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Towards operationalizing complexity leadership: How generative, administrative and community-building leadership practices enact organizational outcomes

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Towards operationalizing complexity leadership: How generative, administrative and community-building leadership practices enact organizational outcomes

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Abstract
Over five years ago, *The Leadership Quarterly* published a special issue on complexity to advance a new way of thinking about leadership. In shifting attention away from the individual to the organizing process itself, complexity added an important focus on process and context to leadership and management research. Yet, the complexity approach creates challenges for researchers who must combine or replace individual level constructs—like those built through surveys or factor analysis—with richer theories that investigate networked meso dynamics, multilevel phenomena, emergent processes, and organizational outcomes. To address this challenge, the present analysis draws on theoretical and empirical work over the last several years to identify five specific areas where complexity inspired research has led to new insights about the mechanisms that enable the organization to perform and adapt. It suggests propositions that describe how leadership and management, defined holistically, might activate complexity mechanisms to perform five essential organizing functions.

Keywords: Complexity leadership, generative leadership, emergence, entrepreneurial leadership, strategic leadership, systemic leadership, information gathering and using systems, ratcheting

Introduction

In the complexity approach, "leadership" is not an individual (a person or persons, i.e. "leaders"). Rather, it is a recognizable pattern of social and relational organizing among autonomous heterogeneous individuals as they form into a system of action (Hazy et al., 2007; Lichtenstein et al., 2006; Marion and Uhl-Bien, 2001; Shamir, 2012; Uhl-Bien and Marion, 2009; Uhl-Bien and Ospina, 2012; Uhl-Bien et al. 2007). Complexity approaches do not discount individual leaders, but focus instead on the importance of broader organizing effects that include both individual practices and complex system effects. This article describes how organizations can be conceptualized as complex adaptive systems (Gell-Mann, 2002) and identifies five functional demands that leadership must perform if these systems are to sustain themselves.

In Complexity Leadership Theory (CLT), Uhl-Bien et al. (2007) divide leadership into administrative, adaptive, and enabling leadership, each of which supports the organization's needs as a complex adaptive system (Holland, 1975). When observed at the individual level, this type of leadership could be recognized as a dynamically evolving influence pattern (Panzar et al., 2007) that include elements of formal, emergent (Dervitsiotis, 2005), and distributed leadership (Bolden, 2011). Each occurrence of these forms of influence would be guided by prior history as well as the challenges that the organization is facing (Panzar et al, 2007; Uhl-Bien and Ospina, 2012). This article explores complexity-inspired research that clarifies the functional contexts wherein leadership influence in its various forms enables organizations to both perform and adapt.

The argument begins by describing complex organizations in terms of the transient fine-grain interactions that individuals actually experience—such as meeting colleagues in the hallway or running a project meeting—versus the enduring coarse-grain properties of organizations— such as market performance and organizational routines—that are the context within which organizational life unfolds. We then take as a premise that if intentional organizing is to occur within a complex system of human interactions, leadership as a construct must perform certain system functions, what Katz and Kahn (1966) called the "influential increment."

Hazy (2011) interprets this idea in complexity terms, arguing that when human interactions and organizing are considered as complex systems, the leadership process performs three distinct and complementary influence functions: The generative function influences the fine-grain interactions that individuals experience in their daily activities and then changes these interactions to increase the variety of possible coarse-grain properties that might determine what the organization looks like and what it does. The convergent function influences fine-grain interactions to bring activities together and entrain them into enduring coarse-grain properties. Finally, the more traditional community-building function influences fine-grain interactions to hold individuals together in support of collective activity regardless of the coarse-grain properties that are being or will be enacted. Building from Hazy (2011), this article addresses these functions and identifies two additional ones. As shown in Table 1, each of these five functions implies specific leadership practices that facilitate or catalyze fine-grain interactions to enable a unique mechanism of complex organizing, and each implies distinct and measurable system-level coarse-grain outcomes. Taken together, the five functions summarized in the next section form a systemic theory of leadership in organizations when the latter are taken to be complex adaptive systems.

Table 1. Leadership functions, complexity mechanisms, and organizational outcomes.

Leadership function	Complexity mechanisms	Organizational outcomes
Generative	*Emergence* of coarse-grain properties	Autonomy ("entrepreneurial") orientation Experimentation Entrepreneurial processes New product/service launches Adaptation
Administrative	*Entrainment* of fine-grain interactions as coarse-grain properties are reinforced in the ecosystem	Integration ("discipline") orientation Consistent routines Role clarity Clear chain of responsibility Efficiency Performance
Community-Building	*Belonging* and forming shared *identity*	Identity ("community") orientation Employee engagement Intrinsic motivation Trust Citizenship behaviors Strong shared identity
Information Gathering	*Integration and synthesis* of distributed information	Divergence ("data and model driven") orientation Exploration and data collection Interaction resonance High levels of discourse Listening Learning culture
Information Using	*Ratcheting* successful organizing approaches to embed information about success in recognizable structures and ordering	Convergence ("process evolution") orientation Clear authority over resources Clear responsibilities Success-based status assignment Competence and expertise Accountability culture

See text for more details.

Five functions of leadership for complex organizing

Hazy and Uhl-Bien (2013) show how Hazy's (2011) three complex leadership functions align with the three elements of complexity leadership described by Uhl-Bien et al. (2007). First, leadership serves a *generative function* (Surie and Hazy, 2006) that enables adaptation (Uhl- Bien et al., 2007). It supports trying things like prototyping in multiple iterations, for example. By sorting and influencing fine-grain interactions to enable or stifle experimentation at the margins (Dervitsiotis, 2005), leadership helps drive entrepreneurial activities to identify solutions to local problems across the organization and facilitates the emergence of locally useful coarse-grain properties that might have applicability elsewhere. The use of a locally developed prototype might identify a new source of revenue for the entire organization, for example. *Generative leadership (GL) practices* that support this function (as shown in Table 2) generate a variety of activities and plans and facilitate

Table 2. Leadership functions, illustrative practices, and studies that reflect these practices.

Functions	Illustrative practices	Empirical studies
Generative	• Set high aspirations for future products, services, and processes with external constraints, but without specifying how to get there • Bring diverse experiences and perspectives together and support differences of opinion • Encourage broad adoption of innovations that have been vetted • Provide resources and space to try new things and new directions • Form small teams and rotate membership often to break-up stale thinking • Encourage openness to surprises to learn/do not punish failure	Surie and Hazy (2006) Johannessen and Aasen (2007) Plowman et al. (2007a, 2007b) Tapsell and Woods (2009) Beck and Chong (2009) Garud et al. (2006, 2011) Groot (2009) Shepherd and Woods (2011) Backström et al. (2011)
Administrative	• Establish specific task targets, dependencies, and deliverables • Use discretionary control over resources (like budgets) to reinforce successful projects • Provide clear roles, task-specific training, and follow-up on expected activities • Provide resources and autonomy to "groups" to support their efforts • Establish challenging but achievable goals and objectives • Use resources such as project plans and budgets as structural attractors	Guastello (2002) Guastello and Bond (2004, 2007) Guastello et al. (2005) Garud et al. (2006, 2011) Johannessen and Aasen (2007) Plowman et al. (2007a, 2007b) Phelps and Hubler (2007) Hazy (2008b), Groot (2009) Tapsell and Woods (2009) MacGillivray (2010) Shepherd and Woods (2011)
Community-building	• Articulate an idealized future with shared values and aspirations • Build trust that individuals will have access to shared resources • Initiate and perform inclusion rituals like group celebrations • Clarify in-group/out-group boundaries perhaps by using "us" versus "them" language or "tags" like uniforms • Ask each person to invest their energy and resources in the organization • Initiate and perform inclusion rituals like group celebrations • Make people feel they is part of something valued and significant • Use resource allocation authority to "kill" dead-end projects or wasteful activities	Dal Forno and Merlone (2007) Boal and Schultz (2007) Tapsell and Woods (2009) Backström et al. (2011) Molleman et al. (2010) Hazy, 2008a, 2011 Shepherd and Woods (2011)

