the operation of systems with a minimum of high-echelon intervention. A good example, which we already presented in another context, was the "mission command" in the German army, which allowed officers freedom of action at the tactical level on the battlefield, within the framework of a limited number of pre-set principles (Bungay, 2005. P. 47).

Sometimes, even a single rule is enough for this purpose. The classic example of this is that of reducing the birthrate in China:
The global population growth rate has constituted a problem since the second half of the 20th century, according to the viewpoint of responsible authorities in western countries, considering the limited energy, the damaged ecology, poverty, disease and more. Already back in 1960, the World Population Conference held in Rome deliberated for the implications of the population growth rates in various geographical regions.

One of the assessments had been that, by 2020, there would be more than eight to ten billion citizens in China. Towards the end of the 20th century, the leadership of communist China succeeded in changing the outlook for humanity by enacting a single law – only one child per family. The immediate impact was a halt in the spiraling population growth trend. The trend of widespread poverty and the inability to sustain various public systems changed completely. By 2020, there will not be eight billion Chinese in the world. The number may halt at a mere two billion.

China's gross domestic product (GDP) per capita began to rise significantly; public systems providing services are steadily improving; the educational system, and particularly, higher education, may become a global spearhead within a decade. The connection between the one-child law and the reversal of the trend is unequivocal, and the lesson is of paramount importance.

What is common to the various examples? How – with such an enormous range of possibilities, variables, intensities, etc. – can systems deal with such a limited number of constraints? What may be deduced from this finding in relation to the management of social and organizational systems? How, during planning stages, may we take advantage of the fact that a few rules alone are navigating the entire system towards its objectives? How is it possible that only a few constraints suffice to obtain effective feedback?

These questions will be addressed later in this book.

A very critical portion of the normal routine in organizations relies on programming, and the algorithm that the programmer use is what defines/constrains the operative paths of the system in the future.

The possibility of operating a system by such a small number of directives is contrary to the mindset of generations of managers, who exalted the virtues of the punctilious and pedantic delving into minute details. It turns out that, according to the management paradigm that is relevant to complex systems, all of that is completely superfluous. The focus must be on the existence and enforcement of a few key rules that regulate the future evolution, of course, provided that these are the right rules …

The whole is greater than the sum of its parts

The attributes of complex systems may be characterized as a set. However, they not be explained according to the sum of the parts comprising them. For example, the temperature, pressure and interaction between gas molecules may be measured in relation to millions of gas molecules, but such measurement is problematic when it comes to a single gas molecule.

We have already said that quasi “concealed forces” exist in the interconnections between parts of the whole, which constitute the system’s added value. Sometimes, the addition of a marginal section to a road intersecting two other roads is enough to resolve a “bottleneck.”

Positive and negative feedback to stabilize and improve systems

One of the findings of the founders of systems theory is the identification of the feedback mechanism. The three operations characterizing the work of an organization – an action plan, an execution mechanism and a product – are not to be considered a complete circuit of operation. A circle must be closed, and therefore, there has to be a link between the end of the road and its starting point. This link, which was first indicated by the cybernetics researcher

Norbert Wiener, was called “feedback” (Katzir, 1972, p. 13). Various types of feedback constitute a very material element in any theory relating to systems.

The developers of cybernetics diagnosed the mechanism while they were characterizing mechanisms of men and machines, including the functioning of human systems, like the liver, the eye and the vascular system. Feedback act to maintain the limits of the plan at the foundation of the system, to revise the system operating rules and to drive the process to new directions.

The explanation of the term “feedback” in the scientific encyclopedia, Nationmaster Scientific Encyclopedia distinguishes between types of feedback systems, such as in relation to: electronics and/or mechanical engineering, business, nature, organizations and games.

The feedback mechanisms are the factor that directs the behavior of the system, and are *clearly a driving factor in terms of the dynamics of success and failure* (Dalcher, 2000). It was the British researcher, Darren Dalcher, who reached this conclusion. Based on the works of Ashby, Wiener and others, Dalcher developed the idea of the dynamic interactive relationship between three concepts: “feedback,” “planning” and “control.” The central idea is that feedback plays a key role in dynamic situations, particularly considering that complex systems do not repeat themselves. Such situations were already discussed here in the section on chaos theory, when we addressed a number of types of attractors. The intention is to an attractor in nonlinear situations, when the system does not repeat itself, but the possible results are known. We explained that this attractor has “*random loop movement*,” movement that is expressed in three dimensions, like a spiral. The predictions and maneuvering in it require nonlinear means to navigate the system.

According to Dalcher, the key factors leading up to disasters – such as in Bhopal (the explosion at a major chemical plant in India in 1984); the disaster at Three-Mile Island (the atomic reactor in the United States that nearly exploded in 1979); and the Chernobyl disaster (the atomic reactor leak in the Ukraine in 1986) – were information overload and mismanagement under pressure. From this, Dalcher drew conclusions about the importance of feedback in dynamic situations, which can focus attention on the critical points. By the time problems are identified as being critical, it is already too late. Critical problems tend to build up, and an enormous volume of data only serves to impede the efficient functioning of inspectors or controllers.

> "*When simple feedback loops are aggregated and interconnected within a larger system, they become a complex and dynamic feedback system. Cause-effect relationships become circular patterns that are inherently difficult to anticipate, control or rectify. The understanding that feedback under dynamic conditions is recognized too late and the recognition of the need for rapid response, aid in addressing problems early ...*"
>
> (Dalcher, 2000)

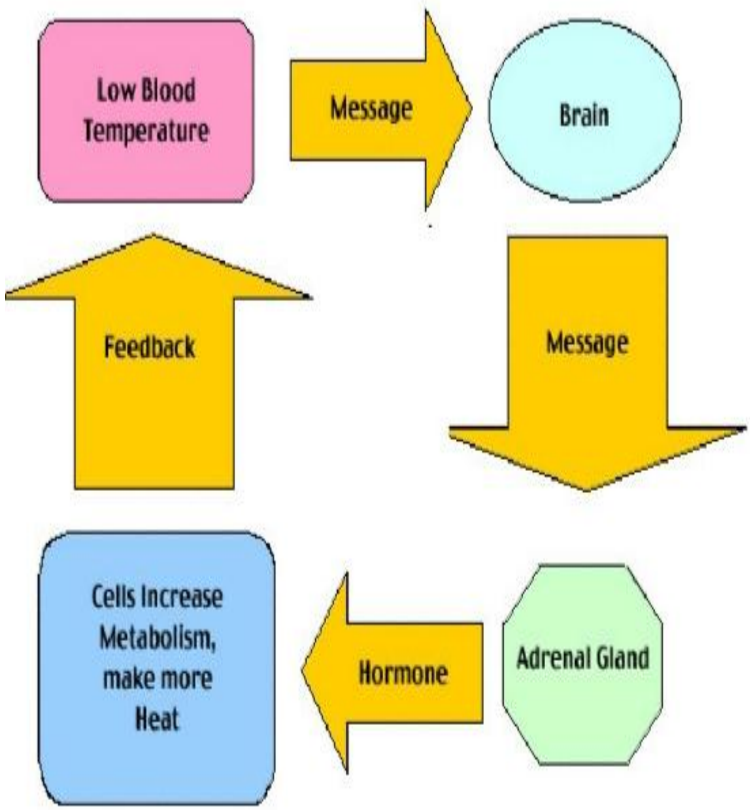
Diagram no. 12 presents a flow chart of a system whose purpose is to regulate blood temperature in humans. The feedback is conducted through the release of the appropriate hormone. The feedback is built on repetitive stages.

Diagram no. 12:

Flow chart of the system regulating human blood temperature

(from: http://www.cgee.hamline.edu/see/questions/dp_bal_feedback.htm, downloaded on 28/8/2005)

Getting Warm again: Regulating blood temperature



The common factors in the process may be regulated and directed, according to the state of the system relative to its designated objectives.

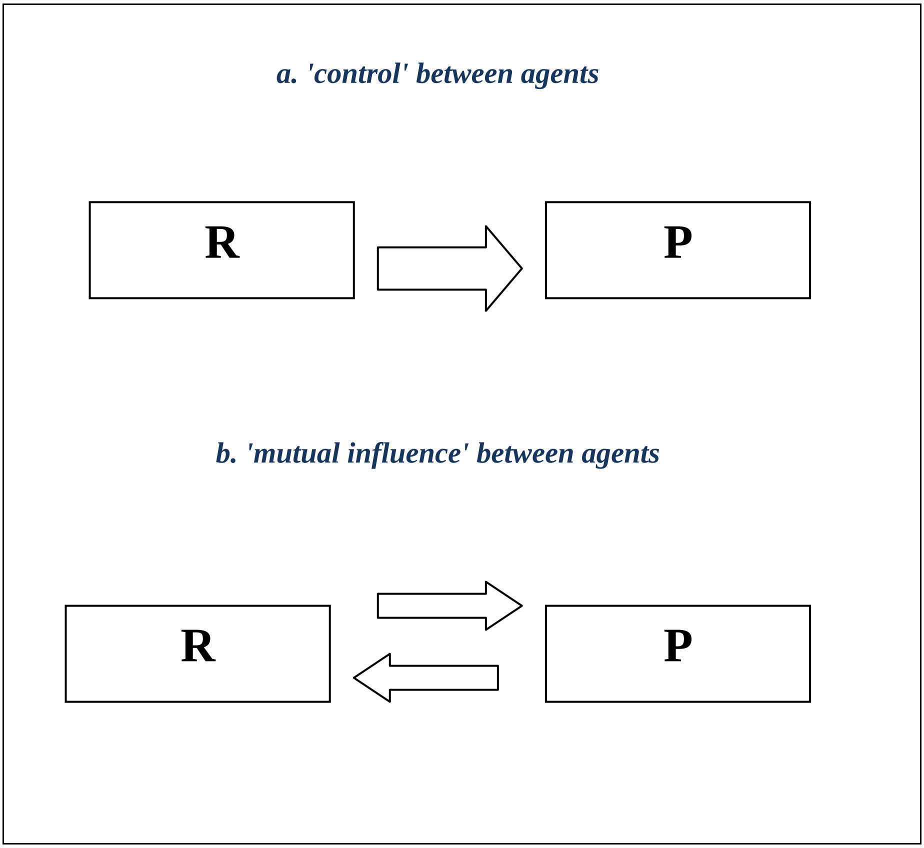
The police laser uses feedback to determine driving speed. Recently, feedback devices have been installed in trucks (tachometers), which are intended to discourage drivers from exceeding the speed limit. For years, Peugeot cars have featured a sensitive dectector providing data on air pressure in the tires, etc.

According to Ashby, in a situation whereby two agents (which can be neuron cells, machines, business companies, public organizations and the like) interact in a way that one dominates the other (see section a. in diagram no. 13), feedback is unnecessary. On the other hand, when each agent affects the other (see section b. in diagram no. 13), both agents constitute a dynamic system with a feedback mechanism in play.

Ashby proves this using a simple theoretical mathematical model to explain a disturbance or perturbation to the system's stability between R and P. In such an instance, at least a portion of the material or information being transmitted through the connection from P to R and vice versa, will reverse direction and cause the disturbance to be reduced or eliminated. He calls this phenomenon “negative feedback” – i.e., feedback in the *opposite* direction to the direction of the problem.

Diagram no. 13:

State of "Control" between agents versus a state of "Mutual Influence"



a. 'control' between agents

b. 'mutual influence' between agents

Ashby stated that simple feedback, as described between two agents (Ashby originally used the term "parts"), takes the shape of a "single loop" (Ashby, 1954, p. 53).

This is the place to discuss the two principal types of feedback loops that have been defined and are relatively well-known in scientific and engineering systems:

- Negative feedback, which helps a system proceed directly to its objective;
- Positive feedback, which serves to improve system performance.

The intention is not that negative feedback is bad feedback, or that positive feedback is good feedback. The intention is that negative feedback is feedback in the direction *opposite* to that of the phenomenon taking place. Negative feedback rectifies the deviation and reverts the system to the point where it heads in the direction of its goal. For example: a ship that is supposed to be tied to a dock is supposed to reach a specific anchoring point. If the ship deviates off course, it has the capability of navigating itself using jets of water flowing from its sides in order to rectify the deviation and reach precisely the desired point.

Positive feedback is feedback driven *straight at* the phenomenon taking place. Positive feedback brings the system to a state that is better than the intended goal. For example: if we manufactured a rocket capable of flying at the speed of Mach 2, and we received feedback that the enemy has a rocket that can fly at the speed of Mach 3, in response, we will manufacture a rocket capable of flying at the speed of Mach 4. Thus, we obtain a system whose performance is better than we had before.

George Soros, a world-renowned financial expert, illustrates the difference between both types of feedback in an example from the financial markets. He called it “reflexism” (Nationmaster Scientific Encyclopedia, 2011):

- When stock prices fall, the tendency of investors is to exit the market and sell their investments in order not to lose money from a further drop in prices. This action is negative feedback, since the sale of the stocks enabled a greater loss to be prevented and left the system at the point closest to the desired point.
- When the stock prices rise, the tendency of investors is to enter the market and buy stocks. Thus, they affect the price rise on the following day. This action is called positive feedback, since the system rose to a higher value than the value at the starting point.

Like the ship that navigates itself to a specific anchoring point, so too, an organization navigates itself towards a particular objective. Sensors are needed in order to verify that it is not deviating from the target. Its sensors are the control tools that it sets up, such as internal audits, accounting, civilian satisfaction surveys, etc.

Internal audits and accounting are negative feedback mechanisms, intended to enable rectification of deviations on route to a specific target. On the other hand, when the emphasis is placed on learning and assimilation processes, like, for example, learning from a civilian satisfaction survey, it becomes possible to ascend a rung in the ladder and achieve positive feedback. It enables the system to attain challenging targets that are higher than the previously set targets.

Processes experimenting with strategies and tactics in government and military planning divisions, as well as in business organizations, are based on positive feedback. The various feedback mechanisms operate in virtual simulation systems like in real systems.

There are additional definitions for feedback, for example: “double-loop feedback” or the less-known “second-loop feedback,” whose primary function is to assist in acquiring adaptability; i.e., the ability to adapt the system and advance from one attractor to another.

Many explanations may be found in relevant literature for the phenomenon of feedback, which make use of different terminology. Following is a collection of such examples:

In his book, *Principles of Systems*, of 1968, Forrester develops the concept of feedback using a number of models, such as: “first-order negative feedback loop” (Forrester, 1968, pp. 2-3); “second-order negative feedback loop” (*ibid*, pp. 2-11); and “positive feedback” (*ibid*, pp. 2-16). We will not dwell on these complex examples in this book, since they are unnecessary within this framework.

The reference to feedback in social systems is less developed, and sometimes, the definitions are dissimilar. In one of the sources, for example, we found the following definition under the heading “Feedback/Learning” (the website of Fairleigh Dickinson University, 2005):

- “Single-loop feedback”: the need for a particular behavior to achieve objectives (effectuation).
- “Double-loop feedback”: the need to change the assumptions/ goals/strategy in order to be effective.

- "Triple-loop feedback": the need to change both concurrently (to change the vision as well).

Table no. 1 assembles the terminology for the various types of feedback and presents examples of its applied uses, from the perspective of environmental conditions (dynamic-static) and objectives:

Table no. 1:

Adapting types of feedback to various system states

Feedback objectives	**Examples from a relatively stable environment**	**Examples from a dynamic environment**	**Feedback concepts/ terminology**
To change the system "phase transfer"; replacement of an attractor; dialectic quantum leap	–	Genetic engineering; flexible and adaptable organizations; application example: educational spokesman committee	Triple-loop feedback (changing the vision, the objective)

Feedback objectives	**Examples from a relatively stable environment**	**Examples from a dynamic environment**	**Feedback concepts/ terminology**
To improve the system progressing to a new equilibrium; improving an attractor; improving the “fitness landscape”	Drug for infectious diseases; adding hours of classroom study	“Jointness”; organizations become more efficient and more effective. Application example: revising the curricula	Positive feedback; double-loop feedback (improving the objective)
To stabilize the system restoring equilibrium; returning to a defined attractor; returning to the “phase space”	Adjusting a clock that is too fast or too slow	–	Negative feedback; single-loop feedback (returning to the objective)

Indeterminacy

Complex systems may be presented as characterized by a lack of determinism. Since deterministic rules compel the results of the process, classical thinking referred to distinctions as mutually exclusive; however, we know that some distinctions may be revised. A distinction made by one observer in a particular context may be completely irrelevant or simply impossible for another observer or in another context. This point was made in quantum mechanics, in which, under certain circumstances, an electron is referred to as a wave, while in other instances, as a particle. The description of an electron both as a particle and as a wave is jointly necessary in order to characterize the electron, but these properties can never be observed together, since the observation setup necessary to distinguish "particle-like" property is incompatible with the one for "wave-like" properties. As a result of this contrast in perception, classical thinking tended to confuse the essence of the object itself with what we see or think that it is. In order to prevent this confusion, Gershenson and Heylighen (2003) proposed distinguishing between the essence of beings – that is, differentiating between their absolute truth as they actually exist and occur – which they call "absolute being" – and the observer's subjective discernment, which they call "relative being." Since the observer can never collect complete information, there is an infinite number of relative descriptions for every absolute being.

Complex systems are, by nature, replete with components and interconnections. They can have such diverse relative beings that it might be impossible to identify them as two aspects of the same thing.

In the social sciences, it is customary to use the term "bounded rationality" in these contexts. This means that people perceive as reality only what they see with their own eyes, and not the real situation, including its latent risks (Strauss, 2000).

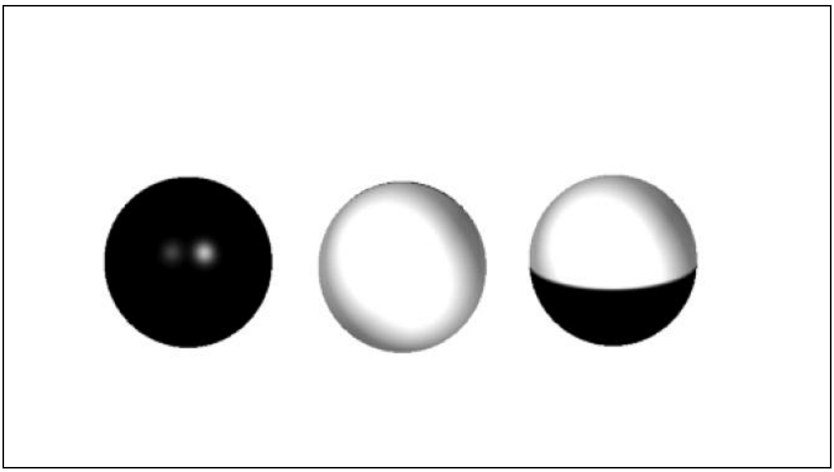
Here too, we find different conceptualizations of the same subject in the literature, deriving from the different terminology being used by the various disciplines.

Gershenson and Heylighen (2003) illustrate this in diagram no. 14, in which one sphere is depicted from three different perspectives. The true description of the sphere (its absolute being) is that of a sphere, half of which is black, while half is white. Practically speaking, this sphere may be attributed to a great number of relative beings and descriptions, depending upon the point of view: a black sphere, a white sphere, a sphere whose upper half is white and lower half is black, etc.

Diagram no. 14:

The same black-and-white sphere seen from three different angles

(from: Gershenson and Heylighen, 2003, p. 3)



Complex thinking allows choice in the method of representing a particular system for understanding a particular context, while being cognizant of the fact that another context will require a completely different method of representation.

An example of bounded rationality from the social sciences is the way in which various population groups in Israel perceived the disengagement from the Gaza Strip and northern Samaria in the summer of 2005. While a portion viewed it as destruction and expulsion, others viewed the operation as necessary to save the Jewish State.

Nonlinearity

A complex system – inclusive of all its structures, processes and emergent behaviors – is characterized by quintessential nonlinearity.

A system is linear if its results (output) are proportional to the factors creating them (input). An example of this is an energy conservation system: the volume of energy generated from the system depends directly on the volume of energy injected into it. But what would happen if a portion or a majority of the output is redirected and added back into the input? Intuitively, one can say that the next output should be larger, since it is being produced both from the input and from the previous output. In the same manner, the subsequent output should be even greater. Over time, the output will increase in a nonlinear manner, and, in this case, exponentially; i.e., there will be an accelerate expand (Gershenson and Heylighen, 2003, p. 4).
According to classical thinking, distinctions change not only among different observers, but also over time. The principle is that equal factors will lead to equal results and vice versa.

This principle is correct for the level of absolute being, but is completely wrong at the level of relative beings, about which we spoke in the previous section. This can be deduced due to the existence of chaos, which can emerge due to a minor change. A rise in the Earth's temperature by merely one degree per annum causes chaotic phenomena to break out in various locations around the world; the crossing of the Suez Canal and the redeployment of a military force over enemy lines into Egypt during the *Yom Kippur* War in 1973 unrecognizably changed the momentum of the events, far exceeding the size of the force; the acquiescence to the nomadic Bedouin lifestyle in the Negev led to three concurrent chaotic phenomena: accelerated population growth, encouraged by budgets from the National Insurance Institute, the occupation of land in the Negev and the undemarcated area turning into a crime-filled stretch of anarchy.
In all of these examples, minor leverage led to major events. Opposite phenomena also exist, like enormous investments that generate negligible profits, or endless discussions about critical matters that led to mutual neutralization.

Chris Langton argues that the problem with complex systems is:

> " … *that you cannot predict in advance how changing the detailed rules of the individual interactions will affect the global behavior. For example, a new juridical law that will affect the conduct of individual participants in a social system may give rise to global side-effects, which will finally yield a collective behavior that is just the opposite of what was originally intended.*"
>
> (Ben-Dov, 1995)

Senge calls this phenomenon "compensating feedback" – "*intervention with good intentions, which result in system reactions that offset the benefit from the intervention and lead, in the long run, to exacerbation of the situation*" (Senge, 1998, pp. 68-72; Senge, 1994, pp. 57-67). At the beginning, a certain benefit is evident in the initial situation due to the intervention, but the more power that is invested in changing the situation, the system pushes back. The greater the investment that is invested in attempts to improve the situation, it seems that even greater efforts are required. The result is that, following the intervention, the situation is worse than the initial state. Many actions by governments and institutions that are done with good intentions fall victims to compensative feedback. An example of this is, for example, Africa: notwithstanding all the monetary investments by western countries in Africa during the last century, the situation there is only getting worse.

Sensitive dependence on initial conditions

Complex systems are extremely sensitive to initial conditions that are undistinguishable, while ordinary systems usually return to their attractors, much like a pendulum returns to the lowest point in its arc. Ordinary systems are not very sensitive to the initial conditions; like the boiling point of water is not sensitive to the temperature of the water being poured into the kettle, but only to the temperature at the boiling point (usually 100 degrees Celsius). In many instances, the classic models assumed initial conditions for the majority of identified parameters. Many parameters were not identified or were assessed as being of little importance. In fact, from the moment that the meteorologist Lorenz discovered the significance of a tiny deviation when inputting weather data on the long-term behavior of the system, the connection to this sensitivity became evident.

Irene Sanders (Sanders, 2002), the executive director of the Washington Center for Complexity and Public Policy, asserted that:

> "*Small changes or small inputs of resources at strategic points in these complex systems can be amplified throughout the entire system, bringing about significant overall shifts ... and while it's not possible to predict the future, it is possible to develop foresight – to identify small changes and new conditions that are beginning to influence the future .... Our inability to see and understand the interconnected nonlinear nature of the world made us vulnerable to the malevolent intentions of those who could.*"
>
> (Sanders, 2002)

Sanders is stressing here that managers need to overcome the problem of their inability to foresee the future because of its nonlinearity. This can be done by identifying those changes that will design the future. We will discuss this issue at length later in this book.

