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INTEGRATING MODERNIST AND POSTMODERNIST PERSPECTIVES ON ORGANIZATIONS: A COMPLEXITY SCIENCE BRIDGE

MAX BOISOT
ESADE

BILL McKELVEY
University of California, Los Angeles

Competition between modernism and postmodernism has not been fruitful, and management researchers are divided in their preference, thereby undermining the legitimacy of truth claims in the field as a whole. Drawing on Ashby's Law of Requisite Variety, on complexity science, and in particular on power-law-distributed phenomena, we show how the order-seeking regime of the modernists and the richness-seeking regime of the postmodernists draw on different ontological assumptions that can be integrated within a single overarching framework.

The study of social systems such as organizations has long been caught between two conflicting bases of legitimacy. On the one hand, we have *positivism*—a set of procedures for creating valid knowledge expressing a *modernist* outlook that originated in the eighteenth century *Enlightenment* project. Positivism presumes a real, relatively stable, and objectively given world, populated by phenomena that can be rationally known and rationally analyzed by independent observers. Such phenomena can be decomposed into observation protocols resting on sense data and predictively related to each other through stable laws integrated via a mathematical syntax (Benacerraf & Putnam, 1964; Lakatos, 1976). Positivism promotes the modernist agenda: the understanding, manipulation, and control of predominantly physical phenomena for beneficial social ends. In contemporary social sciences, neoclassical economics remains positivism's foremost exemplar (Colander, 2006; Friedman, 1953; Lawson, 1997; Mirowski, 1989).

On the other hand, we have *postmodernism*—a movement that emerged in the late 1960s to challenge the basic tenets of modernism and its epistemological ally, positivism. Whereas in modernism the focus is on a phenomenal world directly and unproblematically observed and described by a disinterested actor who remains external to what is being observed, the postmodernist strategy problematizes the relationship of actors to observed phenomena by having language mediate it. Thus, instead of a single direct relationship between an external world, *W*, and an observer, O, we now have two relationships: (1) between an external world, *W*, and a descriptive language, *L*, and (2) between *L* and an observer, O. Language is a *human* resource that places the relationship between *W* and O in a social context where divergent interests (Habermas, 1972) and social power (Foucault, 1969) come into play. These shape language and linguistic usage and, by implication, the regions of the phenomenal world to which they give access. Language, the postmodernists argue, is not a neutral observation tool. It shapes observations in ways that reflect the ontological assumptions of a particular community of observers (Berger & Luckmann, 1966; Kuhn, 1962). Postmodernism, initially a literary movement, emerged in response to the linguistic turn in philosophy. Its claim that "everything is text" (Derrida, 1978) highlights the mediating role of language linking observers to their worlds (Lyotard, 1984; Rorty, 1980).

Organization theory has been pulled in opposite directions by modernist and postmodernist ontologies. Organizational scholars, thus, are caught between two conflicting bases of legitimacy, with little overall consensus on what constitutes valid truth claims. Practitioners have, then, little reason to act on the research findings of academics in open disagreement about their discipline's foundations. Absent any faith in what the positivists are measuring—as they juggle with sample sizes, normal distributions, means, variance, probabilities, and statistical significance—managers will settle for gripping corporate yarns that gain traction from vivid and compelling narratives readily remembered and retold. A good story loads on the dependent variable with gay abandon, leveraging "samples of one" (March, Sproull, & Tamuz, 1991) into universal managerial truths. It constitutes a *meme* (Blackmore, 1999; Dawkins, 1976) that propagates owing to its plausibility, its internal coherence, and its alignment with the experience of its intended audience, rather than any objective probability that it might be true.

If, following the Chicago School Pragmatists (Dewey, 1925; James, 1907), we take knowledge to consist of actionable beliefs, we can view modernism as attempting to substantiate these beliefs according to rationally derived principles and rules. Postmodernism challenges this strategy as suppressing voices that fail to fit the rationalist straitjacket (Calás & Smircich, 1999). While it stabilizes and delineates our different identities, modernism also limits our inherent complexity and potentiality (Deleuze & Guattari, 1984). Order and organization are thus transient achievements based on an infinite rather than a limited set of possibilities, the products of what Deleuze and Guattari call "chaosmosis" (Carter & Jackson, 2004). The proliferation of unconstrained beliefs, however, makes them vulnerable to biases. Which ones, then, form a legitimate basis for action? Does the need to act suggest that we should accept modernist constraints while recognizing them to be contingent? Or should we abandon these as essentially arbitrary and, following Feyerabend (1975: 296), argue that "anything goes?" If so, can organizational research still call itself a science-based "discipline"?

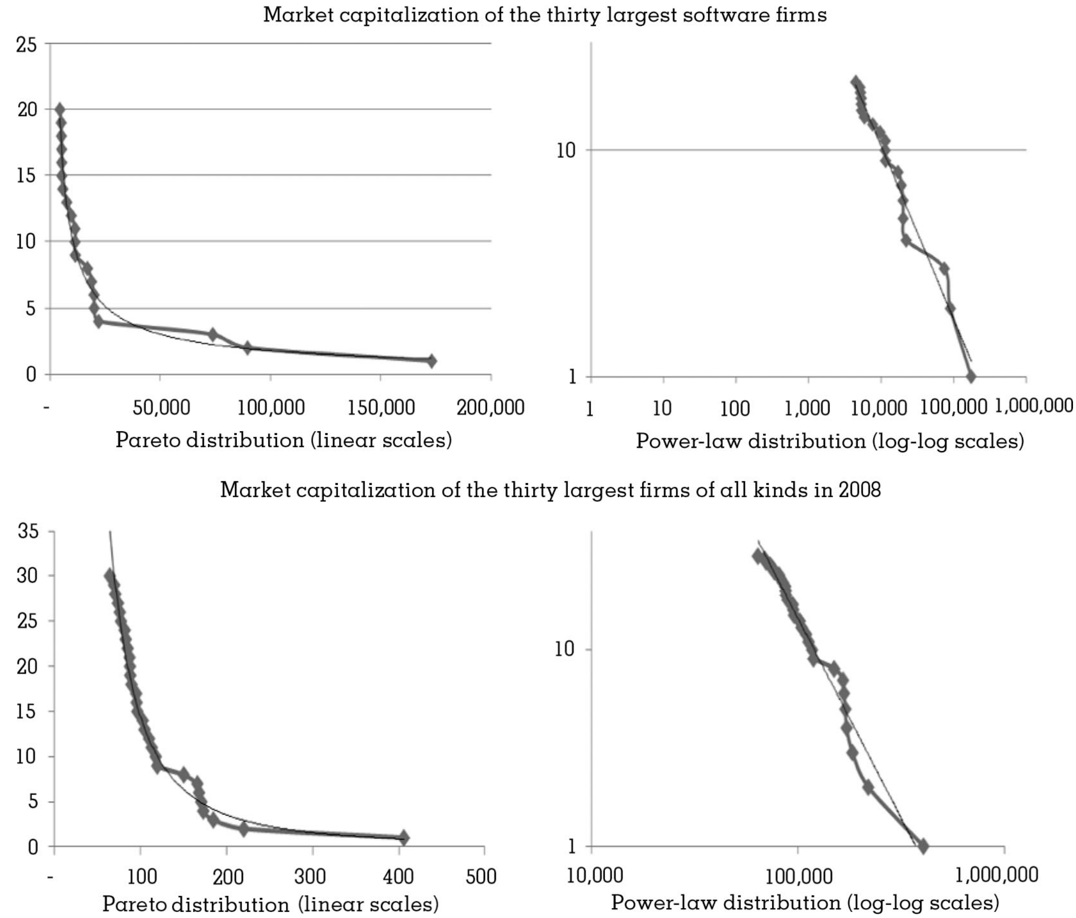
We offer a third alternative that draws on several well-known complexity principles to integrate the ordered world of modernists and the more "chaotic" world of postmodernists. We posit that the conjunction of *adaptive tension*—the gap between the variety internally available to a system and that which confronts it externally (McKelvey, 2001, 2008)—connectivity, and interdependency in social phenomena reflects these principles and challenges the dominant assumption that social events are independent of each other and identically distributed (*i.i.d.*) so as to yield a normal distribution. Such a "Gaussian" default assumption underpins an *atomistic ontology*, one that takes the world as constituted by a collection of objects. Many events connected under tension, however, are often distributed according to a power law, as illustrated in Figure 1, which shows two Pareto distributions on the left and their equivalent power-law distributions on the right. A power-law distribution is a Pareto distribution depicted on a log-log scale. Other (less extreme) skew distributions, reflecting the different ways that phenomena interact, are also possible. Here we focus on rank/frequency power laws.

In the upper left of Figure 2, we show a stylized representation of the myriad small outcomes—such as the approximately 16,000 Californian quakes that go unnoticed each year, or the 17 million ma & pa stores that didn't become Walmarts—that econometricians usually treat as *i.i.d.* and summarize with a normal distribution.[1] Toward the lower right of the figure, in contrast, we see the increasingly high-ranked, very rare, *extreme* outcomes that defy prediction—that is, earthquakes, floods, bankruptcies, stock market crashes, giant firms (Microsoft, Walmart, etc.), and giant cities.

