A "Simple Rule" Approach to CEO Leadership in the 21st Century

[Presented at the Conference on *New Approaches to Strategic Management*, Ostuni, Italy, September 11–13, 2003.]

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August 11, 2003

> The only thing that gives an organization a competitive edge—the only thing that is sustainable—is what it knows, how it uses what it knows, and how fast it can know something new! (Prusak 1996: 6)

Recent writing about competitive strategy and sustained above average performance parallels Prusak's emphasis on how fast a firm can develop new knowledge—the result of higher corporate IQ (McKelvey 2000). High performance is seen to stem from keeping pace with high-velocity environments (Eisenhardt 1989), winning in hypercompetitive environments (D'Aveni 1994), staying ahead of the efficiency curve (Porter 1996), seeing industry trends (Hamel & Prahalad 1994), and staying ahead of value migration (Slywotzky 1996). Dynamic ill-structured environments and learning opportunities become the basis of competitive advantage if firms can be *early* in their industry to unravel the evolving conditions (Stacey 1995). Becker (1975) defines knowledge/skills held by employees and their intellectual capabilities as *human capital*, and having given knowledge and capability economic value, adds it to the Cobb Douglas production function. Burt (1992) claims that superior performance is due to *social capital*.

In contrast to the speed problem, Bennis and O'Toole (2000) say the US faces a failure in leadership because Corporate Boards increasingly fire their CEOs because the latter lack vision. *The Economist* (2001) corroborates the increased firing rate, showing a ~400% increase in CEO firings—from ~30/month in August 1999 to 119/month in February 2001—totaling ~1595 fired CEOs over 19 months. Jeffrey Garten, Dean of the Yale business school, echoes the "lack of vision theory" in a recent Newsweek "comment" (2003). The cost to the US economy, of ineffective CEO leadership is many jobs, human misery, and billions of dollars.

Instead of vision, however, *The Economist* states that the cause of increased firing is because the CEOs job is much more difficult due to flattened corporate hierarchies, increased globalization effects, technology explosion, the Internet and digitized information, mega mergers, and merger assimilation problems. Writing much earlier, Goldstein (1994) predicted that increasing environmental chaos and nonlinearity would be the fundamental cause of seeming CEO incompetence. Snowden (2002) argues that nonlinear, high velocity, multidimensional competitive environment facing CEOs in the knowledge economy calls for effective management of complex adaptive systems—phenomena now best understood within the framework of complexity science (Prigogine & Stengers 1984, Waldrop 1992, Wheatley 1992, Cramer 1993, Kaye 1993, Casti 1994, Merry 1995, Bar-Yam 1997, Mainzer 1997, Marion 1999, Wood 2000).

Wheatley's classic book (1992), which introduced many people to nonlinear, chaotic, complexity dynamics, is titled, *Leadership and the New Science*. Read closely, however, she actually says virtually nothing about what leaders should actually <u>do</u> to "lead" in the new age. Miles et al. (1999) argue that the preferred organizational form to carry out strategies in the 21st century is the "*cellular network*"—an autonomous, bottom-up, emergent structure of employees and subunits. Miles et al. say that their "cells" are entrepreneurial ventures. This is all well and good, but their solution is essentially unstable. We have seen a countless times that entrepreneurial firms, newly acquired, are either over-controlled to the point where they become ordinary control-dominated subunits (Thompson 1967, Miles et al. 1999) or they remain autonomous but become unresponsive to shareholder value (Thomas, Kaminska-Labbe & McKelvey 2003).

Besides the nonlinearity and "edge of chaos" message emanating from the complexity gurus at the Santa Fe Institute, their second fundamental insight is that so-called agent-based computational models are much better suited for studying the nuances of complex systems than are math models. Agent-based models call for the definition of "simple rules" that govern agents' behaviors.[2] Taking a cue from agent-model thinking, I propose a set of simple rules to guide CEOs in creating and maintaining cellular networks.

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[1] I wish to thank coauthors Max Boisot, Renata Kaminska-Labbe, Russ Marion, Catherine Thomas, and Mary Uhl-Bien for the many insights they have embedded in the papers from which I draw ideas to build on here.

[2] "Agent" is a general term that applies wide range of entities that exhibit behavior of some kind—atoms, molecules, biomolecules, organelles, organisms, species, language elements, organizational processes, people, groups, firms, and so on.

1 THEORETICAL BACKGROUND

1.1 METHODS OF BOTTOM-UP VARIETY DESTRUCTION

Ashby (1956) argued, "*It takes variety to destroy variety*." Organizations face environments characterized by some level of uncertainty—uncertainty is a function both of degrees of freedom (the basis of complexity) and the uncertainty and possible nonlinearity of each variable comprising each degree of freedom. Ashby's insight was that a system has to have an internal variety, also defined as degrees of freedom, that matches its external variety. Allen (2001) suggests that an organization actually has to have "excess" internal variety since there is always the probability that some number of internal degrees of freedom—which have to be assembled in advance—are irrelevant when variety destruction actually arrives.

Thompson (1967), reflecting the era of contingency theory, took the view that variety was reduced from the top. Thus, at each level starting with the CEO, some variety is taken out of the system so that at the bottom, workers do their jobs in a machine-like setting of total certainty. This is a top-down approach to uncertainty reduction. Nearly a quarter century later, Mélèse (1991) takes the opposite view, arguing that variety reduction happens best from the bottom up. Simon (1999) observes that it is not just variety that is out there to be destroyed but also high frequency effects. Lower level units, therefore, must absorb variety, leaving upper managers with less frequent, less noisy, less complex, but weightier decisions. The question is, *How to get lower-level subunits to destroy variety effectively*?

1.1.1 CELLULAR NETWORKS

Miles et al. (1999) set up the basic "technology" for variety destruction quite well. They refer to the 21st century as the era of innovation. They see self-organizing employee *learning networks* as essential to effective performance in the knowledge economy. It takes continuously evolving networks to keep up with rapidly evolving elements of the knowledge economy, particularly technology, market tastes, and industry competitors. Miles et al. see *entrepreneurship*, *self-organization*, and *member ownership* as the essential ingredients of effective cellular networks. Cells consist of self-managing teams of employees—the heterogeneous agents for whom complexity scientists design simple rules. The cells have "…an entrepreneurial responsibility to the larger organization" (p. 163). They say that if the cells are strategic business units they may be set up as profit centers. Miles et al. emphasize the instability of the cells, noting that each cell must reorganize constantly. It needs appropriate governance skills to do this.

For Miles et al., the CEO's approach to managing the cells is based on viewing the cells as entrepreneurial firms. Miles et al. offer two examples. In one firm (Technical and Computer Graphics), the cell/firms are joint venture partners within the enveloping organization. In the other (The Acer Group), the cell/firms are jointly owned via an internal stock market. Details remain vague as to how the cells maintain their autonomy in the face of top-down control, or how the CEOs assure shareholder value from the cells. Miles et al. talk about self-organization, learning networks, and emergent cells, but, again, how all this works is vague. Next: *What is a learning network*?

1.1.2 DISTRIBUTED INTELLIGENCE

> My work is in a building that houses three thousand people who are essentially the individual 'particles' of the 'brain' of an organization that consists of sixty thousand people worldwide.

Zohar (1997: xv) starts her book by quoting Andrew Stone, a director of the retailing giant, Marks & Spencer: Each particle has some intellectual capability—Becker's *human capital*. And some of them talk to each other—Burt's *social capital*. Together they comprise *distributed intelligence*). Human capital is a property of individual employees. Taken to the extreme, even geniuses offer a firm only minimal adaptive capability if they are isolated from everyone else. A firm's core competencies, dynamic capabilities, and knowledge requisite for competitive advantage increasingly appear as *networks* of human capital holders. These knowledge networks also increasingly appear throughout firms rather than being narrowly confined to upper management (Norling 1996). Employees are now responsible for adaptive capability rather than just being bodies to carry out orders. Here is where networks become critical. Much of the effectiveness and economic value of human capital held by individuals has been shown to be subject to the nature of the social networks in which the human agents are embedded (Granovetter 1985, 1992; Nohria & Eccles 1992, Burt 1997).

Intelligence in brains rests entirely on the production of emergent networks among neurons—intelligence IS the network (Fuster 1995: 11). Neurons behave as simple "threshold gates" that have one behavioral option—fire or not fire (p. 29). As intelligence increases, it is represented in the brain as *emergent* connections (synaptic links) among neurons. Human intelligence is "distributed" across really dumb agents! In computer parallel processing systems, computers play the role of neurons. These systems are more "node-based" than "network-based." Artificial intelligence resides in the *intelligence capability* of the computers as agents, with emergent network-based intelligence still at a very primitive stage (Garzon 1995). Artificial intelligence models increasingly are used to simulate learning processes in firms, though their intelligence capability is not fully connectionist and the intelligence of their agents is minimal—far below that, even, of PCs (Prietula, Carley & Gasser 1998). My focus on distributed intelligence places most of the emphasis on the emergence of constructive networks. Of course, firms that have constructive networks among geniuses usually will fare better than those having great networks among idiots. The lesson from brains and computers is that organizational intelligence or learning capability is best seen as "*distributed*" and that increasing it depends on fostering network development along with increasing agents' human capital. Now to the speed problem: *How can a cellular network process patterns quickly*?

1.1.3 RAPID PATTERN PROCESSING

Boisot and McKelvey (2003) begin by wondering how the FBI would better get advance warning about the emergence of a network pattern of terrorists planning a 9/11-type attack, or how Federal regulators or stockholder groups would better get advance warning of an Enron-type disaster. In the FBI case, there was lots of talk about "filling in the dots." In the past two years, the main conclusion of those studying the disaster is that more information was necessary—that is, not only better filling in of the existing dots, but more dots. But, a problem results. Boisot and McKelvey observe that for every *N* dots that are added, *N*! patterns are possible. Absent enhanced pattern processing capability, adding more dots simply adds more noise. While Boisot and McKelvey mention the FBI and Enron disasters, it is easy to see that any firm's strategy depends on understanding emerging contextual patterns stemming from new technologies, new markets, and new mixes of Porter's (1980) industry drivers. In these instances, high-speed variety destruction is called for under complicated circumstances.

