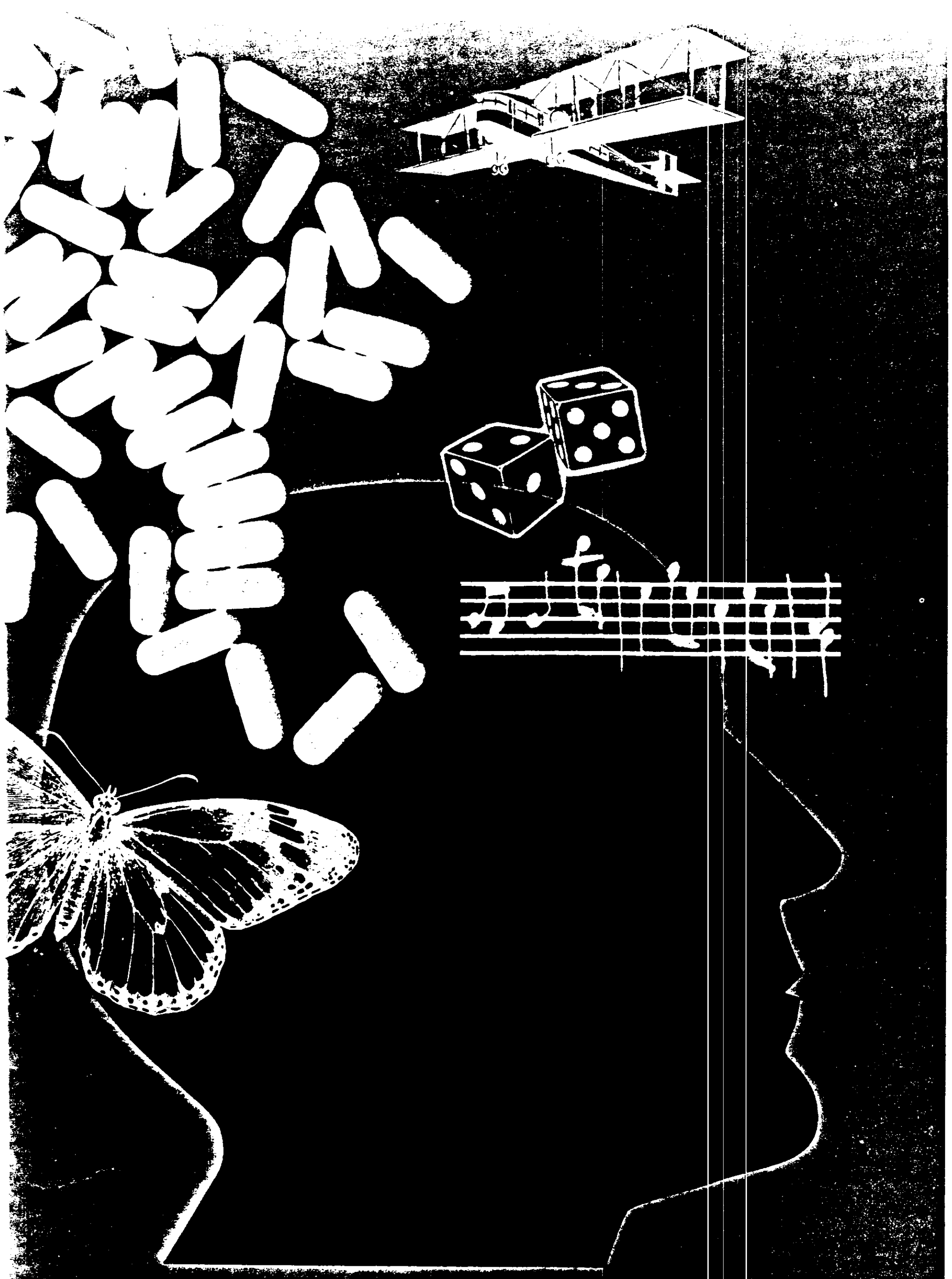

The Challenge of Chaos

An idea borrowed from the world of science has wide-reaching implications for management

by Richard L. Daft and Robert H. Lengel

Studies of top performing small companies by both *Inc.* magazine and *Business Week* have revealed that severe, random changes are the biggest cause of business casualties from one year to the next. Only one-tenth of high-growth companies identified by *Business Week* in 1988 were on the list two years later. What ruined many small companies was the inability to react and change in response to the completely unpredictable.

