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# SELF-ORGANIZING SYSTEMS THEORY
## Historical Challenges to New Sciences

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One sweltering, summer afternoon, I was standing in a room, giving a presentation to our graduate colloquium, on a new piece of research I had just completed with a fellow graduate student. We were very excited to present the manuscript, as it gave us the opportunity to practice for our first presentation at the International Communication Association. After I made it through the presentation (our department chair asked me to present in order to qualify for graduate funding to attend the conference), I began to relax, as people asked questions about the research subjects and amount of time we spent observing the organization. Sitting in the audience that day was a new professor in our department whom I had come to respect and admire. Little did I know she would ask the question that would not only stump me that day, but would also lead to the focus of my dissertation. "What's the difference between self-organizing systems theory and open systems theory?" she asked. Hmmm; not only could I not articulate it at that time, it would take weeks of diving into the literature to even broach an answer. Even then, each time I attempted to answer that seemingly simple question, another would be presented. Uh oh; no easy answers—just the type of trouble I always seem to get into.

I suspect that my plight is one experienced by many attempting to apply the notions underlying what has become known in many circles as self-organizing systems theory or, more popularly but with less linguistic precision, chaos theory. At a local conference that gathered together scholars interested in applying self-organizing systems theory to the communication discipline, I heard many frustrations raised:

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> It wasn't until the last day that I felt like we were getting somewhere, but even (his) brand of ethnography was nowhere close to mine.
> Wow! There are some people with so much history in the field I didn't even get through their papers (in the conference proceedings). It was too much work to try and go back to catch up to where they are.
> Boy, I wish I had done something that simple. It must be nice to make something up and then call it complexity.
> I can't believe it—this person doesn't even have the concepts right.

The self-organizing systems perspective, although complex, proposes simplicity, at times offering one simple solution and at other times proposing many. It is fascinating, yet frustrating—language seems to interrupt its conceptual flow. Applied to many scientific and social scientific problems, its principles are captivating: pattern, process, structure, function, recursion, nonlinearity, emergence, underdetermination, overlapping experiments, and ideas explored by multiple disciplines across the academy at large. Under the domain of the "new science," terms and applications of chaos, complexity, self-organizing systems, and self-producing systems are sweeping the academy. At this point, the vision for the future of the new science is unclear. Morgan (1993) declares, "We are moving into an era where the ability to understand, facilitate, and encourage processes of self-organization will become a key competence" (p. xiii). However, our ability to form such a vision that fulfills the promises of new science are haunted by ghosts of similar past promises of cybernetics, by open systems theory, and perhaps, by the inability of the academy to unite in a focus. One common cycle seems to reappear when social scientists incorporate scientific insights to understand social situations: Social scientists seem to react with initial enthusiasm, adoption, limited success, criticism, and finally rejection. In other words, the impetus for developing a perspective has been to oppose the lack of precise application of the then-dominant perspective and then argue for something new and improved, rather than continue working toward developing the once exciting, current perspective.

With this issue in mind, this article illustrates the sympathetic nature of the numerous predecessors up to and including self-organizing systems theory. This article is not an attempt to continue the endless possibilities and promise of self-organizing systems but, rather, to show how we have never entirely rejected the fundamental roots of self-organizing systems theory that started not only with the Katz and Kahn's (1967) organizational application of open systems theory but also with fundamental epistemological questions as to the nature of the universe. These multiple versions of systems theories have interdependencies or mutual associations that reveal the unnecessary development of oppositional arguments to justify a new perspective.

To accomplish my goal, I begin with a review of the historical basis of this class of systems-based thought in order to develop a more comprehensive understanding of how past development of similar paradigmatic shifts in thinking evolved. Next, I explore some contemporary answers to the combinatory possibilities of the physical and social sciences. Finally, a practical approach to employing self-organizing systems is posed. My hope is that through reviewing the epistemological roots of self-organizing systems theory, we can create a common framework of value commitments in our field of research.