Boisot and McKelvey propose an internal, emergent, connectionist, *semi-autonomic* network as their "technology" for pattern processing. They begin with an $i \times j$ dot-set. This could be a grid composed of terrorists or a state-space described by i variables ranging from zero to j. k adaptive tensions impose on the organization, such as resources, constraints, moves by competitors, economic and demographic trends, etc. These act as lenses serving to emphasize some patterns more than others (like a colored lens emphasizes one color more than others). Focusing on these allows the connectionist network to ignore many other patterns. A further pattern simplification occurs if v different vantage points are used, much as the VLA's movable telescopes can roll up and down 22 miles of track to change their "seeing" basis. Finally, the k and v perspectives may be extended across t time periods, resulting in an additional weeding out of patterns—only patterns remaining intact across time periods are taken seriously.

This connectionist network pattern-processing approach may consist of one level of heterogeneous agents, but more likely, as in the FBI, could consist of a hierarchy of multilevel semiautonomous cells. Boisot and McKelvey note that cellular networks are inherently unstable. Control efforts by higher-level managers tend to reduce the autonomy of the cells, or cause them to take on the more rebellious nature observed in informal organizations (Roethlisberger & Dixon 1939, Homans 1950, Scott 1998). Thomas, Kaminska-Labbe and McKelvey (2003) describe the eleven-year struggle of a firm trying to create a cellular network design that was profitable (see below). *Why are cellular networks unstable and what leads most CEOs to make them worse rather than better*?

1.2 FAILURE OF LEADERSHIP THEORY

1.2.1 MCKELVEY'S CRITIQUE OF "UPPER-ECHELON" THEORY

Could it be that leadership theory is antithetical to CEOs trying to create and maintain a semi-autonomic connectionist cellular network? Dansereau and Yammarino's (DY) (1998a,b) summary table (1998a: xxxix) shows leadership theory to be focused on attributes of leaders and their effects on groups of followers and on individual followers in dyads—corroborated by Klein and House (1998: 9). To use Dubin's (1979) phrases, this is mostly "leadership in organizations" rather than "leadership of organizations." In the DY books, only Hunt and Ropo (1998) concentrate on leadership *of* organizations via their case analysis of Roger Smith's years as CEO of General Motors. The Klein and House (1998) chapter on charismatic leadership focuses on leadership of subordinates at different levels *in* firms—leader-subordinate dyads at different levels—rather than leadership *down through* a firm's several levels.

Leadership in the DY books is multilevel. Visionary leadership is thought to cascade down one level at a time. Bennis and his colleagues (Bennis & Nanus 1985, Bennis & Biederman 1996) zero in on leaders who successfully reorient multilevel sets of followers in organizations. They abandon trait and situational theories for a skill-based theory built around leaders able to get subordinates to follow their vision. Bennis (1996: 149) says:

> The problem facing almost all leaders in the future will be how to develop their organization's social architecture so that it actually generates intellectual capital.

But he also says leadership is like "herding cats;" and:

> Leading means doing the right things…creating a compelling, overarching vision.… It's about *living* the vision, day in day out—embodying it—and empowering every other person…to implement and execute that vision…. The vision has to be shared. And the only way that it can be shared is for it to have meaning for the people who are involved in it. Leaders have to specify the steps that behaviourally fit into that vision, and then reward people for following those steps [his italics].

Bennis follows the charismatic leadership theory of House (1977) and Nanus (1992). Klein and House (1998: 3) say, "charisma is a fire that ignites followers' energy, commitment, and performance." In dwelling primarily on "mythic," "heroic," "visionary," upper-echelon leaders, Bennis works at cross purposes with distributed pattern processing and speeding up the rate of cellular network functioning. In the last quote above it is the brain of the leader that creates the vision and followers are rewarded (in the context of command-and-control structure) for carrying it out. And yet, as Bennis himself says, "…people at the periphery of organizations are usually the most creative and often the least consulted" (1996: 152). He is oxymoronic in his own thinking! Bennis does not answer the question: *How to lead the corporate brain, that is, the connectionist cellular network, without damaging its distributed intelligence and semi-autonomic functioning*?

How does the visionary CEO suppress emergent distributed intelligence? First, heroic visionary leaders tend to create "strong cultures" (Peters & Waterman 1982, Schein 1990). The role of entrepreneurs as visionary creators of organizational culture has been noted (Siehl 1985). Kotter and Heskett (1992) observe that organizational performance is connected to adaptive cultures and that leaders play a key role in culture change. Sorensen (1998) shows that strong cultures are assets in stable environments but liabilities in changing times. Leaders are seen as molding employees' views about a firm and defining their roles within it (Bryman 1996). Willmott (1993) claims that culture management is simply a new form of managerial control. Bryman (1996: 285) notes that Martin's (1992) "integration perspective" points to leaders who go about "creating, maintaining or changing cultures" in the normative manner outlined by the foregoing authors.

Second, consider a recent discussion of CEO-level charismatic leadership by Waldman and Yammarino (1999). They focus on strategy formulation by upper-echelon managers, that is, leadership *across several levels*, using an "eleven-box-plus" theory. Three propositions are:

- Charismatic attributions toward the CEO at lower echelons will result in heightened organizational member effort and intergroup cohesion, especially under conditions of perceived environmental volatility. (p. 276)
- Intergroup cohesion will result in linkages regarding the performance objectives of units within an organization so that the subsequent performance of units will be co-ordinated toward higher-level organizational performance. (p. 277)
- Co-ordinated operational performance of subunits will lead to higher organizational performance, especially when units are interdependent. (p. 278)

Some leaders may have visions that are correct, innovative, and up-to-date in high velocity environments. But what if the heroic leader's single brain is not up to the job? How to get the cellular network—what I call the "corporate brain" elsewhere (McKelvey 2001)—to come to the rescue? Left unsaid, but nevertheless supported by the Waldman/Yammarino propositions, is the idea I wish to stress: Upper-echelon charismatic leadership produces cohesion and leader defined "group think" (Janis 1972) across intervening levels where one would instead want to see a self-organizing cellular network and emergent distributed intelligence. Charismatic leadership, thus, produces a corporate brain mirroring the CEO's, and once it is made pervasive via incentive systems, it also may emerge as a pervasive, rigidifying corporate culture preserving the status quo. Next: *Why "new leadership theory" fails*.

1.2.2 Marion and Uhl-Bien's Critique of Transformational Theory

Bryman's review chapter in Clegg, Hardy, and Nord's *Handbook of Organization Studies* (1996), takes us from trait, style, and contingency approaches to what he calls the "new leadership approach." The latter builds from Bass's two leadership dimensions: transformational and transactive (Bass 1985, Bass & Avolio 1990), which in turn draws on Burns (1978). It also includes the more recently developed "dispersed leadership." *Transformational* leadership consists of four components: vision, charisma, respect & trust; motivation via high expectations; personal attention to followers; and challenging followers with new ideas. *Transactive* leadership consists of two components: rewarding followers for conformance to goals set by the leader; taking action when followers' activities are off the track.

According to Marion and Uhl-Bien (2003), transformational leadership is vision driven, top down, consensus and control oriented, with direct influence attempts by the leader. It focuses on follower "buy-in" to the leader's vision of the future. A strong link between vision and culture emerges. Incentives are arranged to align followers with the vision. In transformational leadership we see a return to the "heroic" leader and, really, the trait theory of the 1940s. These leaders transform organizations by creating future-relevant vision and follower commitment to that vision. They try to encourage followers to rise above their self-interests. The leader's main inducements are charisma, inspiration, intellectual stimulation, and focus on the individual. Transformational leaders also promulgate high expectations. Marion and Uhl-Bien (2003) compare transformational leadership and the kind of leadership necessary to create and maintain cellular networks (what they call "Complex Leadership"), as follows—see Table 1. In summary, transformational leadership emphasizes the leaders vision, charisma, top-down control and the use of incentives to align lower-level employees, creation a strong culture of agent homogeneity in the process. In contrast, leaders of complex adaptive systems, and specifically cellular networks, need to learn how to create agent heterogeneity, and enable connectionist networking, self-organization, adaptive learning, in search of improved agent and collective fitness. Later on I will discuss in more detail how leaders—particularly CEOs—can do this, but we need to go over some of the basic elements of complexity theory beforehand. Before this, however, I wish to briefly summarize present a recent study showing just how difficult it is to appropriately "lead" a cellular network.

Table 1 Comparing T & C Leadership Approaches*

Transformational/Transactive	Complex
Top-down, leader controlled views of organizational processes	Bottom-up, interactive bonding among individuals
Hierarchical- and position-based formal leadership initiatives	Leader influence generated as a function of interactive dynamics
Emphasizes follower carrying out of leader's vision and task objectives	Emphasizes interaction, self-organization, network evolution toward fitness
Manages so as to stimulate followers to align with leader's vision	Facilitates a variety of self-organization activities
Uses symbolic and inspirational leadership to transform culture, align follower interests, promote task accomplishment	Uses contextual forces, structures, and incidents ("tags") to create interaction climates, follower empowerment, unity, collective purpose, and emergent structures
Direct influence efforts to assure following of leader's vision and objectives	Highlights conflicting constraints and unifying symbols, and uses collective stimulation spark self-organization
Emphasizes follower alignment with the core vision rather than relying solely on compliance behavior	Focuses on assuring that the interactive network has sufficient agent heterogeneity and that agents are capable of adaptive learning
Sets up inducements tending to produce homogeneous agents	Capitalizes on agents' diversity and connectionist abilities

* Considerably paraphrased and reduced from Marion & Uhl-Bien's (2003) Table 1.