The complex causal connections that, under tension, generate power-law distributions do not allow us to distinguish ex ante what is usable information from what is noise. Any one of the tiny events located in the upper-left region of Figure 2 could initiate a causal chain reaction, generating an extreme outcome located in the lower-right region of the figure. The Gaussian default assumption is therefore easy to make. Figure 2, however, underpins a *connectionist ontology* that takes the world's fundamental constituents to be relationships. In contrast to normal distributions, power-law distributions have long tails, potentially infinite variance, unstable means, and unstable confidence intervals (Andriani & McKelvey, 2007). If Gaussian thinking takes extreme events to be outliers—too different from other events in the sample to be enter-

[1] "Robustness" techniques (Greene, 2002) translate skew distributions into normal ones—that is, by making the *x* axis a log scale so as to produce a log-normal distribution.

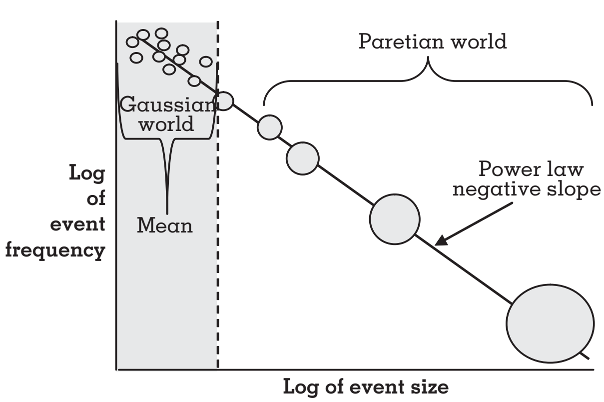
FIGURE 1
From Pareto to Power-Law Distributions: Two Examples—Pareto on Left, Power Law on Right[a]



[a] Reproduced from Glaser (2009).

tained as probable and, thus, to form part of the distribution being studied—power laws incorporate outliers as a significant part of the distribution and therefore meriting attention. Even if they cannot make them *probable*—unstable means and potentially infinite variances prevent it—power laws signify the existence of scale-free phenomena worthy of our consideration. Their scalability—that is, the causal dynamics stemming from multiplicative subunit interactions to produce similar outcomes at multiple hierarchical levels (e.g., network organizations such as the Internet)—renders them *plausible*.

FIGURE 2
Stylized Power-Law Distribution



Numerous complexity researchers (Andriani & McKelvey, 2007, 2009; Newman, 2005; West & Deering, 1995) have found power-law distributions to be ubiquitous in social no less than in natural systems. They have captured social phenomena ranging from the large number of statistically similar entities located in one tail of the distribution to the $N = 1$ extreme outcomes best studied by hermeneutics methods in the other. We argue that modernists and postmodernists have each got hold of one tail of a distribution in which extreme outcomes are not random outliers as interpreted by Gaussians but, rather, the product of tension and connectivity effects. These shift a distribution from an *i.i.d.*-based normal distribution to a power-law distribution. While other distributions are, of course, possible, omitting these from the discussion does not affect the thrust of our argument. Understanding what drives the distribution of social phenomena at different levels of organization allows us to integrate the seemingly opposed modernist and postmodernist epistemologies into a unitary representation. Locating them both along a single causal continuum enhances the epistemic legitimacy of each in the eyes of the other.

The structure of our article is as follows. First, we briefly provide working definitions of the modernist and postmodernist positions. To show where they differ, we present these as idealizations, hoping that readers will see beyond the resulting simplifications. Following this, we draw on Ashby's concept of requisite variety to offer a complexity perspective on the challenges of adaptation. We argue that such a perspective illuminates the modernist/postmodernist debate. We then apply our analysis to organizations and explore its implications for organizational research. We end with a conclusion.

MODERNISM VERSUS POSTMODERNISM

Defining Modernism

Modern science is one of the fruits of the Enlightenment's modernist project. Insofar as the social sciences promote the understanding and use of science to improve modern society, they also pursue a modernist agenda (Israel, 2001). While positing the epistemological and moral unity of mankind (Hollinger, 1994), the modernist project "assumes that human beings are autonomous subjects, whose interests and desires are transparent to themselves and independent from the interests and desires of others" (Calás & Smircich, 1999: 653). Bacon and Descartes are considered to be the main proponents of this "atomistic" ontology (Hollinger, 1994).

Modernism sought knowledge outside religious revelation; Baconian science argued for the empirical rather than the faith-based justification of truth claims. Truth arose from a correspondence between a claim and empirically observed facts, rather than divinely sanctioned revelations transmitted through sacred—and, hence, unmodifiable—texts. This required the repeatability or replicability of facts and the rejection of one-shot events such as miracles. Objectivity, however, could only be fully achieved by an independent and decontexualized observer endowed with a god's eye view—a "view from nowhere" (Shapin & Schaffer, 1985).

If modernism constituted a world view, the rise of positivism at the end of the nineteenth century provided it with a methodology. Ernst Mach's rebellion against Hegelian idealism gave rise in 1907 to the Vienna Circle, a group of physicists and mathematicians whose dream was the attainment of absolute verified truth ("verificationism") based on a rigid correspondence ("correspondence theory") between operational measures and theory terms (Suppe, 1977). Modernism and its methodological handmaiden, positivism, have long underpinned the epistemic legitimacy of the natural sciences. Being essentially concerned with what Reichenbach (1938) called "the context of justification," however—justification being one of Plato's prerequisites for genuine knowledge—modernism and positivism showed little interest in what Reichenbach called "the context of discovery." If, for Bacon, genuine knowledge yielded prediction and control, and hence a basis for action, these forms of justification would separate science from superstition, alchemy, religion, and faith-based revealed truth. Into this world of apodictic certainties, Reichenbach introduced the idea that probabilistic thinking offered a more realistic basis for justification. With Brown's "Brownian Motion" in 1827 (Ford, 1992), Boltzmann's statistical mechanics of 1877 (Boltzmann, 1887), Gibbs's statistical actuarial tables for the insurance industry in 1902 (Gibbs, 1902), and Fisher's statistics of 1916 (Fisher, 1918), a shift occurred, endorsed by Reichenbach (1938), from exact to probabilistic representations.

In a noisy world the structures underpinning the replicability of independent events are captured statistically by the mean. In the case of normal distributions, the variance could often conveniently be treated as mere noise—something to be got rid of rather than explored. Over time, the normality of a distribution became the default assumption—the taken for granted signature of a universal reality that yielded stable, manipulable objects. Gaussian statistics, the statistics of the normal distribution now widely applied in the social sciences (e.g., Greene, 2002), delivers stable means, finite variances, and independent data points (Andriani & McKelvey, 2007; Taleb, 2007). The social sciences, epitomized by neoclassical economics, thus created for themselves the stable and (mostly) computationally tractable social *objects* that had been the focus of Newtonian physics (Colander, 2006; Friedman, 1953; Mirowski, 1989), while at the same time eschewing the more complex, messy interactive and dynamic social *processes* characterizing human social behavior.

Gaussian-inspired statistical truths artificially structure the world so as to achieve significant reductions in complexity, a demultiplication of explanatory entities, and a consequent reduction in the required degrees of freedom—that is, the number, *n*, of observed events that are free to vary minus the number of necessary relations, *r*, obtainable from these observations (Walker, 1940). In line with Occam's razor—the *explanans* should always be more compact than the *explanandum*—they achieve *compressibility* and *parsimony* (Hempel, 1965). In modern cosmology the search for a theory of everything illustrates this concern with compressibility and parsimony (Guth, 1997; Weinberg, 1992). In addition to its parsimony, a theory's worth is also based on its predictive power. Predictability as such, however, does not always require understanding (Bridgeman, 1936). As Feynman famously pointed out, despite its remarkable predictive achievements, "No one really understands quantum mechanics" (1967: 129).

The modernist approach has not gone unchallenged. Unlike the physical sciences, the social sciences have to deal with the fact that although the people they study are subject to physical forces, they act primarily on the basis of representations and interpretations of the world that make *meaning* central to explanations of their behavior. The inability of the physical sciences to deal with the vexing question of meaning led to the rejection of the modernists' stance as a whole by many social scientists. After all, what, exactly, constitutes "replicability" when dealing with a complex social or organizational phenomenon? In what respect might two complex social outcomes be sufficiently similar to justify a claim of replicability? And how robust is the concept of intersubjective objectivity—modernism's substitute for the god's eye view—given the social distribution of power, influence, and bias (Foucault, 1969; Shapin & Schaffer, 1985)? If questions like these suggest an unbridgeable gulf between the natural and the social sciences, sociologists of science go further, pointing out that in the natural sciences no less than in the social sciences, problems of interpretation, meaning, status, and power effectively contaminate all claims to objectivity (Callon, 1986; Golinski, 1998; Latour, 1988). No student research assistant in any physics or biology laboratory long remains unaware of what results the professor wants to see!

Defining Postmodernism

Alvesson and Deetz see modernism as

> the instrumentalization of people and nature through the use of scientific-technical knowledge (modeled after positivism and other "rational" ways of developing safe, robust knowledge) to accomplish predictable results measured by productivity and technical problem-solving leading to the "good" economic and social life, primarily defined by accumulation of wealth by production investors and consumption by consumers (1996: 194).