Rapid change requires company fluidity, with jobs, roles, structures, and products changing continuously. One successful company metamorphosed from building machines for home cardiac patients to providing home clinical services. This complete switch from product to service took less than a year. Another company molted its skin by exiting the business of manufacturing games for sale in retail stores and becoming a company that conducted investment competitions. The ability of these companies to reinvent themselves in response to the unpredictable enabled them to stay top performers over several years.

This acceptance of the unpredictable is at odds with the Newtonian viewpoint that has dominated Western thought for five hundred years, influencing organizational planning and business education. Newtonian thought assumes the world is like a large mechanical system that is understandable and thus amenable to prediction and control. The emphasis is on logic, reason, and rationality—products of the Age of Reason.

The Newtonian mindset assumes *determinism,* which means that everything, including human decisions and behaviors, is logically determined and has a knowable cause. It asserts the world is objective and can be understood by gathering data to explain the linear cause-effect relationships. If something is unpredictable, the Newtonian believes it hasn't been correctly measured or enough data gathered. Few things are truly random or unpredictable. Moreover, in the Newtonian view, phenomena as diverse as Sears Roebuck or a solar system can be understood by reducing them to their smallest parts, a process called *reductionism*, then studying the cause-effect laws surrounding each part.

The important skills needed to survive in a Newtonian world are gathering information through precise measurement, analyzing relationships, predicting outcomes, and making decisions. This approach worked well in the stable organizational world of the 1950s and 1960s, and is the assumption underlying business education today. Using logic and objective data, members of an organization supposedly can predict future demand for products, employees, and raw materials. Diagnosis and rational analysis are king and queen in the Newtonian realm.

Chaos theory provides a different view of our world, and leads to different approaches for knowing and living in it. Chaos acknowledges apparent randomness in many phenomena, recognizing inherent unpredictability that can't be removed by a simple process of collecting and analyzing data. However, this randomness occurs within constraints, within an overall pattern or boundary. The chaotic world is locally unpredictable, but has a global pattern that is stable. Chaotic systems thus display *disorder within order.*

A simple game, played with a die, illustrates the idea of a natural disorder within order. As shown in Figure 1, three dots representing the three corners of an equal-sided triangle are placed on a sheet of paper.[1] One dot is labeled 1-2, the second 3-4, and the third 5-6. Now a fourth dot can be placed randomly on the page. The game works by repeatedly rolling a die, and the next dot is placed exactly halfway between the previous dot and the dot labeled with the number appearing on the die. If the die shows a three, the new dot is placed halfway between the previous dot and the dot marked 3-4. With this

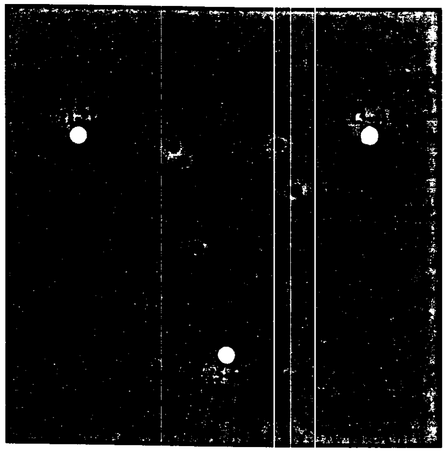

Figure 1

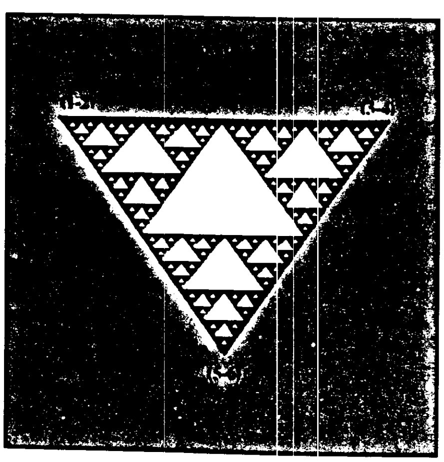

Figure 2

new dot as the starting position, the die is rolled again and the next dot is placed halfway toward the dot labeled with the new number appearing on the die.