There is no shortage of examples of the property of "sensitivity to the initial conditions": expert analysts identify a slight fluctuation in stock prices as a turning point in their assessments of trends and the strength of the stock prices in the future. Models have even been developed in this context, but, for the most part, it is impossible to predict all factors impacting the stock price tomorrow. There are senior managers which pay no attention to changes in trends until it is too late. By the time they take suitable response measures, the crisis is already upon them; lawyers are sensitive to every reaction during negotiations, since a failure to discern nuances is liable to lead them in undesirable directions; mediation proceedings also depend on astute identification and sensitivity. Notwithstanding the sensitivities, still the quantity of unidentified input that can change the course of events is considerable.

One of the known metaphors in this context is *the butterfly effect*: the flapping of a single butterfly's wings produces a disturbance that increasingly intensifies until, over a period of time, it generates a thunderstorm in a very remote location. The significance of the butterfly effect is that we cannot know exactly what the current conditions are in location “a” that could influence and lead to a dramatic change in the anticipated result in location “b.”

An example of the butterfly effect is the publication of an article in mid May 2005. The article reported that copies of the *Qu’ran* had been desecrated at the U.S. military detainment facility in Guantanamo, Cuba. In a world of free and open information, the article started a tidal wave, ignited chain reactions and sparked outrage in the Muslim world. The article provoked the outbreak of riots, from the Gaza Strip to Afghanistan, where 14 people died in the confrontations with police (*Nana* news, 2005).

Another example is the indirect impact of the success of modern medicine in lengthening human life expectancy on the collapse of pension funds in the western world. These funds, which were built on the assumption that they would have to pay a particular number of retirees during a certain period, found themselves in a completely new situation, where the volume of retirees entitled to payment rose dramatically. The inevitable consequence was collapsed and an urgent need for government intervention in order to ensure that pensions will be paid to the insured.

Another example from a different field was the indirect impact of the “constitutional revolution” of the adult probation service in Israel. As a result of this “revolution,” the Penal Procedure Act (Enforcement Authorities – Arrests) 1996, was amended, mainly in order to restrict police authorities in this regard. Detention time was limited to 24 hours and causes for detention until the conclusions of proceedings were defined. A seemingly marginal section of the law, section 21a, enabled judges to instruct the probation service to perform detention reviews. The way in which judges tended to make use of this section of the law created enormous changes in the probation service, which had not been a factor in the legislator’s consideration. Up until then, the primary function of the probation service had been to provide affidavits for sentencing of convicted felons. Now, the service is collapsing due to the sheer volume of demands for detention reviews. At the same time, the status and importance of the probation service also deteriorated in the law enforcement system (see, for example, the remarks by the former president of the Supreme Court, Meir Shamgar, in criminal appeal 344/81). Thus, the butterfly effect of the law, which had intended to restrict the authorities of the police, led to the collapse of another organization that the legislator had not intended to change at all.

Diagram no. 15 presents an example of the butterfly effect. This is a fractal geometry, which presents a sequence of nonintersecting points.

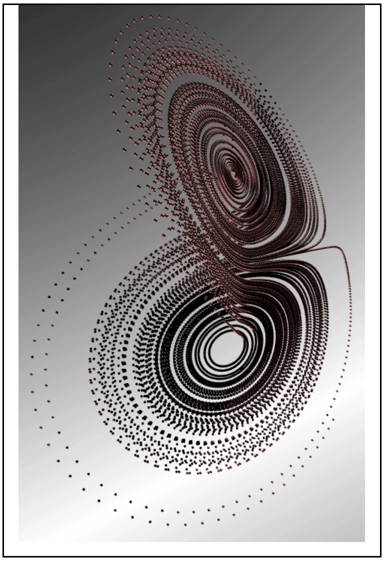
Each point characterizes the state of all the system's parameters at a given point in time. The significance is that the system will never repeat itself and will not arrive at that same point again.

Complex systems may be exhibited by a tangle of positive and negative causal feedback loops, so that some of the effects return to feed the initial conditions in a positive or negative way. Since the interval between the repeating effects varies, it becomes impossible to predict the future results, and know who will affect whom (the positive influencing the negative and vice versa); who will arrive when and whether a particular effect will be amplified or weakened.
An example of this is the stock exchange: stocks are bought and sold depending on their price, while the price depends on the volume of buyers and sellers. The law of supply and demand implies a negative feedback (a negative loop), since a rise in the prices causes a drop in the demand, and, after a time, a drop in prices. On the other hand, the parallel mechanism of speculation creates a positive feedback loop. When the price rises, buyers anticipate an even higher price in the future, thus enticing them to buy more of the stock.
The interaction between these two nonlinear effects produces the chaotic volatility of prices that are so prevalent in stock markets. (Gershenson and Heylighen, 2003, p. 6).

Diagram no. 15:

Butterfly effect fractal

(From: http://local.wasp.uwa.edu.au/~pbourke/fractals/lorenz/lorenz11.gif)



'Self-Organization'

One of the properties most characteristic of “complex systems” is "Self Organization". This is a phenomenon that occurs in every system under defined threshold conditions, such as: the number of participants and the degree of their participation. In this state, a phenomenon of "Self Organization" or self-order occurs in systems, which emerges from the dynamics of the interactions taking place. This attribute is an inherent, spontaneous property of the system. It is usually revealed when the system is losing equilibrium, when suitable

threshold conditions emerge for a phase transition. An example of this is the human body under severe environmental conditions, which tries to restore a state of equilibrium using its amazing sensory detection system: vision, hearing, heat detectors on the skin, etc.
Professor Aharon Katzir, who engaged in the fields of cybernetics, biology and chemistry, made a tremendous contribution to the understanding of brain activity and self-organization. Katzir believed:

> "*In order for these transitions to be applicable, it is essential … that the brain be organized in a manner enabling 'phase transfers' and 'quality leaps' from state to state, and from one level of organization and activity to another.*"
>
> (Ben-Aharon, 2001)

Chris Langton illustrated self-organization, using the way an ant trail is formed:

> "*When ants are looking for food, they walk to a certain distance from their nest, and then they go about randomly. When one of them finds food, it goes back to the nest, dispersing pheromones* [which are odor cues it secretes] *on its way. These pheromones attract other ants, which disperse more pheromones, and so on. In this manner, an organized ant-trail is formed, although no-one planned it in advance. It emerges from the collective behavior of the individual ants*".
>
> (Ben-Dov, 1995)

Through this trail, the group of ants can perform what no single ant is capable of doing.

A physical example of this property of 'Self-Organizations' is the phenomenon of the crystal formulation of a salt crystal, that is formed in the Dead Sea under suitable conditions of heat, humidity and concentration. Another example is the transparent and very precise artificial sapphire crystals are manufactured industrially at the exact high temperature, coupled with specific pressures and other circumstances, which constitute the unique know-how of the manufacturers.

Another example is from biology – the development of the organism from the fertilized egg (ontogeny). The cells develop identically in terms of their genetic composition, notwithstanding the tremendous diversity of genes, and although a different group of genes is active in each of them (Zini, 2004, p. 19).

Biology provides innumerable examples of 'Self-Organization'. One of them is the precise development of human cells, despite the myriad genetic possibilities; the building of new cells from enzymes and proteins, according to their initial conditions. Biology is rich also with examples of the emergence of changes in every environment of interconnectivity between different components, from the development of the eye to the deterioration of the immune system (which is also a system 'Self-Organization').

We can grasp the importance of the phenomenon of "Self Organization" in complex systems, for example, from experiments conducted in the 1920s at Western Electric’s Hawthorne textile plant. During these experiments, everyone was astounded by the extent of the changes in the group as a result of the improvement of the working conditions (lighting, paint, etc.). Increased outputs were achieved, particularly relative to other groups in the factory or to similar factories, and the strategy has become a role model. The phenomenon emerged as soon as the group independently organized itself, under an informal leader from among its ranks.[1]

Notwithstanding these experiments, classic management practices and conceptualization remained in industry for another 80 years without change. It was only when the industry of start-up organizations began to organize themselves that the hierarchic mechanism came into conflict with the freedom of 'Self-Organization'. Each dynamic system organized itself differently, according to the complexity of the interconnections between its parts and its environmental conditions. Sometimes, the results are extremely interesting. What differentiates systems with this capability is that many times they seek solutions by themselves, without needing direction or intervention from a leader. Moreover, these systems are essentially open and flexible, and thus, are capable of adapting to unforeseen changes without needing a central governing body.

"Self Organization" may be motivated by an internal or external catalyst. An example of an internal catalyst is a resident of a neighborhood that conducts an intensive activities to improve the quality of life in his neighborhood, and succeeds in involving his neighbors; an example of an external catalyst is certain activities instituted by city hall in order to encourage residents of the

---

[1] For detailed information about the Hawthorne experiment, see Tabb and Mannheim, (1965, pp. 22-41).

neighborhood to self organize and become involved in an activity pertaining to the quality of life in their neighborhood. In military systemic thinking, the set of these operations is called a "*Disruptive Innovation*" (Zigdon, 2004, p. 5).

According to this perspective, the management needs to perform operations that would cause the 'Disruptive Innovation' to "*germinate*" in the consciousness of the organization's personnel (*ibid*, p. 34), and motivate them to organize themselves to achieve the desired objective. In both instances, a variety of different results are possible in the context of environmental quality, and there is no guarantee that intervention will achieve the preconceived intended outcome.

This fact poses a challenge to managers, who can implement actions that will affect the future. It is important to emphasize that, on the one hand, if the management's actions are too domineering, they will not achieve self-organization, but rather action dictated from above; on the other hand, even if the management's actions do motivate the self-organization, there is no assurance that the objective will actually be achieved. This issue will be discussed at length in the chapter addressing managerial aspects of complex systems theory.

A system capable of 'Self Organization' not only enables but also encourages randomness and indeterminacy. The more frequent the random fluctuations, the faster the system will be propelled towards one attractor out of the variety of possible attractors, which will draw it towards its particular direction. Of course, excessive randomness and perturbation will destroy any system. Natural systems tend to develop according to the prevailing conditions, whether in the direction of order or in the direction of chaos.

This property of 'Self Organization' is recognized as an essential strategy for comprehending the emergence of general behaviors in a wide variety of systems, such as: in economics, in the brain, in ecological systems or in major corporations. Uprisings of populations under certain conditions are likely or liable (as the case may be) to overturn reality, for the most part, without a leader, or at least without one at the outset.

This phenomenon repeats itself also in populations of factors affecting weather conditions, or, alternatively, nationwide revolutions, such as “the Black Panthers,” the “Four Mothers” movement, the “Volunteers’ Line” organization or the first Palestinian “*Intifada*.” At the time these words are being written, 'Self Organization' for a war against corruption is developing in Israel.

The paradigm of hierarchic thinking; i.e., in terms of the ability to control 'Self Organization' by command and control from above, is increasingly losing relevance. It is encountering an environment offering easy access to the media in real time, which does not allow the old behavioral patterns to continue.

The phenomenon of 'Self Organization' is usually curtailed by intervention from above, out of the desire to protect the system from phenomena perceived to be detrimental, and out of the desire to stabilize the system. However, opposition to 'Self Organization' is hopeless in the long run. It is counter-productive and causes enormous damage. Thus, for example, the global news channel, CNN, overcame opposition from government echelons, who, until then, had avoided exposure of their activities. The Arab television channel “*Al Jazeera*” has had similar success opposite the regimes that are hostile to the TV channel’s activities in various Arab countries.

An example of 'Self Organization' from the political arena was the civil protest in Lebanon during the spring of 2005 following the assassination of the former Prime Minister, Rafic Al-Hariri. This spontaneous protest led to the withdrawal of the Syrian forces from Lebanon.

One instance of 'Self Organization' that has not yet occurred, but, which is eagerly anticipated by the western world, is a grass roots uprising in Iran – one that would oust the regime of *Ayatollahs* and establish a democracy in this important country. In Iraq as well, the 'Self Organization' is still lacking that would enable the American forces to withdraw from the country.

Formation of a hierarchy of situations

The nature of processes is that they develop stage after stage. For example: at soccer stadiums, the behavior by the spectators increasingly deteriorates if an appropriate educational or police response is lacking. The processes of degenerating public behavior have accelerated, and what used to be taboo has become a norm. Are we seeing the initiation of any countermeasures? Will such a process gain momentum (hierarchic) of events and achievements?

Will the global war against terrorism, which has evolved through a number of stages, be capable of eradicating terrorism? Here, two opposing trends are in competition. On the one hand, terrorism has been gaining momentum since the day the trade center towers collapsed in New York; on the other hand, global antiterrorism activities are also intensifying: additional countries are joining the cause; new legislation is being enacted that facilitates the war against terrorism; global sanctions are being imposed on the movement of cash, etc. Which of these two trends will prevail? Or, will it result in the maintaining of the status quo?

In 2004, Stanislaw Raczynski developed a sophisticated simulator called PASION, which simulates the dynamic interaction between organizational structures, including terrorist organizations, anti-terrorism organizations and support structures. According to Raczynski, the formation of structures is spontaneous and derives from the legality of the conduct of independent agents (Raczynski, 2004). For example, the emergence of a new small terrorist organization would suffice to change the entire system of relations.
The formulation of a hierarchy of states is identified in the various iterations of the model. For example, an increase in the number of illnesses affects levels (hierarchy), in terms of the number of patients, overcrowding in hospitals and increased consumption of drugs. Urban development processes are also included under this category; federal laws and budgets react (hierarchically) according to a few parameters: population growth causes the community to expand from a community to a local council, and from there, to a city, etc.

Raczynski proposed to his successors to develop a more complex stage in the simulator, in order to characterize more situations and to approximate reality to the extent possible.

'Emergence'

'Emergence' is the changing state of X to Y, as a result of the phenomenon of 'Self Organization'. The Hebrew definition of the term 'Emergence' is a phenomenon of sprouting. This is the emergence of new unexpected structures, patterns or processes in 'Self-Organizing' systems. These phenomena purport to have the capacity to manage independent life and have their own set of laws, as well as capabilities that lower-ranking components do not have. Phenomena of emergent behavior are occurring in organizations everywhere constantly, but their intensity and resonance are still limited, due to the mechanical control of the organizational structures anchored in the hierarchy.

Emergence refers to an attribute or a process, and derives from the greatest (combinatorial) growth of a number of interconnections (K) relative to an increment of agents (N): two agents have one interconnection; four agents have six interconnections; six agents have already 15 interconnections, and so on, incrementally. The interconnectivity – the number of permutations of 20 different chemical substances into new and different molecules is almost incalculable.

An example of 'Emergence' was the situation that arose in Lebanon subsequent to the attractor of the IDF’s withdrawal from Lebanon on

May 24, 2000, and the announcement by the United Nation's Security Council that Israel had implemented resolution 425.

As a result, a process was initiated that led, on the one hand, to more democratization in Lebanon; to pressure on the *Hezbollah* from inside Lebanon (which was unsuccessful) to disarm, become involved in the political game and oust the Syrians from Lebanon;

On the other hand, to the *Hezbollah's* stepping in order to fill the void created on the border once the IDF exited and the southern Lebanese army disappeared, which were among the factors that led to the outbreak of the Second Lebanese War during the summer of 2006.

An example of 'Emergence' in the judicial arena was the trend of Supreme Court justices adopting a prudent and lenient approach to the issue of convictions of public figures. The judges were reluctant to hand done convictions for the offense of "fraud and breach of fidelity," which is very vaguely defined in the Israeli law. The attractor in this issue, which drew the judicial system into a new reality, had been the acquittal of the former chairman of the Jewish Agency, Mr. Simcha Dinitz. Dinitz had been suspected of purchasing personal equipment with the Institution's credit card for a period of five years, at the aggregate sum of USD 22 thousand. The district court convicted him, the judge ruling that Dinitz had known, or at least, had turned a blind eye to the fact that the Jewish Agency had paid his bills by mistake, without charging him. As a result of the appeal lodged by both parties to the Supreme Court, Mr. Dinitz was acquitted. The rationale had been that it was impossible to reach the level of certainty required for the conclusion reached by the district court, certainty beyond any shadow of a doubt (Criminal Appeal Case 4336/96).

Referring to this affair, the judicial commentator, Moshe Negbi (1994, pp. 46-47), wrote that these assumptions led to discrimination in the quality of the proof of criminal intent required. They almost completely eliminated the possibility of indicting or convicting corrupt high-echelon officials. According to Negbi, this is apparently what also explains the enormous gap between the conviction rate of high-ranking accused felons (about thirty percent) and the conviction rate among rank-and-file accused felons (more than ninety percent).

This situation persisted until 2004, when a judicial emergent behavior arose due to a new attractor – the Supreme Court ruling during an additional hearing on the acquittal of the former director-general of the prime minister’s office, Shimon Sheves. The nine Supreme Court justices understood the situation that the law enforcement system was facing, overturned the previous judgment and convicted Shimon Sheves at a ratio of eight to one. The court stated that the purpose of the additional hearing, inter alia, was to formulate the clearest and most precise test possible for the grounds of the offense of “fraud and breach of fidelity” (Additional Criminal Hearing 1397/03).

'Emergence' is a process of developing more complex patterns from simple laws. A person’s brain can change as a result of evolution over millions of years, but, to the same extent, a critical accident can cause an immediate change.

The number of connections alone between the free agents does not ensure that a phenomenon of emergence will develop. Emergence may take shape only after an incubation period without any external perturbation, before it succeeds in passing a critical threshold that ensures that it will proceed until completion.

An example of this is the arms race and the problems in the alliances prior to World War 1. Slowly, their implications accumulated over a long period of peace and created a reality that was destined for trouble. It “exploded” on July 28, 1914, when a Serbian shot and assassinated the Austrian heir to the throne, the Archduke Franz Ferdinand. This shot was sufficient to plunge the international system into chaos, and ignited the spark that destroyed Europe during the First World War.

The formation of emergence is latent in the organization of the *contexts* and not only in their numbers. Decentralized organizations are better environments for the 'Emergence' than centralistic, bureaucratic organizations. Emergence will occur at the intersection of organization, communication, diversity of professional capabilities and connectivity.

'Emergence', as a phenomenon, increases order, even though it does not derive from any command or control (a salient point when building applications). Emergence occurs since complex systems are capable of extracting information and conditions from the environment that lead to order.

An organized system of hundreds of engineers was present in the command and control center of the U.S. Space Agency in Houston, NASA, at the time of the explosion on board the “Apollo 13” spacecraft. However, from the moment that the explosion occurred, they were no longer needed. On the contrary, they stopped working altogether and shut down all of their monitors to save the spacecraft from having to consume noncrucial energy. The malfunction in the oxygen system that caused the explosion was discussed by only a small group of engineers who could help find a solution under those tense circumstances. Based on a list of the inventory of noncritical parts in the spacecraft, the team built a model of a device that produces oxygen. This mode of action created the emergence of a solution in minimal time. It was not developed out of the masses of “ordinary” interactions, but rather from an improvised but focused network of interaction among about ten professionals.

One of the spheres rich in the phenomenon of emergence is computer games. Any group may develop new rules for an existing game, like poker, and to the same extent, may develop a more advanced game. The interaction between developers and players produces the next generation of the game, and so on.

'Emergence' occurs in many places in nature. Various populations (pigeons, bees, ants and more) develop efficient traits and structures that are often aesthetically beautiful, without any instruction or leader. Emergence is also present in humans who are so creative that entire sciences, technologies, buildings, processes and an infinite range of products may be invented out of collaboration among a few brilliant individuals. A single programmer might have invented the “free, open-source” computer language, Linux. Thousands of other programmers, professionals and amateurs alike, joined him, expanded and are still expanding its capabilities, to dimensions of limitless horizons. Examples that are the diametric opposite in the same field are the activities of “hackers,” who are constantly developing ways to break into systems, or “crackers,” who are developing ways to cause substantial damage. Each of these directions triggers a hierarchy of developments.

Thus, information emerges from information, theories replace theories and the process of emergence occurs in diverse forms and ways.

Summary

Complex systems have many diverse definitions and characteristics. It is a new theory, a theory in emergence, that itself supports 'Emergence' as a principal characteristic property. The attempt proves that relationships between free agents, which constitute the infrastructure of complex systems, are short term; they exist in feedback loops; and they are nonlinear. The long-term effects of agents are expressed, inter alia, in 'Emergence', which impacts the system and its operating environment over time.

Organizations can change shape like chewing gum, can change their boundaries like gas, and be very dynamic like a beehive. Subsystems do not see the whole, especially since the boundaries of the whole are difficult to define and certainly are exceedingly dynamic.

Nonetheless, complex systems are simple to describe and understand with the help of the system rules, and particularly, by using networks. The next chapter will provide a background in networks theory, which attempts to help us understand how systems may be analyzed using these networks.

* * *

This chapter is the core of the book. It explains the concept of complexity and the characteristics of complex systems. It elucidates the important concepts in 'Complex Systems Theory', such as nonlinearity, 'Self Organization', a 'Disruptive Innovation', 'Emergence' and more. The salient rationale presented in this chapter is the assertion that complexity may be characterized using merely a few rules. Another rationale is the importance of double-loop feedback to the functioning of complex systems. Positive and negative feedback also affects them, but not fundamentally.

The next chapter discusses networks theory and the tools enabling optimal application of complex systems theory.

Chapter Five
Networks

Introduction

Focusing on the interconnections between a system’s components – the 'free agents' / 'objects' – enables the relations between them to be defined so that the essence and character of these interconnections will be conveyed in a manner understandable to the observer. The tool for this is the network.

The reality in which we live is surprising in the quantity of phenomena that may be characterized by one simple and basic concept – networks. Networks exist everywhere in our lives: from fishermen’s nets to the network of electrical lines; from the human nervous system to a chain of clothing stores; from a network of highways to a network of drug dealers; even the grid game that took our lives by storm recently, Sudoku, is nothing more than a network (see later in this chapter).

Until recently, we were accustomed to discuss individual organizations separately, even though they are, in effect, networks. In recent years, tremendous progress has been made in analyzing the behavior of networks. Now, the knowledge, gained about networks' behavior, can be disseminated among the various organizations.

The first major impetus towards analyzing the behavior of networks and enabling the knowledge's dissemination in the field was provided by Albert Lázsló Barabási, in a comprehensive book that has been translated into Hebrew. In his book on networks theory (Barabási, 2004), he shows, among other things, the links between the various networks.

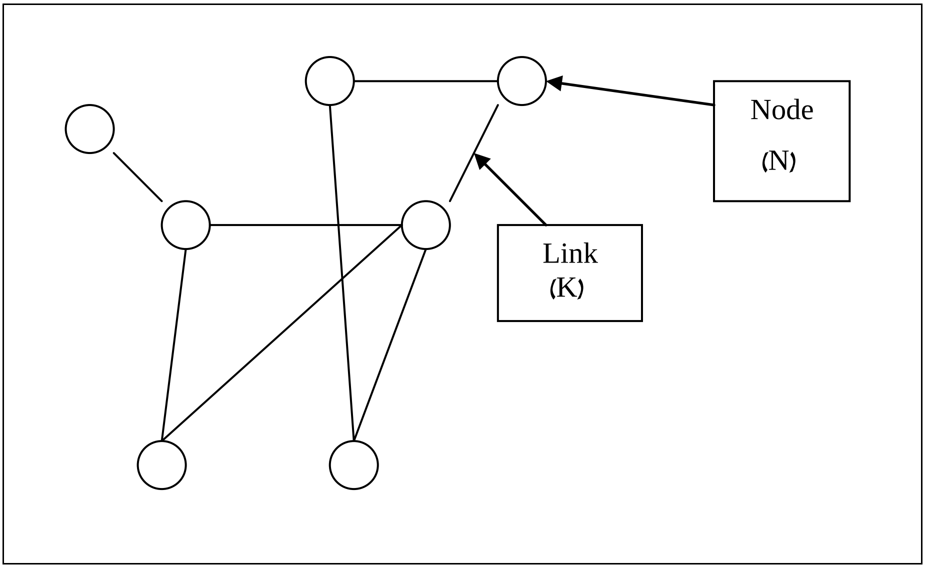
Let’s define a network as a system of links between the independent components of a complex system. This is a collection of organs and their interconnections. We’ll call the organs 'vertices' or 'nodes' and we’ll mark them with the letter 'N.' The vertices are interconnected by links that we’ll mark with the letter 'K' (see diagram no. 16). The links are comprised of 'interconnections' between organizations, and various types of relays (which include information, material and energy), which are transmitted through the interconnections. These interconnections express a sort of technical essence, while the messages being transmitted through them express the essence of a plan.