1.2.3 THOMAS, KAMINSKA-LABBE, AND MCKELVEY'S CRITIQUE

In a recent paper Thomas, Kaminska-Labbe, and McKelvey (2003) (TKM) remind us that Roethlisberger and Dixon discovered the classic control-autonomy duality (formal vs. informal organization) back in 1939. As of now, several dualities have been observed, including: control vs. *autonomy*, *innovation*, *variety*, *change rate*, and *self-organization*, among others. TKM's review shows that the "English" literature tends to persist in looking for bipolar duality solutions in which the opposing forces are balanced or adjusted to achieve an optimum mix. In contrast, Thomas (2001) observes that the received view from the "French" literature holds that control and autonomy—and other dualities—are "*entangled*" in, as the word implies, a *twisted, confusing mess*. Even though one pole dominates (the "*englobing*" force), circumstances are recognized when the opposite can dominate ("*inversion*"), as in Hindu society where, when needed, the *Rajah* dominates the *Brahmin* religious hierarchy (Dumont 1966). Further, the French see the rate of "*inversion/reversion*" between which pole of the duality dominates as varying, with the optimum rate somewhere between the extremes of no change and too rapid change (Dupuy 1992). The French see the dualities as "*jointly regulated*" (Reynaud & Reynaud 1994) by "*regulation processes*" that *emerge and evolve* as requirements across multiple organizational levels change (Reynaud 1987). The French prefer the descriptor, "*tangled hierarchy*" which emerges as a general organizational principle—the "*englobing*" causal disposition offers circumstances allowing and guiding the management of distinct, opposed, and even antagonistic elements. The tangled poles—really forces—of dualities have to be appropriately "managed" if a CEO wishes to create and maintain the "combination of independence and interdependence" characterizing Miles et al.'s (1999) "*cellular network*" design. As 60 years of organizational research shows, this is much easier said than done!

TKM illustrate the dynamics of entangled dualities and the prolonged struggle to find an entanglement solution with an eleven-year analysis of a global cosmetics firm (Thomas 1999) as it tries to cope with overproduction and no profits in the aftermath of a *rapid-growth-by-acquisition* strategy. Our analysis covers eleven years and divides into three phases. The case presents four different forms of tangled hierarchy during the three phases:

1. Autonomous regulation represents the *englobing* level in Phase 1, resulting in many new products but also overproduction and no profits;
2. Rapid oscillation between control and autonomy in Phase 2a—what the French call the "*symmetric*" form, resulting in profits;
3. Reversion to strong control dominance in Phase 2b, after a key Vice President is replaced by a control-oriented VP, showing the fragility of the rapid-oscillation solution; and finally

4. A control oriented *englobing* orientation, with frequent *inversions* in Phase 3—the French call it the "*oriented*" form, resulting in *joint regulation* of the firm by both control and autonomy as required. This form resulted in profits.

It is important to reiterate the fragility of the *symmetric* form, even though the symmetric tangled hierarchy was the best duality solution.

During Phase 2a the firm exhibited all of the essential attributes of a true cellular network. This innovative organizational form, which does not correspond to any known hierarchical mechanism, integrates the two contradictory polarities of the control vs. autonomy duality. However, it is quite delicate to implement and fragile. Dupuy (1992) notes that the *symmetric* tangled hierarchy can very quickly change—it is very unstable and can lead to chaos. This is exactly what happened in the firm that TKM describe. Phase 3 is also a cellular network form.

From their analyses, TKM conclude that:

1. Any attempt to focus only on the non-control end of a duality likely will fail.
2. Effective "leading" of a cellular network requires setting in motion the dynamic *inversion/reversion* of control and autonomy, such that they are "*entangled*" as opposed to "balanced" or "optimized." Further, they evolve in their interactive dynamics over time.
3. The "*rate*" at which the bipoles oscillate is critical. The zero-oscillation periods, whether autonomy *or* control dominates, did not resolve the overproduction and no-profit situations.
4. The control-pole dominating (*englobing*), but with frequent reversions to autonomy-dominance, appears as the most successful organizational form, since it is both stable and produces profits (recognizing that this finding needs further confirmation).

In contrast to Bennis and O'Toole's (2000) conclusion that the recent increase in CEO firings is due to their lack of vision, and *The Economist*'s (2001) view that it is due to flattened hierarchies, globalization, new technology, and mega mergers, TKM conclude that CEOs get fired because they:

1. Improperly manage the dualities and don't understand the underlying coevolving causalities;
2. Don't know how to help cellular networks self-organize and find the joint regulating processes that underlie the *oriented* form; and
3. Aren't trained to help key players in their firms zero in on the most effective oscillation rate of the bipoles within the *oriented* form.

Usually, strong celebrity CEOs, such as Larry Bossidy (see Bossidy & Charan 2002) are programmed to enter a firm and take strong control positions. This invariably sets the classic control/autonomy, innovation, self-organization, etc., dualities in motion. This is usually not successful, leads to more CEO churning, and even more control emphasis by the replacement CEO. Disaster usually follows. So, *How does complexity science point to a solution*?

2 BASIC COMPLEXITY THEORY

Starting with Porter (1980), the strategy field has hooked its star to IO Economics, which brings with it economists' assumptions of homogeneous agents, equilibrium-driven dynamics, reliance on predictive variables, historical time-series econometric analysis, and axiomatic mathematical analysis—all copied from classical physics where all phenomena are governed by the 1st Law of Thermodynamics (the energy conservation law) (Mirowski 1989) in a time scale measured in astronomical time rather than human time (Bar-Yam 1997, McKelvey 2003). In the knowledge economy, however, strategic analysis rests better on new order creation (Mainzer 1997) via phase transitions (Schumpeter 1942), coevolution (Maruyama 1963), nonlinear dynamics (Gleick 1987), positive feedback processes (Arthur 1990), self-organized agents (Kauffman 1993), and chaos-based "butterfly" economics (Ormerod 1998). Instead of IO Economics, complexity science offers a much more assumption-friendly platform (Colander 2000) for the new look in strategic analysis, that is, the idiosyncratic combination of resources highlighted by the *Resource-Based View* (Amit & Schoemaker 1993) and fast-paced competitive contexts (Eisenhardt 1989, McKelvey 2003b). The so-called self-organization biologists (Kauffman 1993, 2000; Salthe 1993; the many authors in Van de Vijver, Salthe and Delpos 1998) now negate Nelson and Winter's (1982) 20-year old use of evolutionary theory as a means of introducing nonequilibrium dynamics into economics—saying that Darwinian selectionist theory is, itself, equilibrium-bound. For further analysis of this view, see McKelvey (2003c).

To see how "New Science" offers insight for organizational CEO-level leadership, I find it appropriate and convenient to divide complexity science into two Schools, European and American. Admittedly, these are fuzzy sets, but they serve to highlight some basic differences in how leading complexity scholars zero in on causes of order creation. My view is that the dynamics highlighted by each School are "*co-producers*" of new order, to use a classic term introduced by Churchman and Ackoff (1950).

2.1 EUROPEAN SCHOOL

Europeans (Prigogine 1955, 1997; Haken 1983, Nicolis & Prigogine 1989, Cramer 1993, Kaye 1993, Mainzer 1997, among others) focus on what sets order-creation dynamics in motion. They draw mostly from the physical sciences, emphasize mathematics, and view imposing energy differentials leading to phase transitions as the cause of order creation. A phase transition occurs because an imposing energy differential, what I term '*adaptive tension*' (McKelvey 2003b) exceeds what is called the 1st critical value, R_{c1}—which defines the lower bound of the region of emergent complexity.

Elsewhere, I have reviewed the several theories about causes of emergent order in physics and biology, some of which have been extended into the econosphere and social behavior (McKelvey 2003c). Kelso, Ding, and Schöner (1992) offer the best synthesis of the European school:

> *Control parameters, R_i, externally influenced, create $R > R_{c1}$ with the result that a phase transition (instability) approaches, degrees of freedom are enslaved, and order parameters appear, resulting in similar patterns of order emerging even though underlying generative mechanisms show high variance.*[3]

This "0th law," the *order-creation law*, summarizes the European school's view. They focus on the Bénard energy-differential process that applies to weather, fluid dynamics, lasers, various chemical materials, the geology of the Earth and, subsequently, to various biological phenomena (Haken 1983, Nicolis & Prigogine 1989, Cramer, 1993,, Mainzer 1997, Prigogine 1997, Gurnis 2001, McKelvey 2003c).

Equilibrium thinking and the 1st Law are endemic in evolutionary theory applications to economics and organization science. Equilibrium thinking, central tendencies, and the use of energy dynamics in independent variables to predict outcome variables is also endemic to organization science empirical methods, whether regression or econometric analyses. However, there now is a shift from the homogeneous agents of physics and mathematics to computational models comprised of heterogeneous, self-organizing agents.[4] As Durlauf (1997, p. 33) says, "A key import of the rise of new classical economics has been to change the primitive constituents of aggregate economic models: while Keynesian models employed aggregate structural relationships as primitives, in new classical models individual agents are the primitives so that all aggregate relationships are emergent." In this statement the 0th law is brought in more directly.

