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Complexity Theory and the Fifth Discipline

Peter J. Murray[1]

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Complexity Theory is a relatively new area of research, which has been applied successfully in the chemical and biological sciences and is now beginning to find applications in the social sciences, especially in economics and organizational analysis. The paper sets out an understanding of Complexity Theory and its application to problems in the Management area and, in particular, relates current Complexity Theory thinking in Management with Senge's approach of the "Fifth Discipline." It puts forward a set of principles for Complexity Theory in organization which form the basis for this comparison. After raising some concerns about the concept of self-organization, which is shown to be one of the key concepts in Complexity Theory, and the apparent lack of focus in Complexity Theory research to date with organizational politics and success criteria, the paper concludes by considering whether, at present, Complexity Theory can be considered to have deeper applications in addition to providing useful metaphors relevant to organizational analysis.

KEY WORDS: Complexity Theory; Organizational Analysis; metaphor; self-organization; organizational politics.

1. INTRODUCTION

Meteorologists have the greatest difficulty predicting the weather more than a few days ahead—and this isn't for want of trying. It is because the weather is complex and intrinsically impossible to predict in detail more than a few days ahead. In this context "complex" means that the behavior of the weather depends on a number of influences which interact in ways so that its behavior cannot be easily predicted. Meteorologists can predict in broad terms what the weather will be: on the basis of historical records (give or take a little bit of global warming), they can predict with some confidence seasons in different hemispheres and the total rainfall or hours of sunshine next month or next July. But they can't tell whether it will rain on your next birthday. However, meteorologists may make detailed predictions for the next 2 or 3 days on the basis of

[1]Graduate Management Center, University of Hull, Hull HU6 7RX, U.K.

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models of weather that incorporate experience of the state of the weather today and how the weather has behaved previously.

This discussion of weather forecasting nicely identifies some of the issues of Complexity Theory. Firstly, a complex system behaves predictably within broad parameters (i.e., roughly how much rain will fall next July), but it is unpredictable beyond the immediate future. Secondly—although a lot is known about how the weather works at a "micro" level (for instance, what the effect of a cold front is or how temperature inversions work), when all the elements of the weather are linked up, these micro elements react with each other in ways that become too complex for us to describe in detail, and we cannot therefore describe the whole. Thirdly, it is sometimes difficult to describe cause and effect (Does a ridge of high pressure cause winds or do air flows cause high pressure?) and so it is important to look at the weather as a system, and that means to appreciate it as a whole. Fourthly, it may be possible to discern ways in which the weather appears to organize and adapt itself to geographical and other features.

Complexity Theory is said to have started with a mathematical model of the weather by Edward Lorenz in 1963 (Stewart, 1989, p. 133). Writing in the *Journal of Atmospheric Sciences*, he analyzed the weather using just three (complicated rather than complex) equations

$$dx/dt = a * y - a * x \tag{1}$$

$$dy/dt = r * x - y - x * z \tag{2}$$

$$dz/dt = x * y + b * z \tag{3}$$

where x is the speed of motion of the air, y is the temperature difference between rising and falling air, and z is the vertical temperature profile.

Without going into detail, we can see that some variables (e.g., y) are mathematically treated as cause (independent) in one equation [e.g., (1)] and as effect (dependent) in another [e.g., (2)], illustrating systemic characteristics. What is also noteworthy is that for a particular starting set of parameters, this system evolves in one direction, and for a set of starting parameters which differ only very slightly from the first, it evolves in quite another, that is there is no equifinality. In both cases it is very easy to see how it evolves—that is, each successive step is comprehensible, but over time the two paths diverge dramatically. This can be illustrated through another watery analogy—a drop of water falling at one point in the Andes might flow down (westward) to the Pacific

systems, technological, and economic coevolution, and even suggest that Complexity Theory can be used to understand political events such as the fall of the Berlin Wall. While Complexity Theory may help us to see some sort of pattern in social systems, it seems likely that, just as the weather cannot be predicted

1 month ahead, political events are similarly unpredictable. A second aim of this article is to consider the role of politics in Complexity Theory. The third aim is to compare and contrast Complexity Theory with Senge's use of the "Fifth Discipline" to uncover the deeper mechanisms of organizational behavior. To begin, however, the principles of Complexity Theory in Organizational Analysis are discussed.

