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CHAOS THEORY

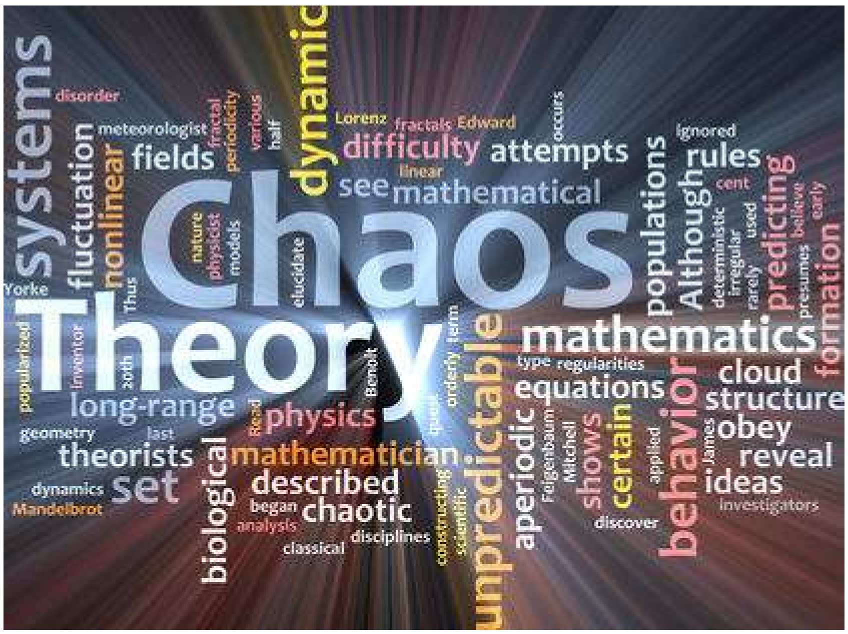

Photo by: Kheng Guan Toh

Chaos theory is a scientific principle describing the unpredictability of systems. Most fully explored and recognized during the mid-to-late 1980s, its premise is that systems sometimes reside in chaos, generating energy but without any predictability or direction. These complex systems may be weather patterns, ecosystems, water flows, anatomical functions, or organizations. While these systems's chaotic behavior may appear random at first, chaotic systems can be defined by a mathematical formula, and they are not without order or finite boundaries. This theory, in relation to organizational behavior, was somewhat discounted during the 1990s, giving way to the very similar complexity theory.

ORIGINS OF CHAOS THEORY

One of the first scientists to comment on chaos was Henri Poincaré(1854–1912), a late-nineteenth century French mathematician who extensively studied topology and dynamic systems. He left writings hinting at the same unpredictability in systems that Edward Lorenz (b. 1917) would study more than half a century later. Poincaré explained, "It may happen that small differences in the initial conditions produce very great ones in the final phenomena. A small error in the former will produce an enormous error in the latter. Prediction becomes impossible." Unfortunately, the study of dynamic systems was largely ignored long after Poincaré's death.

During the early 1960s, a few scientists from various disciplines were again taking note of "odd behavior" in complex systems such as the earth's atmosphere and the human brain. One of these scientists was Edward Lorenz, a meteorologist from the Massachusetts Institute of Technology (MIT), who was experimenting with computational models of the atmosphere. In the process of his experimentation he discovered one of chaos theory's fundamental principles—the Butterfly Effect. The Butterfly Effect is named for its assertion that a butterfly flapping its wings in Tokyo can impact weather patterns in Chicago. More scientifically, the Butterfly Effect proves that forces governing weather formation are unstable. These unstable forces allow minuscule changes in the atmosphere to have major impact elsewhere. More broadly applied, the Butterfly Effect means that what may appear to be insignificant changes to small parts of a system can have exponentially larger effects on that system. It also helps to dispel the notion that random system activity and disturbances must be due to external influences, and not the result of minor fluctuations within the system itself.

Another major contributor to chaos theory is Mitchell Feigenbaum (b. 1944). A physicist at the theoretical division of the Los Alamos National Laboratory starting in 1974, Feigenbaum dedicated much of his time researching chaos and trying to build mathematical formulas that might be used to explain the phenomenon Others working on related ideas (though in different disciplines) include a Berkeley, California mathematician who formed a group to study "dynamical systems" and a population biologist pushing to study strangely-complex behavior in simple biological models. During the 1970s, these scientists and others in the United States and Europe began to see beyond what appeared to be random disorder in nature (the atmosphere, wildlife populations, etc.), finding connections in erratic behavior. As recounted by James Gleick (b.1954) in *Chaos,* a French mathematical physicist had just made the disputable claim that turbulence in fluids might have something to do with a bizarre, infinitely-tangled abstraction he termed a "strange attractor." Stephen Smale (b. 1930), at the University of California, Berkeley, was involved in the study of "dynamical systems." He proposed a physical law that systems can behave erratically, but the erratic behavior cannot be stable. At this point, however, main-stream science was not sure what to make of these theories, and some universities and research centers deliberately avoided association with proponents of chaos theory.

