mandu in September 2010, right before the U.N. forces left home.

Suspicions of a U.N. link to the epidemic have incited protests and violence in Haiti, and the panel does not fan those flames. It says that the outbreak "was not the fault of, or deliberate action of, a group or individual," and that the introduction would never have evolved into disaster without what Lantagne calls a "perfect storm" of other factors, including Haiti's poor infrastructure and the salinity of the Artibonite delta, which favors *V. cholerae*'s growth.

Nevertheless, it proposes a series of measures to prevent such introductions in the future. U.N. installations around the world should get their own waste-treatment facilities so they're independent of questionable local contractors, and U.N. staff coming from cholera-endemic countries should be screened for the disease before leaving home or given a prophylactic dose of antibiotics.

Some scientists have called such measures ineffective or impractical (*Science*, 28 January, p. 388), and Waldor says *The New England Journal of Medicine* made him strike similar recommendations, deemed "inflammatory," from a January paper presenting evidence for an Asian connection. But Cravioto says the measures are not that difficult to implement. Ban Ki-moon has said a new panel will study how to put the advice into practice. **–MARTIN ENSERINK**

PHYSICS

Scientific Link-Up Yields 'Control Panel' for Networks

In principle, scientists could control the worm *Caenorhabditis elegans* as if it were a robot by tapping into the creature's 297 nerve cells—as some are trying to do. The neurons switch one another on or off, and, making 2345 connections among themselves, they form a network that stretches through the nematode's millimeter-long body. How many neurons would you have to commandeer to control the network with complete precision? The answer is 49. And the algorithm that made that tally marks a key advance in the young field of "network science," researchers say.

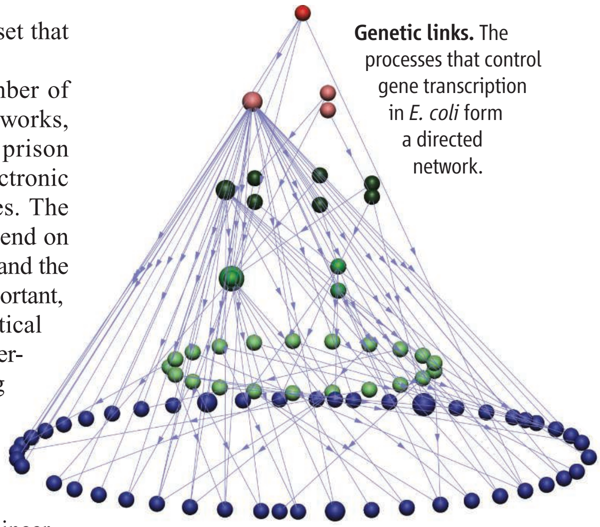
Taking a connect-the-dots approach, researchers have modeled groups of friends, stock markets, the Internet, and countless other systems as networks of points, or "nodes," linked by their interactions. Most research has focused on characterizing different types of networks and their behavior. But physicists Yang-Yu Liu and Albert-László Barabási of Northeastern University in Boston, and engineer Jean-Jacques Slotine of the Massachusetts Institute of Technology in Cambridge, have gone further, taking a step toward manipulating networks.

The trio has found a way to determine the smallest number of nodes that must be externally controlled to force a given network from any initial state to any desired final state. That number can be calculated by brute force, but the size of the computation grows exponentially with the number of nodes. So the researchers take a more efficient tack, as they report this week in *Nature*. For each node in a network, they randomly erase all but one outgoing link and all but one incoming link to create a skeleton called a "matching." They apply a simple technique to make sure the matching contains as many links as possible. In the end, some nodes are left disconnected. And those nodes form a set that can control the original network.

The researchers counted the number of control nodes in 37 real-world networks, including social networks among prison inmates and wiring diagrams of electronic chips, and unearthed some surprises. The number of control nodes doesn't depend on how a network is wired, for example, and the nature of the interactions isn't very important, either. What matters most is a statistical measure of how many nodes have different numbers of incoming and outgoing links, the "degree distribution."

The work is both more general and more practical than earlier efforts to apply control theory to networks, says Guanrong Chen, an electrical engineer at City University of Hong Kong. Previous studies, he says, dealt only with "undirected" networks: special cases in which if node A influences node B, then node B must influence node A in the same way. The new work treats the more-common case of directed networks, in which A can influence B without B influencing A. Also, Chen says, the algorithm for finding a set of control nodes "is very important because it's useful."

The algorithm might help decipher the networks of biochemical interactions within cells, says Rune Linding, a biologist at the Technical University of Denmark in Lyngby. In kinase phosphorylation networks, proteins called kinases attach phosphate groups to one another to alter their functions. Human cells contain more than 500 kinases with more than 200,000 phosphorylation sites. Biologists have traced those interaction networks but don't know how to control them, Linding says. "We've really been lacking a framework with which to derive this from data and not from wishful thinking," he says. "This paper gives us a framework to go forward."



Genetic links. The processes that control gene transcription in *E. coli* form a directed network.

Even so, the paper has its limitations. For example, it doesn't explain how to manipulate the control nodes to get from one state to another. That likely *would* depend on the details of connections and interactions in the network, says Steven Strogatz, an applied mathematician at Cornell University. "I feel that there is a lot missing between 'controllable in principle' and 'controllable in practice,' " he says.

Still, the paper is important, Strogatz says, and so is the collaboration that produced the results. Twenty years ago, physicists and control theorists locked horns over the study of chaos, he says, as the two groups sometimes ignored or dismissed each other's contributions. "What's really appealing about this paper is that Jean-Jacques Slotine is a topflight control theorist, and [in Barabási] he's teamed up with one of the leading network theorists," Strogatz says. In other words, the paper itself has forged a network among fields. **–ADRIAN CHO**

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