2. COMPLEXITY THEORY IN ORGANIZATIONAL ANALYSIS: PRINCIPLES

The discussion in Section 1 has identified some possible metaphors drawn from Complexity Theory which could be applied to complex systems such as organizations, and has given some insight into the ways they may be used. If Complexity Theory is to do more than provide such metaphors (which may in themselves provide ample justification for studying Complexity Theory), then it is necessary to set out rather more systematically the basis of Complexity Theory.

This part of the paper puts together a set of *defining* principles for Complexity Theory in organizations and considers their internal consistency and applicability. These principles are then linked up with other approaches to Organizational Analysis, and some lessons drawn from them. It should be noted that not all of these principles have been clearly demonstrated as necessary for defining Complexity: self-organization is one example.

To put Complexity Theory in a management context, Coveney and Highfield's (1995, p. 7) definition has been amplified with additions in square brackets:

> The study of the behaviour of macroscopic collections [like organizations] of such [basic but interacting] units [like people] that are endowed with the potential to evolve over time.

From the writings on Complexity Theory, four principles emerge as the basis for understanding the behavior described above. They seem to be required by any system demonstrating complex behavior and are therefore discussed first before other principles are introduced. The four principles which define Complexity Theory are

(1) chaotic behavior/nonlinearity,
(2) complex adaptability,

(3) self-organization, and
(4) (co)evolution.

Each of these is discussed below.

(1) Chaotic Behavior/Nonlinearity. The macroscopic collection behaves in a chaotic way in certain circumstances, that is, a small change in its initial state can result in a very large change in its final situation (Coveney and Highfield, 1995).

In an organizational context this relates to the fact that apparently similar actions (e.g., in reprimanding poor performance) can have very different outcomes (improved behavior or a strike) depending on the way in which the action is carried out even when the circumstances are, to all intents and purposes, the same. Equally, the factors determining success and failure in a new product launch may be very sensitive to their initial conditions (except perhaps in hindsight).

The idea of "nonlinearity" is raised again in Section 3.3, especially in the sense of thinking nonlinearly, but another (related) meaning is the fact that doubling one input (e.g., marketing spend) does not always result in a doubling of output (sometimes sales can increase 10-fold—a growth situation—and sometimes not at all—saturation). This nonlinearity is the first of the two features Coveney and Highfield stress as necessary for Complexity.

A second feature of chaotic behavior is the fact that apparently random events or time series may arise because of the presence of an attractor, and, if it is a strange one, the pattern may not be easily discerned (especially over a short time period). In this situation action taken to bring the system back on track may not have the desired effect, and may even be counterproductive. Thus an apparently random pattern of earnings or stock market prices (Arthur, 1996) may arise from the chaotic processes around a strange attractor. Cheng and Van de Ven (1996) have detected chaotic behavior in pharmaceutical R&D projects, and Arthur (1990, quoted by Casti, 1994, p. 264) has looked at the concentration of industries.

(2) Complex Adaptability. Groups and individuals adapt to each other both within the group and in relation to the environment (Kauffman, 1993; McMaster, 1995).

The people in the organization act in relation to each other and the outside environment, and provided there is some clarity as to the organization's purpose, they will tend to reinforce successful behavior, and to build solutions on previous success. This adaptation is not necessarily slavish, but may involve "shaping" the environment to fit strategic intent (Hamel and Prahalad, 1989) and may certainly be very creative in the approaches taken, in some cases going beyond what has succeeded in the past. In this way, the management of a firm may "enact" a new environment and, in so doing, "create a market" for a new

product like the Sony Walkman. Such behavior may be seen as a type of positive feedback loop in which success reinforces itself. (It should be noted that a key issue is how the clarity of purpose is arrived at and that Complexity Theory has not yet addressed this adequately. A further issue is the assumption that organizations act as systems: this point is reviewed in Section 3.1.)

(3) Self-organization. The organization of the whole system cannot obviously be predicted from the behavior of its parts (Kauffman, 1993). This gives rise to, or possibly defines, the emergent behavior characteristic of complex systems.

Going beyond the feedback behavior for complex adaptability, the people in the organization will actually organize themselves in ways which they judge will improve success. Stacey (1996, p. 441ff) sees this as an essentially political process, in which structure and organization will develop or emerge as a result not only of rational analysis of the best way to achieve the purpose, but also by the exercise of power by the players (for their own or for the organization's goals) in promoting their own agenda and, in this way, creating new realities for the organization as a whole. This suggestion provides a clue to how Complexity Theory might treat organizational politics and to explain the process of self-organization.

