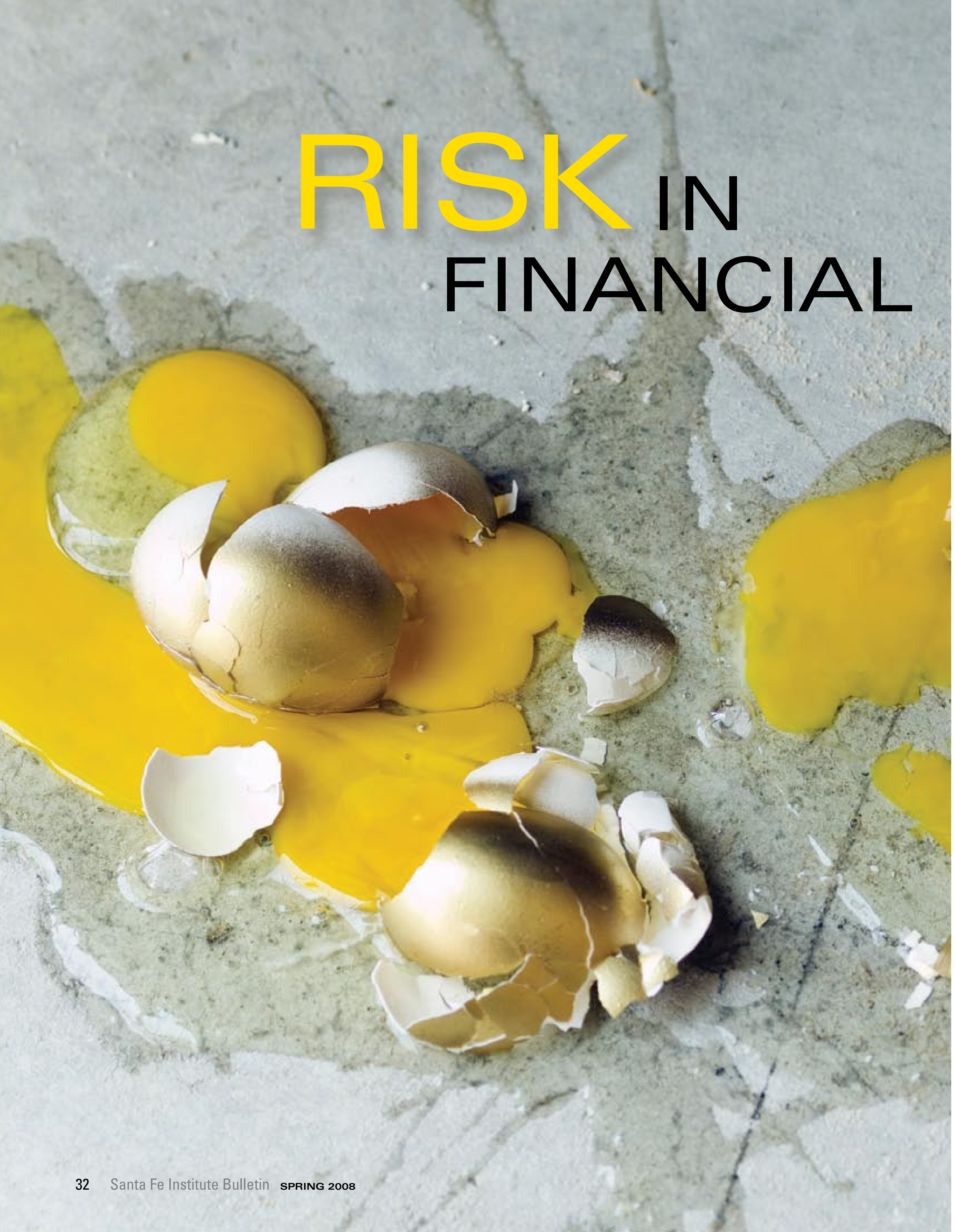

RISK IN FINANCIAL MARKETS—
Learning from Nature

BY JOHN WHITFIELD

On July 19, 2007, the Dow Jones Industrial hit 14,000 for the first time. Less than a month later, it was below 13,000, and was still there three months later. Nor was this a local American difficulty: as of early December the Bank of England had spent £30 billion ($60 billion) propping up the Northern Rock bank, one of the United Kingdom's most notable lenders, which had invested, and lost heavily in the U.S. subprime mortgage market. The European Central Bank, which is responsible for maintaining stability of the euro, spent $205 billion propping up markets across the continent.