(continued)

Table 2. Continued

Functions	Illustrative practices	Empirical studies
Information Gathering	• Make time for thoughtful exchanges and reflection about new information that is being learned across the organization • Encourage exploration and learning expeditions to search for new information from stakeholders • Insist on frank exchanges about what is working or not working • Listen, ask "why?", then "why?" again to challenge assumptions about what is known • Conduct after-action reviews • Encourage cross-team/organization communication/collaboration • Identify successful initiatives and test them more broadly • Help look for and identify common models of what is happening and needs to happen	Barabasi (2002) Surie and Hazy (2006) Tobin (2009) Backström et al. (2011) MacGillivray (2010) Baker et al. (2011) Molleman et al. (2010) Garud et al. (2006, 2011) Shepherd and Woods (2011)
Information Using	• Drive accountability in resource allocation decisions • Delegate authority over resources and responsibilities to leverage success experience and expertise • Find, vet, and place the right people in the right jobs • Clarify individual responsibility for organizational outcomes to enable unambiguous assessment of success or failure • Maintain consistency in personnel and roles in teams	Allen (2001) Solow and Leenawong (2003) Tsoukas (2005) Surie and Hazy (2006) Schreiber and Carley (2006) Dal Forno and Merlone (2007) Molleman et al. (2010) Backström et al. (2011) Groot (2009), Tobin (2009) Garud et al. (2006, 2011) Shepherd and Woods (2011) Hazy, 2008b, 2012 Havermans et al. (2010)

interactions that try them out in experiments. In complexity, variety is important because it enables *emergence* as a mechanism for adapting to change (Ashby, 1956, Hazy, 2006, 2008a, 2008b; Uhl-Bien et al., 2007).

Second, by clarifying and enforcing rules of fine-grain interactions, Hazy (2011) argues that leadership serves a convergent function that focuses and orients the system toward dynamic stability. To do this, we focus on *administrative leadership (AL) practices* (as shown in Table 2) that implement management processes, policies, and procedures (Uhl- Bien et al., 2007), converging the actions of individuals toward coarse-grain properties of various types (e.g. cost targets). It is a leadership function to eliminate confusion by clarifying handoff responsibilities, for example. AL acts according to the complexity mechanism of *entrainment*, which promotes convergence toward patterns of action (Phelps and Hubler, 2007). There is no guarantee, however, that these patterns are beneficial for the organization or its stakeholders.

Third, leadership practices catalyze fine-grain interactions to serve the traditional *community- building function* that engenders a sense of belonging and shared identity among individuals, thus creating a common vehicle that enables complex organizing (Uhl-Bien et al., 2007). It is a leadership function to help individuals identify with the organization through the use of slogans, for example. This function provides a common reference point and establishes the legitimacy of certain types and styles of interactions by using fine-grain interactions to clarify coarse-grain organizational values, validate coarse-grain membership rituals and benefits, and reinforce what the collective believes to be true as coarse-grain properties. Community-building leadership (CBL) practices (as shown in Table 2) enable people to feel that they *belong*, share a common *identity* with others, and that together they can more effectively defend their coarse-grain position in the ecosystem than they could on their own (Hazy, 2011). When this is accomplished, the fine-grain choice and actions of individuals are influenced by common assumptions and beliefs. Individuals who enact leadership practices to support other functions can therefore leverage this sense of community to more easily organize individuals into groups, departments, and organizations.

In addition to these previously identified functions, empirical studies (cf. Backström et al., 2011; Garud et al., 2006, 2011; Havermans et al., 2010) and computational analyses (Hazy, 2007, 2008a, 2012) imply two additional functions. While the functions described previously relate to *how* individuals interact, these additional functions relate to *what* the interactions are about. These information-related functions operate between the fine-grain and the coarse-grain to connect individual actions with organizational processes and outcomes. These leadership practices enable fine-grain interactions and coarse-grain properties to simultaneously impact one another by facilitating fine-grain interactions that gather and use information for the system (Gell-Mann, 2002).

The fourth leadership function is the *information-gathering* function. It enables individuals to sense and absorb information during fine-grain interactions and to recognize what might be relevant to the coarse-grain properties of the system. Sales support personnel may learn about an emerging customer concern related to a particular product line, and it is a function of leadership to clarify how such information should be communicated, for example. Practices that support this function promote activities such as exploring the environment, observing and sharing what is happening in the distributed ecosystem, and maintaining fine-grain diversity of perspectives within the system. At the same time, these practices promote fine-grain interactions that encourage the sharing and filtering of this information during communicative interactions. These practices are used

to recognize patterns as a means to identify signals that are relevant to the coarse-grain properties that currently operate or that are emerging within the system. Goldstein et al. (2010) call this process *interaction resonance*. We call the mechanism whereby distributed information is sensed, decoded, exchanged and interpreted at the fine-grain level and is then found to have coarse-grain relevance: *integration and synthesis.* Information gathering leadership (IGL) practices (as shown in Table 2) promote frank information exchanges with regards the findings of individual exploration and data collection. This might enable organizations to recognize "wicked problems" and begin to deal with them before they become major issues, for example (Bazerman and Watkins, 2004). By identifying and testing patterns at the coarse-grain level through discourse as well as action, they help individuals make sense (Weick, 1995) of internal activities and events in the ecosystem, while working to uncover or assign meaning in what is observed. These practices deepen and strengthen relationships, what Backström et al. (2011) call "relatonics," and promote personalized consideration of others' perspectives (cf. Weick and Roberts, 1993).

Fifth, the *information-using* function of leadership takes outputs that have been gathered through the integration and synthesis mechanism and uses them to irreversibly move the organization in a particular direction. Information using leadership (IUL) practices (see Table 2) use fine-grain interactions to implement coarse-grain structural changes in the way the organization interacts with its environment. A new department might be formed, for example, a business might be acquired; or perhaps a subsidiary might be sold off. When leadership takes these steps, the organization stores and reinforces information about the new way of doing things and also erases system-level information about the old way of doing things. For example, Intel erased its old way of doing things as a DRAM memory company to make way for its new way as a microprocessor business when it exited the dying memory business in the 1980s (Burgelman, 1994). When the old way is lost, the change is irreversible, and the fitness (or performance) gains won within the ecosystem are preserved; the system has *ratcheted* its structure to hold its gains. The *ratchet mechanism* prevents backsliding into the old ways as the system begins the next step of some process or activity. By doing this, the organization "holds on" to those organizing structures that have demonstrated improved performance (Hazy, 2012), and abandons the old way eventually institutionalizing a new structure.

