Complexity theories and organizational change

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Complexity theory or, more appropriately, theories, serves as an umbrella term for a number of theories, ideas and research programmes that are derived from scientific disciplines such as meteorology, biology, physics, chemistry and mathematics. Complexity theories are increasingly being seen by academics and practitioners as a way of understanding and changing organizations. The aim of this paper is to review the nature of complexity theories and their importance and implications for organizations and organizational change. It begins by showing how perspectives on organizational change have altered over the last 20 years. This is followed by an examination of complexity theories and their implications for organizational change. The paper concludes by arguing that, even in the natural sciences, the complexity approach is not fully developed or unchallenged, and that, as yet, organization theorists do not appear to have moved beyond the stage of using it as metaphor rather than as a mathematical way of analysing and managing organizations.

Key words: complexity theories; organizational change; chaos; self-organization; order-generating rules

Introduction

There are very few issues relating to organizations on which there can be said to be broad agreement among and between academics and practitioners. One of the areas where substantial agreement does appear to exist is with regard to organizational change. By and large, there is a consensus that organizations are facing unprecedented levels of change and that, consequently, the ability to manage change is, or should be, a core organizational competence (Brown and Eisenhardt 1997; Cooper and Jackson 1997; Dawson 2003; Dunphy *et al*. 2003; Greenwald 1996; Johnson and Scholes 2002; Kanter *et al*. 1997; Kotter 1996; Peters 1997; Romanelli and Tushman 1994). Despite this consensus, successful organizational change has proved a very elusive creature, with many studies reporting a very high failure rate, sometimes 80% or above (Beer and Nohria 2000; Brodbeck 2002; Bryant 1998; Burnes 2004b; Clarke 1999; Harung *et al*. 1999; Huczynski and Buchanan 2001; Stickland 1998; Styhre 2002; Whyte and Witcher 1992; Witcher 1993; Zairi *et al*. 1994).

Given the prevalence and importance of organizational change, and the difficulty of successfully bringing it about, there has been much debate over the last 20 years in particular as to the most appropriate way to manage change (Beer and Nohria 2000; Dawson 2003; Kanter *et al*. 1992; Kotter 1996; Pettigrew 1990a,b; Romanelli and Tushman 1994; Stace and Dunphy 2001; Stickland 1998; Stacey 2003; Wilson 1992). Though there has been a great deal of criticism of Kurt Lewin's and the Organization Development movement's Planned approach to change, which dominated the field up to the 1980s (see Burnes 2004a), and a great deal of interest in the punctuated equilibrium model of change (Gersick 1991; Romanelli and Tushman 1994), perhaps the fastest-growing area of interest in recent years has been in the continuous transformation model, which seeks to apply complexity theories to organizational change (Brown and Eisenhardt 1997; Fitzgerald 2002a; Hock 1999; MacIntosh and MacLean 2001; Stacey *et al*. 2002).

The term 'complexity theories' serves as an umbrella label for a number of theories, ideas and research programmes that are derived from scientific disciplines such as meteorology, biology, physics, chemistry and mathematics (Rescher 1996; Stacey 2003; Styhre 2002). As Manson (2001) argues, there is not one theory but a number of theories, developed by different scientific disciplines, which gather under the general heading of complexity research. Consequently, it has to be recognized that any particular definition of complexity is coloured by the perspective of the original discipline. To emphasize the diversity of viewpoints among complexity researchers, this paper follows Black's (2000) lead and uses the term complexity theories rather than theory.

Complexity theories are increasingly being seen by academics and practitioners as a way of understanding organizations and promoting organizational change (Bechtold 1997; Black 2000; Boje 2000; Choi *et al*. 2001; Gilchrist 2000; Lewis 1994; Macbeth 2002; Shelton and Darling 2001; Stacey *et al*. 2002; Tetenbaum 1998). In the natural sciences, their proponents use complexity theories to argue that disequilibrium (chaos) is a necessary condition for the growth of dynamic systems, but that such systems are prevented from tearing themselves apart by the presence of simple order-generating rules (Gell-Mann 1994; Gould 1989; Prigogine and Stengers 1984). Those seeking to apply complexity theories to organizations argue that organizations, like complex systems in nature, are dynamic non-linear systems, and that the outcomes of their actions are unpredictable but, like turbulence in gases and liquids, are governed by a set of simple order-generating rules (Brown and Eisenhardt 1997; Lewis 1994; Lorenz 1993; MacIntosh and MacLean 2001; Stacey *et al*. 2002; Styhre 2002; Tetenbaum 1998; Wheatley 1992). For organizations, as for natural systems, the key to survival is to develop rules which are capable of keeping an organization operating 'on the edge of chaos' (Stacey *et al*. 2002). If organizations are too stable, nothing changes and the system dies; if too chaotic, the system will be overwhelmed by change. In both situations, an organization can only survive and prosper if a new, more appropriate, set of order-generating rules is established (MacIntosh and MacLean 2001).

The purpose of this paper is to review the main tenets of complexity theories, to show how these theories are being applied to organizations and organizational change, and to discuss how and in what way they offer a different or new approach to understanding and managing organizations. The paper begins by showing how perspectives on organizational change have altered over the last 20 years. This is followed by an examination of complexity theories and their implications for organizations and organizational change. The paper concludes that, while the adoption of a complexity approach to change could have significant benefits for organizations, at present it is being used as a metaphorical device for creating new insights rather than as a mathematical approach to understanding and managing organizations.