The number that appears on each roll of the die is unpredictable, as is the location of the next dot. It seems reasonable to assume that a random pattern of dots would appear from this unpredictable series of events. The overall result, however, after several million rolls, is far from random, as shown in Figure 2.

Physicists call this overall pattern a *strange attractor* or *basin attractor*. The attractor sets a boundary within which the random events occur. This in in contrast to a *point attractor* which is the exact point that would be predicted for each roll of the die under traditional Newtonian assumptions. Biological systems such as brainwaves and heart rhythms are considered healthy if the strange attractor has a large boundary, allowing wide-ranging behavior within its confines.

The strange attractor concept can set a boundary for an organization in the following way. The president of First American, a medium-size bank in Memphis, can run his organization based on Newtonian or chaos principles. The Newtonian approach would be to predict and control each loan officer's response to every loan application, so the bank would need lots of rules and regulations to accomplish this. A huge administrative and bureaucratic structure would be put into place to precisely define behavior, thereby shrinking the space for random behavior.

An alternative is for the president to define overall boundaries in the form of a corporate culture, shared values, and guiding policies. Loan officers could then respond within this boundary depending on the loan situation, as long as their responses fit within the prescribed guidelines. The *principle of self-reference* is based on the idea that people won't deviate from the overall mission of their organization if they have been imprinted with it. In a chaotic system, the manager's job is to verbalize the guiding vision and define the mission, not to add rules. This management approach allows a rich and diverse set of responses to an unpredictable external environment.

As another example, shown in Figure 3, human beings who display a large three-dimensional brainwave boundary during problem solving have more options and possible solutions to solve a problem than those with small attractors. The two patterns below illustrate the low dimensionality of a brain at rest compared to the high dimensionality of active problem solving. Research into human psychoses shows that people with schizophrenia have small, rigid attractors, limiting them to fixed responses in diverse situations, similar to a bureaucratic organization's responses. A healthy individual, just like a healthy organization, can draw on a wide range or responses, but within overall limits.

Managers operating day to day see hundreds of random events. Research has shown the manager's job to be fragmented, with an average activity duration of nine minutes. A manager's world is truly chaotic. The larger pattern of events may be sensed intuitively by a manager, or may be revealed through time, or may have to be taken on faith. Chaotic systems do have larger patterns even if they can't be measured and calculated in the moment. The evolution of a successful organization is like a big game of "Name That Tune," in which songs are identified by hearing only a few notes. Organizational success is reserved for those who, by brilliance or luck, are able to identify the overall pattern by hearing the fewest notes. The overall pattern is the only basis for understanding how behaviors are linked together or to the future. Chaotic systems exhibit disorder and order at the same time, and winners, by insight or luck, see or create an overall pattern that works within the day-to-day surprises.

Another property of a chaos strange attractor is that it cannot be understood by dissecting it. "Reductionism" doesn't work. Individual dots or small collections of dots make no sense alone, nor does a small part of an overall company vision. Accurate understanding only comes by seeing the whole. Behavioral scientists cannot predict the behavior of a group by intensely testing and observing individuals separately. Even the intuitive skills of a couple hosting a dinner party often fail to predict the interactions that occur across the table. To understand a phenomenon, it must be observed and enjoyed as a whole. Analyzing just its parts will lead to mistaken images and expectations.

The other major difference between Newtonian and chaotic systems is *linearity* vs. *nonlinearity*. In a linear Newtonian system, 2 + 2 = 4. Twice as much force is required to lift twenty pounds as to lift ten pounds. Physicists can predict exactly where a bullet fired from a rifle will land, or how much force is needed to lift a satellite into orbit. But in a chaotic nonlinear system, a small force may have an astounding effect, such as the one additional straw that broke the camel's back, and large forces may have relatively little impact. A manager's thirty-minute talk to subordinates may have no impact, and a single sentence uttered in the hallway may change completely how people see things.