Setting the stage for order-creation-based strategy analysis, Schumpeter, in 1942, quite remarkably wrote about replacing evolution with phase transitions—well before Prigogine (1955) and replacing gradualist evolution with punctuated equilibrium long before Maruyama (1963) or Eldredge and Gould (1972)! Besanko, Dranove and Shanley (2000: 485) summarize Schumpeter's thesis as follows:

> Schumpeter considered capitalism to be an evolutionary process that unfolded in a characteristic pattern. Any market has periods of comparative quite, when firms that have developed superior products, technologies, or organizational capabilities earn positive economic profits. These quiet periods are punctuated by fundamental "*shocks*" or "*discontinuities*" that destroy old sources of advantage and replace them with new ones. The entrepreneurs who exploit the opportunities these shocks create achieve positive profits during the next period of comparative quiet. Schumpeter called this evolutionary process creative destruction. (my italics and underlines)

The application of the 0th law in socioeconomics rests with Haken's control parameters, the first two words in the Kelso, Ding, and Schöner's statement. The R_i adaptive tensions (McKelvey 2003c, in press) can appear in many different forms, from Jack Welch's famous phrase, "Be #1 or 2 in your industry [in better than average growth] or you will be fixed, sold, or closed" (Tichy & Sherman 1994: 108; paraphrased), to narrower tension statements aimed at technology, market, cost, or other adaptive tensions. Schumpeter observes (quote above) that entrepreneurs are particularly apt at uncovering tensions in the marketplace. The applied implication of the 0th law is that new order-creation activities are functions of (1) *control parameters*, (2) *adaptive tension*, and (3) *phase transitions* motivating (4) *agents' self-organization*. Take away any of these and order creation stops. Since the last item refers to self-organization—in cellular networks of interacting heterogeneous agents—the European School offers a direct message upon which to base some of the simple rules CEOs need to follow so as to create and maintain cellular networks.

2.2 AMERICAN SCHOOL

The American complexity literature focuses on coevolution, power laws, and *small* instigating events—Holland's (1995) "*tags*." Coevolution of heterogeneous, adaptive learning, agents is the "engine" of order creation. *What instigates bursts of nonlinear order-creation via coevolution*? The American School draws from the life and social sciences and chaos theory, emphasizes heterogeneous agent-based computational simulation models, and sees large nonlinear effects stemming from coevolutionary agent interactions set in motion by small events, that is, tags.

Gleick (1987) details chaos theory, its focus on the so-called butterfly effect—a tag—(the fabled story of a butterfly flapping its wings in Brazil causing a storm in North America), and aperiodic behavior ever since the founding paper by Lorenz (1963). Bak (1996) reports on his discovery of *self-organized criticality*—a power law dynamic—in which tags (falling grains of sand) can lead to complexity cascades of avalanche proportions. Arthur (1990, 2000) focuses on positive feedbacks stemming from tags. Casti (1994) and Brock (2000) continue the emphasis on power laws. The rest of the early Santa Fe story is told in Lewin (1999). American complexity scientists tend to focus on R_{c2}—the "*edge of chaos*" (Lewin 1999, Kauffman 1993, 2000; Brown & Eisenhardt 1998), which defines the upper bound of the region of emergent complexity. What happens at R_{c1} is better understood; what happens at R_{c2} is

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[3] It is rather ironic, however, that the most complete statement of the European view is in the only paper I have found among the many Santa Fe Institute publications that focuses on the critical values and phase transitions, and cites the European work!

[4] For example, see Masuch and Warglien (1992), Carley and Prietula (1994), Epstein and Axtell (1996), Prietula, Carley and Gasser (1998), and Ilgen and Hulin (2000).

more obscure, if not more catchy and romantic. The "edge of chaos," long a Santa Fe reference point (Lewin 1999), is now in disrepute, however (Horgan, 1996: 197).

It is not hard to find evidence of coevolutionary behavior in organizations. The earliest discoveries date back to Roethlisberger and Dixon (1939) and Homans (1950)—both dealing with the mutual influence of agents (members of informal groups), the subsequent development of groups, and the emergence of strong group norms that feed back to sanction agent behavior (reviewed in Scott 1998). Much of the discussion by March and Sutton (1997) focuses on the problems arising from the use of simple linear models for measuring performance—problems all due to coevolutionary behavior of firms and agents within them. In a recent study of advanced manufacturing technology (AMT), Lewis and Grimes (1999) use a multiparadigm (postmodernist) approach. They study AMT from all of the four paradigms identified by Burrell and Morgan (1979). No matter which paradigm lens they use, they find evidence of coevolutionary behavior within firms. Several of the articles in the *Organization Science* special issue on coevolution (Lewin & Volberda 1999) report out evidence of microcoevolutionary behavior in organizations. Finally, a number of very recent studies of organization change show much evidence of coevolution between organization and environment and within organizations as well (Erakovic 2002, Kaminska-Labbe & Thomas 2002, Meyer & Gaba 2002, Morlacchi 2002, Siggelkow 2002). Occasionally explicit attention is also given to tags.

In his classic paper, Maruyama (1963) discusses *mutual causal* processes mostly with respect to biological coevolution. He also distinguishes between the "deviation-counteracting" negative feedback most familiar to general systems theorists (Buckley 1968) and "deviation-amplifying" *positive feedback* processes (Milsum 1968). Boulding (1968) and Arthur (1990, 2000) focus on "*positive feedbacks*" in economies. Negative feedback control systems such as thermostats are most familiar to us. Positive feedback effects emerge when a microphone is placed near a speaker, resulting in a high-pitched squeal. Mutual causal or coevolutionary processes are inherently nonlinear—large-scale effects may be instigated by very small initiating events, as noted by Maruyama (1963), Gleick (1987), and Ormerod (1998).

To overcome the boiled-frog effect[5] both European and American perspectives are important. Phase transitions are often required to overcome the threshold-gate effects characteristic of most human agents—so that there is a broader coevolutionary dynamic set in motion once the tag occurs. This requires the adaptive tension driver to rise above R_{c1}. Once the adaptive tension force is strong enough to overcome the threshold gates, and given that a tag occurs, and assuming the other requirements are present (heterogeneous, adaptive learning agents, and so forth), coevolution then starts. Neither $R > R_{c1}$ nor tag-plus-coevolution seems both necessary and sufficient by itself, especially in social settings. This is why phase transition and coevolution are "*co-producers*" (Churchman & Ackoff's 1950 term). It seems clear that (entrepreneurial) order-creation via adaptive tension, $R > R_{c1}$, and phase transition, as Schumpeter figured out sixty years ago, fits with the European school's view of what causes self-organization and subsequent nonlinearity. Consequently, research about order-creation by cellular networks is best based on the nascent 0^{th} law than on Darwinian theory. Given adaptive tension, once a tag event occurs, then, following the American school, order creation is about managing the dynamics of coevolution. I develop this topic elsewhere (McKelvey 2002).

2.3 LEADING VIA ADAPTIVE TENSION AND STRANGE ATTRACTORS

How can CEOs initially create, and then maintain cellular networks in their firms? *How can they steer them toward more fruitful directions*? I begin by adding a little more detail to the European School's theory.

By emphasizing one adaptive tension over others, CEOs can steer cellular networks in one direction or another. Cramer (1993) identifies three levels of complexity—defined in Table 2—depending on how much information is necessary to explain the complexity: *Newtonian complexity*, *emergent complexity*, and *stochastic complexity*. The boundaries of emergent complexity are defined by "*critical values*" (Cramer 1993). Nicolis and Prigogine (1989: Ch. 1) describe the function of critical values in natural science. Nothing is so basic to their definition of complexity science as the Bénard cell—two plates with fluid in between. An *energy* (heat) *differential* between the plates—defined here as '*adaptive tension*', *T*—creates a molecular motion of some velocity, *R*, as hotter molecules move toward the colder plate. The energy-differential in the Bénard cell parallels that between hot surface of the earth and cold upper atmosphere—hotter air molecules move upward and if they move fast enough, create storm cells. Complexity science cannot be understood without appreciating the role that *T* plays in defining the region of complexity "at the edge of chaos." If *T* increases beyond the 2^{nd} critical value, the agent system jumps into the region of chaotic complexity. Here the system is likely to oscillate between different states—centered on different *basins of*

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[5] A frog dropped into boiling water will jump right out; a frog put in cold water, which is slowly brought to a boil, will not jump out, cooking to death instead. I have no idea which animal *non*-lover did this first. This is why the European complexity scientists worry so much about critical values and consequent phase transitions—it takes significant shocks to get systems out of unresponsive states. Absent strong adaptive tensions, Holland's tags have no tension dynamics to set in motion.

attraction—thereby creating chaotic behavior. Table 2 gives definitions of *attractors*. Thus, for molecular agents:

- **Below the 1st critical value** of *T*, agents show minimal response in reducing *T*—molecules vibrate in place but "conduct" energy by colliding with each other.
- **Above the 1st critical value** of *T*, agents show collective action toward reducing *T*. Gas molecules start bulk currents of "convection" movement, as the molecules actually circle around from hot to cold and back to hotter plate, or generate strong bulk currents of air flowing up and down from earth's surface to upper atmosphere—the air turbulence and storm cells that create rough airplane rides.
- **Above the 2nd critical value** of *T*, the molecular movements become chaotic. For example, if *T* between hot lower air and cold upper air increases further, perhaps by the conflation of warm moist air from the south and cold air from the north, say over Kansas, the *2nd critical value* may be exceeded. At this point the storm cell may oscillate between two basins of attraction, tornadic and nontornadic behavior.

> > > Insert Table 2 about here < < <

Translating to firms, suppose a large firm acquires another firm needing a turnaround. Suppose *T* stays below the 1st critical value, in which existing management stays in place and the acquiring firm imposes little change. There is little reason for people in the acquired firm to create new structures. Instead, there might be only "conduction" type changes in the sense that new turnaround ideas percolate slowly from one person to another person adjacent in a network. If *T* goes above the 2nd critical value, complexity theory predicts chaos. Suppose the acquiring firm changes several of the acquired firm's top managers and sends in "MBA terrorists" to change the management systems "over-night"—new budgeting and information systems; new personnel procedures, promotion approaches, and benefits packages; new production and marketing systems, and so on. And, further, suppose that the acquired firm's culture and day-to-day interaction patterns are changed as well. In this circumstance, two basins of attraction could emerge: one basin defined around demands of the MBA terrorists and the other centered around the comfortable pre-acquisition ways of doing business and resistance to change. The activities of the system could oscillate between these two basins, seemingly exhibiting the characteristics of a strange attractor.

