Emergence

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Editorial Board

Issue 1-1 4/3/99 5:54 pm Page 1

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Editor's Note

Welcome to the first issue of *Emergence: A Journal of Complexity Issues in Organizations and Management*. *Emergence* publishes articles of a qualitative nature relating complex systems, sensemaking, psychology, philosophy, semiotics, and cognitive science to the management of organizations, both public and private.

The readers of *Emergence* are managers, academics, consultants, and others interested in the possibility of applying the insights of the science of complex systems to day-to-day management and leadership problems.

The emerging theory of complex systems research has resulted in a growing movement to reinvigorate management. Theory, research, practice, and education can all benefit by adopting a more dynamic, systemic, cognitive, and holistic approach to the management process. As interest in the study of complex systems has grown, a new vocabulary is emerging to describe discoveries about wide-ranging and fundamental phenomena. Complexity theory research has allowed for new insights into many phenomena and for the development of new manners of discussing issues regarding management and organizations.

A shared language based on the insights of complexity can have an important role in a management context. The use of complexity theory metaphors can change the way in which managers think about the problems they face. Instead of competing in a game or a war, managers of a complexity thinking enterprise are trying to find

Issue 1-1 4/3/99 5:54 pm Page 4

their way on an ever-changing, ever-turbulent landscape. Such a conception of their organization's basic task can, in turn, change the day-to-day decisions that those managers make.

The most productive applications of complexity insights have to do with new possibilities for innovation in organizations. These possibilities require new ways of thinking, but old models of thinking persist long after they are productive. New ways of thinking don't just happen; they require new models that have to be learned. *Emergence* is dedicated to helping both practicing managers and academics acquire, understand, and examine these new mental models.

To our new community … a most hearty welcome.

Michael Lissack
Editor

Complexity Theory in Organization Science: Seizing the Promise or Becoming a Fad?

Bill McKelvey

Over the past 35 years complexity theory has become a broad-ranging subject that is appreciated in a variety of ways, illustrated more or less in the books by Anderson, Arrow, and Pines (1988), Nicolis and Prigogine (1989), Mainzer (1994), Favre *et al.* (1995), Belew and Mitchell (1996), and Arthur, Durlauf, and Lane (1997). The study of *complex adaptive systems* (Cowan, Pines, and Meltzer, 1994) has become the ultimate interdisciplinary science, focusing its modeling activities on how microstate events, whether particles, molecules, genes, neurons, human agents, or firms, self-organize into emergent aggregate structures.

A fad is "a practice or interest followed for a time with exaggerated zeal" (*Merriam Webster's*, 1996). Management practice is especially susceptible to fads because of the pressure from managers for new approaches and the enthusiasm with which management consultants put untested organization science ideas into immediate practice. Complexity theory has already become the latest in a long string of management fads, such as T-groups, job enrichment, OD, autonomous work groups, quality circles, JIT inventories, and reengineering. A fad ultimately becomes discredited because its basic tenets remain uncorroborated by a progression of research investigations meeting accepted epistemological standards of justification logic. Micklethwait and Wooldridge (1996) refer to fad-pushing gurus as “witch doctors.”

The problem of questionable scientific standards in organization science is not limited to complexity theory applications (Pfeffer, 1993; McKelvey, 1997). Nevertheless, the application of complexity theory to firms offers another opportunity to consider various epistemological ramifications. The problem is exacerbated because complexity theory’s already strong showing in the physical and life sciences could be emasculated as it is translated into an organizational context. Furthermore, the problem takes on a sense of urgency since:

1. complexity theory appears on its face to be an important addition to organization science;
2. it is already faddishly applied in a growing popular press and by consulting firms;[1] and
3. its essential roots in stochastic microstates have so far been largely ignored.

Thus, complexity theory shows all the characteristics of a short-lived fad.

Clearly, the mission of this and subsequent issues of *Emergence* is systematically to build up a base of high-quality scientific activity aimed at supporting complexity applications to management and organization science—thereby thwarting faddish tendencies. In this founding issue I suggest a bottom-up focus on *organizational microstates* and the adoption of the *semantic conception* of scientific theory. The union of these two hallmarks of current science and philosophy, along with computational modeling, may prevent complexity theory from becoming just another fad.

BOTTOM-UP ORGANIZATION SCIENCE

In their book *Growing Artificial Societies*, Epstein and Axtell (1996) join computational modeling with modern "bottom-up" science, that is, science based on microstates. A discussion of bottom-up organization science must define organizational microstates in addition to defining the nature of aggregate behavior. Particle models rest on microstates. For physicists, particles and microstates are one and the same—the microstates of physical matter are atomic particles and subparticles. For chemists and biologists, microstates are, respectively, molecules and biomolecules. For organization scientists, microstates are defined as discrete random behavioral process events.

So if they are not individuals, what *are* organizational microstates? Decision theorists would likely pick decisions. Information theorists might pick information bits. I side with process theorists. Information bits could well be the microstates for decision science and electronic bytes may make good microstates for information science, but they are below the *organizational lower bound* and are thus uninteresting to organization scientists. In the hierarchy of sciences—physics, chemistry, biology, psychology, organization science, economics—the lower bound separates a science from the one lower in the hierarchy. Since phenomena in or below the lower bound—termed microstates—are outside a particular science's explanatory interest, platform assumptions are made about whether they are "uniform" as in economists' assumptions about rational actors, or "stochastic" as in physicists' use of statistical mechanics on atomic particles or kinetic gas molecules. Sciences traditionally adopt the convenience of assuming uniformity early in their life-cycle and then later drift into the adoption of the more complicated stochastic assumption.

Process theorists define organizational processes as consisting of multiple events. Van de Ven (1992) notes that when a process as a black box or category is opened up it appears as a sequence of events. Abbott (1990) states: "every process theory argues for patterned sequences of events" (p. 375). Mackenzie (1986, p. 45) defines a process as "a time dependent sequence of elements governed by a rule called a process law," and as having five components (1986, p. 46):

1. The entities involved in performing the process;
2. The elements used to describe the steps in a process;
3. The relationships between every pair of these elements;
4. The links to other processes; and
5. The resource characteristics of the elements.

A process law "specifies the structure of the elements, the relationships between pairs of elements, and the links to other processes" and "a process is always linked to another, and a process is activated by an event" (Mackenzie, 1986, p. 46). In his view, an event "is a process that signals or sets off the transition from one process to another" (1986, pp. 46–7).

Mackenzie recognizes that in an organization there are multiple events, chains of events, parallel events, exogenous events, and chains of process laws. In fact, an event is itself a special process. Furthermore, there exist hierarchies of events and process laws. There are sequences of events and process laws. The situation is not unlike the problem of having a Chinese puzzle of Chinese puzzles, in which opening one leads to the opening of others (1986, p. 47). Later in his book, Mackenzie describes processes that may be mutually causally interdependent. In his view, even smallish firms could have thousands of process event sequences (1986, p. 46).

As process events, organizational microstates are obviously affected by adjacent events. But they are also affected by broader fields or environmental factors. While virtually all organization theorists study processes—after all, organizations have been defined for decades as consisting of structure and process (Parsons, 1960)—they tend to be somewhat vague about how and which process events are affected by external forces (Mackenzie, 1986).

An exception is Porter's (1985) value chain approach, where what counts is determined directly by considering what activities are valuable for bringing revenue into the firm.

Those taking the "resource-based view" of strategy also develop the relationship between internal process capabilities and a firm's ability to generate rents, that is, revenues well in excess of marginal costs. These attempts to understand how resources internal to the firm act as sustainable sources of competitive advantage are reflected in such labels as the "resource based-view" (Wernerfelt, 1984), "core competence" (Prahalad and Hamel, 1990), "strategic flexibilities" (Sanchez, 1993), and "dynamic capabilities" (Teece, Pisano, and Schuen, 1994).

Those studying aggregate firm behavior increasingly have difficulty holding to the traditional uniformity assumption about human behavior. Psychologists have studied individual differences in firms for decades (Staw, 1991). Experimental economists have found repeatedly that individuals seldom act as uniform rational actors (Hogarth and Reder, 1987; Camerer, 1995). Phenomenologists, social constructionists, and interpretists have discovered that individual actors in firms have unique interpretations of the phenomenal world, unique attributions of causality to events surrounding them, and unique interpretations, social constructions, and sensemakings of others' behaviors that they observe (Silverman, 1971; Burrell and Morgan, 1979; Weick, 1995; Reed and Hughes, 1992; Chia, 1996). Resource-based view strategists refer to tacit knowledge, idiosyncratic resources, and capabilities, and Porter (1985) refers to unique activities. Although the field-like effects of institutional contexts on organizational members are acknowledged (Zucker, 1988; Scott, 1995), and the effects of social pressure and information have a tendency to move members toward more uniform norms, values, and perceptions (Homans, 1950), strong forces remain to steer people toward idiosyncratic behavior in organizations and the idiosyncratic conduct of organizational processes:

1. Geographical locations and ecological contexts of firms are unique.
2. CEOs and dominant coalitions in firms are unique—different people in different contexts.
3. Individuals come to firms with unique family, educational, and experience histories.
4. Emergent cultures of firms are unique.
5. Firms seldom have totally overlapping suppliers and customers, creating another source of unique influence on member behavior.
6. Individual experiences within firms, over time, are unique, since each member is located uniquely in the firm, has different responsibilities, has different skills, and is surrounded by different people, all forming a unique interaction network.
7. Specific firm process responsibilities—as carried out—are unique due to the unique supervisor–subordinate relationship, the unique interpretation an individual brings to the job, and the fact that each process event involves different materials and different involvement by other individuals.

Surely the essence of complexity theory is Prigogine's (Prigogine and Stengers, 1984; Nicolis and Prigogine, 1989) discovery that:

1. "At the edge of chaos" identifiable levels of imported energy, what Schrödinger (1944) terms "negentropy," cause aggregate "dissipative structures" to emerge from the stochastic "soup" of microstate behaviors.
2. Dissipative structures, while they exist, show predictable behaviors amenable to Newtonian kinds of scientific explanation.
3. Scientific explanations (and I would add epistemology) most correctly applicable to the region of phenomena at the edge of chaos resolve a kind of complexity that differs in essential features from the kinds of complexity that Newtonian science, deterministic chaos, and statistical mechanics attempt to resolve (Cramer, 1993; Cohen and Stewart, 1994).

None of these contributions by Prigogine may sensibly be applied to organization science without a recognition of organizational microstates.

THE IMPORTANCE OF THE SEMANTIC CONCEPTION

Philosophers differentiate entities and theoretical terms into those that:

1. are directly knowable via human senses;
2. may be eventually detectable via further development of measures; or
3. are metaphysical in that no measure will allow direct knowledge of their existence.

Positivists tried to solve the fundamental dilemma of science—*How to conduct truth-tests of theories, given that many of their constituent terms are unobservable and unmeasurable, seemingly unreal terms, and thus beyond the direct first-hand sensory knowledge of investigators?* This dilemma clearly applies to organization science in that many organizational terms, such as legitimacy, control, bureaucracy, motivation, inertia, culture, effectiveness, environment, competition, complex, carrying capacity, learning, adaptation, and the like, are metaphysical concepts. Despite years of attempts to fix the logical structure of positivism, its demise was sealed at the 1969 Illinois symposium and its epitaph written by Suppe (1977), who gives a detailed analysis of its logical shortcomings.

It is clear that positivism is now obsolete among modern philosophers of science (Rescher, 1970, 1987; Devitt, 1984; Nola, 1988; Suppe, 1989; Hunt, 1991; Aronson, Harré, and Way, 1994; de Regt, 1994). Nevertheless, the shibboleth of positivism lingers in economics (Blaug, 1980; Redman, 1991; Hausman, 1992), organization science (Pfeffer, 1982, 1993; Bacharach, 1989; Sutton and Staw, 1995; Donaldson, 1996; Burrell, 1996), and strategy

(Camerer, 1985; Montgomery, Wernerfelt, and Balakrishnan, 1989). It is still being used to separate "good normal science" from other presumably inferior approaches.

Although the untenable elements of positivism have been abandoned, many aspects of its justification logic remain and have been carried over into scientific realism. Positivism's legacy emphasizes the necessity of laws for explaining underlying structures or processes and creating experimental findings—both of which protect against attempting to explain naturally occurring accidental regularities. They also define a sound scientific procedure for developing "instrumentally reliable" results. Instrumental reliability is defined as occurring when a counterfactual conditional, such as "if *A* then *B*," is reliably forthcoming over a series of investigations. While positivists consider this the essence of science, that is, the instrumental goal of producing highly predictable results, scientific realists accept instrumentally reliable findings as the beginning of their attempt to produce less fallible scientific statements. Elements of the legacy are presented in more detail in McKelvey (1999c).

Three important normal science postpositivist epistemologies are worth noting. First, *scientific realists* argue for a fallibilist definition of scientific truth—what Popper (1982) terms "verisimilitude" (truthlikeness). Explanations having higher fallibility could be due to the inclusion of metaphysical rather than observable terms, or they could be due to poor operational measures, sampling error, or theoretical misconception, and so forth. Given this, progress toward increased verisimilitude is independent of whether theory terms are observable or metaphysical, because there are multiple causes of high fallibility. This idea is developed more fully by Aronson, Harré, and Way (1994). Second, the *semantic conception of theories* (Beth, 1961; Suppe, 1977, 1989) holds that scientific theories relate to models of idealized systems, not the complexity of real-world phenomena and not necessarily to self-evidently true root axioms. And third, *evolutionary epistemology* (Campbell, 1974, 1988, 1995; Hahlweg and Hooker, 1989) emphasizes a selectionist process that winnows out the more fallible theories. Collectively, these epistemologies turn the search for truth on its head—instead of expecting to zero in on an exactly truthful explanation, science focuses on selectively eliminating the least truthful explanations. Elsewhere I elaborate the first and third of these contributions under the label Campbellian Realism (McKelvey, 1999c).

The semantic conception's *model-centered view of science* offers a useful bridge between scientific realism and the use of computational experiments as a basis of truth-tests of complexity theory-rooted explanations in organization science. Scientific realism builds on a number of points. First, Bhaskar (1975/1997) sets up the model development process in terms of experimentally created tests of counterfactuals, such as "force *A* causes outcome *B*," that protect against accidental regularities. Second, Van Fraassen (1980), drawing on the semantic conception, develops a model-centered epistemology and sets up *experimental* (empirical[2]) *adequacy* as the only reasonable and relevant "well-constructed science" criterion. Third, accepting the model-centered view and experimental adequacy, Aronson, Harré, and Way (1994) then add *ontological adequacy* so as to create a scientific realist epistemology. In their view, models are judged as having a higher probability of truthlikeness if they are:

1. experimentally adequate in terms of a theory leading to experimental predictions testing out; and
2. ontologically adequate in terms of the model's structures accurately representing that portion of reality deemed to be within the scope of the theory at hand.

Finally, de Regt (1994) develops a "strong argument" for scientific realism building on the probability paradigm, recognizing that instrumentally reliable theories leading to highly probable knowledge result from a succession of eliminative inductions.

After Beth (1961), three early contributors to the semantic conception emerged: Suppes (1961, 1962, 1967), Suppe (1967, 1977, 1989), and van Fraassen (1970, 1980). Subsequent interest by Beatty (1981, 1987), Lloyd (1988), and Thompson (1989) in biology is relevant because biological theories, like organization theories, pertain to entities existing in a competitive ecological context. The structure of competition-relevant theories in both disciplines suffers the same epistemological faults (Peters, 1991). Suppes chooses to formalize theories in terms of set-theoretic structure, on the grounds that, as a formalization, set theory is more fundamental to formalization than are axioms.

Instead of a set-theoretic approach, van Fraassen chooses a state space and Suppe a phase space platform. A phase space is defined as a space enveloping the full range of each dimension used to describe an entity. Thus, one might have a regression model in which variables such as size (employees), gross sales, capitalization, production capacity, age, and performance define each firm in an industry, and each variable might range from near zero to whatever number defines the upper limit on each dimension. These dimensions form the axes of a Cartesian space. In the phase space approach, the task of a formalized theory is to represent the full dynamics of the variables defining the space, as opposed to the axiomatic approach where the theory builds from a set of assumed axioms. A phase space may be defined with or without identifying underlying axioms. The set of formalized statements of the theory is not defined by how well they interpret the set of axioms, but rather by how well they define phase spaces across various phase transitions.

> NO THEORY EVER ATTEMPTS TO REPRESENT OR EXPLAIN THE FULL COMPLEXITY OF SOME PHENOMENON

Having defined theoretical adequacy in terms of how well a theory describes a phase space, the question arises of what are the relevant dimensions of the space. In the axiomatic conception, axioms are used to define the adequacy of the theory. In the semantic conception, adequacy is defined by the phenomena. The current reading of the history of science by the semantic conception philosophers shows two things:

1. Many modern sciences do not have theories that inexorably derive from root axioms.
2. No theory ever attempts to represent or explain the full complexity of some phenomenon.

Classic examples given are the use of point masses, ideal gases, pure elements and vacuums, frictionless slopes, and assumed uniform behavior of atoms, molecules, and genes. Scientific laboratory experiments are always carried out in the context of closed systems whereby many of the complexities of natural phenomena are set aside. Suppe (1977, pp. 223–4) defines these as "isolated idealized physical systems." Thus, an experiment might manipulate one variable, control some variables, assume many others are randomized, and ignore the rest. In this sense the experiment is isolated from the complexity of the real world and the physical system represented by the experiment is necessarily idealized.

A theory is intended to provide a generalized description of a phenomenon, say, a firm's behavior. But no theory ever includes so many terms and statements that it could effectively accomplish this. A theory:

1. "does not attempt to describe all aspects of the phenomena in its intended scope; rather it abstracts certain parameters from the phenomena and attempts to describe the phenomena in terms of just these abstracted parameters" (Suppe, 1977, p. 223);
2. assumes that the phenomena behave according to the selected parameters included in the theory; and
3. is typically specified in terms of its several parameters with the full knowledge that no empirical study or experiment could successfully and completely control all the complexities that might affect the designated parameters—theories are not specified in terms of what might be experimentally successful.

In this sense, a theory does not give an accurate characterization of the target phenomena—it predicts the progression of the modeled

Issue 1-1 4/3/99 5:54 pm Page 16

phase space over time, which is to say that it predicts a shift from one abstract replica to another under the assumed idealized conditions. Idealization could be in terms of the limited number of dimensions, assumed absence of effects of the many forces not included, mathematical formalization syntax, or the assumed bearing of various auxiliary hypotheses relating to theories of experiment, theories of data, and theories of numerical measurement. "If the theory is adequate it will provide an accurate characterization of what the phenomenon *would have been* had it been an isolated system" (Suppe, 1977, p. 224; my italics).

MODEL-CENTERED SCIENCE

The central feature of the semantic conception is the pivotal role given to models. Figure 1 shows three views of the relation among theory, models, and phenomena. Figure 1a stylizes a typical *axiomatic conception*:

1. A theory is developed from its axiomatic base.
2. Semantic interpretation is added to make it meaningful in, say, physics, thermodynamics, or economics.
3. The theory is used to make and test predictions about the phenomena.
4. The theory is defined as experimentally and ontologically adequate if it both reduces to the axioms and is instrumentally reliable in predicting empirical results.