Postmodernists hold that such scientific knowledge, shaped by local historical and cultural contexts, represents one story among many (Calás & Smircich, 1999)—a social construction serving the ideological agenda of powerful elites (Koertge, 1998). The postmodern perspective challenges the Enlightenment project by introducing a radical subjectivity and the exercise of power as irreducible constraints on our access to an objective world (Foucault, 1975). To postmodernists, the world—especially the social world—is *not* objectively given. It is kaleidoscopic and unstable, and its constituent components are elusive. The stability that we impute to it and from which we derive laws and theories is partly shaped by our interaction with other observers. Postmodernists therefore distrust the modernist's summary Gaussian descriptions and the confident narratives these produce (Lyotard, 1984).

Postmodernist epistemology is profligate rather than parsimonious. By entertaining multiple representations of phenomena ("voices") as equally valid alternatives, postmodernists shun what they see as the exclusions and repressions underpinning the modernists' claims to singular objective representations. Postmodernists seek "infinite conversations" undistorted by power considerations (Derrida, 1978; Foucault, 1975; Rorty, 1989). Their emphasis on "playfulness" is designed to counter a desire to control everything and the despair at not being able to do so. Life in all its richness and messiness is more important to postmodernists than the impoverished conceptions of it found in psychology, economics, and other positivist-leaning social sciences. Expressed as a statistical strategy, postmodernists invite us to focus on the rich promises latently present in the variance rather than on an impoverished mean. They believe that either the social sciences accommodate the theses of postmodernity or they become irrelevant.

Postmodernism is a broad church that accommodates a multiplicity of views—not always harmoniously (Jenks, 1992). It challenges modernism's unitary vision of science and society, deconstructing the modernist object of study, revealing the fragility of the assumptions underpinning its stability, and greeting modernism's metanarratives with incredulity. Lyotard (1984) would replace these with petit récits—modest narratives—which, like Merton's theories of the middle range (Merton, 1949), would be of limited spatiotemporal reach. Yet while these might promote awareness and reflexivity, they render theorizing elusive (Calás & Smircich, 1999) since, trapped as they are in local Wittgensteinian language games, there is no basis for choosing between competing representations: meaning now becomes undecidable. In fact, modernism overreaches precisely when its all-encompassing metanarratives—Marxist, Parsonian, and so forth—encounter Lyotard's local petit récits. Being embedded and contextual, the latter, far from scaling up into metanarratives, constantly challenge the former's relevance and validity.

In contrast to the natural sciences, postmodernism massively increases the variety of phenomena that social scientists are required to deal with. These can be viewed as manifestations of complexity at work; they point to higher levels of interaction and interdependence among phenomena and to the irreversible effects of time and path dependency. In effect, postmodernism is a theory of *social complexity* (Cilliers, 1998). Assumptions of independence among phenomena are here challenged by the operation of dense feedback loops—both positive and negative—generated as much by how intentional agents construe events (Dennett, 1989) as by physical causal links among them. Given complex interdependencies, focusing exclusively on the mean of a distribution becomes dysfunctional and misleading since its variance now contains much of the relevant information; it is more than just noise.

Given complex interdependencies within densely connected causal networks, how do we proceed? The connectionist ontology implicitly underpinning postmodernism massively increases the number of plausible patterns needing causal analysis and interpretation. For postmodernists, however, computational convenience does not constitute an epistemic justification for a reductionist stance, so Occam's razor is of little use; the complexity must be absorbed and lived with rather than reduced (Boisot & Child, 1999). Postmodernists are interested in unpredictable and emergent phenomena rather than predictable regularities—in process rather than structure. Their methodological preference is for qualitative case-based research. In any tradeoff between understanding and prediction, *understanding should take precedence*.

Postmodernism itself, however—the pursuit of "infinite conversations"—has also come under fire. The relativism resulting when one theory is deemed as good as another and equal airtime is given to all (Hollis, 1982), or when paradigms cannot be reconciled (Kuhn, 1962), makes it impossible to compare, evaluate, and select from competing alternatives. The primacy postmodernism accords to the chaotic nuances generated by the swaying of individual "trees" at the expense of *patterns* discernible in the "forest" effectively paralyzes theory choice, thus undermining justification and practitioner relevance. Yet without a timely and "justifiable" consensus, productive social action becomes impossible. This poses a challenge to management inquiry interested in both valid truth claims and actionable outcomes. How can it contribute to practical action if (1) truth claims cannot be disentangled from the "situated" interests that give rise to them; (2) truth claims are framed in incommensurable languages; (3) competing alternatives are incommensurable across observers;

and (4) any convergence achieved across alternative truth claims reflects the influence of status, power, repression, and coercion?

In what follows we argue that modernism and postmodernism are not so much competing alternatives as alternative *moments* in a single dynamic process of human adaptation to both natural and social phenomena.

ADAPTING TO COMPLEXITY

In the human case, adaptation is about how to respond intelligently to the threats and opportunities embedded in the variety of natural and social phenomena confronting us as a species. To repeat, variety is often the surface manifestation of complexity at work. Since what distinguishes modernists from postmodernists is how they approach this variety, we take it as the starting point for our discussion. In biology the issue is often framed in evolutionary terms—alternative framings are possible (Dooley & Van de Ven, 1999). We draw on the biological approach and apply it to the human and organizational realms.

The Law of Requisite Variety

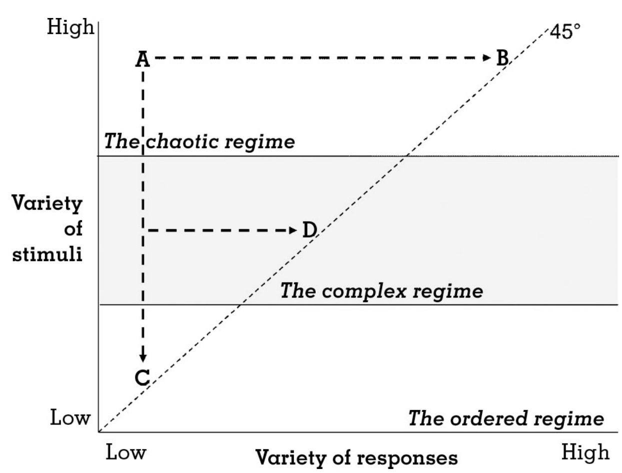
Ashby's Law of Requisite Variety states that "ONLY VARIETY CAN DESTROY VARIETY" (1956: 207). The law holds that for a biological or social entity to be adaptive, the variety of its internal order must match the variety imposed by environmental constraints. We treat variety as a proxy for complexity (McKelvey & Boisot, 2009). Gell-Mann (1994) holds that emergent complexity is a function of the variety present in phenomena. Wherever the variety externally imposed on an adaptive biological or social system exceeds that internal to the system, there emerges an *adaptive tension* (McKelvey 2001, 2008) within it that fills the gap between what the environment requires of the system to ensure its integrity or survival and what it can actually deliver at a given moment.

Although Ashby's law tells us nothing about the nature of the external complexity a system must respond to, the fact that systems such as ourselves adapt and survive suggests that within a certain range such complexity must be manageable. Not all of it will be relevant to the system's survival. Gell-Mann (1994) distinguishes between a "crude complexity" indistinguishable from randomness residing in phenomena and an "effective complexity" residing in the regularities underpinning their structure. By focusing on effective complexity, a system can respond in selective and discriminating ways to the massive variety it confronts (McKelvey & Boisot, 2009).

The Ashby Space

We explore the difference between crude and effective complexity in a diagram (Figure 3) that we label the *Ashby Space* (Boisot & McKelvey, 2007). The vertical axis measures the variety of external stimuli that register with an agent; the horizontal axis measures the variety of responses generated by that agent. The diagonal indicates where the variety of responses matches that of incoming stimuli and is therefore adaptive. Above the diagonal, the variety of the responses fails to match that of incoming stimuli; below it, the variety of responses is excessive relative to what is adaptive and wastes energetic resources. We now partition the vertical axis of the Ashby Space into different regimes: *chaotic, complex,* and *ordered*. We could also partition the horizontal axis, but we do not need to do so. In the chaotic regime incoming stimuli exhibit no obviously discernible regularities; in the complex regime they exhibit some, even if these still have to be teased out; in the ordered regime one can subordinate all the variety encountered in incoming stimuli to some ordering principle—for example, algorithmic

FIGURE 3
The Ashby Space



compression—as when, for example, the sequence a,b,a,b,a,b,a,b,a,b,a,b,a,b,a,b,a,b,a,b can be reduced to 10(a,b).

Using this diagram, we offer a complexity-driven interpretation of Ashby's law. The vertical arrow going down from A to C describes a cognitive process of variety reduction that aims to filter out crude complexity and focus on effective complexity. This, according to modernists, requires interpretation and selection—that is, algorithmic compression. If successful, it reduces the variety calling for responses and gradually moves them into the ordered regime. A postmodernist distrusts such moves, arguing that what constitutes effective complexity lies in the eye of the agent and that where adaptive responses need to be collective, the modernist's reductionist strategy is often coercive rather than cognitive in nature.

Although stimuli can appear at any point along the vertical axis, the horizontal arrow proceeding from point A to point B offers the clearest illustration of a postmodernist implementation of Ashby's law. Since postmodernists here find themselves in the chaotic regime, their default assumption is that there will be no effective complexity to be teased out—that is, no robust underlying structure. All is crude complexity. Lacking any agreed upon basis for interpreting the stimuli—that is, for reducing their variety by traveling down the space prior to formulating a response—postmodernists allow the variety of responses to expand until it matches that of incoming stimuli. They, thus, are willing to remain in the chaotic regime until "Nature shows her hand." In sum, in contrast to modernists, whatever the regime they find themselves in, the postmodernists' default preference is to move horizontally across rather than vertically down the Ashby Space. Yet although Ashby himself does not distinguish between crude and effective complexity—between variety that should be treated as noise by the agent and variety that has relevance for it—in attempting to accommodate *all* variety and refusing to be selective, the postmodernists' response is likely to be costly in terms of energy expended and may well overshoot point B on the diagonal where adaptation is achieved.