Between the 1st and 2nd critical values lies the organizational equivalent of Cramer's emergent complexity. Here, network structures emerge to solve *T* problems. Using the storm-cell metaphor, in this region the "heat conduction" of interpersonal dynamics between sporadically communicating individuals is insufficient to reduce the observed *T*. To pick up the adaptive pace, the equivalent of organizational storm cells consisting of "bulk" adaptive work-flows starts. Formal or informal structures emerge, such as new network formations, informal or formal group activities, departments, entrepreneurial ventures, and so on. Though the *T*s in organization science are unlikely to have the precise values they appear to have in some natural sciences (Johnson & Burton 1994) it seems likely that a probability distribution of such values will exist for individual firms and each of their subunits. Though precise values of *T* for firms do not exist, we do know about symptoms indicating whether a firm is below the 1st, in between, or above the 2nd critical value (Brown & Eisenhardt 1998, McKelvey 2003b).

2.4 MANAGERIAL STEPS TOWARD CREATING AND MANAGING CELLULAR NETWORKS

Adaptive Tension. For distributed intelligence (DI) and to be improved, a CEO's first task is to make sure the corporate brain is exposed to the full range of "*T*s" "out there"—that surround the agents—that might energize emergent order. At GE, Jack Welch uses "*Be #1 or 2 in your industry*," with a very clear motivational valance. *Respond to the T or your division will be sold!* Thus, *T*s are the root motivation causing agents to self-organize.

While agents in a Bénard cell face just one *T*, the adaptive tension confronting the many agents within a firm—as receivers—appears as countless *T*s. In addition, to the many *T*s reflecting forces and constraints in the environment, there may be *T*s created by numerous agents within competing firms—from the CEO down to the people in engineering, production, marketing, sales, and so on. An agent network could emerge virtually anywhere in a firm around an initiative to produce a better part, product, marketing approach, new strategy, and so forth. Consequently, there is danger in *a priori* trying to focus certain kinds of *T*s toward specific kinds of agents. This might preclude the emergence of the most effective new networks. But there is an equal danger in trying to flood every agent with every kind of *T*. It is also clear that "selecting" the nature of the incoming *T*s based on preconceived CEO-level notions, as Roger Smith did at GM for a decade (Hunt & Ropo 1998) puts blinders on the corporate brain. Toyota is well known for its system of increasing the awareness of workers about how well their designs and products compete against the competition—a small set of narrowly defined *T*s. Welch accomplishes the same objective by defining *T*s very broadly as, "Be #1 or 2 in your industry!" This is a perfect example of using a simple piece of information to focus attention on a particular aspect of the competitive environment—everything is boiled down to one *T* that *drives* the lower level systems without the command-and-control structure *defining* them. Strong corporate leadership is shown without setting up a suppressive command-and-control-structure or otherwise inhibiting emergent DI.

Critical Values. Assuming agents are confronted by the appropriate *T*s, managing the critical values aspect of adaptive tension requires three basic activities: (1) checking whether behavioral symptoms of *T*s impinging on one or more agents are below, between, or above the critical values; (2) altering motivational valances to move the *T* levels into the region between the 1st and 2nd critical values; and (3) widening the distance between the critical values.

Critical values are not precisely determined in firms—as they are in natural science. Nor does research indicate what levels of *T*s are below, between, or above the critical values. For now we have to rely on behavioral symptoms for evidence about *T* effects. Brown & Eisenhardt (1998) identify some symptoms. For example, as indications that *T* is *below the* 1^{st} *critical value*, they point to overbearing structure, fiefdoms, little novelty, and reactive strategizing. For evidence that *T* is *above the* 2^{nd} *critical value* they point to random communication, over coordination, politics, modular structures disconnected, and sporadic intense experimentation too narrowly focused.

There are also direct symptoms of emergence. In general *T* between the critical values produces emergent dissipative structures, which then start reducing *T*, at which point they dissipate:

1. Emergent social networks such as dyadic or triadic communication channels, informal or formal teams, groups, or other network configurations;
2. More effective networks within or across groups, more structural equivalence, better proportions of strong and weak ties, increased numbers of structural holes (Burt 1992), more networks emerging between hostile groups—marketing with engineering, or with production, with suppliers, with customers, and so forth;
3. Emergent networks of any kind, networks that produce novel outcomes, new strategies, new product ideas, new directions of knowledge accumulation; and
4. Networks that speed up rates of adaptive-event occurrence.

Widening the region of emergence requires operating on the location of the critical values themselves—lowering the 1^{st}, raising the 2^{nd}—rather than only trying to adjust the *T*s to fall in between. Anything that gets networks to form more easily is essentially lowering the 1^{st} critical value. Raising the 2^{nd} critical value requires training agents to develop (1) more effective emergent structures—so tension stops rising and starts dissipating; and (2) higher 'tension tolerance' to handle higher tension levels before "going chaotic." For example, employees in high-velocity firms in Silicon Valley work routinely in an atmosphere of adaptive tension far higher than might ever appear in large dinosauric firms or government agencies.

Attractors. The previous two sections work on the "fostering-and-speeding-up-emergence" part. Now I turn to the problem of "steering" without inadvertently fostering the emergence of a suppressive command-and-control-bureaucracy. To begin, p*oint* and *strange attractors* are defined in Table 3.

> > > Insert Table 3 about here < < <

Bureaucratic negative feedback systems center around *point attractors*. A visionary CEO operates as one—the vision is the goal, which becomes the equilibrium point toward which negative feedback, managerial control processes define the system. Since firms do need strong leaders, and since some people like being strong leaders and behave like strong leaders, it is pointless to think of avoiding point attractors. The trick is to aim these "strong leader types" toward using point attractors that "*drive*" the system toward reducing the *T*s but do not "*define*" it in the command-and-control ways that inhibit emergence. *T*s *are* point attractors. Activities that serve to reduce *T*s, thus, are point attractors.

Remaining strong leader activities are best redefined to be *strange attractors*. This is probably the best way in which to view Bennis's (1996) "herding cats" metaphor—the "cage" effect of the rabbit and dog metaphor in Table 3. We may use what Morgan (1997: 98) refers to as "*cybernetic reference points*" and "*avoidance of noxiants*" to define the reflective cage of a strange attractor without defining goals that act as point attractors. Strange attractor "definitions of the cage" must be created without determining specific or repeating paths—characteristics of point attractors and opposite the definition of novelty.

Incentives should encourage the proper delineation, separation, and development of point and strange attractors. It is easy to define point attractor incentives—"Here is the goal and I will pay more if you achieve it." Saying "No" is all too easy in firms and seldom needs to be encouraged. Setting up "inexpensive experiment" strange attractor systems seems more risky and learning when to say "No" to continuing an experimental product development activity is problematic. Strange attractors also need to be made attractive for agents "inside the cage."

Agency Problem. Economists define the agency problem as the likelihood that managers, as agents of shareholders, will substitute their own personal interests for those of shareholders (Jensen & Meckling 1976, Eisenhardt 1989a). If slack resources (March & Simon 1958) are made available for DI development, then there is the possibility that the slack could be used against shareholder interests. Slack targeted for developing distributed intelligence should be managed by strange attractors rather than allocated to point attractors. Slack imported into basic research parks is adaptive, but the tension is low as the agents are disconnected from market defined *T*s. Connecting slack with specific *T*s, but still steering the DI system by strange rather than point attractors seems optimal. The more market-connected *T*s are used to create the conditions leading to emergent order, the more likely networks will emerge in response to market related adaptive problems rather than in response to the interests of individual agents. In light of my goal of finding ways that CEOs can produce sustainable rents, CEO activities that inhibit DI appreciation actually contribute to the agency problem. DI appreciation depends on staying in the region between the critical values, which in turn depends on "pointing" agents' attention toward the *T*s (defined to include incentives).

3 SIMPLE RULES FOR "LEADING" CELLULAR NETWORKS

So far I have reviewed arguments why CEO leadership in the knowledge economy is failing. **First**, the knowledge economy calls for the creation of cellular networks in organizations. **Second**, *New Economy* leadership calls for ways in which CEOs can initially create and then maintain cellular networks, given that they are inherently unstable. **Third**, I have then reached into complexity science for more foundational ideas about why self-organizing cellular networks are called for, what their basic "ingredients" are, and what causal forces set self-organizing dynamics in motion. *But what should CEOs actually do "on Monday morning" to get cellular networks to thrive and produce effective results*?

Here is where it pays to think like person trying to code up an agent-based computer simulation model. "Agents" in the computer need to be given very specific rules about what they do in very specific circumstances. Nothing can be taken for granted. Fortunately, CEOs are smarter than most computer agents and may learn more quickly, though at 1–2 gigahertz processing speed, computer agents learn VERY quickly!! Agent-based computer models are an excellent method for translating vague theory into specific rules that simulated agents can put into practice. Then we find out whether the theory works as predicted or not. This way of thinking is also a way of translating vague theory into specific rules that CEOs can follow so as to create and maintain cellular networks in their firms. In what follows, I follow Boisot and McKelvey (2003) in analogizing from the *genetic algorithm* approach to human connectionist networks.

In the past several years I have used GE as an example of a firm that has developed "*simple rules*" that in many ways reflect the message of complexity theory. Since GE developed its "boundaryless organization" approach (Ashkenas et al. 1995), GE has moved to elaborate a system whereby "*best-practices*" discovered in one section are quickly spread to other parts (Kerr 2000) of what is now a vast "related multidivisional" kind of firm. It accomplishes this by developing rules along with fairly draconian incentives to make sure the flow of best-practice discoveries throughout the GE network is speeded up as fast as possible. GE is a particularly important example, since it has outperformed every major corporation around the globe in producing shareholder value (Stone 1998).

GE argues that they have an approach that is not new or complicated. They have just a few simple rules focusing on getting good ideas to be shared around the GE system—that is, GE's cellular networks. They are, however, rather strongly focused on how they attach draconian incentives aimed at producing a rapid flow of newly discovered best-practices. Rules with meaningless incentives are useless! The GE rules lie behind the rules presented in bullet #11.

