Chaos Theory and Organization

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Abstract

Many authors have stressed the existence of continuous processes of convergence and divergence, stability and instability, evolution and revolution in every organization. This article argues that these processes are embedded in organizational characteristics and in the way organizations are managed. Organizations are presented as nonlinear dynamic systems subject to forces of stability and forces of instability which push them toward chaos. When in a chaotic domain, organizations are likely to exhibit the qualitative properties of chaotic systems. Several of these properties—sensitivity to initial conditions, discreteness of change, attraction to specific configurations, structural invariance at different scales and irreversibility—are used to establish six propositions. First, because of the coupling of counteracting forces, organizations are potentially chaotic. Second, the path from organizational stability to chaos follows a discrete process of change. Third, when the organization is in the chaotic domain, small changes can have big consequences that cannot be predicted in the long term. Fourth, from chaos, new stabilities emerge—the strange attractors—which are assimilated to organizational configurations. Fifth, similar patterns should be found at different scales. Finally, during one single organizational life span or between two different organizations similar actions should never lead to the same result.

(*Organization Theory*; *Chaos Theory*; *Nonlinear Dynamic Systems*)

In this article, chaos theory and properties of chaotic systems are used to suggest a new approach to understand how organizations work. The organization is presented as an open, dynamic, nonlinear system subject to internal and external forces which might be sources of chaos. However, chaos—i.e., an apparently random, but deterministically driven behavior—has organizing attributes. These organizing attributes result from the multiple interactions between forces of stability and forces of instability the system is subject to. Forces of instability derive from initiatives organizational actors take. By taking initiatives, actors create internal disorder. Instability, also, can be generated by organizational actors who develop multiple and interrelated managerial artifacts. One purpose of these artifacts is to create the illusion of managing to reduce cognitive dissonance between what managers are supposed to do and what they can really achieve. In the same vein, managerial artifacts can serve the purpose of creating islands of rationality and certainty and, as a consequence, a form of stability. Thanks to their power of closure, the artifacts assist the manager in making decisions and implementation of actions. But, the managerial artifacts are, also, a source of disorder. They tend to stiffen the organization around artificial working rules which prevent a natural adjustment from taking place between the internal and the external dynamic forces the organization is subject to. Divergence between forces of stability and instability and the frequent aperiodic coupling of these same forces lay the groundwork for chaos to appear. When in the chaotic domain, i.e., a domain where a chaotic behavior can be observed, several consequences, based on chaos theory, can be drawn. The purpose of the discussion below is to pinpoint these consequences from the perspective of organization science and to propose a chaos theory-based approach to understanding how organizations work.

Introduction

From books proposing recipes for managerial success to academic research, literature in management is still frequently based on an implicit assumption of stability and a quasi-mechanistic view of organization. For some, management has achieved the status of science. Prediction and replicability are seen possible. This might be taken as an indication of the maturity the field has achieved. However, for those who run organizations, management is not always a straightforward endeavor. It can be much more complex than what simplistic recommendations imply. Prediction is difficult and replicability, hazardous. Researchers such as Fombrun (1986), Jauch and Kraft (1986), Nystrom et al. (1976), Quinn and Cameron (1988) and Weick (1977) have already challenged the view of a rational and mechanistic organization. Instead, political games between organizational actors, intuition, and random events come into play in shaping an organization's future.

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Many managerial practices and research findings are neither universal nor time-relevant. On one hand, their external validity is frequently low. They cannot be easily adapted from one organization to the other. On the other, even in the organizations in which they originate, the findings are often not durable. This is not surprising because practices and research findings are based on idiosyncratic or averaged situations which can't be easily found elsewhere. Furthermore, they are derived from past experiences and conditions which will be rarely the same in the future. A paradigmatic shift is necessary to reconcile apparently divergent approaches to management. The science of chaos provides a new paradigm where two apparently irreconcilable visions of management—rational and quasi-mechanistic on one hand, unexpected and disorderly on the other hand—can be reconciled.

Natural scientists were the first to turn their attention to the study of chaos, i.e., a system behavior which is apparently random even though it is driven by deterministic rules. Their attention was triggered by the Ruelle and Takens' article on fluid flow turbulence. Ruelle and Takens (1971) showed that a simple deterministic model, under certain conditions, was able to generate behaviors as complex as those observed in nature. Later experimental work, as discussed by Swinney (1983), confirmed their assertion that deterministic chaos existed in nature. Simplicity and determinism could, therefore, lead to complexity. Economists soon followed with works in macroeconomics and finance as surveyed by Baumol and Benhabib (1989), Grandmont (1986) and illustrated in Anderson et al. (1988). Since economic data seem random, a logical step was to see if deterministic chaos, i.e., an apparent randomness created by deterministic rules, was present.

