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COMPLEXITY AT A CROSSROADS: EXPLORING A SCIENCE OF EMERGENCE

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INTRODUCTION

Complexity science has been making contributions to management, entrepreneurship, strategy, OB and other fields for more than 30 years. Ulrich & Probst (1984) and others (Nonaka 1988; Smith & Gemmill 1991) started this literature, but it was catalyzed by the well-known 1999 special issue in Organization Science. However, after great interest, there have been fewer and fewer complexity articles in top journals—just three in the past three years in OrgSci, AMR, AMJ, ASQ, SMJ, JBV. Did complexity reach its heyday and is now headed for a demise? How can we leverage its insights for organization science?

Partly this is on us as complexity scholars, to better answer fundamental questions about the causality and dynamics of complex systems. Unfortunately, we still do not have a coherent 'theory' of complexity the way we have a theories of entrepreneurship, for example. My claim here is that a single such theory of complexity is not viable, for complexity is an amalgam of theories. However we may gain traction by applying complexity sciences toward developing a coherent paradigm of emergence.

Complexity Sciences: Origins and Limitations

The origins of complexity were the 'new sciences' of deterministic *chaos theory, fractals*, *system dynamics* developed in the 1970s (see Bygrave 1989; Stevenson & Harmeling, 1990; Goldstein, 1999). Organization scholars also applied other mathematical models of complexity including *fractals*, *catastrophe theory* and *power laws* in organizations (e.g. O'Boyle & Aguinis, 2012). A second set of complexity sciences is derived from biology, ecology and other natural sciences, including *autocatalysis* (Eigen & Schuster 1979), which has been actively applied by Padgett and Powell (2011) and their collaborators. *Dissipative structures theory* (Prigogine & Stengers, 1984) is the basis of a different set of articles (Lichtenstein, 2000; Chiles et al., 2004; Plowman et al, 2007); separately, *ecosystem resilience* (Gunderson & Holling 2001) has been being explored especially in the environmental sciences (Liu et al., 2007).

The third set of complexity disciplines is by far the most recognized: *complex adaptive systems*—computational studies using agent based modeling and simulation. This is the "American School" of complexity (McKelvey, 2004; see Davis, Eisenhardt, & Bingham 2007). *NK landscape* studies originated by Kauffman (1993) and have been published in a host of top tier journal articles (e.g. Gavetti & Levinthal, 2000; Siggelkow & Rivkin, 2006; Billingers & Stieglitzn, 2013; Girod & Whittington, 2015). Other complexity computational models include *cellular automata, genetic algorithms, agent-based* and *multi-agent learning models*. The findings of these simulation models have intuitive appeal: agents following simple rules will create new order (structure) through their interactions.

Overall, the diversity of these sciences identifies why complexity research has not aggregated nor built upon itself. With 15 different theories/methods most researchers do not know about others' findings, nor are able to integrate them. More challenging is the problem of comparing findings across complexity disciplines, for there is often no basis for grouping many

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of the outcomes. For this reason most of the summaries of the field are organized into three general segments or categories; see Maguire et al (2006), Kozlowski et al., (2013).

However, across all these differences in complexity science there is one very important commonality: They all explore emergence – the creation of order in dynamic systems (Goldstein, 2000; McKelvey, 2001). Emergence is the reason-d'etre of the complexity sciences, each of which identifies and explains emerging order in a unique way, whether the emergence of agent-based structures, the emergence of new ventures, or the emergence of macro-level schema and technology. Equally important, a host of emergence papers have been recently published, creating a stronger basis for the integration. Emergence is the phenomenon/a of interest; complexity science provides tools for understanding emergent processes and outcomes. Thus, we begin to explore a discipline of emergence.