In networks, information may be transferred through the connectivity between the nodes. From this, one can understand and characterize a new type of information – not only information that develops within the various organizations, but also integrative knowledge that develops in the *middle* between them (Glassman and Veron, 2005, p. 16). Instead of a railway network or telephone network, a network that transmits information. A conversation between two people, for example, can be understood only by them, due to their words, the tone, the emphases, etc. Another example is the Marranos of Spain -

Diagram 16:

Basic network of nodes and links

(from: Shachar and Arzi, 2005, p. 9)



Jews, who had to behave like devout Christians outwardly, but succeeded in communicating among themselves using various signals and indirect methods.

Kauffman’s research studies were among the first to discuss the links between systems' elements. These links teach us about the importance of the relations between the organization's parts, the contacts' number and their level. The studies have shown that an organization must have sufficient connections between its parts so that critical information will be relayed among its various agents. At the same time, it is problematic to have too many connections, which 'clog' the system and cause it to be completely dysfunctional.

In his article entitled "Basins of Attraction in Network Dynamics: A Conceptual Framework for Biomolecular Networks", Professor Andrew Wuensche wrote:

> *Some of the outstanding questions in genetics, evolution, evolvability and development, including notions of modularity, will involve unraveling and comprehending networks of interacting elements ... Dynamical networks in biology are found wherever one cares to look, from the brain to ecology ... These networks overlap, making 'super-networks,' and break down into sub-networks through many levels ... There appears to be an urgent need for theoretical approximations and concepts to keep pace with the data ...Can methods from complex systems theory and network theory ... provide a conceptual framework for biological and other networks*?
>
> (Wuensche, 2002, p. 1)

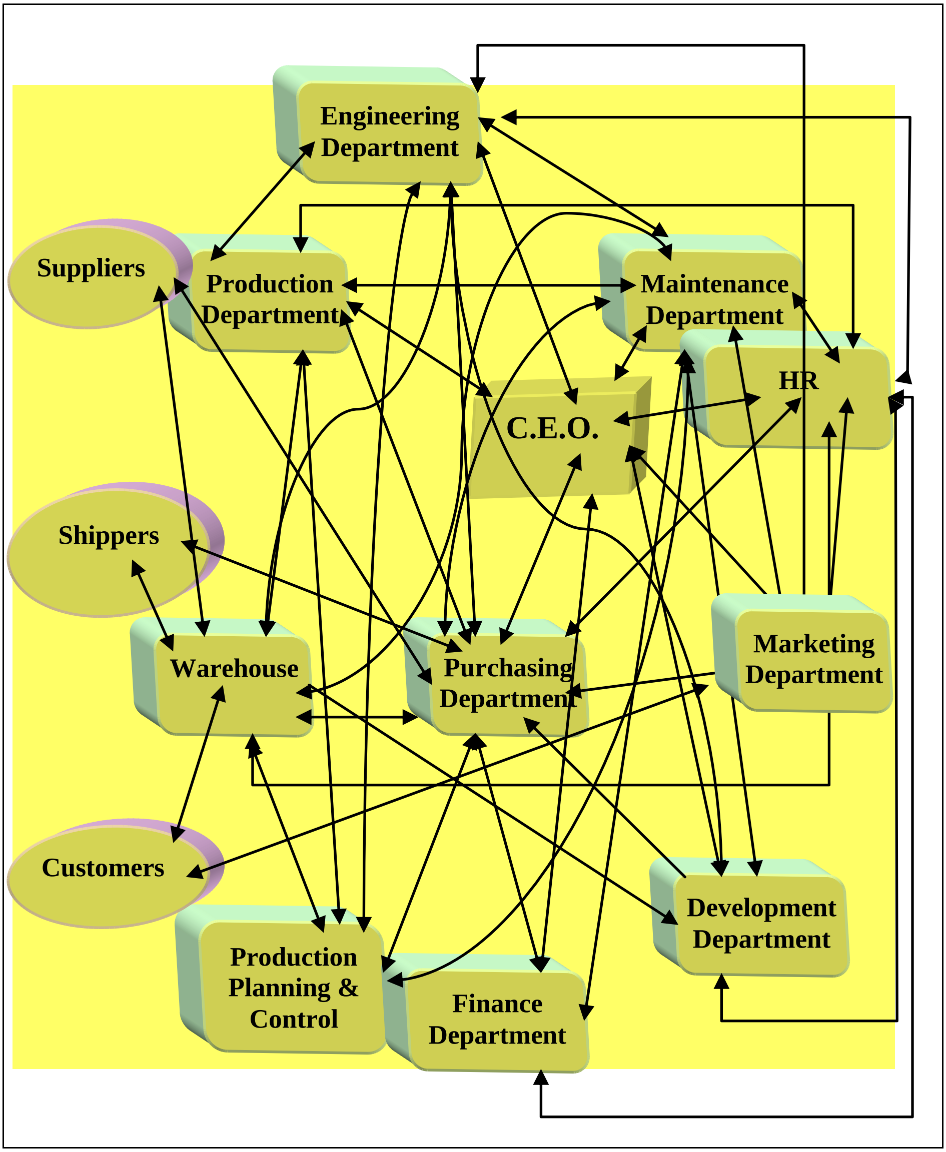
We will be referring to the latter part of this citation later in this book.

Recently, there has been a dramatic evolution in the characterization of interpersonal social connections, including in the depiction of organizational networks. These networks are similar to networks in nature: the human nervous system, metabolic networks, distribution networks like the vascular system, etc. The network's diagram differs from the traditional organizational tree, with the 'official' hierarchy being replaced by the interactions within the organization (for an example of a typical organizational network, see diagram no. 17).

Diagram no. 17:

Example of a network in an organization

(From: Bronstein, 2004)



The study of networks on the mathematical plane has also gained momentum. A typical network analysis is conducted by forwarding a questionnaire to the functionaries in an organization, and asking them to indicate their interactions with others. Based on the data received, the interactions are drawn up in a diagram of the network.

Networks are capturing the most attention in today's information age, both communications networks and the internet. They are governing trends and gaining control over commerce. Networks are the new global empires whose operating results have not yet matured. They affect both, the rulers, and the masses. New patterns of behavior are being discovered in networks every month. Networks facilitate a variety of activities – from real-time interpersonal communication to the ability to maneuver and access diverse locations, which were unheard of only a few decades ago. They enable the rapid germination of negative phenomena, such as the formation of a network of terrorist infrastructure, but parallel to this, they also enable positive mechanisms to develop.

The search engine operating by Google is based on a number of different technologies. Its primary significance is the link that it enables between any home user and each of the information pages stored on the computer network. This is a global network integrating a few subnetworks to a supernetwork. A decade after the birth of the search engine, we cannot imagine how were we able to live without Google and its counterparts.

All of these examples provide answers to the questions regarding the source of networks' power and how they develop. The basis to the answers is found, first of all, in the *connection between the elements.* As we showed, this connection can be illustrated graphically in many layers, jointly and separately; the components of this connection can be controlled through trial and error, and integrated in computing systems.

Whoever is linked and has connections can become involved and make an impact. On the other hand, whoever stands on the sidelines, as if he doesn’t exist, can sometimes constitute merely a hindrance.

When at issue is a network whose agents are people, the relevant questions are: who is more connected, who has more extensive influence and who has less or none at all? Another question is: what is the level of interconnectivity of each of the agents? The argument is that it is reasonable to assume that individuals or organizations having the highest interconnectivity will have the greatest power in their operating environment. That is why networks theory is also essential in order to understand, for example, the study of political processes in organizations.

'Jointness' is a concept based on the level of interconnectivity between various military forces. It was placed on the public agenda following the U.S. military’s war in Iraq in 2003, where its operations in the arena were as a joint force. All forces functioned in a single network, with real-time links among them (Quigley, 2005). 'Jointness' is a transition from a relatively low level of interconnectivity among forces and units comprising the network, to a level of very close interconnectivity, which is done through the use of sophisticated technology.

'Jointness' was also experienced in Israel during the summer of 2005. During the implementation of the disengagement plan from the Gaza Strip and from northern Samaria, the two defense organizations, the I.D.F. and the Israel Police, functioned at a level of jointness that was unprecedented.

Opposite 'jointness', which accelerates enhancement of the level of interconnectivity, public organizations, usually, tend to retain power and “protect territories”, which means that they are *reducing* the extent of the connections. Thus, for example, over the years, the ministries of agriculture and housing intentionally weakened their interconnections with those ministries responsible for the issue of foreign workers, in order to protect the narrow interests of particular sectors. The outcome was that the inflow of foreign workers swelled to a magnitude that is abnormal in other democratic countries.

Sometimes, a high level of interconnectivity can also be abused for negative purposes. For example, the close cooperation between the wealthy and the decision-making echelons can lead to the favoring of the former’s interests at the expense of the public’s interest.

In other words, networks theory is also essential for understanding the studies of political processes inside and among organizations. Networks theory enables organizations to be analyzed as a set of interconnections between agents. This set of interconnections expresses processes, developments, restructuring of the organizational hierarchy and more. The connection between networks, computerization and knowledge [knowledge is predominantly found in the active interconnections among participants in the network, as Katzir pointed out (1972)] opens many options to us, many of which are still waiting to be tapped.

The NKPV model – theoretical aspects

It was Kauffman, who developed the NK model, which represents the various agents (N), the links between them (K) and the laws (P) by which each N operates. Changes in the three variables that he defined as N, K and P can affect the degree of the system's dynamics. These variables can influence other phenomena relating to quality of life, like the addition of a police station to the existing network of stations or expanding the network of municipal inspections, or more than this: integrating them in one large shared system.

We will add another component to Kauffman's NK model – V, the content being transmitted through K (see below). We obtain a model that, for our purposes, we will call NKPV.

Four principle rules may be defined for a network (based on the Kauffman's model of 1997):

1. There are a number of nodes (N) in the system. These nodes can be organizations, people, products, objects, etc.
2. Each node is connected to other nodes by links (K). Interconnectivity between two nodes means that they are exchanging information at least between each other.
3. The links between the nodes are the input being transmitted between them; i.e., the content being transmitted between N1 to

N2 through K. This content can be marked with the letter V (values). There are rules (P) for each node that dictate its behavior, based on the input that it receives from other nodes connected to it.

4. A node that is transmitting input to another node acts as a catalyst for processes. This term is taken from biology and chemistry.

In simple systems, the interactions between the nodes are expressed in the direct link between them, but in complex systems, the nodes can be interconnect in more than one possible way. For example, every link in the internet causes a direct connection and an indirect connection. This is similar to a catalytic process in the chemical industry, in which a link is created to a link that already exists (self-catalyzation). catalyzation). Various types of atoms need a unique catalyst to assemble them into defined molecules. As soon as the catalyst assembles a number of molecules, the molecules will arrange themselves according to the new composition.

An example of a catalyst in social systems is, for example, the game "Sudoku," which was already mentioned at the beginning of the chapter. As we stated, this game is a network with 81 participants (cells). Each of the 81 cells is linked to the 80 other cells (for a total of 6,400 direct or indirect links, deriving from multiplying 80 × 81). At the beginning of the game, there are only about 20 – 30 numbers placed in cells. The addition of a number in any cell depends upon the numbers placed in adjacent and distant cells, which acts like a catalyst to accelerate the placement process later. In effect, there are quite a few other links, relating to the significance of the grid, the rows, columns and squares in the game (see diagram no. 18).

Diagram no. 18:

Sudoku as a network

81 participants (cells) interconnected in 6,400 intermediate direct or indirect connections (80 × 81)

(Demonstration from: Sudoku 4 x 4 Web, 2011)

5		3		9	6	2		4
	1			4				8
8			2			3		
7	4			2			8	
1				5	3			9
	2			6			7	5
		2			9			7
6				3			4	
9		1	6	7		8		2

Defining and protecting the boundaries of organization safeguards and strengthens it. Every node in the organization has a high or low capacity to constitute a catalyst for other nodes, or to prevent the transmission of a particular communication through the interconnections. We already saw in the previous chapter that self-catalyzation can spur 'self-organization'. Thus, independent entities can be changed, expanded or downsized, similarly to business mergers and splits.

Types of networks and their vulnerability

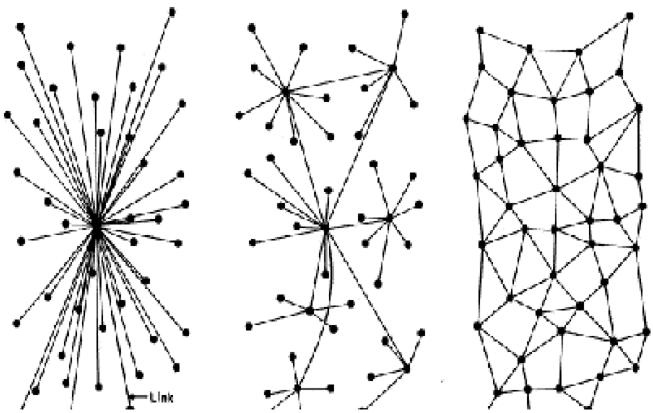
There are various types of networks, and diagram no. 19 presents three examples from right to left: a distributed network, similar to a lattice; a decentralized network; and a centralized network. The type of network has implications on its survivability. The more distributed it is, the less vulnerable, and the more difficult it is to destroy (to cause the system to reach a state of a failure), and vice versa. The more centralized a network is, the easier it is to cause it to collapse by damaging any of its key objects (see discussion by Barabási, 2004, pp. 193-196).

The issue of the vulnerability of networks is becoming increasingly significant: a teenager succeeded in exploiting the vulnerability of the mega-corporation, yahoo.com, by causing hundreds and thousands of computers in the worldwide web to send a brief message at precisely the same time to the company’s website, and caused the system to collapse; in the 1990s, an electricity network in North America collapsed due to a brush fire. The fire caused the disconnection of a single cable between two electrical poles in the energy network of Canada and the United States. The cellular network in Israel collapsed in its early days after terrorist attacks, since it was unable to cope with the volume of calls. The more networks become dominant factors in our daily lives, the greater the impact of the collapse of one of them on our routine schedules.

Diagram no. 19

Types of networks

(from: Barabási, 2004, p. 195)



Centralized network Decentralized network Distributed network

Characteristics of networks

The studies of Albert Lázsló Barabási led to some very significant differentiations regarding the characteristics of networks, which only in recent years have begun to impact spheres of research:

- **Networks are found in all spheres of life and society**: in biology, energy, ecology, in highway networks, railway networks, airports, seaports, in transportation canals, in military and civilian communications networks, in satellite networks and in information. The field of information networks facilitates our understanding of social networks in a new way for the first time, a topic we will be discussing later.

- **Networks are constantly evolving and changing** – in each of the networks mentioned above we can see the addition of hubs in the network, the addition of links between the hubs, on the one hand, and the disappearance of other hubs and links, on the other hand. Examples are plentiful: the toll highway, 'Route 6', changed the national transportation landscape in Israel; so did the addition of suburban routes to Israel Railways; the opening of an international airport in Nevatim is just a matter of time, as is the closing of the Dov airport in Tel-Aviv; the emergence of the *Hezbollah* added a hub in the global terrorist network – its entry into the political arena in Lebanon added a hub to the Lebanese political system and could, in time, eliminate a hub from the map of terrorist organizations; this also applies to the *Hamas* and the Palestinian Authority; military networks are upgraded in step with technological developments, which have transformed the battlefield into an arena that radically differs from that of the 20th century, etc.

In his book, “Operational Art, Emergence of Military Excellence” (2001) Naveh reviews the Russian civil war as marking the emergence of military systemic thinking. He describes the integration of fronts conducting combat operations as independent commands, on the one hand, and the centralization of the strategic control under the political echelons, on the other hand (*ibid*, p. 153). If we translate this description to networks theory, we may draw a network in which the objects it includes are the military command, the political echelon and the enemy. What is fascinating about this network is its dynamic. It can indicate all scenarios that may characterize the relations of the political echelon with the military echelon, and of both with the enemy. The case that Naveh describes is one of the channels in the network. He describes a situation whereby the generals are free to initiate offensives against the enemy without the delays caused by the political echelon; which is released from having to occupy itself with operational details and can focus on its principal function – to win the war. The network can also describe the opposite scenario, whereby a perturbation in the interconnectivity between the political and military echelons would disrupt communications and cause problems on the battlefield.

- **Networks are scale-free and are not random** – for the most part, the networks we are discussing have no characteristic node and no defined scale. In this regard, Barabási (2004) states that:

> *In a real network, there is no such thing as a characteristic node. We see a continuous hierarchy of nodes, spanning from rare hubs to the numerous tiny nodes. The largest hub is closely followed by two or three somewhat smaller hubs, followed by dozens that are even smaller, and so on, eventually arriving at the numerous small nodes.*
>
> (Barabási, 2002, p. 70)

"Fishermen's nets," for example, are exceptions. Since the distribution of the number of edges/events to each node/state is equal or nearly equal, this network is random and a characteristic scale may be described for it. In random networks, most of the nodes have a similar number of links. For example: roadmaps in large countries: the number of entrances and exists to, and from many relatively big cities is similar.

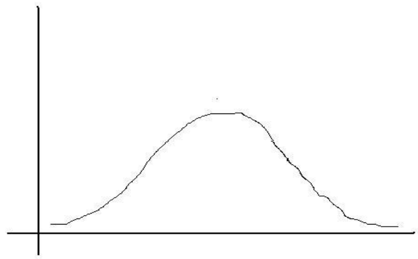
The distribution of this phenomenon in statistics is presented in a curve called a "bell curve" (see diagram no. 20, part a.). This curve presents a state in which most of the events are clustered around a particular value (like: the number of entries into cities; the height of adults; pupils' grades, etc.), while only a few events are clustered around a number of characteristics having different values at both ends of the scale. For example: if we measure the height of human males, we find that most are at the height of between 1.70 to 1.80 meters – they will be concentrated at the center of the bell. Only a few of the males will be taller than 1.90 meters or shorter than 1.60 meters – at the edges of the bell.

Another phenomenon is presented in Poisson's curve (see diagram no. 20, part b.). In this curve, the majority of the events are clustered around a particular value, like in the bell curve, but here, the other events are clustered only on one side, that of the largest quantity in the scale. The "Poisson Distribution" is useful in describing numerous phenomena in nature, society, etc. For example, the number of atoms that decay in a radioactive substance during a given interval; or the

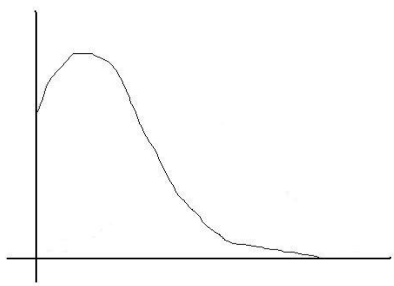
Diagram no. 20:

Types of statistical distributions

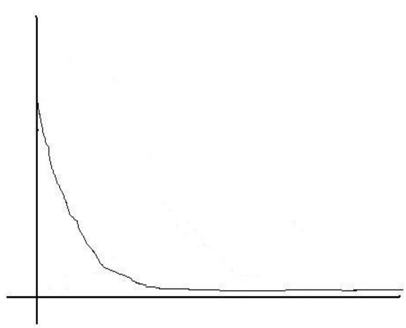
a. ***Bell curve***



b. ***Poisson curve***



c. ***Power Law***



number of automobiles that pass through a particular point on the road during a particular interval, etc. (Wikipedia, 2011).

Diagram no. 21 illustrates a different situation. It depicts the network of airports in India, where one can clearly see that a tiny number of nodes have the largest number of links. We can similarly draw maps of the airports in Europe and the United States, which developed very similarly to the structure described above. This distribution is in line with the power law (see diagram no. 20, part c.), which differs from the distribution known as the bell curve and the Poisson curve. That is to say, the vast majority of nodes have low interconnectivity, while only a few nodes have high interconnectivity (hubs). Barabási wrote the following in this regard:

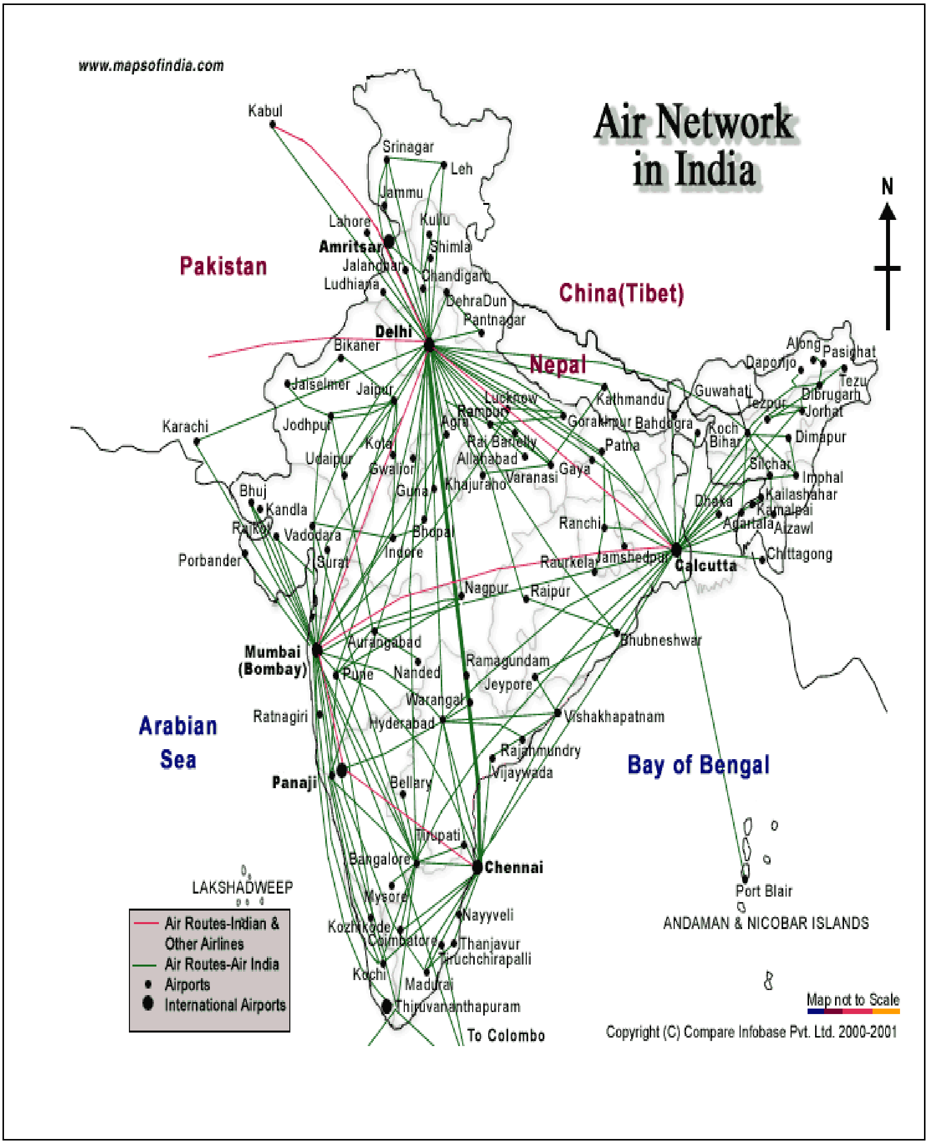
> *The surprising discovery of power laws in the Web forced us to acknowledge the hubs. The slowly decaying power law distribution accommodates such highly linked anomalies in a natural way.* ***It predicts that each scale-free network*** [emphasis added: ER/PY] *will have several large hubs that will fundamentally define the network's topology.*
>
> (Barabási, 2003, p. 71)

The nature of the distribution of many networks analyzed in Barabási's studies relates to the power law. The unique 'exponent' (the parameter) that characterizes the 'power law' is a business, organizational or social parameter, such as an increase in the crime rate. It is the source for the emergence of a nonrandom network, which is also scale-free. The 'exponent' affects the numerator and the

Diagram no. 21:

Air Transportation Network in India

(from: India Map Store, 2011)



denominator in the equation that comprises the index, just like increasing police patrols and/or handing down harsher sentences in the instance of an increased crime rate can affect the crime network's behavior (Barabási, 2004, p. 96). The childbirth network in China is not growing at the threatening pace that it previously had, due to a change in the index of the number of children per family. In Israel, for example, the birthrate may be constrained, and by doing so, would increase the number of ultra-orthodox Jewish families and Bedouin families who live above the poverty line. The National Insurance Institute could grant children's allowances for the third and fourth child only and at higher sums, and not pay any allowance for additional children. Thus, a single law (affecting the exponent) can have a significant impact on an entire system.