This complexity mechanism and its "information-using" name is drawn metaphorically from the mechanisms whereby chemical interactions in living organisms give rise to and sustain dynamic processes. Living systems use "ratcheting" to maintain enduring coarse-grain dynamic structures (like forward motion in single cell animals). Ratcheting enables enduring coarse-grain properties to emerge in living systems even as transient chemical reactions come and go at the fine-grain level (Hoffmann, 2012). In molecular biology, ratcheting mechanisms wait for the emergence of a new coarse-grain property that results from new fine-grain chemical bonds (this is the information in the system that codes the way that fine-grain interactions enact the new coarse-grain property). These new chemical bonds—enabled by the presence of enzymes or catalysts—replace old chemical bonds and thus eliminate the coarse-grain property that these old bonds implied (effectively erasing information about how the old coarse-grain properties were enacted). The new system structure has new fine-grained interactions which imply new coarse-grain properties; when the "ratchet" erases the capacity to go back to the old way, the system has "moved" to a new state, a step in some process, perhaps moving a millimeter forward on the lab bench. Thus, the ratcheting process describes how relevant information about how fine-grain interaction results in coarse-grain properties is used by complex systems to adapt.

By analogy in human organizations, the information gathering and using functions of leadership enable interactions occurring at the fine-grain level to gain their potency and ultimately to change what happens at the coarse-grain level. The most obvious example of "ratcheting" that occurs in organizations is hiring a new CEO or general manager to support a newly emerging organizing structure, particularly if an entirely new team is brought on board and the old one is let go. When this occurs, the organization is irreversibly moved in a new direction, for good or for ill. Information that had been gathered and synthesized when the new team was selected and put in place is now used in an effort to bring about what are expected to be useful coarse-grained properties, and these are expected to emerge through the thoughtful selection of the a certain set of fine-grained interactions, those enabled by the new management team. This *ratcheting* process is intended to hold the coarse-grained properties that are observed (or in some cases just believed or expected) in order to enhance performance. Coarse-grain properties both *influence* and *are influenced by* individual fine-grain interactions.

To summarize, the present analysis explores the underlying complexity phenomena associated with the enactment of five leadership functions in complex organizations. It also associates each of these with a distinct complexity mechanism that has been identified in studies of complex systems more generally. Finally, this analysis synthesizes the results into an overarching holistic model of leadership in complex organizations. Before describing these functions and mechanisms in more detail, however, the next section offers a consistent picture of organizations as complex adaptive systems that informs them all.

A complexity framework to inform leadership research

Gell-Mann (2002) has drawn the distinction between fine-grain interactions and coarse-grain properties (what he calls "regularities") that emerge within complex adaptive systems (CAS). For our purposes, fine-grain interactions are the day-to-day activities of human experience, such as individual meetings, relationships, and the transactions that occur among individuals in the context of organizing. Coarse-grain properties represent the regularities of daily life— such as traffic patterns and daily routines—that individuals count on to get them through their day without being overwhelmed with uncertainty and anxiety. Coarse-grained properties can be observed at multiple levels and can be formal or informal. They can be observed locally as daily office routines, departmentally as accepted work rules, organizationally as differentiated roles and policies, and even institutionally across many organizations as accounting practices are recognized in many businesses. Moreover, these properties at different levels interact with one another.

As a point of departure in the complexity model, every-day relational interactions among executives and members of the top management team (TMT), between executives and their subordinates, and between middle managers and first line management are included in the definition of fine-grain interactions. Although differences in status and reputation are important (the complications that these differences afford are discussed in a later section), these interactions are all part of the fine-grain layer. This is in contrast to what is often implicitly assumed in management research. In complexity, executives are not assumed to be "functionally equivalent" to the organization, and thus to the implementation of its policies, strategies and capabilities (cf. Teece et al., 1997).

Regularities such as policies, strategies, and capabilities are considered to be "coarse-grain" properties of the organization (Gell-Mann, 2002). These properties are distinct from the fine-grain detailed interactions from which they arise, including even the CEO's

decision to push forward on a strategic initiative. Executives do not implement a coarse-grain property such as a quality program; rather, they influence others and seek to focus the fine-grain interactions among individuals who together enable the coarse-grain property—in this case, a quality program—to emerge.

For example, by advocating for a Total Quality Management model at the fine-grain level, managers enable quality outcomes to emerge at the coarse-grain level. This is a critical distinction that is often missed in the day-to-day language of business. It is core to the logic as to why the leadership process is larger than the individual leaders, and why we need new methods such as multilevel modeling (Yammarino and Dansereau, 2010) and simulations (Harrison et al., 2007; Hazy et al., 2007).

Coarse-grain properties emerge from interactions

Coarse-grain properties are regularities or patterns that arise in the aggregate in response to conditions in the ecosystem, but they arise as a consequence of interactions occurring at the fine-grain level. As patterns, they exhibit a kind of predictable sameness that is independent of the details from which they arise. That is, like the observed equivalence among trees in the forest, one meeting can be mapped to another, and to another, independent of the particulars that make them up. As a result, regularities are recognized as patterns that can be observed, and their relationships can be modeled as properties without regard to the fine-grain specifics that are occurring.

In social systems, these patterns become norms and habits that constrain the choices and actions of individuals. The degrees-of-freedom available to individuals as they operate within the social system are reduced by these norms, and therefore a greater proportion of each individual's energy can be channeled or "entrained" toward specific objectives. Regularities include things such as organizational routines (Nelson and Winter, 1982)—which are repeated with variations, but are also pretty much unchanged daily, weekly, or yearly and from one work group to another across the organization. Even operating capabilities, such as the capacity to execute marketing launches, file monthly financial statements, quality management operations, and so forth (Helfat et al., 2007) are roughly equivalent in this way. A meeting is a meeting, and a market launch is a market launch, regardless of the details. These repeating events can be recognized and studied as coarse-grain properties of the system.

Properties across the system allow the observer, and the actor, to ignore the irrelevant details in the trees and to focus on the important patterns at the forest level. Similar regularities that are observed in different local environments can be compared to one another—all Starbucks stores are pretty much the same. However, one is also able to explore their differences. We can ask to what degree the properties hold true across the system, to what degree instances of them vary, and how these compare. For example, which of the many Starbucks stores is the most profitable? Which has the highest customer satisfaction? Observed regularities can be modeled by assigning random variables to certain aggregate quantities and assuming observed relationships among them are stable over time. One can use coarse-grain properties to predict the changing values of relevant variables as events unfold.

Fine-grain interactions are constrained and entrained

When patterns emerge at the coarse-grain level and are reinforced, there are often complementary impacts on interactions at the fine-grain level (Goldstein et al., 2010). For a

Starbucks "tree" in Boulder, CO to be recognizable in the "forest" of commercial businesses so that it can be compared to a Starbucks "tree" in Orlando, FL, similar things must be occurring at the fine-grain level in each Starbucks "tree." All Starbucks stores do things the same way—they entrain the fine-grain interactions occurring locally. This implies that certain fine-grain interactions—such as those entrained as the coarse-grain standard customer greeting routine—become habits (Dewey, 1922). These legitimizing signals are recognized and processed as coarse-grain inputs to fine-grain choice and behavior, forming habits of mind and action, entraining routines of practice.

