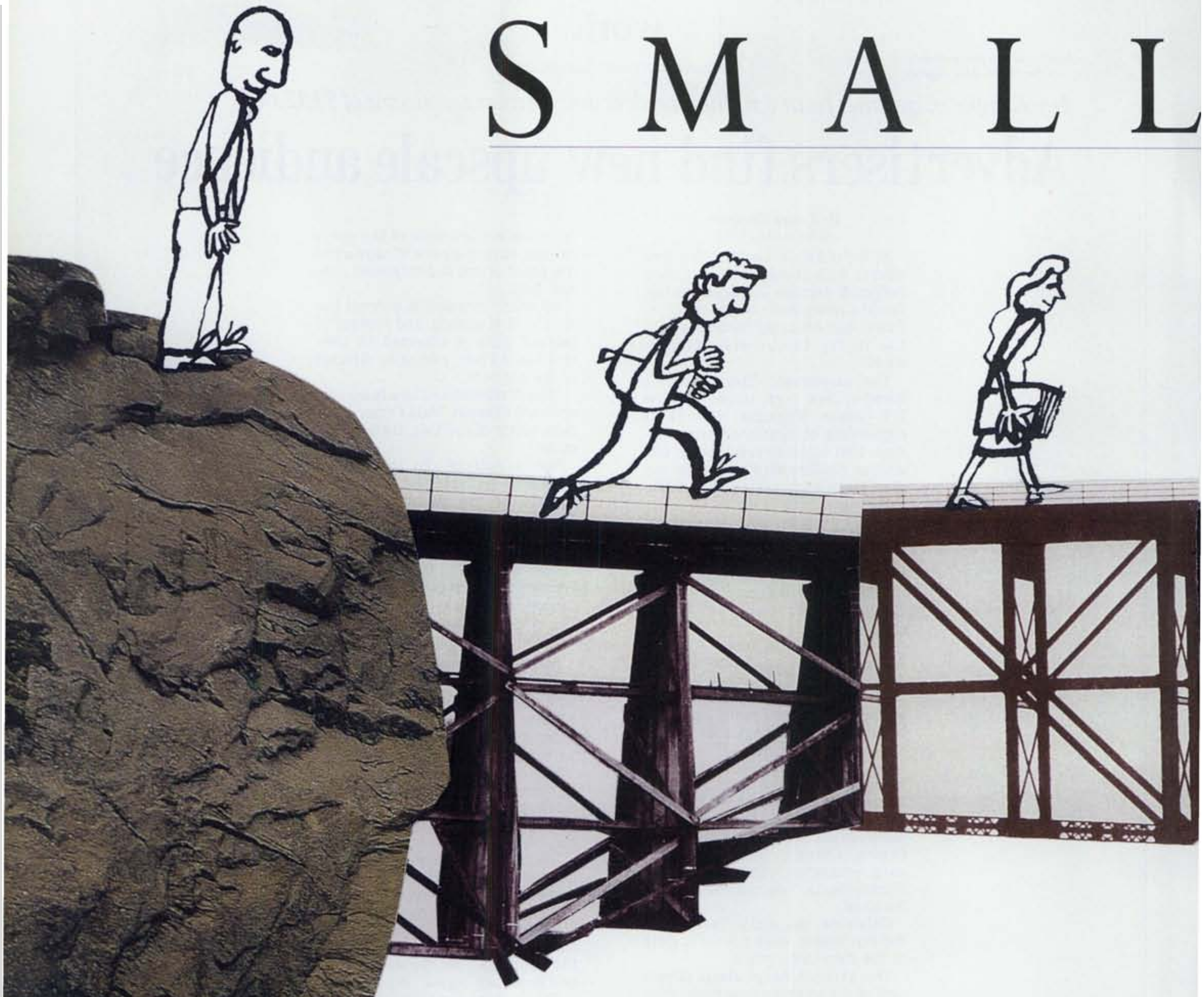
THE SIX DEGREES OF SEPARATION THEORY HAS LONG BEEN PART OF THE CONV

# SMALL

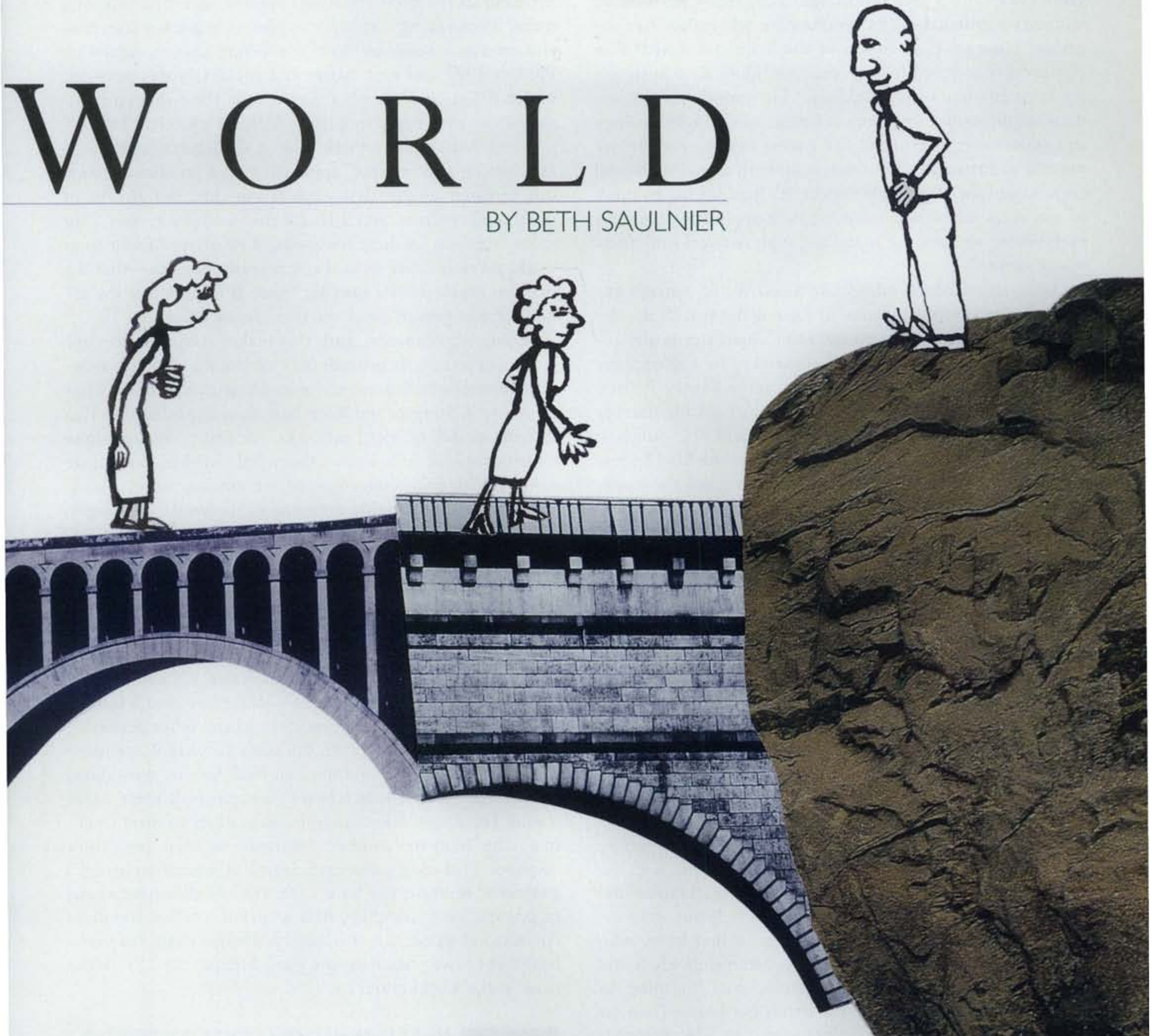


THE GAME GOES LIKE THIS. PICK AN ACTOR, THEN think of another person he's been in a movie with. Then take *that* actor and think of someone *he's* been in a movie with. Keep going, linking actor to actor, until you get to a hard-working, not-quite-superstar named Kevin Bacon. Since it was invented by three Albright College fraternity brothers in 1994, the game has become a beloved time-waster for film buffs everywhere. But to a pair of Cornell-based researchers, it's more than a late-night lark. It's proof that the earth is a small world, after all.

ONAL WISDOM. NOW TWO CORNELL ENGINEERS HAVE THE MATH TO PROVE IT.