The existence of a limited number of major events alongside a great many small events constitute, under crisis conditions, the source of networks' unique power. The fact that the network is not based on a single hub prevents its neutralization in the event of the collapse of one of its hubs. The network will collapse only if most of the critical nodes are neutralized. These breaking points are calculable [see Barabási's calculation of the breaking point in a number of networks, (Barabási, 2004, p. 161)].

- **Every network constitutes a constituent part of a larger network** – this characteristic refers to two areas:
  One area is the scale-free network. That means that it is located in an environment characterized by dynamic frameworks with

which it interacts. The environment that includes the network is also a network. For example: the protein network is located in a cell, while the cell itself is an organ constituting a part of the network of the human body; the network that represents a school is included in the regional network of schools, while this network, on its part, is included in the network of a type of education, which, in turn, is part of the overall network of the educational system.

The second area is the interaction between the large network describing all the possibilities existing in it, and the small network contained in it, and is the direct object of our attention. For example: when we are addressing logistics problems in a given organization, the small network is the organization’s logistics network, while the large network is the network of the entire organization. Every action in the small network has certain implications on the large network and vice versa. This fact is important when constructing a model for a future applications solution.

- **Networks are characterized by levels of interaction and content** – although the level of interaction between us, and a mailman of the postal authority is usually low and flows in one direction only, nonetheless, it is very efficient; the networking between us and the electric company is also unilateral. The electricity network supplies electrical energy to every home and enterprise. Consumers 'draw' the quantity of electricity they need (the content) from the electric pole closest to them. The pole usually receives the electricity (links) from one source only. On the other hand, large consumption centers, like factories, in which expensive processes entirely depend upon a steady supply, will generally rely on an additional source, like a generator or a competitor’s electricity network.

An entirely different network is the internet, which provides a number of types of content, such as: voice, music, image or letter, transmitted from many diverse sources (links). The message arrives in bits, which are transmitted in a variety of ways between both ends depending upon loads and volumes.

While energy is usually transferred at a fixed volume (electricity, for example), information in all its diverse forms can move through the network via image in a variety of different resolutions (number of pixels) in a variety of possible ways. Communication between two people is expressed by the quality of the communication and the quality of the interpersonal message being transmitted through the network.

An airport network can, on the same time, constitute a working tool for control towers and a planning and control tool for airline companies. It can provide vital information simultaneously to the network of airline ticket marketing companies, and more.

At each tier, we expect to receive information about the level of the links and about the content in them, according to the various user needs. For example, information about traffic conditions enables us to decide to take alternate driving routes.

Content visualization – in recent years, researchers all over the world have been devising ways to visually depict information flows in networks. A number of scientists at the University of Arizona in the United States developed a program called "Graphael". This software is capable of inputting information, processing it in the form of networks and generating a visualization of the interconnectivity between agents. These networks facilitate our understanding of the nature of the systems they depict and enable processing and use of the information in the preparation of simulations (Forrester *at al.*, 2005).

Scope of the information flow – oftentimes, the most critical aspect in a network is the level of the information flow among the agents, and not the strength and power of the agents. Prior to the terrorist attacks in the United States on September 11, 2001, the U.S. security services were zealously possessive of their information. Each service operated separately, and it was impossible to assemble the overall picture from the various pieces. Ironically, it was a weak link in the network – the passengers on the hijacked United Airlines flight, no. 93, to San Francisco, who had learned about the crashes in New York via their cell phones and figured out the hijackers' intentions – that thwarted the terrorists' mission. At the price of their lives, the passengers caused the plane to crash in a field in Pennsylvania, far from the terrorists' presumed target – probably the White House (fxp Web, 2007).

- **Networks develop powerful centers and a few dependent subcenters** – the parameter that dominates the system's pattern of behavior influences the self-organization of the nodes and hubs. For example: casinos or free-trade zones increase the prospects that the real-estate prices at a particular junction will rise as a result of the highways and airports they construct nearby.

  Las Vegas, the U.S. city founded 100 years ago in the Nevada desert, whose growth strategy was based on legalized gambling, eventually turned into a tremendously powerful center for money laundering, an unexpected parameter that made many people (nodes) dependent on it. Within a single decade, Las Vegas burgeoned into a major city and has shown steady growth ever since.

  A minister responsible for an important portfolio in the government naturally has connections with many networks through which he amasses power and influence;

  A senior ministerial assistant, who controls the minister's calendar and the access to the minister's chamber, also possesses a considerable power, since he controls the interconnectivity between the minister and the citizenry;

  The power of Tel-Aviv as a central node controlling infrastructure budgets and routine operations enables it to prevent hundreds of small towns and regional councils from developing;

  The infrastructure budget to expand just a tiny section of the Ayalon highway far exceeds the aggregate of most of the other highway budgets in the network.

The transfer of a few foci from a 'node' that has become too concentrated will help to prevent damages (a network crash or segmentation of the network into a few networks). Is it possible to describe the hierarchy of Israeli networks after two power centers are shifted from the center, such as relocation of Tel-Aviv University to Ariel, and the I.D.F. General Staff and the Ministry of Defense to Be’er Sheva?

- **Networks are rigid and flexible** – scale-free and nonrandom networks are, by nature, rigid and durable against possible systems failures. At the same time, they are flexible, which enables them to operate under the most extreme conditions. Failures do occur, but they are abnormal, contrary to the norm, and their vulnerability is only partial and temporary. The collapse of a number of major airports in the United States will not cause the entire aviation system to crash. The crash of the electric company in North America was atypical in its magnitude, and in the damage that it caused.

  It turns out that Nature’s creations, as well as man-made systems, primarily strive to extend their lifespan:

  The DNA chain (see diagram no. 22), which is responsible for the reproduction and continuity of all living organisms, is constructed from only 20 amino acids, which bond in a myriad of possibilities;

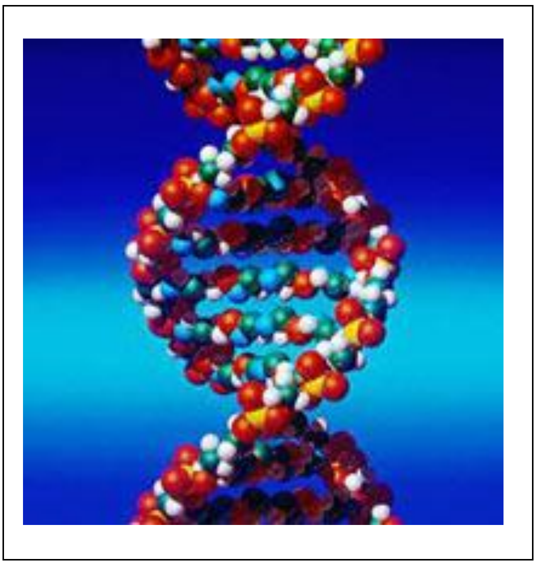
The network of global ecological interconnections has a similar structure.

Both these networks absorb shocks, but they only rarely go berserk or crash. One story of a 'crash' is the biblical story of the flood, which depicts a chaotic state, when Noah rescued pairs of animals of the same species in order to ensure the continuity of life on earth and its ecological environment.

Diagram no. 22:

The DNA chain striving for survival

(from: NOVA beta, 2004)



Then, of course, there is also the human neurological network, which reaches all cells (as input) and the network of bones and muscles (as output), whose response rate is at least as good as that of the internet. All of these networks are spread out in their environment in the most effective way. The initial ones were constructed over billions of years, while the latest ones over a mere decade. The evidence of networks' rigidity and flexibility is the fact that the disappearance of populations in nature or of man-made business corporations and countries is uncommon, excluding instances of negligence in adapting to the environment by the networks themselves (poor corporate management, for example). Only when the food and energy chain to the dinosaurs was broken at a particular stage did they become extinct. The network of neighborhood grocery stores has also been shoved in a corner and has nearly disappeared, due to the attraction of more powerful hubs in the food network. The few cases only prove that most networks are usually stable.

- **Networks' potential is revealed by graphs** – networks may be depicted graphically, and as stated, visualization facilitates human comprehension. Graphical view can provide insights that reams of data and information cannot convey as clearly and easily. Visualizations also facilitate experiments to test possible modes of action in real time. Visualizations allow many dimensions to be added to a single picture. Diagram no. 21, which maps aviation routes in India, simultaneously illustrates a variety of topics, such as:

- The key airports – which airports are the major ones, which airline companies use them, etc.;
- Aviation routes – which routes are the most congested;
- The network's weak points.

This tool is used, for example, by factory designers, who use network visualizations to depict plant processes. Urban planning underwent a complete transformation about two decades ago, when it became possible to use computers to construct a single map showing all infrastructure networks, such as: highway arteries, the sewage system, the telephone, electricity and gas networks, and other municipal infrastructure networks.

Professor David Harel devised, in 1987, the language of state diagrams, called "statecharts"– the unified modeling language (UML) known worldwide as "Harel Charts." These diagrams simultaneously integrate process networks and diagrams (of hierarchy, communications, etc.). UMLs have become one of the most applied utilitarian theoretical tools for handling the complexities of major software systems. Harel was awarded the Israel Prize for his invention, and the judges' rationale behind their decision was as follows:

> *Harel's major research achievement in terms of the scope of its impact on the academic world and on the industrial world is in the discipline of software engineering and systems engineering. Leading software systems contain millions of lines of code, the complexities of which exceed the capabilities of a single programmer or a group of programmers, and cannot be*

> *constructed without tools. The same applies to major complex systems, such as the navigation and control system of modern aircraft ...*
>
> (Gal-Ezer, no date)

Win van der Aalst and his colleague, Minseok Song, succeeded in describing a number of simple equations in a nearly applicable way. Using data mining, ratios may be calculated in these equations and used in simulations that maximize the achievements of models describing the following metrics: closeness, centrality, “betweenness,” emission, determination degree, and sociometric states (van der Aalst and Song, 2004).

This approach towards using visualizations of organizational structures and processes is still in its infancy and is far from exhausting its latent potential.

Networks' Research

In recent years, substantial progress has been made in the study of networks. The focus of the studies ranges from small graphs in which man is represented as a node, to major graphs with quintessentially statistical properties. The evolution of the power of computerization enables vast quantities of information to be collected and analyzed. While in the past, networks of dozens to hundreds of nodes were studied, and the sheer volume of work and hours required were not conducive to fast breakthroughs, today, a study of networks containing thousands or even millions of nodes can be completed quite rapidly.

The focus of such studies has also evolved. From the question: "what has the most critical impact on the network?" the studies proceeded to the questions: "What percentage of nodes which, if removed from the network, will affect the system in a certain manner" or "What are those critical nodes which, if removed, will cause the network to collapse?" (Barabási, 2004, p. 159).

While it used to be possible to analyze small graphs using paper and pencil, today, the major networks are so complex that direct visual analysis is impossible. Therefore, a variety of statistical tools have been developed that are tailored to this type of analysis of complexity, including those that replace the human eye and brain. These statistical tools answer the question: "How can we understand the implications of a network without being able to see it?"

The "Small-World Effect"

According to Barabási, a Hungarian author by the name of Karinthy was the first to propose the concept of "the small-world effect" in 1929, in his book *Chains*:

> *To demonstrate that people on earth today are much closer than ever, a member of the group suggested a test. He offered a bet that we could name any person among the earth's one and a half billion inhabitants, and through at most five acquaintances, one of whom he knew personally, he could link to the chosen one.*

(Karinthy, quoted by Barabási in "How Everything is Connected to Everything Else and What It Means for Business, Science and Everyday Life – Barabási, 2003, p. 26)

Barabási (2003) relates that, 30 years later, Stanley Milgram conducted an experiment whose purpose was to find the "distance" between any two people in the United States. He did this by choosing two target people and sending letters to a number of people who were asked to relay the letters to the target people through people whom they know. He discovered that the median number of intermediate persons was 5.5 – a relatively small number and remarkably similar to Karinthy's proposal. The famous phrase "six degrees of separation" was coined later, during the 1990s, in a play by that name who conveys the same concept. The notion of six degrees of separation says that, notwithstanding the society's enormous size, humanity is, in effect, a small world. Each of us is at a "distance" of six handshakes from every other person. Studies in recent years have shown that the "small-world effect" characterizes many other networks, and not only the human social network (Barabási, 2003, pp. 29-30)

Hubs

Random networks are relatively homogenous and are characterized by the fact that all nodes are similar and each of them has on average the same number of links. In networks that characterize the real world, the situation is different. Barabási (2003) describes a study in which he and his colleagues mapped all web pages and the links connecting them. They discovered that for 90% of the web pages, there are only up to 10 links. Only a few web pages won the majority of 'hits', and Barabási calls these dominant nodes by the name 'hubs' (Barabási, 2004, p. 77). If the internet had not been a random network, the chance of there being a page with 500 links would be nearly zero. The significance is that hubs do not develop in random networks. Hubs control networks and cause them to look like a small world. They create short pathways between nodes in the network. Hubs appear in networks in all disciplines, and have rigid mathematical laws.

Summary

In his book, *Linked: the New Science of Networks*, Barabási (2004) calls the 21st century “the century of complexity” (*ibid*, p. 294). According to him, new discoveries in the field of network science provide a new perspective on the linked world around us and point to the fact that networks rule the 21st century, to a greater extent than many are prepared to admit. Networks are everywhere; we only need to adapt and see them. They are what will be leading the central issues that will be designing our perspective of the world.

In the field of networks, more is hidden than is visible, and we can only guess what reverberating discoveries are latent in this field (Shachar and Arzi, 2005, p. 9).

* * *

This chapter reviews the gist of networks theory, the types of networks, their characteristics and properties. It is based on Kauffman's NK model, which enables complex systems to be translated into a network. Using the examples presented in the chapter, it is evident that networks have taken control over many facets of our lives.

One of the major advantages we received from the computer revolution is the field of visualization. This field enables us to visually discern things pertaining to complex systems theory that previously we would have lost sight of. The main tool for visualization is networks theory, while the computer helps us to overcome the problem of the tremendous complexity of networks.

Once we have a grasp of complex systems theory and the tool that provides us with networks theory, we will try to apply this knowledge to organization theory and present ideas for a new management approach.

Chapter Six

The Need to Adopt a New Paradigm

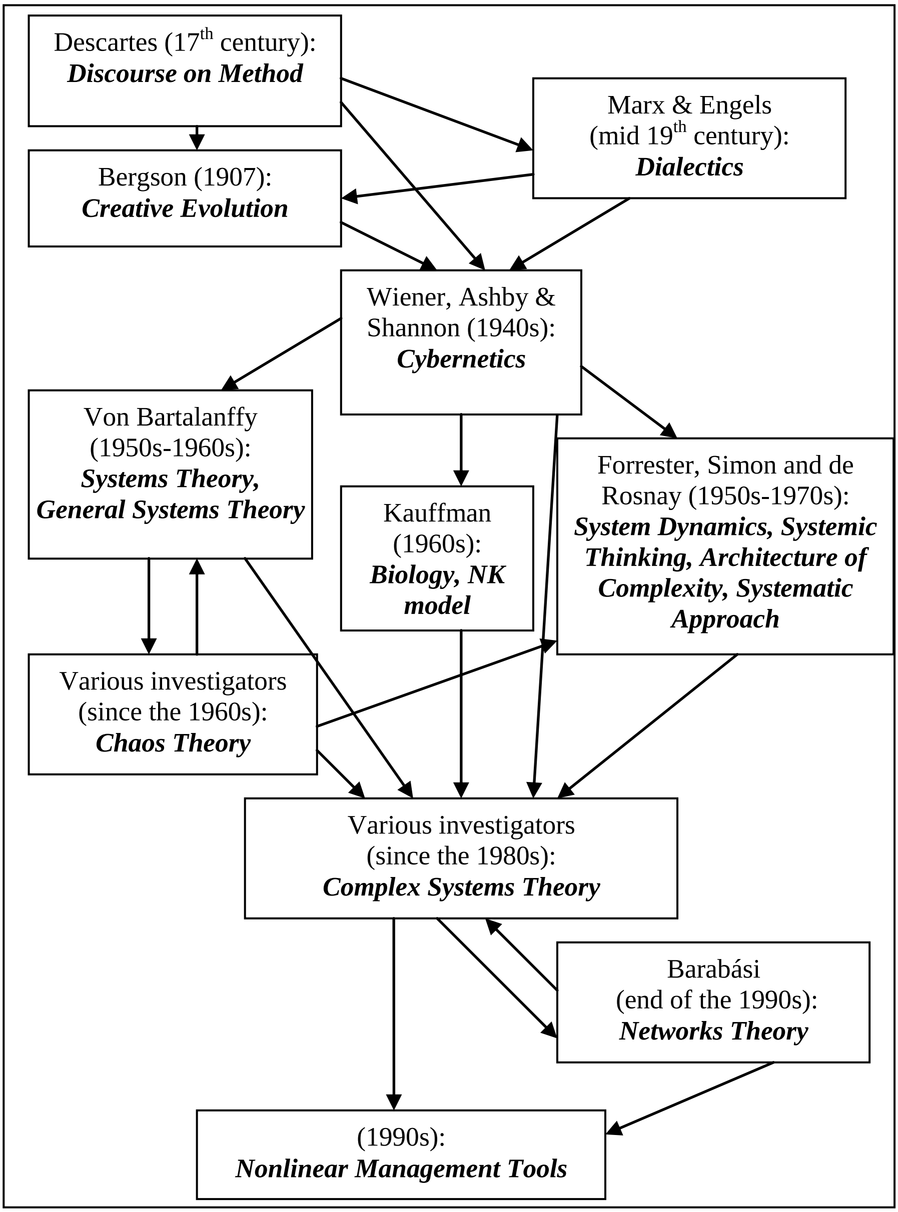
Up to this point, this book has presented the salient points of 'Complex Systems Theory' and its theoretical origins; 'Networks Theory' that had been developed only recently; and a few aspects of 'Chaos Theory' that preceded both.

The purpose of this chapter is to summarize the evolution of the theories over the last century and, through them, to impart an understanding of the dramatic changes in the reality of our lives. In this way, we will illustrate the need to adapt the paradigm used by organizations to the realities of life and to the new theoretical reality.

The systemic methodology's evolution – summary

Diagram no. 23 summarizes the evolution of the theories using the tools discussed in this book. The diagram lays out the various theories on a network and draws the pathways interconnecting them. Thus, we can visualize the evolution of theories from Descartes (*Discourse on Method*) and the dialectics of Marx and Engels, through the 'Cybernetics Theory' of Shannon and Ashby, the 'General Systems Theory' of von Bertalanffy, the 'Systems Dynamics' of Forrester, 'Chaos Theory', 'Networks Theory' and up to 'Complex Systems Theory'.

Diagram no. 23:
Evolution of systemic methodologies, from Descartes to the threshold of the development of nonlinear management tools



Adapting the existing management paradigm to the theoretical evolution

The wide-scale developments in the theoretical arena warrant adaptation of the existing management paradigms to the evolving reality and to the evolution of theories in the wake of these changes.

Diagram no. 24 depicts the routine management process: we use the implementation tools deriving from our adopted paradigm in order to carry out the organization's functions and obtain results. The discrepancies between planning and execution pose dilemmas, that make us adapt the tools in order to close the gaps (between planning and execution) and be efficient.

The linear paradigm relies on a defined connection between cause and effect. It views an organization as structure and content, determined to achieve goals, while maintaining equilibrium. Ultimately, it is measurable quantitative results.

The paradigm was developed through a deductive process, as the science developed. For example: the study of molecules led to the study of the atoms comprising them, and when the atoms were cracking, the electrons, neutrons and protons comprising them were discovered.

The problem is that using a linear paradigm in a world of complex systems creates dilemmas that apparently cannot be resolved within the scope of the existing paradigm. In numerous disciplines, the linear tools have already been tapped to their maximum, and we are incapable of fixing all of these implementation tools (in the same way that railroad tracks installed for diesel trains are compatible for trains travelling only up to a certain speed. They are no longer relevant for the trains in Japan and France, whose speeds are too fast for them). In order to cope with dilemmas in an efficient way, we need to adopt a new paradigm that is inductive and holistic in nature, a paradigm that is more suitable to reality. From this paradigm, we need to derive implementation tools and vice versa. The adoption of a new paradigm will be, for us, a quantum leap, because this time, it is not an issue of increasing organizational efficiency by a few percentage points, but rather, increasing efficiency by tens and sometimes even hundreds of percentage points (see diagram no. 25).