While there will be many situations in which agents confront regimes that are either wholly chaotic or wholly ordered, many management and organizational research challenges arise in the complexity regime, where both effective and crude complexity operate. Intelligent agents in this regime initially move down from point A toward point C but are led to turn right toward point D when they encounter irreducible uncertainty. Organizational researchers entering this region of the Ashby Space need to tolerate higher levels of epistemic variety than modernists but must then be willing to select from it. In effect, they must become evolutionary epistemologists, progressing toward a higher probability of truth by slowly weeding out inferior theories (Hahlweg & Hooker, 1989; McKelvey, 1999; Radnitzky & Bartley, 1987). They must, however, defer to postmodernist sensibilities by making their selection more forgiving than modernists would wish, but then devise effective procedures to home in on the most promising interpretive schemata. Where a collective interpretation is possible, some of these can gradually be moved into the ordered regime.

Phase Transitions and Scalability

Our discussion so far has centered on the respective responses of modernists and postmodernists to stimuli appearing high on the vertical axis of Figure 3, where the world will be experienced as chaotic. But what determines where on the vertical scale stimuli will actually appear? Complexity science studies elements in interdependency—and increasingly in living systems (Gell-Mann, 2002). Absent such connectivity, one has atomistic aggregations to which *i.i.d.* assumptions apply. Complexity increases with the number of interacting elements and the density and nonlinearity of the interdependent outcomes (Holland, 1988, 2002). Beyond certain thresholds, complexity can lead to phase transitions toward either emergent order—that is, dissipative structures that maintain themselves in existence by continuously importing free energy from their environment and exporting bound energy back into it (Nicolis & Prigogine, 1989)—or greater chaos (Kauffman, 1993; Kaye, 1993).

Some scholars study interdependencies among heterogeneous agents—these could range from nucleotides to individual human beings and to organized collectivities of these—operating at what was early on called the "edge of chaos" but is now seen as a *region of emergent complexity* between the "edge of order" and the edge of chaos. For Nicolis and Prigogine (1989), the edge of order is the "1st critical value"—a level of energy sufficient to cause phase transitions in many physical phenomena (as when the level of heat in a teapot causes a rolling boil). This region of complexity, varying in size (and separating ordered from chaotic regimes), is what Kauffman (1993) labels the *melting zone*. When, through the amplification of feedback, connectivity-enabled interdependencies reach a specific intensity, they can trigger phase transitions from one of the regimes of Figure 3 to another. In some systems new order emerges from such phase transitions when existing structures come to be dominated by unstable modes that become order parameters for a new regime; Haken (1983) describes these as becoming enslaved. His "slaving principle" constitutes a disruption of equilibrium (symmetry breaking; Mainzer, 2007/2004) that reflects choices made by agents within the system.

In social systems such choices may reflect the exercise of power by those in a position to reduce critical uncertainties within the system (Crozier, 1964). Often, the connections themselves are established and amplified when the system is put under adaptive tension—is forced across the edge of order into the melting zone. Here we see tension, such as that between supply and demand, which causes entrepreneurs to start up possibly innovative new enterprises—in effect, phase transitions out of the status quo. Social systems put under tension, through recession, poverty, migration, ethnic conflict, and so forth, can also be torn apart by forces starting with tiny initiating events. Given these conditions, the initiating event may add pressure to neighboring interdependencies so as to take the system up to, if not over, the edge of chaos. An analogy is with a fishing net lying loosely in a pile. Cut one of its cords and nothing happens. Now stretch it taut and cut one of its cords; the cut of one link transmits tension to neighboring links, propagating a tear across the net.

Yet interdependencies are raw materials for any kind of organization. Bak (1996) argued that, to survive, a system must be able to stay within the melting zone, in a state that precariously maintains its effective complexity near the edge of chaos, which he called "self-organized criticality" (SOC). Bak illustrated SOC with a sandpile. Keep adding grains of sand to a sandpile, thus increasing the adaptive tension it is subjected to, and at some critical point the slope becomes steep enough that tiny to large avalanches occur that reduce the steepness of the slope and restore stability. At this point the causal influences generated by the tension become *scalable* and propagate throughout the sandpile in unpredictable ways, influencing grains far removed from each other. The size-frequency distribution of avalanches in the sandpile follows a power law that Bak claimed to be universal. They also exhibit a *fractal structure*—they are self-similar across a range of scales—meaning that their appearance and the underlying causal dynamics are essentially the same across multiple scales or hierarchical levels (Mandelbrot, 1982).

Andriani and McKelvey (2007, 2009) identified such connectivity-based outcomes extending across thirty-two magnitudes of physical phenomena, twenty-seven magnitudes of biological phenomena, and eleven magnitudes of social phenomena. They also showed how pervasive power laws are in physical, biological, social, and organizational phenomena—listing over 100 of the latter. Barabási (2002) saw power laws, scalability, and fractal structures operating in social networks. Here, connections are often established through communication, and their effects, both positive and negative, are amplified through the operation of feedback loops. A power-law distribution includes many social "loners" at one network extreme and a single highly connected "star" at the other. As Brunk observed, "Instead of the bulk of the data being produced by one process and the 'outliers' by another, all events—both minuscule and the historically monumental—are produced by the *same* process in an SOC environment" (2002: 36).

Two Ontologies: Friends or Foes?

Our analysis suggests that we do not have to choose between connectionist and atomistic ontologies. The high variety and low variety they engender, pursued respectively by postmodernists and modernists, are but transitory moments in a broader process in which each has its place. Connectionism and atomism are lenses that we bring to bear on events for particular purposes. Complexity theory—about the dynamics of connectivity and interdependence—provides us with an overarching conceptual framework that accommodates both. Within it, Gell-Mann's concept of effective complexity is well placed to fruitfully integrate modernist and postmodernist insights.

Atomistic and connectionist ontologies are thus complementary and contingent, rather than alternatives. Under certain circumstances, although they do not have to, phenomena *can* connect. When this yields extreme events, we account for them through a detailed retracing of causal connections presented as a *historical* narrative or a case study: the fall of Constantinople, the Cuban Missile Crisis, etc. Yet since these causal connections and the resulting causal patterns are improbable, they do not lend themselves to systematic replication and experimentation. The lessons of history are thus rarely unequivocal. The causal components of an extreme event, taken individually, *may* lend themselves to systematic replication and experimentation, but the predictions yielded by such an atomistic approach remain strictly limited in scope, offering little purchase on the more richly connected patterns typically covered by historical accounts. All attempts at grand narratives ignore this point (Lyotard, 1984). We know, for example, that beyond a certain threshold, social tensions and instability, for good or evil, can throw up charismatic leaders, but we cannot predict when or how. Anticipation rather than prediction is, then, the best that we can hope for.

BRIDGING TO ORGANIZATIONS

To summarize, modernism advances knowledge when phenomena are independent of each other or can be made so via controlled experiments. It targets the ordered regime in the Ashby Space, one in which phenomena can be predicted and responded to efficiently. What we have called an atomistic ontology takes the independence of phenomena as its default assumption, allowing them to be described by a normal distribution. In the case of socially produced knowledge, postmodernism takes this assumption to be an unwarranted simplification of realities that include coercive social processes. It emphasizes the idea that new order creation draws on the arbitrary—and sometimes illegitimate—use of power (Foucault, 1975). Postmodernism implicitly builds on a connectionist ontology and power-law dynamics to argue that there exists no socially legitimate basis for moving down the Ashby Space. Yet modernists and postmodernists are like blind people who have each seized different parts of the complexity elephant, little realizing that their ontologies complement rather than compete with each other. The challenge is to understand when each applies.

Existing Discourse

Modernist discourses seek to maintain a high level of generality that becomes increasingly unsustainable as they travel down the power-law slope of Figure 2, toward ever-smaller samples of ever-larger and more extreme outcomes. In so doing, however, they often impose oversimplified interpretations (i.e., unjustified algorithmic compressions) on the data that may obscure the effects of power and bias. Seeing this, postmodernists challenge the legitimacy of theorizing even in those regions of the power-law slope—the upper-left region of Figure 2—where Gaussian assumptions may actually be warranted. However, by arguing that error-eliminating statistical strategies eliminate more than just errors—they also eliminate "weak voices"—postmodernists underplay the methodological value of replicability and explanatory coverage (Mayo, 1996) that makes some theories more plausible than others.

Since for postmodernists all theory choice is, at base, politically driven, they find no convincing basis for moving down the Ashby Space of Figure 3. Yet the "infinite conversations" they advocate are a luxury that a practical resource-constrained manager can ill afford; they constitute counsels of perfection that have little adaptive potential. Thus, just as the truth claims of the atomistic ontology underpinning modernist discourse become increasingly suspect when made too far down the power-law slope of Figure 2, so the connectionist ontology underpinning the postmodernist discourse overreaches itself when it claims that meaning—belonging as it does to the realm of language and social interaction effects—remains unconstrained by the real-world dynamics operating in the figure's upper-left-hand regions.