To maintain coarse-grain properties, comparable fine-grain interaction differences must be enforced at each Starbucks—distinct, physical layouts are maintained, recipes are precisely followed, store hours are set, and so forth. Even though there is variation in the fine-grain details in each instance, the self-reinforcing aspects of the coarse-grain properties imply that certain patterns are "entrained," and these entrained coarse-grain patterns shape fine-grain interactions. In other words, coarse-grain properties "emerge" as self-reinforcing patterns within fine-grain interactions. As the rules governing these interactions are institutionalized into bureaucratic structures, they are legitimized as acceptable practice.

Coarse-grain properties can be recognized, evaluated and selectively reinforced by individuals

Locally initiated fine-grain interaction patterns—when they are intentional plans of action—can lead to the intentional emergence of coarse-grain properties first locally, and then potentially more broadly. Once the coarse-grain pattern emerges, the details of fine-grain interactions become less relevant because they can be assumed to occur regularly through entrainment.

One property that might emerge is coarse-grain differences in the roles followed by different individuals. This occurs if some types of routines entrain certain interactions for some members, and other coarse-grain routines entrain different interactions for other individuals. This creates distinctions or roles that can be recognized as dividing possible fine-grain interactions available to individuals into legitimate "partitions," or specializations. At a local Starbucks, baristas do their thing; managers do theirs; customers do theirs, and so forth. Although the formal organization and its bureaucracy maintain much of this entrainment, evolving this partitioning into roles takes vigilance and effort on the part of individuals who enact the appropriate leadership practices that are needed to embed information regarding what constitutes allowable interactions in the system's structure. For example, an observer using this information, perhaps a customer, can ascertain how the organization relates to the environment—as a Starbucks. They know whom to address when placing an order and they know where to go to pick up their food. The division of fine-grain interactions into roles enables individuals, like customers, to recognize coarse-grain patterns and take advantage of the regularities that might benefit them. A customer might be excited, for example, to recognize a pattern on the next corner: a pattern called a "Starbucks."

In sum, fine-grain interactions are constrained at various organizational levels by coarse-grain rules that both limit and enable differentiated choices and actions through entrainment. Because the rules result from coarse-grain properties, they are malleable. As such individuals can choose to follow or challenge the rules that would otherwise constrain them.

Leadership functions that navigate the coarse-grain/fine-grain duality

Core to the complexity framework is the following duality: Through *entrainment*, regularities in coarse-grain properties influence what is happening at the fine-grain level. Through *emergence*, changing the rules governing fine-grain interactions evolves the functioning of the coarse-grain properties that characterize the organization's functioning. In this swirl of circular causality (Haken, 2006), an individual is able to influence outcomes, but is also influenced by them. The nature of this duality, what Giddens (1984) calls the "duality of structure," is that both entrainment and emergence are happening in organizations all of the time even as the situation changes and evolves. As the tensions inherent in this duality occur, individuals must maintain a sense of *belonging and identity* as they struggle to determine where they fit, what they are to do, and how they might benefit from all of the organizing that is occurring around them (cf. Tapsell and Woods, 2009). Complexity leadership seeks to clarify and inform the spiraling order creation and destruction processes of human experience.

Generative leadership and adaptation: the emergence mechanism

Complexity provides a new lens through which to view the role of leadership in the *emergence* of new and innovative organizing processes and outputs. The construct of GL (Su-

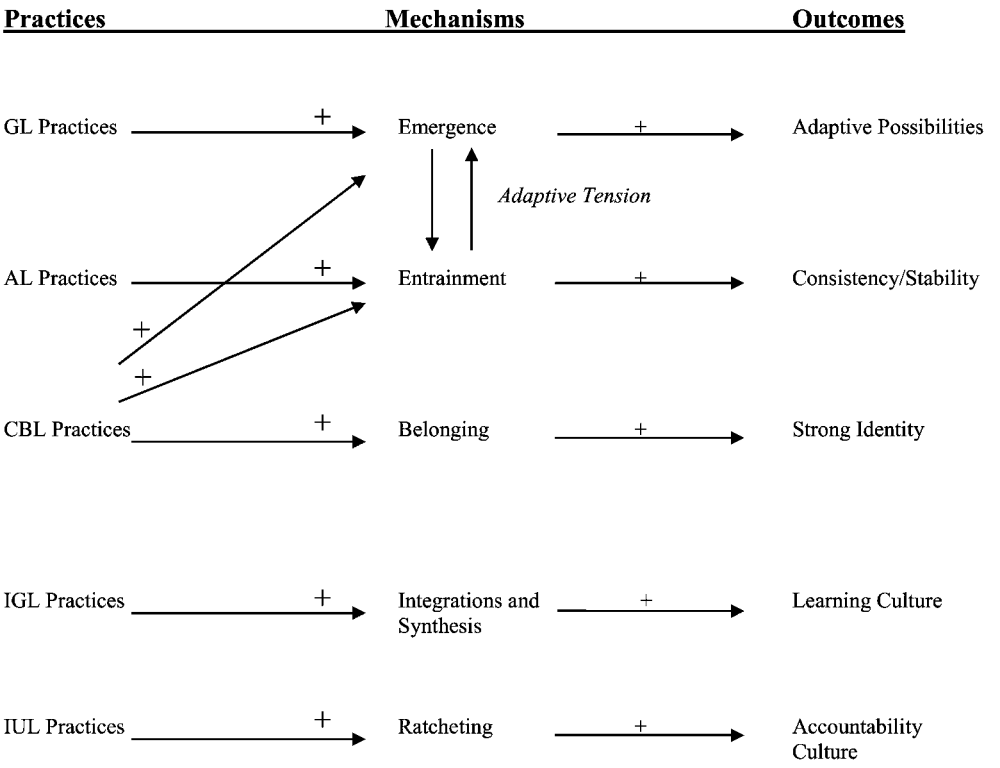

Figure 1. Hypothesized relationships between different leadership practices, complexity mechanisms, and organizational outcomes.

rie and Hazy, 2006) creates interaction conditions that generate variations, experiments at the margin (Dervitsiotis, 2005), and initiatives that challenge current thinking. GL practices also facilitate fine-grain interactions that recognize emergent coarse-grain properties as they arise locally in disparate areas. These practices select some of the fine-grained activities that are producing promising coarse-grain outcomes that might be broadly significant for the organization. They reinforce these or replicate them in other areas of the organization to leverage their impact. GL practices enact bottom-up organizing.

A straightforward illustration of local emergence can be found in the actions of the Starbuck's manager: In response to an influx of customers (i.e., a change to external conditions), the manager would reassign employees to various customer service locations. These well-timed and intentionally constructed changes to the fine-grain interaction rules of specific individuals combine with others to make patterns recognizable to observers. They gain significance as an adaptation of coarse-grain properties that allows the system to stabilize at a higher level of throughput. If these new coarse-grained properties are broadly applicable, what emerged locally might be replicated more broadly through GL practices that spread innovation across the organization. For example, when Starbucks opened stores in Chicago over a thousand miles from its home market in Seattle, store managers and regional managers intentionally changed local fine-grained interactions in an effort to foster the emergence of new coarse-grained processes that addressed the new conditions. Eventually, many of these new coarse-grain properties were adopted more broadly (Goldstein et al., 2010).