## HISTORICAL FOUNDATIONS OF SELF-ORGANIZING SYSTEMS

### ASSUMPTIONS OF CLASSICAL SCIENCE

To fully appreciate the complex and varied roots of self-organizing systems theory, a few traditional paradigmatic assumptions that have shaped our approach to scientific inquiry are examined to help realize the paradigmatic shift that took place when "systems" thinking was introduced. First, the influence of the classical science conceptualization of time-ordered processes must be understood because it shapes the role of methodology and relationships studies in a systems perspective. In classical Newtonian science, we find time processes to be calculated phenomena that are reversible. Subsequently, most laws concerning relationships are expressed in terms of determinism and time reversibility (Coveney & Highfield, 1990). This conceptualization of time is the precursor to understanding the potentialities of relationships in the physical world. If we conceptualize a system on the assumption that time is reversible, then the relationships between variables must be reversible. However, in the real world, a world in which time is not the result of Newton's mathematical calculations, no one ever expects to encounter perfectly reversible systems. Poincare (as cited in Coveney & Highfield, 1990) questioned this predictability of relationships as conceptualized by the Newtonian universe and was the first to posit the potential for complexity and chaos within a system. The traditional conceptualization of time is excessively structural and yields a reductionist perspective that simplifies complex relationships in systems.

Another paradigmatic assumption of classical scientists in the 20th century that greatly influenced our study of systems stems from its roots in structural functionalism. The overarching principle of structural functionalism assumes a bounded system consisting of a set of interrelated parts that operate to maintain (or change) the system by meeting its needs for survival. Functional theorizing calls for the generation of a basic needs—such as entropy, feedback, homeostasis, requisite variety, and equifinality—that a system requires so that it may survive in its environment (context). For example, a system's feedback mechanism provides data about changes in the environment, so that the system can adjust to maintain its equilibrium. Because classical science assumes that these static elements are knowable and predictable for the observer, emphasis is then placed on material aspects of systems. Consequently, we find that elements of a systems are then analyzed based on which need they fulfill or, conversely, do not fulfill (referred to as a dysfunction of the system). Although conceptualized as dynamic, systems processes are frequently examined by analyzing static, linear properties rather than dynamic elements that may produce complex processes. The following sections introduce the theorists and concepts that challenge some classical scientific assumptions and that form the underpinnings of the new science.

## GENERAL SYSTEMS THEORY: OPEN SYSTEMS

In the 1960s, biological scientist von Bertalanffy (1968) introduced the broad framework of General Systems Theory that eventually captivated social scientists. von Bertalanffy sought to solve a dilemma of the Second Law of Thermodynamics (i.e., when a machine is running down, a system's energy dissipates over time). In his science of wholeness, von Bertalanffy proposed that living systems engage in an open interchange with the environment, in which inputs and outputs can be largely explained in terms of feedback loops. This open exchange would allow systems to continue to thrive rather than to fall into disarray. Because an open system needs to find ways to survive in its environment, it follows logically that there is a boundary separating the system from its environment. In turn, this boundary forces conceptualization of the environment as a causal chain of events in relation to the system. What this means is that system change is often activated by external forces; therefore, a system self-regulates to buffer itself from its environment. This thinking introduced the notion of interdependence—that systems are reliant on, yet are also constrained by, feedback from other subsystems. The work of von Bertalanffy established systems thinking as a major scientific movement (Capra, 1996).

## CYBERNETICS

During a similar time frame, several scientists, in fields ranging from mathematics to neurology to computers, introduced the theory of cybernetics (e.g. Ashby, 1956; Wiener, 1961). Wiener's (1961) conceptualization of cybernetics stemmed from his observations of patterns across different systems of communication, control, and feedback. Wiener focused on these elements as nonmaterial entities that are crucial to the description of life (Capra, 1996). According to Wiener (as cited in Ashby, 1956, pp. 6-7), the contribution cybernetics offers is, "a method for the scientific treatment of the system in which complexity is outstanding and too important to be ignored." The behavioral focus of cybernetics tends to focus the researcher on process rather than on just the object of the system: “Cybernetics typically treats any given, particular machine not by asking, what individual act will it produce here and now? but rather questions, what are all the possible behaviors it can produce?” (Ashby, 1956, p. 3). Overall, cybernetics deals with all forms of behavior, insofar as they are regular, determinate, or reproducible (Ashby, 1956). Wiener (as cited in Ashby, 1956, pp. 6-7) concurs, “cybernetics is the science of control, and communication, in the animal and in the machine.” Although their intention from the beginning was to create an “exact science of the mind,” cybernetics is marked by the inquiry into circular and recursive processes.