Both modernists and postmodernists aim for reliable knowledge, but, holding competing ontologies, they end up talking right past each other. Figure 2, however, suggests that there is a time to be atomistic and a time to be connectionist and that it is the degree of adaptive tension present in a system—as determined by some order parameter—that influences the degree of connectivity present among phenomena. The seemingly incompatible ontologies can thus be reconciled. Given connectivity, one has to accept the possibility of power-law-distributed, occasionally extreme, and unpredictable outcomes and, hence, be willing to settle for being roughly right rather than precisely wrong. In the connectionist world of living systems, the "justification" of knowledge resides primarily in its contribution to efficacious adaptability and survival rather than to the attainment of a predictive law-like truth (Gell-Mann, 2002). Falsification, Popper's (1935) criterion of demarcation between science and nonscience, remains in force since "false" knowledge threatens both adaptation and survival. Sooner or later, reality kicks back (Popper, 1983).

In pursuit of a stable and predictable order, modernists who find themselves in the chaotic regime of Figure 3 aim at reaching point C, located in a region of the Ashby Space where compact statistical representations have purchase. Postmodernists finding themselves in the same regime, in contrast, are drawn toward point B, located in a region where the description of events is incompressible and only detailed narrative is possible. The complexity perspective, however, identifies point D as more relevant to organization science. Given adaptive tension of some kind, intelligent, interdependent agents in the Ashby Space constitute *complex adaptive systems* (CASs; Holland, 1988, 2002) striving for improved fitness, growth, and survival via self-organizing processes that we associate with the complex regime of Figure 3. Many of their interdependent behaviors give rise to scale-free dynamics and result in power laws. In order to economize on scarce energetic and computational resources, for example, many agents typically seek out the ordered regime of Figure 3. Yet because of their own collective actions and unpredictable events, they often find themselves in the chaotic regime.

Organizational researchers study phenomena that typically fall somewhere within the complex regime—that is, they are neither so lacking in structure as to remain stuck in the chaotic regime nor so structured as to end up in the ordered regime. The complex regime is the one in which the power-law distributions of Figure 1 (stylized in Figure 2) make their appearance. Here, compact symbolic representations coexist with more discursive narrative ones. Yet while the ebb and flow of adaptive tension causes behaviors to shift toward the upper left or lower right along the distribution, modernist thinking wants to draw organizational research permanently down into the ordered regime of Figure 3. This accommodates normally distributed phenomena located in the upper-left "Gaussian" region of Figure 2. Postmodernist thinking, on the other hand, believes that the natural home of organization research is the chaotic regime—the region that occasionally produces the unique and sometimes extreme events located in the lower right of Figure 2. Yet since low-to-high variations in adaptive tension often cause scalable outcomes to progress from upper left to lower right down the power-law slope, so should management and organizational analysis. Traveling left *up* the slope, one deduces observable behaviors from underlying patterns in causal dynamics. Traveling from upper left *down* the inverse slope, however, requires more than induction. It calls for an inferential strategy that we label *scalable abduction*. Scalability is what causes the target phenomenon to spiral out into the extreme outcomes located on the lower right of the power-law slope.

Scalable Abduction

According to Peirce, "Abduction . . . consists of examining a mass of facts and in allowing these facts to suggest a theory" (1935: 205). Abduction seeks *inference toward the best explanation*, one that turns on the coherence with which a novel or anomalous event can be related to a background theory (Aliseda, 2006; Thagard, 2006; Thagard & Shelley, 1997). The observed behavior of workers in the Hawthorne experiments, for example, was anomalous relative to prevailing background theories of worker motivation (Roethlisberger & Dickson, 1964). These theories then had to be either modified or broadened to "explain" the anomaly. Scalable abduction infers toward the *best scalable explanation*. As outcomes move down the power-law slope, scalable abduction calls for explanations based on theories about causes operating in the same manner across the multiple levels/scales of a system (Gell-Mann [2002: 23] called this "middle-level" theorizing); it focuses on tiny initiating events coupled with scale-free causes operating from the very small to the very large so as to explain infrequently occurring extreme outcomes. Thus, associating a Gaussian epistemology with the upper-left region of Figure 2 and a "narrative" epistemology with the lower-right region, scalable abduction offers an inferential engine that can travel between them and track the dynamics by which certain tiny events get amplified into extreme outcomes.

When applied to distributions of phenomena governed by power laws, scalable abduction allows one to derive limited but nonetheless useful expectations concerning scale-free dynamics and the causal processes that underpin them. Scale-free dynamics emerge from myriad lower-level "tiny initiating events" (Holland, 2002), some of which propagate out causally and explode into the larger events that make up one end of the power-law distribution (Andriani & McKelvey, 2007, 2009; Gell-Mann, 2002). The metaphor is of a butterfly flapping its wings over eastern Brazil and ultimately triggering a tornado in Texas—a "butterfly event" (Lorenz, 1972). Here, events uncovered at one scale justify some forms of extrapolation out to less frequent, more extreme events at another.

Lying between idiosyncratic inductions and predictions based on deductive tests, scalable abduction offers *anticipation*. Anticipation is "softer" than prediction, bridging between the strong predictive claims achievable in, say, classical physics and the unpredictable, often seemingly chaotic press of singular events confronting us daily at the human scale. Both prediction and anticipation shape our expectations and orient our responses. Both draw on evidence for their justification, although anticipation, often only expressible in a loose, narrative form, achieves less precision than prediction. While predictability is problematic given complexity, anticipation remains fluid with respect to changing conditions and tensions, thereby facilitating adaptive action and survival.

IMPLICATIONS FOR MANAGEMENT RESEARCH

Four points emerge from our analysis:

1. The atomistic and connectionist ontologies that respectively underpin modernist and postmodernist positions have been treated by organizational researchers as being antagonistic to each other (McKelvey, 2003).
2. They each occupy different end points of a power-law distribution that reflects complex dynamics such as SOC and new order creation (McKelvey, 2004).
3. Under adaptive tension, these dynamics connect hitherto disconnected small events so as to produce ever-larger, more complex, but less frequent outcomes (Andriani & McKelvey, 2007).
4. A power-law distribution thus reconciles the two antagonistic ontologies in a single overarching ontology that makes the appropriateness of either modernist or postmodernist perspectives contingent on the degree of tension and connectivity present in the system (stylized in Figure 2).

What implications do the above points carry for organizational researchers? We identify five:

1. Engage with the properties of power-law distributions and the different epistemic strategies in the Ashby Space that these suggest. In this space, for example, the chaotic regime describes the world of Heraclitus, who famously said, "The river where you set your foot just now is gone. Those waters giving way to this, now this" (Haxton, 2001). Frequently, ours is an epistemically fragile world of unique yet connected phenomena that unfold unpredictably and can only be narrated, not analyzed into simplistic formulas. To the extent that living (social) systems exhibit any regularities—that is, phenomena that repeat—we can move down into the complex regime where connections become contingent and some analysis becomes possible. Here we discover the world of power laws—distributions in which small events sometimes scale up into extreme outcomes. Such phenomena cannot be summarily summarized by the means and standard deviations of "normal" Gaussian statistics. Instead of analyses and theories based on our conventional statistical methods, we need scalable abduction and scale-free causal theories (Gell-Mann's middle-level theories [2002]). In Table 1 we briefly define eight of the fifteen scale-free theories that readily apply to organizations (Andriani & McKelvey, 2009).

Epistemic robustness may only be achievable in the ordered regime of the Ashby Space, where normally distributed phenomena are sufficiently similar and disconnected that the statisticians' *i.i.d.* assumptions apply. They can then

TABLE 1
A Sample of Scale-Free Theories of Nature[a]

Theory	Definition
Phase transition	Exogenous energy impositions cause autocatalytic interaction effects such that new interaction groupings form (Prigogine & Stengers, 1997)
Spontaneous order creation	Heterogeneous agents seeking out other agents to copy/learn from so as to improve fitness generate networks; with positive feedback, some networks become groups, and some groups become larger groups and hierarchies (McKelvey & Lichtenstein, 2007)
Preferential attachment	Given newly arriving agents in a system, larger nodes with an enhanced propensity to attract agents will become disproportionately even larger (Barabási, 2002)
Combination theory	Multiple exponential or log-normal distributions or increased complexity of components (subtasks, processes) sets up, which results in a power-law distribution (Newman, 2005; West & Deering, 1995)
Least effort	Word frequency is a function of ease of usage by both speaker/writer and listener/reader (Zipf's [power] Law [1949]), now found to apply to firms and economies in transition (Ishikawa, 2006; Podobnik, Fu, Jagric, Grosse, & Stanley, 2006)
Square-cube law	Surfaces absorbing energy grow by the square, but organisms grow by the cube, resulting in an imbalance; fractals emerge to balance surface/volume ratios (Carneiro, 1987)
Connection costs	As cell fission occurs by the square, connectivity increases by $n(n-1)/2$, producing an imbalance between the gains from fission and the cost of maintaining connectivity; consequently, organisms form modules or cells so as to reduce the cost of connections (Simon, 1962)
Self-organized criticality	Under constant tension of some kind (gravity, ecological balance), some systems reach a critical state where they maintain stasis by preservative behaviors, such as Bak's small to large sandpile avalanches, which vary in size of effect according to a power law (Bak, 1996)

[a] We use eight out of fifteen scale-free theories discussed in Andriani and McKelvey (2009).

be aggregated into stable classes and their behavior deductively predicted. Although these conditions can only be met by some of the phenomena that humans encounter as they go about their business, they do bring better understanding of behavior when applicable. While no natural boundaries separate the three regimes—they interpenetrate—the first is the natural home of the historian, the second of social scientists and biologists, and the third of scientists who study nonliving phenomena. Needless to say, since effective representations in each regime will call for a different mix of narrative and abstract symbolic resources, *epistemic flexibility and tolerance* are called for.