Figure 1b stylizes a typical *organization science approach*:

1. A theory is induced after an investigator has gained an appreciation of some aspect of organizational behavior.
2. An iconic model is often added to give a pictorial view of the interrelation of the variables or to show hypothesized path coefficients, or possibly a regression model is formulated.
3. The model develops in parallel with the theory as the latter is

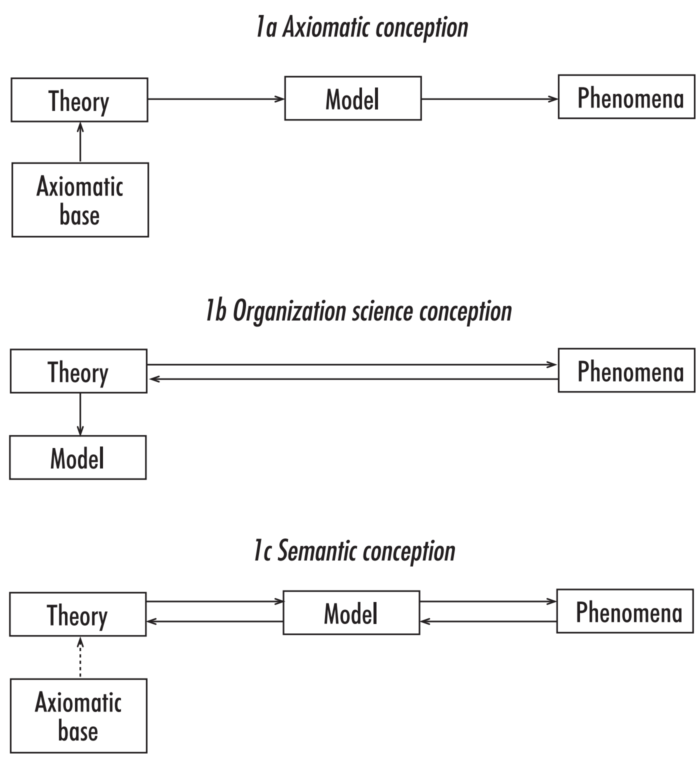

Figure 1 Conceptions of the axiom–theory–model–phenomena relationship

tested for both experimental and ontological adequacy by seeing whether effects predicted by the theory can be discovered in some sampling of the phenomena.

Figure 1c stylizes the *semantic conception*:

1. The theory, model, and phenomena are viewed as independent entities.
2. Science is bifurcated into two independent but not unrelated truth-testing activities:
   (a) experimental adequacy is tested by seeing whether the

theory, stated as counterfactual conditionals, predicts the empirical behavior of the model (think of the model as an isolated idealized physical system moved into a laboratory or onto a computer);

(b) ontological adequacy is tested by comparing the isomorphism of the model's idealized structures/processes against that portion of the total relevant "real-world" phenomena defined as "within the scope of the theory."

It is important to emphasize that in the semantic conception, "theory" is always hooked to and tested via the model. "Theory" does not attempt to explain "real-world" behavior; it only attempts to explain "model" behavior. It does its testing in the isolated, idealized physical world structured into the model. "Theory" is not considered a failure because it does not become elaborated and fully tested against all the complex effects characterizing the real-world phenomenon. The mathematical or computational model is used to structure up aspects of interest within the full complexity of the real-world phenomenon and defined as "within the scope" of the theory. Then the model is used to test the "if *A* then *B*" counterfactuals of the theory to consider how a firm—as modeled—might behave under various possibly occurring conditions. Thus a model would not attempt to portray all aspects of, say, notebook computer firms—only those within the scope of the theory being developed. And, if the theory did not predict all aspects of these firms' behaviors under the various relevant real-world conditions, it would not be considered a failure. However, this is only half the story.

Parallel to developing the experimental adequacy of the "theory–model" relationship is the activity of developing the ontological adequacy of the "model–phenomena" relationship. How well does the model represent or refer to the "real-world" phenomena? For example, how well does an idealized wind-tunnel model of an airplane wing represent the behavior of a full-sized wing on a plane flying in a storm? How well does a drug shown to work on "idealized" lab rats work on people of different ages, weights, and physiologies? How well might a computational model, such as the Kauffman (1993) NK model that Levinthal (1997a, b), Rivkin (1997, 1998), Baum (1999), and McKelvey (1999a, b) use, represent coevolutionary competition, that is, actually represent that kind of competition in, say, the notebook computer industry?

A primary difficulty encountered with the axiomatic conception is the presumption that only one fully adequate model derives from the underlying axioms—only one model can "truly" represent reality in a rigorously developed science. For some philosophers, therefore, a discipline such as evolutionary biology fails as a science. Instead of a single axiomatically rooted theory, as proposed by Williams (1970) and defended by Rosenberg (1985), evolutionary theory is more realistically seen as a family of theories, including theories explaining the mechanisms of natural selection, mechanisms of heredity, mechanisms of variation, and a taxonomic theory of species definition (Thompson, 1989, Ch. 1).

Since the semantic conception does not require axiomatic reduction, it tolerates multiple models. Thus, "truth" is not defined in terms of reduction to a single model. Mathematical, set-theoretical, and computational models are considered equal contenders to represent real-world phenomena. In physics, both wave and particle models are accepted because they both produce instrumentally reliable predictions. That they also have different theoretical explanations is not considered a failure. Each is an isolated, idealized physical system representing different aspects of real-world phenomena. In evolutionary theory there is no single "theory" of evolution. There are in fact subordinate families of theories (multiple models) within the main families about natural selection, heredity, variation, and taxonomic grouping. Organization science also consists of various families of theories, each having families of competing theories within it—families of theories about process theory, population ecology, organizational culture, structural design, corporate performance, sustained competitive advantage, organizational change, and so on. Axiomatic reduction does not appear to be in sight for any of these theories. The semantic conception defines a model-centered science comprised of families of models without a single axiomatic root.

MODEL-CENTERED ORGANIZATION SCIENCE

If the semantic conception of science is defined as preferring formalized families of models, theory–model experimental tests, and the model–phenomena ontological tests, organization science generally misses the mark, although population ecology studies measure up fairly well (Hannan and Freeman, 1989; Hannan and Carroll, 1992). Truth-tests are typically defined in terms of a direct "theory–phenomena" corroboration, with the results that:

1. Organization science does not have the bifurcated theory–model and model–phenomena tests.
2. The strong counterfactual type of theory confirmation is seldom achieved because organization science attempts to predict real-world behavior rather than model behavior.
3. Formal models are considered invalid because their inherent idealizations invariably fail to represent real-world complexity; that is, instrumental reliability is low.

Semantic conception philosophers do take pains to insist that their epistemology does not represent a shift away from the desirability of moving toward formalized (while not necessarily axiomatic) models. However, Suppe (1977, p. 228), for example, chooses the phase space foundation rather than set theory because it does not rule out qualitative models. In organization science there are a wide variety of formalized models (Carley, 1995), but in fact most organization and strategy theories are not formalized, as a reading of such basic sources as Clegg, Hardy, and Nord (1996), Donaldson (1996), Pfeffer (1997), and Scott (1998) readily demonstrates. In addition, these theories have low ontological adequacy, and if the testing of counterfactual conditionals is any indication, little experimental adequacy either.

Witchcraft, shamanism, astrology, and the like are notorious for attaching *post hoc* explanations to apparent regularities that are frequently accidental—"disaster struck in 1937 after the planets were lined up thus." Nomic necessity—the requirement that one kind of protection against attempting to explain a possibly accidental regularity occurs when rational logic can point to a lawful relation between an underlying structure or force that, if present, would produce the regularity—is a necessary condition: "If force *A* then regularity *B*." However, using an experimentally created result to test the "if *A* then *B*" counterfactual posed by the law in question is critically important. Experiments more than anything else separate science from witchcraft or antiscience. Without a program of experimental testing, complexity applications to organization science remain metaphorical and, if made the basis of consulting agendas and other managerially oriented advice, are difficult to distinguish from witchcraft.

WITHOUT A PROGRAM OF EXPERIMENTAL TESTING, COMPLEXITY APPLICATIONS REMAIN METAPHORICAL AND ARE DIFFICULT TO DISTINGUISH FROM WITCHCRAFT

An exemplar scientific program is Kauffman's 25 years or so of work on his "complexity may thwart selection" hypothesis, summarized in his 1993 book. He presents numerous computational experiments and the model structures and results of these are systematically compared with the results of vast numbers of other experiments carried out by biologists over the years. Should we accept complexity applications to management as valid without a similar course of experiments having taken place?

Agreed, the "origin of life" question is timeless, so Kauffman's research stream is short by comparison. No doubt some aspects of management change radically over only a few years. On the other hand, many organizational problems, such as centralization–decentralization, specialization–generalization, environmental fit, learning, and change, seem timeless, are revisited over and over, and could easily warrant longer research programs. Computational models have already been applied to these and other issues, as Carley's review indicates. But the surface has hardly been scratched—the coevolution of the theory–model and model–-phenomena links has barely begun the search for the optimum match of organization theory, model, and real world.

AGENT-BASED MODELS

It is clear from the literature described in Nicolis and Prigogine (1989), Kaye (1993), Kauffman (1993), Mainzer (1994), and Favre *et al.* (1995) that natural science-based complexity theory fits the semantic conception's rewriting of how effective science works. There is now a considerable natural science literature of formalized mathematical and computational theory on the one hand, and many tests of the adequacy of the theoretical models to real-world phenomena on the other. A study of the literature emanating from the Santa Fe Institute (Kauffman, 1993; Cowan, Pines, and Meltzer, 1994; Gumerman and Gell-Mann, 1994; Belew and Mitchell, 1996; Arthur, Durlauf, and Lane, 1997) shows that although social science applications lag in their formalized model-centeredness, the trend is in this direction.

Despite Carley's citing of over 100 papers using models in her 1995 review paper, mainstream organization science cannot be characterized as a model-centered science. There seems to be a widespread phobia against linear differential equations, the study of rates, and mathematical formalization in general. A more suitable and more accessible alternative may be adaptive-learning agent-based models. The fact that these models are not closed-form solutions is an imperfection, but organization scientists recognize that equations may be equally imperfect due to the heroic assumptions required to make them mathematically tractable. Is one kind of imperfection better or worse than any other? Most of the studies cited by Carley *do not* use agent-based models.

I began this article with a section on process-level theory, with special attention paid to organizational microstates, in order to set up my call here for more emphasis on agent-based models. This follows leads taken by Cohen, March, and Olsen (1972), March (1991), Carley (1992, 1997), Carley and Newell (1994), Carley and Prietula (1994), Carley and Svoboda (1996), Carley and Lee (1997), Masuch and Warglien (1992), and Warglien and Masuch (1996), among others. Adaptive learning models assume that agents have stochastic nonlinear behaviors and that these agents change over time via stochastic nonlinear adaptive improvements. Assumptions about agent attributes or capabilities may be as simple as one rule—"Copy another agent or don't." Computational modelers assume that the aggregate adaptive learning "intelligence," capability, or behavior of an organization may be effectively represented by millions of "nanoagents" in a combinatorial search space—much like intelligence in our brains appears as a network of millions of neurons, each following a simple firing rule. Needless to say, complexity science researchers recognize that computational models not only fit the basic stochastic nonlinear microstate assumption, but also simulate various kinds of aggregate physical and social system behaviors.

Although relatively unknown in organization science, "interactive particle systems," "particle," "nearest neighbor," or, more generally, adaptive-learning agent-based models are well known in the natural sciences. Whatever the class of model, very simple-minded agents adopt a neighboring agent's attributes to reduce energy or gain fitness. The principal modeling classes are *spin-glass* (Mézard, Parisi, and Virasoro, 1987; Fischer and Hertz, 1993), *simulated annealing* (Arts and Korst, 1989), *cellular automata* (Toffoli and Margolus, 1987; Weisbuch, 1993), *neural network* (Wasserman, 1989, 1993; Müller and Reinhardt, 1990; Freeman and Skapura, 1993), *genetic algorithm* (Holland, 1975, 1995;

Goldberg, 1989; Mitchell, 1996), and, most recently, *population games* (Blume, 1997). For a broader review see Garzon (1995). Most model applications stay within one class, though Carley's (1997) "ORGAHEAD" model uses models from several classes in a hierarchical arrangement. More specifically within the realm of complexity applications to firms, Kauffman's (1993) *NK* model and rugged landscape have attracted attention (Levinthal, 1997a, b; Levinthal and Warglien, 1997; Rivkin, 1997, 1998; Sorenson, 1997; Baum, 1999; and McKelvey, 1999a, b). These are all theory–model experimental adequacy studies, although Sorenson's study is a model–phenomena ontological test.

CONCLUSION

If we are to have an effective complexity science applied to firms, we should first see a systematic agenda linking theory development with mathematical or computational model development. The counterfactual tests are carried out via the theory–model link. We should also see a systematic agenda linking model structures with real-world structures. The tests of the model–phenomena link focus on how well the model refers, that is, represents real-world behavior. Without evidence that both of these agendas are being actively pursued, there is no reason to believe that we have a complexity science of firms.

A cautionary note: Even if the semantic conception program is adopted, organization science still seems likely to suffer in instrumental reliability compared to the natural sciences. The "isolated, idealized physical systems" of natural science are more easily isolated and idealized, and with lower cost to reliability, than are socioeconomic systems. Natural science lab experiments more reliably test nomic-based counterfactual conditionals and have much higher ontological representative accuracy. In other words, its "closed systems" are less different from its "open systems" than is the case for socioeconomic systems. This leads to their higher instrumental reliability.

The good news is that the semantic conception makes improving instrumental reliability easier to achieve. The benefit stems from the bifurcation of scientific activity into independent tests for experimental adequacy and ontological adequacy. First, by having one set of scientific activities focus only on the predictive aspects of a theory–model link, the chances improve of finding models that test counterfactuals with higher experimental instrumental reliability—the reliability of predictions increases. Second, by having the other set of scientific activities focus only on the model structures across the model–phenomena link, ontological instrumental reliability will also improve. For these activities, reliability hinges on the isomorphism of the structures causing both model and real-world behavior, not on whether the broader predictions across the full range of the complex phenomena occur with high probability. Thus, in the semantic conception instrumental reliability now rests on the joint probability of two elements:

1. predictive experimental reliability; and
2. model structure reliability.

If a science is not centered around (preferably) formalized computational or mathematical models, it has little chance of being effective or adequate. Such is the message of late twentieth-century (postpositivist) philosophy of science. This message tells us very clearly that in order for an organizational complexity science to avoid faddism and scientific discredit, it must become model-centered.

NOTES

1. A review of some 30 "complexity theory and management" books, coedited by Stu Kauffman, Steve Maguire, and Bill McKelvey, will appear in a special review issue of *Emergence* (1999, #2).
2. I substitute "experimental" for the term "empirical" that van Fraassen uses so as to distinguish more clearly between the testing of counterfactuals (which

could be via formal models and laboratory or computer experiments) and empirical (real-world) reference or representativeness—both of which figure in van Fraassen's use of "empirical."

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What Enables Self-Organizing Behavior in Businesses

Henry J. Coleman, Jr.

The complexity of the political, regulatory, and technological changes confronting most organizations today causes an urgency to adapt or even radical organizational change (Greenwood and Hinings, 1996). The increasing interconnectedness of people across the globe is helping to accelerate change, as diverse new customer demands are communicated faster and innovative organizational responses are enabled by collaboration through information technology. The environment is becoming more complex and self-organizing, and often organizations seek to adapt by mirroring it with requisite variety (Miles *et al.*, 1998).

Complexity theory views organizations as "complex adaptive systems" that coevolve with the environment through the self-organizing behavior of agents navigating "fitness landscapes" (Kauffman, 1995) of market opportunities and competitive dynamics. Changing external and internal "attractors" influence the process of adaptation by agents (Kauffman, 1995; Morgan, 1996; Stacey, 1996). Apart from the concepts of agents and attractors, complexity theory suggests that self-organizing behavior will naturally occur without addressing what causes it (cf. Stacey, 1996). Behavior is self-organizing when people (agents) are free to network with others and pursue their objectives, even if this involves crossing organizational boundaries created by formal structures. Complexity theory suggests that self-organization is the natural "default" behavior, while organization studies recognize barriers to such freedom in bureaucratic structure.

The purpose of this article is to explain more fully self-organizing behavior in adaptation to change by applying concepts of organization theory and organizational behavior. Knowledge has emerged as the creator of wealth in today's global economy: knowledge applied to work is productivity; knowledge applied to knowledge is innovation (Drucker, 1993). Particularly with the increasing customer demands for innovation, the "management" of knowledge through enabling organization design and controls promotes self-organizing behavior in businesses. Accumulating knowledge is applied to the marketplace by some self-organizing, entrepreneurial companies in the process of adaptation to change (Miles *et al.*, 1998).

COMPLEXITY THEORY SUGGESTS THAT SELF-ORGANIZATION IS THE NATURAL "DEFAULT" BEHAVIOR

COMPLEXITY THEORY

"Diversity begets diversity, driving the growth of complexity" (Kauffman, 1995, pp. 296–7). In today's business world, the variety of new opportunities is created by the emergence of new knowledge structures in scientific discoveries. These new market opportunities as attractors "pull" a variety of entrepreneurs and their teams of colleagues to innovate within existing firms or found new enterprises (Miles *et al.*, 1998). As mentioned above, the increasing interconnectedness of people (agents) enables ideas to be translated into innovative offerings in response to rapidly communicated customer demands.

As agents coevolve with the environment of "fitness landscapes," they do so through a process of self-organization intended for both survival and growth from innovation. The impetus for creativity comes from the shadow system of learning communities with enough diversity to provoke learning but not enough to overwhelm the legitimate system and cause anarchy. Another factor is the degree of connectivity between the agents in a system: the necessary variety in behavior depends on the strength and number of ties, with few and strong ties producing stable behavior—too little variety for effective learning—and many and weak ties producing unstable behavior—too much variety for effective learning (Stacey, 1996).

Kauffman (1995) explains that instability comes from sensitivity to small changes while stability comes from canalization, or "lock-in," perpetuated by some rules in an agent's schema because the rules involve redundancies. "This duplication of functions gives stability to the system, making it much more robust in the face of turbulent change" (Stacey, 1996, p. 85). To operate at the edge of chaos, agents and systems balance canalization and redundancy such that they form landscapes that are neither too smooth nor too rugged (Stacey, 1996).

CREATIVE TENSION AND EXPERIMENTATION

The space for creativity in an organization is a dialectical state of tension between overcontrol, embodied in the legitimate system, and chaos, embodied in the shadow system (Pascale, 1990; Stacey, 1996). For employees to have enough confidence to take risks and experiment, there must be some stability in the organization; similarly, some order is necessary for employees to recognize novelty. Then, organizations learn when there is new information that is combined with knowledge and applied to new opportunities provided by changes in the external environment. People in the shadow system (learning communities) seize such opportunities to be innovative. If the structure is flexible enough, the firm can adapt and form new project teams or even new business units; otherwise, the path of self-organizing behavior tends toward the founding of new companies.