Nonlinear phenomena are characterized by recursive feedback processes whereby the outcome of one event becomes the input for the next event, each one skewed further from linear, straight-line predications. Rather than events unfolding like a string of pearls on a necklace, one event bumps into the next like billiard balls, knocking hoped-for or planned alignments out of kilter. Consider a busy manager's tidy schedule for the day. Something goes wrong about 9:30, and that event upsets the planned 10:00 meeting, which when rescheduled upsets the remaining day. Events cascade along until the schedule for the entire day is wrecked.

Human consciousness, the force

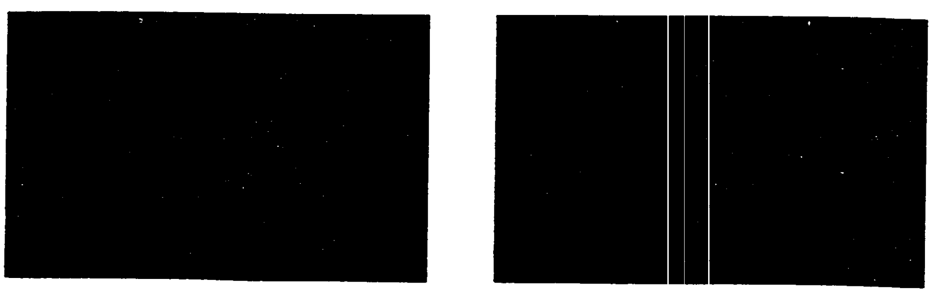

Figure 3. Low dimensional attractor, left; high dimensional attractor, right.

underlying all organizational activity, is nonlinear. A thought at one moment becomes the input for the next thought. Thoughts linked over a period of time define a stream of consciousness that is in no way equivalent to the ballistic flight of a bullet or satellite. Can you predict what you will be thinking two hours from now, or what you will be talking about at a social gathering tonight? A seemingly insignificant stimulus, like finding a quarter on the sidewalk or noticing an attractive person of the opposite sex, can cause a major shift in your thought pattern. Forcing human consciousness into a linear pattern would effectively destroy its value.

For nonlinear phenomena, prediction error seems to be complete. Looking back over a person's thoughts historically might reveal a pattern of overall order, a strange attractor. But this understanding does not allow someone to predict when a specific thought will appear next or how the future stream of consciousness will unfold. Nonlinearity means that for the most part, paraphrasing philosopher Sören Kierkegaard, organizational life is understood backward and lived forward. We may glimpse overall patterns by being historians, but no amount of Newtonian analysis will enable managers, or consultants, or behavioral scientists, to predict future thoughts and events with any accuracy.

Two significant aspects of nonlinearity in chaotic systems are called the *butterfly effect*, more formally known as "sensitivity to initial conditions" and *bifurcations*. In a complex system like the weather, for example, future weather patterns are "infinitely" sensitive to the past. Small, unmeasured events have

The evolution of a successful organization is like a big game of "Name That Tune," in which songs are identified by hearing only a few notes.

cumulative effects far beyond their initial strength. If a scientist could create two weather systems, two organizations, or two groups of people that are identical with respect to all known measurements, within a short time the weather systems would be vastly different, and the seemingly identical organizations and groups would reveal markedly different forms and activities.

Why? Because of microscopic differences that were not measured. These tiny deviations don't cancel each other out. They trigger the recursive process, and accumulate with exponential speed, like feedback in a microphone that picks up its own signal and amplifies it again and again, causing an ear-splitting screech. A butterfly flapping its wings over Peking can create air disturbances that eventually affect the weather conditions in the United States, hence the term "butterfly effect." Likewise, the same organization or the same group of people placed in ever so slightly different circumstances will develop into different forms and behaviors. Anyone who has tried to repeat an outstandingly successful dinner party with the same guests, menu, etc., knows that it won't work. Small differences in mood or in the day's experience make replication impossible.

Sensitivity to initial conditions means that it is impossible to predict very far into the future anything about the weather or organizations. Indeed, weather forecasters could cover the world with sensors placed every square foot, measuring precisely the temperature, pressure, humidity, and everything else imaginable, with the data fed into a super computer the size of Dallas, Texas. This near-perfect monitoring system could not accurately predict the weather over Chicago a month from now because of microfluctuations that take place between the sensors. Computer simulations reveal that tiny errors multiply so quickly that weather patterns soon diverge from their predicted course.