2. Explore the power-law distribution before you exploit it. Complexity and power-law thinking offer researchers and practitioners a choice of strategies. A move toward the world of Heraclitus leads them to samples of one and epistemic fragility. Finding themselves in unfamiliar territory, they are in March's (1991) *exploratory* mode of learning and must behave like hunter-gatherers. A move toward the world of normal distributions, in contrast, leads them toward large *i.i.d.* samples and epistemic robustness. Here the territory is more familiar, allowing them to operate in March's *exploitative* mode of learning and to behave like settled farmers (Hurst, 1995). It is in the world of power-law distributions, however, that management and organizational researchers operate in frontier scientific territory and have to balance out exploration and exploitation as described by March—call this "homesteading."

Good science requires us to deploy a research strategy appropriate to our epistemic circumstances. Hans Reichenbach, a friend of the Vienna Circle, claimed that exploration—he called this "discovery logic"—was of no interest to the philosophy of science. Only exploitation—"justification logic"—was of relevance (Reichenbach, 1938). Yet the positivists advocated so stringent a conception of knowledge that neither the natural nor the social sciences could satisfy it. But we don't get to exploit anything unless we have paid our dues in the coin of exploration. Homesteading precedes farming, and a long period of hunter-gathering may, in turn, precede homesteading. Effective research requires us to travel up and down the Ashby Space—and, by implication, in both directions along the stylized power-law distribution of Figure 2. There is scope for a division of labor since differences in the cognitive style of researchers will push them into different regions of the space. *Useful* knowledge creation, however, ultimately requires such labor to be coordinated and integrated.

3. Do not privilege one part of the power-law distribution at the expense of another. The world is a dynamic place, subject both to the emergence of order and, according to the second law of thermodynamics, its erosion. The first law of thermodynamics holds that the conservation of energy drives the creation of matter. In neoclassical economics the first law fostered an equilibrium-focused mathematics (Colander, 2006; Mirowski, 1989). The second law of thermodynamics holds that ordered energy-based structures eventually deteriorate into randomness—a process called "entropy production" (Swenson, 1989). While some structures temporarily stabilize, others rapidly disintegrate. To understand organizational phenomena is to understand these opposing processes.

If we view organizations through a network lens (Boisot & Lu, 2007), we see that organizational research studies the regularities that govern the interdependencies among different nodes in a network—that is, the structure and the dynamics of their connectivity. Since nodes can be individuals, departments within an organization, or whole organizations, we see that many of these regularities are scalable (Barabási, 2002). And since connectivity is a variable that reflects the level of adaptive tension in the network, organizational research must engage with the power-law distribution *as a whole*, without privileging one particular region at the expense of another. It cannot therefore presume that studies of "average" or "typical" organizations accurately reflect organizational properties ranging across an entire power-law distribution. Just as Axtell (2008) invoked the power-law distribution of firm size in the United States to claim that there is no such thing as the typical firm, so we hypothesize that *the "average" organization does not exist*.

4. Study the causal dynamics that call for scalable abduction. Power laws are the signature of SOC in natural and social systems. By focusing on circumstances under which independent events and processes connect, scalable abduction becomes the inferential strategy of choice for studying SOC in particular and organizational phenomena in general. Scalable abduction turns out to be the basis of Dilthey's (1959) *Verstehen* (understanding), a diacritical concept distinguishing natural from cultural sciences. While scalable abduction does not necessarily yield strong or precise predictions (Burrell & Morgan, 1979), it offers a new answer to the old question of whether a science of history is possible. Historicism argues that history is subject to laws that allow prediction. From a modernist perspective, however, samples of one—unique events—cannot exhibit law-like behavior and, hence, remain beyond the reach of prediction (Popper, 1945).

Yet do we not also hear that those who fail to learn the lessons of history are condemned to repeat them? Although it does not allow the levels of prediction achievable in some of the natural sciences, for living systems like organizations, abductive inference offers a useful level of anticipation, one that can be efficaciously adaptive. A key challenge here is to separate the small events that are likely to remain independent and random from the small events that, driven by tension-induced connectivities, are likely to become scalable. Such events don't usually come with labels attached, so without some understanding of how scalable causal dynamics arise in organizations (see Table 1), it is hard to distinguish butterfly events ex ante from random, independent ones. Here, by their fine-grained analyses of individual events, the narrative strategies advocated by postmodernists come into their own. They invite us to proceed cautiously and to avoid the premature closure that overhasty, statistically driven hypothesizing can produce.

5. Link the methodologies available for studying different points on the power-law slope. Graham Allison's (1971) analysis of the Cuban Missile Crisis illustrates some of the issues we are discussing. As Allison tells it, the crisis came very close to generating the ultimate extreme event: a thermonuclear war. Given the race against time, the level of adaptive tension was extremely high—at certain moments during the crisis, the slightest mishap could have triggered a nuclear missile exchange between the Soviet Union and the United States. Had Kennedy not engaged with the causal texture of the events that made up the crisis at the appropriate level—had he not been sensitive to the presence of butterfly events—the world would have plunged into a nuclear abyss.

In the book Allison develops three different models through which the crisis can be analyzed: Model I, the rational actor; Model II, organizational process; and Model III, governmental politics. Model I treats the state as a stable and independent object whose behavior is rational and predictable, Model II unpacks the state to reveal a more complex and organized entity subject to divergent rules and routines that undermine some of the rationality imputed to it by Model I, and Model III subordinates the behavior of the different components that make up the state to the games played by political actors. Each model adds a layer of complexity—and, by implication, of narrative richness—to the analysis and improves its explanatory power. The first seeks predictability; the third understanding.

Model III is the most complex—not to say chaotic—of all three models. As Allison points out, the information needed by Models II and III dwarfs that required by Model I. In fact, to advocates of Model I, the information requirements of Model III reflect an "undue concern with subtlety" (Allison, 1971: 251). Model I is coarse grained, offering an informative summary of tendencies, whereas model III is fine grained. Allison's three models complement each other. The best foreign policy analysts weave strands of the three models into their accounts. The key difference between Allison's and our approach is that whereas he produced three different perspectives that *happened* to fruitfully complement each other—after all, they may well have turned out to be based on incommensurate paradigms—we locate our three ontologies along a single continuum that theoretically integrates the different perspectives we have discussed and identifies the inferential conditions for moving along the continuum in either direction.

Historical case-based narratives such as Allison's look at the way events *have* connected. But history as currently conceived only delivers useful lessons if events connect this way again; it then has predictive value. Heraclitus, however, tells us that events never connect in the same way twice. Anticipation is both less demanding and more demanding of history. It does not ask how things *will* connect but how they *could* connect. It is less demanding in that it does not seek predictive accuracy or precision. It is more demanding because it has to explore a much larger space of possibilities than prediction requires.

Today, high-powered, agent-based simulation models make it possible to engage in such explorations. If deduction was the inferential strategy of choice of a prestatistical age and induction that of the statistical age (Stigler, 1986), we hypothesize that scalable abduction will become the inferential strategy of choice in the age of computational modeling (Epstein & Axtell, 1996; North & Macal, 2007; Tesfatsion & Judd, 2006). It allows one to move methodically across levels of resolution and analysis and to explore statistical and narrative data in ways that were not available to Allison. As he put it in the concluding section of his book,

> What we need is a new kind of "case study" done with theoretical alertness to the range of factors identified by Models I, II, and III (and others) on the basis of which to begin refining and testing propositions and models (Allison, 1971: 273).

CONCLUSION

By accommodating the dynamics of tension and connectivity, an epistemology based on complexity science offers management and organizational researchers a more encompassing legitimacy than either modernist or postmodernist epistemologies on their own—one that is well aligned with emerging concepts of organizational complexity (Allen, Maguire, & McKelvey, in press; Lewin, 1999; Maguire, McKelvey, Mirabeau, & Öztas 2006). If effective organizational complexity lies between order and chaos, then, by implication, so does the effective legitimacy of management research. This location implies a methodological expansion out from the world of stable, normally distributed entities toward the more kaleidoscopic and problematic world captured by power-law distributions.

Ours is a plea for a new direction in organization and management research—and more broadly in the social sciences. The paradigmatic competition between modernism and postmodernism has not been fruitful. Natural scientists and neoclassical economists continue to espouse a modernist stance, and many social scientists continue to espouse that of postmodernism (Colander, 2006; Kelso & Engstrøm, 2006; Mirowski, 1989; Ormerod 1994, 1998). Consequently, the legitimacy of management research's would-be truth claims remains stuck in an epistemological quagmire. Morin (1992), however, pointed out that the new complexity sciences are now dissolving the distinction between the natural and the social sciences. The complexity perspective suggests that where prediction is problematic, anticipation offers usefully adaptive information and, hence, becomes a legitimate goal for scientific endeavors. Thus, while the criteria of demarcation that separate science from nonscience need not be abandoned—as advocated by Feyerabend (1975) and some postmodernists—they need to be rather more accommodating than those promulgated by modernists.