Just as I have relied on some basic complexity science ideas to suggest the design and process of a human connectionist network, in what follows, I also rely on complexity science principles to outline some managerial implications of how to set up such a network and keep it running. Installing the rules discussed below may seem daunting, but one must remember that all organizations are *already* latent or somewhat active cellular networks. Think of the rules below as calling for incremental additions to existing human and social capital formations. Even so, I am not saying it is easy. We have already seen how United Airlines and Continental both failed to copy the cellular network that is Southwest Airlines. There is the added problem, as United and Continental encountered, of overcoming existing well-formed, antagonistic cellular networks—such as labor unions!

While I call them "simple rules" in human complex adaptive systems, they are more like "*guidelines*" for CEOs to follow so that they can enable and steer cellular networks in ways that destroy autonomy, agent heterogeneity, and/or produce an organizational culture dominated by top-down control.

3.1 BASIC "SIMPLE RULES"

The rules (guidelines) required to set up and maintain cellular networks in firms are as follows:

1. **Assemble Heterogeneous Agents:** If all the agents are the same, there is no advantage to networking (Holland 1995). End of story. We have 3+ billion years of mutation and crossover creating biological diversity—Campbell (1974) called it "blind variation." He argued that "blind" variation was much more relevant for social innovation than "rational" variations. Furthermore, agent-based models by Allen (2001), LeBaron (2001), Johnson (2000) all show that novelty, innovation, and learning all collapse as the nature of agents collapses from heterogeneity to homogeneity. The definition of creativity favored by psychologists—"remote associates"—essentially holds that creativity emerges when agents having different ideas or concepts interact and, consequently, notions heretofore separated are joined to produce something new.

   Heterogeneity loses its effect if agents become too similar or have no "mutual" absorptive capacity (Cohen & Levinthal 1990). Agents need to be able to absorb and understand to some extent ideas from agents they interact with. Nor can the continuing availability of heterogeneous agents be taken for granted. The control systems that are so prevalent in organizations (Morgan 1997, Jones 2000) invariably damp out heterogeneity. It may undermine corporate control, which then sets control forces in motion that in turn undermine heterogeneity and lower level autonomy, as shown in Thomas, Kaminska-Labbe, and McKelvey (2003).

2. **Assure Human Capital Formation:** Human capital is the basis of agent heterogeneity. The idea of networked idiots doesn't offer much promise. The "human capital" idea dates back to Becker's (1975) early work on the subject. He argued that the economists' Cobb-Douglas production function needs a component to reflect the knowledge people hold, as well as capital and labor. This is especially true in today's knowledge economy—the economic advantage of the US, today, is much more a function of human capital than financial capital or labor. Darby and Zucker find that one genius appropriately networked is superior to larger networks comprised of less talented agents (Zucker & Darby (1996, Darby, Liu & Zucker 1999). The actual performance of a pattern-processing cellular network, according to Boisot and McKelvey (2003) depends on the following skills.

    a. Agents specializing in *dot-set* collection;
    b. Agents specializing in *contextual tension* analysis;
    c. Agents specializing in *vantage point* analysis;
    d. Agents specializing in *time period* analysis;
    e. Agents specializing in "running" the ***i***, ***j***, ***k***, ***v***, ***t*** array analysis.
    f. Agents with networking skills.
    g. The need for absorptive capacity has already been mentioned.

    The foregoing bullets define the human skills the agents in a network need to have to evolve toward an accurate appreciation. Take away any of these skills and perspectives and the network won't be innovative or creative.

    The "absorptive capacity" literature (Cohen & Levinthal 1990) implies that if agents don't have some preexisting level of skill in ***i***, ***j***, ***k***, ***v***, and ***t*** they won't be very good at collecting additional, perhaps somewhat stranger, information pertaining to these dimensions. Also, absorptive capacity is a positive feedback process—the more absorptive capacity an agent has the more new, technical information he/she absorbs; the more information absorbed, the higher his/her absorptive capacity.

    There is considerable training involved that is really of the human and social capital kind—training in what the agents do "technically" over and above how they network. Specifically, special training may be needed so employees can:

    a. Develop all the human capital skills implicit in performing according to the simple rules outlined above;
    b. Develop all of the social capital skills implicit in appropriate networking;
    c. Learn about "who knows what about what" across the network (transactive memory; Argote 1999);
    d. Define and cycle through the ***i***, ***j***, ***k***, ***v***, ***t*** array without missing anything;
    e. Do it at a fast enough rate.

    Needless to say, emergent trends toward nonlinearities keep changing. It takes special training to constantly look for novel/unfamiliar patterns rather than known patterns or fitness functions. While the Arab terrorist threat could remain for some time, and hence the ***i***, ***j***, ***k***, ***v***, ***t*** array could stay in place for some time, at the firm level, the actual elements of the array could constantly change. An array could be different for each major competitor. Or, dimensions could change for global firms as political economies change around the globe. A firm should think of constantly redefining its state space and, consequently, also redefining the rest of the array.

3. **Aim for "Moderate" Numbers of Connections:** The main argument throughout Kauffman's entire book (1993), is that some connections—not very many, actually—among agents improves system fitness, but that fitness deteriorates as the number of connections between each agent and various other agents increases toward the maximum. He calls this effect "*complexity catastrophe*," arguing that it thwarts Darwin's selectionist evolution-toward-improved-fitness theory. Using his *NK*[*C*] model, Kauffman also finds that the upper bound at which "catastrophe" sets in is raised if intrasystem agents are connected to a moderate extent with agents outside the system. Barabási and Bonabeau (2003) find that number of connections per node follow a power law, so it should be expected that one individual in a network will have many links and some will have almost none; it is not necessary that all agents have the same number of connections. CEOs should remember that connections are like fertilizer: Just because some is good doesn't mean that a lot is better!

4. **Create Appropriate Physical Conditions:** People who see each other all the time usually develop strong ties. People who never see each other tend not to interact. This is to say, networking is a function of physical adjacency. Of course, the Internet, electronic mail, telephones, and so forth, overcome many limitations of physical adjacency, but many remain. Therefore, it is important to create physical "mixing" events that bring heterogeneous agents into person-to-person contact. Combining these mixing events with increased awareness of newly appearing adaptive tensions meets some of the basic conditions of new order creation, as outlined in McKelvey (2003b,c)—especially the action of the 0^{th} law of thermodynamics discussed earlier. CEOs can also create "tags," which serve to set off coevolutionary dynamics (Holland 1995). Job related "new" mixing is also

possible. Moving people who have succeeded at one job into another—that is, changing their job position and physical location is a way of creating new weak-ties, as GE has found out (Kerr 2000).

5. **Arrange Coaching:** The OD literature (French & Bell 1984) and people applying complexity theory both realize that coaching is needed to help many employees form network connections expeditiously (Goldstein 1994; Kelly & Allison 1998). One can't assume that all relevant employees arrive with networking skills. Given the possibility of both personal conflict and task conflict, there is every reason to expect that coaches need to act as catalysts to help networking along.
6. **Aim for Near Decomposability:** How to create the "cells" in cellular networks? Simon (1962) argued that systems (i.e., cellular networks) evolve toward fitness fastest when the cells (modules) are nearly, but not totally, disconnected from higher levels in biological or social system hierarchies. Sanchez (1993, 1999; Sanchez & Mahoney 1996) confirms this empirically in his extensive research on the effectiveness of modularly designed firms; also corroborated by Schilling (2000). As noted earlier in my discussion of agency theory, economists have long argued that we have to worry whether autonomous agents—they talk about managers—always serve the best interests of shareholders. It is clear from the recent Enron, WorldCom, and investment bank investigations that CEOs and lower-level managers *do not* always put shareholder interests first. Even so, this rule is here so as to make it clear that the alternative—of strong top management control—is also antithetical to shareholders' best interests. CEOs have to aim at giving cellular networks much freedom and autonomy, but not total autonomy. I discuss the various problems pertaining to this rule in Section 2.4.
7. **Take Advantage of Adaptive Tension:** An externally imposing, and internally recognized *adaptive tension* serving to activate the agents (McKelvey 2003b) is required. Tensions are not point attractors, but they serve as energizing devices for CEOs to take advantage of. I have discussed how CEOs can use adaptive tension and distinguish between point and strange attractor management earlier and won't repeat that discussion here.
8. **Work with the Critical Values:** Adaptive tensions, as I discussed earlier, cause phase transitions, (that is new order type nonlinearities), if the tension is above the 1st critical value $T > R_{c1}$. Use of the 1st and 2nd *critical values* to define the region of emergence—below the 1st critical value and bureaucratic behavior prevails; above the 2nd critical and chaos prevails (Brown & Eisenhardt 1997, McKelvey 2003b), as I discussed earlier. No need to repeat this here. Agent training and experience works to lower threshold gates so that adaptive tensions may take effect at lower values. Agents can also become trained so as to work in high tension conditions without becoming dysfunctional.
9. **Set Up Strange Attractors:** Steering of the network by "*strange attractor limit setting*" rather than by point attractors created by top-down goal setting (McKelvey, 2003b)—which is reminiscent of Bennis's "herding cats" phrase, and Morgan's (1998) "avoidance of noxiants." I don't need to expand on this rule here either.
10. **Create Periodic Weak Tie Flooding:** Granovetter's classic research finding is that novelty and innovation happen more frequently in networks consisting mostly of "*weak ties*" as opposed to "*strong ties*" (1973, 1982). The latter tend to produce group think (Janis 1972). This weak-tie effect is reconfirmed by Burt's (1992) discovery of the entrepreneurial power of "*weak-tie bridges*." And, of course, weak-tie effects go hand in hand with my first rule's emphasis of agent diversity. Given an existing system, which tends toward strong-tie formations as agents get to know each other better and experience the build-up of what McKelvey (2003a) terms "*entanglement ties*." These are ties that build up over repeated interactions, with the effect that the behaviors of entangled tie agents become increasingly similar and predictable. Essentially, they set up the forces of path dependency. To offset this effect, the "weak-tie flooding" rule is necessary. As can be seen in the histories of 15th century Florentine banking (Padgett 2001) and American Broadway Musical industries (Uzzi 2002), for example, the natural tendency of industry participants to evolve into strong-tie networks is offset by the rapid entry—that is, flooding—of each industry by newcomers having different values, skills, priorities, connections, and so on. In each example industry this happened several times. While modularization speeds up adaptive response rates (see rule #6), modules (cells) are also prone to become strong-tie cliques. Therefore:
    a. New agents must be rotated into a firm's cellular networks so as to avoid the effect of path dependencies and weaken strong-tie cliques (McKelvey 2003a);
    b. Weak-tie bridgers are encouraged so as to avoid noncommunicating strong-tie cliques or modules (Burt 1992);
    c. Besides "flooding" a network with new entrants, moving people around an organization into new positions has the same effect.
11. **Manage Coevolution:** The root force of the American School is coevolution. In biology, coevolution is kept under control by damping mechanisms and organisms have no control over the speed of its progression toward a nonlinearity event (new order). But, as I discuss elsewhere (2002), coevolving systems are always liable to coevolve in unwanted directions, not coevolve fast enough in the right directions, start at a good rate and then suffer the effects of damping processes, and so on. As a result, the basic coevolutionary process has to be managed. I mention twelve ways in which this may be pursued but space precludes my getting into this here.