The above assumes that organizations are open systems—open to flows of data and information that facilitate learning and the construction of new knowledge. The goal is to encourage experimentation (Senge, 1990; Vicari *et al.*, 1996). “Experiments may be planned, but they may also occur spontaneously as ‘errors’, i.e. perturbations. Leaps in the knowledge development of a company typically stem from events that the firm has neither planned nor hypothesized” (Vicari *et al.*, 1996, p. 189). Experimentation is encouraged by reward-and-control–system incentives that tolerate some failure. A prime example of this working is at Minnesota Mining and Manufacturing (3M): employees are encouraged to spend 15 percent of their paid time working on whatever new projects they choose, and Post-It notes™ developed from the failure of a search for an adhesive substance.

Human agents in organizations respond to the stresses of conflicting demands by ignoring some of the constraints some of the time. Ignoring constraints in a judicious way can help avoid being trapped on poor local optima. Furthermore, as independent “patches” within the system selfishly seek their own optima, they can at least temporarily move the entire system the wrong way on the fitness landscape; thus, such independent actions can allow the entirety to avoid bad local minima (Kauffman, 1995).

AUTOPOIESIS

The ideas of boundaries and identity are addressed by autopoiesis. According to autopoietic theory, organizations are open to data inflows but are closed systems with respect to information and knowledge; the emphasis is on knowledge as personal and not transferable; written documents are seen as data outside the cognitive systems of persons (von Krogh and Roos, 1996). Autopoietic theory refers to systems that maintain their defining organization throughout a history of environmental perturbation and structural change and regenerate their components in the course of operation (Maturana and Varela, 1987). Entrepreneurial behavior is spontaneous in response to perceived opportunities to create an organization in the first place. Self-organization can take place once there is a circular exchange of energy with the environment that maintains the identity of the organization through different interactions. To be self-organizing, there has to be a cognitive domain of interaction; spontaneous entrepreneurship precedes self-organization.

ORGANIZATION THEORY AND ORGANIZATIONAL BEHAVIOR

With the increase of market opportunities calling for innovative offerings and accumulating knowledge seeking outlets in the marketplace, leading-edge organizations are being designed to "manage" knowledge (Davenport and Prusak, 1998; Miles *et al.*, 1998). The capacity for adaptation in turbulent environments is enhanced by the operating logic of new organizational forms like the emerging "cellular" form (Miles *et al.*, 1997). With autonomous small teams, or "cells," each pursuing entrepreneurial opportunities and sharing knowhow among themselves, the overall organization is more potent than each cell operating alone. When environmental demands change, new cells can be formed and old ones disbanded as necessary; like an amoeba changing with its surroundings, the operating logic of the form is based on flexibility with accepted protocols of knowledge sharing substituting for hierarchical controls. Thus, cellular organizations are designed to be reconfigurable according to shifts in the market and/or the emergence of new knowledge. Because the scientific community organizes itself in small groups, or pockets, of knowledge, a cellular design in response to complexity provides some order that creates enough stability for employees to feel comfortable in taking risks and experimenting. The cellular concept compares favorably with Kauffman's (1995) notion of "patches."

New knowledge is constructed in "communities of practice" (Brown and Duguid, 1991), the shadow system of learning organizations (Stacey, 1996). Knowledge workers join communities because they have something to learn and something to contribute (Stewart, 1997). Self-organizing behavior in communities of practice is partially predicated on incentives to construct, articulate, share, and use new knowledge for innovative products/services (Coleman, 1998). Even more important may be the motivation of knowledge workers to collaborate in pursuit of innovation; besides intrinsic and extrinsic incentives in reward systems, knowledge workers may be motivated primarily by the urgency to develop new offerings before competitors do, like at Intel (Ghoshal and Bartlett, 1997; Quinn, Baruch, and Zien, 1997).

ORGANIZATION DESIGN

The organization design/structure can facilitate change by being flexible. The concept is to design the organization for the purpose of evolution with the changing environment, to design for emergence by avoiding the rigidities of bureaucratic hierarchy. This means creating organizational arrangements that do not inhibit evolutionary change and that accept discontinuous change in the environment as entrepreneurial opportunity. The idea is to design the formal organization such that structures, systems, and processes "fit" the goals, rewards, and structures of the informal organization (Nadler, 1998). To extend this concept a little further, change is facilitated by a formal design that exists only to validate informal behavior in line with the corporate mission. Leadership may be anywhere, and everyone is a champion of change, with no need to bust bureaucracy because there is none.

An emerging example of this is the cellular form at Technical and Computer Graphics (TCG), headquartered in Sydney, Australia, and at the Acer Group, based in Taiwan (Miles *et al.*, 1997). Top management in these firms has recognized that organizational survival as well as growth is best nurtured through tolerating disequilibrium; that disorder is the price of progress in a dynamic world (Quinn *et al.*, 1997). Alignment of members with the company purpose is reinforced by both identity-creating information about how each unit is contributing to the enterprise goals and extrinsic incentives of member ownership that support this identity. The intrinsic incentives are the challenge of the task, personal recognition, and freedom of activity in pursuit of entrepreneurial innovation (Quinn *et al*., 1997). Accepted protocols for knowledge sharing are consistent with intrinsic incentives and substitute for hierarchical controls (Miles *et al.*, 1997). Because the strategy is to be opportunistic and the culture is entrepreneurial, the basic organization design at a cellular firm like TCG would not require radical change unless new attractors were to cause it to "flip" to a whole new identity (Morgan, 1996), to change its perceived mission by entering a new industry and exiting the old one.

The lack of bureaucracy at TCG is illustrated by the fact that cells consist of 12–15 technical professionals coordinated by accepted protocols of knowledge sharing. These cells conduct business by partnering with a large customer, which receives a customized product, and another firm (e.g., Hitachi), which has technological expertise, distribution channels, and financial capital to invest in the TCG entrepreneurial venture (Miles *et al.*, 1997). When technical professionals at TCG perceive a new entrepreneurial opportunity, they may draw on the expertise in other cells, and they are free to seek the necessary outside partners.

The "organic" model of formal structure enables employees to pursue a shared direction through self-control. Such direction is innate in the identity of the firm, guided by the corporate equivalent of DNA, as each cell embraces an entrepreneurial vision. By weaving the sense of purpose into the structure of the organization, organic models like the cellular firm do not need visionary leaders to control them; rather, they need senior managers to act as the central nervous system by coordinating the activities of the parts and monitoring the overall health of the system so that each cell is free to be entrepreneurial (Baskin, 1998).

According to Stacey (1996), leadership is different from traditional direction of the legitimate system when the organization is adapting on the edge of chaos; then, leaders operate on the boundary of the shadow system and serve to contain anxiety for others while provoking double-loop learning. "Provoking double-loop learning requires the capacity to play with metaphor and images and pose stretching challenges for others and the ability to listen and hold oneself open to changing one's mind" (Stacey, 1996, p. 276). When an organization is operating on the edge of chaos, not even its leaders can know its future direction. At such a time it is appropriate to operate in a mode of inquiry, surfacing and questioning assumptions (Senge, 1990).

LOOSE–TIGHT CONTROLS

The freedom of activity in entrepreneurship is a key to enabling self-organizing behavior. This relative autonomy within boundaries for opportunity seeking works according to a system of "loose–tight" controls (cf. Peters and Waterman, 1982). The shared values of corporate culture in belief systems provide tight control as a form of protocol, and control systems that are based on interaction between supervisor and employees encourage information sharing and learning (Simons, 1994). Together, belief systems and interactive control systems create intrinsic motivation in employees (Deci and Ryan, 1985) and provide the context for empowerment to pursue entrepreneurial initiatives. The key to loose controls is management's confidence and trust in employees to act according to the shared values, therefore setting them free to search for opportunities, learn, and apply accumulating knowledge to innovative efforts.

THE FREEDOM OF ACTIVITY IN ENTREPRENEURSHIP IS A KEY TO ENABLING SELF-ORGANIZING BEHAVIOR

The tension between empowerment and control is managed by measuring outputs and holding people accountable for them, as opposed to a focus on inputs. At firms like Sun Microsystems, this means using a system of management by objectives (MBO) that is linked to the reward system through the criteria for awarding bonuses. At Sun, reward systems linked to MBO encourage collaboration by employees because performance on bonus criteria cannot be achieved by individuals working alone. Employees freely seek each other out, regardless of organizational boundaries, and share knowledge in order to achieve their performance criteria.

HUMAN NEED SATISFACTION

Whether the force of entrepreneurial behavior is spontaneous or self-organizing, the point is that people are behind it; in the course of satisfying their own needs, they have the intention to achieve change and take advantage of new market opportunities. We must not be confused by any abstract conceptualizations of either autopoiesis or complexity theory that treat systems as entities that we observe outside ourselves. We are parts of both the solution and the problem; the organizations and society we get, we deserve.

Similarly, the accelerating pace of change is often attributed to the advance of technology, but technology is only the catalyst. What effects rapid change is what people do with the tools they have. Computers and telecommunications have dramatically increased the interconnectedness of people and the speed of sharing knowledge and information. This has fueled an explosion of innovation, but it would not have been the case if people had not been motivated to use technology for new products and services. Spontaneous and self-organizing behaviors are intended to satisfy human needs, and the variety of needs and market opportunities drives the growth of complexity.

EMPOWERMENT

Ultimately, self-organizing behavior depends on the firm's being staffed with people who respond to empowerment practices by taking the initiative to resolve creative tension through experimentation. Empowerment is defined as enabling feelings of meaning in work, autonomy, choice, and having an impact on outcomes (Thomas and Velthouse, 1990; Spreitzer, 1995, 1996).

Empowerment means releasing the self-motivation of employees to take responsibility and initiative by trusting them to accept deep-seated psychological ownership of results and encouraging them to think, experiment, and improve (Coleman 1996). Empowerment will not work if employees do not have some intrinsic motivation to make a contribution (Coleman, 1996). Trust in the efficacy of employees and their own feelings of efficacy increase self-esteem and motivation to make a contribution (Gardner and Pierce, 1998). Given employee self-motivation, management's task is to build trust, responsibility, and initiative.

At TCG, employees also have financial ownership, which reinforces the psychological contract that they can make a difference, that they are personally competent and valued. TCG's employees take responsibility because they are trusted and because the reward system reinforces initiative taking; all the technical professionals are contributors, and there are no obstacles to good performance because of organization design or bureaucratic controls.

The cellular structure is based on the concept of "small within big" and capitalizes on the informality of personal relationships made possible by small units. Employees are empowered when they are treated as whole individuals with dignity. Even such a performance-oriented manager as Jack Welch, chief executive officer at General Electric, believes in informality and the power of self-motivation in people (Byrne, 1998). Self-organization in businesses is not, at its root, an abstract concept of systems, but rather a process of human motivation enabled by empowerment practices. Without trust and informality of relationships, bureaucratic controls choke off creativity.

Self-organizing behavior is enabled by boundarylessness, "a matter of cooperation across all the artificial barriers that can separate people with common interests" (Tichy and Sherman, 1993, p. 285). The idea is to encourage:

> teamwork on a grand scale, making cooperation an essential characteristic of organizational success. Given the right kind of people and clearly understood goals, intricate webs of informal networks among employees can accomplish much more than any rigid, traditional organization, producing tangible competitive advantages. (Tichy and Sherman, 1993, p. 286)

A CONCEPT IN COMMON: ADAPTATION TO CHANGE

Complexity theory and organization studies find some common ground in the concept of adaptation to change. Increasing interconnectedness between people both accelerates customers' demands for innovation and enables self-organizing behavior in response to produce new offerings. Major issues that require the concepts of both complexity theory and organization studies to resolve are whether change in the external environment is perceived to be continuous or discontinuous, and whether the response is reactive or proactive.

If the change is reactive to a performance crisis, an overhaul to a new mission, strategy, and structure is called for:

> Typically, discontinuous changes require dramatic changes in strategy and abrupt departures from traditional work, structures, job requirements, and cultures, which in turn necessitate a complete overhaul of the organization. (Nadler, 1998, p. 51)

On the other hand, if the organization has been operating in a continuous entrepreneurial mode, change otherwise perceived as discontinuous may be anticipated by boundary-spanning units and the response may be proactive on the edge of chaos. An organization may "flip" to a new identity in response to new attractors in any case, but its success is more likely when there is a proactive entrepreneurial decision rather than one reactive for mere survival.

With organic flexibility in the logical fit of cells and an entrepreneurial culture focusing on the external environment, cellular firms like TCG are designed for continuous, proactive adaptation; and member ownership reinforces principles of responsibility and initiative. Empowerment practices based on loose–tight controls and a sense of "stretch" (Ghoshal and Bartlett, 1997) derived from the natural ambition to excel in lead employees, especially knowledge workers, to continue learning and searching for new entrepreneurial opportunities. Consequently, it is less likely that organizations designed to coevolve with their environments will be forced into performance crises by discontinuous change than if there were the rigidities of bureaucracy in their structures.

As Baskin (1998) points out, models of organization that are based on living systems are naturally organic and adaptive. This is in contrast to the mechanistic models of bureaucracy, where discontinuous change requires a complete overhaul of the organization if it is to survive (Nadler, 1998). Put another way, adaptive change by organic systems rarely needs to be radical, even when there is discontinuous change in the environment, because the interface between the organization and its environment is on the edge of chaos. Cellular organizations tend to mirror the complexity of the environment with requisite variety, as individual cells sense new entrepreneurial opportunities and self-organize in response to change.

MODELS OF ORGANIZATION THAT ARE BASED ON LIVING SYSTEMS ARE NATURALLY ORGANIC AND ADAPTIVE

Consequently, it may no longer be appropriate in the age of innovation to use the change model of "unfreezing, transition, and refreezing." The increasing interconnectedness of diverse voices provides enough new ideas and perspectives to keep many organizations on the edge of chaos and to keep them from refreezing. There may not be a defined future state, as change may be continuous and seen as incremental because the organization and its environment are always in a state of flux (Morgan, 1996). There may be no future disequilibrium to anticipate because the current state is *always* one of disequilibrium. This does not mean that equilibrium is necessarily good; rather, the point is that we may have to learn to live and work in disequilibrium.

POSSIBLE CHANGES IN THE FUTURE

Although the cellular organization design facilitates adaptation to complex, changing environments, if the paradigm of market demand shifts, radical change may be required. For example, we are currently in the age of innovation fueled by customers' increasing demands for better customized solutions to their diverse problems (Miles *et al.*, 1998) and of responsiveness enabled by the increasing interconnectedness of people through information technology. If markets in the developed world become saturated, the demand paradigm could shift to an age of dissemination; specifically, a focus on customers in the developing world who seek a better standard of living.

In such a case, firms' tasks become more focused on reducing the prices and costs of both manufacturing and distribution than on developing innovative products and services. Then, effective organization design would aim for utilization of existing knowledge and streamlining the supply chain, rather than for speed in constructing new knowledge for innovative outputs. The process of self-organization might well cause cellular firms to flip back to more hierarchical designs in order to maximize efficiency.

With respect to such a reversal of power sharing, a question is whether the genie can be put back in the bottle. Once firms transform themselves in terms of empowerment, partnership, and as a team-based organization without bureaucratic controls, will employees accept an increase in hierarchical relationships? In the same way that hierarchical power structures inhibit self-organization, does empowerment cause resistance to change toward more bureaucracy even in the quest for efficiency required by the marketplace; or, does self-organizing behavior mean that employees maintain open minds toward hierarchy and organize on a case-by-case basis?

CONCLUSION

The current concepts of complexity theory provide some explanations of what causes self-organizing behavior in human systems. Although some theorists approach the subject by discussing "complex adaptive systems" as a whole, the concepts of attractors and agents begin to deal with motivated activity, such that attractors "pull" agents toward opportunities. Thus, the question is which attractors arise and when they do so.

Our understanding of self-organizing behavior is enhanced by considering variables in organization theory and organizational behavior such as organization design and control, human need satisfaction, and employee empowerment. The combination of enabling organizational context and purposive human behavior helps to "explain" complexity theory in practical terms. Emerging forms of organization designed to "manage" knowledge operate in a self-organizing mode through building trust, responsibility, and reward systems that reinforce a culture of entrepreneurial initiative freed from bureaucratic constraints.

Finally, in today's global economy, the concepts of complexity and organization studies need to be combined to explain the evolution of the knowledge/network era environment and self-organizing adaptation to it. Similarly, in the future global economy, the concepts of organization studies will combine with complexity theory to anticipate the possibility of radical organizational change in response to a shift in the paradigm of market demands.

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Issue 1-1 4/3/99 5:54 pm Page 49

Emergence as a Construct: History and Issues

Jeffrey Goldstein

Emergence, as in the title of this new journal, refers to the arising of novel and coherent structures, patterns, and properties during the process of self-organization in complex systems. Emergent phenomena are conceptualized as occurring on the macro level, in contrast to the micro-level components and processes out of which they arise.

In a wide variety of scientific and mathematical fields, grouped together loosely under the title "complexity theory," an intense search is now under way for characteristics and laws associated with emergent phenomena observed across different types of complex systems. As a prelude to the study of emergence in organizations, in this article I want to discuss some of the main issues surrounding the explanatory use of the construct of emergence in general, as well as place it in a historical context in order to gain a better grasp on what is unique about its contemporary manifestations.

Although emergent phenomena appear differently in different types of systems, e.g., whether they occur in physical systems or in computer simulations, they share certain interrelated, common properties that identify them as emergent:

- *Radical novelty*: emergents have features that are not previously observed in the complex system under observation. This novelty is the source of the claim that features of emergents are neither predictable nor deducible from lower or micro-level components. In other words, radically novel emergents are not able to be anticipated in their full richness before they actually show themselves.
- *Coherence or correlation*: emergents appear as integrated wholes that tend to maintain some sense of identity over time. This coherence spans and correlates the separate lower-level components into a higher-level unity.
- *Global or macro level*: since coherence represents a correlation that spans separate components, the locus of emergent phenomena occurs at a global or macro level, in contrast to the micro-level locus of their components. Observation of emergents, therefore, is of their behavior on this macro level.
- *Dynamical*: emergent phenomena are not pre-given wholes but arise as a complex system evolves over time. As a dynamical construct, emergence is associated with the arising of new attractors in dynamical systems (i.e., bifurcation).
- *Ostensive*: emergents are recognized by showing themselves, i.e., they are ostensively recognized. Bedeau (1997) refers to their ostensive quality when he defines emergence in terms of simulations such as are found in artificial life (Langton, 1986). Because of the nature of complex systems, each ostensive showing of emergent phenomena will be different to some degree from previous ones.

In respect to its use in scientific explanation, the construct of emergence is appealed to when the dynamics of a system seem better understood by focusing on across-system organization rather than on the parts or properties of parts alone. Yet, appeals to emergence follow more of a continuum than a discrete jump from part to whole (Bechtel and Richardson, 1993; see Figure 1).