Today's companies and their environments are more similar to the weather than to the precise assembly-line systems typical of Newtonian thinking. An insignificant lawsuit against AT&T's long distance monopoly had worldwide ramifications. MCI and other long distance carriers emerged, creating an entirely new order for telecommunications. On Black Friday, October 13, 1989, the stock market fell more than 190 points. Many analysts believed the drop was caused by the collapse of a single leveraged buyout negotiation involving American Airlines. The entire stock market was operating at a level of stress that was triggered by this event, causing a huge and unpredictable price movement. A lonely crackpot's idea to insert poison in Tylenol capsules started a ripple effect that hit not only Johnson & Johnson, the entire pharmaceutical industry, and its suppliers in the packaging industry, but ultimately spilled over into related

A lonely crackpot's idea to insert poison in Tylenol capsules started a ripple effect that hit the entire pharmaceutical industry and its suppliers in the packaging industry, and ultimately spilled over into related industries such as food products.

industries such as food products. New product designs were required, and new companies emerged to provide these services. In each case small, unpredictable events started a chain of events that produced enormous outcomes no one would have predicted in advance—the butterfly effect.

Bifurcation means that unexpected catastrophic changes also occur in a system. The world of chaos often hides beneath apparently smooth-running, unstressed systems. The recent history of management and organizational thought emerged in the relatively calm economic waters of the 1950s and '60s. Linear, Newtonian thinking seemed to work in this world because of its stability. For the most part, statistical planning models were helpful in predicting the future, because the future was a straight-line extension of previous events.

Suddenly accumulating effects appear as a fracture, as an earthquake. Consider the crumbling of the Berlin Wall or the rapid dissolution of the Soviet Union, events most people believed they would not witness in their lifetime. In the physical world, a pot of water can be heated from 100 degrees to 200 degrees, with water volume and movement accurately predicted from previous behavior. But using that model the prediction of water behavior and volume at 220 degrees and above would be totally wrong, because boiling water represents a different state, a bifurcation. Blowing air into a balloon follows linear laws until it explodes.

An organization such as Navistar became severely stressed from unpredicted events and underwent an epic transformation to survive. Or consider the crises that seem to be hitting companies more frequently. Silicone breast implants became a catastrophe for Dow Corning, and the disputed side effects of Halcion may yet devastate Upjohn. A few years ago, neither company could have accurately predicted these problems. Indeed, Dow and Upjohn managers were proud of these products.

Time after time, linear thinking and tranquil conditions mislead managers about chaos. Natural gas producers have learned the near impossibility of making long-run predictions about natural gas price and demand. Utility companies predicted increasing demand for electrical power on a linear basis. Nuclear power plants were built based on that demand, which hasn't materialized, prompting some utilities to stop nuclear plant construction. Randomness and unpredictability so devastated Lloyd's of London that the company was reorganized because of unexpectedly huge insurance losses. Events such as the crash of PanAm flight 103, the Exxon *Valdez* oil spill in Alaska, Hurricanes Hugo and Andrew, the earthquake in San Francisco, the fires and riots in Los Angeles, and the Phillips Petroleum explosion in Pasadena, Texas, caused billions of dollars in losses.

What are some lessons from chaos theory for the social world of people and organizations? The most obvious implication is that *life is as predictable as a roll of the dice.* Randomness is revealed in something as simple as an unexpected rainstorm, as momentous as the dissolution of the Soviet Union, as heart wrenching as a car accident or an injury on the shop floor. People and organizations do not live in straight lines. Unexpected, irrational changes are the fabric of organizational existence, just as research has shown randomness is part of brainwaves, heartbeats, the weather, dripping faucets, the stock market, and rioting crowds.

