The economist Paul Krugman says that there are three types of economics: up-and-down economics ("stocks were up and unemployment was down today"), airport-bookstore economics (Ten Easy Steps to Avoid Global Depression), and Greek-letter economics. Greek-letter economics is the mathematical variety, practiced in universities and published in academic journals. And it is in serious trouble.

Historically, Greek-letter economics has rewarded mathematical pyrotechnics over fidelity to the real world. The core theories that Greek-letter economics has produced over the last few decades, such as "rational expectations" and "general equilibrium" theory, are mathematically elegant but lacking in empirical validation.

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The dismal state of the dismal science matters to managers, chief operating officers, consultants, and business professors because much of modern management thinking has been built on a foundation of Greek-letter economics. The bad news is that this foundation is now in serious doubt. But take heart—the good news is that a radically new one is being put in place.

The roots of management thinking

Many of the most successful and widely used strategy tools today—the five-forces framework, cost curves, the structure-conduct-performance (SCP) model, and the concept of sustainable competitive advantage, to name a few—owe their origins to ideas developed in the 1950s in a field known as the theory of industrial organization. Industrial organization theory, which is concerned with industry structure and firm performance, is in turn based on microeconomic theory.

Modern neoclassical microeconomics was founded by Leon Walras, William Stanley Jevons, and Carl Menger in the 1870s and synthesized into a coherent theory by Alfred Marshall at the turn of the last century. Seeking to make economics more scientific, Walras, Jevons, and Menger borrowed ideas and mathematical apparatus from the leading science of their day: energy physics. They copied the mathematics equation by equation, translating it metaphorically (and, according to many physicists, incorrectly) into economic concepts.¹

In the mid-19th century, energy physicists developed a theory of closed equilibrium systems, which provides the core metaphor of Alfred Marshall’s traditional economics and much of today’s management thinking. Consider a ball at the bottom of a bowl. If no energy or mass enters or leaves the bowl—that is, if the system is closed—the ball will sit in equilibrium at its bottom forever. In economic terms, the sides of our bowl represent the structure of a market (for instance, producer costs and consumer preferences), and the gravity that pulls the ball to its lowest energy state represents profit-seeking behavior, pulling a firm to its highest-profit state. If we know the economic forces at work, and if firms are rational, we can predict where the ball will come to rest in the bowl—in other words, the prices, quantities produced, and profitability of firms under equilibrium. If some exogenous shock hits the system (if, say, a technology shift alters producer costs), the sides of the bowl change shape, and the ball rolls to a new point of equilibrium (Exhibit 1).²

In a typical modern strategic analysis, a company looks at its position in the current industry structure, considers the shocks and changes that are occurring or might occur, and then develops a point of view on how the industry is likely to change and what that means for its own strategy. Such an approach makes three important assumptions: that the industry structure is known, that diminishing returns apply, and that all firms are perfectly rational. But what happens if rapid technological or business system innovation makes producer costs and consumer preferences uncertain, as is increasingly the case in today’s dynamic, high-tech, and service-dominated economy? What if we face not diminishing returns (where each additional acre of soybean planted is on poorer land and thus yields a lower return), but increasing returns (where each extra Netscape browser sold increases the value of the World Wide Web and thus yields a higher return)? What if firms lack complete information, or different firms interpret the same information in different ways?

Should the fundamental assumptions underlying the equilibrium model be relaxed, the effect on the ball in the bowl will be dramatic. The sides of the bowl start to bend and flex, losing their smooth shape and becoming a landscape of hills and valleys; and the ball can no longer tell which way is up. Now it is impossible to predict where the ball will roll, and Alfred Marshall loses his equilibrium. And this is not merely a theoretical problem, since the ball-in-the-bowl equilibrium model is the basis for our ideas on strategy.

**Complex adaptive systems**

Anthills are marvelous things. With elaborate labyrinths of tunnels, layouts reflecting their occupants’ social hierarchies, chambers dedicated to specific

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functions, and carefully sited entrances and exits, they are as thoughtfully constructed as any condominium complex. Yet who is the engineer? Where is the blueprint?