Diagram no. 24:

Routine management process

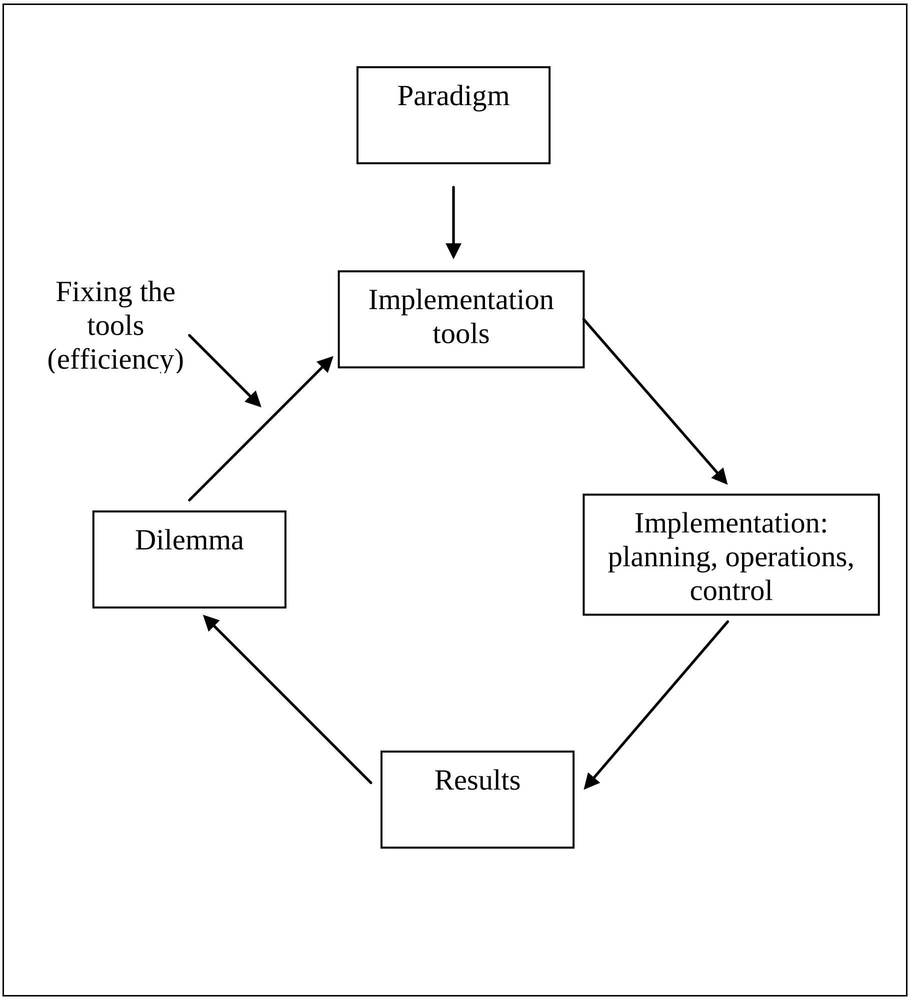
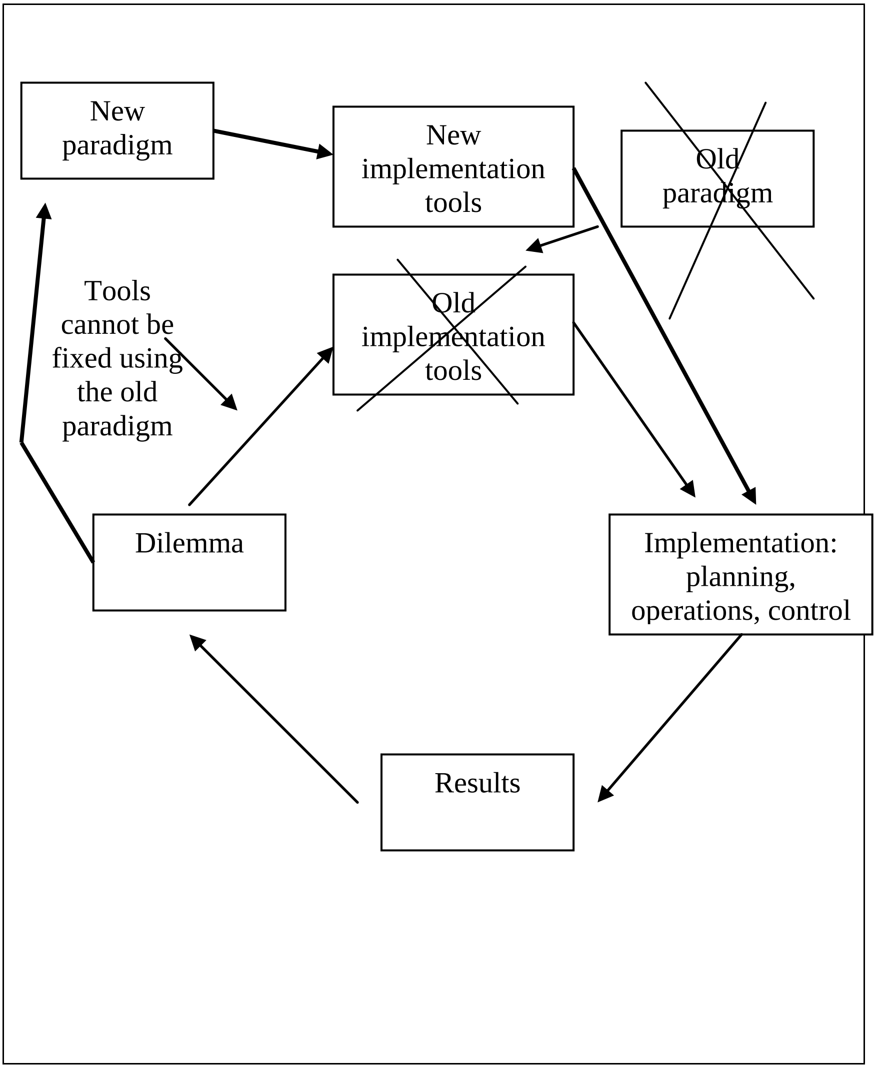


Diagram no. 25:

Adopting a new paradigm



The nonlinear paradigm is based on the following assumptions: that event can develops in a spectrum of unforeseeable possibilities; that unique events transpire at a low frequency; and that the level of interconnectivity between those parameters influencing events has an impact on their development. This paradigm has been evolved in an inductive process opposite to its antecedents. It was focused on interdisciplinary studies and has a comprehensive, holistic perspective, which constitutes the fundamentals of its approach.

The paradigms are represented, of course, in additional aspects that affect thoughts and actions, but, for the purposes of our discussion, the above will suffice. The scientific approach, such as mathematics, which supports the first paradigm, is already existed. However, the approach supporting the new paradigm is still in its infancy. It is not necessarily more complicated mathematics, but rather laws, some of which have not yet been sufficiently resolved.

After we have presented here the fundamentals of the various theories ('Chaos Theory', 'Complex Systems Theory' and 'Networks Theory') and their historical basis, a few questions arise: What are the implications deriving from their integration? What opportunities will they pose for us? What risks, if any, derive from developing them?

The greatest challenge facing us today is to derive a nonlinear management tools from the new scientific thinking, which will enable us to correctly navigate organizations in a dynamic reality. If you prefer, this is a progression of Forrester's attempts in the 1970s. The unsophisticated computer capabilities and the lack of programming capabilities in order to 'translate' the 'Systemic Dynamics' for application by social sciences, detracted from Forrester’s research.

The impact of the changing organizational reality on management

The tremendous development in the field of theory helps us to better understand what the primary dilemmas are, which impose dynamic environmental conditions on organizations operating such an environment.

At the outset, we can presume that a number of trends will apparently accompany us in the coming period:

- The current disruptions in organizations will increase as a result of one or more key parameters 'escaping' from the 'path' expected of it. This is a basic effect in complex systems.
- Technological systems, including information fields, will penetrate markets at an accelerated speed. Optimization of organizations will derive from improvements to efficiency (improvement by a few percentage points) to upgrading of effectiveness (improvement by dozens and even hundreds of percentage points, as a result of a quantum leap). The interconnectivity among organizations in the future will differ from those existing today.
- Distribution of the income and the value for human capital will undergo a change to increase the ratio of satisfied participants. A

company as a whole will not be able to accept the current low rate of the human factor's contribution to the global product. The widening gap between the poor and the wealthy will create substantial pressure to bring about a substantive increase in the number of employed persons earning an adequate income.

- Suitable solutions will have to be found for the energy crisis and its ecological effects; otherwise chaos will reign over humanity.

According to our assessment, during the last two decades the management world has been faced with dilemmas deriving mainly from excess information, when the conditions for converting that information into useful knowledge have not yet matured. Another reason for the dilemmas is the use of management tools that are linear in nature, in an extremely dynamic, rapidly changing reality – a nonlinear reality.

We will focus on five of the main dilemmas:

- Availability and accessibility of knowledge to consumers;
- Optimization of "subsystems" versus optimization of the "supersystem";
- Short-term optimization versus long-term optimization;
- Management's need to function effectively under the constraints of a multitude of relevant elements;
- Optimal motivation of the human factor.

Knowledge availability and accessibility to an organization's consumers

The first dilemma addresses – the availability and accessibility of knowledge to an organization's consumers (knowledge management), which are a precondition to attaining organizational effectiveness.
Every organization, and particularly a new organization, requires know-how in fields relevant to its operations. For example: the "disengagement administration" – which had been set up for the purpose of rehabilitating the evacuees from the Gaza Strip and northern Samaria during the summer of 2005 – needed know-how relating to be real-estate; historical lessons learned from the experience with the evacuees from Yamit; the lessons from the absorption of Jewish immigrants from the former Soviet Union about 15 years earlier; and the like.

It is important to understand the difference between information and knowledge (the significance of the information). In many instances, we will possess a great deal of information, but we will not have the tools to convert it into knowledge. Organizations differ in their ability to extract knowledge from existing information. This difference stems from the organization's motivation to extract knowledge and its objective ability to do so.
In order to clarify this dilemma, we will reiterate that, as the environment becomes dynamic, yesterday's knowledge becomes increasingly incompatible with the knowledge required tomorrow.

Following are three additional examples of the conflicts facing managers pertaining to information and knowledge accumulation:

- How much information should be retained? This is a conflict between short-term retention of a large volume of information and the retention of a limited volume of vital information for the long run.
- How much should be invested in extracting knowledge from the information stored in the company? This is a conflict between focusing on the storing of a great deal of information at the expense of converting it to knowledge, versus placing the priority on converting information into knowledge and building up knowledge.
- Should we invest in the knowledge gleaned from the information retained at the company in a very dynamic reality, or should we develop and/or purchase new knowledge having different approaches?

The classic example is the Israeli intelligence section's assessments prior to the *Yom Kippur War*. There was an over-flow of information, but the wrong conclusions were drawn, due to misinterpretation.

Another example is the fact that armies, like, for example, the armies of France and Great Britain during the Second World War, often have the tendency of going to war equipped with the combat arms and battle management strategies of the previous war.

Sometimes, the knowledge that is required does not derive at all from knowledge that we are capable of accumulating. For example: the IDF, which had to contend with four years of confrontations with the Palestinians between the years 1987 and 1991, had been forced to cope with new combat characteristics. Its ability to draw on knowledge from previous wars about this type of combat was extremely limited.

For years, researchers have been competing with each other to find a breakthrough on the subjects of memory, learning and comprehension processes in the human brain. Knowledge emerges from the interaction between the free agents in the brain. The more dynamic man's environment became, the faster the human body's responses had to adapt to new situations. Therefore, the brain increasingly depends on the acquisition of new knowledge, shortly after the emergence of each new situation.

The achievements in computer research of the past decade received expression of powerful computing capability in computers. They were intended to serve the purpose of knowledge processing, but this ability has not yet reached consumers in the form of professional tools. Furthermore, the assumption that focusing on the acquisition of a larger volume of information will eventually provide knowledge has also not been proven to be a correct one.

It is possible that, in the final analysis, it will be proven that, in this context too, there is no direct relation between input and output, and it will be found that less information is required for more knowledge.

This possibility contradicts the clear interests of computer, data processing and consulting companies, who want to take advantage of the “inflation” in the supply of information services and to 'push' it on consumers who have not yet been exposed to. Unlike such companies, who lack foresight, IBM – one of the pioneers in computerization, which already proved its capabilities in adapting and adjusting itself to changing market conditions – prepared the groundwork for a new age. According to IBM’s assessments, consumers would need less information that is irrelevant to effective management, and therefore, less computer equipment, fewer maintenance services, and more knowledge management services.

Optimization of the “subsystem” versus optimization of the “supersystem”

The second dilemma arises due to the conflict created between the subsystem in a complex organization, which tries to optimize itself, and the need to achieve optimization of the entire system.
Organizations’ goals in their 'organization environment task' can differ from the 'Ultimate Goal' of the system; for example, in the overall systemic battle against violence between spouses. The Israel Police defined the arrest of violent couples as a criterion of optimization (of a subsystem), while the criterion for optimization of the entire law enforcement system had been “stopping the abuse of the victim.” These two criteria were contradictory in extreme cases. Precisely, in the most serious cases, when at issue are a violent couple suffering from a mental disorder, the police arrest is liable to act as a catalyst

for one of the spouses to commit murder (Yehezkeally, 2002). That is the reason why the police had to adopt the criterion of the "supersystem" (that of not making an arrest in cases where there is a concern that it might lead to exacerbation of the abuse), in order to be more effective at stopping the abuse.

Short-term optimization versus long-term optimization

The third dilemma emerges from the need to decide between prioritizing and investing in urgent, short-term matters and investing in long-term essential matters.

We will use an example relating to the economics of constructing an interurban road, refers to three criteria: cost, duration and financing.
One alternative is to construct the road in sections each time that a budget becomes available (short-term), as Dimona – Be'er Sheba road was built, for example, over the years. This alternative resolves problems of short-term financing, but, in the long run, will cost far more and take far more time than the other alternative.
The second alternative is to invest the entire sum at once (long-term).
This alternative will be less costly and take far less time, although it requires a major capital recruitment of the entire financing.
Business corporations make little use of tools for dynamic analyses of complexity, which would compare the benefits of two alternatives. Usually, business corporations fail to conduct comparative analyses at the necessary depth, since their perspective is clouded by personal

values and they rely too heavily on intuition. Social organizations make no use whatsoever of such tools.

Our first example of the dilemma of short-term investment versus long-term investment is from the field of Planning: should a four-lane highway on a busy transportation artery be planned in advance, in line with the long-term needs (global optimization), or only a two-lane highway, due to the short-term budgetary constrains (local optimization)?

A second example is from the field of Operations: if we manufacture identical volumes during fixed timeframes, we will cut the per-unit manufacturing costs; however, this will increase the inventory cost. Thus, a local conflict arises between two subsystems within one supersystem. On the other hand, handling of the conflict in terms of global optimization requires a dynamic comparison of both alternatives and a periodic shift to the least-expensive alternative, according to the prevailing market conditions.

Another example is when the State Comptroller considers two alternatives: to conduct an in-depth investigation of one ministry (local optimization) or to make a show of his oversight role by conducting shallow audits of a number of government ministries at the same time (global optimization). The state comptroller, who took office at the end of 2005, Judge Micha Lindenstrauss, illustrated this dilemma, de jure and de facto when, contrary to his predecessors, he preferred the second alternative. He conducted focused audits of a great number of government ministries simultaneously.

Management's need to function effectively under the constraints of a multitude of relevant elements

The fourth dilemma pertains to management. How can the organization function effectively in a wide range of planes of reference simultaneously? These planes of reference include the interrelations (the in-house relations), and the organization's relations with outside sources operating in the organization's task environment.

Management activity may be described as a system in the form of a dynamic network of effects and feedback among four planes of reference: "*result*," "*problem*" (discovered in the result we obtained), "*cause*" (that led to the problem), and "*selection*" (of a mode of action to resolve the problem and enhance the system – positive feedback). Naturally, each of the elements has myriad possible modes of action, to the extent that this magnitude of permutations of possibilities becomes uncontrollable and requires a new applicable solution.

Analyzing all the possibilities is costly, in terms of time and money, while a limited analysis will be neither efficient nor effective. Moreover, the myriad possibilities in each of the four planes of reference: "*result*," "*problem*," "*cause*" and "*selection*", and more when they are combined, cannot be analyzed in a in a practical way. Analysis using linear tools, including statistical tools, also does not allow for sufficient openness. On the contrary! many rigid concepts prevent maximum openness, and particularly prevent attentiveness to as many echelons as possible in the organization. Such linear tools and concepts, in effect, minimize the chances of finding the optimal solution.

As a result of all these, in many instances the preferred alternative is selected intuitively or based on probabilistic tools. One can live with such a situation, as long as at issue are inconsequential decisions and events with few dynamics; however, when an organization must take decisions regarding material issues and when highly dynamic events are occurring within the organization and in its environment, a real problem is created. For example: the long-standing conundrum regarding the handling of the “security wall” between the State of Israel and the Palestinian region. Another example is the manufacture of the “Lavi” combat aircraft, whose costs were formidable for the State of Israel. It would have been possible to achieve the objective of developing advanced technologies by focusing on another, less expensive and no less promising field of development, such as various types of helicopters.

Organizational action plans receive expression in annual and multiyear budgets. The budgetary control of many organizations slides from 'order' into 'chaos' during the budget period and by the time that the budget is fully utilized, the planning is completely irrelevant. Despite this fact, budgetary control is still being expressed in terms of comparisons of the actual utilization of the budget and the budget as initially planned. In other words, the basis for the comparison, in practical terms, is already irrelevant. In lieu of such comparisons, perhaps it would be worthwhile to consider comparing the actual utilization with what could have been utilized. This, of course, is a new paradigm that we will not elaborate upon here.

In the 1970s, neighborhood "E" in Be'er Sheva – Israel had been planned as an upper-class neighborhood. A comparison of the planning with the actual performance shows that the planning had been correct in terms of the investment cost; however, in the meantime, a population of affluent residents relocated to satellite communities, such as Omer, Meitar and Lehavim, and the planning and capital investment became irrelevant. In retrospect, it is evident that the planning and subsequent capital investment should have been in completely different directions. Had the neighborhood been planned for single-family construction using the "build your own home" plan, the affluent population might have stayed in Be'er Sheva in general and in the new neighborhood in particular.

The importance of control in engineering and scientific systems is high, relative to its usually low importance in social systems. In the field of operations for example, dynamic updating is awkward for hierarchic organizations. Their control tools are ineffective, and the chances of their identifying problems are slim. Even if these tools do identify a problem, not all the associated problems will be identified and certainly not all the causes of the problems. Obviously, this has a tremendous impact on management's decision-making.

Attempts by many committees to study the causes of social problems will succeed or fail depending upon the management culture of the public bodies. In local authorities for example, which control and affect a very substantial portion of our lives, the control processes have been breached nearly to the point of impotency. The outcome may be seen in the audit reports of the state comptroller. The audit findings reported by the controller "*indicate a long list of deficiencies in the management and functioning of the audited authorities*" (State Comptroller, 2004, p. 7).

Optimal motivation of the human factor

The fifth and last dilemma addresses the leadership of managers in a world of complex systems, as it relates to optimal motivation of the human factor. The status of the human factor in systems changed from the moment we understood that various operations (in sciences, technologies and in organizations) have a common foundation. This foundation may be quantified and processed – information.
Is the role of man steadily diminishing in an age when computer capabilities are being integrated in systems as a substitute for man? The opposite is the case. The more that knowledge is increasing, and deeper levels of information are being accessed (such as the penetration of atoms, and later, their constituent parts, then the deciphering of the genetic code), the more expansive is the human functional space and interpersonal intuition. Consequently, modes of "utilization" of the human factor are steadily developing.

If, according to processes and concepts of the 1950s, a worker was part of the machine (measurement of output per employee, sales turnover per employee, etc.), today, employees should be allowed more real involvement. The higher the employees' involvement becomes, the more significance is attributed to employee motivation. During the last decade, the attempts made to increase employee motivation focused excessively on "extrinsic factors,"[1] mainly on material rewards. It may be that these attempts increase the motivation of a few, but they definitely reduce the motivation of the very poorly paid masses.

The more successful strategy addressed intrinsic factors,[2] such as the implementation of "improvement teams" in organizations, which instituted a rule to *accept* the teams' recommendations. Examples of this exist in Israel in such companies as Israel Chemicals and Teva Pharmaceuticals. It should be noted that this idea is not a new one. Theories about the unequivocal preference of intrinsic rewards over extrinsic rewards for creating employee satisfaction and motivation had been common in the management world back in the 1960s.

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1 The terms "extrinsic factors" and "intrinsic factors" are associated with "Herzberg's Two-Factors Theory" (Herzberg, 1966; 1968). This theory was developed in order to explain employees' attitudes towards their jobs and their work environment. Herzberg emphasized that two types of factors lead to employee motivation and job satisfaction:
"*hygiene factors*" (or maintenance factors), which do not directly relate to the employee's job. These factors characterize the employee's work environment or partts of company policies, such as: salary, job security, physical working conditions, etc.;
"*motivators*", which directly relate to the job that the employee performs, including opportunities for self-fulfillment, personal growth and significant experience, such as: opportunity for achievements, recognition of achievements, opportunity to take on responsibilities, promotions, and the nature of the work itself.

2 See previous footnote.

Example of this includes: Herzberg's "motivators" and "hygiene factors" (*Motivation – Hygiene Theory*) (Herzberg, 1966; 1968).

Management using intrinsic rewards typically characterizes high-quality, professional managements. Such managements are sorely lacking in many segments of civil service, which are tainted, inter alia, by the phenomenon of nepotism in middle and upper echelon job placements. Discriminatory appointments have adverse effects on organizations in a number of aspects: the excessive costs versus poor output; and the impact of a negative management culture that permeates the entire organization. Every "weak" department head in a municipality, for example, causes both short-term and long-term damage that cannot be quantified.

"The Disruptive Innovation" for developing new principles

We view complex systems theory, coupled with networks theory, as a gateway to a new management environment. This environment will know how to utilize the tools provided by these theories in order to develop innovative models and tools for managing complex organizations. The conceptual and practical objective of the beginning of this chapter is to attempt to use these theories and, particularly, the original thoughts of their developers, to derive tools that may be proven on the practical plane. Academic experts and business and corporate leaders have passed through this gateway recently.

The transition from content and concepts to practical recommendations has been successfully accomplished in certain cases.

For examples, see Jim Collins' book, *Good to Great*, which highlights eleven exemplary companies that have succeeded in accomplishing this transition (Collins, 2001, ch. 9, pp. 263-292).

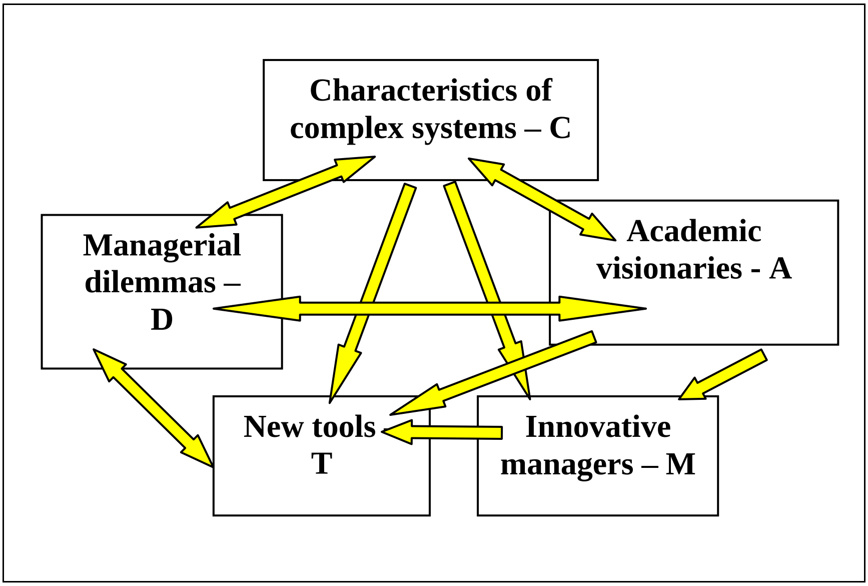
The new management tools that we need relate to interconnectivity. They may be characterized as a network of interactions with the following factors (see diagram no. 26): characteristics of complex systems; people, the leaders of systemic thinking; the managerial dilemmas deriving from the age of complex systems; the organizational advantages of managers at the "spearhead." All of these constitute a starting point for us in the development of the management tools that we need.

The five foci in a network (hereinafter: the agents, objects) interact among themselves, similarly to any communications network that may be characterized. This communication and the information accumulated in the database of the system of network links will later provide the planned transition from a dilemma to an applicable solution.

From among all possible interconnections in a network, the most significant from our point of view are: (see diagram no. 26):

Diagram no. 26

Network for developing nonlinear management tools



- CD link represents the source of the managerial dilemma;
- AC link represents the potential for resolving the problem;
- AM link represents the learning process;
- MT link represents initiative and the assimilation of new tools;
- TD link represents the feedback for analyzing the impact;
- And, of course, the special AD link between the academic visionaries and the managerial problems.

An attempt to construct the network will require the performance of the following operations:

1. Defining the main characteristics of complex systems and the fundamental properties of the networks.
2. Defining a list of managerial problems deriving from the functioning of organizations in the age of complex systems.
3. Selecting a list of sources of the major theorists in the relevant theories, the most influential of whom we have reviewed in this book, and analyzing the concepts relevant to our needs.
4. Identifying innovative managers, who have advanced far ahead of the stagnant majority of "conservative" managers, and assembling and documenting the application or applications that they developed or adopted in their organizations.
5. Characterizing the tools that have been proven to be successful, as well as the environmental conditions under which they operate, and adding them to the database for use in future cases identified as being similar.

Performance of the operations described above requires research far more comprehensive than the scope of this book. However, in our opinion, the insights that may be gleaned from this book should be sufficient to draw a general picture of the management world in the age of complex systems.