Organization science has not yet given full attention to nonlinear dynamics and their properties. Apart from the works of Gemmill and Smith (1985), Smith (1986) on dissipative structure and social systems transformation, Nonaka (1988) on firms self renewal, Priesmeyer and Baik (1989) on organizational chaotic behavior, Rasmussen and Mosekilde (1988) on chaotic behavior of management systems, Stacey (1992, 1993) on chaos and management, and Zimmerman (1990) on chaos theory and strategic processes, the literature is still rather sparce and does not always provide insights on what we can infer from chaos theory.

An Overview of Chaos Theory

Chaos theory takes its root in the study of nonlinear dynamic systems. Nonlinear dynamic systems have specific properties that mathematicians have studied for more than a century (Poincaré, 1892–1899). However, during these last 30 years, interest in these systems has grown among researchers of different scientific fields such as physics, chemistry and economics. Interest has been mainly stimulated by these systems capabilities in representing what were perceived, in the past, as noise and randomness. What seemed strange and could not be explained with traditional models was largely left aside. Much of the work done was focusing on regularity, equilibrium, stability, predictability. We have to wait for the sixties and especially the seventies to see researchers start focusing on what was left aside before, i.e., the apparent unexplainable, the complex, the "stable-unstable."

Properties of Nonlinear Dynamic Systems

A nonlinear dynamic system is a system where relationships between time-dependent variables are nonlinear. This system has three types of equilibrium. On one hand, when the system is directed by negative feedbacks, which dampen the influence of variables, after a change, the system always comes back to its initial state. This is the first type of equilibrium: stability. On the other hand, when the system is driven by positive feedbacks, which reinforce the original change made in one of its variables, small changes are accumulating exponentially to lead to an explosive situation. In an explosive instability situation, it is difficult to forecast where the system goes but to a complete collapse. This is the second type of "equilibrium": explosive instability. Finally, when we are in the simultaneous presence of counteracting influences, positive feedbacks which tend to reinforce the initial change and increase instability, negative feedbacks which dampen the original change and tend to increase stability, we find new interesting situations (Ruelle 1988). First, the system can reach a stable equilibrium or point attractor which is independent of time. We can also observe a form of periodic stability (periodic attractor) where the system periodically comes back to its previous state. Finally, we may also find a more complex behavior. On one hand, the behavior can be completely erratic and generate a deterministic noise. On the other hand, it can be contained within a strange shaped surface, dubbed strange attractor. In this situation, there is a sensitive dependence to the initial conditions, i.e., a small initial change has an unexpected and important impact. The behavior is said to be chaotic.

When in a situation of counteracting forces, chaos is not always observed. Ceteris paribus, the state of the system—chaotic or stable—depends on the dynamic combination and on the relative strength of the relationships among its various elements. The passage, or bifurcation, from stable equilibrium to periodic behavior to chaos takes place when an increasing number of variables with different frequencies are coupled between each other. Feigenbaum (1978) shows that a system passes from a stable to a periodic and from a periodic to a chaotic situation when the strength of the link (the value of a parameter) between variables changes. Chaotic behavior is likely when the number of variables is equal to or greater than three. Furthermore, when the number of variables with different periodicity increases, a resulting more complicated behavior is observed. As a consequence, the simultaneous presence of a minimum number of counteracting forces create an apparent randomness, or chaos, similar to phenomena observed in nature.

Chaotic systems and their properties have received a considerable amount of attention in the natural sciences (Allen and Sanglier 1978, Artigiani 1987, Prigogine and Stengers 1984, Ruelle 1991) and to some extent, but more recently, in economics (Brock and Malliaris 1989). From tomorrow's weather, water turbulence, jet engine gas propulsion to demographic evolution, economic cycles and stock market evolution, systems seem to be governed by relationships which dynamically interact with one another and are prone to chaotic behavior. The multiple interactions between these relationships turn the simplest relationship we can imagine into a highly complex network of which behavior is impossible to anticipate. As Ekeland (1988, p. 62) says "even if reality is deterministic, it may well happen that what we observe in this way is unpredictability and randomness."

When in a chaotic state, the impact of a variable change can be predicted only for the very short term. This property makes long-term forecasting impossible. In fact, a small initial change, the effect of which multiplies as time passes, can lead to a dramatically different evolution. It is an exponential instability. A small cause can have a big effect. The sensitivity to initial conditions is not new. A mathematician, Hadamard (1898), was the first to suggest that if a small error in the initial conditions of a system is made, then the system long-term evolution is impossible to predict. But, we have to wait for Lorenz (1963 *a*, *b*) and his famous metaphor of the flap of a butterfly's wing which creates, a few months after, a storm, to see awareness of this phenomenon growing among the scientific community. That is to say that small variations in some of the variables might have monumental consequences; consequences which could not have been predicted beforehand.