The answer, of course, is that none exists. The plan for the anthill does not reside in any individual ant. Rather, each ant is programmed by its DNA to obey a set of relatively simple rules, such as “stand between two other ants and pass along anything that is handed to you.” Ants communicate with each other via chemical signals known as pheromones, which provide inputs and outputs for the rules and switch them on and off. It is the dynamic interaction of the rules and signals that creates the anthill structure.

An ant community is an example of a complex adaptive system.1 Such systems share the following three characteristics.

First, they are open, dynamic systems. The Marshall ball-in-a-bowl system is closed; no energy or mass enters or leaves, and the system can settle into an equilibrium state. By contrast, the energy and mass that constantly flow through a complex adaptive system keep it in dynamic disequilibrium. An anthill, for example, is a perpetual-motion machine in which patterns of behavior are constantly shifting; some patterns appear stable, others chaotic.

Second, these systems are made up of interacting agents, such as ants, people, molecules, or computer programs. What each agent does affects one or more of the other agents at least some of the time; this creates complexity and makes outcomes difficult to predict. The interactions of agents in a complex system are guided by rules: laws of physics, codes of conduct, or economic imperatives such as “cut prices if your competitor does.” If the repertoire of rules is fixed, the result is a complex system. If the rules are evolving, as with genes encoded in DNA or the strategies pursued by players in a game, the result is a complex adaptive system.

Third, complex adaptive systems exhibit emergence and self-organization. As individuals, ants don’t do much. But put them in a group where they can interact, and an anthill emerges. Because the anthill rises out of the bottom-up

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dynamic interactions of the ants and not from a top-down master plan, it is said to be self-organized. The emergent structure is independent of specific agents; while individual ants may come and go, the pattern of the anthill persists.

Other examples of complex adaptive systems include cities, forest ecosystems, the immune system, and the Internet. Over the past 20 years—aided by advances in mathematics, physics, chemistry, and biology and by the wide availability of cheap computing power—scientists have begun to find that complex adaptive systems are governed by deep common laws. Just as the laws of statistics can help us understand such ostensibly different systems as poker games and the spread of disease in populations, the laws of complexity may yield new insights into problems ranging from the origins of life to traffic jams in Los Angeles.

**The new economics**

To managers, this should be more than just interesting science. A number of economists are beginning to say that economies are complex adaptive systems. The case has yet to be proved, but there is circumstantial evidence as well as support from some eminent economists, among them Kenneth Arrow, a Nobel Prize winner and one of the prime architects of the modern neoclassical model, and Brian Arthur of the Santa Fe Institute. (Indeed, the new economics is sometimes referred to as the Santa Fe school of economics, after the interdisciplinary research center with which many economists working on ideas of complexity are affiliated.)

A new economics based on complex adaptive systems is still in its infancy, but enough work has been done to suggest what the key components might be.

**Wisdom**

First, the new economics will be based on a realistic model of cognitive behavior. Traditional economics assumes that people are alike in their thought processes (though their preferences may differ) and that they make choices as if they were solving complicated deductive equations that would enable them to make the best possible decisions. Economists have long realized that these assumptions are too simple, but such assumptions were needed to make the math work for the ball-in-the-bowl model. Computer simulation techniques and advances in cognitive science now allow economists and others to make much more realistic assumptions about people's decision-making processes—assumptions based on skills such as the ability to recognize patterns and to develop inductive rules of thumb by learning from experience. Early work suggests that replacing perfect rationality with more realistic assumptions about inductive, nonoptimal decision making produces new insights and different strategic recommendations.
Webs

Second, the new economics will see agents interacting with one another in a dynamic web of relationships. It will not be enough to have a sound model of a firm's behavior; you must also know how people interact within the firm, how it interacts with other firms in its market, and how these interactions change over time.