* * *

This chapter drew the map of the knowledge-map that gave birth to complex systems theory and networks theory and proceeded from there. The theoretical evolution that took place during the last century enables us to understand the changes in our reality, and to adapt the managerial paradigm to the realities of life, as well as the new theoretical reality.

The chapter presented four principal managerial dilemmas, the aim being to examine the possibility of tailoring a new paradigm to the circumstances, and, later, to examine basic directions of appropriate action.

Additionally, the chapter defined **“The Disruptive Innovation”** as a network that is relevant for developing nonlinear management tools.

Based on all these, in the next chapter we will map out an initial outline for new management principles.

Chapter Seven

Initial Applications in the Field of Management

The essence of this chapter is to formulate the intrinsic values and conclusions drawn from the facts presented to you earlier in the book as a basis for checking into the possibility of the existence of a new management perspective.

For our purposes, we will examine six aspects of the implications of the new paradigm on the fields of management, which are interdependent and mutually affect each other:

1. Structure, content and emergent behavior;
2. Positioning of the organization between chaos and order;
3. Planning and decision-making;
4. Systems operation;
5. Operations control;
6. Knowledge characterization and retention.

These aspects encompass activities that organizations require daily and for their future survivability. Our analysis of these aspects will also address the main dilemmas and sources of possible solutions.

1. Structure, content and emergent behavior

Two issues that are critical to the functioning of an organization are its division into its constituent parts and the number of connections that should exist between these parts. Sometimes redefining the division or the interconnectivity between an organization’s parts (addition or subtraction, strengthening or weakening) can help an organization improve its results (Coffman, 1997b, p. 5, Levkowitz, 2004, p. 10). Of course, other aspects also have a considerable impact, such as the various content being transmitted in the pathways (in the links between the various organizations/departments), and the emergent behaviors and processes formed in and among themselves within the organization, and between them and the links between the organization and its environment.

Transition from depicting the organization as a tree to depicting it as a network

In the 20th century, the diagram used to depict the structure of most companies and organizations in the various fields was 'a tree structure'. This formation indicated authorities and hierarchy. It did not show problems that emerged as a result of various constraints, did not express processes, and represented only organizational rigidity. An example of this may be seen in relation to the automobile plants of the Ford Motor Company – one of the first manufacturing enterprises to implement a hierarchic organizational structure. The production lines were so tightly interlocked and operated with such strict organization that even the tiniest modification in the design of a car and/or in a mode of operation caused a work stoppages and even plant shut-downs for weeks or months. Organizations, which are over-organized to the point that they are not open to new content and to external emergent phenomena – of the type that needs to be expressed on those possible interconnections which are not being used – become completely inflexible and unable to respond to changes in the business environment (Glassman and Varon, 2005, p. 22; Barabási, 2003, p. 201).

Considering that stated above, the most striking aspect of the dramatic change in describing organizational structures as a network instead of a Tree structure. Depicting an organization as a tree expresses mainly the importance of the Closeness relationships between echelons. On the other hand, describing an organization as a network expresses the importance of the connections' existence and strength, including the importance of the content being transmitted through them. This is a structure that is flatter and far more elastic, which is based on an organization’s understanding of its reality as a dynamic evolving network. Networks enable responses to be formulated by virtue of the many interconnections among its nodes. Furthermore, the shift from depicting an organization as a tree to depicting it as a network expresses a transition from a relatively static state to a dynamic state. Organizations wanting to compete in fast-moving markets are learning that it is critical that they switch to a dynamic, evolving network structure (Barabási, 2003, p. 202).

The following example illustrates the importance of understanding networks, as a means for an organization to reach better strategic and operational decisions: on February 1, 1997, a wide-scale fire broke out at Toyota’s supply plants in Japan. Toyota had become a network organization that integrates external suppliers and had developed a strategy called “just in time” (JIT), a strategy of operating with minimal inventories. Had Toyota retained a hierarchic organizational structure, it would have faced the threat that its 20 plants in Japan would be closed for weeks due to the fire damages. Under this emergency situation, Toyota's external suppliers functioned as an integral part of the organizational network, cooperated with Toyota and continued to supply materials. Consequently, Toyota's plants resumed operations only five days after the fire (Braha and Bar-Yam, 2004).

Manager as a preferred factor in a company's network

An important issue is the degree of closeness among the participants in a network, both among themselves and between them and the organization's managers. Recall the model presented earlier in this book that simulates the flocking movement of birds, which was developed by Craig Reynolds. According to Reynolds' model, there are three rules under which a flock succeeds in flying and reaching its destination: separation, alignment and cohesion (Reynolds, 1995) (see diagram no. 11).

It is reasonable to assume that such a model is compatible to the way in which organizations function during their "lifetimes." The potential interactions in the organizational network and the quality of these interactions constitute a practical expression of the proximity or distance between managers and employees in the organization. The quantity and intensity of the interactions can serve as indices that may be used to characterize the degree of closeness among the participants in the network, and particularly, to the organization's managers.

A flock of birds has no permanent leader leading them, and the birds rotate among themselves in the leadership role. The reason for this is not yet clearly understood, but apparently, the rotations take place based on “personal” suitability for the role at any given moment, and considering the prevailing environmental conditions, such as: wind velocity, humidity, longitudinal and latitudinal location, etc. A phenomenon similar to this has not yet been observed in human organizations. That is to say, a dynamic rotation has not yet been observed in organizations based on managers’ qualities relative to the environmental conditions. One of the characteristics of the operation of mega corporations is that a chief executive officer is appointed to lead the company for many years. Thus, for example, there have been only seven managers at the helm of the General Electric Corporation over the period of more than one hundred years since its founding (Colvin, 2005).

Although we are not convinced that this is the only answer for the management crises and the resignations of managers during times of crises, the alternative of dynamic rotations in the management of organizations is certainly one that should not be disregarded.

Decentralized management

That stated in the previous paragraph leads to another conclusion – that the management of an organization needs to be less centralized and more decentralized. No person, institution, or combination thereof should have the authority to completely control decision-making. Rank-and-file employees can be responsible for more important matters than those delegated to them today; thus, project teams, alliances inside and outside the organization and outsourcing will flourish and prosper. All functions and functionaries in an organization can compete among themselves, yet still be interconnected and cooperate in order to achieve their mutual goals – "*coopetition*." In such instances, the balance between the unit's optimum and the organization's optimum sometimes still gives preference to the first over the second.

It is advisable that the activity in the network be bidirectional (listening and talk), rather than unidirectional (giving orders and commanding). The more interconnectivity will be extensive and utilized – insight may be relayed from the field through the network and influence the content passing through it. Understanding the latent potential of high traffic in a network enables the elimination of the middle-management echelons in organizations. Under the current technological conditions, including the computer capabilities and knowledge-management tools being used by an organization's members, the justification for middle management simply dissipates.

One example of a company that based itself on these principles is Visa, which was founded in 1970. Visa employed a few managers in a small business center, which operates an enormous network of hundreds of thousands of suppliers (the merchants), hundreds of financial organizations (the card marketers) and millions of customers. This was a company growing at dozens of percentage points per annum. E-Bay can also serve as an example, as it is a mega company operating without a significant hierarchy or large business center. These two companies, like many others, have been recording success rates that are unprecedented since the industrial age began a century ago. These companies internalized the potential that is latent in a number of characteristics of complex systems theory.

The dynamic relations between employees and organizations

Organizations' managements need to know that a change in their behavior's patterns – in order to contend with the dynamic reality of their operating environment, and employees' desires for personal and professional development – will increase the *'Mobility of Labor*'[1]. The outcome is expressed by a higher incidence of *'labor turnover'*[2] for employee-related reasons, for reasons relating to the organization and for reasons relating to changes in the labor market as a whole.

Mobility of labor and labor turnover are key topics in businesses, and constitute an issue entailing management risks and opportunities. The purpose of employee-retention activities, including training programs, is to minimize the labor turnover; i.e., to retain their connections and

[1] *Mobility of Labor* is "the extent of employees' ability and desire to move between different types of occupations and residential areas, as a way to adapt themselves to changes in the labor market. High mobility of labor contributes to lower unemployment, while low mobility expresses structural unemployment" (Hilan-Tech glossary, 2011).

[2] *Labor Turnover* is "the ratio between the number of employees hired during a given period in order to man positions vacated by employees who left, and the total number of employees. The main causes of labor turnover are: retirement of employees who reached the retirement age; resignations by employees who found better jobs; and dismissals of employees who were found to be unsuitable … the objective of employee-retention activities is to minimize the labor turnover." According to the dictionary, "a high labor turnover" is not a normative situation, since it causes a high expenditure on employee recruitment and training, and indicates that the particular workplace is not sufficiently attractive and is contending poorly in the labor market." (Hilan-Tech glossary, 2011). However, in the new dynamic reality, labor turnover becomes the normative situation.

the know-how and experience that the employees acquired in the organizations where they worked.

In the business sector, the cost of labor mobility and turnover is high, particularly when the company's informal knowledge is not being managed. Labor mobility and turnover are a source of assets' loss, to the point of their being transferred to competitors. For example, in 2001, it was reported that 7.7% of the knowledge existing in organizations is lost each year. This occurs, inter alia, due to labor turnover (Rom Magazine, 2001), Furthermore, labor turnover causes an organization to lose its investment in employee training, which, in many companies, constitutes a considerable monetary expenditure. This investment goes down the drain when employees leave for other occupations/are transferred to other positions, and also causes an immediate need to recruit new employees and pay for their training.

In the management sector, the process of recruiting new employees is becoming ever more complex. In 2001, it was found that about 50% of the organizations reported difficulty in recruiting professional and technical employees, mainly in information-technology fields. When there is a manpower shortage, the employees' salary demands skyrocket and organizations try to "snatch" employees at any price from fellow organizations. Such was the situation in Israel's high-tech industry prior to the market crash in 2001. The shortage of manpower caused employers to recruit foreign employees for this sector. In an article citing statements made by Danny Goldstein, the C.E.O. of Formula, regarding the situation created in the market, Goldstein likened the phenomenon to "cannibalization in the high-tech market". According to him, "*There are high-tech companies that hit a labor* *turnover rate of 46% per annum, a phenomenon that adversely impacts the growth of the entire industry*" (Kauffman, 2000).

Four causes (out of many others) of the increasing complexity of the employee-management mechanism (recruitment, training, turnover, etc.) may be highlighted:

The first cause is the *employees' inability to cope with change*. This fact leads to their being replaced. The president and chief executive officer of Intel, Andrew Grove, stated that:

> "*When an industry goes through a strategic inflection point* [a phase transfer – ER/PY], *the practitioners of the old art may have trouble. On the other hand, the new landscape provides an opportunity for people, some of whom may not even be participants in the industry in question, to join and become part of the action.*"
>
> (Grove, 1996, p. 48)

A second cause is the employees' perspective. They view *the workplace also as a place of self-fulfillment*. Young employees, who have not adopted the occupational perspectives that were widely accepted by the Israeli labor force during the 20th century, do not view a tenure-track job as their ultimate goal, and loyalty to a workplace is not high on their scale of values. During their career, if they lose interest in their current job, they tend to replace it with a job that offers wider opportunities for self-fulfillment.

A third cause is the replacement of the public service budgetary pension with an Accrued Pension, which may be transferred from one workplace to another. This is an example of the system of government adapting and adjusting to the new “rules of the game,” with the revision of the pension element greatly simplifying labor management.

The fourth cause is the *transition of organizations and institutions to utilizing outsourcing.* Outsourcing is a technique of transferring an activity outside the organization. “*Companies can unload noncore activities, shed balance-sheet assets and boost their return on capital by using third-party service providers"* (Craumer, 2002, p 11).
This is not a new phenomenon in the global economy, but the scope of its use has been expanding significantly in the last two decades, due to the opening of the global market to constant competition and the labor-cost differentials between the developed world and developing countries. Thus, for example, Microsoft is employing no less than 2,000 employees in India! (Sinha and Mishra, 2005).

The technological capabilities developing in the fields of communications and computerization and the desire to optimize business results are constantly increasing. Additionally, the willingness to adapt to mobility of labor is also increasing. In this way, we can find Indian engineers at a wage cost of USD 15 per hour, and not only programmers, as was customary until recently. These engineers participate in the design of aircraft for U.S. companies while working at home, replacing American engineers, whose wage cost is USD 70 per hour. The only constraint to the acceleration of this trend is the shortage of a sufficient quantity of computer engineers in India (Sinha and Mishra, 2005).

Command and control are approaching ground level

Command and control processes in an organization, and therefore, also the performance of the operations, will redeploy as closely as possible to the action out in the field. For example, in the late 1980s, the Zara fashion company completely reversed its thinking and adopted a “bottom to top” strategy, whereby the sales staffs at every store around the world are advising the designers about the upcoming fashion trends. These methodologies can also be applied in bureaucratic organizations. The revolution in community policing, which began in police forces in the western world at the beginning of the 1980s, is based, inter alia, on decentralization of authorities and delegating authorities at the level of the single officer on the street, who lives this reality daily (Yehezkeally, 2004b, p. 51).

Substantial cutting of organizational barriers: rules, behaviors and procedures

In order to increase an organization’s adaptability, organizations should increase interconnectivity (Levkowitz, 2004, p. 11; Coffman, 1997b) and/or allow more decisions to emerge from interactions among nodes.

This can be accomplished by eliminating layers of rules, behaviors and procedures, designed to prevent many inputs from reaching all those requiring it in the organization.

In an organization with abundant interconnections, information transfers among employees relatively easily (Glassman and Varon, 2005, pp. 32-34; Levkowitz, 2004, p. 10; Storr and Fryer, 2000). The problem is that the more input required for decision-making purposes, the more energy-consuming conflicts arise in the system, when sometimes, these are energies that are needed elsewhere in the organization.

The classic hierarchic management is dealing with a chaotic state arising in a system due to these two factors (too much information, and the cost of energy involved in conflict resolution) by regulating the impact of most input that one node receives from another, by prescribing rigid rules to limit the information flow in the organization and by strictly enforcing these rules. As a result of all the above, the organization stifles its capacity for adaptability and innovation (Levkowitz, 2004, p. 11).

The biologist, Kauffman, maneuvered between increasing order by reducing the dependence on interconnections, and increasing adaptability by increasing the interconnectivity among agents. In order words, there is room here for a variety of directions of thought relating to aspects of operating organizations in various states (Coffman, 1977b). In this context, we have already stated that in the phase space of possibilities in a dynamic environment the attractors by which organizations operate do not repeat themselves. Therefore, under the new situations constantly arising, managers will have to select their path according to a combination of updated information, experience together with instinct and intuition. Grove states in this context that:

> "*Even those who believe in a scientific approach to management will have to rely on instinct and personal judgment. When you're caught in the turbulence of a strategic inflection point* [i.e., a phase transfer –

> ER/PY]*, the sad fact is that instinct and judgment are all you've got to guide you through. But the good news is that even though your judgment got you into this tough position, it can also get you out … the strategic inflection point is the time to wake up and listen.*"
>
> (Grove, 1996, p. 35)

2. An organization's positioning between chaos and order

Researchers of complex systems and networks have characterized *a theoretical state of being* "on the edge of chaos". Organizations operating in dynamic environments must position themselves at the edge of chaos. When an organization is seeking ways to compete and develop markets, it has the maximum ability to adapt itself to its operating environment and develop a high level of creativity.

Adapting to change is problematic, particularly for organizations that were very successful prior to a phase transfer. When the attractor pulls the industry towards a new reality, then, the more successful the organization was in its old structure, the more threatened it feels by the change, and the more reluctant it is to adapt to it (Grove, 1996, p. p. 50). This same logic also applies to employees:

> "*…the person who is the star of a previous era is often the last one to adapt to change, the last one to yield to the logic of the strategic inflection point, and, therefore, his fall will be harder and more painful than the others.*"
>
> (*ibid*, p. 68)

Organizations must identify and design high-quality, quantitative management indices for regulating and directing the activities being carried out in their organizations. This enables maneuvering between order (organizations have a human tendency to maneuver towards order) and chaos (organizations have a tendency not to enable movement towards chaos). When an organization is initiating new ideas and planning, it should strive to navigate towards the edge of chaos; when it is in implementation stages, it should strive to navigate in the direction of order.

This navigation is not a simple matter. It requires juggling between factors pushing towards chaos and those pushing towards order. It is a kind of art, and is perhaps one of the most important tasks facing organization leaders.

There are usually no handbooks or recipes for "do this and don't do that" when seeking the correct point of equilibrium. The organization has at its disposal the experience of the managers themselves from similar situations (although, as stated, there are no identical situations), the experience of others, and a great deal of intuition.

How can we identify an organization approaching "The Edge of Chaos"?

In one of the research studies of Ralph D. Stacey, who was a research colleague of the biologist, Kauffman, he defined five parameters of control for regulating the location of a system in the scale between order and chaos (Storr and Fryer, 2000, pp. 12-17):

- the level of information flow between the nodes in an organization;
- the extent of the variety and diversity of possible modes of action;
- the abundance of interconnections (between the various nodes) within the organization and between the organization and its environment;
- the degree of motivation and involvement of the nodes in the organization;
- the degree of hierarchy in the organization.

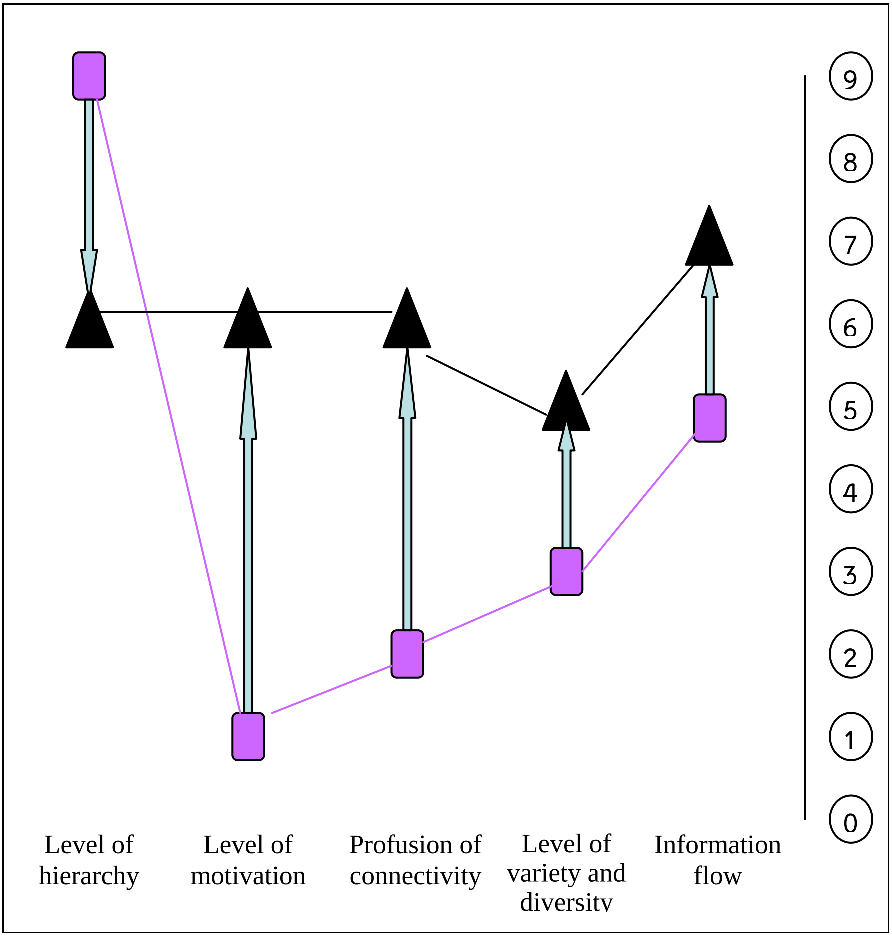
In our opinion, each of these parameters, or other parameters of control, as the case may be, enables a complex system to be measured. These parameters help us to better understand the connection between an organization's positioning on the scale and the implications of that positioning on the organization's behavior. The possibility of comparing the actual positioning of the organization and its optimal state was demonstrated by Zini (2004) and Wiell (2004). They compared the actual and optimal positioning of companies on the order-chaos scale, which was arbitrarily affixed at between 1 and 9 (diagram no. 27). The "optimal positioning" was processed from the data on eleven successful companies referred to in Collins' book (Collins, 2001).

Diagram no. 27 illustrates the measurement of Stacey's parameters in a particular organization relative to an optimal organization. He places the above-mentioned scale on one axis, and the five parameters on the other axis.

Diagram no. 27:

Model comparing control parameters (Stacey) in companies on the "order" – "chaos" scale

(developed by: Oren Zini, Raphael Wiell and Efron Razi; see: Zini, 2004, p. 114; Wiell, 2004)



The control group is represented in the diagram by triangles, and constitutes the target for organizations. The gap between the squares and the triangles shows the optimum distance set in the model.

3. Planning and decision-making

Traditional thinking views long-term strategic planning as an essential, applicable and viable tool. The typical imagery was that planning assembles the parts of the plan, just like a clock is assembled from its various parts and, once a source of energy is added, the clock will work for a long time.

Strategic planning in organizations began in the 1950s, and was particularly common during the 1960s and 1970s, when it was believed to provide a solution for all organizational problems. Many organizations formulated annual work plans and even detailed multi-year plans, which, in many instances, were never realized. The more dynamic reality became, the faster these plans became obsolete and without value. The main reason for this is that, in complex systems, the future cannot be predicted. This unpredictability is very conspicuous, inter alia, in A publicly traded companies in Israel and globally, which report profits that are higher or lower than the analysts' forecasts.

Subsequent to the publication of the consumer price index of August 2005, which had risen by 1.1%, the journalist Gideon Eshet wrote a derisive article entitled, “If economists make forecasting errors, why should we let them manage our money?” Eshet presented the various forecasts for the August CPI, as announced by the different financial analysts:

- the economists of the Ministry of Finance, the Federation of Israeli Chambers of Commerce, and Clal Finance and Trust predicted that the August CPI would rise by 0.5%;
- the economists of Union Bank, Discount Capital Markets, Clal Finance, Provident and Psagot predicted a rise of 0.6%;
- other forecasts predicted a rise in the range of 0.5%-0.8%.

Eshet argued that "*what distinguishes the CPI of August was that the factors for the unforeseen rise of the CPI were very well known: the fluctuations in the fuel prices and the fluctuations in the dollar exchange rate. Notwithstanding the known, available and measurable information, all the economic forecasters were proven to be false prophets*" (Eshet, 2005).

Similarly, the fundamental assumptions made by the finance ministries in various countries regarding their annual budgets are not being realized either. The actual economic growth usually differs from the projections, and the ministry of finance finds itself with a budgetary surplus or deficit at the end of the budgetary year. For the sake of illustration, since the beginning of 2005 and until these lines were written in the autumn of 2005, the government recorded a surplus of 200 million ILS in domestic activity in Israel, compared with a record deficit of 18.4 billion Israeli Shekels during the corresponding period last year. The reason for this was the discovery that its income's forecast had been erroneous (Klein, 2005).

This limited forecasting ability obligates managers to contend with five different aspects:

- Planning and deployment for the short-term only and at high-frequency;
- Creativity during planning;
- The professionalism of the manager’s decision-making and the timing thereof;
- The organization's rapid response, mainly in the area of development;
- Ability to design means to shape the future, as a substitute for the inability to forecast.