Approaches to Change

Though there are many different approaches to organizational change and many ways of categorizing these, there is general agreement that the two dominant ones are the Planned and Emergent approaches (Burnes 2004b; Cummings and Worley 2001; Dawson 1994; Kanter *et al*. 1992; Pettigrew 2000; Stace and Dunphy 2001; Weick 2000; Wilson 1992). From the 1950s until the early 1980s, the field of organizational change was dominated by the Planned approach, which originated with Kurt Lewin and was fleshed out and extended by the Organization Development movement

(Cummings and Worley 2001). Planned change is aimed at improving the operation and effectiveness of the human side of the organization through participative, group- and team-based programmes of change (Burnes 2004a; French and Bell 1999). However, by the early 1980s, with the oil shocks of the 1970s, the rise of corporate Japan and the severe economic downturn in the West, it was clear that many organizations needed to transform themselves rapidly, and often brutally, if they were to survive (Burnes 2004b; Dunphy and Stace 1993; Kanter 1989; Peters and Waterman 1982). Given its group-based, consensual and relatively slow nature, Planned change began to attract criticism as to its appropriateness and efficacy, especially from the Culture-Excellence school, the postmodernists and the processualists (Burnes 2004b).

Proponents of Culture-Excellence argued that Western organizations were too bureaucratic, inflexible and slow to change (Peters and Waterman 1982). Their view of Planned change is probably best summed up by Kanter *et al.*'s (1992, 10) scathing comment that:

> Lewin's model was a simple one, with organizational change involving three stages; unfreezing, changing and refreezing … This quaintly linear and static conception – the organization as an ice cube – is so wildly inappropriate that it is difficult to see why it has not only survived but prospered. … Suffice it to say here, first, that organizations are never frozen, much less refrozen, but are fluid entities with many 'personalities'. Second, to the extent that there are stages, they overlap and interpenetrate one another in important ways.

In place of Lewin's model, Culture-Excellence called for organizations to adopt flexible cultures which promote innovation and entrepreneurship and that encourage bottom-up, continuous and co-operative change. Its advocates maintained that top-down coercion, and rapid transformation, might also be necessary to create the conditions in which this type of approach could flourish (Kanter 1983; Peters and Waterman 1982).

At the same time, others were drawing attention to the role of power and politics in decision-making. Writers such as Pfeffer (1981, 1992) claimed that the objectives, and outcomes, of change programmes were more likely to be determined by power struggles than by any process of consensus-building or rational decision-making. For the postmodernists, power is also a central feature of organizational change, but it arises from the socially constructed nature of organizational life:

> In a socially constructed world, responsibility for environmental conditions lies with those who do the constructing. … This suggests at least two competing scenarios for organizational change. First, organization change can be a vehicle of domination for those who conspire to enact the world for others … An alternative use of social constructionism is to create a democracy of enactment in which the process is made open and available to all … such that we create opportunities for freedom and innovation rather than simply for further domination. (Hatch 1997, 367–368)

The other important perspective on organizational change which emerged in the 1980s was the processual approach. Processualists argue that change is continuous, unpredictable and essentially political in nature (Pettigrew and Whipp 1993; Wilson 1992). As Dawson (1994, 3–4) comments:

> The processual framework … adopts the view that change is a complex and dynamic process which should not be solidified or treated as a series of linear events. … central to the development of a processual approach is the need to incorporate an analysis of the politics of managing change.

As Weick (2000) noted, the main critics of Planned change have tended to assemble under the banner of Emergent change. Weick (2000, 237) states that:

> Emergent change consists of ongoing accommodations, adaptations, and alterations that produce fundamental change without a priori intentions to do so. Emergent change occurs when people reaccomplish routines and when they deal with contingencies, breakdowns, and opportunities in everyday work. Much of this change goes unnoticed,

> because small alternations are lumped together as noise in otherwise uneventful inertia …

The rationale for the Emergent approach stems, according to Hayes (2002, 37), from the belief that:

> the key decisions about matching the organisation's resources with opportunities, constraints and demands in the environment evolve over time and are the outcome of cultural and political processes in organisations.

Underpinning the rise of the Emergent approach were new perspectives on the nature of change in organizations. Up to the late 1970s, the incremental model of change dominated. Advocates of this view see change as being a process whereby individual parts of an organization deal incrementally and separately with one problem and one goal at a time. By managers responding to pressures in their local internal and external environments in this way, over time, their organizations become transformed (Cyert and March 1963; Hedberg *et al*. 1976; Lindblom 1959; Quinn 1980, 1982).

In the 1980s, researchers began to draw attention to two new perspectives on change: the punctuated equilibrium model and the continuous transformation model. The former approach to change:

> depicts organizations as evolving through relatively long periods of stability (equilibrium periods) in their basic patterns of activity that are punctuated by relatively short bursts of fundamental change (revolutionary periods). Revolutionary periods substantively disrupt established activity patterns and install the basis for new equilibrium periods. (Romanelli and Tushman 1994, 1141)

The inspiration for this model arises from two sources: first, from the challenge to Darwin's gradualist model of evolution in the natural sciences (Gould 1989); and secondly, from research showing that, while organizations do appear to fit the incrementalist model of change for a period of time, there does come a point when they go through a period of rapid and fundamental change (Gersick 1991).

Proponents of the continuous transformation model of change reject both the incrementalist and punctuated equilibrium models. They argue that, in order to survive, organizations must develop the ability to change themselves continuously in a fundamental manner. This is particularly the case in fast-moving sectors such as retail and computers (Brown and Eisenhardt 1997; Greenwald 1996). Like a rapidly growing number of academics and practitioners, many supporters of the continuous transformation model base their ideas on the work of complexity theorists (Bechtold 1997; Black 2000; Boje 2000; Choi *et al*. 2001; Gilchrist 2000; Lewis 1994; Macbeth 2002; Shelton and Darling 2001; Stacey *et al*. 2002; Tetenbaum 1998).