Another characteristic of chaotic systems is worth noticing. Especially in the case of dissipative systems—those which dissipate their energy—the chaotic evolution may get organized around structures that we find at different scales, named the strange attractors. A new form of order is found out of chaos. The apparent random behavior gets "attracted" to a given space and remains within its limits. These attractors were first called strange by Ruelle because of their unexpected and strangely regular shape such as the ring-shaped attractor of Hénon, the butterfly wing shaped attractor of Lorenz or the sugar bread shaped attractor of Rössler (see Briggs and Peat, 1989, for illustration).

The attractor creates an implicit order within chaos. Inside the attractor space, the system behavior is highly complex and unstable. However, when looking at this complexity we can observe that it is also organized and that it reproduces at a smaller scale what is observed at a more global level. This scale invariant property has been well analyzed by Mandelbrot (1982*a*) in his work on fractals. For instance he showed that stock market evolution over several years reflected daily and monthly evolutions. For Mandelbrot (1982*b*), a stock market is "self similar" from the largest to the smallest scales. As a consequence, it seems that chaos has several layers of ordering properties which are similar at different scales.

Finally, a last property we would like to discuss is time irreversibility of a chaotic system. In theory, any system has to come back one day to its initial state. However, due to the perfect synchronism in time and space between the different variables that this requires, it is unlikely that the same conditions will be found again in a reasonable future. Consequently, the probability to see a system "reverse" to its initial state is extremely low. System behavior, from practical reason, when in a chaotic state is considered, as time, irreversible. Once in a state of chaos, the system will probably not find itself again in the same situation in the foreseeable future.

The Organization as a Nonlinear Dynamic System

Organizations also are dynamic systems governed by nonlinear relationships. As Thompson (1967, p. 6) pointed out, "the complex organization is a set of interdependent parts which together make up a whole in that each contributes something and receives something from the whole, which in turn is interdependent with some larger environment." Multiple organizational actors, with diverse agenda, inside and outside the organization, try to coordinate their actions to exchange information and to interact in other ways, and they do all this in a dynamic manner; i.e., yesterday's action activates a reaction today which may lead to a new action tomorrow. In the same vein, actions undertaken by some actors influence the actions initiated by others later on. We are in the realm of nonlinearity and time.

Effects of decisions are rarely direct and instantaneous. As Mintzberg and Waters (1990, p. 4) said, "preoccupation with the decisions runs the risk of imputing a direct relationship between the abstraction of mental intention at the individual level and the concreteness of action at the organizational level." They stress the indirect origins of the action which is observed. Pettigrew (1990, p. 10), also, recognizes that "changes have multiple causes and are to be observed by loops rather than by lines." Moreover, organizations encompass numerous actors. These actors have different frames of reference (Kahneman and Tversky 1984; Tversky and Kahneman 1981, 1986), value systems and preferences which change over time and with experience (Lichtenstein and Slovic 1971, Tversky et al. 1990). They sometimes have contradictory objectives and stakes and they intervene at different phases of the evaluation-choice-action process. As a result, no direct relationship can exist between the different actions and action-takers of the organization.

With regard to strategy formation processes, we generally observe that systematic, coordinated, planned and thought-out approaches are combined with muddling through, hesitation, and impulsive responses. In this situation, the process is not as linear and as smooth as a rational mind might wish. The rational, linear, planned process, where risk is measured, evaluated and implemented by a unique leader is mixed with intuition, chance, and other processes where several internal and external organizational actors act and interact, hesitate, take advantage of opportunities and miss others, and all of these in a dynamic mode.

Mintzberg and Waters (1985), for instance, stress the importance of emergent strategies in the strategy formation process. They show that the strategy formation process is based not only on deliberate processes but generally involves a lot of dynamic interactions. In the same vein, other authors such as King and Cleland (1978), Lorange and Vancil (1977), Steiner (1979), Wooldridge and Floyd (1989) suggest that separation between formal and informal systems (or between synoptic and incremental processes) is difficult to make. We also know that structured and unstructured processes (Mintzberg et al. 1976), on one hand, and induced and autonomous approaches (Burgelman 1983), on the other hand, coexist within the firm. Finally, Pinfield (1986) shows that structured and anarchic processes are complementary. In the former, decisions follow an orderly progression: problem identification, search for solution and selection (Glueck 1980, Springer and Hofer 1978, Stagner 1969). In the latter, decisions originate from organizational "garbage cans" in which problems are generated from inside and outside the organization and the solutions are the outcome of an apparent random process between actors (Cohen et al. 1972, March and Olsen 1976, Padgett 1980, Starbuck 1983).