Moving Toward a Discipline (Science) of Emergence

In examining emergence as a discipline or worldview, we should start by focusing on emergence within organization studies, especially in the subfields of organizational behavior, entrepreneurship, organizational management theory, business policy and strategy, technology and innovation management, and organizational development and change—although virtually all fields have access points to emergence. Importantly, note the many levels of analysis that emergence has examined. For example, scholars have explored emergence of cognitive development, of leadership interactions, and of teams—within the individual, across agents, and at the group level. As well, a host of studies have studied emergence of organizations (e.g. Brush, Manolova, & Edelman, 2008), and new products. Within organizations, emergence has been examined in terms of human capital, design, and values (e.g. Gehman, Trevino, & Garud, 2013), and innovation researchers have examined the emergence of technologies and new inventions. At the macro level, researchers have explored emergent collaborations and the creation of new fields, schema, industries and institutions (e.g. Lawrence, Hardy, & Phillips, 2002; Purdy & Gray, 2009; Dew, Reed, Sarasvathy, & Wiltbank, 2011; Fiol & Romanelli, 2012). As a whole, emergence incorporates virtually all units-of-analysis studied by management scholars, from individual behavior to teams to companies to innovations to alliances to markets/schema to global institutions.

At the same time, these levels (micro-organizational-macro) are themselves an incomplete picture of emergence as a science. Researchers have examined emergence phenomena using every discipline of the natural sciences, For example in physics, Haken (1977) showed how the emergence of self-organized coherence in energy would create a much more powerful beam of light. In biochemistry, Eigen & Schuster (1979) explained the emergence of mutually reinforcing feedback loops that drive key biochemical processes, as *autocatalysis.* In biology Margulis (1971) identified the emergence of mitochondria in the cell, through *symbiogenesis*. Other insights have been gained in cross-level analyses, especially by Sawyer (2002, 2005), Corning (1983), and contributors to Clayton & Davies (2006). In combination, this rich scholarship has the potential to generate a coherent field of emergence studies.

Overall my goal is to shift attention onto emergence phenomena—emergence as a phenomenon. This shift generates two initial questions about defining emergence, which I examine next. Should emergence be seen as a process or as an outcome? And, what causes emergence—what drives emergent order?

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Defining Emergence: Outcome vs. Process

Organizational scholars hold two divergent views about what emergence entails. In one, emergence produces in an outcome—emergence yields something tangible. For example, Fulmer & Ostroff (2015) define emergence as: "…a higher-level 'whole' that is formed from the individual 'parts' in the system. …A new pattern or form emerge[s] as a collective, higher-level phenomenon." In this view, emergence refers to a tangible, perceptible outcome—an emergent. In organization science emergents have included a new company, a new technology, a new product, a new set of values or goals, a new sector, and so on. Scholars using this frame examine the ontological presence of the emergent, measuring specific outcomes in social systems (Goldstein, 2000; Sawyer, 2005), and the dynamics which bring that emergent into form.

The alternative view is equally compelling: Scholars see emergence as a continuous process of organizational becoming (Tsoukas & Chia, 2002). Social entities are consistently emerging, each one constantly (re)making itself over time. Researchers have exemplified this lens through studies of continuous morphing (Rindova & Kotha, 2001), emerging design (Garud et al., 2006), and qualities that lead to collective identity (Fiol & Romanelli, 2012). Garud and his colleagues have done the most to understand process in the relational and temporal aspects of emergence (e.g. Garud, Gehman, & Guiliani, 2014). This view of emergence as an ongoing accomplishment eschews attempts to fix an 'outcome' at any given point. There are no emergents in this definition of emergence, as they are not necessary for explaining emergence processes.

These two divergent views are both necessary for a complete understanding of emergence. We see emergence in its ongoing organizing process, the continual unfolding of social reality—the *becoming* of things (Tsoukas & Chia, 2002). At the same time, successful organizing does produce tangible outcomes or artifacts: Things do emerge. In combination, emergents are visible expressions of ongoing emergence; thus, *emergence* yields *emergents*—emergence processes yield emergent outcomes. Emergence as a process can stand on its own, and emergents are also viable topics of study. Any given study of emergence will likely view only one of these.

Defining Agency in Emergence

A second key issue to untangle about emergence is its genesis—what drives emergence? What initiates it? There are likely to be only a small number of causalities, what I call *prototypes* of emergent order. Four prototypes of emergence are presented here (but see others in Lichtenstein, 2014), each of which emphasizes agency in a particular way. The first two are very salient; they are the most common in the literature and they appear to point in opposite directions in terms of the instantiation of emergence.