Certainly, as will be shown below, many of the aspects of the complexity approach, such as the self-organizing dimension, fit very nicely with and give support to the Emergent approach to change. Also, in many respects, the complexity approach seems similar to the recommendations advanced by leading writers such as Tom Peters (1989, 1993, 1997), Rosabeth Moss Kanter (1983, 1989, 1997) and Charles Handy (1989, 1994, 1997) over the last 20 years or so. If this is so, does the complexity approach offer anything new or different to the understanding and practice of managing and changing organizations? In order to address these issues and to understand better what is meant by complexity, the next two sections will examine the origins of complexity theories and their implications for organizational change.

Complexity Theories

In terms of their application to organizations, it is only in the last decade that a sufficient body of academic work has been amassed to allow those studying organizations to recognise the potential of complexity theories. The credit for initiating and sustaining much of the work on complexity and organizations must go to Ralph Stacey and his colleagues at the Complexity and Management Centre at the University of Hertfordshire, and to the *Journal of Organization Change Management*, under the editorship of

David Boje. Stacey, in his 1991 book *The Chaos Frontier*, was one of the first to link complexity with organizational change. Since then, he has published extensively on the topic; in 1995, he created the Complexity and Management Centre to provide a focus for the study of the topic; and in 2002, he launched the book series *Complexity and Emergence in Organizations*, which is published by Routledge (see, for example, Griffin 2002; Stacey *et al*. 2002). The *Journal of Organization Change Management* has been the journal which has probably done more than any other to encourage the complexity debate, both by encouraging the publication of individual papers on the topic and, in 2000 and 2002, giving over entire issues to it (see *Journal of Organization Change Management*, Vol. 13, No. 6 and Vol. 15, No. 4). Nor has complexity been of interest just to academics. From the early 1990s onwards, leading consultants, such as Coopers & Lybrand, McKinsey, and Ernst & Young, sent senior staff to the Santa Fe Institute, one of the leading centres for the study of complexity theories in nature, to find ways of using these 'new sciences' in their consulting practice (Tetenbaum 1998).

Nevertheless, even today, what most people know about complexity stems from what has been labelled the 'butterfly effect', so named from the title of a paper given by Edward Lorenz (1979) based on his work on weather systems (Lorenz 1993). He observed that the tiniest alteration in starting conditions could result in radically different weather forecasts (Sullivan 1999). Lorenz illustrated this by stating that, if a butterfly flaps its wings today, tiny changes in air pressure could eventually lead to a hurricane at some point in the future (Haigh 2002). Therefore, before examining the implications of complexity theories for organizations and organizational change, it is useful to review briefly their origins in the natural sciences.

Complexity theories are concerned with the emergence of order in dynamic non-linear systems operating at the edge of chaos: in other words, systems which are constantly changing and where the laws of cause and effect appear not to apply (Beeson and Davis 2000; Haigh 2002). Order in such systems is seen as manifesting itself in a largely unpredictable fashion, in which patterns of behaviour emerge in irregular but similar forms through a process of self-organization, which is governed by a small number of simple order-generating rules (Black 2000; MacIntosh and MacLean 2001; Tetenbaum 1998).

One of the first things that strikes the reader when approaching complexity theories for the first time is the plethora of strange and exotic terms, such as autocatalytic change, fitness landscapes, non-linearity, bifurcation, Feigenbaum constants, Mandelbrot sets, strange attractors and many, many more (Bechtold 1997; Frederick 1998). This is the language of mathematics, and very exotic mathematics at that. Without mathematics, there would be no complexity theories. The origins of complexity theories lie in attempts by meteorologists to build mathematical models of weather systems (Lorenz 1993). Subsequently, biologists, chemists, physicists and other natural scientists sought to apply a similar approach to their areas of research (Styhre 2002). Though the advocates of complexity see it as a means of simplifying complex systems, in practice, complexity is anything but simple (Manson 2001). By the 1990s, there were so many competing and confusing definitions of complexity that Horgan (1995), surveying the topic in the journal *Science*, entitled his paper 'From Complexity to Perplexity'. Given the explosion of interest since then, it is not surprising that the range of definitions has increased yet further (Parellada 2002; Richardson and Cilliers 2001). Inevitably, in reviewing the topic, Corning (2002, 56) concluded that: 'In short, contradictory opinions abound.'

Though recognizing the disparity of views, Lissack (1999, 112) does point to some common ground among complexity researchers; he argues that it is

> a collection of ideas that have in common the notion that within dynamic patterns there may be underlying simplicity that can, in part, be discovered through large quantities of computer power …

> and through analytic, logical, and conceptual developments …

Stacey *et al.* (2002) go further. They maintain that, though there are many competing ideas and theories, there are three key ones: chaos theory; dissipative structures theory; and the theory of complex adaptive systems. Each of these will now be briefly described.

Chaos theory is derived from Lorenz's work on weather systems. He defined chaotic systems as: 'Processes that appear to proceed according to chance, even though their behaviour is in fact determined by precise laws' (Lorenz 1993, 4). Chaos theory concerns dynamic systems that are constantly transforming themselves in an irreversible, and thus evolutionary, manner (Bechtold 1997; Haigh 2002). The weather, for example, comprises patterns in interdependent forces such as pressure, temperature, humidity and wind speed that have a non-linear relationship (Stacey 2003). Lorenz found that, in weather systems, even a small, apparently insignificant, amount of turbulence, such as the flutter of a butterfly's wings, could lead to radical and unpredictable consequences. However, he also found that, though the specific patterns of the weather are unpredictable in the long term, they always follows the same global shape; we do not get snow in the Sahara or heat waves at the North Pole (Stacey 2003). Therefore, there are boundaries outside which the weather system hardly ever moves, and if it does, it soon returns to its shape. Lorenz (1993) found that the weather system, like other chaotic systems, is not subject to laws of cause and effect. Chaos theory, therefore, rejects Newtonian, mechanical laws and linear causality (Styhre 2002). Instead, chaotic systems are non-linear, i.e. they display complex patterns of behaviour which are not proportional to their multiple causes and which cannot be predicted from them (Fitzgerald 2002b). Chaos can amplify small changes in the environment, causing the instability necessary to transform an existing pattern of behaviour into a new, more appropriate one. Systems may pass through states of instability and reach critical points where they may spontaneously self-organize to produce a different structure of behaviour pattern. These higher-order structures are referred to as dissipative structures (Stacey 2003).