Not surprisingly, the mortgage crisis and its secondary effects on other markets were on everyone's mind at a forum in New York in October 2007 on modeling risk in financial markets, co-hosted by the Santa Fe Institute and SAC Capital Partners. Why do such crashes happen? And how can we design and regulate markets to reduce the risk of them happening in the future?

Many of the speakers looked to biology for ideas, comparing the behavior of financial and ecological systems, and hoping to learn from the adaptations that life uses to deal with risk and uncertainty. And one of the hottest questions in biology—and another focus of SFI research—is, what makes ecosystems robust, and what causes them to collapse?

It certainly looks as if finance might have something to learn from biology about stability. Author and hedge fund manager Rick Bookstaber pointed out that despite the U.S. economy as a whole being more stable, with fewer recessions and less variation in gross domestic product (GDP), financial markets have become less so. This destabilization seems to have come from within: Michael Mauboussin of Legg Mason Capital Management and Columbia University reported that four-fifths of the large movements in markets are uncorrelated with outside events such as terrorist attacks, elections, and so on.

One key consideration for both financial and ecological systems is the link between their diversity and their stability. In nature, changes in diversity—for example, when a species is lost from a place—can trigger a cascade of secondary extinctions among species that depended directly or indirectly on the missing species, either for food or to keep their own predators in check.

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AP PHOTO / RICHARD DREW

Traders on the floor of the New York Stock Exchange, Monday, August 6, 2007. Stocks fluctuated in early trading that Monday following a sharp pullback the previous Friday.

Why do such crashes happen? And how can we design and regulate markets to reduce the risk of them happening in the future?

As humans increasingly dominate and manipulate wild ecosystems, understanding this process takes on a keen practical importance.

And yet what makes for robustness and stability in ecology, and how this relates to diversity, is still unclear. It might be that the flow of insight can go both ways: the goldmine of data on decisions, strategies, and their effects to be found in stock market transactions can tell us something about how, in general, the behavior of many individuals—each pursuing a particular goal, be it money or offspring—creates large-scale dynamics and emergent patterns. SFI researchers, working to take the comparisons between the two systems from the metaphorical to the concrete and quantitative, certainly hope so.

In both biology and finance, diversity can mean lots of different things. Genetic diversity within individuals, and between the offspring of a single individual, seems to be a means of coping with external threats and environmental uncertainty. For example, animals, including humans, prefer the scent of potential mates whose immune-system genes are different from their own; it's thought that this makes for healthier offspring. Queen honeybees mate with many males—at the cost of increased physical wear and tear and exposure to predators—but the resulting increase in the genetic diversity of their brood makes for a more able workforce and a better-functioning nest. And species in harsh and unpredictable environments, such as annual desert plants and shrimp that breed in ephemeral pools, produce offspring that spread their germination or hatching over a number of years. Many ecologists see this as a form of bet-hedging, a means of reducing the variance in their reproductive success.

Such forms of diversity are analogous to one of the central tenets of finance: keep a diverse portfolio. Fund managers try to ensure that the performance of their various holdings is not too closely correlated. They are paying to reduce variance: their whole portfolio will not hit the jackpot at once, but nor will it all go south at once. "Moderation is key," said Aaron Brown, a risk manager at AQR Capital Management. "The idea is to do a little of a lot [of different things], so that you do well in the good times and survive the bad times."