By the mid-1980s, chaos was a buzzword for the fast-growing movement reshaping scientific establishments, and conferences and journals on the subject were on the rise. Universities sought chaos "specialists" for high-level positions. A Center for Nonlinear Studies was established at Los Alamos, as were other institutes devoted to the study of nonlinear dynamics and complex systems. A new language consisting of terms such as *fractals, bifurcations,* and *smooth noodle maps* was born. In 1987, James Gleick published his landmark work, *Chaos: Making a New Science,* chronicling the development of chaos theory, as well as the science and scientists fueling its progress.

THE SCIENCE OF CHAOS THEORY

As stated by James Gleick, chaos is a science of the "global nature of systems," and so it crosses many disciplinary lines—from ecology to medicine, electronics, and the economy. It is a theory, method, set of beliefs, and way of conducting scientific research. Technically, chaos models are based on "state space," improved versions of the Cartesian graphs used in calculus. In calculus, speed and distance can be represented on a Cartesian graph as *x* and *y.* Chaos models allow the plotting of many more variables in an imaginary space, producing more complex imaginary shapes. Even this model assumes, however, that all variables can be graphed, and may not be able to account for situations in the real world where the number of variables changes from moment to moment.

The primary tool for understanding chaos theory (and complexity theory as well) is dynamic systems theory, which is used to describe processes that constantly change over time (e.g., the ups and downs of the stock market). When systems become dislodged from a stable state, they go through a period of oscillation, swinging back and forth between order and chaos. According to Margaret J. Wheatley in *Leadership and the New Science,* "Chaos is the final state in a system's movement away from order." When a system does reach that point, the parts of a system are manifest as turbulence, totally lacking in direction or meaning. Wheatley quotes researchers John Briggs and F. David Peat explaining the process of oscillation:

Evidently familiar order and chaotic order are laminated like bands of intermittency. Wandering into certain bands, a system is extruded and bent back on itself as it iterates, dragged toward disintegration, transformation, and chaos. Inside other bands, systems cycle dynamically, maintaining their shapes for long periods of time. But eventually all orderly systems will feel the wild, seductive pull of the strange chaotic attractor.

In simpler terms, every system has the potential to fall into chaos.

The above "strange attractor" is the very same that a French mathematical physicist identified in the early 1960s. In complex systems, where all should fall apart, the attractor comes in, magnetically pulling system variables into an area and creating a visible shape. Because previous efforts to graph such phenomena could only be completed in two dimensions, this effect could not be visualized. However, computers now allow the phenomena of "strange attractors" to become visible, as images of multiple dimensions representing multiple variables can finally be created.

Part of the difficulty in studying chaos theory arises because complex systems are difficult to study in pieces. Scientists's efforts to separate pieces of dynamical systems often fall apart. The system depends on each minute part of that system and the way it interacts with all other components. As Briggs and Peat state, "The whole shape of things depends upon the minutest part. The part is the whole in this respect, for through the action of any part, the whole in the form of chaos or transformative change may manifest."

In the same breath, it is important to establish the importance of the autonomy the smallest parts of a system possess. Each component of a complex system has the ability to fluctuate, randomly and unpredictably, within the context of the system itself. The system's guiding principles (the attractors) allow these parts to cohere over time into definite and predictable form. This runs contrary to the impression many have of chaos theory, believing there is no order to be had in such a system. But chaotic movement does possess finite boundaries, within which is the capacity for infinite possibility. Even lacking direction, parts of a system can combine so that the system generates multiple configurations of itself, displaying "order without predictability." These systems never land in the same place twice, but they also never exceed certain boundaries.

PRACTICAL APPLICATION OF CHAOS THEORY

By the early 1980s, evidence accumulated that chaos theory was a real phenomenon. One of the first frequently-cited examples is a dripping water faucet. At times, water drops from a leaky faucet exhibit chaotic behavior (the water does not drip at a constant or orderly rate), eliminating the possibility of accurately predicting the timing of those drops. More recently, the orbit of Pluto was shown to be chaotic. Scientists took advantage of applications using chaos to their benefit; chaos-aware control techniques could be used to stabilize lasers and heart rhythms, among multiple other uses.