# WORLD

BY BETH SAULNIER



The concept is known as the Small World phenomenon—the idea that even on a planet of five billion people, everyone is connected in a tight network. Also called Six Degrees of Separation, the theory has been part of the conventional wisdom for years, inspiring a hit play and movie. Now, engineering professor Steve Strogatz and his former graduate student, Duncan Watts, have proposed a mathematical basis for it. "They have solved a major problem in social science," says Columbia sociologist Harrison White. "They've done a brilliant job of exploring different ways of thinking about it." Their work, which prompted a minor media frenzy when it was published in the journal *Nature* in June, could have implications for dozens of disciplines, from economics to epidemiology to entomology. "The more you think about it, the more fields come to light where the network could be very important," says Watts, whose doctoral dissertation on the subject was recently accepted for publication by Princeton University Press. "It's a Rorschach test for the listener."

How do diseases spread? Can anyone break into the old-boy network? Can an

ILLUSTRATIONS BY SCOTT MENCHIN

accident at a single power station bring down the rest of the grid? How does a joke spread across the Internet? Why do women's menstrual cycles synchronize when they live together? How are the neurons of the brain connected? Can you prevent a crowd from panicking? How do you design the most efficient office building? "Their work has tremendous implications," says Simon Levin, who taught ecology and systematics at Cornell for twenty-seven years before moving to Princeton. "It's interesting both as an intellectual exercise and for its possible impact. It's hard for me to think of any areas where this wouldn't have applications. Almost everywhere we look, we're dealing with networks of interacting agents."

Long an anecdotal oddity, the Small World concept entered the public consciousness in force in 1990 with the debut of *Six Degrees of Separation*, John Guare's critically acclaimed play about a wealthy couple tricked by a charismatic con man claiming to be the son of actor Sidney Poitier. (Based on a true story, it was made into a film starring Stockard Channing, Donald Sutherland, and Will Smith in 1993.) Guare says he got his inspiration for the Six Degrees concept from a comment by Guglielmo Marconi, the inventor of the wireless telegraph. "I read somewhere," Guare says, "that after Marconi connected the world, it would take an average of 5.83 stations to link any one person to another."

In terms of social science, the theory traces its roots to famed psychologist Stanley Milgram. A notoriously brilliant researcher, Milgram is perhaps best known for his disturbing experiments, conducted at Yale, in which the subjects thought they were electrocuting someone. The "victim" was actually an actor who feigned agony and even death as the subjects gave him increasingly stronger shocks simply because the experimenters told them to. Milgram's conclusion: when under orders from a "higher authority," even some apparently mild-mannered people will punish others to death.

In 1967, while a professor at Harvard, Milgram did the first real-world study of the Small World phenomenon by sending packets of letters to people in the Midwest, with the goal of eventually getting them to a Boston stockbroker and a Harvard divinity student's wife. The participants were instructed to pass the letters on to whomever they knew who might be most likely to know the target recipients. He found that it took an average of five intermediaries (meaning six degrees of separation) before the letters got home. Then, he decided to try to go from a white sender to a black recipient, figuring it would take more steps to get from one racially isolated community to another. "It turned out that it didn't," Watts says, "because all you need are a couple of people to bridge the divide."

Milgram's initial findings have been borne out by Watts and Strogatz, who found that those "bridges," people who unite disparate social groups, were the key to the Small World system. Milgram himself had found a whopping demonstration of the phenomenon in his first experiment. Of the sixty-four letters received by the Boston stockbroker, sixteen were delivered by the same person, a local clothing merchant. "But like a lot of things Milgram did," says White, "no one else was smart enough to do much with it."