But, Brown added, you can't tell which stocks are synchronized until they all move at once. A famous example is the 1998 collapse of the hedge fund Long Term Capital Management (LTCM). The fund sought to risk-proof its investments by assuming a 30 percent correlation between their performances, far higher than that usually seen. But when the Russian economy collapsed, this correlation went up to 70 percent, and the fund went out of business. LTCM had no exposure to Russian markets, just as Goldman Sach's Global Alpha Fund, one of those worst hit during recent events (although Goldman Sachs as a whole has done well), kept away from subprime mortgages. The problem was that in both cases, the funds that did hold such mortgages sold other assets that LTCM and Global Alpha held, causing their value to fall. Highly leveraged funds, such as LTCM and Global Alpha, were then forced to sell, which caused the price of their holdings to fall, which forced them to sell more, and so on. LTCM lost $4.6 billion in four months; Bloomberg, one of the top financial news sources, has reported that Global Alpha might end 2007 $6 billion worse off than it started, a 60 percent decline.

The network structure of the market may have exacerbated the effects of the problems in the mortgage market. Ironically, the collateralized debt options—where mortgage debt was parceled out and sold on to other investors—that widened the impact of the subprime mortgage crisis were intended to *reduce* risk, by spreading the loans. But this seems to have increased risk, by making the banks overconfident about who they loaned money to. Brown compared subprime mortgages to a contagious person infecting others with their disease. How such contagion spreads through markets is still poorly understood, as is the markets' network structure at all scales, from the transactions within a market to the way that, for example, the mortgage market affects the stock market.

Market structure is not the only network that affects how markets behave. The social network of dealers is also important. Jason Karp, director of research at CR Intrinsic Investors, a division of SAC Capital Advisors, told the New York meeting that traders' strategies are heavily influenced by their social contacts. "People make investment decisions based on a note written on a napkin," Karp told the meeting. Such social connections can also spread damage, he said: influenced by their friends, traders buy stocks that they know little about, only to sell them at the first sign of trouble, again creating a downward spiral in prices. The crowding in markets caused by this sort of copying behavior is an important, but poorly understood influence on their behavior, he said.

In general, there was a sense at the meeting that diversity is a good thing, that diverse systems should show smaller fluctuations and quicker recovery times, and that loss of diversity augurs trouble. For example, crop monocultures can be wiped out by a single pest or pathogen, and the onset of groupthink in a market—when the wise crowd becomes a Gadarene herd—is thought to herald a crash. Some studies using agent-based models, which simulate the behavior of large groups of interacting individuals, seem to bear out this view.

On the other hand, both Karp and Bookstaber suggested that one source of instability in markets

JOHN M. COFFMAN / PHOTO RESEARCHERS, INC

The yucca moth *(Tegeticula yuccasella)* is the yucca's only pollinator. Scientists find such dependency in nature can provide insight into what happens in financial markets.

(although this view is controversial) is the increasing number and complexity of financial instruments such as derivatives, which allow investors to speculate on the performance of a market or stock without actually buying that stock. And it is still not clear what diversity actually means,

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Easily influenced by their friends—like sheep—some traders buy stocks that they know little about, only to sell them at the first sign of trouble, creating a downward spiral in prices.

in financial terms. Here, ecology might provide an insight, because it seems that it's not species diversity per se that counts, but what you do with it—robustness or volatility results as much from the form taken by the network of interactions between the different players as from the number of players.

Early theoretical ecologists also thought diversity a good thing. In 1955, Robert MacArthur hypothesized that the more links there were between species, the more stable the ecosystem, as it reduced the destabilizing effects of any one species becoming dominant. A large number of links, he suggested, is easier to achieve in more diverse communities. But in 1972, Robert May turned the field on its head—and launched the modern study of how diversity and complexity influences ecological stability—in a now-classic paper in which he showed that if you add species or links to a randomly structured network of interacting species it becomes less, not more stable, with species more likely to go extinct. Ecologists have spent the past quarter century trying to reconcile May's model with their observations that nature is full of large groups of species interacting in complex ways, and with field and lab studies suggesting that more complex, diverse ecosystems, in fact, show smaller fluctuations in their population sizes.