12. **Set Up Appropriate Incentive Structures:** Ideas here are mostly patterned after network incentives developed at GE, under the leadership of Jack Welch (Kerr 2000). Some of the things Kerr mentions are:

Defeat Barriers to Information Sharing

- Hoarding vs. "Not Invented Here"—people have to get new best practices they have discovered out onto the network
- The "Core" of Most Ideas Mostly *is* Generalizable
- Reject Only After Trying to Make it Work
- Make Expertise Readily Available
- Put People in Positions Where They Might Fail—which to say, keep moving them around
- Constant New Learning Opportunities
- "Popcorn Stands"—places where new ideas can be tried out without doing damage to other parts of the organization

No Secrets Allowed

Strong Incentives

- GE's Incentives Are Best Described as "Draconian"
  - ✓ You Can Get Rich
  - ✓ You Can Get Fired
  - ✓ Little Mercy for Incompetents

Though not explicitly drawn from complexity science, or explicitly aimed at what Miles et al. call cellular networks, the foregoing GE "rules" have the effect of greatly improving GE's network functioning. This, coupled with Welch's reliance on the broad adaptive tension rule ("Be #1 or 2 or you will be divested…"), does indeed, amount to an unknowing application of basic ideas from complexity science.

Here are some rules generalized from the foregoing GE-explicit rules:

a. Agents incentivized to get information out on the network in a form abstract enough for all users to try out;
b. Agents gaining success in one part of the network, or with one kind of human capital, are moved around—given additional "opportunities to fail"—which is a way of building competence, diversity, and weak ties;
c. Agents incentivized to use "popcorn stands" as places to surface trial novelties (innovations, strategies, entrepreneurial approaches, and ideas in general), for broader analysis by the collective, before taking the results to higher levels;
d. Agents incentivized to produce novelties via using the ***i***, ***j***, ***k***, ***v***, ***t*** array analyses in a power law distribution, with the most critical (top priority) novelties expected at a consistent rate each year (say, five "most critical" novelties per year)—novelties created in response to the prevailing contextual tensions and rates of change in the external environment;
e. Agents "above" the cellular networks, such as CEOs, are incentivized to expect and review some specific number of "most critical" novelties, and some novelties of lesser criticality without reservation—but remember the "near decomposability" rule;
f. Agents incentivized to keep the network circling through the ***i***, ***j***, ***k***, ***v***, ***t*** array so that it equates to the search procedure characteristic of connectionist simulation models that underlie cellular network development—the genetic algorithm in particular. Otherwise it won't reach its "fitness" objective, which is recognizing a novel pattern or solution only after cycling through all dot-sets, contextual tensions, vantage points, and across time periods.

3.2 KEEPING HUMAN CONNECTIONIST NETWORKS OPERATING EFFECTIVELY

How can CEOs create "semi-autonomic" cellular networks without destroying them at the same time? With current theories and/or styles of leadership, the more aggressively managers try—using a top-down control approach—the more they will fail to create and maintain a connectionist network (Marion & Uhl-Bien 2003, Uhl-Bien, Marion & McKelvey 2003). This is also a very clear lesson from the coevolutionary causality theory developed by Thomas, Kaminska-Labbe, and McKelvey (2003), bolstered by data from their eleven-year case study of a global cosmetics firm that demonstrates the erosive effects of top-down control on bottom-up network autonomy.

Though I can't say my list of simple rules is exhaustive, it *is* the most comprehensive list of rules currently available for initiating and running human semi-autonomic connectionist cellular networks. At this point I will claim that each rule is surely "necessary" but none is "sufficient" by itself. The failure of any one of the foregoing rules means the connectionist network will cease to function as designed or desired. That the list comprises twelve elements is daunting—especially when viewed from the prospect that any one rule missing and the network becomes ineffective. On the other hand, it also shows that there are, indeed, reasonably well-understood architectural elements discussed in the literature that one can use to guide the building of an effective human connectionist network—note that I show support in the literature for each simple rule. Though not easily put in place, nevertheless, they offer rather obvious *guidelines* for CEOs to use in creating such networks.

Like any building, organizational cellular networks need constant maintenance, even if they are built perfectly in the first place. Since any real-world network is highly likely to have been built *imperfectly* to begin with, ongoing maintenance and improvement—even remodeling—are essential. While forces of erosion and parts failures plague all buildings, these forces seem relatively slow as compared to the interplay of social forces in organizations. The human players operate on a faster time scale; many aspects of their work lives are intangible and, thus, are even more susceptible to change over time. Thomas, Kaminska-Labbe, and McKelvey (2003), focusing on the coevolution of causalities, detail the interaction and coevolution of top-down and bottom-up initiatives, show that it is:

1. Easy for the autonomous bottom-up "force" to become dysfunctional without effective steering;

2. Easy for top-down control to inadvertently shut down autonomous group activity—the cellular network in our case;
3. Difficult to maintain an equal balance of both over the long run; and
4. A network run by semi-autonomous agents is, essentially voluntaristic and, as such, is very sensitive to both effective and ineffective leadership by the CEO.

In organizations falling behind on risk-taking, innovation, good networking, and so forth, the strategic and social skills of the people assembled to form the initial cellular network are critical. Much like the well-known role of a key "product champion" (Clark & Wheelwright 1992) or key "change champion" (Bennis 1969), the founding network members can't be just "ordinary" people—especially those given leadership positions. Absent these "champions" the formation of effective networks seems daunting, indeed. Fortunately, the public record indicates that many, if not most organizations actually have some number of these kinds of people already available. They just need to be identified, collected together, encouraged, and set to work building—or better yet, enabling—connectionist networks. The most relevant example from the past could be the process GM went through in sifting through the many employees that used to work in what became the NUMIE plant in northern California—they had a set of criteria in mind and then searched through some 4000 former employees to find the right set with which to begin the new Toyota/GM production plant. If GM could do it, well, I suspect that just about any firm could do so!!

Rapid operating speed of a cellular network is not easily attained, but *is* readily eroded. Maintaining a high rate of functioning is critical if the network is to stay ahead of changing technologies and markets, changing adaptive tensions imposed from the environment, changing strategies and behaviors of competitors, not to mention emerging patterns foretelling yet to happen nonlinearity events. The 9/11 attack and Enron's bankruptcy are good examples. These nonlinearity events were sending up discernable patterns one or more years in advance. It is just that the FBI and regulators didn't pay attention. Just as players on sports teams age and slow down, so we can expect human and social capital capabilities to age, get into strong-tie cliques, settle into known niches, contexts, vantage points, become encumbered by path dependencies, and so on, all of which work to slow down novelty development and pattern-finding searches.

3.3 LEADERSHIP PROBLEMS

Some of the foregoing simple rules are more vulnerable to traditional leadership styles than others, though all are apt to be undone by mismanagement. The invidious aspect of the problem is that the more a "charismatic visionary" leader (Bennis 1996; Waldman & Yammarino 1999) *tries* to lead an autonomic network, the worse the situation is apt to get. In other words, the more leaders use top-down enforced goals and objectives (point attractors) to try to create well-working connectionist cellular networks, the more they will actually destroy them, or worse, turn them into network engines working against them rather than for them (see the review of "natural system" emergence by Scott 1998). As previously discussed, adaptive tension is a fundamental means of not only energizing the autonomic network but also for aligning agent purposes with those of the firm. CEOs who do not use the rules described previously, to incentivize and steer the agents in the network, will inadvertently end up with the opposite of what they strive for.

3.3.1 THE VISIONARY LEADER PROBLEM

As noted above, all simple rules are necessary (but not sufficient) to build semi-autonomic human connectionist networks. But some are more vulnerable to traditional leadership styles than others. I list these in shortened form next, using the numbering from the original list above:

1. Heterogeneous agents…
3. Moderate # of connections…
6. Nearly decomposable cells (modules)…
7. Imposed adaptive tension…
8. 1st and 2nd critical values…
9. Strange attractor limit setting…
11. Coevolution and its management

Marion and Uhl-Bien (2001, 2003) and Uhl-Bien, Marion, and McKelvey (2003) give much more detailed analyses of just how much traditional leadership, even what Bryman (1996) calls "new" leadership, is antithetical to the kind of CEO leadership required in the modern knowledge economy to create and maintenance cellular networks envisioned by Miles et al (1999). There can be no doubt that all of the "best-practices" in leadership, as developed from the past three decades, are totally inappropriate for what CEOs need to do in firms aiming to compete in the 21st century.