Agents Following Simple Rules. As already mentioned, complexity claims that agents, following simple rules, will create structure. According to this stream of research and writing (Kauffman, 1993; Davis et al., 2007; Johnson, 2009) emergence occurs when agents interact according to a few basic heuristics; over time a network order emerges out of these interactions. This idea is central to all computational models of complexity, which enact this logic-of-action through the decision rules of their agents, in their continuous search across the network/landscape. It turns out that this driver alone, with no other motivations, can lead to new structural order in the system (Davis et al., 2009). The emergent structure of the system is not

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initiated by any particular agent, but resides in the complexity of their interactions; this alone yields systemic order.

Importantly, there is very little that a computational agent can *do* to produce emergence in these models. No intentionality is necessary; emergence is a kind of accident (good fortune). The locus of activity is not in the agent per se, but within the (external) system. Thus, simple rules will generate order. Many people think this *is* what complexity means.

Generative Emergence. An alternative view of emergence is seen in the creation of new social entities (emergents); e.g. the emergence of a new company, a new product, project, or initiative. This is what I call generative emergence, in which agents actively pursue the creation of new order (Lichtenstein, 2014). Specifically, agents push the system far-from-equilibrium toward the possible emergence of an innovation or a new system. In this prototype of emergence, individual agents use their personal agency to create the conditions within which something new can emerge.

The core science behind generative emergence is Prigogine's dissipative structures theory, which explains the emergence of new systems in far-from-equilibrium conditions. Applications of this paradigm of emergence were initiated by Smith (1986) and Leifer (1989), and have been used to explain emergence in entrepreneurial firms (Lichtenstein, Dooley, & Lumpkin, 2006), organizations (Plowman et al., 2007), and in regions (Chiles et al., 2004). In generative emergence agents have an intention to create something; this intention drives the system into a disequilibrium state. As tension mounts, experiments and combinations are tried to find the right solution. At the peak of this influx the system will hit a critical point, on the other side of which is emergent order, or failure. If the process is successful, what emerges is a new way of organizing that improves the system in a fundamental way. However the entity may not undergo emergence, and instead collapse and end. Many entrepreneurs are familiar with this result, although it is rarely reported in complexity studies.

These elements—disequilibrium, tension, experiments, re-combination—are present in all major studies that draw on dissipative structures theory. Likewise, the drive to create new entities (projects, companies, collaborations) is central to the generative emergence prototype.

Contrasts in Agency Between the Two Prototypes of Emergence. Note the profound contrast at the heart of complexity. With simple rules, agents do not need to have a drive—indeed, computational agents don't have access to such personal preferences at all. Instead, ongoing interactions with other agents are all that's necessary to create emergent order. In contrast, the driver of generative emergence is entrepreneurial passion—individual and shared effort that drive the creation of a new system or entity. Here, committed effort is the driver of emergence.

Each emergence scholar follows their own path, of course. Although I have not pursued computational studies I have great appreciation for the insights I've gained from those who do. Yet as an entrepreneurship scholar, my focus is drawn toward generative emergence, which for me provides a more grounded explanation of emergence in that context. However—and more importantly—these are not the only two prototypes of emergence.

Further Prototypes of Emergence

Although these two categories of emergence are by far the most common in organization studies, other prototypes have been identified as well: symbiotic processes and macro emergence. These are briefly presented next.

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Symbiotic Processes: Symbiogenesis, Autocatalysis, Resilience. A third causal process for emergence occurs in the co-generation of organic structures which increases their effectiveness by orders of magnitude. A core exemplar is symbiogenesis, whereby an emergent system within the cell begins to envelop organelles into itself, creating mitochondria. These allow the cell to produce 2000% more energy than was possible before this emergence (Corning, 1995). Another exemplar is ecological resilience (Gunderson & Holling, 2001) which describes an adaptive cycle of development and re-development in ecosystems across many scales. This cycle is self-reinforcing, based on an ongoing interchange across system levels; the term *panarchy* reflects this multi-layer effect. This framework has been particularly applied to issues of sustainability in natural and social systems (Folke et al., 2004; Walker et al., 2004).

Macro Emergence Prototypes. A fourth prototype examines emergence in more macro contexts. Collaborative emergence (Sawyer, 2005), in particular, shows how non-linear dynamics in a social system can lead unexpectedly to social movements and institutional emergence, where individuals' combined efforts aggregate into a broader collective. Studies of this social process have been done on complex innovations, inter-organizational collaborations, new organizational forms, emergent schema, new institutional fields and new markets. Unfortunately the variety of theoretical frames across studies makes it difficult to distinguish a specific driver for emergence. Still, this prototype is often cited in sociological instances of emergence.