Ecologists are pursuing a variety of ideas, sometimes conflicting, about what gives rise to stability, which—like diversity and complexity—has been defined in several ways. One significant difference between real ecosystems and May's model is that species interactions are not random. Using data and models drawn from real-life food webs (networks describing who eats whom in ecosystems), researchers including SFI research fellow Jennifer Dunne have found that they show consistent non-random patterns in their degree distribution (how the number of feeding links per species is distributed across the whole set of species). Dunne has shown that highly connected food webs, with many links between the different species, are less likely to experience cascading extinctions from loss of a particular species or set of species, and thus are more robust than simpler, less well-connected webs.

Models also show that food webs, like other networks such as the Internet, are vulnerable to loss of the most highly connected players. But it turns out that in real systems, highly connected species are very unlikely to go extinct. In a study of the food webs of fish and plankton species living in lakes in the Adirondacks, Dunne and colleagues found that the species most vulnerable to extinction are the ones that result in the fewest secondary extinctions. This suggests, at least in the absence of human manipulation, that the structure of ecosystems maximizes biodiversity persistence. Researchers are now trying to deduce what shapes ecological networks into these robust configurations—forces such as natural selection or thermodynamic constraints on energy flows within the food web might each be at work.

SFI Professor J. Doyne Farmer, who also spoke at the conference, has been exploring the connections between biology and finance for a decade. For example, he compares different strategies—such as value investors, who look for companies whose share price underestimates their true worth, and trend-followers, who bet that a rising market will continue rising, and vice versa—to species. Farmer also draws parallels between the amount of money invested in each strategy to its population size, and the flow of money through a market to the flow of energy through a food web. He has found that the same mathematics used to describe how predators and prey affect each other's population dynamics—thought to be another contributor to the robustness, or otherwise, of ecological systems—can also describe the way that different trading strategies interact with one another.

Recently, Farmer and his colleagues obtained access to transaction data from exchanges in London, Spain, New York, and Taiwan. The Taiwan data set, for example, has tens of billions of trades, with information on who made them. This will allow the team to analyze financial markets in unprecedented detail. In effect, they hope to fast-forward through the past 250 years of the study of species, from basic taxonomy (identifying and classifying the different strategies found in the market), to cutting-edge ecology (understanding the interactions of different strategies, and their effect on the market as a whole). If one strategy increases its profits while another slumps, for example, the former might be said to be preying on the latter. And over periods of months to years, evolutionary changes in strategies and composition of the market may also emerge.

Ultimately, the team hopes to be able to reveal the market's network structures, and to test the idea that diverse markets function better than homogenous ones. This, in turn, could reveal the effect that the rules governing exchanges, such as the charges levied on different forms of trades, have on individual trades, and how this influences the health of the market as a whole.

Wild fluctuations in markets are difficult to explain with the dominant theory in financial economics—the "efficient market hypothesis"—which assumes that the behavior of markets reflects rational actors making the best use of perfect information. In this case, any volatility reflects accurate adjustments to new knowledge. But there is increasing evidence that perfect rationality cannot explain the behavior of markets, and that some, or much, of their volatility is noise that impedes decision making. Understanding the sources of this noise should help reduce it, and improve markets' performance.

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Of course, even the best-regulated market is vulnerable to human error; the subprime mortgage crisis was triggered by old-fashioned bad decisions—loaning money to people who couldn't pay it back. Most organisms and ecosystems have been around long enough to have experienced repeated cycles of good times and bad, and, as the food webs of Adirondack lakes show, to come to terms with a variety of stresses, so that dealing with risk is an important part of their makeup. They know that bubbles burst and easy money cycles don't last forever. Perhaps the world of finance could learn from life that, in the long term, survival is a more realistic aim than victory. ◀

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