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A Brief Introduction to Complexity in Organizations

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The sciences of chaos and complexity include arcane investigations of complicated natural phenomena. Organizational applications of the sciences are no less complicated. Talented persons around the world are struggling to make sense out of the strange and surprising behaviors of complex adaptive systems in nature and in human organizations. This paper presents a brief introduction to some of the major themes of the applications of chaos science to organizational development and behavior. Because of its brevity, this paper cannot include all of the rich and subtle insights that emerge from a study of complex adaptive systems. On the other hand, the paper will provide relatively simple definitions of terms and concepts that form the foundation of the theory and practice of complexity in organizational settings. Full Article

Why Chaos and Complexity?

Statements about change have become clichés in today's organizations. You have heard them; you have probably even said them:

- Change is the only constant in our organization.
- Change or die.
- Focus on continuous improvement.
- The future will be different from the past.
- Change is growth, so get used to it.
- We need a paradigm shift.

Questions, frequently unspoken, resound in organizations that are undergoing change. They, too, have become clichés:

- Why should I change?
- Can't you see that it is the other guy who needs to change?
- How will things be different in the future?
- Why change now?
- When will this preoccupation with change blow over so we can get back to work?

Institutions of all kinds are expending tremendous resources to implement change. All too frequently, however, the resultant change is minuscule compared to the investment, and every bit of progress must be sustained with continuing investments of time and energy. When change does occur, often it brings unpredictable consequences. As long as we continue to think about our organizations in the same old ways, we will continue to misunderstand change, incorrectly

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predict the consequences of change, and misdirect the leverage for change. Perhaps we need to examine our basic assumptions about relationships, organizations, cause and effect, and management control of organizational behavior. We need to explore how the new paradigms of science--chaos and complexity--can affect our understanding of social systems. These new sciences involve a world view, vocabulary, and set of assumptions that account for the interconnectedness, global nature, and unpredictability of the contemporary corporation.

What is Chaos?

In its traditional sense, chaos meant total disorder and randomness. In the context of chaos science, however, chaos is not disordered, and it is not random. Chaos is used to describe the behavior of certain nonlinear systems that behave in strange and unpredictable ways. In a chaotic system, a simple set of starting conditions may generate complicated and unpredictable outcomes. Chaotic systems are a special case of systems that are considered to be complex (thus the sciences of chaos and complexity.) Complex systems also behave in surprising ways, but they may not meet the specific criteria that denote technical chaos. In general, a complex system can be defined as one that has the following characteristics:

- Indefinite number of parts
- Nonlinear relationships among the variables that describe the parts
- Feedback mechanisms within the system
- Behavior that may appear random, but which can be described by deep, underlying patterns
- Behavior that is unpredictable

The weather is an excellent example of a complex system. It involves an indefinite number of parts. Every oxygen, nitrogen, and water molecule, along with stray dust particles, move around in the atmosphere. As they change direction, speed, concentration and so on, measurable temperature, pressure, and humidity variations emerge. For example, the air over a large land mass is warmer than air over a mass of water. As it is warmed, the air over the land rises, and cold air from the water rushes in to fill the low pressure area generated by the rising warm air. The new, cooler air is warmed, and it, too, begins to rise. As the air rises high enough, it begins to cool and to fall toward the earth. It cannot fall toward the land mass because the warmed air is rising from there, so it must fall over the water. This, in turn warms the air mass over the water. This cycle of warming and rising and cooling and falling is the relationship that provides the emergent behavior of high winds at sunset on the beach.

Everyone, including most media meteorologists, will agree that the weather is not predictable. Even the most powerful computer cannot determine specific weather conditions at a specific place in the distant future with any degree of reliability. The components that affect the weather are highly interdependent--molecular components of the atmosphere work together to determine temperature, pressure, and humidity. Any change in one of these characteristics will result in

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some variation in the others, but the exact relationships among all of the characteristics is not known. At the systemic level, we see patterns in weather conditions, in spite of the fundamental unpredictability. Warm fronts, cold fronts, climatic changes, and seasonal temperature patterns all emerge from the interactions of atmospheric components and their measurable characteristics.

There seems to be little question that the weather is a complex, nonlinear system, but do human systems share these same behaviors? Many persons are beginning to think about human organizations as complex systems. They seek to apply what they know about complex systems, either mathematically or metaphorically, to the behavior of organizations. The purpose is to understand how human systems function and to develop tools and techniques to help individuals function effectively within their own environments.