Waves

Third, markets will be viewed as inherently dynamic rather than static systems, thus making possible an explanation of growth and innovation that traditional economics has never been able to provide. When adaptive agents interact in a web of relationships, evolutionary changes in one agent affect the evolution of others. This effect, known as coevolution, is frequently seen in nature and also occurs in economics when an innovation (such as the invention of the automobile) produces ripple effects throughout the whole economy (the development of the oil industry, motels, the growth of suburbs, and so on).  

Would-be worlds

Not only the substance but also the research techniques of economics will be transformed. Although the new economics will continue to make use of traditional mathematical proofs, it will increasingly turn to sophisticated computer simulations based on more realistic assumptions. In agent-based models, for example, a company can be modeled as an intelligent computer program capable of learning and adapting. You can put a set of these programs into a simulated competitive market, unleash the forces of evolution on them, and watch different futures unfold. Since complex systems can be difficult or impossible to forecast, such models will be of little help in forecasting the precise path an industry might take; however, they will be valuable in helping to determine how and why markets behave as they do.

Early thinking on management

The new economics has advanced far enough for us to begin to make preliminary hypotheses about its implications for strategy and organization. One characteristic of complex adaptive systems is punctuated equilibrium (Exhibit 2). This natural endogenous feature of the evolutionary process occurs when times of relative calm and stability are interrupted by stormy restructuring periods, or “punctuation points.” Punctuated equilibrium makes it difficult for participants to survive for long periods, as their strategies and skills tend to get finely optimized for the stable periods and then

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suddenly become obsolete when the inevitable restructuring takes place. Similarly, companies have a hard time surviving the upheavals, shakeouts, and technology shifts that punctuate the evolution of markets. To prosper in the long run, a company must adapt as readily as its market, or more so. More specifically, it must be both a strong competitor in the current regime and a smart evolver, able to innovate ahead of the market or to adapt with it.

The equilibrium view of strategy has focused on how to be a good competitor; let us consider five critical aspects of being a good evolver.

Focused versus robust strategies

Traditional strategy tends to emphasize a single focused line of attack—a clear statement of where, how, and when to compete. In a complex adaptive system, a focused strategy to dominate a niche is necessary for day-to-day survival but not sufficient in the long run. Given an uncertain environment, strategies must also be robust—that is, capable of performing well in a variety of possible future environments.1

Competitive advantage versus continuous adaptation

Evolutionary systems exhibit a phenomenon known as the Red Queen effect, after that character’s remark in *Through the Looking Glass*: “It takes all the running you can do to keep in the same place.”2 In nature, the Red Queen effect is at work when a predator learns to run faster; its prey responds by acquiring better camouflage; the predator then develops a better sense of smell; the prey starts to climb trees; and so on. Evidence suggests that the business world resembles a Red Queen race. A study of the performance of more than 400 companies over 30 years reveals that firms find it difficult to maintain higher performance levels than do their competitors for more than about five years at a time (Exhibit 3, on the next page). Long-term superior performance is achieved not through sustainable competitive advantage but by continuously developing and adapting new sources of temporary advantage and thus being the fastest runner in the race.

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1 For an in-depth discussion of this topic, see Eric D. Beinhocker, “On the origin of strategies,” on page 167 of this anthology.

Conservative operator versus radical innovator

In a complex adaptive system, an agent that is resistant to change and not adaptable will have low fitness, and so, conversely, will an agent that is oversensitive to shifts in its environment and constantly making radical responses. But between these extremes of stasis and chaos lies a region—the edge of chaos—where fitness is maximized (Exhibit 4). Being at the edge of chaos means something more subtle than pursuing a moderate level of change. At the edge of chaos, one is simultaneously conservative and radical.

Evolution is adept at keeping things that work while at the same time making bold experiments. The morphology of the spinal cord is a robust adaptation that has survived eons of evolution and enormous environmental shifts. Yet nature has experimented wildly around this core idea, producing vertebrates that range from birds to whales to humans.

