Behind the Six Degrees of SARS

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The concept that each person on the planet is just six handshakes removed from every other person has frightening implications when it comes to a highly communicable disease like SARS.

Yet the "small world" effect, also known as the "six degrees of separation" phenomenon, may also help explain how severe acute respiratory syndrome has spread so rapidly around the globe, some researchers believe. The disease has infected 8,221 people and killed 735 worldwide, according to the World Health Organization.

Physicists, psychologists and mathematicians who study network effects, the scientific field that the six-degrees-of-separation notion has engendered, are busy creating mathematical models that attempt to explain the quick spread of SARS.

"We're modeling interactions within households, between households, in schools, shopping malls and other public areas," said Lauren Ancel Meyers, an assistant professor of integrative biology at the University of Texas at Austin.

Meyers and her colleague, Babak Pourbohloul, director of the division of mathematical modeling at the British Columbia Centre for Disease Control, will use these models to predict which strategies will work best to control the spread of SARS.

The two researchers are working closely with Canadian public health workers on the project. After a brief respite from new cases, Toronto recently reported eight unique cases of the disease, which can cause death from symptoms of pneumonia, re-instituting a travel advisory from the Centers for Disease Control and Prevention in the United States.

"We would like to do something very useful for them," Meyers said. "We're working with a whole team of Canadian scientists who are developing vaccines and trying to characterize (and control) the virus."

They also intend to develop software that would allow public health workers to predict the effectiveness of various methods for stopping the spread of the disease, such as face masks or quarantines.

Mathematicians have long used equations to examine the spread of epidemics, and to help public health officials control them. A recent paper in *Science* applied these methods to SARS.

In the *Science* article, the researchers assume that most people -- excluding those who come in contact with so-called superspreaders, have about the same chance of developing SARS. Superspreaders, researchers believe, have the ability to infect more people than most patients.

Network science, on the other hand, assumes that each person's social habits can increase or lessen his or her chances of getting infected. For example, one might be much more likely to come into contact with someone with SARS by traveling on a plane to Taiwan, a country that has recently seen a high rate of SARS infections.

"You take account of the fact that you don't have contact with everyone, but rather certain people," said Mark Newman, a professor of physics and complex systems at the University of Michigan, who pioneered the application of network effects to epidemics. "Then you can make predictions about how the disease would spread or about how you could deploy vaccine programs or treatment programs to try to prevent its spreading."

The study of network effects grew out of a 1967 experiment conducted by the Yale psychologist Stanley Milgram.

Milgram instructed 300 randomly selected people around the country to send important packages to recipients they did not know.

The "senders" were given clues about the recipients, such as their general geographic locations and occupations. Based on those clues, the senders were instructed to forward the packages to someone else they thought might be "closer" to the intended recipients. This process was repeated until the letters finally reached the correct people.

Milgram published a paper in *Psychology Today* that said that the letters that made it to their intended destinations passed through an average of about six sets of hands. The six-degrees-of-separation school of thought was born.

The phrase "six degrees of separation" was made famous by playwright John Guare, who wrote a play of the same name (later made into a film) about a young black man who scams an upscale New York couple into believing he's Sidney Poitier's son and a classmate of their children. He does the same to other members of the upscale Upper East Side community, and since they are all connected, they discover the scam.

Film buffs came up with a parlor game that challenges players to connect other actors to Kevin Bacon by six degrees.

The concept also influenced science. In 1996, Duncan Watts applied the idea to his doctorate research on the mating chirps of crickets.

Watts wanted to understand how large groups of crickets synchronized their chirps. He realized they do this not by listening to the whole group but to their close neighbors. Gradually, a chain reaction occurs as each cricket synchronizes its chirping with a nearby cricket and so on down the line. The phenomenon, he concluded, is another example of the six-degrees effect in action.

When he and his advisor at Cornell, Steve Strogatz, published a paper on the phenomenon in *Nature*, it caused a stir. Researchers in various disciplines -- from business to computing to epidemiology -- wondered if network effects might apply to them as well.

Watts eventually wrote two books on network effects, *Small Worlds* in 1999, and in February he published *Six Degrees: The Science of a Connected Age*.

Others have written on the role of network effects in the spread of epidemics, including Albert-Laszlo Barabasi, a professor of physics at the University of Notre Dame and author of *Linked*.

"The small-world property is bad news for all viruses: it means that if the virus is not contained, and very virulent, it could, in principle, reach every single person on earth," said Barabasi. "I do not need to know an individual to pass the virus to him. It is enough to be close to him."

Despite the flurry of interest in network effects, the six-degrees-of-separation theory itself came into question in 2001. A researcher named Judith Kleinfeld, a professor of psychology at the University of Alaska at Fairbanks, dug up the Yale data and found that only 29 percent of the packages Milgram sent actually made it to their recipients, and some that did make it required more than six intermediaries.

Kleinfeld couldn't find any evidence that the world, or even the country, is connected by six degrees. Other studies, like Watt's, she argues, use variations on Milgram's original study. They were more likely to achieve a network effect, she said, because they took place in smaller communities, such as high-rise apartment buildings, a specific urban area or a college campus.

But researchers say the size of the group doesn't matter. For the network researcher, what's important is the ability to define the essential characteristics of the network itself.

In Meyers' study, that would include the people with whom SARS patients and their caregivers come in contact. Using that information, Meyers can create a model for predicting the effectiveness of proposed strategies for fighting the disease.

"Despite questions surrounding the original (Milgram) experiment," Meyers said, "there is no doubt that network models of various biological, sociological and technological systems can offer great insights."