3.3.2 THE CELEBRITY LEADER PROBLEM

The "celebrity leader," who is hired at a very high price to come in and turn around a firm, dominates much of the modern business media and seems to be the most sought-after person to bring about significant change. Opposite is the research by Collins (2001) who finds that, over the years, the self-effacing, internally grown leader has made a much more lasting contribution. It is difficult to imagine conditions where most current celebrity leaders could come in and accomplish what I have in mind. Remember, Jack Welch wasn't a celebrity leader brought in from outside, he worked his way up the GE ladder in chemical engineering.

Without knowing much if anything about complexity science, Welch nevertheless developed a leadership approach that appears to exhibit many of the "management by tension" and "making the coevolving network work" ideas at the core complexity-science and my application of it to CEO-leadership aimed at setting cellular networks in motion. I have already incorporated my interpretation of his simple rules (from Kerr, 2000) in bullet # 12 above. I think that it is not by chance that his early experience chemistry and Ph. D. in chemical engineering laid the groundwork for thinking of (chemicals/people) under (energic/adaptive tension), finding (special molecules/human capital), and the importance of social capital emerging from studies of chemical bonding. Whereas physicists and biologists spend most of their time explaining order that already exists, chemists spend most of their time looking for new molecules—new order. As a result, they think differently.[6]

In going down the list of bulleted "necessary" conditions, I think it unlikely that an outsider can come in and put in place the kind of CEO-level leadership that can create cellular networks. I do believe, however, that a CEO, having learned how to do it in one firm, could then do it again in other firms. But I qualify this in recognition that most of the GE-trained executives that have left to become CEOs of other firms have had little positive impact. In fact, according to a recent *Wall Street Journal* story, and our own analyses, they mostly have had a quite negative impact.

Of course, just because a CEO is an insider and self-effacing does not, willy-nilly, mean that he/she is automatically a master at using the network-architecture elements I suggest earlier. But it would appear that some of the preconditions are in place for identifying the starting "network champions," initializing the relevant absorptive capacity, and having enough feel for the best direction of the firm and enough sense about its current adaptive tension contexts to take on the needed initializing of "*management by tension*" and subsequent steering activities.

4 CONCLUSION

Intangible assets—human and social capital—and speedy adaptation rates, are critically important as firms enter the 21st century. CEOs seem poorly prepared for either of these conditions because the CEO firing rate is up (Bennis & O'Toole 2000, *The Economist* 2001). Bennis and O'Toole, and all the other "traditional" leadership theorists (Dansereau & Yammarino 1998a,b) have relied on the following "VCC" mantra for some 50 years: *The answer lies with* "*CEO Vision, Charisma, & Control*." It might as well be blowing in the wind. Many scholars have joined to create a new approach, culminating in Miles et al.'s "*cellular networks*," and yes, high velocity adaptation (Eisenhardt 1989, Prusak 1996). Traditionally the need for speed encourages even more CEO reliance on the VCC mantra. Cellular networks are, indeed, slower to initiate but faster to produce effective adaptive solutions in the long run.

In developing my rationale for a "simple rule" approach to leadership theory, I begin with Ashby's (1956) classic statement that "*It takes variety to destroy variety*." Opposite Thompson's (1967) top-down, executive-control based view, Mélèse (1991) and Simon (1999) argue for a bottom-up approach. This is exactly what Miles et al.'s cellular network is aimed at accomplishing. In addition, I point out that social networks in organizations, along with rapid pattern processing capabilities (Boisot & McKelvey 2003), are critical for high corporate IQ—that is, a firm's ability to process, learn, and remember information and knowledge (McKelvey 2000, 2001, 2003b). I follow this with a review of why traditional leadership theory fails in the world of modern CEOs—and why they get fired as a result. My critique draws from an appreciation of the knowledge economy from the perspective of complexity science. Mine is followed by a critique of "new leadership theory" by Marion and Uhl-Bien (2001, 2003). My review ends with findings from a new study by Thomas, Kaminska-Labbe and McKelvey (2003) suggesting that driving forces in organizations coevolve and that the classic control/autonomy duality is best seen as "*tangled*" (Dumont 1966, Dupuy 1992), coevolving, and always in motion rather than something that can be balanced or optimally designed into stasis—like a machine.

The VCC mantra leaves CEOs and so-called leadership gurus looking for vague, ephemeral, personal qualities like "vision" and "charisma," and of course "control," because how else can a CEO make sure that everyone else in his/her firm is carrying out the vision? I suggest, instead, a set of simple rules for CEOs to follow. The rules are simple, but they really act as guidelines for CEOs to follow in setting up the much more complicated human connectionist cellular networks. Simple rules work for simulated agents in computers, but admittedly the real world is more difficult to deal with. Still, my "rules" set forth the essence of what CEOs need to focus on to "enable" the creation and maintenance of corporate cellular networks without inadvertently setting the VCC mantra in motion. My rules draw on *New Science* (Wheatley 1992, McKelvey 2002, 2003b,c) to help CEOs deal with the *New Economy*. The rules I present are:

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[6] I suppose chemical engineering is half way between chemistry and physics. I am assuming that a chemical engineer has some considerable knowledge of chemistry, chemical bonding, and especially processes used to find new molecules.

1. Assemble Heterogeneous Agents;
2. Assure Human Capital Formation;
3. Aim for "Moderate" Numbers of Connections;
4. Create Appropriate Physical Conditions;
5. Arrange Coaching;
6. Aim for Near Decomposability;
7. Take Advantage of Adaptive Tension;
8. Work with the Critical Values;
9. Set Up Strange Attractors;
10. Create Periodic Weak Tie Flooding;
11. Manage Coevolution;
12. Set Up Appropriate Incentive Structures.

As you can see, and appreciate even more strongly after reading my foregoing more detailed discussion of these earlier, this view of what Marion and Uhl-Bien (2003) call "'*new*' new leadership" is strikingly different from the VCC mantra. *There IS an alternative to VCC*! Of course, "new" new leadership is not a quick fix that can be installed over night (Uhl-Bien, Marion & McKelvey 2003). What is important is that it does bring *New Economy* and *New Science* thinking together to offer CEOs a better way to bring old-line firms into the *New Age*—the 21st century.

[13,538 words]

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Table 2 Definitions of Kinds of Complexity by Cramer (1993)*

'***Newtonian complexity***' exists when the amount of information necessary to describe the system is less complex than the system itself. Thus a rule, such as $F = ma = md^2s/dt^2$ is much simpler in information terms than trying to describe the myriad states, velocities, and acceleration rates pursuant to understanding the force of a falling object. "Systems exhibiting subcritical [Newtonian] complexity are strictly deterministic and allow for exact prediction" (1993, p. 213) They are also "reversible" (allowing retrodiction as well as prediction thus making the 'arrow of time' irrelevant (Eddington 1930, Prigogine and Stengers 1984).

At the opposite extreme is '***stochastic complexity***' where the description of a system is as complex as the system itself—the minimum number of information bits necessary to describe the states is equal to the complexity of the system. Cramer lumps chaotic and stochastic systems into this category, although deterministic chaos is recognized as fundamentally different from stochastic complexity (Morrison 1991, Gell-Mann 1994), since the former is 'simple rule' driven, and stochastic systems are random, though varying in their stochasticity. Thus, three kinds of stochastic complexity are recognized: ***purely random***, ***probabilistic***, and ***deterministic chaos***. For this essay I narrow stochastic complexity to deterministic chaos, at the risk of oversimplification.

In between Cramer puts '***emergent complexity***'. The defining aspect of this category is the possibility of emergent simple deterministic structures fitting Newtonian complexity criteria, even though the underlying phenomena remain in the stochastically complex category. It is here that natural forces ease the investigator's problem by offering intervening objects as 'simplicity targets' the behavior of which lends itself to simple rule explanation. Cramer (1993, p. 215–217) has a long table categorizing all kinds of phenomena according to his scheme.

* For mnemonic purposes I use '*Newtonian'* instead of Cramer's "subcritical," '*stochastic'* instead of "fundamental," and '*emergent'* instead of "critical" complexity.

Table 3 Definitions of Attractors by Gleick (1987)

"***Point attractors***" act as equilibrium points. A system, even though oscillating or perturbed, eventually returns to repetitious behavior centered around the point attractor—traditional control style management decision structures may act in this manner (appearing as Newtonian complexity);

"***Periodic attractors***" or "*limit cycles*" (pendulum behavior) foster oscillation predictably from one extreme to another—recurrent shifts in the centralization and decentralization of decision making, or functional specialization vs. cross-functional integration fit here (also appearing as Newtonian complexity);

If adaptive tension is raised beyond some critical value, systems may be subject to "***strange attractors***" in that, if plotted, they show never intersecting, stable, low-dimensional, nonperiodic spirals and loops, that are not attracted by some central equilibrium point, but nevertheless appear constrained not to breach the confines of what might appear as an imaginary bottle. If they intersected, the system would be in equilibrium (Gleick 1987: 140) following a point attractor. The attractor is "strange" because it "looks" like the system is oscillating around a central equilibrium point, but it isn't. Instead, as an energy importing and dissipating structure, it is responding with unpredictable self-organized structure to tensions created by imposed external conditions, such as tension between different heat gradients in the atmosphere caught between a hot surface of the earth and a cold upper atmosphere, or constraints in a fluid flow at the junction of two pipes, or tension created by newly created dissipative structures, such as eddies in a turbulent fluid flow in a canyon below a waterfall, or "MBA terrorist" structural changes imposed in an attempt to turnaround an acquired firm.

As a metaphor, think of a point attractor as a rabbit on an elastic tether—the rabbit moves in all directions but as it tires it is drawn toward the middle where it lies down to rest. Think of a strange attractor as a rabbit in a pen with a dog on the outside—the rabbit keeps running to the side of the pen opposite from the dog but as it tires it comes to rest in the middle of the pen. The rabbit ends up in the "middle" in either case. With the tether the cause is the *pull* of the elastic. In the pen the cause is *repulsion* from the dog unsystematically attacking from all sides.