While cyberneticists were examining process, another order, second-order cybernetics, emerged. Second-order cybernetic scholars, who include Bateson (1979), Mead (1968), Keeney (1983), and von Foerster (1962, 1974), invoked a focus not only on the properties of the systems and the interaction of the environment and the system but also on how observers are made part of any description by their act of observation (Steier, 1991). Bateson (1979) and Mead (1968) would be most notably associated with this movement, linking second-order cybernetics to practical problems such as family therapy, alcoholism, and other mind-body phenomena. In so doing, second-order cyberneticists were responsible for bringing a systems-based approach to a wide range of social phenomena.

## THE NEW SCIENCE

Similar to its historical predecessors in some ways, yet more expansive in others, the study of systems that fall under the rubric of the “new science” also represents a move away from the Newtonian model that is characterized by materialism, reductionism, and, a focus on things rather than on relationships (Wheatley, 1992). Scientists in a wide range of disciplines from physics (Prigogine & Stengers, 1984), to meteorology (Lorenz, 1963), to statistics (Wolfram, 1984, 1986), explore the notion of a science that examines relationships beyond the superficial and apparent order of the universe to reveal a hidden dimension, one that contains an underlying order and structure that is unobservable when reduced to its parts (Briggs & Peat, 1989). This principle is, of course, illustrative of the elements similar to the older order of systems (i.e., pattern, process, structure, function, and recursion) but also innovates some new concepts (i.e., nonlinearity, creative destruction, emergence, and underdetermination).

Developments in biology and neurobiology (Maturana & Varela, 1980, 1987) take the explanation of how system structure and identity is created and recreated a step further. Through the process of autopoiesis, or self-production, systems are continually self-producing in terms of the processes from which they are created—not in terms of their relationship with an environment. That is, for a system to know itself as a system, it must establish a separate and closed loop of interaction. For this reason, self-producing systems are self-contained with everything necessary readily available. Yet, there is an interdependence between the system and the environment; self-producing systems are paradoxically open and closed. They are open because they exchange energy within their environment, while they are closed to information and control because they create meaning through the process of self-reference. Self-reference represents knowledge accumulated by the system about itself that affects its own structure and operations (von Krogh & Roos, 1995, p. 39).

## SIMILARITIES ACROSS SYSTEMS INCARNATIONS

The similarities between developments in self-organizing systems and cybernetics are important. First, they show a similar pattern of questions emerging in major conceptual models and movements throughout time. They questioned the classical science-based deterministic, linear notions of simple cause-and-effect relationships in self-contained systems. Second, they exhibit a continuous pattern of development. Rather than outright rejection, each perspective takes on elements of previous incarnations. For example, Maturana and Varela (1980, 1987) agree with von Bertalanffy (1968) that systems are open, but they also require systems to be closed so that they maintain a distinct identity and are self-productive. Although Ashby (1956) argues that the possibilities of behaviors within a dynamic system are infinite, he suggests that a study should be limited to that that is determinate. Self-organizing systems theorists have set out to understand the probabilities and possibilities of the underdetermined. This development reveals that we have never absolutely rejected previous perspectives but rather have worked to extend them. Third, several core concepts are threaded throughout all of the systems-based perspectives. When taken together, general systems theorists, cyberneticists, and the "new" scientists appeal to the need to understand a whole system and the relationships among varying subsystems. This need to understand the whole leads to another commonality, nonreductionism. Interdependence in cybernetics, along with interchange in the environment, acknowledges the emergent dynamics of a system process. Finally, the cybernetic principle of self-regulation seems to represent a starting point for carrying out the notion of self-production. The following section reviews the variety of social science fields that have used the principles associated with self-organizing systems and also examines the role of science in the development of a social science–based form of self-organizing systems.

## DEVELOPMENT OF SELF-ORGANIZING SYSTEMS IN THE SOCIAL SCIENCES

Within the past few years, research on self-organizing systems theory in the humanities and social sciences has burgeoned. Many scholars, from those interested in literature (Hayles, 1991), public relations (Cottone, 1993), economics (Arthur, 1989), and groups and organizations (Contractor, 1994; Contractor & Seibold, 1993; Goldstein, 1994; Gregersen & Sailer, 1993; Morgan, 1993; Svyantek & DeShon, 1993; Taylor, 1995; Thietart & Forgues, 1995; Wheatley, 1992) are exploring the applicability of self-organizing systems to the social phenomena of life. Links drawn between the so-called hard sciences and the humanities represent boundary crossings of interdisciplinary extremes. The applicability of this new science perspective to human systems seems to be easily drawn from the scientific theorists themselves. Several self-organizing theorists have either commented on the possibilities of their work being applicable to many different disciplines (e.g., Prigogine, 1980) or have their own social scientific applications themselves (Varela, Thompson, & Rosch, 1991). However, recent popularizations of theory (including a car commercial!) have taken a toll on attempts to extend self-organizing systems theory to human organization. What began as an exciting and beautiful journey into a new land has turned into a frustrating attempt to articulate a self-organizing systems-based understanding of human experience. What was once met with intellectual enthusiasm now risks being rejected with wry cynicism. If we fail to articulate the interdisciplinary, posthumanist nature of self-organizing systems theory, we face the reproduction of earlier mistakes made by those who rejected open systems theory, cybernetics, and second-order cybernetics. The following sections describe current attempts at articulating possible solutions to creating a unidimensional approach to the question of how to combine the natural or hard sciences with social sciences.