The separation between the manager as a planner and organizer, on one hand, and as a hesitating and sleepwalking actor, on the other hand, is artificial. Reality is more complex, interactive and dynamic than the one which is presented by reduced models which are incomplete at best. Reality contains elements of rationality, formality and order mixed with intuition, informality and disorder.

However, organizations cannot be totally assimilated to natural systems, where laws are immutable. It is likely that the structure of the nonlinear dynamic organizational system changes due to the action of actors inside and outside the organization. It also changes subject to learning and experience. Relationships between different organizational system elements do not remain the same forever. This adds a source of instability and, at the same time, a new layer of complexity. To complicate things further, the organization evolves in an environment which has its own dynamics and with which a continuous exchange of information, resources and energy takes place (Thompson 1967). As Barnard (1968, p. 6) says, "the cause of the instability and limited duration of formal organizations lies in the forces outside." Organizations can attempt to insulate themselves from the environment by controlling the external resources it provides (Pfeffer and Salancick 1978) or they can enact it (Weick 1979). The environment might also act in selecting the organizations best fitted for survival (Aldrich 1979, Hannan and Freeman 1977). As a result, the organization behavior is subject to external forces. And the dynamics of these forces are impossible to predict or even describe with precision and comprehensiveness.

Chaos theory, which has received a great deal of attention from researchers in the natural sciences, is probably difficult to apply to less structured areas such as management. However, it seems that the qualitative properties of chaos theory have an explanatory and integrative power that organization theories could use to their advantage. The qualitative properties evoked by chaos theory—sensitivity to initial conditions, strange attractors, scale invariance, time irreversibility, and bifurcation processes—are powerful enough to offer another perspective from which to view the way organizations work.

The Organization as a Chaotic System

In the review presented above on nonlinear dynamic systems and chaos theory, we have seen that deterministic chaos can be found when there is the simultaneous influence of counteracting forces. Organizations also have counteracting forces at play. Some forces push the system toward stability and order; these include the forces of planning, structuring and controlling. Some other forces push the system toward instability and disorder: the forces of innovation, initiative and experimentation. The coupling of these forces can lead to a highly complex situation: a chaotic organization.

Work on entrepreneurship (Burgelman 1983, Bygrave 1989) is illustrative of the way some organizations create the necessary instabilities to experiment with different types of innovations. By giving the organizational actors enough freedom to experiment with new ways of doing things or by giving them enough resources to explore, without constraint, new areas of growth, the organization creates a catalogue of responses to different and, as yet, unknown demands from the competitive environment. In the same vein, implementation of new forms of operation, in parallel with traditional ways of doing things, is based on the same premise. The objective is to experiment and learn various modes of work which may later become the dominant feature. These experiments, through "bootlegging" or through planned decisions, enable the organization to create a repertory of responses to environmental demand. The responses in this repertory which will ultimately prove to be useful cannot be predicted in advance.

The creation of such a repertory is perfectly coherent with the recommendations of Nystrom et al. (1976). These authors stress the need for the organization to develop a set of new responses. When confronted with an uncertain environment, the organization, if forced to change its traditional responses, can select from its repertory of new forms of relationships and arrangements. In the same vein, Weick (1977) and March (1981) suggest that activities which are not directly connected with the organization's mission are a means to improve its capacity of response to complexity and to changing conditions. Weick (1977), for instance, thinks that self-organization originates from experimentation. Self-organization is an organization which is able to discover, through experimentation, answers to its problems. It selects adapted modes of action to its changing working conditions. Since prediction is difficult in this situation, the organization develops a catalogue of responses and stimulates learning opportunities through multiple experiments. As a consequence, it prepares itself for new forms of operation which can be implemented when these new forms become the required answers to the emergent working conditions. As Weick (1977, 1979) has suggested, it is frequently preferable to let organizations find for themselves the types of operation they are best adapted to. Furthermore, as Nonaka (1988, p. 64) says, "for an organization to evolve continuously, it is necessary to allow freedom among the constituent units in the organization, to generate creative conflicts between them." By doing so, the organization is free to question and challenge its ways of operating and, as a consequence, might be in a better position to find an adequate course of action. Thus experimentation is deliberately not aimed at a specific objective, even though the faculty for experimentation has been given deliberately to the organization. Finally, Pascale (1990) describes the self-renewing organization as one which deliberately creates internal instability. Contributions on self-renewing and self-organizing organizations are coherent with works on organizational learning. For instance, according to Senge (1990), learning is a willingness to experiment and to search for other ways of doing things than those used in the past. It is through experimentation that organizational actors, and then the organization itself, build their knowledge. Knowledge, once put into practice, becomes the real source of learning. In the same vein, Argyris and Schön (1978) see seeds of change behind the numerous instabilities and incoherences which generally go with programmed actions.