Thus, in order to stimulate creativity, senior management may choose to set up groups of people from different levels in the organization, who can then organize themselves in ways which will produce results that are not envisaged by senior management. Whether senior management perceives these results as "beneficial" to the firm will be determined by the skill with which they are able to set the boundaries around the self-organizing group.

A fundamental issue in relation to the idea of self-organization is the assumption, which is clearly important to Complexity Theory, that the behavior of the whole is not predictable from the behavior of the parts. It may be that the only way to demonstrate self-organization is to take too narrow a view of the implications of the lower-order properties (of the units), so that by looking at the system as a whole, they lead to macroscopic behavior (in the collection).

(4) (Co)evolution. The collection does not reach an equilibrium state (either point or cyclical) but continues to develop (Kauffman, 1993; Kelly, 1994).

Extending beyond complex adaptability and complementary to the idea of self-organization is the concept of evolution. By definition (and remembering Coveney and Highfield's irreversibility), Complexity Theory deals with the evolution of systems, but this principle implies that they progress (in terms of some broadly accepted criterion such as profitability or growth or sustainability) in some direction, as a result of the adaptability of the organization which enables it to become more and more successful (or as Kauffman puts it, to reach higher and higher peaks). It is worth pointing out that the idea of irreversibility in a complex system does not imply progress; it simply means that the system cannot

return to its previous state and that, therefore, it is always moving to states which may or may not be seen as "better" by the groups who exert influence over it.

Taking this thinking further, organizations may *co*evolve with other organizations, in the sense that all the interest groups which influence the organization (or its senior management) are influenced by the organization itself. The organization therefore forms part of a network of evolving (or at least changing) organizations, many of whom are achieving their purposes and (in more economic terms) are profiting/growing/self-sustaining on the basis of each other's profits/growth/sustainability. Here again, the issue of the exercise of power is apparent, and also that between organizations, as well as within organizations; there are winners and losers, so that coevolution does not always lead to a win–win "success" for all.

Of these four fundamental principles flow three characteristics of Complex Systems (numbered 5, 6, and 7 following the four principles):

(5) emergence,
(6) recursion (or the lack of it), and
(7) process based.

(5) Emergence. Organizational action cannot be predicted in detail but can be predicted in broad terms and tends to emerge from the complex interactions between groups and individuals (Kauffman, 1993).

The whole basis of creativity is that its outcomes cannot be predicted even in principle. Complexity Theory appears to provide a model for this process in that the principles above point to the creation of new ideas, approaches, and products which those who control the organization cannot preplan. Creativity might occur at the level of innovative interactions between the people and groups within the organization and those both inside and outside (complex adaptability) and, also, in new formulations of the organization itself (self-organization) and its relationships at the level of purpose with others (coevolution). For example, in allowing a group to develop a strategy, management will allow that group to influence the strategy, but may have a problem maintaining control over the agenda (Murray, 1996). As pointed out in relation to the principle of self-organization, the characteristic of emergence has the same problem of whether the order is intended by those who have control over the system or simply arises from the interplay of interest groups who have more or less political power.

(6) Recursion. Recursion (or the lack of it) also relates to the idea of self-organization and has two aspects:

(a) the whole is greater than the sum of its parts, and
(b) an approach at one level of complexity (e.g. survival in biology) is not appropriate at another level (e.g. behaviour in economics).

Although Complexity Theory can be applied at all sorts of levels (e.g., at a corporate level, a business level, a functional level, or a project level), this recursion is not always precisely mirrored. Firstly, this is true because the issues in managing a small section of, say, 12 people and a large corporation of 20,000 people are clearly different, so that from a management point of view, the whole corporation is not just the sum of its sections but, rather, requires a set of controls and procedures which do not need to exist at the section level.

Secondly, it is true because the type of issue dealt with at each level (and the purpose) is qualitatively different. Thus at a corporate level the issues will be long-term and might relate to the financial situation, while at a business level there may be a (possibly shorter-term) market orientation. Functional strategy might relate largely to people and relationships with other parts of the organization, customers, suppliers etc., and a project may have a single short-term focus on one issue.