People have always dealt with complex, nonlinear systems. We have talked about the weather, put money into the stock market, evaluated and manipulated evolutionary processes, and marveled at the whirlpools at the bottom of a waterfall. But our sciences have worked under the assumption that the systemic behaviors of these systems could be understood if we knew enough about the individual parts. By using the scientific method, humans have endeavored to divide a complicated system up into its parts and understand the parts individually. This reductionist approach did not allow for the complexity, unpredictability, interdependency, or emergent behavior of complex, nonlinear systems.

When the scientific method was not sufficient to explain phenomena, some people adopted mystical language as an alternative. Persons who could not understand emergent behavior by analyzing the components of the system frequently abandoned science and turned to mystery, spirituality, or superstition for explanations. This subjective approach, though potentially satisfying on a personal level, limited the ability to resolve disagreements between groups with different mystical foundations.

Chaos science and its related areas of investigation use mathematical, objective, scientific strategies to describe systemic behavior that defies the reductionist strategies of the past. In the same way, it is possible that a complex systems paradigm might lend cohesion to the plethora of organizational and management models that are driving organizational change today.

Patterns in Complex Systems

Researchers and practitioners who use the sciences of complexity to describe organizational behavior have identified a variety of patterns in organizations that parallel those in complex physical systems. Brief definitions of some of these characteristics appear below.

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Nonlinearity--Traditional mathematics, like you learned in high school, is based on a fundamental assumption: If you know the value of one variable, and you use the correct procedures, you can determine a unique value for another variable. This assumption holds true as long as the equation that related the variables is linear in nature, or it is one of a small set of simple, nonlinear equations. These mathematical constructs are not sufficient to describe most complex, nonlinear systems. In some physical systems, it is impossible to determine the value of a second variable, even when a first variable is known. Metaphorically, an organization experiences nonlinear phenomena when a team begins with the description of a problem and ends with an elegant and effective solution--the outcome could not be predicted from the starting point.

Unpredictability--Given the complex interdependencies of a complex or chaotic system, its exact state at some future time is unknowable. Scientists can investigate a myriad of possible futures, but a unique future state is unknowable. Participants in any organization will recognize this characteristic of unpredictability. At the beginning of a project, it is impossible to know for sure what the course, outcomes, or unforeseen factors will be. Change agents must investigate multiple possible futures, without knowing which one will become a reality.

Interdependency--An individual component of the system influences, and is influenced by, the behavior of other components of the system. Physical scientists call this phenomenon coupling. Two parts of a system are said to be tightly coupled if they have a great influence on each other. The parts are loosely coupled if the influence is present, but not extreme. They are uncoupled when neither influences the other. Frequently, the level of coupling in a system affects the amount of time required to propagate a change from one part of the system to the other. In an organization, coupling affects the speed of information transfer and the effectiveness of efforts to encourage change. For example, if research and development are tightly coupled to the rest of an organization, then the manufacturing processes had better be flexible and adaptable. The factory will be expected to produce new and radically different products frequently and with minimal cycle times. On the other hand, if the organization is uncoupled from research and development, then findings will not be reflected in product designs, and management might see R&D funds as wasted resources.

Emergent behavior--The behavior of individual components of the system work together to create the behavior of the whole system. The whole system behavior is not just the summation of the behavior of the parts, rather systemic behavior emerges from the interdependent activities of the parts. In organizations, this behavior can be used to explain how and why the behavior of a whole group may have coherence, while the behavior of individuals may appear to be random. For example, a commonly-held value may require that different employees behave quite differently within their respective areas of influence, but a pattern of behavior emerges to indicate that the underlying value is the same.

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Autopoiesis--Biologists recognize the ability of an organism to adapt to its environment, and yet to retain its identity as separate from that environment. This dual ability is referred to as autopoiesis. In organizations, autopoiesis would indicate that the corporation as a whole retains its identity, even though, over time, employees come and go.

Boundary--Every complex system encompasses difference. One part of the system will be different in some way than other parts of the system. The area of distinction between the differing parts of a complex system is called a boundary. The boundary is not imposed from outside the system, rather it emerges because of differences within the system itself. The boundary becomes the focal point for change and adaptation of the system, like a cold front in a weather system. Boundaries abound in organizations, and they are focal points of change and turbulent behavior. A few examples include management hierarchies, customer interfaces, geographical separation, departmental barriers, functional differences, educational and cultural diversities.