Dissipative structures are so called because they dissipate unless energy is fed in from outside to maintain them. Dissipative structures are most closely associated with the work of Ilya Prigogine (Prigogine 1997; Prigogine and Stengers 1984). Prigogine and his colleagues won the Nobel prize for work which showed that, under appropriate conditions, chemical systems pass through randomness to evolve into higher-level self-organized dissipative structures (Rosenhead 1998). As with chaotic systems, a dissipative structure, according to Prigogine, is a semi-stable configuration that operates in accordance with non-linear logic. For example, in certain positions, it can absorb significant external pressure while, in others, it can be radically changed by even the smallest disturbances (Styhre 2002). Dissipative structures may pass through states of instability and reach critical (bifurcation) points where they spontaneously self-organize to produce a different structure or behaviour that cannot be predicted from a knowledge of the previous state (Stacey 2003). Convection is an example of this. When a liquid is at rest, it exhibits a particular type of structure where the position and movement of its molecules are random. However, as heat is applied to the liquid, its structure begins to change and, when a critical temperature is reached, a new structure emerges in which the molecules move in a regular direction setting up hexagonal cells (Stacey 2003; Stacey *et al.* 2002). The new structure cannot be predicted from the previous state but is determined by the liquid's own internal dynamic which causes spontaneous self-organization to take place (Prigogine 1997). Both chaos theory and dissipative structures theory focus on whole systems and populations; however, the complex adaptive systems approach seeks to understand the behaviour of the individual elements of systems and populations (Stacey *et al.* 2002).

Complex adaptive systems (CASs) consist of a large number of agents, each of which behaves according to its own principles (rules) of local interaction which require each agent to adjust its behaviour to that of other agents (Stacey 2003; Stacey *et al*. 2002). The main focus of work in this area has been on non-linear biological systems. All living organisms, whether a rhinoceros or a rhododendron, are seen as CASs (Goodwin 1994). CASs are self-organizing in that there is no overall blueprint or external determinant of how the system develops; instead, the pattern of behaviour of the system evolves or emerges from the local interaction of the agents within it. It is this self-organizing ability which allows such systems to adapt to their environment in order to survive though, just as the environment in which a rhododendron seed is first planted can radically affect the flowers it produces, CASs are extremely sensitive to their originating or initial conditions (Frederick 1998).

According to Stacey (2003), the main difference between these three theories is that the first two, chaos and dissipative structures theories, seek to construct mathematical models of systems at the macro level (i.e. whole systems and populations). Complex adaptive systems theory, on the other hand, attempts to model the same phenomena by using an agent-based approach. Instead of formulating rules for the whole population, it seeks to formulate rules of interaction for the individual entities making up a system or population and from this explain the behaviour of the population as a whole. However, there are many other, differing, views (Goldberg and Markoczy 2000). For example, Cohen and Stewart (1994) argue that complexity is about how simple things arise from complex systems, and chaos is about how complex things arise from simple systems.

Nevertheless, whether one is looking at weather systems, turbulence in liquids and gases, or biological systems, there do appear to be common elements in the main complexity theories (Lissack 1999). In particular, they portray systems as both non-linear and self-organizing. In order to understand this apparent paradox, there are three central concepts of complexity theories which need to be explored further: the nature of chaos and order; the 'edge of chaos'; and order-generating rules.

Chaos and order: In common parlance, chaos is often portrayed as pure randomness or the complete absence of order but, from the complexity viewpoint, it can be seen as a different form of order (Arndt and Bigelow 2000; Fitzgerald 2002b). Indeed, as Frederick (1998) maintains, dynamic, non-linear (complex) systems contain their own instability and their own sense of order. Fitzgerald (2002a) states that chaos and order are not opposites to choose from but twin attributes of such systems and, within chaos, a hidden order may be concealed beneath what looks like utter randomness. From the complexity perspective, chaos describes a complex, unpredictable, and orderly disorder in which patterns of behaviour unfold in irregular but similar forms; snowflakes are all different but all have six sides (Tetenbaum 1998).

Stacey (2003) identifies three types of order–disorder in complex systems: stable equilibrium; explosive instability; and bounded instability. However, only under the last of these, bounded instability, are complex systems seen as having the ability to transform themselves in order to survive. If systems become too stable, they ossify and die. If they become too unstable, as with cancer, they may get out of control and destroy themselves (Frederick 1998).

Edge of chaos: Under conditions of 'bounded instability', systems are constantly poised at the edge between order and chaos. Elsewhere, Stacey *et al*. (2002) refer to this as a 'far-from-equilibrium' state, while Hock (1999) coined the term 'chaordic'. However, the term most commonly used to describe this condition is the 'edge of chaos':

> complex systems have large numbers of independent yet interacting actors. Rather than ever reaching a stable equilibrium, the most adaptive of these complex systems (e.g., intertidal zones) keep changing continuously by remaining at the poetically termed 'edge of chaos' that exists between order and disorder. By staying in this intermediate zone, these systems never quite settle into a stable equilibrium but never quite fall apart. Rather, these systems,

> which stay constantly poised between order and disorder, exhibit the most prolific, complex and continuous change. … (Brown and Eisenhardt 1997, 29)

It is argued that creativity, growth and useful self-organization are at their optimal when a complex system operates at the edge of chaos (Frederick 1998; Jenner 1998; Kauffman 1993; Lewis 1994). The key question here, of course, is: what is it that allows some systems to remain at the edge of chaos, while others fall over the edge? This is where we need to address the third issue: order-generating rules.