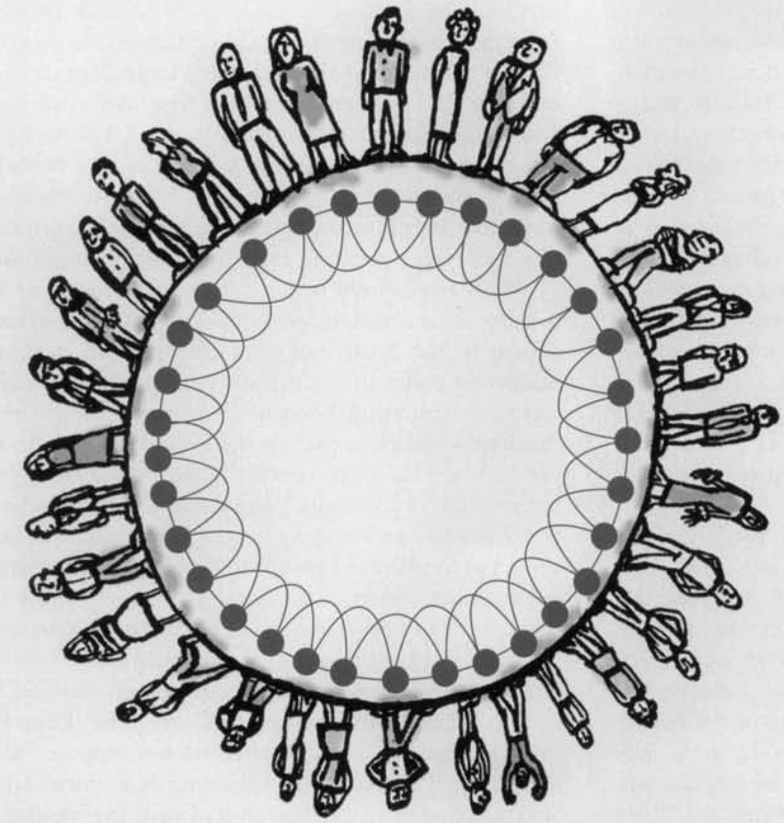
Then along came Watts and Strogatz, and supercomputers powerful enough to crunch their data. Strogatz is a mathematician in the theoretical and applied mechanics department, whose faculty includes engineers, materials scientists, and even an astronomer. Watts, his former advisee, earned his PhD in 1997 and now works as a social sciences post-doc under White at Columbia. Levin calls their theory, hammered out over many months in Strogatz's Kimball Hall office and Watts's ersatz think tank at Collegetown Bagels, a "fascinating and original" approach to the problem. "I view this research as the first exploration into the nature of interconnectedness, and a lesson that we have to pay a lot more attention to these networks," Levin says. "From their work, we've learned what is not patently obvious—that the world is much smaller than we think. It implies that the actions of one person affect the activities of others."

Using experimental math that makes even some college professors scratch their heads (a combination of graph theory, computer simulations, and non-linear dynamics or "chaos theory"), Strogatz and Watts base their hypothesis on two extreme models of social networks. The first posits a world in which everyone only knows the people in their immediate vicinity, with few connections to the outside. Strogatz illustrates it like this: Imagine everyone in the world standing in a circle. Your friends—your "one degree of separation" pool—consist only of the 500 people on your left and the 500 on your right. That means there are only 1,000 people in the world who are two degrees of separation from you, another 1,000 who are three degrees of separation from you, and so on. This purely linear situation, a simplified example of what Watts calls the "Caveman" universe, is about as big as the world could theoretically get—an average of 2.5 million degrees of separation between you and any other person.

On the opposite end of the scale is what Watts nicknamed the "Solaria" world, after an Isaac Asimov story called *The Naked Sun*. In that scenario, people pick their 1,000 friends purely at random; they're just as likely to meet someone who lives on another continent as their next-door neighbor. That means that each degree of separation brings a geometric increase. You have 1,000 friends; they have a total of one million friends; they have a total of a billion friends of friends, and so on. "In that case, you're no more than four handshakes away from anyone else," Strogatz says. "That's as small as the world could be."

THE REAL WORLD, OF COURSE, IS SOMEWHERE in between. Social networks are a complicated pastiche of deliberate choice (where you live, what you do for a living) and random luck (who you go to college with, who sits next to you on an airplane). But the shift from a Caveman world to a Solaria world isn't a gradual one. The researchers found that when just a few random interactions are introduced, the system hits a tipping point, and a world of 2.5 million degrees of separation becomes something like six. "The small world effect kicks in very quickly," Strogatz says. "It's like dropping off a cliff." Almost immediately, they say, the world becomes as small as it can get; any further shrinking is so minimal as to be unnoticeable. Whether you have 1,000 friends or 5,000, you're still about six degrees away from your most re-

## THE 'CAVEMAN' WORLD



THE "CAVEMAN" MODEL, IN WHICH YOU'RE ONLY CONNECTED TO THE PEOPLE NEAREST YOU, IS AS BIG AS THE WORLD COULD GET—2.5 MILLION DEGREES OF SEPARATION. BUT IN "SOLARIA," THE CONNECTIONS ARE RANDOM, AND THE WHOLE WORLD IS JUST FOUR HANDSHAKES AWAY.

## THE 'SOLARIA' WORLD

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