Operative planning and deployment for the short-term only and at a high frequency

According to 'Complex Systems Theory', Long-term planning has only little value when organizations are operating in a nonlinear and unpredictable environment [We mean 'operative planning' as opposed to 'strategic thinking', in which there is also an ability to design means to shape the long-term future; i.e., designing of means as a substitute for the inability to predict the reality in which the organization will be operating in the future (see hereunder in this chapter)].
The new paradigm is limited to the short-term business horizon and differs, depending upon the type and nature of the organization. Therefore, organizations must focus their use of forecasts, particularly under abnormal conditions, and if warranted, the range of the forecasts should be shortened to the essential minimum (as we already

mentioned, even a weather forecast for more than a few days is irrelevant) (Glassman and Varon, 2005, pp. 32-34; Levkowitz, 2004, p. 10; Storr and Fryer, 2000). Planning cannot extend over a period of more than a few weeks or a few months at the very most, and, in any case, it is advisable that the detailed planning will take place close to the event.

Some organizations in the business sector have already recognized the problem in this context, and have begun to develop a culture of a continuous planning process using relatively simple models.[3]

Creativity during planning

When we are about to formulate effective planning in an organization, we must keep in mind that sometimes, the analyses that appear to be less reasonable at any given point in time are precisely those, which prove to be accurate. When internet search companies failed, such as Alta Vista, the founders of the internet search company, Google – Larry Page and Sergey Brin – rejected the generous cash offer to acquire the company from them for a total of 750 thousand USD, as well as all the conservative offers of their advisors, despite the fact that they had no business model, and expenses threatened to wipe out their dwindling treasury, Page and Brin persisted on their path (Battelle, 2005) and the outcome is obvious. During its initial public offer in August 2004, Google recruited 1.7 billion USD. It slammed the analysts' forecasts in all of its first four quarters as a publicly-

[3] One of the ways to overcome the forecasting limitations in complex systems and in a dynamic reality is risk management. This topic is beyond the scope of discussion in this book.

traded company, and earned 3.19 billion USD in 2004. During its second public offer, which is being launched at the time these lines are being written in September 2005, Google is expected to recruit some USD 4.4 billion (*Yediot Aharonoth*, 2005). In John Battelle's book, *The Search*, which analyzes Google's success, Battelle lists three possible reasons for its success: the founders' determination and focus, the analytical capability of the interconnectivity linking the internet, and the wisdom of refraining from integrating animated commercials (Battelle, 2005).

The key to creativity in planning, and the foundation for effective planning in a company is the principle that analyses by a number of observers should identify a wider variety of possibilities than a single person (walking on the edge of chaos). In instances whereby power struggles prevent the identification of options and lead to ineffective implementation of processes, it is reasonable to assume that the results will be accordingly ineffective. This is the situation today in many bureaucratic organizations.

An example of creative processes, ironically, in a bureaucratic organization, was cited by Haim Assa and Yedidya (Didi) Yaari in their book, *Decentralized Warfare – War in the 21st Century*. They related that, at the end of March of 2003, the chief of the general staff of the I.D.F. at that time, Moshe (Boogie) Yaalon, decided to appoint what they called the "alternative think tanks". According to Assa and Yaari, it had been clear that "*something fundamental had changed in the way present-day wars are being waged, both in terms of the enemy and inside the I.D.F.*" and that it had become "*essential to stop and* *analyze what we are learning from the dramatic course of events…and what this means in terms of the I.D.F.'s basic conventions"* (Assa and Yaari, 2005, p. 9). When they said "dramatic course of events," the authors were referring to the dynamic reality at the beginning of 2003. Then, the defense system faced an unprecedented budget cut and the building of a new multiyear plan which "*would mean a different I.D.F.*" Beyond Israel, the Americans had completed their conquest of Iraq and began to suffer casualties that began to threaten the social order (*ibid*). Assa and Yaari stated that "*The need for change was 'on the air'*" (*ibid*). The chief of the general staff established a number of 'think tanks', and his instructions were "*challenge me … show me what we are not doing right*" (*ibid*, p. 11).

It should be emphasized that creative behavior does not necessarily mean a change in an organization's modes of functioning. Bureaucratic organizations have a tendency to torpedo proposed reforms in their structure and culture. A recent example of this is the 'Dovrat Committee' of January 2005 for education system's reform, which, to a great extent, was neutered during the power battles between the initiators (the ministry of education) and the participants (the teachers) ('Dovrat Committee', 2005).

The professionalism and timing of a manager's decision-making

While in the world of management so familiar to us, the ability to make a decision quickly – and not always in favor of it – constitutes one of the strong traits of an effective manager, in the world of complex systems, effective management often requires more consideration and even avoiding decisions. Back in the 1930s, for example, Chester I. Barnard asserted that "*the fine art of management decisions includes not deciding*" in the following instances (Tillett *et al*, 1970, p. 338):

- "*When questions are irrelevant or not attributed to the subject and circumstances at that precise moment"*;
- "*When it is too early"*;
- "*When decisions cannot be carried out effectively";*
- "*When the decisions should be made by others*".

This topic has already received professional attention for decades. We only wish to add our suggestion that an understanding of secondary issues should be added to the level of professionalism required from managers, such as: the characteristics of complex systems, the power of expression of networks, and perhaps also an understanding of the issue of 'the disruptive innovation' and how to use it.

Rapid response by the organization, mainly in the area of development

The manager must correctly use successful rules of selecting among options in relation to all subjects relevant to the organization, both in the internal market and in the external one, while recognizing its inability to control the rules exclusively (Kauffman, 1997). The dynamics of the market require the organization to base itself on learning and on immediate responses to the environment. These responses should occur right away after an event or a new challenge arises in a company (Storr and Fryer, 2000). The organization must acquire the capability of responding rapidly to changes, and must accept that constant change must be a way of life. One example of this is the General Electric Corporation. In an article in *Fortune* magazine, three characteristics of the behavior of a mega corporation were highlighted, two of which are relevant to our discussion (Colvin, 2005):

First characteristic – when decisions are made, the company culture dictates decisions' implementation without postponement or delay. The article stresses that "*the discipline of implementation is rooted in the company's core culture*" (*ibid*, p. 35).

Second characteristic – the manager is expected to periodically prescribe new policy guidelines, even guidelines that contradict previous ones.

The ability to design means to shape the future, as a substitute for the inability to forecast

Managers must develop a perspective enabling them to identify minor changes and new conditions that begin to impact the future (foresight) (Sanders, 2002). They must focus on those few rules that enable the organization to change the reality in a way that facilitates the achievement of its vision and objectives. In other words, managers must identify that 'Disruptive Innovation' that will serve as the organizational attractor, and they must design the organization's infrastructure so that spontaneous 'self-organization' is feasible from the outset. 'Self-organization' in the organization will allow 'emergence', which leads to the achievement of its objectives (Kauffman, 1997).

It is important to reiterate our warning of earlier in this book. The selection of a 'Disruptive Innovation' does not guarantee that this is the correct one, even if it is successfully assimilated in the organization.

Raviv Drucker and Ofer Shelah present a good illustration of a manager in a major organization taking this course of action. In their book, *Boomerang*, they outline the functioning of the I.D.F.'s Chief of Staff at that time, Moshe (Boogie) Yaalon, during the armed conflict with the Palestinians (Drucker and Shelah, 2005).

The book relates that the 'Disruptive Innovation' that Yaalon had imparted to his staff, back in the days when he held the office of OC Intelligence, through his offices as the GOC Central Command and as Deputy Chief-of-Staff, and during his term of office as the Chief-of-Staff, was the absolute delegitimization of the Palestinian leader, Yasser Arafat (*ibid*, p. 80). The book describes in detail the process dictated from above in the I.D.F.: the Intelligence Division tended towards severe assessment, contrary to the position of the GSS, for example, which relied on papers lacking any substantive proof in the raw materials (*ibid*, p. 77). Everyone was recruited – from the general staff divisions down to the last of the soldiers – to find *prima facie* evidence to support 'the disruptive innovation'. Yaalon acted on this even opposite the legislative authority (*ibid*, p. 81) and opposite the political echelons (*ibid*, pp. 81-82).

The success in assimilating this 'disruptive innovation' was achieved beyond all expectations. The course of action affected the future, to the extent that the vast majority of western countries finally reached the same conclusion. However, did this 'disruptive innovation' lead to the achievement of the Israelis’ objectives in the conflict? The answer is far from being unequivocal …

The need to change managerial habits

To summarize the topic of planning and decision-making, we’ll state that, in order for a manager to successfully handle the aspects described above, his schedule must be more flexible than is customary today. He must learn to make time for thinking, and to surround himself with thought-provoking “devil’s advocates". He must understand that there is no point to delving into the minute details of the organization’s routine activities, since, in complex systems, the organization’s state of affairs may be examined using only a few key indicators. There is no reason for exhausting his staff and himself by engaging in pointless scrutiny of excessive details.

It is important to make use of the computerized resources of the modern world for thought processes, planning and decision-making. Parallel computing resources provide advantages when building thought capabilities and supplements intuition by illustrating real and virtual situations. The purpose of computer systems is to help diagram the relevant network, including all components that impact the network, in order to achieve a defined objective. The role of the network is to generate a spectrum of possible trajectories. The decision about the preferred alternative will be made after we run iterations describing the anticipated future implications of each of the alternatives on the other factors in the network.

The solution lies in the understanding that only a few rules regulate change. It is essential to keep in mind that, for future success, the future must be designed by a mechanism enabling simulations of risks and opportunities and by designing rules in the network. These rules are intended to be catalysts for that 'self-organization' that advances the manager towards achieving his objective. Just like the Chinese who 'implanted' a single law in the network – China’s one-child policy – and changed the world, so too, the captain of the organization needs to find those certain rules (catalysts) that will steer his organization to its destination.

4. Systems operation

In recent years, computerized systems have become the primary means assisting management echelons in the various organizations in the operation of their operating systems. In these instances, the dependence on hardware components is extremely high, especially considering the fact that, in the near future, software will be actively participating in decision-making. Complex training and adaptation programs will be essential in order to enable managers to successfully contend with this evolutionary process. However, one must keep in mind that computer systems are solely decision-support systems, since, at least for the time being, computers cannot substitute for human thinking and decision-making.

The primary principle in complex systems is that *the organization needs to allow 'self-organization'*, and to give all its members the opportunity to establish independent “governments”, like service-

providers within its framework, or even in external frameworks interconnecting through special relations.
The system's 'self-organization', both in a society, in an economic or social sector, and in a global framework, is expressed through the development of flexible tools, such as when a supplier directly supplies (automotive parts) to production lines (in the automobile industry); commercial cooperation in order to cut logistics costs; computerized planning of direct orders to a production line; product design from initial concept to prototype on a computer monitor, and more.

The operation of physical service systems (like waiters) and development systems (like start-up organizations) is not similar to the more automated manufacturing systems. The component of independent personal activity in these service systems is a major component, and the local solutions increasingly multiply. The uniqueness of each service depends more on creativity and innovation and less on the uniform standards that computers can provide. Internet start-up companies are popping up in the hundreds and thousands. Most of them are struggling to survive and struggling to differentiate themselves from the others by at least one significant feature. Unlike these, a chef can be aided by a computer, but diners come to his restaurant because of his uniqueness. The chef also does not need an ISO 9000 certificate so that diners will recognize the quality of his cuisine…

Operational subunits and project administrations in organizations are supposed to be autonomous systems, requiring them to operate according to defined goals deriving from the organization’s goals. The military 'think tanks' described in the book by Assa and Yaari referred to earlier in this chapter also claimed that the offensive aspect of modern warfare is decentralized warfare – warfare, which is comprised of small forces that are autonomic a great extent, and operating simultaneously across the entire combat arena (Assa and Yaari, 2005, pp. 54-55).

The managements of organizational units and project administrations need to focus on the following aspects (Zini, 2004, p. 17):

- Maintenance of organizational communications among the subsystems;
- Operation of the agents in the organization/project;
- Coordination of the interfaces among the subsystems;
- Encouragement of managerial autonomy in each of the subsystems, innovation and initiative.

Do not be concerned about conflicts. Set target deadlines; focus on standards of quality; and let the system flow according to the targets and environmental conditions. Refrain from instituting rules and procedures that cause the regime to be too restrained, in which any attempt to adapt to changes will be worthless. Examples: religious organizations during periods when conservatism reigned, like during the Inquisition in Spain and in Portugal, and during the 70 years of stagnation caused by communist regimes, etc. (Glassman and Varon, 2005, pp. 32-34; Levkowitz, 2004, p. 10; Storr and Fryer, 2000).

5. Operations control

Industrial, social or other operations assume the consequences, in any case, whether or not they are planned and controlled. There is no shortage of results, including those that are expressed in *quantitative,* physical indices using computerized methodologies. Nonetheless, the accounting tools being employed by organizations have many shortcomings, both in relation to professional aspects and in relation to findings and conclusions. The problem is that *qualitative* results in this field have not yet been achieved.

According to 'Complex Systems Theory', an organization’s control system needs to be decentralized, and units need to develop measurement tools tailored to each unit’s requirements (Zini, 2004, p. 17).

In order to adapt to any change, compensating for any identifiable deviation from the planned track is sufficient. This is the basic principle of the “feedback control” methodology; i.e., rectifying an error after it occurs. This technique can be very effective if the deviation is rectified with sufficient speed, before the problem mushrooms.

Management control processes can always adopt tools taken from engineering disciplines, where control is part of the completed circuit. Unlike social outcomes, engineering products do not work when the circuit is not closed; i.e., without feedback. For example, the management process in diagram no. 24 will not work if one of the components is missing (while in social systems, processes can proceed, at least in the short run, even without feedback). Citing another example, Professor Ephraim Katzir referred to the communist regime during the days of Stalin and Khrushchev and emphasized the conflict between the desire to become an industrialized nation, on the one hand, and the unwillingness to enable feedback in the form of freedom of expression, a free press, and criticism of results, on the other hand. The repercussions of this conflict were, as we know, far-reaching (Ben-Aharon, 2001).

The understanding that feedback must be a facet as important as the operational activity itself is not an accepted culture in devout capitalistic organizations (the faith in managing double-entry bookkeeping) or in public organizations (which comply with “compulsory transparency” only).

Just like in engineering systems, computerized systems also, of course, incorporate feedback, but the reliability of the picture obtained is contingent upon input of all relevant information that was given to them.

Regarding control through “second-loop feedback” – the inclusion of the feedback responsible for learning and adapting is not yet assured in business organizations and certainly not in social organizations, because assimilation of this type of control requires a high level of professionalism, investment in human and financial input and a considerable degree of attention.

6. Knowledge characterization and retention

One trend that has become popular in every self-respecting company in recent years is the incorporation of a knowledge management system. The more dynamic a company is and the more it operates in an environment on the edge of chaos, the more it needs new and up-to-date knowledge in order to contend with the conditions that will be prevailing in its task environment in the future. Therefore, information on past performance, even when the information has been successfully transformed into knowledge, often becomes irrelevant. An optimum applications solution for the problem of irrelevance has not yet been formulated. The knowledge that will be retained in organizations will be, apparently, only on fewer dynamic subjects.

In terms of biology, we are aware that knowledge is accumulated, apparently, in our brain cells too (analogous to the hard disc in computers for example). According to the new theories in this book, the knowledge retained by organizations is accumulated in the network of connections *between* “the free agents” (analogous to the computerized networks themselves, which may constitute a knowledge warehouse). The significance of this is that knowledge emerges and accumulates both in the agents comprising the system’s network and in the interactions between them. Up until now, extraction of knowledge from agents has been an extremely difficult task for many organizations, especially extracting knowledge from the interactions *between* them.

Interdisciplinary knowledge is generated only rarely. The knowledge developed through collaboration between the I.D.F. and the Israel Police on the issue of contending with the task of evacuating Israeli settlements from the northern Gaza Strip, and from northern Samaria in the summer of 2005 was interdisciplinary knowledge. *The compelling need to work together and the fear of failure* led to meticulous plans, during which the knowledge of both organizations was shared and processed for building a new “combat theory” for the evacuation teams, which was a combined force of military and police personnel. In this way, original knowledge was created. Tactics created out in the field were added to the new joint knowledge gleaned before the evacuation began. For example, when the settlers began to view the police as a force that was more assertive and aggressive than the I.D.F. (the opposite of their initial preference, that the task be assigned to the police and not to the army), a 'good evacuator' / 'bad evacuator' tactic was employed. The commanders of the evacuation units agreed to the settlers’ requests to leave the police out of the picture and to proceed with the evacuation using soldiers; alternatively, special police patrol units and the border guard were employed, in instances when the evacuation became problematic (Harel, 2005).

Massive marketing of the field of 'knowledge extraction' from the interactions between agents has made this a very prestigious field in the business world, and considerable capital has been invested in it. The issue of the difficulty in designing tools that will provide “knowledge” is still far from being resolved, and the conceptual difficulty of this subject has not yet been internalized. The practical tools in the linear paradigm do not constitute a solution, despite the tremendous investment (like the billions injected in vain to extend weather forecasts to more than a few days; therefore, even the knowledge that might be attained for an organization grappling with the complexities of a dynamic environment would be helpful only for a short period).

The issue of knowledge existing in the interactions between agents was addressed in relation to the field of academics by Dr. Zvi Lanir in his article discussing the crisis in higher education in Israel in March 2005, against the difficult state of the universities. Lanir stated in his article, entitled "Purposeless Streamlining will not be Useful," that, due to the difficulties in developing knowledge, the institution of universities, in its current format, has lost its relevance:

> "*The main reason behind the universities losing their standing in the field of knowledge development relates to their belief in sanctifying and preserving the delineations of the various disciplines ... all this when the majority of the knowledge is now being developed in the fields 'between' the existing disciplines. Off-campus university entities are developing new ways for interdisciplinary integration, and their work embodies exciting possibilities for knowledge development.*"
>
> (Lanir, 2005)

Therefore, constant learning by all members of an organization is extremely important. Satisfaction of the increasing thirst for knowledge will help to correctly handle the unknown future. Organizations must constantly analyze their positions in their fitness landscapes, while creating a clear landscape that presents the organization's position on the topography representing its environment and adjusting its position to that topography; i.e., a way to try and improve positioning in space. Depending upon the organization's situation at that moment, task-related, specific recommendations should be developed and coordinated (Glassman and Varon, 2005, pp. 32-34; Storr and Fryer, 2000; Levkowitz, 2004. p. 10).

Attributes of managers in the age of complex systems

To summarize this chapter, we would like to emphasize, albeit not in any precise scientific way, a number of guidelines that managers should consider adopting in this age of dynamic, rapidly changing realities:

- Perceive the world holistically, instead of focusing on the ability to break down problems into their parts (Altman *et al*, 2004);
- Understand complexity and adopt a multidimensional, multidisciplinary perspective (Ben-Yishai and Raviv, 2004);
- develop the capacity to think in opposing and complementary terms, and have the emotional capacity to include opposites – the ability to perceive the world in relative terms, rather than in unequivocal general terms (Altman *et al*, 2004);
- Acquire the ability to identify trends, opportunities, threats and crises when they are still emerging (Ben-Yishai and Raviv, 2004), and maybe even before that!
- Acquire the ability to analyze the significance and ramifications of organizational courses of action in a changing environment (Ben-Yishai and Raviv, 2004);
- Start thinking 'outside the box', in order to come up with new ideas (Ben-Yishai and Raviv, 2004; Altman *et al*, 2004);
- Maintain an intellectual, broad perspective (Ben-Yishai and Raviv, 2004);

- Acquire the ability to function under ambiguous circumstances for a prolonged period (Altman *et al*, 2004).

* * *

This chapter attempts to illustrate how principles of complex systems theory and networks theory may be translated into a new management paradigm. This field is still in its infancy, and our primary objective is to challenge readers to use this knowledge for a more in-depth analysis. The main challenges and those awaiting future developments will be elaborated in the following chapter.

Chapter Eight

What about the Future?

In this book, we presented a list of veteran scientists and researchers, some of whom were active in the beginning of the 20th century and ahead of their times. However, it was impossible for them to make the phase transfer using the materials, they provided to us, due to the absence of suitable computing resources in terms of hardware, and certainly in terms of software.

This problem was resolved once computers were launched on the market that features parallel working capabilities and once a number of software language types were developed, such as "*fuzzy logic*," "*genetic algorithms*" and "*cellular automata*." Some of these languages have unlimited learning and dissemination capabilities thanks to the internet (like the free "Linux"). The combination of sophisticated ideas and computing resources has led us to the edge of a phase transfer.

The challenge facing those engaging in this field is to analyze those sources of ideas vis-à-vis the primary dilemmas in the current paradigm, to develop possible solutions from them and to try to use them to resolve the aforesaid dilemmas. A concise illustration is presented in table no. 2.

Earlier, we emphasized (in diagram no. 23, p. 171) an important link in the network for developing nonlinear management tools – the AD link, which reflects the interaction between academic visionaries and management dilemmas. This interaction is the foundation for the idea behind table no. 2.

The table headings present the dilemmas deriving from the uselessness of tools of the old linear paradigm in a dynamic reality. The left column indicates a number of ideas for solutions as raised by experts espousing the new paradigm. We can formulate a list of recommended solutions from these ideas. At this point, the new proposals and their possible results need to be compared with the results using the tools of the old paradigm, a comparative analysis not performed within the scope of this book.

In the column “solution sources” in table no. 2, we included a number of researchers, and theoreticians referred to in this book. Their ideas may be used to overcome the weak points of the dilemmas. We will elucidate this with a number of examples:

Ross Ashby’s theory (Ashby, 1957) (source 2 in the table) may be used to develop a way to deal with management dilemmas, aided by the development of the use of networks. For example, for the purposes of an effective transition between a 'problem' to the 'selection' of alternatives for action, an original investigative approach must be developed that is integrated with a company’s networks of relations.

Table no. 2:

The main dilemmas in the current paradigm and sources of a possible solution from a new paradigm

No.	Dilemmas / Solution sources	Local vs. global policies	Management: "result"- "problem" "cause"- "selection"	Effectiveness of knowledge development and retention	Leadership - the human factor
1	Information theory (Shannon, 1948)	x	x	x	X
2	requisite variety of possibilities (Ashby, 1957)	x	x		
3	Control parameters (Stacey, see Storr and Fryer, 2000)	x	x		
4	Self organization (Kauffman, 1997)	x	x	x	X
5	Spontaneity (Kauffman, 1997)	x		x	X
6	"Free agents" (Sycara, 1998)	x	x	x	
7	Power laws (Barabási, 2004)	x	x	x	
8	Brain activity (Katzir, see	x	x	x	x

No.	Dilemmas / Solution sources	Local vs. global policies	Management: "result"- "problem" "cause"- "selection"	Effectiveness of knowledge development and retention	Leadership - the human factor
	Ben-Aharon, 2001)				
9	Successful companies (Collins, 2001)	x	x	x	x
10	Double-loop feedback (website of Fairleigh Dickinson University, 2005; Dalcher, 2000)	x	x	x	
11	State diagram (Harel, 2004)		x		
12	From information to a force-directed network (Arizona U. group, see: Forrester *et al*, 2005).	x	x	x	x

We are convinced that a dynamic model of the networks in an organization will facilitate the identification of the majority of the causes of problems. It will also simultaneously enable the processing of a number of possible solutions using a high-speed computerized quantification of the alternatives for action.

Another example is the development of the networks' model called “Graphael”, which was developed by a number of researchers at the University of Arizona in the United States. The model turns information into networks using unique software. These networks may be processed and analyzed and are capable, for example, of expressing and retaining the information as knowledge. The software is operated based on relatively small databases (Forrester *et al*, 2005).

The last example is a potential viable combination of three sources: we will adopt Stacey’s control parameters (source 3 in the table) (Storr and Fryer, 2000); we will incorporate the significance of Barabási’s power laws (source 7 in the table) (Barabási, 2004); and we will adopt Katzir’s behaviors of the networks in the brain under crisis conditions (source 8 in the table) (Ben-Aharon, 2001). It might be possible to use this combination to extrapolate a practical model for organizations, and to create the response team to handle a problem or external opportunity. The problem would be analyzed according to parameters that are suitable for analyzing the problem or opportunity and for quantitative measuring of the selected response. The optimization process of the analysis and control would be based, most certainly, on an algorithm to be constructed according to the power law of networks.