Feedback loops--Most complex systems include some form of feedback. Feedback describes the tendency of a system to use its own output to make adjustments in its inputs and/or processes. Positive feedback amplifies the system outputs, and negative feedback opposes them. A thermostat is a classical example of a negative feedback system. Increased temperature (an output from an earlier action of the thermostat) causes the thermostat to adjust the furnace or air conditioner, which in turn changes the temperature in the room, which affects the thermostat, and so on. This is an example of negative feedback, because the mechanism works counter to the trend that would continue without any interference. Positive feedback, on the other hand, tends to magnify the existing trend. A bonfire is an example of a positive feedback system. The heat from the blaze ignites more fuel, which in turn generates more heat. If left unchecked, the system will continue to expand until all available fuel is consumed. Organizational mechanisms can function either as positive or negative feedback loops. A performance appraisal for a creative contributor, for example, might be intended to reduce creativity and variation (a negative feedback loop) or it might encourage an employee to be even more innovative (a positive feedback loop). Feedback is the primary means of "control" in a complex system, so the design of feedback systems within an organization are critical to adaptation and effective functioning.

Fractal--Special kinds of computer analysis of some nonlinear equations generate geometrical objects of infinite complexity and beauty. These objects, called fractals, are sometimes considered to be a visual image that represents a complex, chaotic system. A fractal is generated by solving a simple, nonlinear equation many, many times and plotting the solutions on a complex number plane. Fractals all share some basic characteristics: self-similarity, scaling, discontinuity, infinite variety. The fractal may provide a rich metaphor for the characteristics of a complex, adaptive organization. For example, in a fractal the same shape or feature appears at many different levels of magnification (scaling). So, too, in organizations, many of the same

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features are discernible from top to bottom of the management chain. Language, attitude, personal style, and fundamental values are replicated throughout an organization, just as a recognizable pattern can be seen in a fractal structure.

Neural network--A new generation of computer hardware and software systems has been designed to mimic the neural connections in the human brain. These computer systems incorporate many interrelated processing units. Each unit is capable of receiving messages from and distributing messages to other processors. Some researchers see a striking similarity between the structures and functions of a neural network and the mechanics of an organization. For example, communication paths used frequently are strengthened over time, while those that are infrequently used tend to weaken.

Self-organization--When a complex system is open to its environment, it may get more and more disorganized (move far from equilibrium). At some point it moves far enough from equilibrium that it spontaneously reorganizes itself into some new structure. This phenomenon is called self-organization. The new structure that results from self-organization, called a dissipative structure, occurs spontaneously from the emergent behavior of the whole system. Many believe that organizations will self-organize when they are pushed far enough from equilibrium. Spontaneous group activity, dissenting factions, cliques, and groups of close-knit personal relationships may be examples of self-organization in human systems.

Butterfly effects (sensitivity to initial conditions)--In a complex system, a very small cause may have a tremendous effect, so any small change in the beginning state of a system may change the system outcome tremendously. This extreme sensitivity to initial conditions is sometimes called the butterfly effect because the flap of a butterfly wing in Hong Kong may result in a hurricane off the coast of Florida. Organizations show evidence of butterfly effects when rumors spread uncontrollably, when one person's invention becomes a new and profitable product line, and when a difference in style becomes a destructive "personality conflict."

Simulation--Because of the complexity of chaotic systems, it is very difficult to observe and experiment with them in nature. For that reason, many scientists use the computer to create models of complex systems. These models simulate the behavior of the real complex systems. Scientists can then use the simulation to manipulate and observe the behavior of the complex system. A few organizational researchers are seeking to model organizational systems using a variety of mathematical techniques. These models will help us understand and adapt to the infinite number of possible futures that await us.

Strange attractor--An attractor represents the dynamic tendencies of a system. A point attractor describes the fact that a system moves to a single value. A periodic attractor describes the fact that a system moves from one value to another at regular time intervals. (A periodic attractor is sometimes called a limit cycle because the behavior of the system does not move outside of the

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limit of the attractor.) A strange attractor, which is characteristic of chaotic systems, describes the tendency of a system to cluster its behavior around a set of acceptable values, though one, exact value or sequence of values is never repeated. A spirited discussion is underway to apply this concept metaphorically to organizations. Some think that belief systems function as strange attractors. Others see policies and procedures as fulfilling this role. Still others believe that the attractor of a system reflects the accumulation of the personal histories of all individuals involved in the organization. All of these interpretations may shed light on the behavior of complex organizations, while none of them may be totally accurate.

Conclusion

The information provided in this paper is only a summary of the concepts that are emerging in the fields of chaos science or the application of complex systems science to organizations. A great deal of work will be required before a comprehensive presentation of this wide-ranging and complicated field will be possible. We hope, however, that this paper has provided the information you will need to recognize the significance and relevance of the study of complexity science as it applies to the behavior of human organizations. To extend your knowledge further, consider:

- Reading some of the popularized versions of chaos and complexity (see bibliography)
- Talking with others about how you see the metaphors in your environment
- Beginning to base your practical decisions on your intuitions and current understanding about complexity.
- Seeking training from someone whom has worked extensively in the field and is willing to help you apply the ideas in your own local situations.