Experimentation, innovation, and individual initiative, when they exist, are sources of instability and tend to push the organization out of its programmed course, out of its stable equilibrium. They do not keep the organization on its planned track and objective. On the contrary, by exploring new areas, they are a source of disruption and disorder. However, the organization is not made only of experimentation, disorder and change; indeed, under such circumstances, the organization, literally, could not be an organization. It would be a maelstrom in perpetual change and revolution. As Daft and Weick (1984, p. 286) say, managers will be forced to "wade into the ocean of events that surround the organization and actively try to make sense of them."

The organization needs order and stability to be able to achieve its mission as an organization. As Daft and Lengel (1984, p. 192) put it "in response to the confusion arising from both the environment and internal differences, organizations must create an acceptable level of order and certainty." They concur with Barnard (1968, p. 6) for whom "the survival of an organization depends upon the maintenance of an equilibrium of complex character in a continuously fluctuating environment." Order is necessary, also, to enable the organizational actors to position themselves within the power structure and the hierarchy. Order is also necessary to create the facilitating conditions of decision making. Furthermore, order contributes to the closure of a too complex system for a cognitively limited mind. As Weick (1979, p. 3) suggests, organizing "is defined as a consensually validated grammar for reducing equivocality by means of sensible interlocked behavior." Finally, order helps in creating the appearance of certainty. For instance, reliance on standardized decision rules is used to "avoid" uncertainty (Cyert and March 1963). With certainty, traditional rational management schemes can be applied to their full extent. Moreover, cognitive dissonance, which is created when managers are confronted with a problem that they intuitively know to be impossible to solve, can be reduced.

Internal control proceeds from the same logic: to master what the organization is doing. For instance, the control of managers by the organization's shareholders (Fama and Jensen 1983, Jensen and Meckling 1976) is supposed to result in a better alignment of the managers' and the owners' interests. It should make their actions more coherent and predictable. Since, to fight against the cognitive limitations of the organizational actors, the organization's task is decomposed in a hierarchical manner, management control as a means of coordination is helpful. Management control, at the different organizational levels, aims at minimizing the agency costs between the various layers of the hierarchy. Here, also, it secures a better alignment of the different organizational actors' actions. As a consequence, management control, as formal tool of management, contributes to a better coordination and monitoring of the diverse tasks the organization has to undertake in order to fulfill its mission.

Planning is frequently presented as an effective means that firms use to achieve their mission. This affirmation, however, has been strongly challenged. Cyert and March (1963), for instance, suggest that planning might only be an artifact. If this is the case, why do so many organizations still use planning? Sinha (1990) provides an answer. He shows that formal planning systems contribute to decisions which are perceived as being important and risky. Here, planning is presented as a means to manage uncertainty. He is in agreement with Armstrong (1982), who suggests that planning is particularly important in situations where changes are crucial. By formalizing the decision-making process, managers create islands of certainty. And on these islands, they can proceed in a rational manner. Furthermore, planning, by providing an information network and encouraging communication (Quinn 1980), is a means to deal with important decisions; important decisions which are generally characterized by numerous ramifications and complexity. Thanks to the decomposition of a broad mission into elementary tasks, planning improves the readability of the organization and its numerous links with the environment. It helps in closing a complex system that is too complex to be dealt with in a global manner.

The question remains as to what the real contributions of formalized approaches are and what pushes the organization to control and plan? Langley (1988, 1990) shows that the use of formal tools has other objectives than contributing substantively to the decision. Formal tools are also used as a means of persuasion and to save time. She agrees with Quinn (1980) when he says that planning is partly used to make managers feel more comfortable. She also agrees with Bower (1970), Hickson et al. (1986) when they suggest that formal analysis is frequently used to justify decisions after the fact. These reasons, which stress the apparent nonutilitarian purpose of formal approaches, probably have a psychologically-based origin that the cognitive dissonance theory of Festinger (1957) can help to explain.

To fight against the feeling that they are in a situation where they are powerless, which is in total contradiction with their mission and "raison d'être," managers rely on formal tools to create an illusion: the illusion of managing. For instance, "the gathering of information provides a ritualistic assurance that appropriate attitudes about decision making exist. (...) Displaying the symbol reaffirms the importance of this social value and signals personal and organizational competence" (Feldman and March 1981 pp. 177, 182). By doing so, managers avoid a reality which is in complete contradiction with what they are supposed to do and are paid for. It is more the sense of doing and mastering that the formal tools provide, than their effective use which matters. As a consequence, managers can reduce a dissonance which has been created by their feeling of powerlessness, when confronted by a too complex and unpredictable reality.