The emergence and entrainment duality has been described as the "spiral of innovation" (Tapsell and Woods, 2009: 479) within social entrepreneurial ventures of Maori populations in New Zealand. These duality dynamics have also been shown empirically to have other significant impacts such as innovation in subsea technology development (Johannessen and Aasen, 2007), the rise of new innovation processes at NCR (Garud et al., 2006, 2011), performance improvements on the Dutch railroad (Groot, 2009), and the birth of an Internet safety coalition for young children (Shepherd and Woods, 2011).

Within this duality, the mechanism of emergence is the complexity construct that enables individual action to cross from local fine-grain interactions to global coarse-grain properties. It does not have to occur in the context of a fixed population, nor does it necessarily follow the intentional path of those who occupy a command role. New people can enter the group and act in ways that create entirely new properties for the organization, even an entirely new identity. Plowman et al. (2007a, 2007b) described such a radical realignment scenario within a Mission Church, for example. Such changes often start with experiments at the margins (Dervitsiotis, 2005; Goldstein et al., 2010) which test new possibilities. This is why "leadership" is broader than a person, even the one who is nominally "in charge."

Drawing from the Mission Church case studies (Plowman et al., 2007a, 2007b), Lichtenstein and Plowman (2009) describe the emergence process as unfolding in phases. First of all, the potential for emergence is signaled by a sense of coarse-grain disequilibrium, or loss of stability where external and internal conditions have changed such that the previous sense that the organization had been exhibiting operating stability is lost. The sense that one knows the rules is questioned, and what is expected at the fine-grain level is weakened. This sense of loss must be backstopped by GL practices that support experimentation and innovation.

To deal with the uncertainty, some individuals try things; they experiment to see what works. Some experiments move the organization and its properties forward and are sustained or amplified through repeated imitation by others. These local activities main-

tain successful efforts as possible elements of a new coarse-grain way to organize the system. In the Starbucks illustration, calls for help from employees are heard, recognized, sustained, and amplified by calls from others until the manager recognizes the need. He or she then expends energy to bring additional workers off break. He or she puts them to work at various service stations. Both actions, the call for help and the assignment of baristas, are experiments; each consumes energy or resources. Each may or may not help to bring stability back to the system. They are trials, not solutions. Solutions are found as these actions are given coarse-grain significance through further leadership practices.

In the next phase of emergence, some successful experiments that have been maintained in the organization (due to local success) are recombined to create new or modified coarse-grain properties at the system level. In the local Starbucks operational illustration, the fine-grain interactions of new baristas at the register improve throughput *at the register* and this combines with increased throughput *in the kitchen* and so forth. Improvement at the register is significant (for the system) only when the kitchen is also more effective and so on. Only when all of the changes to fine-grain interaction combine do they reorganize the overall coarse-grain operation in a significant way.

All of these employees work together to solve the problem, taking actions they feel are significant. Offering stabilizing feedback about what is working—and what is not—*overall* and in combination, brings the system back to stability at a new coarse-grain system of order. This is celebrated as a significant event. But now the organization is reorganized with a qualitatively different level of throughput. For example, the initial experiment might have assigned too many additional employees to the register. Eventually, one or two might have moved to the kitchen or even gone back on break. Note that this analysis implies that the manager did not bring the system back to stability nor did he or she alone lend significance to events; all of the individuals involved did so through their GL practices of experimentation and signification.

GL and the emergence it fosters have also been used to explain the formation of entrepreneurial ventures formed to solve social problems in Indonesian villages (Beck and Chong, 2009) and among aboriginal peoples in New Zealand (Tapsell and Woods, 2009). However, although emergence has been described qualitatively relative to these phases, exactly how this process unfolds in the details, and what this might mean for leadership, remains underresearched. Such research could be guided by the following proposition (see Figure 1 for a summary of all five propositions):

> ***Proposition 1:*** *GL practices (shown in Table 2) are positively related to the capacity of the emergence mechanism to express new coarse-grain properties (i.e. organizational routines, capabilities, and properties) which may enable the organization to adapt in a changing ecosystem.*

The GL function results in new possibilities for the system. GL practices catalyze fine-grain interactions that drive the emergence of new coarse-grain properties. These coarse-grain properties can then "entrain" a new fine-grain pattern in the system as is discussed in the next section.

Administrative leadership and performance: the entrainment mechanism

The construct of AL relates to practices that enact the downward influence of coarse-grain properties—like a product group's capability to deliver profitability, or the sales teams' routines that deliver growing sales—on the fine-grain interactions that are occurring be-

hind the scenes among individuals. This might influence the way that certain individuals on product teams were assigned to monitor profit margins or how sales executives schedule sales calls for their teams. This influence occurs through the mechanism of *entrainment.* This is NOT the same thing as the assertion in traditional leadership theory and practice that senior management influences or "aligns" managers in the furtherance of organizational objectives. The assertion is that the coarse-grain properties themselves—by virtue of their being recognizable, stable, significant, and therefore *useful* in some way as "the way things are done around here"—begin to influence the behavior of individuals. AL practices catalyze the top-down organizing process.

When a self-reinforcing regularity exhibits recognizable coarse-grain properties—the company books are closed every quarter—it also implies predictable outcomes. These outcomes can be modeled either conceptually, or mathematically. Finance people mark their calendars for the quarterly close without needing to ask anyone whether the hours will be long; they can predict these future event. Because models predict regularities, they often accurately predict events and can be trusted to unfold. Taken together, these coarse-grain properties make up the administrative system of the organization that entrains fine-grain behavior and improves efficiency, a practice long associated with executive leadership (Barnard, 1938). As shown in Table 2, setting clear expectations and objectives is an example of this.

Regular break times emerge by convention, for example. As individuals learn these routines through social interaction and experience, they learn to trust and support the AL function. The result is a set of human habits and routines that increasingly synchronize the routines of many people. In this way, the AL function aligns practices for effective operations (Barnard, 1938). This process of expectation-action-feedback leading again to new expectations acts to *entrain* individual interactions. Entrainment is enabled by what Simon (1990) called docility; individuals accept beliefs and models from others and trust the models as reality.

The tendency to conform to a synchronized set of routines can be a powerful force, particularly when the practice of assigning incentives is used to reinforce behaviors that optimize the variables in the model of the coarse-grain property, such as the profitability model, rather than being attuned to the results that are actually occurring, sometimes with counter-productive effects (Buckle-Henning and Dugan, 2007). Bonuses might be tied to reported sales rather than actual customer sales, for example, a practice that can lead to "stuffing the channels."

Allen (2001) has shown how this process might work when entrainment is occurring in conjunction with a physical resource or asset such as a warehouse, a transportation hub, or even a written business plan. In these cases, what might have once been an arbitrary decision about where to locate the firm's office can become a predictor of other variables. Sales prospects might be more likely to become customers if they are close to the office, or the location might predict which suppliers are selected, for example. This is because in a market economy, the AL function exerts pressure to minimize costs, in this case transportation costs, which pulls system elements closer to a physical warehouse, which therefore acts as an "attractor." The exercise of power over resources to create and reinforce *structural attractors* such as the warehouse is an example of the domination structuration perspective on leadership practices.