Accordingly, the construct of emergence can be employed

Figure 1 Continuum of emergence explanations

along with, not in exclusion to, appeals to the functioning of the parts of a system. In fact, it is often the very interplay between the parts and the whole that has been emphasized in studies of complex, self-organizing systems (see Lewin, 1992).

PARTS/WHOLES/GESTALTS

It must be emphasized, however, that there is much more going on with emergent phenomena than has traditionally been included under the whole/part relationship. This can be shown by contrasting the construct of emergence as it is currently used with two similar ideas from the history of western thought: that of a "whole before its parts" and that of "gestalts."

"Whole before its parts" refers to the granting of explanatory precedence to a whole entity over the parts of which the whole is made up (Tiles, 1989). For example, Aristotle responded to a famous paradox put forward by Zeno through positing a notion of a "whole before the parts." Zeno insisted that a distance of any length could be divided into an infinite number of shorter segments. This meant that covering the distance required traversing an infinite number of shorter segments. However, traversing an infinite amount of segments would take an infinite amount of time; yet we obviously do cross distances in finite lengths of time!

Aristotle's answer to Zeno was that a length was first and foremost a whole. True, this whole might be divided into an infinite number of parts—nevertheless, the whole was fundamentally irreducible to those parts. In fact, it was only because a distance was a "whole before its parts" that it could be traversed.

Although the idea of a "whole before its parts" resembles the coherence of emergent structures as consisting of more than a mere collection of the parts, there is a crucial difference between the two constructs: a "whole before its parts" connotes a pre-given coherent entity, whereas emergence, as stated above, is not pre-given but a dynamical construct arising over time.

The non-dynamical nature of a "whole before its parts" can also be seen in one of its more recent embodiments, the concept of a "gestalt" (whole forms or configurations). The modern meaning of "gestalt" had its origin with the German Romantic poet, philosopher, and scientist Johann Wolfgang von Goethe, who used the term to refer to a natural unity that was the endpoint of an entelechetic development out of primordial chaos (Harrington, 1996; this meaning of "gestalt" does indeed seem loaded with notions also found in contemporary complexity theory, such as how order emerges out of chaos). Goethe's "gestalt" went through various ramifications before it eventually wound up as the basic unit of perception for gestalt psychology; one of whose progenitors, Christian von Ehrenfels, sounded very much like a contemporary complexity theorist when he remarked that perception takes place through recognizing whole patterns: "the whole is greater than the sum of the parts" (Harrington, 1996). Several proto-emergentists borrowed the term "gestalt" for describing emergent phenomena. Nevertheless, like the "whole before its parts," a gestalt is a pre-given whole and, thus, does not have the dynamical sense of emergence.

The dynamical characteristic of emergence can be better appreciated by considering its association with the arising of attractors that are not pre-given in the sense of a gestalt. New attractors show themselves when a dynamical system bifurcates, this event signifying both a quantitative and a qualitative metamorphosis. These new attractors then dominate the system and thereby allow for the emergence of something radically novel in respect to what came before.

PROTO- AND NEO-EMERGENTISM

PROTO-EMERGENTISM: EMERGENT EVOLUTIONISM

The technical meaning of the term "emergence" as used by complexity theorists is not a new one. It was coined over 100 years ago by the English philosopher G.H. Lewes (1875). Building on J.S. Mill's earlier differentiation of types of causation, Lewes distinguished between "resultant" and "emergent" chemical compounds coming about from a chemical reaction (Lewes, 1875: 368–9):

> although each effect is the *resultant* of its components, we cannot always trace the steps of the process, so as to see in the product the mode of operation of each factor. In the latter case, I propose to call the effect an *emergent*. It arises out of the combined agencies, but in a form which does not display the agents in action … Every *resultant* is either a sum or a difference of the co-operant forces … [and] is clearly traceable in its components … the *emergent* … cannot be reduced either to their sum or their difference (italics added).

From this quote we can see that "emergent" is very much like the modern usage, in which nonlinear interactivity leads to novel outcomes that are not sufficiently understood as a sum of their parts.

Lewes's term was borrowed during the 1920s to form the backbone of a loosely joined movement in the sciences, philosophy and theology known as emergent evolutionism (for a history and review see Blitz, 1992). The main proponents of this movement (we shall call it "proto-emergentism" to distinguish it from the "neo-emergentism" of current-day complexity theory) were the animal behaviorist C.L. Morgan (1923), the philosophers Samuel Alexander (1966) and C.D. Broad (1925), and the entomologist W. Wheeler (1926). The concept of emergence was hotly debated and stimulated some of the most significant thinkers of the age, including Alfred North Whitehead.

As a movement, proto-emergentism died out during the 1930s (McLaughlin, 1992), yet the construct of emergence continued to exert an influence, mainly via philosophies of science where it was used as a bulwark against aggressive forms of scientific and philosophical reductionism. This usage of emergence was mostly of a defensive nature, carving out a position between vitalism on one side and reductive mechanism on the other.

When it came to understanding how emergence itself was at all possible, proto-emergentism had few answers. Alexander (1966), for example, said that the appropriate response to an emergent was "natural piety." In proto-emergentism the process of emergence remained a black box, so that one could discern both the lower-level inputs and the higher-level outputs but not how the lower was transformed to the higher during emergence. However, contemporary complexity theory is proving capable of prying open the black box of emergence due to the advent of high-speed computers, the discovery of pertinent mathematical constructs, and new research methods. As a result, the construct of emergence is acquiring a much surer foundation and usefulness in scientific explanations.

THE CONSTRUCT OF EMERGENCE IS ACQUIRING A MUCH SURER FOUNDATION AND USEFULNESS IN SCIENTIFIC EXPLANATIONS

NEO-EMERGENCE: COMPLEXITY THEORY

We can better apprehend the unique features of emergence today in contrast to proto-emergentism by briefly sketching out the scientific and mathematical sources of emergence in complexity theory. The current investigation of complex systems has roots in various, sometimes closely associated, approaches to the study of the dynamics of systems in the physical sciences, mathematics, and computer science going back to the Second World War and its aftermath (see Figure 2, adapted from Goldstein, 1998).

In the early system sciences of cybernetics, information theory, and general systems theory (seen on the left side of Figure 2),

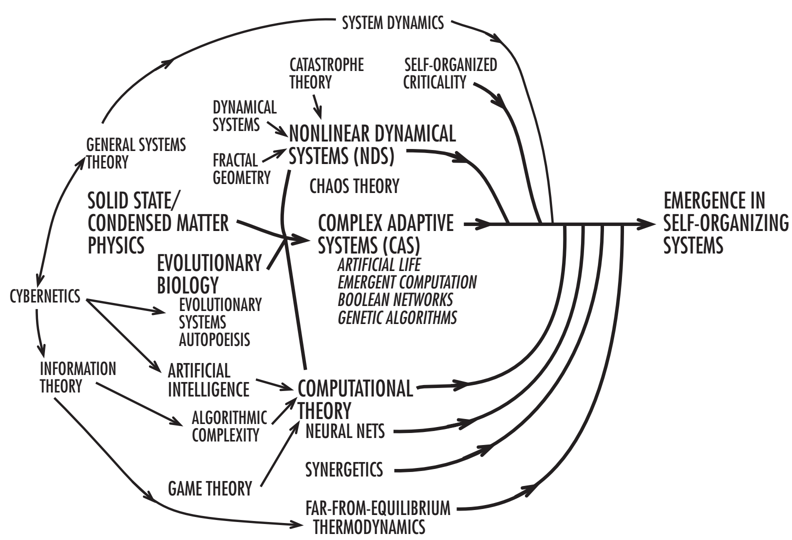

Figure 2 Mathematical and scientific roots of emergence

emergent phenomena *per se* were not explicitly the focus of research, since the systems investigated by these earlier approaches were simple, linear and equilibrium seeking, in contrast to the complex, nonlinear, and nonequilibrium systems in which complexity theory is interested. Emergence requires systems with at least the following characteristics (in spite of potential confusion caused by the heterogeneous vocabularies and methodologies of the diverse sources of emergence, there are certain ideas that cut across them):

1. *Nonlinearity*. Although the systems studied by the earlier theories include a degree of nonlinearity to the extent that they were depicted in terms of negative and positive feedback loops that are nonlinear in nature, they include neither the "small cause, large effect" nor the intense focus on nonlinear interactivity found in emergent phenomena.

2. *Self-organization*. Although the term self-organization was occasionally used by earlier systems thinkers, it referred primarily to self-regulatory processes, whereas in complexity theory the term refers to the creative, self-generated, adaptability-seeking behavior of a complex system. Emergent phenomena are novel structures that confer this adaptability.
3. *Beyond equilibrium (multi-, non-, or far from equilibrium)*. Earlier systems theories explored how systems tend toward a final state of equilibrium or homeostasis (see, for example, the notion of "equifinality" in general systems theory), whereas complexity sciences are far more interested in the "beyond equilibrium" conditions that foster emergence. One of the origins of the radically novel order seen in emergent phenomena is the manner in which far-from-equilibrium conditions allow for the amplification of random events (see Nicolis, 1989). This amplification of random events, in turn, is a key reason for emergence having unpredictable characteristics.
4. *Attractors*. The only "attractor" available to earlier systems theory was a final state of equilibrium, whereas in complexity theory there are different kinds of attractors (e.g., the fixed point, limit cycle, and the so-called strange attractor). As stated above, emergent phenomena are coincident to the new qualitative levels introduced as complex systems enter new attractor regimes.

These four characteristics of complex systems have been extensively studied by the central schools of research making up the backbone of complexity theory (in Figure 2 they are listed downward in the central part of the diagram, immediately to the left of "emergence in self-organizing systems"):

➨ *Complex adaptive systems theory*, which has been made famous at the Santa Fe Institute and which explicitly uses the term "emergence" to refer to the macro-level patterns arising in systems of interacting agents (see Holland, 1998; Kauffman, 1995; and Langton, 1986);

- *Nonlinear dynamical systems theory*, which as the mathematical grandfather of chaos theory promulgated the central concept of attractors, including the strange attractor that the philosopher of science David Newman (1996) classifies as an authentically emergent phenomenon.
- The *synergetics school*, founded by the German physicist Hermann Haken (1981), which helped initiate the study of self-organization in physical systems and which brought us the crucial idea of an *order parameter* in explaining the onset of macro-level, coherent phenomena.
- *Far-from-equilibrium thermodynamics*, which was introduced by Ilya Prigogine and which refers to emergent phenomena as dissipative structures arising at far-from-equilibrium conditions (see Nicolis, 1989).

Applications of the construct of emergence for understanding organizational dynamics will need to borrow from all these sources as well as taking advantage of the new insights that are rapidly coming forward as the study of complex systems intensifies.

PHILOSOPHY OF SCIENCE ISSUES

WHAT IS THE ROLE OF EMERGENCE IN EXPLANATION?

As stated above, emergence is appealed to when the configuration of the components of a complex system offers more explanatory insight into the dynamics of the system than do explanations based on the parts alone. Therefore, explanations that include the construct of emergence contain the claim that emergent phenomena are neither predictable from, deducible from, nor reducible to the parts alone. Turning to the new, higher, emergent level for explanation is, then, equivalent to admitting that an explanation of the system's dynamics purely in terms of the lower level of the parts is insufficient. But besides this admission, what explanatory mileage is gained by bringing in the construct of emergence? To answer this question we must take a closer look at the actual role of emergence in scientific explanation.

In fact emergence functions not so much as an explanation but rather as a descriptive term pointing to the patterns, structures, or properties that are exhibited on the macro-level. For example, the hexagonal convection cells seen in the Benard system are emergent phenomena, since they are higher-level patterns representing an across-the-system correlation not present on the lower level of system components (see Nicolis, 1989). Calling the convection cells emergent places them on the appropriate level from which the explanation can proceed. The explanation then elicits the special, higher-level laws that further elucidation of the emergent phenomena. In the case of the Benard cells, this would include determining the far-from-equilibrium conditions that prompt the emergence, measuring the correlation found in the cells, or, in other words, determining the "order parameters" of the emergent level that aid in our understanding of this startling occurrence.

> COMPLEXITY THEORY IS DEVELOPING THE NECESSARY TOOLS, METHODS, AND CONSTRUCTS THAT RENDER THE PROCESS OF EMERGENCE LESS OPAQUE

An appeal to emergence is thus a way to describe the need to go to the macro level and its unique dynamics, laws, and properties in order to explain more adequately what is going on. The construct of emergence is therefore only a foundation on which to build an explanation, not its terminus. The proto-emergentists foundered on this issue since, because they had no access to the kinds of processes that are powerful enough to bring about emergent phenomena, they had to be content with a mere designation of something as emergent. But complexity theory can go much further in uncovering the many factors involved in the coming forth of emergent phenomena. That is, complexity theory is developing the necessary tools, methods, and constructs that render the process of emergence less opaque and, thereby, less prone to the tag of "miraculous."

IS EMERGENCE MERELY A PROVISIONAL CONSTRUCT?

Since the heyday of emergent evolutionism, a standard criticism leveled at the idea of emergence has been to contend that it has nothing more than a provisional status, that it is simply an epistemic recognition of the inadequacy of any current theory for deriving macro-level properties from micro-level determinants. When a better theory comes along, appeals to emergence will no longer be necessary since this better theory will be able to predict, deduce and reduce emergent phenomena to micro-level processes (Henle, 1942). Emergence then becomes just a temporary mark for something about which we don't *yet* know enough, but eventually will.

According to Hempel and Oppenheim (1948), since emergence could only be defined in respect to a specific theory, and since theories are always developing, the construct of emergence will eventually be discarded. Lewes himself inclined to the provisional view of emergence, while proto-emergentists like Morgan and Alexander thought that emergent phenomena were neither deducible nor predictable, even "in principle" (Stephan, 1992). Indeed, for Morgan, the provisional nature of emergence did not account as evidence against its scientific status but rather supported it, since he felt that science always dealt with things of which it did not have perfect knowledge. The issue of the provisional character of emergent unpredictability was an important one for emergent evolutionists, since unpredictability buttressed their claim for the type of novelty they required for their various schemes of cosmic evolution.

It turned out that a better theory did come along to explain the prototypical example of emergence described by the proto-emergentists. The better theory was that of quantum bonding, which explained the new properties of compounds in terms of the micro-determinants of their reagents. In fact, the development of the theory of quantum bonding was one of the factors leading to the demise of proto-emergentism (McLaughlin, 1992). It needs to be pointed out, however, that it wasn't emergence itself that was the problem but the examples that the emergentists used to exemplify it. Thus if, following David Newman (1996), we take a strange attractor as an example of an emergent phenomenon, then mathematical theorems support the inviolable unpredictability of this particular emergent at least. Here, an exemplification of emergence can defend itself against the argument that its unpredictability will someday become totally predictable.

To be sure, studies of emergence in simulations (such as the Game of Life) show that unpredictability is only absolute the very first time emergents are observed. Thereafter, the emergent patterns yield to greater and greater unpredictability (see Poundstone, 1985). But does this mean that emergents are only emergent the first time they are observed? This is, of course, very similar to the issue of whether emergents are merely provisional.

In complexity theory there is a built-in limitation to predictability having to do with the non-analytically solvable nonlinearity of complex systems, such that there will be differences in the emergent phenomena at each turn of their evolutionary trajectory. In effect, there seems to be no end to the emergence of emergents. Therefore, the unpredictability of emergents will always stay one step ahead of the ground won by prediction and, accordingly, emergence will always stay one step ahead of the provisionality argument. As a result, it seems that emergence is now here to stay. Of course, this doesn't mean that there will be no great inroads into making the unpredictability of emergence more predictable. Rather, it goes along with the general reframing of the entire issue of predictability in scientific explanation that complexity theory has begun. Similar to the role of the uncertainty principle in quantum mechanics, the nonlinearity of the complex systems under investigation by complexity theory introduces a degree of unpredictability that even in principle will not completely yield to more and more probing.

EMERGENCE, REDUCTIONISM, AND THE PLURALITY OF LEVELS

Hidden behind the charge of provisionality is a metaphysical, not a scientific assumption: there is only one basic ontological level and the aim of scientific explanation is to reduce all apparently new levels to this primordial level (an example of such reductionism in criticisms of proto-emergence can be seen in Pepper, 1926). We can call this metaphysical assumption "ontological-level monism." This assumption shows itself with respect to provisionality by containing the further assumption that what appears now as an emergent level will, when a better theory of micro-determination comes along, turn out to be reducible to the micro level.

However, scientific explanations need not claim fealty to ontological-level monism. The physicist and philosopher of science Mario Bunge has shown how emergence is a viable construct by sketching out a scientifically founded pluralistic ontology of levels (Blitz, 1992). In a similar vein, the philosopher of science William Wimsatt (1976) has indicated that when selecting a particular level on which to focus our attention, we are doing so on the basis of recognizing that this level consists of entities and their relations that hang together more strongly with one another than they do with other units and relations on other levels. Accordingly, that particular level, in our case the emergent, macro level, should be where one starts one's explanation. As Wimsatt notes, this way of explanation via levels follows from the statistical reference theory of explanation by looking for factors that give a better partitioning of the phenomena into different classes.

Those who cannot accept the possibility of more than one ontological level also cannot accept the possibility of the radical novelty that accompanies the new level coming into being with emergence. They have a bias against real novelty. With nonlinear dynamics and complexity theory, hard-core reductionism of the ontological-level monist variety has finally come upon natural processes that will not yield to the reductionist onslaught because of the very mathematics of such processes. The nonlinear mathematics of these complex systems disallows exact prediction of future states, since the equations governing such systems are not analytically solvable.

In spite of protestations to the contrary, a rigorous philosophical defense can be erected to support a pluralism of levels. Recently, the philosopher of science Carl Gillett (1988) has shown how the ontological commitments of the proto-emergentist philosopher Samuel Alexander can shed light on contemporary ideas on emergence. The recognition of a plurality of levels, moreover, does not require an abandonment of physical causality, as was done, for example, by C.L. Morgan (1923). However, it does require a rethinking of the role of causality in complex systems manifesting emergent processes (see Goldstein, 1996).

One strategy that has been used to support the reality of the emergent level is to attach to it a causal efficacy. For example, the neuroscientist Roger Sperry (1986) argued that the mind emerges out of brain functioning, yet the mind has causal power in affecting the brain. Furthermore, if emergents have causal power, then how can they be merely provisional (see Schroder, 1988)? Of course, this kind of "downward causation" does not come problem free. For example, there is the apparent conundrum of how an emergent that is "caused" by lower-level components in turn has causal power over these lower-level components. Going further down that path will have to be saved for a future article. The point, nevertheless, is that there are various ways of conceiving emergence that give the emergent, macro level its due.

ARE EMERGENTS MERELY EPISTEMOLOGICAL?

Related to the supposed provisionality of emergents is the issue of their ontological status. Are emergent phenomena part of the real, authentic "furniture of the world," or are they merely a function of our epistemological, cognitive apparatus with its ever-ready mechanism of projecting patterns on to the world?