Another arena within which chaos theory is useful is that of organizations. Applying chaos theory to organizational behavior allows theorists to take a step back from the management of day-to-day activities and see how organizations function as unified systems. An organization is a classic example of a nonlinear system (i.e., a system in which minor events have the potential to set off grave consequences or chain reactions, and major changes may have little or no effect on the system whatsoever). In order to exploit the chaotic quality of an organization, one needs to try to see the organizational shape that emerges from a distance. Instead of pinpointing causes in the organization for organizational problems, the company is better served, according to chaos theory, by looking for organizational patterns that lead to certain types of behavior within the organization.

Organizational expectations for acceptable behavior, and the degree of freedom with which individuals are allowed to work, shape the way a company's problems and challenges are handled by its members. By allowing people and groups within an organization some autonomy, businesses encourage the organization to organize itself, enacting multiple iterations of its own functioning until the various pieces of the organization can work together most effectively. An organization that encourages this type of management has been termed a *fractal organization,* one that trusts in natural organizational phenomena to order itself.

However, applying chaos theory to organizational practice tends to go against the grain of most formal management patterns. Order can be confused with the more popular notion of control. Defined by organization charts and job descriptions, traditional management does not generally seek to add disorder to its strategic plan. As Wheatley states, "It is hard to open ourselves up to a world of inherentorderliness." Organizations are focused on structure and design. Charts are drawn to illustrate who is accountable to whom or who plays what role and when. Business experts break down organizations into the smallest of parts. They build models of organizational practice and policy with hope that this atomizing yields better information on how to improve the organization's functioning. However, chaos theory implies that this is unnecessary, even harmful.

Self-organizing systems are those enabled to grow and evolve with free will. As long as each part of the system remains consistent with itself and the systems's past; these systems can harness the power of creativity, evolution, and free will—all within the boundaries of the organization's overall vision and culture. In this respect, chaos theory shows the need for effective leadership, a guiding vision, strong values, organizational beliefs, and open communication.

During the 1980s, chaos theory did begin to change decision-making processes in business. A good example is the evolution of high-functioning teams. Members of effective teams frequently recreate the role each member plays, depending on the needs of the team at a given point. Though not always the formally-designated manager, informal leaders emerge in an organization not because they have been given control, but because they have a strong sense of how to address the needs of the group and its members. The most successful leaders understand that it is not the organization or the individual who is most important, but the relationship between the two. And that relationship is in constant change.

One of the most influential business writers of the 1980s and 1990s, Tom Peters (b. 1942), wrote, *Thriving on Chaos: Handbook for a Management Revolution* in 1987. Peters offers a strategy to help corporations deal with the uncertainty of competitive markets through customer responsiveness, fast-paced innovation, empowering personnel, and most importantly, learning to work within an environment of change. In fact, Peters asserts that we live in "a world turned upside down," and survival depends on embracing "revolution." While not explicitly concerned with chaos theory, Peters's focus on letting an organization (and its people) drive itself is quite compatible with the central tenets of chaos theory.

As the global economy and technology continue to change the way business is conducted on a daily basis, evidence of chaos is clearly visible. While businesses could once succeed as "non-adaptive," controlling institutions with permanently-installed hierarchical structures, modern corporations must be able to restructure as markets expand and technology evolves. According to Peters, "To meet the demands of the fast-changing competitive scene, we must simply learn to love change as much as we have hated it in the past."

Organizational theorist Karl Weick (b. 1936) offers a similar theory to Peters's, believing that business strategies should be "just in time…supported by more investment in general knowledge, a large skill repertoire, the ability to do a quick study, trust in intuitions, and sophistication in cutting losses." Though he did not articulate his theories in terms of the explicit ideas offered by quantum physics and chaos theory, his statements support the general idea that the creation and health of an organization (or a system) depends on the interaction of various people and parts within that system. However, as Wheatley states in her book:

Organizations lack this kind of faith, faith that they can accomplish their purposes in various ways and that they do best when they focus on direction and vision, letting transient forms emerge and disappear. We seem fixated on structures…and organizations, or we who create them, survive only because we build crafty and smart—smart enough to defend ourselves from the natural forces of destruction.

SEE ALSO: Complexity Theory ; Trends in Organizational Change

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Revised by Hal P. Kirkwood , Jr.

FURTHER READING:

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