Members of the TMT, executives, and middle managers also show docility (Simon, 1990) and are not immune to *entrainment*. In the 1980s when the Intel organization consolidated its strategy around microprocessors, the membership of the TMT was itself adjusted. Andy Grove was the strongest advocate of the microprocessor business as it

developed around experiments (Dervitsiotis, 2005) and had the requisite experience, success, and status at Intel (Burgelman, 1994). As fine-grain interactions consolidated coarse-grain properties around the new microprocessor-based business model, it simply made sense for power to consolidate around Grove as CEO. Grove himself became a structural attractor (Hazy, 2008b).

In general, as the models used by members of the TMT are reinforced beyond the TMT's boundaries (for example though the incentive system), coarse-grain organizing become increasingly stable and "controlled" (really reinforced) by management. Research to explicate the entrainment mechanism and its relation to leadership could proceed according to the following proposition:

> ***Proposition 2:*** *AL practices (shown in Table 2) are positively related to the capacity of the entrainment mechanism to improve the stability and predictability of coarse-grain properties (e.g. organizational routines, capabilities, and processes).*

Additional examples of the administrative function of leadership include project management procedures and activities, the enactment of quality processes such as total quality management (TQM), and other initiatives that decrease variance and increase capabilities in producing quality process outcomes. In addition to enacting entrainment, leadership must also bring people together.

Community-Building Leadership and community-identity: the belonging mechanism

As coarse-grain properties emerge, individuals operating at the fine-grain level must recognize that they have a part to play and that others do as well. Given each person's individual position, perspective, and preferences, however, it is not always clear to them exactly what their part is, what they get for it, and what they are trying to accomplish through their fine-grain interactions. More perplexing for the individual—and therefore an additional opportunity for leadership intervention—is determining what others are doing, what they are trying to accomplish, and whether their activities further one's interests or oppose them. CBL practices catalyze this process and support the ability of individuals to recognize those with whom they are expected to cooperate and how. Tapsell and Woods (2009), for example, describe how these individual tensions impacted and were overcome in complex organizing across generations among the indigenous people of New Zealand.

Depending on the various social groups with whom individuals interact, their differences in position, perspective, preferences, and beliefs might call forth distinct *identities* for the agents (Tajfel and Turner, 1986). Each agent sees the world differently, at least to a degree, and herein these differences are assumed to relate to differences among individual identities and the groups with whom they identify. For simplicity, the present analysis departs from social identity theory (Tajfel and Turner, 1986) and defines an *agent-identity* for an individual (who can have multiple identities) as those aspects of the rules governing one's interactions that are identified as being equivalent in some way to those of others when determining choice and action (Hazy, 2012). (For example, "I can *identify* with that person because we are all on the same team" or ". . . we speak the same language"; that is, we are equivalent to one another in some way.) In short, CBL practices hold the organization together.

Fine-grain CBL practices support the adoption of identities that are necessary to further the coarse-grain properties of the organization. When someone self-identifies as an accountant, for example, others have expectations of that person's skills and ethical practices.

These leadership practices enable participants to sort out and simplify the tasks in which they participate. They clarify who else is participating in common efforts, who might benefit from them, and how. These practices help individuals understand where they *belong*.

Identities establish categories of fine-grain interactions to simplify the choices and actions that must occur to maintain coarse-grain properties. As a result, they enable the entrainment of the right individuals for the right tasks, and avoid entraining the wrong people for a particular task. Accountants (individuals properly identified with other accountants) are entrained with new coarse-grained accounting procedures. The administrative assistant is not expected to be entrained as an accountant because he does not *belong* with the accountants; he has a different identity. As a result, he is entrained in a different set of routines. Individuals can categorize their fine-grain choices and actions so as to be acting with like-others, with, for example, other IBMers, or union members, or certified public accountants (CPAs). Individuals *belonging* to a *community-identity* are the same in this respect—they are interchangeable along some dimension. The *belonging mechanism* simplifies fine-grain interaction and enables individuals to focus on what is important for the organization.

The construct of CBL relates to the fine-grain practices enacted to build and legitimize (Giddens, 1984) coarse -grain beliefs and values about the identity-groups that are foundational for these communities. They operate on the fine-grain activities of individuals as they communicate with one another, and they work to clarify identities for themselves, recognize the identities of others, and identify with others—all at the fine-grain level—to make common cause at the coarse-grain level (Backström et al., 2011). Although not by name, the CBL function was explored in a laboratory study which looked into the factors that individuals weighed as they chose to participate or not in various coarse-grain initiatives (Dal Forno and Merlone, 2007). The researchers found that conditions of fine-grain equity, and of organizational justice engendered by CBL practices, were important considerations when choosing to belong to a group.

The community-building function identifies and reinforces these common models and beliefs, and brings people together into communities by engendering the feeling of *belonging*— of acting as an agent within a community-identity. Research to explore these dynamics could develop around the following proposition:

> ***Proposition 3:*** *CBL practices (shown in Table 2) are positively related to the strength of the belonging mechanism that enables individuals to identify with others in a community-identity and to make choices and act in ways that support this identity.*

CBL practices might, for example, instill an ethical climate within an organization in an effort to facilitate both generative and administrative leadership practices. Activities that support training programs, workplace awareness signage, and peer-to-peer reinforcement programs would be examples of CBL practices that support an ethical community-identity. Multilevel modeling techniques, as exemplified by Molleman et al. (2010), could be a useful strategy for exploring this relational function of leadership.

Functions for gathering and using information as a system

As shown in the above discussion, what is happening at the fine-grain level has potency to affect coarse-grain organizing. This occurs because influence flows both from fine-grain interactions to coarse-grain properties through emergence, and from coarse-grain properties to fine-grain interactions through entrainment. However, neither level is static. Both

are dynamic, and both are broadly distributed. For a system to perform and to adapt, it must be able to use fine-grain interactions to *gather information* about the changing environment and interpret it *as an organized system* in the context of its *coarse-grain properties.* However, they must use information being sensed by individuals who are widely distributed and have different perspectives, and they must use the information *in fine-grain interactions* in ways that impact the organization's coarse-grain properties. Processing this information is key to determining how the system is doing and determining what must be done next.

The complexity mechanisms described in the last section embody the "how" of leadership, but not the "what." Determining the "what" requires these information processing mechanisms. Information gathering and using leadership practices set, evolve, and maintain system conditions, such that the system can sense distributed information relevant to the organization, bring it into the system, and then use it *as a system*. More specifically, IGL practices set, evolve, and maintain the conditions that enable the system to have the capacity to sense, recognize, and interpret information distributed among many individuals—across the organization and the environment. IUL practices shape fine-grain interactions in a manner consistent with each particular local situation and do this in many local environments *as a system.* These processes enable individuals to gather information locally through fine-grain interactions and to orchestrate the system's broader coarse-grain responses to environmental stimuli. In the complexity framework, this occurs without any one person fully comprehending either the stimuli or the system's responses (Hazy, 2013). Gell-Mann (2002) calls such a system an information gathering and using systems (IGUS).