An example of a perceived pattern turning out to be a mere epistemological artifact is offered, in another context, by the evolutionary biologist Richard Dawkins (1996). He describes a photograph of the side of a hill at a certain time of day with sunlight shining from a certain position in the sky. Looking at this scene from a particular vantage point, one can see what appears to be the profile of John F. Kennedy. Of course, JFK is not there on the hill but is merely the confluence of air and wind and seismic patterns and being in the right place at the right time. In a similar vein, the computer scientist John Holland, whose work has been very influential in complexity theory and who has written a book on emergence (see Holland, 1998), makes a distinction between authentically emergent phenomena and what he calls "serendipitous novelty," such as the play of light on leaves in a breeze.

No one has more clearly remarked on this issue of epistemological status than the chaos and complexity physicist James Crutchfield (1993, pp. 3, 4):

> Indeed, the detected patterns are often assumed implicitly by analysts via the statistics they select to confirm the patterns' existence in experimental data. The obvious consequence is that "structure" goes unseen due to an observer's biases … It is rarely, if ever, the case that the appropriate notion of pattern is extracted from the phenomena itself using minimally-biased discovery procedures. Briefly stated, in the realm of pattern formation "patterns" are guessed and then verified … At some basic level, though, pattern formation must play a role. The problem is that the "newness" in the emergence of pattern is always referred outside the system to some observer that anticipates the structures via a fixed palette of possible regularities … When a new state of matter emerges from a phase transition, for example, initially no one knows the governing "order parameter" … After an indeterminate amount of creative thought and mathematical invention, one is sometimes found and then verified as appropriately capturing measurable statistics.

Crutchfield (1993, p. 8) has pointed out that emergent structures elude traditional physics, "since there are not physical principles that define and dictate how to measure natural structure." Whereas traditional physics has had tools for detecting either complete order or complete randomness, the middle ground of order has been left out. But it is precisely this middle ground that is the locus of emergence. As a consequence, the lack of sufficient frameworks for grasping emergent order is what interferes with accepting emergents as having an ontological status.

Crutchfield's own tactic in addressing the epistemological status of emergence is to examine the *intrinsic* computational capacity effectuated by emergent phenomena, which renders complex systems adaptive. However, defining emergence in terms of an intrinsic computational capacity raises all sorts of scientific and philosophical issues, such as the philosopher John Searle's (1994) contention that computational capacity always contains an external connection so that it is not really totally an intrinsic property. Crutchfield's postulation, nevertheless, like the aforementioned idea of "downward causation," points to how emergence has the potential of generating self-maintaining mechanisms that serve to distinguish it from subjective impressions, serendipitous novelty, or merely epiphenomenal activity. As the field of complexity theory matures, we can look forward to many more insights into the issue of the ontological/epistemological status of emergents. For now, we simply need to be careful in our recognition of emergent phenomena and continually ask the question of whether the pattern we see is more in our eye than the pattern we are claiming to see.

ORGANIZATIONAL APPLICATIONS OF EMERGENCE: AREAS OF FUTURE RESEARCH

EMERGENCE AND THE INFORMAL ORGANIZATION

Although research focusing explicitly on emergence in organizations is a new field, there already exists a substantial body of work on emergent phenomena that has not been recognized as such because of the lack of a suitable theoretical and methodological framework. Specifically, I have in mind studies of what is typically referred to as the "informal" organization, i.e., spontaneously occurring organizational events, structures, processes, groups, and leadership that occur outside of officially sanctioned channels. Much of this "informal" organization can be considered as authentically emergent in terms of what we have been discussing, and considering it so can provide insights that have not been forthcoming with pre-existing models. For example, complexity theory can aid in uncovering the conditions that lead to the "informal" organization as well the adaptive role that various aspects of the "informal" organization may play. Indeed, if it can be shown that the "informal" organization offers greater adaptability to an organization, these organizational dynamics will be given more of the attention they deserve, not only by researchers but by the managers of existing organizations.

EMERGENT LEADERSHIP

We can better understand the place of emergence in organizations through a two-by-two grid that relates the source of a organizational structure to its type (Figure 3; "source" refers to whether or not it is imposed, while "type of structure" identifies it as hierarchical or not).

The upper left quadrant displays a hierarchical type of structure, the source of which is self-organized rather than an imposed hierarchy. This is the aforementioned "informal" leadership, which we can henceforward call emergent leadership. Much of the research on emergent leadership is concerned with how leaders emerge in leaderless groups (see for example Kolb, 1997). Recently, Guastello (1998) has used a nonlinear, dynamical perspective to elucidate emergent leadership behavior in groups.

The study of emergent leadership phenomena is ripe for further exploration using the insights of complexity theory on emergence in general. This line of research would offer insight into how potentials for emergent phenomena are inherent in the dynamics themselves, that is, there is a kind of "order for free" (see

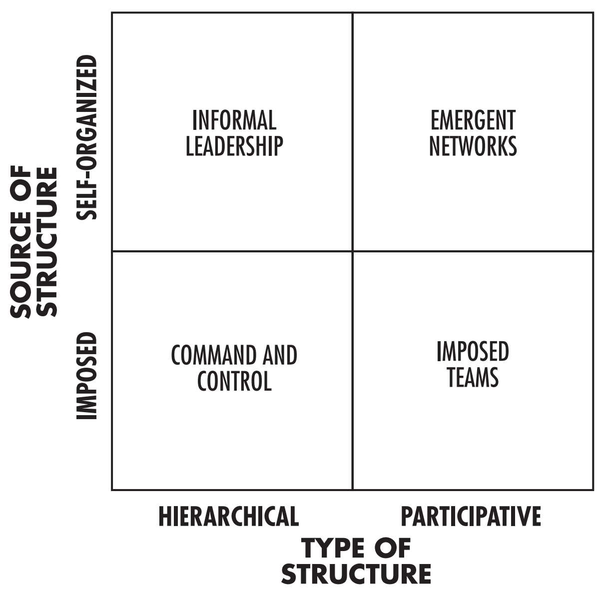

Figure 3 Emergence and organizational dynamics

Kauffman, 1995) that may eventuate in emergent leadership. Studies of emergent leadership need to appreciate the factor of this inherent dynamics before it can establish the significance of the other, non-complexity factors to which it has previously devoted its attention.

EMERGENT NETWORKS

The upper right quadrant, however, is a new area of research opening up due to complexity theory. Sometimes the upper right and lower right are conflated. It must be emphasized that the lower right quadrant, although made popular by total quality management (TQM) and other similar programs and supposed to ensure a participatory work environment, is not emergent in the sense of complexity theory. Instead, team structures are typically imposed and hierarchically driven. Emergent networks, however, the upper right quadrant, represent authentic instances of emergence in organizations as complex systems. Emergent networks can include both intra- and intergroup dynamics and also pertain to the spontaneously arising organizational structures and practices that accompany mergers and acquisitions and the newly shaped strategic alliances that are so rife in our contemporary business world.

An example of an emergent network that also includes emergent leadership can be found in Murnigan and Conlon's (1991) research into the organizational success factors of string quartets in the UK. The organization of successful quartets was observed to be a function, not of the imposition of an official management structure, but instead of allowing for the emergence of effective strategies, work processes, and leadership roles (see a more in-depth discussion of this in Goldstein, forthcoming). For instance, successful quartets exhibited the emergence of conflict resolution as they rehearsed, whereas unsuccessful quartets tried to resolve these conflicts through imposed rules and roles.

However, this does not mean that all spontaneous occurrences deserve the appellation of emergent and are therefore worthy of study. Indeed, one of the issues confronting researchers will be how to distinguish authentic emergent networks from Holland's "serendipitous novelty." Much of this distinction will depend on carefully discerning the adaptive functionality offered by authentic emergent phenomena as opposed to "serendipitous novelty." But this will then necessitate a deeper investigation of what constitutes an adaptable organization.

Another crucial area of research in emergent networks will be their role in organizational creativity, particularly as the latter can be aided by the impressive strides made in cognitive studies of creativity (see Finke, Smith, and Ward, 1996). These studies in fact portray creative processes in ways that are quite similar to how emergence takes place. Here it is the radical novelty characterizing emergence that needs attention. This radical novelty includes the critical role played by serendipity in organizational creativity. Serendipity, in this sense, has to do with the taking advantage of accidental occurrences that James Austin (1978) has identified in so many scientific discoveries. Indeed, complexity theory is exploring how the structure and properties seen in emergence partly result from the serendipity-like amplification of random events in complex systems. The chance or "noisy" event can be utilized by the organization to explore or test different system configurations and, therefore, may represent an evolutionary response of the social system to changes in the environment (see Allen and McGlade, 1987; and Goldstein, 1994).

However, a caveat is in order here. Emergence can be constructive as well as destructive. Witness, for example, the emergent political divisiveness that occurred in the former Yugoslavia. Therefore, there is a great need to ascertain how to channel the process of emergence in constructive directions. One hint in this regard is the crucial role of firming up organizational boundaries that can contain the powerful currents of self-organizing, emergent processes (see Goldstein, 1994).

Finally, there is the fact that complexity science is only in its infancy. As it matures, better quantitative tools will be coming forth that offer richer ways of studying emergent phenomena. For example, recent work by Dooley and Van de Ven (1998) used various analyses of time series data to understand diverse organizational dynamics. Indeed, emergent phenomena are there for the taking by future researchers.

CONCLUSION

Emergence is not an entirely new topic. Conceptual constructs resembling emergence can be found in western thought since the time of the ancient Greeks, and have at times had a significant impact on intellectual culture. However, emergence is emerging today as a construct of complex, dynamical systems. And what is exciting are the tremendous advances being made in understanding emergent phenomena. These advances are opening up the black box that had previously obscured the real process of emergence.

Since emergent phenomena are ubiquitous in organizations, the advances being made in the study of emergence can only have a huge impact on the study of organizational dynamics. Complexity theory, with its investigation into emergent phenomena, promises to provide both a methodology and a theoretical framework for studying something that is already playing a crucial function in our businesses and institutions.

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Issue 1-1 4/3/99 5:54 pm Page 73

The Gurus Speak: Complexity and Organizations

A Panel Discussion at the Second International Conference on Complex Systems

October 30, 1998

The last day of the Second International Conference on Complex Systems hosted a rather unique event. Seven management gurus were brought together under the same roof to discuss the role of complexity science in management theory. Rather than treat the occasion as merely another monologue between panel members and the audience, the scene was set for a more interactive process. Some in attendance even agreed with the phrasing of Micklethwait and Wooldridge, the authors of Witch Doctors*: "American managers are fond of the word guru because they aren't sure how to pronounce charlatan." The resultant emergent behavior gave rise to some interesting and possibly controversial debate. The following extract from the transcript of the event gives some flavor of what happened…*

THE PANEL

Bill McKelvey, the Director of Strategy and Organization Science at the Anderson School at UCLA.

Henry Mintzberg, Professor of Management at McGill and the author of many seminal books, the most recent and perhaps important of which is *The Rise and Fall of Strategic Planning*.

Tom Petzinger, writer of "The Front Lines," a weekly column in the *Wall Street Street Journal*, and author of *The New Pioneers*.

Larry Prusack, managing principal in the IBM consulting group, director of its Knowledge Management Institute, and editor of *Knowledge in Organizations*.

Peter Senge, founder of the Center for Organization Learning at MIT and author of *The Fifth Discipline*.

Ron Shultz, a writer, speaker, broadcast producer and Director of Publishing at Sendelaney Leadership Consulting in Santa Fe, and the co-author, with Howard Sherman, of *Open Boundaries*.

With comments from:

Yaneer Bar-Yam, president of the New England Complex Systems Institute, and author of *The Dynamics of Complex Systems*.

Dean Lebaron, founder, Battery March Financial.

Petzinger: Anyone recognize this woman? She is Mary Parker Follett. Mary Parker Follett was a management theorist back when there really was no such thing. This is pre cyberneticists, pre Norbert Weiner, pre general systems theory. "No one can understand the labor movement, the farmer movement, or international situations unless he is watching the internal stimuli, and the responses to the environment." This writing is vintage 1920. She called this a circular response: "We cannot watch the strikers, and then the mill owners. Trade unionism today is not a response to capitalism, it is a response to the relation between itself and capitalism. What about authority? Where does it emanate from? It is not something from the top. It comes from the intermingling of all. Of my work fitting into yours, and yours into mine, and from that intermingling of forces a power is created which will control these forces. Authority is a self-generating process."

The Austrians were not complexifiers, *per se*. But they used the very language that we now take as recent. The emphasis in this quote is in the original, the emergence of new patterns as a result of this increase in the number of elements means that this larger structure as a whole will possess certain general abstract features which recur independently of the particular values of the individual data.

Anyone recognize this fellow? This is Abraham Maslow, the great humanist psychologist best known for postulating the hierarchy of human motivations. Less well known is that Maslow also spent a sabbatical in an industrial plant in Southern California. He spent the summer walking around with a tape recorder in his hand, and having his thoughts transcribed; to my knowledge, the only time he was ever in a business or a firm-type setting. And he walked out with these kind of thoughts on such subjects as holistic business: "A business in which everything is related to everything else. Not like a chain of links of causes and effects, but rather a spiderweb, or geodesic dome, in which every part is related to every other part." These writings, incidentally, are vintage 1962. As for creativity, he noted that it is correlated with the ability to withstand lack of structure, lack of predictability of control, the tolerance for ambiguity, for planlessness…

> IN THE COURSE OF NAMING SOMETHING, YOU RUN THE DANGER OF OVERSIMPLIFYING IT

I'm going to pose a problem: in the course of naming something, or in explicitly linking so much deep thinking from across sciences, or many fields, or many intellectual traditions, you run the danger of oversimplifying it. And in oversimplifying it, you draw in the corrupters, the charlatans, people seeking pat solutions. This forces us to use the *F* word: Is this a management fad? Is it possible that the management folks will wreck this concept, even for the scientists perhaps? Just to contemplate this, I invite you to consider this quote from the business world: "In the world we enter, chaos is order. Evolution is revolution. Adaptation is survival. Order, truth, perhaps even beauty, will emerge from the constructive chaos of disruptive change." How many buzzwords in that sentence? We run the risk of wisdom becoming confused with word salad.

Here, from one authority, are words of warning, which I take just a little bit personally: "As soon as one management fad disappears, another is waiting in the wings to replace it. What? You didn't catch on to quality circles? That's okay. The big guy read an article about chaos science in the *Wall Street Journal*, and wants to implement it throughout our North American operations right away." Before going to the first of our speakers, I'm going to boldly assert that we are in very little danger of creating a management fad for these reasons. Complexity describes the world as it is. It is not an idealization tool. It emphasizes removing behaviors over adding behaviors. It's not a program. It's not something you can start on Monday morning. It's behavior you have to stop doing on Friday. It rewards our humility over our conceits. It defies methodology in packaging. It has to be customized. It is the situation that complexity addresses. And lastly, it is science, rather than a fad.

McKelvey: When I was at MIT, I was a student of Warren Bennis, one of the leading gurus on leadership. I want to tell you that in 30 years this is the first time I've had a paper that had the *L* word in it. So this is a new venture for me.

Yaneer Bar-Yam said that when a single component controls a collective behavior, then the collective behavior of the system cannot be more complex than the individual behavior; i.e., there is no emergent complexity. So what that means is, if we don't have CEOs and leaders in the firm who can create complexity, there's no reason for any of you to exist.

Back to Bennis. He talks about visionary, heroic leadership, and he talks about this as herding cats. Now I don't know how many of you have cats—I live with a couple cats—cats are really dumb, and they have no network. There is no human capital, or social capital, involved in Bennis's statement. What this means is that his view of how you get organizations to work in firms is essentially irrelevant to the modern age. There's no capital, there's no labor, there's no human capital, and there's no social capital in that statement. It all depends on having this visionary leader. And if you have a visionary leader who can't get leadership down into the lower parts, you don't have any complexity. So we're dead if we follow Bennis.

What I think we ought to talk about, if we're in the complexity business, is: Do we have human capital in firms? How do we get it? Do we have social capital in firms? Do we have intelligence distributed or some combination between these two? That's the next thing. The disconnect is most of the work on leadership, and all of this talk in the guru books. The information gets us to the point where we have firms dealing in a rapidly changing environment, we have hypercompetition. And the only response we have is that the leaders should be visionary. How do you have a leader direct an emergent system? Because if the leader really leads, according to the current conception, he or she shuts down emergent structure.

How do we actually do leadership in a way that fosters emergent structure in a firm without the leader somehow creating a bunch of passive followers following some vision? And further, in a rapidly changing world, what chance is there that the leader has the right vision at the time, or at the right level of technology, and so forth? Very little chance.

That is when I turn to complexity theory for an idea. Think of the organizational context. We have a firm facing an energy differential. It's out of date, it's obsolete, it's not keeping up with the rapidly changing world. It's under a lot of adaptive tension. You see it with a lot of M&A activity. We buy a small firm in New England. We send in the MBA terrorists, we get rid of the management, we change the culture, we change the accounting system, we change the IS systems. And right away we just create a lot of chaos. And if we don't do all of that, if we just passively buy the firm and hope for the best, this little firm pretty much just stays the way it is, and not much of any good happens.

What we're trying to do is to get managers to set up strange attractors, so that you get relevant behavior without somehow identifying a point in advance where you want the system to go. Clearly, there's a lot of stress managing the agency problem. The owner is going to say: We're going to pay for these people to do whatever they want to do? How do we know it's for the good of the organization? How do we know it's for the good of the shareholders or the owners?

Senge: I'm inclined to connect to one of the themes that Bill talked about and, since we already touched on the problems with heroic leadership, to come back to the whole business of knowledge. As I'm sure a lot of you know, all of you in business *certainly* know, knowledge management is what would qualify as a fad today. And it is remarkable to me how much time, and money, and all sorts of resources we can invest in something that people can't even define. There is a very strong tendency for us to define knowledge as information, or place it the other way around—for us to regard information as if it's knowledge.

I'VE ALWAYS FOUND A REALLY USEFUL DEFINITION OF KNOWLEDGE TO BE "THE CAPACITY FOR EFFECTIVE ACTION"

I don't know what the world's greatest definition of knowledge is, I can only tell you what's been helpful for us in our work: knowhow. I've always found a really useful definition of knowledge to be "the capacity for effective action." Therefore learning in that sense is about the enhancement of capacity for effective action. While that's very simple, and undoubtedly has some limitations, it really gets you out of the confusion that knowledge is somehow information. Everybody is saying yes, knowledge isn't quite information, it's like really important information, or like really big information, there's something really different about it. But I think any of those definitions ultimately ends up not adding much of value. And I do think it is very challenging if you think of knowledge as the capacity for effective action. It clearly has to do with highly complex, interdependent realities, and how people build knowledge; that is, not get ideas, not even build better theory—although I think theory is essential—but actually develop enhanced capacities for effective action.

Most of what's talked about in a conference like this is dynamic complexity. I'm not sure how well-defined, or consensually defined, dynamic complexity would be in this community; but by dynamic complexity I do mean things like emergence. I mean situations where cause and effect are not close in time and space, where in the behavior of a complex, non-linear system, the areas of most significance are very often very distant from the symptoms of the problems. So managers in organizations are—for all kinds of reasons—not only interested in the way the organization is organized and structured, but in the patterns of or the habits of our thought, e.g., if we're losing market share we ought to crank up a marketing intervention. Or if product development is somehow not up to snuff, we ought to reorganize the product development organization. Very often these are symptoms of the interactions of the enterprise as a whole, and the greatest leverage might lie in very distant parts of the organization.