History simply does not unfold as a sequence of numbers 2, 4, 6, 8, 10. This is a linear system that allows accurate prediction of the next number or the 54th number or the 2,000th number. Prediction is not possible for truly random numbers because no patterns repeat themselves. The whole sequence is uniquely determined. The 54th number in sequence can only be known by actually experiencing the 54th number. This is the reality of chaotic systems—phenomena are understandable only through experience and are utterly unpredictable through information gathering. *There are no shortcuts.*

Another implication is that in a chaotic system, *information for prediction loses its value.* Gathering and analyzing more data does not lead to better predictions about the future any more than analyzing 53 numbers can predict the 54th number in a random series. We will not uncover nature's big surprises in advance. Management theory has assumed that organizational success comes from gathering more data, faster and cheaper. No way. This will not work in a chaotic system. Forget data, which is an outgrowth of Newtonian beliefs. Chaos theory says more data for prediction is not better. It's not a linear world out there.

Next, *successful organizations recognize and nurture butterflies*, which means operating with positive feedback loops. Negative feedback loops are used for control in most companies, such as when production quantity is not up to standard and managers correct it. Positive feedback occurs when managers recognize unexpected happenings as opportunities for growth and possible spectacular transformation. In chaotic systems, fortunes are made and places in history reserved for those people and organizations who become the butterflies that have disproportionate impact on the people and world around them.

Michael Milken's idea to finance businesses with junk bonds was a butterfly. His discovery that bonds paying higher-than-average returns were relatively safe provided financing for enterprises like MCI Communications, and backed takeover bids for hundreds of corporations, virtually changing the corporate landscape in a few years. Milken's employer, Drexel Burnham Lambert, made hundreds of millions of dollars issuing junk bonds.

Sometimes the butterfly arrives looking like a caterpillar. After a horrendous financial loss in 1987, United Electric, a moderate-size manufacturer of industrial controls, tossed out its bureaucratic approach to operations. Senior managers let go of control. The new openness and randomness produced an astonishing number of clever and creative ideas—often just little things like an employee finding a better way to test diaphragm assemblies against leaks, or someone keeping track of her own parts so less time was spent running to the supply room. These butterflies were reinforced throughout the company, turning it around, as if by magic.

Overall, *chaos adds up to a new way of managing*. It's time to adopt a new way of leading and designing organizations. The place to start is with an overall vision or mission that can serve as a strange attractor, an outer boundary that leaves lots of room for creative behavior of groups and individuals. Imprinting the vision on employees enables managers to let go of authority, trusting employees to find solutions to local problems, and to reach their performance potential without close supervision. With a strong vision, the principle of self-reference will keep decentralized subgroups working in the direction of the company whole. This new way of managing is decentralized, encourages trial and error, rewards butterflies, and lets the organization get lucky.

After the vision, some theorists argue that the next step is to harness the "invisible" forcefield in organizations, the magnetic-like energy that connects people through relationships, culture, and shared values. Invisible leadership skills supplement traditional procedures, management by objectives, and close supervision. Employees are bonded to one another and to the organization by caring and information sharing. Positive emotion, which some leaders call love and caring, binds people together. Moreover, the more information that is shared, the more people feel a part of things, as owners. The best organizational information resembles a virtual reality machine, with each employee plugged into customers, clients, or other employees on a real time basis to adjust continuously to whatever is needed. Managers make all financial and production information available to everyone, sharing both good and bad news. Information shared during difficult times can be more bonding than information during good times because employees pull together to save the organization.

In a chaotic world, managers can relax their vigilance for data, and quiet their desire for prediction and control, relying instead on a broad vision for the future and facilitating the flow of information and positive emotion among employees. Perhaps not too far away in our organizational future, as seen through the lens of chaos, leaders will resemble Jedi warriors like the Luke Skywalker character in Star Wars. Jedis learn to trust their intuition, to serve a lofty vision, stand for the highest values, use "the force" to create the future, and to facilitate the flow of change rather than control it. Now that will be an exciting future—and for many organizations it is already here.

Endnote

1. The figures in this article are adapted from the PBS *Nova* program, "The Strange New Science of Chaos."

Richard L. Daft, Ralph Owen Professor of Management, teaches courses in leadership, organization theory, and organization management. He is currently working on a book with Robert Lengel entitled "The Fourth Cell: Leadership Excellence for the Chaotic Organization," from which this article is adapted.