Organizational researchers study interacting, interdependent agents—individuals, departments, firms, etc. These simply do not behave like a collectivity of autonomous agents. Informed interdependencies are the stuff of organization and, indeed, of life itself. Postmodernist organizational researchers are right in thinking that the complexity that results is not well captured by the analytical tools forged by modernist thinking. They are, however, wrong in thinking that such complexity is beyond the reach of any kind of managerially useful analysis. Agent-based simulation modeling, for example, today provides both natural and social scientists with tools for studying the complex scalable processes outlined in this paper (Epstein, 2007; Epstein & Axtell, 1996; North & Macal, 2007; Tesfatsion & Judd, 2006). It is ideally suited to exploring the wide range of possible outcomes out of which more probable ones might emerge. Such *possibility thinking*—Kauffman (2000) calls it the "adjacent possible"—would place organization scholars more firmly in the context of discovery (Reichenbach, 1938) so long shunned by modernists, without in any way undermining the case for a subsequent justification. The narrative strategies of the postmodernist would then be used by scholars to select *the most plausible* of these possibilities—those that square abductively with their prior experience. The approach would, in effect, legitimate a more creative, exploratory approach to organizational research that prevails in many Ph.D. programs, one that acknowledges the contingent nature of many organizational processes even as it seeks a robust understanding of their exploitable regularities.

REFERENCES

Aliseda, A. 2006. ***Abductive reasoning: Logical investigations into discovery and explanation***. Dordrecht: Springer.

Allen, P., Maguire, S., & McKelvey, B. In press. ***The SAGE handbook of complexity and management***. London: Sage.

Allison, G. T. 1971. ***Essence of decision: Explaining the Cuban Missile Crisis.*** Boston: Little, Brown.

Alvesson, M., & Deetz, S. 1996. Critical theory and postmodernism approaches to organizational studies. In S. R. Clegg, C. Hardy, & W. R. Nord (Eds.), ***Handbook of organization studies:*** 191–217. London: Sage.

Andriani, P., & McKelvey, B. 2007. Beyond Gaussian averages: Redirecting organization science toward extreme events and power laws. ***Journal of International Business Studies***, 38: 1212–1230.

Andriani, P., & McKelvey, B. 2009. From Gaussian to Paretian thinking: Causes and implications of power laws in organizations. ***Organization Science***, 20: 1053–1071.

Ashby, R. W. 1956. ***An introduction to cybernetics.*** London: Methuen.

Axtell, R. L. 2008. ***Nonexistence of a typical firm in the U.S. economy: Extremely heavy tails in firm size and growth.*** Paper presented at the Organization Science Winter Conference, Squaw Creek, CA.

Bak, P. 1996. ***How nature works: The science of self-organized criticality.*** New York: Copernicus.

Barabási, A.-L. 2002. ***Linked: The new science of networks.*** Cambridge, MA: Perseus.

Benacerraf, P., & Putnam, H. (Eds.). 1964. ***Philosophy of mathematics: Selected readings.*** Cambridge: Cambridge University Press.

Berger, P., & Luckmann, T. 1966. ***The social construction of reality.*** Middlesex, UK: Penguin Books.

Blackmore, S. 1999. ***The meme machine.*** New York: Oxford University Press.

Boisot, M., & Child, J. 1999. Organizations as adaptive systems in complex environments: The case of China. ***Organization Science***, 10: 237–252.

Boisot, M., & Lu, X. 2007. Competing and collaborating in networks: Is organizing just a game? In M. Gibbert & T. Durand (Eds.), ***Strategic networks: Learning to compete:*** 151–169. Malden, MA: Blackwell.

Boisot, M., & McKelvey, B. 2007. ***Extreme events, power laws, and adaptation: Towards an econophysics of organization.*** Paper presented at the annual meeting of the Academy of Management, Philadelphia.

Boltzmann, L. 1887. Über einige Fragen der Kinetische Gastheorie. ***Wiener Berichte***, 96: 891–918.

Bridgeman, P. 1936. ***The nature of physical theory.*** Princeton, NJ: Princeton University Press.

Brunk, G. G. 2002. Why are so many important events unpredictable? Self-organized criticality as the "engine of history." ***Japanese Journal of Political Science,*** 3: 25–44.

Burrell, G., & Morgan, G. 1979. ***Sociological paradigms and organizational analysis.*** London: Heinemann.

Calás, M. B., & Smircich, L. 1999. Past postmodernism? Reflections and tentative directions. ***Academy of Management Review,*** 24: 649–671.

Callon, M. 1986. Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St. Brieuc Bay. In J. Law (Ed.), ***Power, action and belief:*** 196–229. London: Routledge & Kegan Paul.

Carneiro, R. L. 1987. The evolution of complexity in human societies and its mathematical expression. ***International Journal of Comparative Sociology,*** 28: 111–128.

Carter. P., & Jackson, N. 2004. Gilles Deleuze and Felix Guattari: A "minor" contribution to organization theory. In S. Linstead (Ed.), ***Organization theory and postmodern thought:*** 105–126. London: Sage.

Cilliers, P., 1998. ***Complexity and postmodernism: Understanding complex systems.*** London: Routledge.

Colander, D. 2006. ***Post Walrasian macroeconomics: Beyond the dynamic stochastic general equilibrium model.*** Cambridge: Cambridge University Press.

Crozier, M. 1964. ***Le phénomène bureaucratique.*** Paris: Éditions du Seuil.

Dawkins, R. 1976. ***The selfish gene.*** Oxford: Oxford University Press.

Deleuze, G., & Guattari, F. 1984. ***Anti-Oedipus: Capitalism and schizophrenia.*** (Translated by R. Hurley, M. Seem, & H. R. Lane.) London: Athlone.

Dennett, D. 1989. ***The intentional stance.*** Cambridge, MA: MIT Press.

Derrida, J. 1978. ***Writing and difference.*** London: Routledge & Kegan Paul.

Dewey, J. 1925. ***Experience and nature.*** Chicago: Open Court.

Dilthey, W. 1959. ***Gesammelte Schriften.*** Stuttgart: Teubner.

Dooley, K. J., & Van de Ven, A. H. 1999. Explaining complex organizational dynamics. ***Organization Science,*** 10: 358–372.

Epstein, J. 2007. ***Generative social science: Studies in agent-based computational modeling.*** Princeton, NJ: Princeton University Press.

Epstein, J. M., & Axtell, R. 1996. ***Growing artificial societies: Social science from the bottom up.*** Cambridge, MA: MIT Press.

Feyerabend, P. K. 1975. ***Against method.*** London: New Left Books.

Feynman, R. P. 1967. ***The character of physical law.*** Cambridge, MA: MIT Press.

Fisher, R. A. 1918. The correlation between relatives on the supposition of Mendelian inheritance. ***Philosophical Transactions of the Royal Society of Edinburgh,*** 52: 399–433.

Ford, B. J. 1992. Brownian movement in clarkia pollen: A reprise of the first observations. ***The Microscope,*** 40: 235–241.

Foucault. M. 1969. ***L'archéologie du savoir.*** Paris: Gallimard.

Foucault. M. 1975. ***Surveiller et punir: Naissance de la prison.*** Paris: Gallimard.

Friedman, M. 1953. ***Essays in positive economics.*** Chicago: University of Chicago Press.

Gell-Mann, M. 1994. ***The quark and the jaguar.*** New York: Freeman.

Gell-Mann, M. 2002. What is complexity? In A. Q. Curzio & M. Fortis (Eds.), ***Complexity and industrial clusters:*** 13–24. Heidelberg: Physica-Verlag.

Gibbs, J. W. 1902. ***Elementary principles in statistical mechanics.*** New York: Charles Scribner's Sons.

Glaser, P. 2009. ***Fitness and inequality in an increasing returns world: Applying the tools of complexity economics to study the changing distribution of US stock market capitalizations from 1930 to 2008.*** Unpublished paper, UCLA Anderson School of Management, Los Angeles.

Golinski, J. 1998. ***Making natural knowledge.*** Cambridge: Cambridge University Press.

Greene, W. H. 2002. ***Econometric analysis*** (5th ed.). Englewood Cliffs, NJ: Prentice-Hall.

Guth, A. 1997. ***The inflationary universe.*** Cambridge, MA: Perseus Books.

Habermas, J. 1972. ***Knowledge and human interests.*** London: Heinemann.

Hahlweg, K., & Hooker, C. A. (Eds.). 1989. ***Issues in evolutionary epistemology.*** New York: State University of New York.

Haken, H. 1983. ***Synergetics, an introduction*** (3rd ed.). Berlin: Springer-Verlag.

Haxton, B. 2001. ***The collected wisdom of Heraclitus.*** New York: Viking Penguin.

Hempel, C. G. 1965. ***Aspects of scientific explanation.*** New York: Free Press.

Holland, J. H. 1988. The global economy as an adaptive system. In P. W. Anderson, K. J. Arrow, & D. Pines (Eds.), ***The economy as an evolving complex system:*** 117–124. Reading, MA: Addison-Wesley.

Holland, J. H. 2002. Complex adaptive systems and spontaneous emergence. In A. Q. Curzio & M. Fortis (Eds.), ***Complexity and industrial clusters:*** 24–34. Heidelberg: Physica-Verlag.

Hollinger, R. 1994. ***Postmodernism and the social sciences: A thematic approach.*** London: Sage.