The construction of a computerized system based on a network model and enabling simulations in order to analyze the feasibility of limited operations for 'designing' the future (creating a quasi 'butterfly effect', to the extent that it is controllable), is one of the greatest challenges facing developers.

Epilogue

We hope that this book has opened a broad spectrum of possibilities and interest, particular to those engaging in initiatives, innovation and the development of dynamic markets – whether in the business sector, in the field of public administration or in any area requiring evaluations of situations and decision-making. The implementation of ideas stemming from complex systems theory will offer a different thinking and management alternative, and will ensure the managers among them an advantage over their potential competitors.
As is the route of pioneers driving towards reach promising implementation, they can expect that the journey will be long, difficult and quite frustrating.

Most organizations in the business world and in public service alike are still unaware of complex systems theory and of networks theory. Moreover, oftentimes organizations take action to torpedo management initiatives in this direction, since their senior management and their control systems are programmed for hierarchic, linear modes of action.

A local illustration of this is the story of Colonel P., who commanded some 3,500 military personnel from many diverse subunits having a very expansive span of control. These units operated extremely complex technological systems. Colonel P. related that when asked 'micro management' questions during a general audit conducted in his unit, he had responded that these fields are delegated to his subordinate officers. He emphasized that he had no intention of delving into minute details, since they are irrelevant to his role as a senior manager and prevent him from focusing on the important issues. The auditors did not accept these arguments; Colonel P. claimed paying a personal price for it. This had been one of the reasons that his promotion was blocked (Colonel P., 2005).

A global illustration is the fact that bookkeeping and accounting systems have proven themselves, to a great extent, to be irrelevant. This occurred during the financial crisis of the 1990s at major corporations in the west (mainly the collapse of the Enron Corporation in the United States) and, to a certain extent, in the east (such as the banking crisis in Japan during the same decade).

Notwithstanding that stated above, there are already pioneering organizations in the western business world. Currently, they are applying management approaches based on principles from this new scientific field with great success. When companies are coping with the information explosion and with an unprecedented need for flexibility in a constantly changing market, the "arm's reach" stretches from a domestic range to a global one, inventory duration are slashed from months to hours, 'top-down' business strategies become 'bottom-up' and employees become free agents. This is a fundamentally new line of thinking – about the way to respond to the changes in the business and social environment – and is a dramatic evolution of the business model.

If we have succeeded in finding our way to the consciousness of those engaging in the trade and have accelerated their management progression a bit more in the direction of this innovative nonlinear management approach – then we have attained our goals.

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http://www.uni-klu.ac.at/users/gossimit/sdyn/gdm_eng.htm,
downloaded on 15/8/11.

Place of complex systems theory in the network of theories:
http://www.math.boisestate.edu/~tconklin/images/emergence.gif.

Appendix:

Glossary of 'Complex Systems', 'Chaos' and 'Networks' Terminology

(Compilation of definitions from the following websites:
http://www.cna.org/isaac/Glossb.htm
http://www.calresco.org/glossary.htm
http://www.plexusinstitute.org/edgeware/archive/think/index.html)

Adaptability

The ability of organisms/systems to learn and respond to changes in their environment over the course of their lifetimes. This enables them to improve their compatibility with their environment relative to their starting position. An example of adaptability is the ability of natural species to evolve in response to changes in their environmental conditions over many generations. This ability requires a change in genetic structure in a way that increases the single species' compatibility with the change.

Agents

An agent is a single factor within an interacting population (like people, software, proteins, etc.), with each such agent having some degree of freedom to interact and perform a number of simple actions with their surrounding agents. This ability creates behavior that enhances the complexity of the agent population.

Collections of agents are sometimes called “swarms.” Models based on the behavior of agents in swarms are central to research on complex systems.

Agents are also customarily called “free agents,” due to their capabilities and degrees of freedom of action.

Attractor

An attractor is a point (or goal) to which a system tends to move, either freely or constrained by system parameters (laws). The point is one of the possible movements of the system in the absence of constraints (laws) on the system, or subject to other rules or constraints. The three standard attractor types are called “fixed-point,” “cyclic” and “strange” (or chaotic). Two secondary movements are also depicted in cyclical attractors: one like a wheel, representing a number of recurrent results; while the second is like a bagel, showing a wider variety of fewer predictable results (see diagram no. 28).

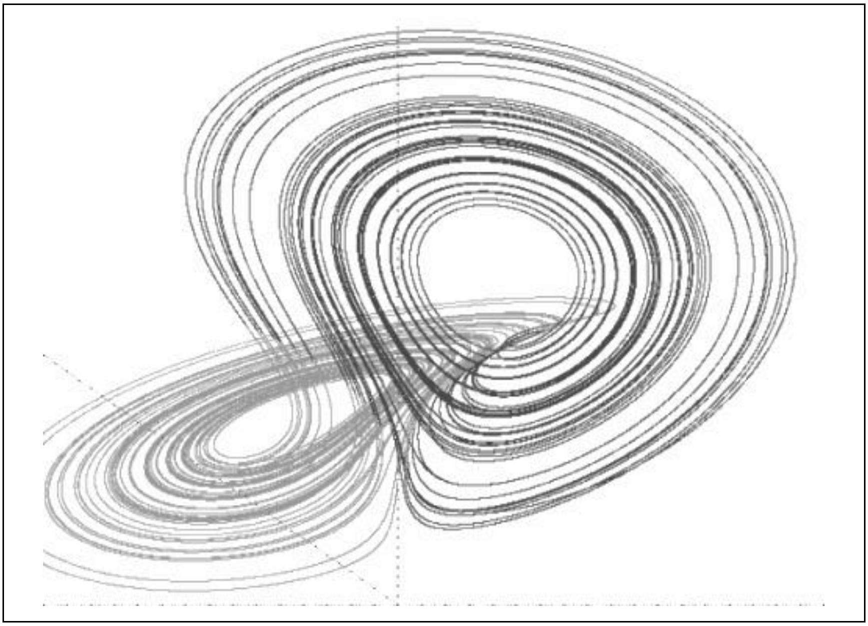
Attractors relating to chaotic movement are called “strange attractors.” Examples of this type of attractor can be seen in the growth cycle of man from birth, or in the behavior of a tornado.

Diagram no. 28:

Example of a bagel-shaped attractor

(from: http://www.pha.jhu.edu/~ldb/seminar/attractors.html,

downloaded on 28/8/11)



Basin of Attraction

The set of possible states that are the starting points of the attractors. In other words, the basin is the convergence place of points, so that, every time a process begins from one of these points, the system will be drawn towards the attractor defined by the basin.

Bifurcation

A point at which a system splits into two alternative behaviors, either being possible, with the second alternative appearing unpredictably after the first. After a number of additional bifurcations are similarly formed, the system is liable to slide into chaotic states.

Instances of transitions from one state to another are called 'phase transfer'. An example of a 'phase transfer' is a change in the number of fish in a lake at a certain ratio of the occurrence of a change in the environment, such as a flow of alluvium containing food, an increase in the number of fisherman, etc.

Butterfly Effect

The possibility that a minor shift in the initial conditions of a system will have a huge impact on the state of the system over time. This concept has two possible sources: the first derives from the analogy that a small butterfly flapping its wings on one side of the world may eventually cause colossal activity on the other side of the world. Another source of the term may be seen in computer-generated images of attractors, which take on the shape of butterfly wings.
The sensitivity to initial conditions that this term represents is an important concept characterizing many complex systems.

Cellular Automata ,CA

'Cellular automata' are a variety of software used to study traits of system growth and decay. The computer programs display a structure of agents' network interacting in a number of dimensions (by choice). The system receives a set of rules that generates the new state of each 'agent'. The change occurs after a move and check of each agent, and its new state is determined. The set of rules relates to the state of each agent at the next stage, relative to its state and the state of its neighboring agents in the present state. As an example of applications using CA, applications running simulations can provide insights into the form and nature of network growth.

Chaos

Chaos is a way to describe the state of a system whose long-term behavior is unpredictable. A tiny change in the initial condition can lead to any possible state in the spectrum of all possible system states. Statistical predictions can identify attractors that can be useful for predictions, even in systems that initially appear to be chaotic (having chaotic traits).

Coherence

The emergence of structural attributes in self-organizing systems, which create internal coherence. When observing the development of a system, often a kind of order is shown that is not visible in simple systems. One can deduce from this phenomenon that the more complex a system is, the more potential there is for innovative attributes to emerge. Businesses and institutions can utilize the coherence of emergent structures in lieu of the imposed order found in traditional bureaucratic hierarchies.

An example of technological coherence is a pinpointed laser beam versus the dispersion of light from an ordinary light bulb.

Complex Adaptive Systems

A complex, nonlinear, interactive system endowed with the ability to evolve and adapt to a changing environment. Such systems are characterized by considerable potential for self-organization and survival in an environment lacking equilibrium. 'Complex adaptive systems' evolve by random mutation, self-organization, the transformation of their internal models relative to the environment, and through natural selection. This type of system contains many free agents who self-organize in a co-evolutionary way in order to optimize their separate values. Examples of complex adaptive systems include living organisms, the nervous system, the immune system, economic systems of countries, corporations, companies, etc.

Complexity

Complexity derives from the interaction between a number of agents or subsystems in a system.

The reproduction of these interactions increases the difficulties in analyzing the results of their effects using linear or reductionist tools, due to the dynamic reciprocal effects that impact the stability (or instability) of the system at an unpredictable level.

Examples of complexity are the human nervous system and the internet, which have many agents and interconnections. These networks represent an unpredictable 'complexity'.

Cooperation

Cooperation is the idea that two or more agents can improve their own situations by mutual assistance, rather than by competition, which will adversely affect them both. This assumes that resources adequate for both exist, which are required in order to carry out the cooperation.

Cybernetics

'Cybernetics' is a branch of science relating to processes of communication, command and control in biological and artificial systems.

The objective of the developers of cybernetics (Wiener, Ashby, Shannon and others) was to scrutinize the similarities and differences in processes in organic and artificial systems, and to formulate joint principles for all systems in order to understand their behaviors. Typically, cybernetics uses combinations of activity detectors, feedback loops and responses in systems from diverse fields – from electronics to robotics and from psychology to neurophysiology.

First-order cybernetics relates to closed systems. Second-order cybernetics includes the observer's perspective; i.e., open systems. Third-order cybernetics examines their co-emergence and reciprocal effects.

Diversity

'Diversity' is the range of features or niches available, which increases parallel to the increase in the number of participants in the system. The different types and nature (i.e., the variety) constitute the infrastructure for complexity (see Ashby's "law of the requisite variety," which defines the laws in nature as a variety-restricting factor). Another example of restricting variety is through procedures in organizations).

Dynamics

A system's changes in behavior over time constitute the essence of complexity. The existence or absence of dynamics is a characteristic symbol of systems, which are categorized, inter alia, as either static or dynamic.

Edge of Chaos, EOC

The term relates to the idea that many adaptive systems, including life itself, are naturally drawn towards a state roughly midway between 'order' and 'chaos'. The term is used as a metaphor, due to the similarity between the dynamics when approaching phase transfers and the dynamics of information processing. In both, the edge of chaos is near the transition points.

The edge of chaos – the environment in which organizations, species or information systems should find a balance between excess methodologies (procedures) and inflexibility (a lack of creativity) in order to adapt.

As an example of transition points, one can recall the phases of liquids, which is midway between two states: solid (static) and gas (random). According to information theories, the edge of chaos is the environment that contains maximum information.

Emergence

'Emergence' is a system property deriving from all of its components, but not from a simple aggregate of the system’s individual parts. An extraordinary phenomenon occurs at emergence, of the formation of new structures and shapes that undergo self-organization, in a way that is unpredictable most of the time. Such phenomena derive from their ability to live independent lives under their own specific rules, which simpler systems are incapable of doing.

Instances of emergence occur everywhere at any time, but their importance is secondary where there is a mechanical control, reinforced by the hierarchy.

Evolution

This is a universal idea, which is generally defined as a process of variation, selection and retention. The process of evolution emphasizes methodical improvement over time, through a learning process of trial and error.

The study of processes influencing the evolution can provide insight into the evolutionary processes of systems, and is applied in software called "genetic algorithms, GS."

Feedback

'Feedback' is a linking of a portion of the output of a system that returns to the system as input. It is customary to define this as "*negative feedback*," when at issue is a tendency to restore the system to a planned and desired state, or as "*positive feedback*," when at issue is a tendency to drive the system (usually in a positive direction) from its initial state towards the target. Life employs both these types of 'feedback'.

'Feedback' is a way to describe nonlinear relations between system components. The concept of feedback designs the foundation of dynamic systems and is used as a way to create work flow charts in organizations.

In '*negative feedback'*, a subsystem uses information that it receives to suppress another subsystem. For example, relations between predators and prey may be depicted as a 'negative feedback' loop. The minute that the number of predators increases, a decrease in the number of prey will be recorded. On the other hand, when the drop in the number of prey becomes significant enough, the population of predators will shrink, due to the food shortage.

In *positive feedback*, a subsystem uses information that it receives to enhance another subsystem.

Other types of feedback are being used; for example, *double-loop feedback*, which constitutes essential feedback in learning and adaptive processes.

Fitness Landscape

The fitness landscape is the number of separate niches available within the defined fitness range. It is a graphic way to measure and explore the adequacy (fitness) value of various elements in a system. Each point is graphed relative to its neighbor as a lower or higher peak on the fitness map, i.e., peak points are analyzed, according to certain parameters, such as: time, cost, etc., to ascertain, which offers the better solution.

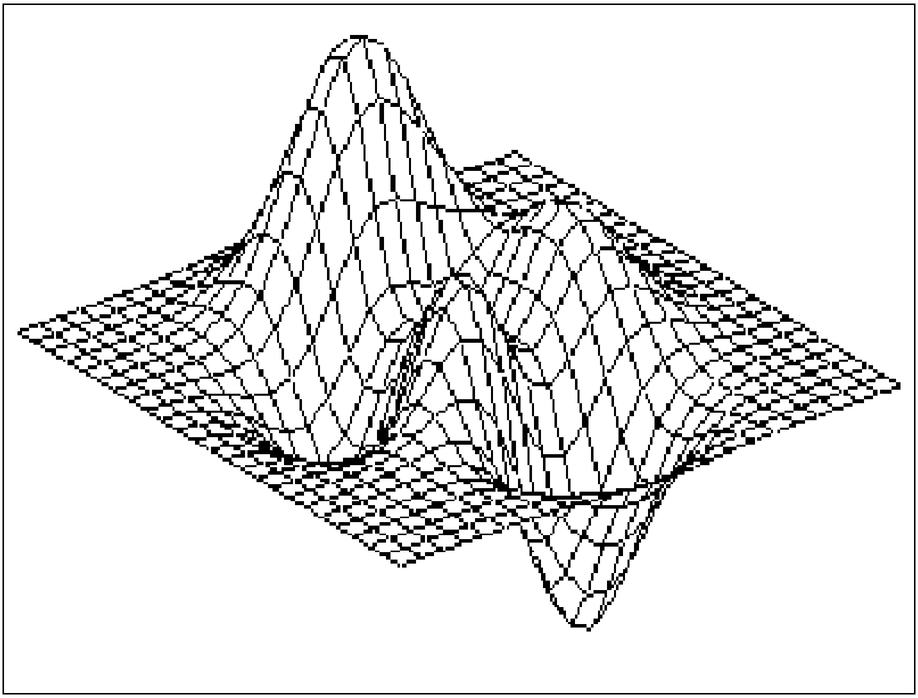
The landscape is dynamic and is affected by all participants and the interactions between them, and affects selection processes in the trajectories; i.e., management decision-making. Fitness landscapes can be used to gain insight into a system's possible modes of action, and they provide information about those courses of action that are more promising. Sometimes, a particular downward slope can be a condition for a more optimal uptrend (see diagram no. 29).

This term was defined by the biologist, Kauffman, during his studies of the behavior of random boolean networks and his development of the NK model (inter-fas, 2005).

Diagram no. 29:

Fitness Landscape

(from: http://www.inter-fas.com.sg/mapping_where_value_resides.htm)



Fractal

A geometrical pattern, structure, or set of points or lines being self-similar (exhibiting an identical or similar pattern) at different resolutions. Fractal geometry is a new geometry developed by

Mandelbrot, who succeeded in expressing systems of fractional numbers depicting multidimensional states with geometric shapes. When observing these fractal shapes at various scales, self-similarity of branching patterns is repetitively seen, such as continental coastlines, the branching of trees, leaves, etc.

Typical fractals are, for example, the “strange attractors” of nonlinear dynamic systems that exhibit deterministic chaos.

Fractals have many uses in applications engaging in artificial intelligence, in data compression, music and other art forms.

Fuzzy Logic

Fuzzy set theory provides a formal framework in which the conventional binary logic, based on choices of "yes" and "no," is replaced with a continuum of possibilities of the alternative of "maybe." It is a way of handling uncertain or missing information, based on its “level of truth,” and replaces the conventional boolean logic based on “true or false.”

The theory was developed by Dr. Zadeh of Berkeley, who had been working on computerized translations of various languages. According to Zadeh, the Boolean logic is an extreme case of fuzzy logic.

Since this approach approximates brain thought processes, fuzzy logic may be used in decision-making involving degrees of uncertainty.

General Systems Theory, GST

GST is the idea that systems of any type and specialization can be described by a common set of characteristics relating to the holistic interactions among their components.

This nonlinear theory rejects the idea that the description of a system as a whole can be expressed by the linear properties of the system's distinct components.

Genetic Algorithm, GA

An algorithm based on the hypothesis that genetic information develops and evolves over time through reproduction, random mutations, and natural selection. In a manner analogous to the principles in a genetic algorithm, a better solution will be obtained through the mixing of new properties and an openness to random or chance events. Thus, genetic algorithms can provide insight into the creative processes of problem-solving and decision-making.

The algorithm was applied in a type of computer software developed by the computer scientist John Holland, whose strategy of arriving at solutions to problems was based on principles taken from genetics.

Global Optimum

The global optimum describes the optimal fitness of an entire system, over all possibilities it can achieve in the entirety of state space. On the other hand, the optimum can also relate to subsystems. The discussion of the choice between them is a management problem. The biologist, Kauffman, developed the “NK model,” which addresses various ways to achieve a global optimum.

Homeostasis

This is a system property that resists change, which has the ability to perform essential adjustments in order to restore the system to a predefined state.

Initial Conditions

The state of a system at the beginning of a period of observation or measurement. The initial conditions are determined at a specific time, so that they may be used as a basis for future comparison and measurement. Chaotic systems demonstrate sensitivity to initial conditions; i.e., the system will observe different results due to even a tiny change in the initial conditions, which reduces the predictability of later states of the system.

Instability

The state of a system that is easily perturbed by internal or external forces or events. Examples of instability are a pencil positioned vertically on its eraser, or a coin balanced on its edge, since the slightest breeze or movement will cause a change in state – they will fall. Since attractors can easily change in unstable systems, in terms of complex systems, such a system, even under minor attack, proceeds to a state in which other results are possible (phase transfer).

Interconnectivity

Joint activity among “free agents” in organizations are comprised, inter alia, of interconnections among organizations constituting a type of infrastructure, and of various types of relays (including “information,” material and energy) passing between them. Interconnectivity expresses a quasi technical essence, while the messages being relayed between them express the essence of a plan.

Local Optimum

A local optimum may be identified relatively easily, but there is no assurance that it also constitutes the global optimum.

Networks

A system whose properties do not entirely depend on its components as distinct elements, but do depend on the dynamics of the interconnections among them. The elements in a network are nodes. The more nodes and the more interconnections there are in a network, the more complex the system is.

Advanced studies identify networks everywhere: networks of interrelations between people, among software, among proteins, etc. Many theories and software are attempting to use networks to describe and predict the functioning and development of systems in dynamic environments.

Neural Network

Device that offers a simplified emulation of the network of interconnections among neural and other human brain cells, the objective being to use the software to facilitate the investigation and study of processes of self-organization in artificial environments.

"NK" Model

The model was developed by Stuart Kauffman (Kauffman, 1997) for the purpose of understanding the evolution of complex systems based on the structure of nodes (N) and the links between them (K).
Based on this concept, the description of the system's fitness landscape may be changed by manipulating (increasing or decreasing) the N values in the system and the K value for each N.
Various social studies have expanded this hypothesis by adding a third parameter, V or S, representing values.

Nonlinear System

A system that behaves in an unexpected manner, which does not change proportionately to a change in input. Sometimes, they respond negatively when they are expected to respond positively, sometimes they do not react at all or issue a drastic response, even when the activity expresses minor input (see the “butterfly affect,” which illustrates how minor input in one location can cause drastic responses in other locations).

Open System

Open systems allow resources, such as material or information, to enter or leave the system, while the input and output of the various resources can be at different volumes.

Optimization

The search for the global optimum, or best overall compromise within a multivalued system that is typical to its environment. Where interactions occur, a few optimum points may be present (the fitness landscape is rugged, with no conspicuous peaks). Since in such a situation, an analytical solution will not be found, the solution usually employed is that of adjustment and adaptation.

Perturbation

A change caused by a factor external to a system. Such change can result in a shift in the system to a new state, an immediate system restore to the previous state or a protracted fluctuation in one trajectory or another.

Phase Space

The theoretical set of all possibilities states available to the system; i.e., all permutations of possible states that the system can occupy. The phase space is also the aggregate of all possible states that the system can engage or occupy over the general space. According to complex systems theory, only a relatively limited number of such states can be found, and the system is supposed to occupy a particular portion of a state or phase space only for a moment.

Phase Transition

A vacillation between static, ordered or chaotic states. Such movement is similar to a change in physical states, from solid to liquid or to gas and back again. This term is frequently used in complex systems theory.

Self Organization

A process occurring in complex systems whereby new structures, patterns and properties emerge without control or direction. Self organization is a process that occurs in every system and in all parts of the system. The attribute of self-organization requires a complex, nonlinear system and suitable conditions, which are usually described as being far-from-equilibrium in order to be activated.
Under certain circumstances, self organization can lead the system to a phase transfer or to the edge of chaos.

Today, this attribute can be observed using computerized simulations, such as cellular automata.

Shadow Organization

A concept in management and complex systems that describes the entire set of informal relationships or networks among people in an organization, which underlies the official and "legitimate" network. In the management arena, this concept is also called the “informal organization” (Tabb and Manheim, *5725* – 1965, p. 131-199). Since a shadow organization does not always have the same rationale as the official organization, it provides fertile soil for instability. A shadow organization is necessary in order to enable self-organization and thus facilitate greater flexibility in structures and processes.
Effective leaders take into consideration the latent capabilities inherent in the shadow organization, in addition to those of the formal organization itself. Often the friction between these “two” organizations can be exploited for the needs of the formal organization and/or for management needs.

Simulation

Simulations characterize system features for computer processing, and construct a model of the original system. If all of the system’s features are transferred to the model, an actual result will be obtained rather than an approximation. There are instances where this is impossible, such as a simulation of volcanic activity. The main feature of a volcanic system is heat, and therefore, cannot be computer simulated (since it would melt). The outcome of the simulation will only be an approximation.

Stability

A static state, unchanging over time, in which nothing changes. In complex systems, multiple states of stability are possible; i.e., many semi-stable states in a single system.

Trajectory

The path or transition through system states or state space. The trajectory is a consecutive sequence of states or paths plotted on a time axis.
Two general forms of paths affect a system's fitness: a positive sum that indicates a trajectory that improves the fitness landscape, and a negative sum, marketing the reverse trajectory.

Values

The targets and dimensions we employ to measure the system's variables. We attempt to maximize the attainment of these targets in order to optimize the fitness of our activities. Due to neural activity in the brain, human imagination often mingles 'facts' with 'values'; however, we must isolate values from facts in order to chart the courses of action of those around us in the materialistic world.