(7) Process-Based Approach. Complexity Theory is more about the process of emergence and complex adaptability than the detailed analysis of particular situations (Waldrop, 1992).

This appears to be Complexity Theory's strength and also its weakness. In some circumstances one may consider using Complexity Theory to predict accurately some aspect of organizational behavior, but in many cases Complexity Theory will give a qualitative feel or analogy for some aspects of the situation rather than the detailed prediction one might hope for. In this sense Complexity Theory may be compared with the concept of the life cycle or growth curve, in which companies (or products or markets) are seen to go through the stages of embryo, growth, maturity, and eventually decline: here, too, the metaphor points the way to a qualitative or even quantitative analytical technique from which it may be difficult to obtain accurate predictions.

Finally, it is worth spelling out the four necessary conditions for complexity to occur (continuing the numbering system from above):

(8) a collection or collections of people,
(9) a purpose or purposes for the organization(s),
(10) adjacency, and
(11) diversity.

(8) A Collection or Collections of People. This does not need to be a formally constituted organization, but may be a subgroup, department, or project team. One of the issues discussed in Section 3.1 is whether the boundaries of the collection can be properly defined.

(9) A Purpose or Purposes for the Organization(s). A significant challenge for Complexity Theory is how it deals with political activity within the organization: where different people are following different agendas and how these are resolved into some common measures for organizational "success" (and

therefore for its purpose) (Kauffman, 1993; Stacey, 1996). Going back to the discussions on self-organization and emergence, it is clear that while a success criterion may not be essential for Complexity, it nevertheless is necessary for organizational survival.

(10) Adjacency. For evolution to occur, it is necessary that the collection can find suitable paths along which it can migrate to further evolutionary possibilities (Kauffman, 1993). The issue here is that, in general, quantum leaps are not normal, and therefore organizations tend to evolve by short steps. Thus a major investment program can be taken only if the funds and the managerial talent are available or can be acquired—and sometimes "start-up" entrepreneurs do not have the necessary funds or the managerial skills. Equally, a large organization which decides to enter a major market needs to have a workable entry strategy.

(11) Diversity. Groups and individuals have their own (emergent) agendas, which come together and influence one another (Stacey, 1996; Kelly, 1994). The process of coevolution depends on a reasonable level of diversity, both within and between organizations, and in putting a team or task force together it is key that a range of skills and of levels in the management is brought to bear.

This part of the paper has tried to take an analytical look at what makes up Complexity Theory in order to draw out some of its key themes for discussion in the next part. It has provided some examples of organizational situations where the metaphors drawn from the sciences can be applied to obtain further insight into organizational complexity. In the next part of the paper, Complexity Theory is compared with Peter Senge's "Fifth Discipline," on the basis of the principles described above.

3. THE FIFTH DISCIPLINE: HOW IT RELATES TO COMPLEXITY THEORY

3.1. Overview of the Learning Organization

Senge's (1990) approach to the learning organization, which he defines as "an organization that is continually expanding its capacity to create its future" (p. 14), draws very heavily on the "Fifth Discipline" of systems theory, which in his writing is very much of the system dynamics variety. It is clear in reading his account of system dynamics that there is similarity to the Complexity Theory approach of applying rigorous mathematics to a behavioral situation. After an overview of Senge's five disciplines, and their parallels with Complexity Theory, the discussion focuses on the Fifth Discipline.

Senge lists five disciplines which he says (p. 6) "are gradually converging to innovate learning organizations" and summarizes (p. 375) their "essences"

and principles as in Table I. Complexity Theory's impact on each of these disciplines is analyzed, before comparing it with Senge's overall thesis.

Senge sees systems thinking as having the essence of holism and interconnectedness, based on the principles that structure influences behavior, of policy resistance and of leverage. None of these contradict the principles of Complexity Theory, which addresses the issues of interconnectedness and structure, but provides many examples of resistance and leverage, depending on the interactions which govern the behavior of its units.

Complexity Theory may be related to the subconscious principle of personal mastery in that the phenomena that are observed are the (superficial) effects of the behavior of the individual units for the collection as a whole.

The parallels are greater for mental modes, where the idea of Complexity Theory providing a model for an organization may be seen to make use of some of the principles such as the "espoused theory vs the theory in use" and the ladder of inference. Frequently the behavior of a complex adaptive system is counterintuitive, which is quite different from what might be expected. This

and Senge is that, in both cases, the need for a shared vision may prove to be a key issue in demonstrating the applicability of the approach.