The theory that I was most interested in, or became most interested in, was a theory constructed by the practitioners. To talk about theory in the world of business is usually a way to have yourself shown to the door—but I think that the best practitioners are theorists. They are thinking: What are my assumptions behind these actions? Why does one strategy make more sense than another, in terms of the world view that it is based on? And in so doing, if they're really good, they are quite reflective about their assumptions about that world view. So they know that they're just constructing a view on which their decisions are based, and ultimately the continual inquiry into that view is critical to their work.

In a human world, that means you have to deal with human complexity. You have to deal with the fact that people are different. They see the world differently. They construct different realities. They have very different assumptions, and oftentimes even

Issue 1-1 4/3/99 5:54 pm Page 80

different values. So in a sense, what we've been trying to do is pose the question: How do you make progress in this domain, in this space? Because there are a lot of tools for generating insight about complex systems which don't necessarily enable the human actors in those systems to become more effective. There are a lot of tools and methods for helping people listen to one another, appreciate one another, slow down enough so that we can start to see that the person who appears crazy, may not be crazy. And if I really could hear the process they have gone through to come to their view, I might learn something about the reality that I'm facing. And so in a funny, simple way, everything we have been doing has been trying to integrate tools and theories from these different dimensions.

The thing that's kind of interesting about this to me is it's always dangerous when you pick a little tiny piece of an example. You get a thread, but you don't get the weave. There is a weave here. People are spending a lot of time talking about why they don't get things done on time, and conceptualizing the kind of interdependent world they live in. Why is it that nobody will tell people they're behind? Because they're afraid of telling people things they're not good at, because of all the left-hand column stuff that nobody ever talks about. Most engineers, and most engineering cultures, will love to talk to their peers about problems they have solved. But often—in some organizations I've found this to be really extreme—they really do not want to talk about problems they don't understand.

WE'VE GOT TO GIVE UP THIS NOTION THAT LEADER IS BOSS, AND BOSS IS LEADER

One of the things that's a huge limitation in our thinking, and taking more effective action, in this whole area is we've got to give up this notion that leader is boss, and boss is leader. It's everywhere, it's in our language: we use leader as a synonym for boss. And I would suggest to you if we do that, we are actually saying two things which we probably don't intend; but we're saying them very clearly. The first is, obviously, other people aren't leaders; and the second is we have no definition of leadership.

I don't think there's a snowball's chance in hell of redefining leadership in this day and age. There are people who stick their necks out—there are people who step forward—there are people who initiate—and there are people who work to sustain significant forces for change; all of which is what I would consider the core work of leadership. It's not just initiating, because when you initiate you bring a lot of difficult stuff out of the closet. And many times people who initiate aren't very effective at dealing with that difficult stuff. The main point is that these people are all over the place.

What are their rules of thumb? I don't know. It's the kind of question that I have to tell you I'm not too used to thinking about. What comes to my mind first are all the things like timeless verities, commitment to the truth, which doesn't mean truth with a capital *T*. People as individuals do not create anything. Creation, or bringing something new into being, is always a product of human communities. I would say the closest and simplest word that comes to mind on this is *love*. The real appreciation of the other and the appreciation of the quality of our relationship. As far as I'm concerned, the quality of thinking in organizations is very, very strongly influenced by the quality of relationships. These are not very new or novel ideas; and I'm sure it's much too simple.

Prusak: I come as an emissary from Big Company Land. I specialize in knowledge. I think I invented the term "knowledge management." *Mea culpa*. We did this because we're paid to invent terms. There is a real subject, in economics and sociology, of what people know, and what organizations know, and how it's manifested. This is a real thing, it has a lineage. It's in epistemology, and other subjects too. And I tried to study a great deal of that, and then did some writing on knowledge management. You can't manage knowledge, because you can't see it. This is a given.

American commercial society tends to take things and turn them into something I can sell to you on a disk. All the consulting firms I know sell something called packaged enabled business transformation—something that makes no sense whatsoever if you look at the words, but they're making billions of dollars on this.

I work for IBM, a very big firm. They have big consulting and services type of practices. And they talk a lot around knowledge. They already beat out data, they did a lot of data. They work with information, which is sort of a message that's bounded by repositories. You know, Peter's exactly right, and I think Bill was right. Information and messages, me to you. *Guernica* is a message. Schubert's music is a message, so are Emily Dickinson's poems, and so are memos. Knowledge is what people know, and what groups of people know. It's the space between them, very often, rather than the people themselves.

And now IBM and all the other firms want to sell you something about knowledge. So they go to these large firms, and say we want to do something around knowledge in order for you to buy services, and software, and hardware. And I and people I work with get called in to say, let's do something about knowledge. It's an interesting job. You end up with large firms, talking to executives, people who have the budgets and the power to do something. They say: What are we going to do about knowledge?

Let me tell you how I try to answer that within the realm of trying to maintain some integrity, and still pay my mortgage. First thing I try to do is understand where is the knowledge in the organization. Is it in people? Is it in processes? Is it in routines? Is it in documents and databases? Is it in the social networks?

Once we begin to talk about that, with whoever wants to listen, we begin to say: What's a unit of analysis? What are you going to analyze? An event? A group? An individual? The entire enterprise? Its past history? A GM is interested in analyzing decisions. The decision is the unit of analysis. What's knowledge in input? Knowledge in output? Some firms use communities of practice, communities of knowers.

Not long ago the Ford Motor Company did a little experiment in this area, and found they had about 560 people across the firm who were passionate about the technology of brakes. This might not turn you on, or me. If you're Ford, it's big-time stuff. You have some 500 people across the world, across functions, across boundaries, across rank. What do you do with that? Do you give them money? Do you give them space and time? Do you acknowledge that they're really valuable to the firm because they share knowledge? They talk to each other, they take that extra step, they read something and send it to you, when it's not in their job description. That's a real issue. Is there an intervention you can make in an emerging group, a community, people who are not organized by the hierarchy, but have self-organized themselves around a passion? What do you do with those people? It's a legitimate question. You want to help them. You want to make an improvement. How do you improve their behavior? What do you do, if anything?

Another question people ask is: If we can identify networks and communities, what can you do about them? The most valuable thing you can do if you want to optimize what an organization knows is to make it more visible, so others can use what others know. In a very raw sense, what we're talking about is that knowledge, what people and groups of people know, is local, contextual, and sticky, and that there needs to be respect for the localness of knowledge. People talk about knowledge transfer; they used to use the term technology transfer. It's very, very difficult to transfer knowledge in organizations, because the knowledge is embedded in social capital and social networks.

Knowledge is not Cartesian. It's not out there. It's not an individual. It's embedded, embodied in groups of people who share common goals, common ideas, common emotions. And that's a very elusive subject. What do you do when knowledge is embedded in social capital? It's the space between people. What can you do? What's an interventionist stance towards that? Professor Nonaka, who also writes about knowledge, talks about the need for *space*, and this is something I have come to agree with.

A lot of firms are run with mechanical models. The model they have in mind is a lean machine. This is just ridiculous, but it's still very current—the way people think. Machines don't need knowledge, they just need energy and direction. If you think of an organization as a machine, you're not going to make much progress. And I have to fight, we fight against this.

Nothing happens without reflection, and there's no reflection without space—cognitive space, social space. I'll give you a real example. Again, I hate speaking in abstractions without stories. People only learn through stories anyway.

If you don't have space to learn, what do we mean by space? Physical space, cognitive space. You can get all the technology you want. You can get money for technology. It pays off my debts, it will pay off yours. Sell all—you can't get space, and you can't get attention. The two things that are most valuable for doing knowledge stuff, or learning stuff in organizations, are space and attention, and you can't get them. They're becoming a scarcer and scarcer commodity.

I would then that add another key thing to do, along with space, is trust. Ken Arrow wrote a book 20 or 30 years ago, *Limits of Organization*, where he talked about trust being the most efficient economic tool, because you don't need to negotiate when you have trust. You don't have to barter or bargain. If you trust someone, you trust them. And trust is anticipated reciprocity. It's an options model. I will help you, with the understanding, tacit or covert, that you will help me in time, and that you have something that I would want to have help with. It's a long way of saying that it makes a tremendous difference.

There are things that can be done to enhance trust in organizations. Charles Sable at MIT wrote a very interesting paper on how if nations could recreate their myths, you'd have less wars. Companies can sometimes change stories. That's why I like that learning history stuff. Sometimes if you change stories about the past, it will help engender trust.

IBM owns Lotus. We didn't merge with Lotus, we bought Lotus, and we're eating it. The Lotus-eaters. One of the things we're doing is changing the way they tell stories about IBM, which of course are not dissimilar to the stories I heard from my parents about Germans in the 1940s. But we're changing the stories, and it changes the legends, the myths, the way people understand; and it will help build trust.

The third very important element, which again is not science so much as heuristics, is perceived equity, which is a form of trust. If you sense in an organization that you're not getting your due, that there's wealth being created that is not being accrued by you, not only financial wealth, social wealth, intellectual wealth—a sense of a proportion of equity is not coming your way, however you define equity. You're going to underoptimize, you're going to underperform, and it kills trust. So perceived equity is a key ingredient in social capital. Networks will occur, but within these social networks that we're talking about, within the growth of social capital, it creates a tremendous constraint if you have a sense that someone is going to misuse what you have or give. Again, they'll be thrown out of the network. Not formally, but slowly their calls don't get answered. But if the whole firm has a sense of this, it's deadly.

If you can get across in these organizations a sense that there are interventions that enable cooperation, so knowledge can be moved, can be generated. People in firms know how to do things. And what they know how to do can sometimes be made more valuable if more people knew who knew what, if some of them had a little time, a little space, a little money, a little technology, a little pat on the back. With the diffusion of technology, you have a sense that knowledge gets more visible in organizations. As it becomes more visible, because of intranets and web sites, people get a sense of who knows what. And there's a real disparity in organizations between who knows, and who has the money, and who has the power. This guy helps me, but that person has the budget, and has the power. It's a very interesting sense of social stress. Knowledge isn't free, it isn't cheap, it's expensive, and it takes interventions.

KNOWLEDGE ISN'T FREE, IT ISN'T CHEAP, IT'S EXPENSIVE, AND IT TAKES INTERVENTIONS

We need, again, a big element of social capital. Children need it, adults need it. You need to be recognized. You need a sense of identity. And identity, for better or worse, is often wrapped up in where you work, and what you do. We live in a society—and I've never heard it said better than by C.B. McPherson—that is possessively individualistic. You're not different when you enter a firm's door. It's possessive, and people want to possess something. It's not enough to know things. It's enough to know, and be recognized for what you know, and be rewarded for what you know.

Mintzberg: One of the things I discovered here is I guess I've been a complexity theorist for a long time, probably before anybody even used the word "complexity theory." I went out to observe managers, and I discovered that all kinds of funny things were going on in the office, and they were being interrupted all the time. They were doing short things. Their job was all oral, there was very little written. And a journalist described managerial work as calculated chaos, which I kind of like.

And it occurs to me that managers have to act. That's what management is about. It seems to me that because managers have to act, or intervene, or change things, they have to simplify. So no matter how complicated the world is, managers have to act. The worst thing a manager can possibly do is not act. Saying no, doing nothing, is far worse for a manager than doing something, no matter what it is. The best thing is to do the right thing, the worst thing is to do nothing, and the second best thing, or middle thing, is to do something, even if it's the wrong thing. Because at least you can correct it.

I think that leads to something I called emergent strategy. You don't make a strategy as some kind of Moses-like process where you walk down from the mountain, and present the tablets, and everybody else runs around implementing—you make a strategy by trying something, and testing, and changing. There's a three-part process to what management does. There are initiatives that people take, and those can happen anywhere in an organization;

often down on the ground, where people know what's going on. There's a kind of championing or promoting role, which is somebody who recognizes the initiative for more than it looks to the person who started it, and promulgates it, to some extent. And then there's a kind of acceptance role. But part of the promoting role is to seek some kind of convergence in the initiatives. And I think strategy becomes simply the consistency or pattern that develops in behaviors. So management is really about that.

I just did an article called "Managing quietly." And what managing quietly is about is that the hype really gets in the way, and the big sort of initiatives get in the way, these big turnarounds where people come in, doing dramatic things to organizations, and driving everybody nuts, because they don't know what's going on. Managing quietly basically means building up the system—quietly, and slowly, and low key—by which other people take initiatives and by which you encourage people to take initiatives.

You act, in order to think. And it seems to me that the more complex something becomes, the more you have to act first, and the less thinking is actually useful, at least initially, as a starting point. I don't know how many of you are familiar with the "garbage can" view of decision making, organized anarchy. Is this the complexity of the process we're talking about, or is this the inability of the observer to understand what's going on? Because anything we don't understand is, by definition, chaotic.

For example, there's a lot of talk about turbulence. I hate that word. I think it applies well to hurricanes, literally, but I don't think it applies well to anything in management. Claims about turbulence are just an effort to pat ourselves on the back, and to say we're really important because big things are happening now. I see very little turbulence anywhere. If you want, take turbulence to be something like the siege of Leningrad. I grant you that was turbulent for the people who lived through it. I don't mean to be callous, but the use of the word is absolute and utter nonsense most of the time.

Issue 1-1 4/3/99 5:54 pm Page 88

I accept the notion of complexity, and complex systems. But how much of the complexity we supposedly see around us is real complexity, and how much is simply that we're confused by things because we just don't have the right theories, or approaches to understand things, which may in fact be a lot simpler than we think? How much of the complexity is the unexplained variance, and how much is real, true complexity?

HOW MUCH OF THE COMPLEXITY WE SUPPOSEDLY SEE AROUND US IS REAL COMPLEXITY, AND HOW MUCH IS SIMPLY THAT WE'RE CONFUSED BY THINGS?

S*hultz*: I have the unenviable task here of trying to summarize what has gone before. Peter began with this idea that knowledge is the capacity for effective action. And what that is really saying to me, on one level, is that our ideas are shaping our behaviors, so that what we think shapes what we do.

Henry was talking about the mechanical perspective as well, and how we get locked in. But what happens when we get locked in? We limit our possibilities. And when we limit our possibilities to respond, we limit our ability to respond to unexpected occurrences. And when we limit our responses to strategies, we become vulnerable to catastrophic events. When we are vulnerable to catastrophes, an unexpected occurrence can wipe out the system. This in my estimation is why it's important for us to understand how ideas shape behaviors.

What I want to provide for you here is what I call a sustainable model for inconceivable development. The process is very simple, there are only three steps. It begins by understanding the system.

As soon as we have a new understanding of the system, as with complexity, it requires us to do something. It requires us to adjust our relationships according to that new understanding. So we go in, and we adjust all our relationships with people that we work with. And what happens? Something emerges out of that interaction of our understanding and that adjustment of relationship.

Now we have a new understanding because of what's emerged. So we have to go back in, and create a new understanding of how the system works. That means that we have to go back, and we have to adjust our relationships according to that new understanding. And when we do that, something new emerges, which means we have to go back in, and readjust our understanding of the system, and the system continues on down.

What happens when we do this in a organization? By the time you get three levels down in this process, what emerges would have been absolutely inconceivable. What usually happens is that by the time we get beyond the first emergence, we stop. We don't go back in, and readjust our understanding, and continue the process on down. The system then dies.

On one level, complexity is really an outcome, because it arises out of the very active organizing within an ever-changing environment. In business it comes out of our interactions with each other and with the environment. The interpretations of those interactions are all based on one common experience. And that one common experience is our thinking. Therefore, when we don't get stuck in our outmoded ways of thinking, we can greatly affect the way in which we operate. If our thinking is hectic, and overly busy, the way in which we operate is hectic, and overly busy. And if our thinking is quiet and calm, so too are our interactions.

Bar-Yam: I think it is very important to put the human back into the organization, also into the thinking about organizations in the context of complex systems. That is in contrast to the usual discussion of chaos, and the concept of edge of chaos, and so on, where people are being pushed to the limit, in order to be able to exist in a complex environment. And the discussion that is relevant here is a talk that Herb Simon gave at the banquet last year. He spoke about the concept of homeostasis, which was very important in the previous generation of complex systems thinking but is missing in much of the current thinking. And the idea is that there is a complexity that the organism exists in, in the context of the environment; but the parts of the organism are not in the complexity of the environment outside. This is because the organism is shielding and protecting its own components. Realizing that a complex system is protecting and shielding its components from the complexity that they otherwise would encounter is an important part of understanding how complex systems thinking should be applied in the context of human organizations.

One of the things that we have to recognize is that it is important to have both abstract, larger-scale models, and models that allow us to deal with the emotional or individual human content. In addition, we need to recognize that there are all those different levels of treating a system.

Lebaron: It's my observation, over an extraordinarily small sample size, that the floor or limitation in the description of what we're talking about of having a very nice emergent system is the individual. The individual does not want to live at the edge of chaos, or near to it. When you introduce a system which is periodically, or continuously, emergent and adaptive, nonforecastable in a linear or hierarchical sense, it appears to be out of control. The individual, wherever the individual is in the organization, will do whatever it can to freeze it up. Periodically you can get some pulses through. You can send through some shocks. That's what a merger or an acquisition is, it is a shock. Or you can change people around, shuffle them around. You can't do that very often, but they sort of restart the clock. But you can't keep it up continuously.

Petzinger: I'm going to close the session by returning to a thought. The aspect of complexity that is most in line with what I do is the realization that as valuable as living systems may be as metaphors for organizations, they are not nearly as valuable as the knowledge that complexity teaches us—which is that human organizations are biological systems. We are biology. The organizations we create are just like the organizations that exist in the natural world. We aren't the natural world, but nevertheless, we operate according to, if not identically to, the laws of dynamics that scale from species to species—from organism to organization. There's a lot of science, including quantitative science, in the life sciences, and the physical sciences that we can learn a lot from. The question for us as managers is, "Do we dare? And do we care?" In our answer may rest our competitive position for the decade and century ahead…

Issue 1-1 4/3/99 5:54 pm Page 92

Is Management an Art or a Science? A Clue in Consilience

Nicholas C. Peroff

Is effective management an art or a science? Can it be both? How, exactly, should we think about the management of an organization? For years now, an often spirited art-versus-science debate has ranged through an extensive body of literature on organizational management (Bohn, 1994; Calkins, 1959; Hubner, 1986; Mathur, 1994; Schiemann and Lingle, 1997; Shallenberger, 1960; Weick, 1996), and many subfields of management, including organizational behavior (Caminiti, 1995; Choo, 1995; Watkins, 1993) and leadership (Lester *et al*., 1998, Pitcher, 1997a, b).[1]

An art-versus-science dialogue flourishes in business administration (Ashkenas *et al.*, 1998; Bort, 1996; Gilad and Herring, 1996; Haslip, 1996; Lewis, 1997; Marullo, 1998; Mullin, 1994; "Outfitting an Office…", 1997; Sexton and Smilor, 1986; Sherden, 1994; Smith, 1998; Timpe, 1986–9) and related areas such as banking ("Evasive Action…", 1995; "Risk Management…", 1997; Wray, 1996). The debate also continues in public administration (Beard, 1939; Lepawsky, 1949; Lynn, 1996; McDonough, 1998) and related areas such as health administration (Jeska and

Rounds, 1996; Kay and Nuttall, 1995; Meszaros, 1997) and corrections (Bowker, 1982).