Order-generating rules: One of the most significant findings of complexity theorists is that, even in the most complex systems, the emergence of order manifests itself through a process of self-organization. This occurs through the operation of a limited number of simple order-generating rules, which permit limited chaos while providing relative order (Frederick 1998; Lewis 1994; MacIntosh and MacLean 2001; Stacey *et al*. 2002; Wheatley 1992). As Gell-Mann (1994, 100) puts it:

> In an astonishing variety of contexts, apparently complex structures or behaviours emerge from systems characterized by very simple rules. These systems are said to be self-organized and their properties are said to be emergent. The grandest example is the universe itself, the full complexity of which emerges from simple rules plus chance.

Reynolds (1987) illustrated this self-organizing principle by simulating the flocking behaviour of birds. He attributed to each bird (agent) the same three simple rules of interaction:

(1) Keep a minimum distance from other birds.
(2) Fly at the same speed as other birds.
(3) Move towards the centre of the flock.

Reynolds argued that by each individual bird behaving according to its own local rules of interaction, a self-organised, coherent pattern emerged for the entire system.

Therefore, the concept of order-generating rules explains how complex, non-linear, self-organizing systems manage to maintain themselves at the edge of chaos, even under changing environmental conditions. Complex systems have a further trick up their sleeve. Under certain conditions, they can even generate new, more appropriate order-generating rules when the old ones can no longer cope with the changes in the system's environment (Bechtold 1997; MacIntosh and MacLean 1999; Wheatley 1992). An example would be the hunting behaviour of wild animals. Complex though this behaviour may seem, it is governed by a set of simple rules appropriate to the animals' environment (Stacey 2003). However, a small rise in global temperatures could have a dramatic effect on the animals' environment and invalidate the existing rules. In order to survive, the animals would need to change their hunting rules.

By reducing the workings of the natural world to mathematical models and simple order-generating rules, complexity theories have an attractive elegance, especially for those of us who seek to understand the complexity of the organizational world. However, before moving on to look at the implications of complexity for organizations, it is necessary to issue a health warning.

Complexity is a relatively new science and, like any new science, is not fully accepted within the scientific community (Arndt and Bigelow 2000). Advocates of complexity can point to the work of leading scientists to support their cause. However, it should be noted that much of this work is controversial. Many writers from within and outside the scientific community have expressed doubts about the validity of complexity theories (see Hiett 2001). For every study supporting complexity, a host of criticisms seem to be raised. For example, the biochemist Michael Behe (1996), in his book *Darwin's Black Box*, used complexity to challenge Darwin's Theory of Evolution. However, five years later, he acknowledged that his arguments had been the subject of considerable criticism by fellow scientists (Behe 2001).

Furthermore, much of the evidence produced by scientists which seeks to show that complexity can explain the natural world comes from computer simulations rather than empirical studies. These models take simple rules of behaviour and seek to see how they translate into long-term developments or macro behaviour (Kauffman 1993). However, many researchers would dispute whether such simulations constitute proof that, in the real world as averse to the virtual world, the simple rules being modelled actually produce the behaviour claimed (Cilliers 2002; Rosenhead 1998). This is a point also made by Lissack and Richardson (2001) when discussing whether or not it is possible to build meaningful computer models of human behaviour. They comment that computer models are just that, models, and are not the direct study of the people or social systems being modelled. Lansing (2002) and Parellada (2002) make a similar point in observing that just because we can model something does not mean that the model can teach us anything about what happens in the real world. Such models, they maintain, have to be interpreted, and different observers can interpret the same data in radically different ways.

Therefore, while the attractions of complexity theories are apparent, it is necessary to recognize that, even in the natural sciences, they occupy a developing and contested terrain which makes their translation to the social sciences somewhat more problematic than many organization theorists appear to acknowledge (Cilliers 2002; Eve *et al*. 1997).

Implications for Organizational Change

Before examining the implications of complexity theories for organizations, it is necessary to recognize that each author has their own perspective on what complexity is, ranging from the apparently superficial (Lewis 1994) to the clearly well-considered and extensive (Stacey 2003). In reviewing the literature on complexity and organizations, it is therefore necessary to try to select from the latter group rather than the former. In the main, the following review is based on authors who have made a recognized contribution in the area of complexity and management and/or from journals and books which have a reasonably high standing. However, even where experienced and respected management and organization theorists present a well-considered view of complexity, it has to be recognized that they are not experts in the scientific fields whose findings they report and rely upon. Therefore, as Wheatley (1992) has observed, for most management authors, the first step in applying complexity to organizations begins with an 'act of faith' that such theories are valid and that they can be transferred from the natural to the social sciences.

Nevertheless, a wide range of organizational theorists and practitioners have argued that organizations are complex, non-linear systems whose members (agents) can shape their present and future behaviour through spontaneous self-organizing which is underpinned by a set of simple order-generating rules (Arndt and Bigelow 2000; Bechtold 1997; Black 2000; Fitzgerald 2002a; Lewis 1994; MacIntosh and MacLean 2001; Morgan 1997; Stacey 2003; Tetenbaum 1998; Wheatley 1992).