The collective intelligence and the *dia logos* of team learning come very close to the Complexity Theory idea that at a higher level the collection will demonstrate features which are not obvious at the level of the units, often brought about by the mutual interactions between the units. Indeed Complexity Theory provides a way of working out how dialogue between units can produce a collective position which may differ from the individual perceptions.

Complexity Theory is closest to Senge's thinking in the areas where he uses systems dynamics to enlighten managers' mental models of themselves and the world. Its greatest impact could be in developing understanding of the processes of building shared vision and of team learning and, thus, confirm its potential role as the "sixth discipline" (p. 363) by integrating the five disciplines by establishing their relationships on a more rigorous basis.

3.2. Focus on the Discipline of Systems Thinking

The discussion now looks specifically at Senge's treatment of the systems thinking with some general comment as on his approach and its similarities and differences from Complexity Theory. A much fuller overview of Senge's ideas appears in this issue (Flood, 1998).

Senge (1990, pp. 57–67) introduces the Fifth Discipline (of systems thinking) with a series of what he calls laws, which challenge the reader to look at systems, in general, and organizational systems, in particular, in a more radical light. They are reproduced here to enable the reader to focus on their impact before they are related to the principles of Complexity Theory.

1. Today's problems come from yesterday's "solutions."
2. The harder you push, the harder the system pushes back.
3. Behavior grows better before it grows worse.
4. The easy way out usually leads back in.
5. The cure can be worse than the disease.
6. Faster is slower.
7. Cause and effect are not closely related in time and space.
8. Small changes can produce big results—but the areas of highest leverage are often the least obvious.
9. You can have your cake and eat it too—but not at once.
10. Dividing an elephant in half does not produce two small elephants.
11. There is no blame.

When the laws are compared with the principles of Complexity Theory, the issues that appear most critical are the stability of the system and the way that it tends to absorb attempts to change it, the time dependence of action and

outcome and the unpredictable response to change events, the notion that the whole is the sum of its parts and that one needs to view the whole system rather than seeking narrow cause–effect relationships, and the point that an intervention in the appropriate part of the system allows a very large degree of leverage.

All of these issues may be compared and contrasted with the principles of

[redacted]

can be "frozen" (and therefore cannot be made to change because of internal rigidity), but also that a system near the "edge of chaos" will tend to organize itself to oppose a change. Complexity Theory stresses the macroscopic behavior (and does not imply that the underlying mechanisms are known), while Senge, as will appear, tends to imply that this knowledge can be achieved.

The next issue, of time dependence, has strong links with the unpredictability of the results of an initial effect. Complexity Theory (or more precisely chaos theory) focuses on the unpredictability of the detail of the result—within a broad envelope of possible results—based on the nonlinearity of the system's response, while Senge focuses on the timing of the result. The picture of the system moving around an attractor is helpful here: the unfolding "result" will demonstrate unpredictability in detail behavior as well as in its timing.

The principle of emergence was introduced as one of the principles of Complexity Theory in terms of the whole being more than the sum of its parts.

- an action has one set of consequences locally and a very different set of consequences in another part of the system, and
- obvious interventions produce nonobvious consequences.

This "definition" (which seems to consist of consequences of the type of behavior he is thinking about) may be compared to some of the consequences of Complexity.

Thus the time effects of changes due to the complex interactions, as pointed out above—indicate that the long-term change may not initially be detectable

as much to do with chaos as complexity.

The difference between local and other parts is another illustration of the butterfly effect, and points out the difficulty of being sure that the results of a change can be predicted with any degree of certainty.

Perhaps the most intriguing issue is that of "nonobvious consequences": this paper highlights the issue that what is obvious is very dependent on the beholder. Both Senge and Complexity Theory clearly have a role in raising managers' awareness to the possibility that their actions may have unforeseen

successful innovation. On the other hand, and in contrast to the innate unpredictability of many complex systems, such a "complexity structure" would imply that some features of a complex system can be so clearly understood that they enable an intervention to be carried out with some certainty of success.