Summary of Prototypes. These four prototypes of emergence—simple rules, generative emergence, symbiotic processes, and macro emergence—are each based on a distinct causal logic. Like the dual nature of process and outcome in emergence, all four are necessary and relevant; links between them and others will be a continuous source of innovation for the field.

Potential for a Science of Emergence

Two claims have been made about this prospective discipline. First, emergence is both a process and an outcome: emergence processes yield emergent outcomes. Both of these are equally valid, yet they are nearly incommensurate, making it hard to pursue research across those boundaries. By being more clear about which orientation is taken in any article, we may be able to better distinguish the two, and integrate ideas within and potentially across these frames.

Second, emergence does not have a single driver or unique cause; instead, emergence occurs through (at least) four prototypes. These may be arranged on a continuum of sorts. On one end is simple rules: Emergence is not caused by an agent but occurs through unintentional interactions between agents, all directed by simple rules. Here the driver is rules, interdependencies, and interactions—all of which reside outside the agent. At the opposite pole is generative emergence: agents actively pursuing emergence with passion and commitment. Here the drivers are within the agent, who leverages opportunity and creativity to generate order in a given system. In between these two are other dimensions of mixed causality. The notion of prototypes allows these different causalities to each be valid for exploring emergence.

Future work should explore several research avenues. One key extension is to see complexity research as but one of many avenues for examining emergence in/of/across organizations. This speaks to literatures that go beyond complexity, including effectuation and bricolage (from entrepreneurship), and relational coordination/leadership. At a macro level emergence has been examined in terms of social movements, institutional entrepreneurship, alliances and collaborations, shared innovation, and so on. Moreover, although many emergence

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studies don't rely on complexity science per se, they do still emphasize its non-linear and relational influence in their analysis. In combination, emergence studies has a remarkably broad foundation of knowledge.

With this extension we can explore additional issues. To begin, are the two types of emergence—process and outcome—really dichotomous? In other words, a valuable next step would be to examine how the full range of methods and theories can reveal their interdependence, of 'things' that emerge within the emergence (organizing) of those things.

Second, according to my characterization the agency of generative emergence is internal to the agent(s)—it is within their control and due to their intention. In contrast, the CAS prototype puts agency outside the agents, i.e. in the rules and interactions in the network. Perhaps a middle ground can link these two. Specifically the process framework views emergence as *entrepreneuring*—action that is directed but stochastic, essentially unplannable, with outcomes that can transcend (redefine) the initial organizing context itself. This third space, in the realm between control and lack-of-control, may be the origin of emergence.

Finally, emergence seems particularly well-suited to explaining and supporting social innovations. On the surface, the prototypes of autocatalysis and resilience may reveal a host of new insights into social entrepreneurship and sustainability. Beyond that, the combination of tangible and intangible factors for emergence are a good match to the economic and non-economic value of triple-bottom-line initiatives. This connection holds particularly high potential.

Limitations

Several questions remain about the core ideas presented here. First, the paper reviews four prototypes, but my current conceptualization of the prototypes limits what we can see in emergence. Much more collaborative thought should be directed to understanding the full range of emergence prototypes. A second limitation is in my descriptions of complexity science, which are drawn from my own knowledge of the field. For example, my version of complex adaptive systems may appear to be somewhat uni-dimensional, emphasizing the aspect of simple rules. However, there are computational programs that do allow agents a good deal of decision-making capacity, which is not captured in my sense of following rules. Thus, limitations in my arguments may be based on the way I've characterized these approaches. Finally, much more attention is needed to integrate the process and content versions of emergence.

Prospects

It is presumptuous to think one can 'initiate' a science. Instead, science is a conversation, an amalgam of research and shared schema within a growing professional/disciplinary network. I've attempted to present a wide range of research on emergence, to exemplify the vitality and engagement across fields. My hope is this paper can support and help catalyze that conversation about emergence in organization studies and beyond.

REFERENCES AVAILABLE FROM AUTHOR