Just as it is the case that complex systems in nature need to transform themselves continuously in order to survive, so it is argued do organizations (Stacey 2003). Frederick (1998) argues that the best-run companies survive because they operate at the edge of chaos by relentlessly pursuing a path of continuous innovation, and, indeed, because they inject so much novelty and change into their normal operations, they constantly risk falling over the edge. Brown and Eisenhardt (1997) draw a similar conclusion from their research into innovation in the computer industry. They maintain that continuous innovation is necessary for survival and that this is brought about by a process that resembles self-organization in nature. From his research on 'lean organizations', Jenner (1998, 397) states that they

> are successful because their fundamental structure embodies many of the characteristics of 'self-organizing' dynamic systems, such as 'dissipative structures', which balance 'chaos' with 'order'. …

> [they are] … characterized by continual reorganization, rapid new product development, and constant search for increased efficiency, all of which are the results of self-organizational processes.

It is claimed that the best example of a self-organizing organization is Visa (Tetenbaum 1998). It was founded in 1970 by Dee Hock, who coined the phrase chaordic to describe its operations (Hock 1999). Visa has grown by 10,000% since 1970, comprises 20,000 financial institutions, operates in 200 countries and has over half a billion customers. However, as Tetenbaum (1998, 26) notes:

> you don't know where it's located, how it's operated, or who owns it. That's because Visa is decentralised, non-hierarchical, evolving, self-organizing and self-regulating. … it is a chaordic system conceived as an organization solely on the basis of purpose and principle. Its structure evolved from them.

If, as Hock (1999) argues with regard to Visa, it is the case that organizations are complex systems, management and change take on a new dimension. Beeson and Davis (2000) make the point that, while it might be fruitful to see organizations as non-linear systems, to do so will require a fundamental shift in the role of management. Like many others (e.g. Boje 2000; Stacey *et al*. 2002; Sullivan 1999; Tetenbaum 1998; Wheatley 1992), they point out that self-organizing principles explicitly reject cause-and-effect, top-down, command-and-control styles of management. Brodbeck (2002) suggests that the belief by managers that order and control are essential to achieve their objectives needs to be redressed. Morgan (1997) maintains that complexity will require managers to rethink the nature of hierarchy and control, learn the art of managing and changing contexts, promote self-organizing processes, and learn how to use small changes to create large effects. For Tetenbaum (1998), the move to self-organization will require managers to destabilise their organizations and develop the skill of managing order and disorder at the same time. Managers will need to encourage experimentation, divergent views, even allow rule-breaking, and recognize that 'people need the freedom to own their own power, think innovatively, and operate in new patterns' (Bechtold 1997, 198). For Jenner (1998, 402), the key to achieving this is structure: '[t]he dissipative enterprise must be organized into flexible basic units that permit new organizational structures to be identified and to emerge, and which promote efficient exchanges of information'.

In studying innovating organizations, Brown and Eisenhardt (1997, 29) refer to such flexible structures as 'semistructures', which they maintain

> are sufficiently rigid so that change can be organized, but not so rigid that it cannot occur. … sustaining this semistructured state is challenging because it is a dissipative equilibrium and so requires constant managerial vigilance to avoid slipping into pure chaos or pure structure.

Brown and Eisenhardt (1997) claim that organizations can only survive in highly competitive environments by continuously innovating and improvising, which, they argue, relies on intensive, real-time communication within a structure of a few, very specific rules. Beeson and Davis (2000) echo this point and argue that, in such situations, change becomes an everyday event undertaken by all in the organization. Brown and Eisenhardt (1997, 28) also claim that in the firms they studied in the computer industry

> The rate and scale of innovation … was such that the term 'incremental' seemed, in retrospect, stretched. Yet it was not radical innovation such as DNA cloning, either. … Similarly, managers described 'constantly reinventing' themselves. This too seemed more than incremental (i.e., unlike replacing top managers here and there) but also not the massive, rare, and risky change of the organizational and strategy literatures. And so we realised that we were probably looking at a third kind of process that is neither incremental nor radical and that does not fit the punctuated equilibrium model …

Brodbeck (2002) makes a similar point and draws attention to studies which cast doubt on the ability of large-scale, company-wide change programmes to effect real change (see Clarke 1999; Harung *et al*. 1999). For Styhre (2002), the problem is that such programmes ignore the lessons of complexity theories and assume that it is possible to predict the outcomes of such programmes and plan, control and manage them in a rational, top-down, linear fashion.

These writers are depicting organizations operating at the edge of chaos and, therefore, needing to respond continuously to changes in their environments through a process of spontaneous self-organizing change if they are to survive. However, it is argued that, as in the natural world, this process is driven by order-generating rules which themselves can be subject to transformation in certain situations (Lewis 1994; MacIntosh and MacLean 1999, 2001; Stacey 2003). MacIntosh and MacLean (2001) claim to provide evidence of the existence and importance of order-generating rules in organizations, based on a case study of a long-established manufacturing company. The company in question had been in decline for over 30 years. MacIntosh and MacLean found that this appeared to be brought about by a combination of inappropriate order-generating rules (such as 'Don't innovate unless it leads to cost reduction') and a rigid structure which stifled innovation. Once this was recognized, over a period of 12 months, the company evolved more appropriate order-generating rules (such as, 'better, faster, cheaper') and implemented a new structure which gave greater freedom for self-organization to its constituent parts.

Stacey (2003) offers a word of caution in applying the concept of order-generating rules to organizations. He points out that when order-generating rules are transformed in nature, it is an automatic process; in organizations, this is rarely likely to be the case. Stacey argues that people are not unthinking molecules; they can and do exercise free will, they can and do pursue their own objectives, and they can and do interpret events in widely differing ways. This does not mean that order-generating rules cannot guide self-organizing actions in organizations or that such rules cannot be changed, but it does mean that neither will be an automatic process and that both will depend on the nature of the organization (Griffin 2002).