Hollis, M. 1982. The social destruction of reality. In M. Hollis & S. Lukes (Eds), ***Rationality and relativism:*** 67–86. Oxford: Blackwell.

Hurst, D. K. 1995. ***Crisis and renewal: Meeting the challenge of organizational change.*** Boston: Harvard Business School Press.

Ishikawa, A. 2006. Pareto index induced from the scale of companies. ***Physica A,*** 363: 367–376.

Israel, J. 2001. ***Radical enlightenment.*** Oxford: Oxford University Press.

James, W. 1907. ***Pragmatism: A new name for some old ways of thinking.*** New York: Longman Green.

Jenks, C., 1992. The post-modern agenda. In C. Jenks (Ed.), ***The postmodern reader:*** 10–39. London: St. Martin's Press.

Kauffman, S. A. 1993. ***The origins of order.*** New York: Oxford University Press.

Kauffman, S. A. 2000. ***Investigations.*** New York: Oxford University Press.

Kaye, B. 1993. ***Chaos & complexity.*** New York: VCH.

Kelso, J. A. S., & Engstrøm, D. A. 2006. ***The complementary nature.*** Cambridge, MA: MIT Press.

Koertge, N. 1998. ***A house built on sand: Exposing postmodernist myths about science.*** New York: Oxford University Press.

Kuhn, T. S. 1962. ***The structure of scientific revolutions.*** Chicago: University of Chicago Press.

Lakatos, I. 1976. ***Proofs and refutations: The logic of mathematical discovery.*** (Edited by J. Worrall & E. Zahar.) Cambridge: Cambridge University Press.

Latour, B. 1988. ***The Pasteurization of France.*** Cambridge, MA: Harvard University Press.

Lawson, T. 1997. ***Economics & reality.*** New York: Routledge.

Lewin, A. Y. (Ed.). 1999. Special issue. ***Organization Science,*** 10(3).

Lorenz, E. N. 1972. ***Predictability: Does the flap of a butterfly's wings in Brazil set off a tornado in Texas?*** Paper presented at the meeting of the American Association for the Advancement of Science, Washington, DC.

Lyotard, J.-F. 1984. ***The postmodern condition.*** Manchester, UK: Manchester University Press.

Maguire, S., McKelvey, B., Mirabeau, L., & Öztas, N. 2006. Complexity science and organizational studies. In S. R. Clegg, C. Hardy, T. Lawrence, & W. Nord (Eds.), ***Handbook of organizational studies*** (2nd ed.): 165–214. Thousand Oaks, CA: Sage.

Mainzer, K. 2007. (First published in 2004.) ***Thinking in complexity*** (5th ed.). New York: Springer-Verlag.

Mandelbrot, B. 1982. ***The fractal geometry of nature.*** New York: Freeman.

March, J. G. 1991. Exploration and exploitation in organizational learning. ***Organization Science,*** 2: 71–87.

March, J. G., Sproull, L. S., & Tamuz, M. 1991. Learning from samples of one or fewer. ***Organization Science,*** 2: 1–13.

Mayo, D., 1996. ***Error and the growth of experimental knowledge.*** Chicago: University of Chicago Press.

McKelvey, B. 1999. Toward a Campbellian realist organization science. In J. A. C. Baum & B. McKelvey (Eds.), ***Variations in organization science: In honor of Donald T. Campbell:*** 383–411. Thousand Oaks, CA: Sage.

McKelvey, B. 2001. Energizing order-creating networks of distributed intelligence. ***International Journal of Innovation Management,*** 5: 181–212.

McKelvey, B. 2003. Postmodernism vs. truth in management theory. In E. Locke (Ed.), ***Post modernism and management: Pros, cons and the alternative. Research in the sociology of organizations,*** vol. 21: 113–168. Amsterdam: Elsevier Science.

McKelvey, B. 2004. Toward a 0th law of thermodynamics: Order-creation complexity dynamics from physics and biology to bioeconomics. ***Journal of Bioeconomics,*** 6: 65–96.

McKelvey, B. 2008. Emergent strategy via complexity leadership: Using complexity science & adaptive tension to build distributed intelligence. In M. Uhl-Bien & R. Marion (Eds.), ***Complexity and leadership. Volume I: Conceptual foundations:*** 225–268. Charlotte, NC: Information Age.

McKelvey, B., & Boisot, M. 2009. Redefining strategic foresight. In L. Costanzo & B. MacKay (Eds.), ***Handbook of research on strategy and foresight:*** 15–47. Cheltenham, UK: Edward Elgar.

McKelvey, B., & Lichtenstein, B. B. 2007. Leadership in four stages of emergence. In J. K. Hazy, J. Goldstein, & B. B. Lichtenstein (Eds.), ***Complex systems leadership theory:*** 93–107. Boston: ISCE.

Merton, R. K. 1949. ***Social theory and social structure.*** New York: Free Press.

Mirowski, P. 1989. ***More heat than light.*** Cambridge: Cambridge University Press.

Morin, E. 1992. ***Method: Toward a study of humankind.*** New York: Peter Lang.

Newman, M. E. J. 2005. Power laws, Pareto distributions and Zipf's law. ***Contemporary Physics,*** 46: 323–351.

Nicolis, G., & Prigogine, I. 1989. ***Exploring complexity: An introduction.*** New York: Freeman.

North, M. J., & Macal, C. M. 2007. ***Managing business complexity: Discovering strategic solutions with agent-based modeling and simulation.*** Oxford: Oxford University Press.

Ormerod, P. 1994. ***The death of economics.*** New York: Wiley.

Ormerod, P. 1998. ***Butterfly economics: A new general theory of social and economic behavior.*** New York: Pantheon.

Peirce, C. S. 1935. ***Collected papers,*** vol. 5. (Edited by C. Hartshorne & P. Weiss.) Cambridge, MA: Harvard University Press.

Podobnik, B., Fu, D., Jagric, T., Grosse, I., & Stanley, H. E. 2006. Fractionally integrated process for transition economics. ***Physica A,*** 362: 465–470.

Popper, K. R. 1935. ***Logik der Forschung.*** Vienna: Springer Verlag. Reprinted as Popper, K. R. 1959. ***The logic of scientific discovery.*** New York: Harper & Row.

Popper, K. R. 1945. ***The open society and its enemies. Volume 1: Plato. Volume 2: Hegel and Marx.*** London: Routledge & Kegan Paul.

Popper, K. R. 1983. ***Realism and the aim of science.*** London: Hutchinson.

Prigogine, I., with Stengers, I. 1997. ***The end of certainty.*** New York: Free Press.

Radnitzky, G., & Bartley, W. W., III. 1987. ***Evolutionary epistemology, rationality, and the sociology of knowledge.*** La Salle, IL: Open Court.

Reichenbach, H. 1938. ***Experience and prediction.*** Chicago: University of Chicago Press.

Roethlisberger, F. J., & Dickson, W. J. 1964. ***Management and the worker.*** New York: Wiley.

Rorty, R. 1980. ***Philosophy and the mirror of nature.*** Oxford: Blackwell.

Rorty, R. 1989. ***Contingency, irony, and solidarity.*** Cambridge: Cambridge University Press.

Shapin, S., & Schaffer, S. 1985. ***Leviathan and the air-pump.*** Princeton, NJ: Princeton University Press.

Simon, H. A. 1962. The architecture of complexity. ***Proceedings of the American Philosophical Society,*** 106: 467–482.

Stigler, S. M. 1986. ***The history of statistics: The measurement of uncertainty before 1900.*** Cambridge, MA: Belknap Press of Harvard University Press.

Suppe, F. 1977. ***The structure of scientific theories*** (2nd ed.). Chicago: University of Chicago Press.

Swenson, R. 1989. Emergent attractors and the law of maximum entropy production: Foundations to a theory of general evolution. ***Systems Research,*** 6(3): 187–197.

Taleb, N. N. 2007. ***The black swan.*** New York: Random House.

Tesfatsion, L., & Judd, K. 2006. ***The handbook of computational economics,*** vol. 2. Amsterdam: Elsevier.

Thagard, P. 2006. ***Hot cognition.*** Cambridge, MA: MIT Press.

Thagard, P., & Shelley, C. P. 1997. Abductive reasoning: Logic, visual thinking, and coherence. In M. L. D. Chiara, K. Doets, D. Mundici, & J. van Bentham (Eds.), ***Logic and scientific methods:*** 413–427. Dordrecht: Kluwer.

Walker, H. W. 1940. Degrees of freedom. ***Journal of Educational Psychology,*** 31: 253–269.

Weinberg, S. 1992. ***Dreams of a final theory.*** New York: Vintage Books.

West, B., & Deering, B. 1995. ***The lure of modern science: Fractal thinking.*** Singapore: World Scientific.

Zipf, G. K. 1949. ***Human behavior and the principle of least effort.*** New York: Hafner.

Max Boisot (max.boisot@gmail.com) is a professor at the ESADE business school in Barcelona; an associate fellow at the Said Business School, University of Oxford; and a fellow of the Snider Center at the Wharton School, University of Pennsylvania. He received his Ph.D. from Imperial College, London University. His current research is on knowledge creation at CERN's Large Hadron Collider.

Bill McKelvey (mckelvey@anderson.ucla.edu) is a professor at the UCLA Anderson School of Management. He received his Ph.D. from MIT. His current writing focuses on philosophy of science, organization science, complexity science, agent-based computational modeling, and complexity leadership.