However, the order that formal tools provide, is also unsettling, as Weick (1977), in his famous study on the Apollo 3 mission has shown. In the same vein, Miller and Friesen (1980, p. 611) conclude that momentum, i.e., continuity and stability of change in strategy and structure due to past experiences, organizational culture, political coalitions and the existence of formal programs, can be "very costly when it protracts an orientation that has proved to be dysfunctional." Finally, search for order through excessive rationalism can be disruptive. For instance, "managers in big companies often seek orderly advance through early market research studies or Pert planning. Rather than managing the inevitable chaos (*taken here as a metaphor*) of innovation productively, these managers soon drive out the very things that lead to innovation in order to prove their announced plans" (Quinn 1985, p. 77, our parenthesis). Even though formal approaches help in closing the organizational system and make it more predictable, they increase the resistance to change and contribute, through aperiodic coupling, in creating a highly complex situation. In this complex situation, order may lead to chaos.

A Potentially Chaotic Organization

Counteracting forces are at play in most organizations. Some organizations might be dominated by forces of stability, some by forces of instability or, finally, both forces might be at play in a balanced manner and lead to deterministic chaos. We know that many nonlinear dynamic systems are frequently chaotic when the number of system variables is equal to or greater than three. This is obviously the case for many organizations. Chaos is also more likely when the system variables follow different periodicity patterns and are highly coupled with each other, a condition which is frequently met in organizations. For example, Perrow (1984), in his study of "normal accidents," stresses the fact that complex systems tend to develop behaviors of their own. As a consequence, he shows that crises are more the result of complex, tightly coupled relationships than the outcome of inadequate human actions.

Based on the empirical and theoretical evidence discussed above, it seems reasonable to assume that organizations are subject to counteracting forces which follow various periodic patterns and which may contain the seeds of chaos. This leads to the first set of propositions:

PROPOSITION 1. *Organizations are potentially chaotic.*

PROPOSITION 1a. *The greater the number of counteracting forces in an organization, the higher the likelihood of encountering chaos.*

PROPOSITION 1b. *The larger the number of forces with different periodic patterns, the higher the likelihood of encountering chaos.*

Bifurcation Process Toward Chaos

We have seen that a system evolves from one state to the other through a process of period doubling or bifurcation when the coupling between various periodic variables changes. This change does not follow a continuum but takes place abruptly in a discrete manner. We expect to see a similar phenomenon taking place in organizations. This is consistent with the quantum change theory of Miller and Friesen (1984) and the works of Greiner (1972), Miller and Friesen (1980), Mintzberg and Waters (1985) where they show that organizations do not evolve in a continuous manner but step-by-step.

Whatever the state—stable equilibrium, periodic or chaotic—the organization is in, it can be disrupted. For instance, organizational actors have the power to change the relative importance of the dynamic forces at work. The change can also take place through learning (Lant and Mezias 1992, March 1991) and experience (Tushman and Romanelli 1985). Indeed, learning and experience modify the strength and the nature of the relationships between organizational variables. The change, for instance, can lead the organization from a stable to a chaotic state or from a chaotic to a stable state via periodic behaviors. Meanwhile, the organization is likely to remain in one of its dynamic equilibria. This leads to the second proposition:

PROPOSITION 2. *Organizations move from one dynamic state to the other through a discrete bifurcation process.*

PROPOSITION 2a. *An organization will always be in one of the following states: stable equilibrium, periodic equilibrium, or chaos.*

PROPOSITION 2b. *A progressive and continuous change of the relationships between two or more organizational variables leads an organization, in a discrete* *manner, from a stable to a chaotic state via an intermediary periodic behavior.*

Prediction Impossibility

When in a chaotic domain, nonlinear dynamic systems have a sensitive dependence on the initial conditions, i.e., a small change in one variable has an unpredictably large impact on the system's evolution. This is the famous "butterfly" effect. There is an equivalent in the realm of organizations. For instance, Eisenhardt and Schoonhoven (1990), rejoining Kimberly (1975) and Stinchcombe (1965), speculate that organizational growth strongly depends on the founding conditions. They observe that initial, small advantages created new advantages in the future for the newly founded firm. In this situation, also, a small cause can have a big effect.

As a potentially chaotic system, the organization's evolution cannot be predicted. Even in the case of a small change, without radical shocks, it is just a question of time before an unexpected behavior develops. As a consequence, no one can predict the long term behavior of an organization when in a chaotic state, regardless of the type and degree of change. Numerous examples exist where events do not take place as expected and where managers admit their powerlessness to predict what will happen tomorrow (see, for example, Isenberg 1988). In many situations, managers make bets on the future since they cannot rely on forecasts. Whatever the quality of the managers and the quality of the actions, it is the environment and the internal organizational dynamics that matter most.