In particular, a number of writers have argued that in order for organizations to promote continuous change through self-organization, they need to operate on democratic principles, i.e. their members will have to have the freedom to self-organize. For example, Bechtold (1997) argues that organizations seeking to adopt a complexity approach will need to have a balanced distribution of power, strong customer focus, a strategy of continuous learning and an orientation towards community service. A further strand in this argument is provided by Kiel (1994), who argues that, because small actions can have large and unpredictable consequences, individual human activity assumes great importance. Jenner (1998) claims that, for self-organization to work, authority must be delegated to those who have access to the broadest channels of information that relate to the issue or problem concerned. Nevertheless, Stacey (2003, 278) sounds a further note of caution:

> This seems to assume that self-organisation is some new form of behaviour rather than a different way of understanding how people have always behaved. The question is whether such self-organizing behaviour produces patterns that block or enable change.

Therefore, as can be seen, while there seems to be a body of management and organization theorists who strongly believe in the complexity approach to organizations, there is also a divergence as to the extent that complexity in nature and complexity in organizations behave in the same way. In addition, it should be noted that none of the writers is attempting to apply the same mathematical approach to studying organizations as lies at the core of the complexity theories as applied to the natural sciences.

With these reservations in mind, we can now address one of the key questions with regard to complexity and organizations: what is different about the complexity approach to organizational change? Despite the tendency of some to see

Table 1. Applying complexity theories to organizations

Implication 1	There will be a need for much greater democracy and power equalization in all aspects of organizational life, instead of just narrow employee participation in change (Bechtold 1997; Kiel 1994; Jenner 1998).
Implication 2	Small-scale incremental change and large-scale radical-transformational change will need to be rejected in favour of 'a third kind' which lies between these two, and which is continuous and based on self-organization at the team/group level (Brodbeck 2002; Brown and Eisenhardt 1997).
Implication 3	In achieving effective change, order-generating rules have the potential to overcome the limitations of rational, linear, top-down, strategy-driven approaches to change (MacIntosh and MacLean 1999, 2001; Stacey 2003; Styhre 2002).

it as some magical cure for all known organizational ills, we need to be clear about what the complexity-based approach has to offer organizations that is different from other approaches (Frederick 1998). If we look at what appears to be being said about management, structure, behaviour and change, much of it seems very familiar. Writers from Peters and Waterman (1982) onwards have been arguing for the last 20 years that managers need to abandon top-down, command-and-control styles, that organizational structures need to be flatter and more flexible, and that greater employee involvement is essential for success (Handy 1989; Kanter 1989, 1997; Kanter *et al.* 1997; Kotter 1996; Peters 1989, 1993, 1997). However, as the implications listed in Table 1 show, there are three areas where those seeking to apply complexity theories to organizations appear to depart from, or extend, the received wisdom of the last 20 years.

The basis for Implication 1 is that, unless employees have the freedom to act as they see fit, self-organization will be blocked, and organizations will die because they will not be able to achieve continuous and beneficial innovation. The rationale for Implication 2 is that neither small-scale incremental change nor radical transformational change works: instead, innovative activity can only be successfully generated through the 'third kind' of change, such as new product and process development brought about by self-organizing teams. The third implication is based on the argument that, because organizations are complex systems, which are radically unpredictable and where even small changes can have massive and unanticipated effects, top-down change cannot deliver the continuous innovation which organizations need in order to survive and prosper. Instead, it is argued that organizations can only achieve continuous innovation if they position themselves at the edge of chaos. This position can only be achieved and maintained through self-organization, which in turn depends on the possession of appropriate order-generating rules. However, should the order-generating rules cease to be appropriate for the organization's environment, the process of self-organization allows new, more appropriate rules to be generated. Therefore, in a chicken and egg fashion, order-generating rules create the conditions for self-organization, and self-organization creates the conditions which enable order-generating rules to be transformed (Bechtold 1997; Hoogerwerf and Poorthuis 2002; Tetenbaum 1998).

Conclusions

As Thomas (2003) observed, the world of organizations is a messy one which is full of controversies, many of which appear irresolvable. In such a situation, it is not surprising that organization theorists cast envious glances at their colleagues in the natural sciences who appear to have, or be developing, theories which explain the workings of the natural world. It is also not surprising that organization theorists, from time to time, borrow ideas and insights from the natural sciences in an attempt to resolve the messiness of the organizational world. These have included field theory, sociometry, information theory, cybernetics and game theory, not to mention Frederick Taylor's use of the term *Scientific* Management to label his approach to work organization. Obviously, if these had met the expectations of their promoters, we would have no need to have recourse to complexity theories now. However, the failure of these approaches to transform our understanding and management of organizations does raise the question: What is so different about complexity theories, that we should take any notice of yet another set of theories from the natural sciences?

The answer to this question is twofold. The first part of the answer is that managing and changing organizations appears to be getting more rather than less difficult, and more rather than less important. Given the rapidly changing environment in which organizations operate, there is little doubt that the ability to manage change successfully needs to be a core competence for organizations (Cummings and Worley 2001; Kanter *et al.* 1997). It is equally clear from the failure rate of change projects that the majority of organizations appear to lack this competence (Brodbeck 2002; Burnes 2004b; Clarke 1999; Harung *et al.* 1999; Huczynski and Buchanan 2001). In order to explain and overcome the failure of many change projects, there has been an explosion of interest among management academics and practitioners in the complexity-based continuous transformation model of change.