Gathering information: integration and synthesis of models and beliefs across scale

The construct of IGL relates to practices that enable the sensing and interpretation of information in the context of the organization's coarse-grain properties. This occurs through leadership practices that engender the integration and synthesis of external and internal information gathered at the fine-grain level but perceived to be relevant for the coarse-grain level. It is enabled through shared reflection about relevant events (Molleman et al., 2010). These framing, storytelling (Boal and Schultz, 2007), and questioning practices enable individuals to share their models and beliefs about how the relevant coarse-grain world works. Potential opportunities (for example a coarse-grain variable that describes a new market opportunity)—and hypothesized relationships among them—can be communicated through fine-grain interactions. These discussions help to synchronize perspectives regarding the organization's capabilities and opportunities, and how these might come together. They also explore the fine-grain choices and actions that are needed to support the emergence of the requisite coarse-grain properties (see Table 2). IGL practices make an organization aware of its situation in the ecosystem.

Goldstein et al. (2010) argue that the process of information gathering, storing, and processing can be understood in the context of game theory. Stable strategies in multiplayer, multi-round games are called "attractors" because once they are adopted, they tend to be stable. When the notion of stable game strategies is framed from the individual agent's perspective, Goldstein et al. (2010) call stable individual strategies *choice attractors.* They describe these as, "stable modes of [fine-grain interaction] behavior" (p. 66) that are consistent over time and across multiple iterations of a process that forms coarse-grain properties. Drawn from game theory, they are multiplayer, ". . . 'game' strategies that have worked in the past, and thus draw the players to stay within their sway" (p. 66). They involve anticipating the moves of others, forecasting the consequences of these, and deter-

mining the best move. Taken together, these relatively stable configurations of fine-grain choices that are maintained in the attractor predict a desirable outcome that the agents can obtain through a hypothesized but perhaps not yet realized coarse-grain property. Thus, the choice attractor notion from game theory describes how individuals become entrained at the fine-grained level to prospective collective action that is expected to lead to an emergent coarse-grain property. Choice attractors are coarse-grain properties that emerge through sharing, analyzing, discussing, and synthesizing information that has been attained by disparate individuals and informs their fine-grained interactions. However, the information must be processed in the context of potential collective coarse-grain action to achieve expected fine-grain benefits for the players. A choice attractor drives entrainment about a hoped-for outcome, rather than an existing routine or habit.

The continuing prospect of potential benefit that might come from correctly anticipating the actions of others, reacting to these forecasts, and trusting in those who share a common community-identity, entrains participants into the coarse-grained properties promised by the choice attractor. Eventually, if events do not change, behaving according to the choice attractor becomes the default behavior, the "habit" (Dewey, 1922) and the expected coarse-grain property actually emerges. However, if events change, the choice attractor and thus the expected emergent coarse-grain property will also evolve in response to events. Continually facilitating the maintenance and evolution of choice attractors among multiple players over multiple rounds of the "organization game" across many individuals within a changing ecosystem is the challenge addressed by the information gathering function of leadership. It uses the mechanism of *integration and synthesis* to observe and communicate events in an effort to reach a common understanding about how these affect the game. Cooperating individuals continue doing what is working—reflecting together jointly on surprises through fine-grain interaction in the context of the game, gathering new information from events, and integrating the information into their strategies. As new information is gathered, the collective strategy for "playing the game" incorporates, and thus "stores," these data as an enduring configuration of fine-grain choices in the context of a choice attractor.

An example of a "game strategy" that leverages the benefits of identity is one where the choices support the identity of "acting as an IBMer." This simple choice attractor stores information gathered all around the world about events that relate to "being an IBMer" and applies specific choices to, for example, a coarse-grain IBM customer service encounter. This allows a company with hundreds of thousands of "players" to share experiences locally but also work well together around the world, and it enables individual success in the process. Being an IBMer can also make one's department operate better, and each workgroup acts like a winner, etc. In organizations, IGL practices enable choice attractors, such as internalized mission and value statements, to be implemented at multiple scales of organizing and at locations scattered around the world (Goldstein et al., 2010).

A function of IGL is to facilitate the storing, sharing, and interpretation of information gathered from locally occurring events. This disparate and distributed information is synthesized with other local patterns and with other properties that are emerging at the coarse-grain level. It does this when individuals change their choices within the "games" they are playing based upon the events they witness. One would expect that the fidelity with which information from the ecosystem is gathered and synthesized in the organization across scale, and over time is positively related to success in both performance and adaptation. Research in this area could be pursued according to the following proposition:

Proposition 4: *IGL practices are positively related to the capacity of the integration and synthesis mechanism to enable individuals to identify information from the environment that is relevant to the organization's coarse-grain properties, to store it, and to interpret it for the benefit of other individuals and of the organization.*

As an example, Surie and Hazy (2006) describe Indian manufacturing companies who, while partnering with Western companies, identified new markets to support and sustain their growth, and this occurred through fine-grain interaction among employees. The realization of the value of this information as it relates to new coarse-grain "variables" grew rapidly within the firms. This occurred as it incorporated customer feedback (gathered through fine-grain interactions and integrated and synthesized through further fine-gain interactions) into their next generation product designs (or "models") in an iterated mapping of one generation onto the next. Growing success led these firms to divide, or "partition," their market into two coarse-grain types, local and global markets (each with new coarse-grain property), essentially dividing one game into two games. This is an example of how the people in an organization use information to change the organization's structure.

Using information: ratcheting gains by enacting irreversible changes in fine-grain interaction structure

IUL relates to the practices that take advantage of the information that has been gathered, integrated, and synthesized across the organization. These practices facilitate the efficacious use of this synthesized information to make enduring coarse-grain changes to the organizing structures of the system. It does this through practices that (a) identify gains in coarse-grain properties that are beneficial in the ecosystem, (b) hold these gains, and (c) avoid the risk of sliding back to its old ways. When a successful coarse-grain property is observed (and this occurs through interactions at the fine-grain level), IUL practices reinforce the fine-grain- interactions that enabled its emergence. In parallel, the old fine-grain interaction patterns are discouraged. Together, these practices have the effect of eliminating the old coarse-grain property and replacing it with the new and hopefully improved one. By using this *ratcheting mechanism* – moving forward and not sliding back – IUL practices enable irreversibly progress in a particular direction. By doing so, they enable an effective collective response to changes in the ecosystem.

At the coarse-grain system level, organizations need resources to sustain themselves. At the same time, there is a wide variation at the fine-grain level with regard to the relative access to and control over resources among individuals. An earlier section of this paper described how entrainment reinforces the stability of coarse-grain properties simply because these coarse-grain properties are recognized by individual participants as "what I must do." Individuals "join in" without regards to that coarse-grained property's potential for success or failure.

However, "what is happening" can be influenced by differences in status, reputation, and power among the individuals who act. For example, the exercise of power over resource allocation can be used to create structural attractors (Allen, 2001)—like new computer systems or warehouses at the institutional level, or a new conference area or office layout at the department level—that enable the entrainment of certain coarse-grain properties (at their respective levels). When this occurs, the flow of resources and information is irreversibly changed within the system, either locally or more broadly—even institu-

tionally. Because they control resources, high status individuals are able to leverage their influence. In short, it matters who controls the resources in human organizations.

One way this *ratcheting mechanism* is actualized in practice is by adjusting the relative status and authority of the individuals who are involved with the old versus the new way of doing things. This can involve assigning authority and changing the hierarchy, instituting differentiated roles, encouraging specialization, and varying the reputations of those doing new things versus the old ones. Note that this leadership function is not the same as when individuals use the information as a means to adjust their own fine-grain interactions. These practices change how information is used within—and potentially across—the organization, as the organization acquires and uses resources as a coarse-grain system.