However, better predictability can be achieved if the system is linearized. Linearization of the system makes the link between cause and effect more direct. In mathematics, linearization is brought about with a small variations analysis. By proceeding by small steps, nonlinear systems are transformed into linear relations. Small variations analysis is the mathematical equivalent of what Braybrooke and Lindblom (1970), with their disjointed incrementalism, and Quinn (1980), with his logical incrementalism, propose for the organization. These are step-by-step approaches which allow managers to proceed marginally. By doing so, the managers are in a position to observe the direct effects of their actions. As a consequence, they can modify the thrust of their effort in an almost continuous manner and make the necessary reorientations. Proceeding incrementally improves the predictability of what managers do. However, when the organization is in its chaotic domain, prediction can only be in the very short term, because in the long term, even the slightest variation can have a great impact on the organization. In the same vein, there are many instances where incrementalism is impossible and where large changes will have to be made. In such cases, initial conditions will have a definite impact on the organization, whatever the horizon. Based on the discussion above, a third proposition can be made:

PROPOSITION 3. *Forecasting is impossible, especially at a global scale and in the long term.*

PROPOSITION 3a. *When in a chaotic state, ceteris paribus, the impact of a change has an unpredictable long term effect.*

PROPOSITION 3b. *When in a chaotic state, ceteris paribus, the impact of an incremental change can be predicted in the very short term.*

[illegible] chaos

Organizational Configurations as Strange Attractors

Within the chaotic domain, two situations may occur: first, a situation where the entire domain can be explored by the organization (this is the case of "deterministic noise") and, second, a situation where attractors limit behavior to a subset of the domain. In the former case, unpredictability is the highest. In the latter, patterns appear: the strange attractor. Within an attractor, there is still a high degree of freedom, but behavior and, as a consequence, unpredictability are limited. Particularly in the case of dissipative systems which exchange energy with their environment (as it is the case of organizations), islands of stability are likely to emerge in a sea of chaos. These islands are the strange attractors. It is admitted that the greater the dissipation is, i.e., the greater the exchange of energy and resources with the environment, the faster the system tends towards its attractor. These attractors have an organizational equivalent: the organizational configurations which demonstrate regularities in their macro characteristics even though they may reveal large differences in their internal processes. Organization configurations have been widely discussed in the literature (Miles and Snow 1978, Miller 1986, Miller and Friesen 1984). They are recognizable patterns of structures and processes. Within the configuration, however, a high complexity exists and predictability is low. Nevertheless, they constitute an "envelope" to feasible behavior. As a consequence, they contribute to closing a complex system. This leads to the fourth proposition:

PROPOSITION 4. *When in a chaotic state, organizations are "attracted" to an identifiable configuration.*

PROPOSITION 4a. *When in a chaotic state, organizations are more likely to adopt a specific configuration than a deterministically "random" pattern.*

PROPOSITION 4b. *The greater the openness of an organization to its environment, the more likely is the "attraction" by the organization to a given configuration.*

Organizational Scale Invariance

Inside the attractor space, the system's behavior is highly complex and unstable. However, we can observe that this complexity is also organized and that, generally, it reproduces at a smaller scale what is observed at a more global level. As a consequence, similar behaviors and configurations should, generally, be observed at different scales. This is the scale invariance property. If the assumption made on the chaotic nature of organizations is correct, we should, generally, observe scale invariance in the organizational world. That is to say that, in their chaotic domain, organizations should have a fractal form. For instance, we should observe several layers of similar patterns and configurations at the organizational, at the suborganizational, at the group and at the individual levels.

Research in organizational learning and cognitive processes makes assumptions that resemble our scale-invariance premise. This literature generally assumes that there is a similarity between processes taking place at the organizational and the individual levels. For example, in his review essay, Cohen (1991) shows emerging convergences between results of research made on individual and organizational learning. The point here is not to confirm the assumptions made by these works but to rely on theories which have implicitly assumed scale invariance of some sort in organizations. Other theories, however, tend to go against this scale invariance property. For example, the work of Lawrence and Lorsch (1967) on the structural differentiation of organizational subunits needed to adapt to different environments is inconsistent with the preceding argument. If the scale invariance property of chaotic systems, generally, holds for natural chaotic systems, it seems unlikely to be the case for organizations. Even though there are opposite arguments for the existence of scale invariance in organizations, we nevertheless suggest a fifth proposition, consistent with chaos theory, which asserts that such a property does exist.