Edward O. Wilson is not known as a contributor to the literature on management. His early work is on the study of social insects, particularly ants. When he wrote *Sociobiology: The New Synthesis* (1975), he inaugurated the scientific study of animal societies and communication. All told, he is the author of 18 books, and two of them, *On Human Nature* (1978) and *The Ants* (1990, with Bert Holldobler), received the Pulitzer Prize. He is currently Pellegrino University Research Professor and Honorary Curator of Entomology of the Museum of Comparative Zoology at Harvard.

With the publication of his latest book, *Consilience: The Unity of Knowledge* (1998), Wilson entered the management as art versus science debate, simply because his book is about everything. Consilience means a "jumping together," which is what Wilson wishes would happen with the natural and social sciences, the arts, politics, ethics, and every other form of human knowledge. He believes that all real phenomena, from galaxies and planets to people and subatomic particles, are based on material processes that are ultimately reducible to a small number of fundamental natural laws that explain everything. All explanations for everything are causal and all causes are material.

Wilson laments the increasingly complex, specialized, and fragmented state of human knowledge today and argues that the progress of science has always been a story of increasing consilience. Is management an art or a science? If Wilson's belief in a unified theory of everything is correct, maybe we should be asking a much larger question. Is a consilience of all of our ways of thinking about management feasible?

WILSON'S DESCRIPTION OF SCIENCE

Science is extraordinary. With the aid of science, we can visualize matter across 37 orders of magnitude, from the largest galactic cluster to the smallest known particle (Wilson, 1998a, p. 47). When science is done correctly, it can advise us in all of our day-to-day decisions and actions. Wilson only acknowledges one resource limitation on the pursuit of scientific knowledge, a lack of data.

Wilson is a natural scientist and, for him, science is not a philosophy or belief system. Science is science. It involves the expansion of sensory capacity by instruments, the classification of data, and the interpretation of data guided by theory. Scientific theories are falsifiable. They "are constructed specifically to be blown apart if proved wrong, and if so destined, the sooner the better" (1998a, p. 52).

Science is a method of doing things. It "is the *organized, systematic enterprise that gathers knowledge about the world and condenses the knowledge into testable laws and principles*" (1998a, p. 53, author's emphasis). There are five "diagnostic features" that distinguish real science from pseudoscience. The first is the repeatability of research results, preferably by independent investigators. The second is a reporting of research as simply and elegantly as possible. Third, scientific findings are subject to universally accepted and unambiguous scales of measurement. Fourth, scientific research stimulates new learning and new knowledge. And finally, science is consilient. Research results can be connected and proved consistent with one another.

Astronomy, biomedicine, and physiological psychology possess all of the features of real science. Astrology, ufology, creation science, and Christian Science do not (Wilson, 1998a, p. 54). Wilson is silent on the matter, but there is certainly plenty of other support for placement of a science of management among the former and not the latter "sciences."

MANAGEMENT AS A SCIENCE

The origin of a modern science of management can be traced to the work of Frederick Taylor (1911) and Luther Gulick (1937). However, when James D. Thompson helped launch the first issue of *Administrative Science Quarterly*, he remarked that "the possibility of a science of administration is only now coming to be taken seriously" (1956, p. 103). Thompson envisioned an applied science built from a combination of both deductive and inductive techniques for the development of logical, abstract, tested systems of thought. A science of administration would "be distinguished from administrative lore by the methods used to build that knowledge of administration" (1956, p. 104).

From its struggle to be taken seriously in the 1950s, the science of management and administration has become a principal component of management theory and practice in the 1990s. It is prominent in the academic literature (Assad *et al.*, 1992; Austin, 1993; Culbert, 1996; Mingers and Gill, 1997; Plane, 1994; Reisman, 1992; Sproull, 1997)[2] and in business school classrooms (e.g., Anderson *et al.*, 1996; Eppen *et al.*, 1998; Taylor, 1998). In public administration, a "new" science of administration (Daneke, 1990; Dennard, 1996; Kiel, 1994; Neumann, 1996; Overman, 1996) is establishing a presence with the literature of traditional administrative science (Dunsire, 1973; Lee, 1990; White, 1975).

WILSON'S DESCRIPTION OF THE ARTS

Wilson thinks that the creative arts and science are very different from one another (Lester, 1998). Scientific knowledge is useful to us because it provides us with objective, verifiable knowledge about the real world around us. The creative arts, broadly defined, are also beneficial, but in a different way. They are in tune with our underlying "human nature," which Wilson says is an inborn ensemble of instinctive or "epigenetic rules" that govern our behavior (Lester, 1998).

Epigenetic rules are hereditary predispositions in our mental development that are anchored in neural pathways in our brain and are prescribed by our genes. Natural selection favors epigenetic rules for behaviors that foster our survival; for example, parental investment in children, territoriality, taboos against incest, and keeping contractual agreements. Taken together, these norms of behavior or action become the elements of human cultures.

Artistic expression, then, arises from and resonates with our human nature. Wilson argues that creativity, ethics, culture, in fact all products of the mind, are materially grounded in physiochemical activities of the brain in interaction with the human body. Emotions link artistic expression and human nature. If we see a movie that encourages or condones incest, it arouses a feeling of disgust because the images on the screen trigger a negative emotional response linked to one of the underlying epigenetic rules (the incest taboo) that define human nature. A knowledge of words, images, archetypes, and abstractions that resonate with our epigenetic rules helps us make decisions that support our survival as social beings.

MANAGEMENT AS ART

When viewed as an art, effective management is a remarkable, but natural, expression of human behavior. It is intuitive, creative, and flexible. Lee G. Bolman and Terrence E. Deal, authors of *Reframing Organizations: Artistry, Choice, and Leadership*, see managers as leaders and artists who are able to develop unique alternatives and novel ideas about their organizations' needs. They are attuned to people and events around them and learn to anticipate the turbulent twists and turns of organizational life:

> Artistry in management is neither exact nor precise. Artists interpret experience and express it in forms that can be felt, understood, and appreciated by others. Art allows for emotion, subtlety, ambiguity. An artist reframes the world so that others can see new possibilities. (Bolman and Deal, 1997, p. 17)

Modern organizations rely too little on art in their search for attributes like quality, commitment, and creativity. "The leader as artist relies on images as well as memos, poetry as well as policy, and reflection as well as command" (Bolman and Deal, 1997, p. 17). Artistic leaders and managers help us see beyond and improve collective performance.

Like management science, management as art is also well established in the general literature on management (Badaracco, 1998; Blaise, 1998; Goldberg and Sifonis, 1994; Morgan, 1993; Rabinovitch, 1997; Selznick, 1996; Smither, 1998; Tead, 1951) and leadership (Degree, 1989; Magill and Slocum, 1998; Wheatley, 1992). It is also prominent in business administration (Eden, 1997; Mann, 1971; Pascal and Amos, 1991; Thomas, 1994) and public administration (Baseman, 1993; Vickers, 1965).

A search for consilience à la Wilson

Wilson assumes that all phenomena are based on material processes that are causal and, "however long and tortuous the sequences," ultimately reducible to the laws of physics (1998a, p. 266). A consilience of knowledge about the management of organizations would demand a vision capable of sweeping from whole societies to an individual human brain. It would involve both reduction and synthesis. To dissect something into its elements is consilience by reduction, and to reconstitute it is consilience by synthesis (1998a, p. 68).

Wilson offers an example of consilience in practice from his early research on ants (1998a, pp. 70–71). To explain communication within an ant colony (e.g., an internal alarm alerting an entire colony to an attack by a predator), Wilson and his associates studied an ant colony across four levels of organization, from superorganism (the whole colony), then reductively to organism (individual ants), to glands and sense organs, and finally to molecules (pheromones). He also worked in the opposite direction (synthesis) when he predicted the meanings of signals observed in the colony (e.g., "alarm, danger" versus "food, follow me") by linking various signals to matching changes in the molecular composition and concentration of individual ant pheromones. The result was a comprehensive or "holistic" study of ant communication.

Follow the lead of Wilson, and the strategy in the search for consilience in management theory and practice would require the pursuit of coherent cause-and-effect explanations for all relevant phenomena across multiple levels of organization from society to neuron. The cutting edge of investigation would be reductionism. And dealing with increasing complexity from the brain, to an organization, to society as a whole would be the major challenge in the search for consilience in approaches to the management of organizations.

A MORE INCLUSIVE SEARCH FOR CONSILIENCE

Wilson readily acknowledges the limited reach of conventional scientific thinking when he notes that "at each level of organization, especially at the living cell and above, phenomena exist that require new laws and principles, which still cannot be predicted from those at more general levels" (1998a, p. 55). Part of this limitation may be rooted in a reluctance to make a distinction between complex systems—between non-living systems, living systems, and living systems with people in them. They differ from one another. Probing the differences would open the door to new kinds of data and new ways to think about complex systems, especially complex human systems.

Although Wilson's search for consilience is courageous and sweeping, he is too confined to traditional theoretical perspectives from the physical sciences. Several years ago, Paul Diesing said that if we knew the whole truth our "predictions would always be correct; but since all existing theories (and approaches) are incomplete and partly false, it is better to bring together a variety of partial theories to better approximate the whole truth" (1962, p.179). Wilson unnecessarily limits his consideration of all of the ways we come to understand things.

Playwright Tom Stoppard contends that "science and art are nowadays beyond being like each other. Sometimes they seem to be each other" (Miller, 1997, p. 41). For Wilson, the arts were a necessary "prescientific" step in our evolutionary quest for knowledge (1998a, pp. 210–37). But he argues that, unlike science, the arts do not contribute anything truly concrete and verifiable to our knowledge of reality. In fact, he thinks that a future consilience of scientific knowledge may include an explanation of art. Wilson unnecessarily minimizes the ability of human imagination, like that commonly exhibited in the arts and in the sciences—in symbols, images, and metaphor—to contribute anything tangible to a consilience or "jumping together" of all the ways in which we come to understand and explain the world.

SCIENCE AND ART ARE NOWADAYS BEYOND BEING LIKE EACH OTHER. SOMETIMES THEY SEEM TO BE EACH OTHER

MANAGING HUMAN SYSTEMS

When management is considered a science, the knowledge that a manager uses to keep an organization moving effectively in a given direction largely has its origin in rigorous scientific research acquired in strict adherence to the scientific method. When management is viewed as art, knowledge about how to keep an organization moving successfully in the right direction is in tune with primal human nature and springs from a manager's intuition, imagination, and creativity. It is apparent that inclusion of the well-established and enduring body of literature and research that addresses management as an art in a consilience with our accumulated knowledge about the scientific management of organizations will require a significant change of Wilson's rules for consilience.

While it is true that the great successes of the natural sciences have been achieved by reducing and explaining physical phenomena in terms of their constituent elements, organizations involve human perceptions, interactions, emotions and feelings—all things that cannot be dissected and reassembled to explain how an organization works. And while mathematics is the "natural language" of physics, it is not the natural language of organizations. If a consilience of the art and science of management is to happen, it will require a greater general willingness to think about organizations as complex, nonlinear human systems, and it will require an open-minded exploration of the as yet unproven explanatory power of metaphor as a theoretical concept.

New scientific theories evolving out of a variety of disciplines, including physics, biology, and computer science (see Dennard, 1996; Evans, 1996; Heylighen, 1998; Kirshbaum, 1998; Neumann, 1996), are generating new ways to think about organizations as living nonlinear human systems. Human systems possess the dynamism and other characteristics of non-living nonlinear systems (e.g., the weather) and the familiar features of other living systems, including the ability to grow, recreate themselves, and die. And, because human systems include people, the metaphor generated and used exclusively by people is a unique feature of all living human systems.

An organization, like all human systems, is made up of an extremely varied collection of "parts" that, taken together, form the organization's tangible or material basis of existence. The parts of a typical organization include managers, employees, offices, equipment, written policies and procedures, e-mail, logos, memos, and an almost infinite variety of other things. An organization exists as highly interactive and meaningful relations between all of the parts that constitute it in interaction with elements of its environment. An organization cannot be successfully reduced or dissected with the instruments of physics or chemistry, which are the sciences of matter. A living human organization is not entirely quantifiable or explainable by the methods of the conventional physical sciences.

A LIVING HUMAN ORGANIZATION IS NOT ENTIRELY QUANTIFIABLE OR EXPLAINABLE BY THE METHODS OF THE CONVENTIONAL PHYSICAL SCIENCES

The concept of emergent properties or behaviors is critical to understanding an organization as a complex, living nonlinear system. The emergent behavior of living systems may be expressed by the behavior of the elements of a system in interaction with one another and the environment, but the emergent behavior of a system is not a property of any individual element and it cannot be explained as a summation of the properties of those elements. Examples include behavior in such diverse nonlinear living systems as Wilson's ant colonies, the Department of Defense, traffic jams, and the Dow Jones composite stock market index.

Like all living organisms, organizations contain within themselves a way to control relationships between their parts and relationships between their parts and the environment. In a biological system, DNA is the instrument or plan that distributes the control of interactive relationships between the parts of the system to the parts themselves (Langton, l989). The resulting relationships between parts of the living system (muscle groups, nervous system, organs, etc.) then express life, the emergent behavior unique to all living organisms. The property of "aliveness" can be traced to an organism's DNA.

The corresponding mechanism or internal frame of reference that distributes control of interactive relationships to the elements or parts of an organization is a common body of metaphor (CBM). Through metaphor, our understanding of things is acquired, defined, and organized in terms of our existing knowledge of things already retained in our minds as remembered images, ideas, symbols, and stereotypes (Morgan, 1986; Morgan, 1993; Roher, 1997). We come to know things in terms of what is already known to us. Our understanding of ourselves and the world around us, in turn, guides our behavior. Acquired through shared experiences, an organization's unique CBM influences the way organization members characteristically interact with each other and with other people, and how they interact with elements of the physical environment.

In more conventional terms, an organization's CBM is comparable to its culture. "A culture may be conceived as a network of beliefs and purposes in which any string in the net pulls and is pulled by others, thus perpetually changing the configuration of the whole" (Barzun, 1989, p. 89). Like organizational cultures, a CBM defines and, at the same time, is defined in interactive relationships between the parts of an organization. Over time, the resultant interactive relationships between parts of an organization, in interaction with a CBM and with the features of the organization's environment, express the identity of an organization as a living human system.

Organizations are physical systems like the weather, Wilson's ant colonies, and other complex systems, but the vital presence of a common body of metaphor or CBM distinguishes human organizations from other complex systems. Wilson may be correct when he assumes that all tangible phenomena are based on material processes that are causal and, however long and tortuous the sequences, such phenomena are ultimately reducible to the laws of physics; but like it or not, an organization is more than physical phenomena and causal relationships. Certainly, in its early stages at least, a consilience of knowledge about the management of organizations will have to consider the inclusion of knowledge beyond that obtained exclusively from research grounded in the traditional sciences.

COMPLEXITY THEORY AND METAPHOR

At first glance, complexity theory and the concept of metaphor seem particularly well suited to the task of developing new ways to think about organizations as complex human systems. However, Wilson thinks that the value of both the theory and the concept is, at best, very uncertain. If he is correct, they will contribute little if anything to a consilience of our knowledge about the management of organizations.

Wilson knows that all living systems are complex and he acknowledges the work of a group of computer-oriented "complexity theorists" who are searching for precise mathematical models or algorithms to explain the emergence of such phenomena as cells, ecosystems, and minds (see Kauffman, 1993; Langton, 1989; Morowitz, 1995). He writes that he is impressed by their sophistication and spirit, and his heart is with them, but his mind is not, "at least not yet" (1998a, p. 88).

Wilson thinks that, so far at least, complexity theorists lack data, their propositions need more detail, and their conclusions tell us little that is really new. His real concern, however, is that none of the elements of complexity theory has anything like the generality and adherence to factual detail that he would like to see in a true scientific theory. Living systems are complex, but after giving all due respect to complexity theory, Wilson still thinks that "the laws of physics and chemistry … are enough to do the job, given sufficient time and research funding" (1998a, p. 91).

If Wilson is skeptical about complexity theory, he sees even less scientific value in the concept of metaphor. This is curious, because he recognizes the importance of metaphor, especially in the creative arts (1998a, pp. 218–22). And when he writes about culture, he could easily be writing about a CBM or common body of metaphor. "Culture, rising from the productions of many minds that interlace and reinforce one another over many generations, expands like a growing organism into a universe of seemingly infinite possibility" (l998a, pp. 223). It "is historical; includes ideas, patterns, and values … is based upon symbols; and … each society creates culture and is created by it" (1998a, pp. 130–31).

The inborn ability to generate metaphors with ease and move them fluidly from one context to another is a special human adaptive power granted to the arts by the genetic evolution of the brain (1998a, p. 219). But Wilson argues that art is the antithesis of science because it has no scientific meaning or value (1998a, p. 218). Metaphor does not lend itself to reduction and cause-and-effect scientific analysis. Therefore, by its very nature, metaphor cannot precisely explain why anything occurs and cannot contribute anything meaningful to a consilience of factual knowledge about the management of organizations.

CONCLUSION

Is a consilience of the art and science of managing organizations possible? Maybe. Wilson believes that the search for a consilience of all scientific knowledge will provide coherent explanations for all relevant phenomena across multiple levels of complexity, from neuron and brain, to organization, and to society as a whole. He begins with the assumption that all tangible phenomena are based on material processes that are ultimately reducible to the laws of physics. All explanations are causal and all causes are material. Unfortunately, his beginning assumptions are far too restrictive to guide the formative stages of a consilience of our knowledge about organizations and other complex human systems.

Art and science both foster new and creative ways to understand organizations and communicate what we know about them. They both generate and employ metaphors of management that help us form our perceptions, assumptions, and new ideas about organizations. Both inspire our imagination. Research in the art and science of management will continue systematically to gather knowledge about the behavior of people in organizations and try to present that knowledge in new and testable theories, concepts, and hypotheses. But future research also must be pursued with enough flexibility to permit the emergence and investigation of entirely new knowledge about organizations and the way we manage them.

NOTES

1. The selection of literature on an art versus science of management is intended to be representative of an ongoing debate in the literature, and does not include a commensurate recognition of management as a craft and other portrayals of the management of organizations.
2. In addition to the *Administrative Science Quarterly* (established in 1956), other journals to advance the science of management in business and public

administration (with date of introduction) include the *Journal of Applied Behavioral Science* (1965), *Journal of the Academy of Marketing Science* (1973), *Management Science* (1954), *Marketing Science* (1982), and *Organization Science* (1990).