The *ratcheting mechanism* that enables forward motion in human organizing is analogous to the complex process in molecular biology that enables living organisms to take advantage of emergent order within their structures. Molecular reactions are fine-grain interactions in this case. Dynamic processes such as protein synthesis and folding, DNA replication, or membrane functioning are the coarse-grain properties. In molecular biology, these complex structures are enabled through "ratcheting," the process that allows the system to "hold onto" performance-enhancing structures that emerge at the molecular level (Hoffmann, 2012). One key observation from molecular biology is that the "ratchet" takes time to work. This is why coarse-grain properties necessarily have a longer time horizon than fine-grain interactions. The system waits while fine-grain interactions unfold. It continues to wait until a relatively rare event occurs among the many "experiments" or chance occurrences that are going on at the fine-grain level. When a waited-for event occurs—a relatively uncommon chemical reaction, for example—the system invests some of its free energy to capture and sustain the new structure. In the process, it also "resets" the system to include this newly emergent coarse-grained structure (for example, it moves one step closer to a synthesized protein molecule) by irreversibly replacing the prior structure with the next-stage structure. The use of free energy to "erase" information about the prior structure—in this example, information erasure occurs as chemical bonds are permanently broken (erasing the information embedded in them)—necessarily increases entropy as heat is released (and thus preserving the second law of thermodynamics). New chemical bonds are now formed in a progressive process (where new information about these new structures becomes embedded in the system). In this way, the ratcheting mechanism irreversibly incorporates newly emerging dynamic structures (e.g. requisite proteins are formed from their constituent ingredients) to enable the next level of functioning within living systems. Since the old way is erased, progress is made, step-by-step until a desired result is attained. In the molecular example, the result is that a needed protein is synthesized (Hoffmann, 2012).

Human organizations likewise work to "hold the gains" in coarse-grain properties to enable step-by-step improvements in performance even as the environment is changing. By analogy to the molecular case, IUL practices enact fine-grain interactions that are intended to hold onto the new information that is embedded into new and innovative capabilities or performance gains that have emerged. These leadership practices reinforce the new patterns of fine-grain interaction and support the resultant coarse-grain properties. By offering this temporary support, IUL practices give the entrainment mechanism and its related AL practices time to institutionalize the new way. In effect, the new innovation is propped up as the old way is erased, allowing the new way to replace it. As a result, the system "holds the coarse-grain gains." Energy is expended to support the transition to institutionalized change and to eliminate the risk of regression to the old way. This

has the effect of "ratcheting" the coarse-grain change by making the change both enduring and irreversible. A typical leadership practice to do this is to bring in a new manager with the requisite experience in the desired approach and with no prior "baggage" about how things used to be done. With this new person in charge, her way, the new way, becomes the only way. Old routines are "erased" and this always comes at the cost of adaptive tensions in the organization.

IUL practices actualize this *ratcheting mechanism* to determine which information stored at the fine-grain level is used to enable the emergence of coarse-grained properties. Those who enact these practices do this without necessarily knowing what information is important (i.e. what exactly the relevant individuals are doing right) or how these fine-grain interactions will enable the emergence of new coarse-grain properties. Thus, IUL practices help to institutionalize new and different structures into the organization. In this way, leadership facilitates how the system as a whole selects what works, and preserves information about how it works within the very structure of the system, irreversibly replacing the old way. As the new way is perfected, outcomes become increasingly predictable. For example, when organizational participants recognize a new way of doing things in the marketing department—perhaps because a new leader has been put in charge—one gradually learns how to predict the new kinds of coarse-grain "marketing activities" that are likely to occur.

In sum, IUL practices at the fine-grain level orchestrate and evolve irreversible structural changes to a system's coarse-grain properties. As such, these practices are important aspects of the leadership process (Dal Forno and Merlone, 2007; Schreiber and Carley, 2007; Solow and Leenawong, 2003). While the integration and synthesis mechanism described in the prior section builds-up the new information that is available to the agents of the system, the ratcheting mechanism embeds selected new information into the structure of the system and erases old information. This discussion implies a final proposition:

> ***Proposition 5:*** *IUL practices are positively related to the capacity of the ratcheting mechanism to irreversibly create new organizing structures and eliminate old ones.*

One way this is done is by differentiating relative positions and the roles of individuals in the organization, including, for example, their relative status, specialization, and their authority to allocate resources and to determine the status of others. One would expect that the extent to which the experiences and expertise of individuals match the requirements of opportunities arising in the ecosystem would be positively related to an organization's success at both performance and adaptation, an application of Ashby's (1956) requisite variety. The Intel example from a prior section shows this. Once it became clear across Intel that microprocessors were the company's primary business, it was also clear that given his history and skills, Andy Grove was in the best position to formulate and articulate the beliefs and models of the new Intel *and to weaken their old way of doing things*. Leadership practices that resulted in the promotion of Grove to the top spot had the effect of loosened old structures enabling the new way to take hold (Hazy, 2008b).

Future directions

The application of complexity to leadership research has progressed significantly since the *Leadership Quarterly* special issue over five years ago. This paper has reflected upon twenty-plus publications and has synthesized their results to advance thinking about complexity leadership. By focusing primarily on the complexity concepts of emergence and entrainment and how these connect fine-grain interactions with coarse-grain prop-

erties, it clarifies how leadership functions help individuals in the organization recognize relevant coarse-grain properties within unfolding events and then coordinate an effective collective response.

The complex organizations of today cannot be managed like machines. Rather, they emerge from purposeful interactions among individuals, each of whom balances personal needs against collective success—success that might also result in personal benefits. In complex organizing, leadership involves the furtherance of the emergence mechanism. It does this through GL practices that engender experiments at the margin (Dervitsiotis, 2005; Goldstein et al., 2010), and thus create new opportunities for organized action. To realize their value, the choices and actions of the others who are also disposed to participate must be organized, and this occurs through the entrainment mechanism that is actualized through AL practices. The choice to participate, however, is not assured. This is enabled by the belonging mechanism and is engendered through CBL practices which foster community-identities as a means to facilitate organized activity.

These complexity mechanisms embody the "how" of complex organizing, but not the "what." Determining the "what" requires two information-processing mechanisms. The integration and synthesis mechanism, enabled by IGL practices, senses, and processes events in the ecosystem. The ratcheting mechanism enabled by IUL practices holds the gains of the organization by irreversibly embedding information about how success was achieved into the organization's structure. It does this through leadership practices that differentiate individual power and authority by status and by partitioning individuals into specialized functions and roles.

These five leadership functions have been deduced by framing organizations as CAS, and the practices that enact them each has been supported through empirical research (for a review see Hazy and Uhl-Bien, 2013). More research is needed to explore these mechanisms, their links to the functions of leadership, how these relate to previous traditions of leadership research, and how together they can be used to drive preferred organizational outcomes. For this to occur, the field needs new research methodologies. For example, multilevel modeling, agent-based modeling, dynamical systems modeling, dynamic network analysis, and improved data analysis techniques could be combined with traditional methods to inform process-related leadership research. Together these theories and methods will ignite a new era of complexity informed research that has the potential to fully acknowledge the contextual nature of leadership as practiced in today's increasingly complex organizations.

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