## CONSILIENCE

Recent movements across the academy in both camps have proposed different ways to deal with the problem of crossing disciplinary boundaries. The most current of these is Wilson's (1998a, 1998b) argument for "consilience." Wilson declares that the humanities and sciences should "jump together" to create a systematic approach to and understanding of the universe. Wilson (1998a) believes that "the Enlightenment thinkers got it mostly right," which means to him that we should still be chasing a "lawful, material world, the intrinsic unity of knowledge and the potential of indefinite human progress" (p. 41). As a biological scientist, Wilson (1998a, 1998b) argues that a common groundwork of explanation linking facts and fact-based theory should be created, that everything in our world is organized in terms of a small number of fundamental natural laws that underlie all branches of learning.

In light of developments in systems theories, this search for common ground and a common system of knowledge threatens to destroy the fabric of variety that is already threaded through the sciences and social sciences by systems thinkers. This "jumping together" of the social sciences and sciences is a retrograde step: It leads back to modernist thinking that we can know the unknowable, solve all the mystery, and control our universe and behavior. Furthermore, we love the diversity we have fought hard to preserve. The disorder in the universe represents its strength, rather than its weakness. For example, Nobel Prize winning physicist Prigogine's (1980) research on dissipative structures revealed that the points at which discontinuities appear indicate where systems' variables exhibit random behavior, yet there is a pattern or order that emerges out of the chaos introduced by the discontinuity. A variety of diverse interactions causes a creative destruction of individual inputs and thereby generates a coherent unity. This process of creative destruction emphasizes underlying, nonlinear processes that rely on diversity to produce a self-organized unity.

At this point, there seem to be two questions that need to be addressed. First, how do we reconcile the difficulties that exist between the sciences and social sciences? Part of the unrest lies between the sciences and the division between humans and machines. Second, what is the practical step to take from here if we are going to continue to use a self-organizing systems-based perspective to understand processes in the social sciences? Because scientists' assumptions shape the values of perspectives in both the physical and social sciences, we need to explore the values underpinning both the new and the old scientific paradigms. Both Varela (1987) and Capra (1996) argue that we need to have a radically different epistemology that allows us to be in the middle—to see, relate to, and argue from both sides. Table 1 outlines the underlying values of the two competing systems of thought—the traditional, classical science and the new science of self-organizing systems.

Altogether, the polarity of these values points to the need for an epistemology that allows us to have diversity of perspective, while allowing us to work within the whole. Additionally, because scientific research emerges from our values and actions, we also need a

**TABLE 1: Values of Classical Science, Sympatrics, and the Holistic, New Science**

| *Values of . . .* | *Classical, Old* | *Sympatric* | *Holistic, New* |
|---|---|---|---|
| ____________________ | Correspondence | ☐ | Coherence |
| ____________________ | Foundationist | ☐ | Holistic |
| ____________________ | Externalist | ☐ | Organic |
| ____________________ | Rational | ☐ | Intuitive |
| ____________________ | Analysis | ☐ | Synthesis |
| ____________________ | Reductionist | ☐ | Holistic |
| ____________________ | Linear | ☐ | Nonlinear |
| ____________________ | Competition | ☐ | Cooperation |
| ____________________ | Expansion | ☐ | Conservation |
| ____________________ | Quantity | ☐ | Quality |
| ____________________ | Domination | ☐ | Partnership |

SOURCE: Adapted from Capra (1996, p. 10).

perspective that encourages us to take responsibility for the role we play in creating knowledge used by the rest of the world.