Its proponents claim that a complexity approach to change offers an explanation as to why organizations find change so difficult, and a method of overcoming this. They maintain that organizations are dynamic, non-linear systems and, as such, the outcome of their actions is unpredictable but, like turbulence in gases and liquids, they are governed by a set of simple order-generating rules (Lewis 1994; MacIntosh and MacLean 1999, 2001; Stacey 2003). From this, it is argued that most change efforts fail because they seek to impose top-down, transformational change instead of adopting the self-organizing approach necessary to keep complex systems operating at the edge of chaos (Styhre 2002). The implications for organizations from this perspective are that, as Table 1 shows, organizations need to promote structures, policies and practices which allow the democracy and power equalization which create the conditions for self-organization. Self-organization then allows the constituent parts of an organization to respond in a timely and appropriate manner to environmental changes through a process of continuous innovation which focuses on local 'third kind' change, such as new product development, rather than organization-wide transformation (Brown and Eisenhardt 1997). Organizations also need to recognize the symbiotic relationship between self-organization and the presence or creation of appropriate order-generating rules (Bechtold 1997; Hoogerwerf and Poorthuis 2002; Tetenbaum 1998).

This brings us to the second part of the answer to the question: what is so different about complexity theories? Why is complexity better suited to understanding and changing organizations than previous attempts to apply science to organizations? Its proponents claim that the exotic mathematics which have, arguably, revealed the workings of the natural world have also given us the key to understanding the complexities of the social world. Though this all sounds very attractive to organizations who find the world a confusing and difficult place in which to live, we have to remember, as Arndt and Bigelow (2000) warn, that new ideas are often prematurely transferred into normative prescriptions. A more serious criticism is that some social scientists misuse chaos and complexity theories by espousing them, even though they do not understand them, or importing them into the humanities without the slightest conceptual justification (Goldberg and Markoczy 2000; Sokal and Bricmont 1998).

Certainly, in seeking to apply complexity theories to organizations, it is important to be clear that, as Lissack (1999, 112) notes, complexity 'is less an organized, rigorous theory than a collection of ideas …'. Also, once one moves beyond generalities, it becomes very difficult to grasp what is meant by complexity

(Manson 2001; Stickland 1998). This is why, as Arndt and Bigelow (2000, 36) so rightly observe, complexity theories have 'caused consternation as well as delight'. It is especially important that those who seek to promote complexity-based prescriptions for managing and changing organizations should make it clear that these are not, as yet, based on any hard evidence that they actually work (Rosenhead 1998).

Also, in applying complexity theories to organizations, there appears to be a lack of clarity or explicitness regarding how writers are treating them (Arndt and Bigelow 2000; Brodbeck 2002; Hayles 2000; Morgan 1997; Stacey *et al*. 2002; Stacey 2003; Stickland 1998). Are they:

- A metaphorical device which provides a means of gaining new insights into organizations?
- Or, a way of mathematically discovering how and why organizations operate as they do?

Mathematical models based on complexity theories have been used by General Motors and Deere & Co. to address scheduling problems in their manufacturing operations (Tetenbaum 1998). However, this is a far cry from applying complexity theories to human behaviour in organizations. If complexity is to be applied to organizational life, as McKelvey (2000, 24) maintains:

> we should first see a systematic agenda linking theory development with mathematical or computational model development. … We should also see a systematic agenda linking model structures with real-world structures. … Without evidence that both these agendas are being actively pursued, there is no reason to believe that we have a complexity science of firms.

Not only is there no evidence that these twin agendas are being pursued, there is no indication that mathematical techniques used by complexity theorists in the natural sciences have been or can be applied to the complex and dynamic human processes in organizations (Stacey 2003). Goldberg and Markoczy (2000, 94) issue the warning that: 'If the explicit modelling of complexity is removed, it is disturbing to imagine what will actually remain.' What actually appears to remain is the use of complexity as a metaphorical device.

As Morgan (1986, 12–13) noted, metaphors are powerful devices:

> our theories and explanations of organizational life are based on metaphors that lead us to see and understand organizations in distinctive yet partial ways … By using different metaphors to understand the complex and paradoxical character of organizational life, we are able to manage and design organizations in ways that we may not have thought possible before.

Certainly it has been argued that, as a metaphorical device, complexity theories can be used in a creative and useful manner both to gain new insights into organizations and to test empirically the value of these insights (Fitzgerald 2002a; Hayles 2000; Stacey 2003). Also, many of the studies which have sought to explore and apply complexity theories to organizations, whether in nursing, teaching or manufacturing, do seem to use complexity as a metaphor (Boje 2000; Hayles 2000; Jenner 1998; MacIntosh and MacLean 1999, 2001; Styhre 2002). However, there is a world of difference between restructuring an organization because science has discovered that this action is necessary, and doing the same thing because that is what a computer simulation has shown that a flock of birds would do if faced with wind turbulence. The former is proven and testable fact, the latter merely a metaphorical device. Also, as Morgan (1986) demonstrated, there are a range of powerful metaphors which have been applied to organizations, but there is little evidence to show that, as yet, complexity has displaced these. Even if it did, Rosenhead (1998) argues that if complexity is used as a metaphor, it may offer some interesting insights into how organizations might work, but it loses any prescriptive force. This is perhaps why Allen (2001) suggests that complexity does not offer organizations a concrete picture of 'what is' or 'what will be' but instead offers a picture of 'what might be'.

In conclusion, though complexity theories may be bringing about a fundamental re-evaluation of how we view the natural world, it is difficult to support the claim that they also have the potential to bring about the same sort of fundamental re-evaluation of the nature, purpose and operation of organizations. If organizations are to be re-conceptualised as dynamic non-linear systems capable of continuous transformation through self-organization, advocates of this approach will need to show either that it is more than just a metaphorical device, or that even as such it is able to resolve the problems of managing and changing organizations more effectively than other approaches that are on offer.

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