The Walt Disney Company is a firm that prospers at the edge of chaos. Its theme parks and other businesses are run in a deeply conservative fashion.
A strong culture supports Disney's mission of providing family entertainment. In operations, no detail is too small, right down to the personal grooming of the parking-lot attendants. This culture is ingrained in the organization and constantly reinforced through management processes.

At many organizations, such a conservative culture and such tightly controlled operations would snuff out creativity. Yet Disney manages to be one of the most innovative companies in the world. It pioneered animated films and destination theme parks, built EPCOT, linked media and retail with its Disney Stores, and took an early lead in cable television. Disney manages the tension between conservatism and innovation by maintaining an almost cultlike attention to detail and discipline but at the same time forgiving honest mistakes made in the pursuit of innovation.

**Routinized versus diverse strategies**

Another requirement for success in evolutionary systems is a rich pool of possible strategies. This diversity represents the source of the innovations that keep a player ahead in the Red Queen race and can be drawn on to develop responses when the environment changes. But diversity also has its cost. Many mutations are harmful and selected against, limiting the diversity found in a species. Moreover, a certain level of standardization is beneficial: a relatively narrow range of mating behavior, for example, probably makes it easier for interested parties to find one another. Evolution strikes a balance, standardizing designs that work but seeding the population with enough variation to provide a basis for future innovation and adaptation.

Few companies are skilled at striking this balance. The result is firms that are either chaotic or vulnerable at punctuation points because they no longer have a well-stocked pool of ideas and experiences from which to draw.

**Scale versus flexibility**

In traditional strategic and organizational thinking, big is good. Benefits of scale are easy to identify in purchasing, operations, marketing, and so on. Why is it, then, that big companies can have such a hard time responding to attacks by smaller competitors? A complexity-based view can shed light on the downside of size.

A simple system with relatively few parts and interconnections isn't highly adaptable; the number of states it can manifest is small compared with the number of situations it might encounter. As the system grows bigger and more complex, the number of states it can manifest, and thus its repertoire of possible responses to changes in its environment, grows exponentially. However, beyond a certain level of scale and complexity, its adaptiveness
drops off rapidly in what Stuart Kauffman calls a complexity catastrophe. This occurs when the epistasis, or interaction between the parts, builds to such an extent that any positive change in one part has ripple effects that cause negative changes elsewhere. The system thus becomes more conservative as it grows, and finding adaptations that don’t have harmful side effects gets harder and harder.

When Dell Computer began to do well at selling inexpensive personal computers by mail, no doubt someone at IBM said, “Why don’t we do that too?” But IBM couldn’t follow suit without damaging its extensive distribution channels of dealers and direct salespeople. Its history and size created a trade-off that Dell didn’t face and made it difficult for IBM to respond.

Companies can mitigate the effect of complexity catastrophes through strategic and organizational changes. GM started Saturn in a greenfield organization precisely to free it from the constraints of corporate bureaucracy. AT&T split itself in three to create smaller organizations and reduce strategic conflict.

Becoming competitors and evolvers

As a complexity-based view of economics develops, new tools will be devised to help managers fashion better-evolving companies. Some of these tools will be analytical: options theory and evolutionary modeling to help develop robust strategies, for example. Others will be conceptual: new organizational forms that help avert complexity catastrophes, say, or practices that promote a rich fund of ideas.

Becoming a better evolver will be a major challenge for most companies; it is difficult enough just to be a successful competitor. And how do you motivate a thriving organization in a stable regime to take on the task of becoming more innovative and adaptive so as to meet challenges it can’t even foresee? Equally, a company struggling through a major punctuation point finds it hard to worry about its long-term evolvability.

But for companies that do accept the challenge, the payoff promises to be considerable. Unlike creatures in nature, we are not blind, passive players in the evolutionary game. Through the sciences of complexity, we can come to understand how evolution works, the tricks it has up its sleeve, and the skills needed to survive in a complex world. If we do so, we may be able to harness one of the most powerful forces of all: evolution will then be the wave we ride to new levels of creativity and innovation rather than the tide that washes over us.