A unique response to this need is to adopt a sympatric perspective, one that allows us to embrace all constitutions that occupy the same range without losing their individual identity. This response would then acknowledge the need for diversity allowed by two simultaneous, yet not competing, positions. Commensurate with the development of such a perspective, we need to be able to articulate values that create some unity between humans and nature, the physical and the social. Recent developments of the fields of ecofeminism and cyborgology attempt this type of decentering of essentialist, contradictory positions. The following section outlines some of the basic tenets of these new standpoints.

## ECOFEMINISM AND CYBORGOLOGY

Ecofeminism is a perspective that focuses on the value of all nonhuman life. It recognizes the interdependence of all ecological communities, thus moving it away from anthropocentric values, or human-based values, and toward ecocentric, or earth-centered values. This type of awareness places living systems on a level-playing field—humans are no longer the center of the universe and this self-reflective awareness of being a part of what Capra (1996) called the web of life ensures our care for all living things.

Similarly, cyborgology embraces the "nonhuman." As a posthumanist perspective, cyborgology disintegrates the artificial distinctions between organic and machine processes, between humans and machines. Cyborgs are the melding of the organic and mechanic, or the engineering of a union between separate organic systems (Gray, Mentor, & Figueroa-Sarriera, 1995, p. 2). Furthermore, Gray et al. (1995) note that the notion of a cyborg applies not only to individual bodies but also to many other human-based entities: "As these larger 'bodies'—of people, business, and government—are more closely tied to vast technologies, they too become cyborgs and we struggle to find ways to predict how they are shifting" (p. 7). Adoption of these new posthumanist perspectives would enable us to more easily shift between the values of the new and old sciences, while offering a new perspective on the artificial and misleading distinctions among humanity, nature, and technology.

After developing a value-centered, sympatric perspective, the question that remains is, How do we engage in research based on self-organizing systems? While recognizing that the traditional values of science are still desirable, if our interests are process, interdependence, holism, and nonlinearity, then we need to examine the range of possible events and the interacting selection mechanisms that produce one possible outcome over another. The following section outlines the possibilities for searching for generative mechanisms as a tool for creating knowledge about the systems in which we operate, produce, and reproduce.

## GENERATIVE MECHANISMS: THE PRACTICAL POSSIBILITY

The processes in systems are represented by the products or surface effects of an underlying mechanism in the system. This notion, known as a generative mechanism, is similar to Chomsky's (1980) idea of deep structure. These underlying mechanisms are an aid to interpreting observable events because they guide how a system produces and reproduces itself.

The fundamental nature of a generative mechanism is a multifaceted concept. Within the structure of a generative mechanism, there are two functions: (a) an overarching ordering mechanism, and (b) an underlying logic that produces surface behavior. The former is explained by Danziger (1990) as, "a basic common framework within which communication is possible, while at the same time providing scope for differences of emphasis" (p. 332). In such a framework, differences of emphasis are encouraged to stimulate theoretical development (Danziger, 1990), while maintaining a consonant line of research. Interpretations of these images remain open, and those who share them are in the position to emphasize different sets of implications. From this perspective, self-organization can be seen as an appropriate mechanism to connect society as a whole, an organization, or even a small group. Berggren (1963) speaks of this type of generative mechanisms as the presiding schema of a scientific theory, which he likens to the presiding image of a poem.

Another function of a generative mechanism is to provide understanding of the deep, underlying logic that produces surface behavior. According to Morgan (1986), generative mechanisms can be explored as the process that generates patterns of meaning that create and change systems. A generative mechanism is an imagery that describes "the basic dynamics that generate and sustain organizations and their environments as concrete social forms" (Morgan, 1986, p. 235). Exploring the processes of self-organization as a generative mechanism provides a way of explaining how the reality of life may be embedded in the logic of change itself. In the context of change, it explains deep processes of transformation as a function of self-organizing behavior that produces surface phenomena. Life processes might then be understood as self-producing systems, which is a function of creating an identity. In other words, self-organizing systems provides a means of explaining how the explicate reality of life is formed and transformed by underlying processes.

## CONCLUSION

In sum, a generative mechanism is an underlying phenomena for a complex set of events; it defines something essential about the nature of a system and focuses on what is felt to be crucial about its structure. A self-organizing mechanism is dynamic, not static, something that is constantly regenerated through interaction. The identity of a system is then a self-referential act, through which a system knows itself as distinct from, yet connected to, its environment. Identity then becomes a center of knowledge about the self. A value-centered, posthumanist perspective on self-organizing systems seems to be consonant with our need to create knowledge, while allowing us to maintain some of the mystery and unpredictability of life.

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