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Complexity: the Science, its Vocabulary, and its Relation to Organizations

Michael R. Lissack

Every day voices in the mass media tell us that we live in a world in which complexity is rising and institutional orders are dissipating. In such a world, organizational science studies ways of fending off the forces of chaos that are, so to speak, always just around the corner. Management is portrayed as the process not only of fending off, but also of sometimes seizing hold, of those very forces. The traditional management literature—the stuff from which most of our MBA-led generation is taught—tends to speak of an objective world where interactions can be described in linear terms, where words have singular meanings, and where prediction and control are paramount. The focus on control provides one perspective on "chaos" and the manifold changes occurring all around us. A contrasting perspective evolves from complexity science. Complexity theory challenges the traditional management assumptions by noting that human activity allows for the possibility of emergent

IN THE STUDY OF EMERGENCE, COMPLEXITY SCIENCE AND ORGANIZATION CONVERGE behavior. In the study of emergence, complexity science and organization converge.

Organizations can be viewed as systems of interpretation and constructions of reality (Berger and Luckmann, 1967). In order to survive, organizations must find ways to interpret events so as to stabilize their environments and try to make them more predictable; organizations must also find ways to interpret events so as to be one with the environment, an environment that they choose. A central concern of organization science is that of understanding how people construct meaning and reality, and exploring how that enacted reality provides a context for action. When managers "enact" the environment, as Weick (1995) put it they: "construct, rearrange, single out, and demolish many 'objective' features of their surroundings … they unrandomize variables, insert vestiges of orderliness, and literally create their own constraints." Through this process of sensemaking and reality construction, people in an organization give meaning to the events and actions of the organization. This occurs at two principal levels—the individual and the organization.

Organizations often experience change as an "emergent" process. Casti (1997) defines "emergence" as an overall system behavior that comes out of the interaction of many participants—behavior that cannot be predicted or "even envisioned" from a knowledge of what each component of a system does in isolation. This is the experience of change, yet this approach is scarcely found in the organization science literature. When emergent change is recognized within the literature, it is discussed superficially and metaphorically, with the organizational whole as the unit of analysis (Alvesson, 1990, 1995; Comfort, 1994). The emergent nature of change as experienced by other members of the organization is often overlooked. Change, instead, is treated as continuous, step like, or even chaotic, but with a definable scope and focus (Stacey, 1996). The experienced sense of change—that the whole is bigger than the sum of the parts, and that the patterns observed and felt are unexpected—is not captured. It is this sense of the whole that points organization science to complex systems theory.

As Levy (1994) phrased it:

> By understanding industries as complex systems, managers can improve decision making and search for innovative solutions. … Chaos [complexity] theory is a promising framework that accounts for the dynamic evolution of industries and the complex interactions among industry actors. By conceptualizing industries as chaotic systems, a number of managerial implications can be developed. Long-term forecasting is almost impossible for chaotic systems, and dramatic change can occur unexpectedly; as a result, flexibility and adaptiveness are essential for organizations to survive. Nevertheless, chaotic systems exhibit a degree of order, enabling short-term forecasting to be undertaken and underlying patterns can be discerned. Chaos [complexity] theory also points to the importance of developing guidelines and decision rules to cope with complexity, and of searching for non-obvious and indirect means to achieving goals.

What is this complex systems theory? As of 1999, it is less an organized rigorous theory than 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 the use of large quantities of computer power (Horgan, 1995; Casti, 1995, 1997) and through analytic, logical, and conceptual developments (Bar-Yam, 1997). It is also the discipline that has self-organized to examine the question of how coherent and purposive wholes emerge from the interactions of simple and sometimes non-purposive components. The theory includes such ideas as phase changes, fitness landscapes, self-organization, emergence, attractors, symmetry and symmetry breaking, chaos, quanta, the edge of chaos, self-organized criticality, generative relationships, and increasing returns to scale.

Some have chosen to distinguish the science components (both qualitative and quantitative) as the study of complex systems, while allocating the word "complexity" to be inclusive not of the science but also of the more popular fad-like uses of complex systems terms. Whichever label one uses, the ideas of complexity are important. Witness this quote from Overman (1996) in his "The New Science of Management":

> Are traditional social science methods incapable of dealing with the complex and indeterminate problems facing management today? It is not so much the wedding of scientific logic and method to management theory and practice that is problematic, as it is the outdated models of scientific inquiry that slow our progress. The new sciences of chaos and quantum theory [complexity] offer valuable metaphors and methods that can challenge the management research agenda into the next century [with] … the image of self-organization, dissipative structures, and dynamic complexity.

A short list of books would be sufficient for those unfamiliar with the field to get a decent handle on complexity.[1] One might begin with *Complexity: the Emerging Science at the Edge of Order and Chaos* (Waldrop, 1992), which is an overview of the origins of complexity theory through the eyes of its explorers and the book with which to begin exploring this field. Although as early as 1986 there was an academic book published with the title *Complexity, Managers, and Organizations* (Streufert and Swezey, 1986), *Chaos: Making a New Science* (Gleick, 1987) is considered to be the classic work in the field and introduced laypeople to the complexities of complexity. *At Home in the Universe: the Search for the Laws of Self-Organization and Complexity* (Kauffman, 1995) explores what complexity theory might mean for the future of economics and organizations. *Leadership and the New Science: Learning about Organization from an Orderly Universe* (Wheatley, 1992) provides a broad survey of quantum mechanics as well as complexity theory and then extends its speculations to their relevance to leadership and organization. *Figments of Reality: the Evolution of the Curious*

Mind (Stewart and Cohen, 1997) and *The Collapse of Chaos: Discovering Simplicity in a Complex World* (Cohen and Stewart, 1994) bring some history of simplicity to the exploration of chaos and complexity. *Complexity and Creativity in Organizations* (Stacey, 1996) illustrates applications of new science to organizational dynamics and change.

THE COMPLEXITY METAPHOR: SOME EXAMPLES

Complexity theory, as used above, has its own vocabulary and its own metaphors. One such metaphor is the notion of an edge of chaos, the most fervent proponent of which is Kauffman. Through his research, Kauffman:

> began to see that living systems operated at their most robust and efficient level in the narrow space between stability and disorder—poised at "the edge of chaos." It was here, it appeared, that the agents within a system conducted the fullest range of productive interactions and exchanged the greatest amount of useful information. People recognize this in everyday life: A slightly messy office is a productive one; rollicking families are happy; economies flourish under scant regulation. The edge of chaos, but not quite chaos itself. (Petzinger, 1996b)

In a complex world, strategy is a set of processes for monitoring the behaviors of both the world and of the agents of the organization, observing where potential attractors are and attempting to supply resources and incentives for future moves. It may be that command and control are impossible (at least in the absolute and in the aggregate), but the manager retains the ability to influence the shape of what complexity theory (and biology) refers to as "the fitness landscape"(Lane and Maxfield, 1995).

Identification of value-added knowledge as a task can be represented by the metaphor of search for optimal fitness on a landscape. The landscape is rugged, in that there are hills and valleys, and it is turbulent, in that it coevolves with both the outside environment and with the very participants (employees, customers, suppliers, regulators, competitors, etc.) who make up the essence of that landscape.

Kauffman carried out a number of studies of search on rugged landscapes, which demonstrate that, when fitness is average, search is best carried out far away across the space of possibilities. But, as fitness increases, the fittest variants are found ever closer to the current location in the space of possibilities (Kauffman, 1993).

On complex surfaces (i.e., rugged fitness landscapes with many hills and valleys), systems can become trapped on poor local optima (the wrong hill). Kauffman's research has developed a variety of approaches to "simulated annealing" to assist in getting organizations away from these local optima and moving toward a more "global optimum." Simulated annealing is an optimization procedure based on using an analogue of temperature, which is gradually lowered so that the system nearly equilibrates at each temperature and is gradually trapped into deep energy wells. The general concept lying behind simulated annealing is that at a finite temperature the system sometimes "ignores" some of the constraints and takes a step "the wrong" way, hence increasing energy temporarily. Ignoring constraints in a judicious way can help avoid being trapped on poor local optima (Kauffman, 1993, pp. 111–12).

Within this language clearly is a "how." Kauffman says break up the organization into patches, yet emphasizes that these patches must interact. This advice is different from the old management standby of the independent, self-sufficient business unit. It is in the nature and quantity of the interactions that Kauffman finds that the organization as a whole can be moved toward a global optimum, even though each patch is acting selfishly. Interactions require language or some other mechanism of fairly continual communication. He stresses that the patches must be coupled. In management jargon, the pieces must communicate, and not just at quarterly review sessions:

> The basic idea of patch procedure is simple: take a hard, conflict-laden task in which many parts interact, and divide it into a quilt of non-overlapping patches. Try to optimize within each patch. As this occurs, the couplings between parts in two patches across patch boundaries will mean that finding a "'good" solution in one patch will change the problem to be solved by the parts in adjacent patches. Since changes in each patch will alter the problems confronted by neighboring patches, and the adaptive moves by those patches in turn will alter the problem faced by yet other patches, the system is just like our model co-evolving ecosystems. (Kauffman, 1995, pp. 252–3)

Kauffman's other two procedural suggestions are to ignore some of the inputs coming into the organization (the theory seems to be that accommodating all inputs leads to freezing and that the necessary degrees of freedom for better finding optima can only be accomplished by deliberately ignoring some of the inputs), and to recognize that too much data ceases to be information (that which informs the agent or actor) but instead acts like a brake on the system.

The annealing process can also be looked at as one of deliberately introducing noise into a system to see what happens. Guastello refers to this as "the chaotic controller":

> Chaotic control works counter-intuitively by first adding a small amount of low-dimensional noise into the system. The reasoning is that the amount of sensitivity to initial conditions is not uniform throughout the attractor's space; sensitivity is less in the basin of the attractor and least in its center … Adding noise to the system allows the attractor to expand to its fullest range. (Guastello, 1995, Ch. 4)

This is a very different concept of noise than the statistical view (which suggests that noise should be discarded). Where traditional managers may have wished to delete the extraneous, the complexity research-educated manager may be attempting to cause the deliberate addition of noise at various places along the way. Of course, noise can still be noise, and search strategies must be able to separate wheat from chaff if the enterprise is to be at all successful.

Managers who can make use of the metaphors of complexity see their companies in a different light than those who do not and, in a sense, are competing in a different world (Lakoff and Johnson, 1995). Corporate managers may, for example, view their companies as being in a race—be it for success, market share, revenues, or survival. That metaphor influences the way they see the world and the way they manage their companies.

MANAGERS WHO CAN MAKE USE OF THE METAPHORS OF COMPLEXITY SEE THEIR COMPANIES IN A DIFFERENT LIGHT THAN THOSE WHO DO NOT

In the race metaphor, the landscape is fixed even if the course is not. One has an identified goal and a set of competitors. In the fitness landscape metaphor, the landscape itself is always changing. One's goals, course, and competitors are but factors, which can and do affect the shape of the landscape itself. The objective is to climb to a nonlocal peak and your peaks may be very different from your competitors'.

In the race metaphor, information and data can be confused. Too much data leads to a loss of vision, a potential diversion from the goal, and the risk of overload. In the complexity metaphor, data is merely unused potential information. Information changes the landscape and data becomes information when it is ascribed value (whether correctly or not). Noise is a risk and a diversion in the race metaphor and a source of new understanding and potential information in the complexity metaphor.

Table 1 illustrates some of the complexity theory metaphors. What these metaphors can do is provide access to new ideas and analogies for use in confronting the unexpected and the unfamiliar:

Table 1 Complexity theory metaphors

Metaphorical concept	**Inference**	**Practical application**
Fitness landscape	Local vs global optima	Search (for improvement) strategies
Fitness landscape	Coevolving deformations	Be aware of feedback loops and interactions with all levels of stakeholders
Attractor	Behavior that passively follows a pattern	Choice is more important than trying to influence predestined behavior
Simulated annealing	Use "chaos" to control "chaos"	A bit of bedlam can be a good thing for crowds, data flow, and information retrieval
Simulated annealing	"Noise" can add creativity	Seek out controlled elements of noise, new voices, and outside perspectives
Patches	Selfish bits can be better than a holistic whole	Subdivide the organizing into interactive pieces with constant communication
Tau	Too much data causes a clogging of the pipes	Limit the quantity of simultaneous change that the organization attempts to recognize
Generative relationships	Seek tomorrow's returns in each encounter today	Approach each encounter by asking how this will help me grow
Increasing returns	Knowledge-based components of economy differ from traditional	Promote network and community affects where possible
Sensitive dependence on initial conditions	Prediction is impossible	Control *per se* won't work

> When any aspect of our experience strikes us as worth understanding, either for the first time or in a new way, we begin to search for [analogous instances] … I would say that just as we turn to a dictionary for the definition of unknown words in terms of unfamiliar words, so we look to phenomena of other sorts, whether natural or artificial, for analogs of things, qualities and events—including aspects of our own experience and activity—that we wish to comprehend. (Leary, 1990)

COMPLEXITY SCIENCE AND ORGANIZATION SCIENCE: A LONG RELATIONSHIP?

While complexity science may only, thus far, have contributed metaphors and models to the organization science literature, it would be foolhardy to write off such contributions as insignificant or minor. These metaphors and models are world constituting for those who use them (Astley, 1995; Cilliers, 1998). Both complexity science and organization science have a common problem they wish to address: uncertainty. And in their joint concern for uncertainty lies the basis for what is likely to be a very long relationship.

A lesson from complexity science is that it is always valuable to examine what occurs when foreground and background are shifted (Bechtel and Richardson, 1993; Mitchell, 1994; Bar-Yam, 1997). The added insight can suggest new relationships and new categories of thought. Management theory rarely takes up this challenge, yet much can be gained. For what a different picture emerges when one reverses the prominence of the boxes and the arrows in the typical management and leadership models taught to most MBAs and popularized in business texts. These models are likely to use boxes and similar shapes to indicate reified entities—things that have an ontological status.

IT IS ALWAYS VALUABLE TO EXAMINE WHAT OCCURS WHEN FOREGROUND AND BACKGROUND ARE SHIFTED

They use arrows to indicate relationships, flows, and exchanges—items to which is granted no ontological basis other than fleetingness. By contrast, consider models that reverse the ontology. The relations, flows and exchanges are deemed to be "real" and "extant," while the items formerly designated by shapes—the organization, its hierarchical structure, work climate, systems, mission, and strate—are afforded only the fleeting recognition of a snapshot in time. The analogy here is to a balance sheet or to those bad Polaroid pictures one takes on vacation. Each is but an inadequate reflection of a flowing reality temporarily stopped for the purpose of having a record created.

Consider the notion of "uncertainty." Thirty years ago, Thompson (1967) was able to write: "Uncertainty appears as the fundamental problem for complex organizations, and coping with uncertainty, as the essence of the administrative process." The intervening decades have marked little progress. Connell and Nord (1996) write of the "Infiltration of Organization Science by Uncertainty and Values," making note of the increased emphasis on language and meaning. Gergen and Thatchenkery (1996) note that methods may be sought to generate "new realities." Jacobson and Jacques (1997) can write of "Destabilizing the Field" by introducing a poststructuralist approach to the questions of meaning within organizations.

If the study of organizations is itself plagued by uncertainty and doubt, that is a reflection of the uncertainties felt by organizations themselves and their members. Perhaps what is occurring is that, as time marches inexorably forward, we are encountering more of what Rittel described as "wicked problems"—"a class of social system problems which are ill formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing" (Churchman, 1967). Or perhaps we just feel like we are.

For 50 years organization science has focused on "controlling uncertainty." For the past 10 years complexity science has focused

Issue 1-1 4/3/99 5:54 pm Page 121

on how to understand it so as to better "go with the flow" and perhaps to channel that flow. In the possibilities created when we question whether the control or the uncertainty occupies the foreground lies the potential convergence of complexity science and organization science. John Seely Brown of Xerox PARC refers to such convergence items as "boundary objects."

At the overlapping boundaries of complexity science and organization science is where the importance of vocabulary, language, metaphors, and models comes in to play. The possibility space of the organization is constrained by the language of interpretation available to it and its members—for it is in that language that their reality will be constructed. Managers choose the environments they attend to, and their internal views shape these choices. The choice of frames (which endow meaning) and metaphors (which can provoke new images) within an organization can be determinative of what an organization can both extract and absorb from the environment around it. Kauffman (1996) refers to nearby possibilities as "the adjacent possible." The sequence of activities within and by an organization represents both movement within the possibility space and an enactment of how it defines the adjacent possible. In the interplay between language and activity, one finds both meaning and tension. Organizations must not only act, but their understanding of those actions—their sensemaking—must be coherent if identity is to be preserved (Lissack and Roos, 1999).

Weick, in his (1995) work on sensemaking, notes that "as ways of talking and believing proliferate, new features of organizations are noticed." New features of the organizations' environments are surely noticed as well. The use of metaphor, in as simple a form as in naming a situated activity, is a generative process. Any given label is also an invitation to see an object as if it were something else; through the resonance of possible connotations, new contextual meaning can be created. Word choice is thus a fundamental tool for the manager, whose role is to shape and create contexts in which appropriate forms of self-organization can occur.

The adoption of complexity science terms into the day-to-day lingo of corporate managers is much more than a Wittgensteinian "language game" (cf. Astley and Zammuto, 1992). Word choice in usage delimits possibility space and helps to determine the adjacent possible. Thus, it is an active process with real consequences and not just a symbolic toy. Management must deal with the consequences of the language adopted, and it is the managers' choice whether or not to do so in a purposeful manner. What complexity science metaphors do for an organization is give its members access to both new words and new possibilities for action. With the access to new actions comes the potential for new identity. The most prominent example of this is Monsanto, which not only adopted complexity science lingo, but also reorganized the entire company around it.

> Experience teaches us that thought does not express itself in words, but rather realizes itself in them. A word in context means both more and less than, the same word in isolation: more, because it acquires new context; less, because its meaning is limited and narrowed by the context. The sense of a word … changes in different minds and situations and is almost unlimited. It is not merely the content of a word that changes, but the way reality is generated and reflected in a word. (Vygotsky, 1986)

Monsanto's chairman, Robert Shapiro, grabbed hold of complexity science concepts and, in the immortal words of Microsoft, chose to embrace and extend. The result was a spinoff of Monsanto's chemical businesses and a headfirst rush into becoming the largest biotech company in the world.

Complexity science words and models give new tools to business leaders. By actively seeking to guide language choice, managers can influence the perceptions and actions of the remaining members of the organization. Leaders' effectiveness lies in their ability to make activity meaningful for those they lead. They do this not by changing behavior, but by giving others a sense of understanding about what they are doing. In this sense lie the potential strengths of complexity as a management tool—and the conceptual underpinnings of the journal the first issue of which you have just finished reading.

NOTE

1 The next issue of *Emergence* will contain a review of more than two dozen books on complexity and management.

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The Next Issue

A review of complexity and management books in 1998

This special issue aims to be a complete review of the books on complexity and management that can be found on bookstore shelves as of December 1998.

Editors:

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Summer 1999

Issue 1-1 4/3/99 5:54 pm Page 129

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We ask that authors set their paper clearly within the context of the notion of complexity and complex systems, however they chose to define such, and that the practical implications and transferable lessons from their work be clearly described.

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