Here is the heart of the contrast between Senge and Complexity Theory. Senge expects that the "right" intervention will have the leverage required to produce the change in the system that the change agent requires. Complexity Theory teaches that while this may occur in some situations, other situations will, by definition, not allow a detailed prediction to be made within a predictable envelope of possibilities. To imply that Senge ignores this problem is not correct, but it may well be that culturally the (U.S. and U.K.) managers with whom he works are not ready to acknowledge this level of unpredictability and that he must stress the models which underlie the reality observed. Of course, it is clear that neither Complexity Theory nor Senge addresses the fundamental issue of whose interests are being served in an intervention, and it is this political dimension, and the associated (taken for granted) cultural issue, to which the discussion now turns.

3.3. Including Culture and Politics: Total Systems Intervention (TSI)

It need hardly be said that Systems Thinking has traveled a long way from its OR and Cybernetic roots, first by taking up the issue of Soft Systems Thinking (Checkland and Scholes, 1990) and then in the development of the system of systems methodologies, known as TSI, rigorously documented by Flood and Jackson (1991) and made more accessible to executive practitioners by Flood (1995). This paper does not set out to describe the TSI approach, but takes one element of the insight TSI provides in order to point toward an approach to including the issues of culture and politics into the study of complex systems required by Complexity Theory and Senge.

In the first book, Flood and Jackson (1991) set out their metamethodology for critically determining the problem context for which any methodology is suitable, based on their guiding philosophy (pp. 46–49) of complementarism, sociological awareness, and human well-being and emancipation. In essence they group problem situations in terms of the systems (simple or complex) and the participants (unitary, pluralist, or coercive), thus providing six groupings, for example, simple–unitary, complex–pluralist, and so on. The discrimination between participants (unitary, complex, and coercive) was elaborated (and pragmatized) by Flood (1995) into four dimensions of organizational design, process, culture, and politics, and it is this distinction between problem contexts which we now utilize.

In holding up Complexity Theory to the mirror of TSI, it is worth reflecting that the idea of chaos in physical systems is very clearly what Flood and Jackson refer to as a unitary context (and Flood as a design or process problem) since

the behavior of the elements in a physical system are not taken to be a matter of debate (or at least not of prescriptive debate). On that basis the "units" in a "collection" behave in a predetermined fashion and the unpredictable behavior of the system arises from its technical context, which may be simple (as in the behavior of water molecules in an ice crystal) or complex (in the population ecology of a prairie).

The problem becomes more interesting when one applies Complexity Theory to economic, social, and political systems where the behavior of the units is not programmed, and where the units have the opportunity to choose, moves Complexity Theory into a pluralist (or political) context. It may be the case that Complexity Theory's insights are relevant here too, but the different context means that it is much harder to define the possible behaviors of the units.

Since most organizations are essentially political entities, where the extent to which the management is in control is a direct consequence of its relative power (Murray, 1996), Complexity Theory would, if it were shown to be an appropriate approach, need to meet the requirements of a Coercive context, although the term "political" might be a more appropriate one.

From this discussion, it is clear that Complexity Theory can be fitted into a complementarist framework and that a key issue is the extent to which its units can be sociologically aware. The issue of emancipation is now discussed. Complexity Theory does not address the issue of the "objectivity" (or lack of it) of its analysis. As pointed out in condition 9 above, the assumption of contributing to organizational success is not supported by a desire to understand the process by which the success criteria arise, even though Complexity Theory itself may explain that process. In considering the principle of emancipation, it is worth considering Complexity Theory in relation to Habermas' technical, practical, and emancipatory interests (described by Flood and Jackson, 1991, p. 49). Complexity Theory clearly relates and meets the test of the technical interests, insofar as it is able to make useful predictions or show that such predictions cannot be made. In relation to practical interests, its use of metaphor and its ability to demonstrate aspects of the behavior of complex systems will assist in "securing and expanding the possibilities for mutual understanding" which, according to their account, are required for the practical interest. Complexity Theory's emancipatory role appears to be limited, and likely to remain so, until its approach to the issues of power described below is resolved.

4. CONCLUSIONS

Before setting out the conclusions, it is worth reviewing the current status of Complexity Theory in Organizational Analysis. Complexity Theory is not so much a clearly formulated mathematical model but, rather, a set of ideas which are not yet completely coherent, with characteristics which have not yet been

clearly demonstrated and which are assumed to arise from the basic complexity of the underlying system. As such, it is expected that Complexity Theory can provide at this point only an approach to understanding complex phenomena in broad terms rather than in a detailed predictive way. This paper therefore attempts to describe and comment on a not entirely coherent theory, and this emergent status may account for some of the more extreme hopes invested in Complexity Theory.