PROPOSITION 5. *When in a chaotic state, organizations, generally, have a fractal form.*

PROPOSITION 5a. *When in a chaotic state, similar structure patterns are found at the organizational, unit, group and individual levels.*

PROPOSITION 5b. *When in a chaotic state, similar process patterns are found at the organizational, unit, group and individual levels.*

Actions' Irreversibility

The last proposition deals with the irreversibility of chaotic systems. In theory, a system can encounter the same situation several times. However, the probability of seeing such a recurrence is so low that we can consider that a chaotic system will never find itself twice in the same situation. Consequently, in an organization, it is unlikely that the same action, taken twice, will lead to the same result. As an example and based on his thorough study on how successful organizations fail, Miller (1990) shows that the very actions which once produced excellent results might lead one day to failure. Not only are the results unpredictable but, even in the case where actions are based on similar past experiences, results are different. This argument gives support to Nystrom and Starbuck (1984), who advise organizations to "unlearn" in order to avoid falling into the trap of routine when new responses are required to confront organizational crises.

In the same vein, since the number of organizations is limited and much smaller than the number of possible situations and outcomes, it is very unlikely that two similar situations across organizations will ever be observed. As a consequence, no cause in one organization can have a same effect in another organization. This challenges many approaches based on what the best organizations are doing. To rely on successful practices as a basis to manage in a different context can only lead to deception. A sixth proposition follows:

PROPOSITION 6. *Similar actions taken by organizations in a chaotic state will never lead to the same result.*

PROPOSITION 6a. *When in a chaotic state, two identical actions taken by a same organization always lead to two different results.*

PROPOSITION 6b. *When in a chaotic state, the same action taken by two organizations never leads to the same result.*

The six sets of propositions above are derived directly from the qualitative properties of chaos theory. When possible, the propositions were related to research in the field of organization. We are aware that some of the work, put forward as a support to the propositions, is more suggestive and does not constitute undeniable proof. Empirical research now needs to be done in order to explore in detail the implications of what has been proposed.

Concluding Comments

Chaotic organizations are driven by counteracting forces of change and stability. These forces contain the seeds of order and chaos. On one hand, forces of change are destabilizing because of their tendency to push the system out of its "orbit." Experimentation, incoherence, diverse and diverging activities from the organization thrust are all sources of instability. They create demands which are not necessarily consistent with the planned objectives. They are sources of internal disorder which might lead to major changes in the future. However, the forces of change favor, paradoxically, the emergence of a new form of order and stability. They can become an organizing device and create the conditions for a new order to come. Disorder gives an opportunity to explore new ways of doing and acting. As a consequence, it might facilitate adaptation to the unknown demands of the environment. Since the evolution of the environment is unpredictable, internal disorder, by generating multiple responses, provides a means to explore diverse modes of operation. And one or several modes can become the new organizational equilibrium whose characteristics are impossible to anticipate. Smith (1986), for instance, referring to the works of von Bertalanffy (1975) and those of Jantsch (1980), insists upon the necessary experimentation that organizations must undertake if they want to survive. Experimentation with new organizational paradigms permits the development of catalogues of configurations from which the organization will be able to choose when the forces of change are more powerful than organizational viscosity and resistance.

On the other hand, forces of order and stability are used to close a system which is too complex to be mastered by cognitively limited organizational actors. Search for order is an attempt to build islands of certainty and rationality where purposeful action can be undertaken. Furthermore, order is a means to create the illusion of management. This illusion is forged by organizational actors who are confronted with the impossible challenge of achieving a mission without having the capacity to succeed. However, order is also an unsettling force. Order can lead the organization to act incoherently with respect to the constraints it is subject to. It creates resistance to change and leaves the organization in an artificial limbo. Also, through multiple coupling, the forces of order may create a high level of complexity and may be a source of chaos.

The combination of the forces of stability and change can push the organizations towards chaotic domains where deterministically induced random behavior is the rule. Furthermore, because of the dissipative nature of open systems such as organizations, chaos has an underlying order: the strange attractor or the organizational configuration. As a consequence chaos contains the seeds of new stabilities. It is an organizing force. Thus, organizations face two contradictions: first, let chaos develop because it is the only way to find new forms of order. Second, look for order, but not too much, because it may be a source of chaos.

Researchers and managers are confronted with a major challenge that the incompleteness of traditional models cannot help to meet. The incompleteness is not too bothersome if models are limited to description and interpretation without attempting to prescribe and predict. Prescription and prediction imply perfect knowledge of the interrelationships between variables and their dynamics over time that we do not have. Global reality, from the individual to society as a whole, is impossible to grasp. The consequence of relying on submodels is that what we observe may be apparent randomness.

Chaos theory, which is generally well explored in the natural sciences, needs to be further researched in the realm of social sciences. Already, the qualitative properties of chaos theory have provided several interesting insights on how organizations might work. Among these features, several seem worth exploring. For instance, such features as prediction impossibility (sensitivity to initial conditions), nonreplicability of past situations (time irreversibility), attraction toward configurations (strange attractors), invariance at different organizational scales (fractal forms), and stepwise change processes (bifurcation) give a complementary theoretical support to several existing theories and, at the same time, open new avenues for research.

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