This section is confined to five pragmatic points, beginning with a review of the three ways in which Complexity Theory (and related aspects of the Fifth Discipline) might apply, that is, at the levels of metaphor, as a practical approach or framework for organizational problem solving, or as a mathematical model or description of organizational behavior.

1. Complexity Theory has many useful metaphors for understanding organizations. Many of the characteristics attributed to complex systems are in fact the type of behavior one might experience in organizations, including emergence, self-organization, and the (co)evolution of several organizations. Complexity Theory is a fertile field of metaphor, and whether or not one is keen on the study of physical or biological worlds, there are many ways in which Complexity Theory can provide images to illustrate organizational standpoints. Some of the chief of these are

- freezing and melting,
- "the edge of chaos,"
- coevolution of organisms and businesses in ecologies and economies,
- the adjacency by which strategy can emerge from incremental actions, and
- self-organization at many different levels, from molecules to people.

Complexity Theory's role of metaphor is further elaborated by Morgan (1997). He suggests (p. 261ff) five key ideas for modern management arising from Chaos and Complexity Theory, including "rethink[ing] . . . hierarchy and control," "us[ing] small changes to create large effects," and "liv[ing] with continuous transformation and emergent order as a natural state of affairs."

2. Complexity Theory might be investigated to see whether it can explain some of the emergent phenomena that arise in organizations in terms of bounded uncertainty, and of the sensitivity of the basic assumptions. Going beyond metaphor, it is clear that it would be valuable to explore ways in which Complexity Theory could be used to illuminate organizational issues, by attempting to use Complexity Theory to explain behavior beyond simple analogy, and in particular, whether it will raise any new research questions. The suggestion made above of "complexity structures" which can be used to articulate the processes going on beneath the surface of a complex system would be of this kind. Such

research is progressing with papers detecting chaotic behavior (Cheng and Van de Ven, 1996) and studies of complexity in organizations (Cohen, 1996; Matthews, 1996). Specifically this could include the issue of what measure of success (whether this is "innovativeness," "creativity," short-term profit, or whatever) to use and how this arises. Discussions to date do not address who arrives at this measure or, equally importantly, how this is reached. An agenda for such research appears on the *Organization Science* (1996) web page listed in the References.

3. Complexity Theory may be able to provide a mathematical model of organization, but it is unlikely that this would allow the kind of precise prediction which might be hoped for. By analogy with the weather, detailed predictions are accurate only for a limited time, and after that they become of the type envisaged in the previous conclusion. What may be useful is the construction of a mathematical model which simulated the behavior of complex systems and demonstrated the features of Complexity Theory, for use in educating managers and consultants to the lessons of Complexity Theory, rather as Senge uses his archetypes.

The remaining two conclusions address issues which seem fundamental if Complexity Theory is to be more than a management toy.

4. Complexity Theory needs to address the issue of politics and divergent views of "success." It is important that Complexity Theory addresses the issue of where the agenda for "success" arises: this process may itself be a complex phenomenon and needs to form part of the Complexity Theory for an organization. This proposal is in accord with the Complexity Theory concepts of complex adaptability and self-organization, and will go some way toward providing a Complexity Theory of control and creativity. Although this criticism of Complexity Theory could be viewed as relating to people's perceptions, culture, and politics which cannot be expressed in the form of predictive mathematical models, it is clear that if Complexity Theory is not able to address this issue, its ability to deal with issues that *do* have a cultural or political dimension, including many applications in Organizational Analysis, will be significantly affected.

5. The notion of self-organization seems to present a problem in that it implies unexpected emergent order, but the emergent order is unexpected only if, in considering the behavior of the units, one loses sight of the behavior of the collection. While in one sense, the behavior of an airplane emerges from that of its components, Boeing's business is based on the fact that one *can* understand and predict why and how this occurs.

This paper has set out the principles on which Complexity Theory is based, and has presented Complexity Theory as far as possible as a coherent whole. Its similarities and differences from Senge's Fifth Discipline have been dem-

onstrated. Finally, the paper has concluded that its potential for providing insights beyond those of metaphor will depend on its addressing several key issues, including its treatment of political interests and the reality of self-organization. Clearly, much work remains to be done, not least in providing an empirical basis for the range of its predictive ability.

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