Editorial

It's the Network, Stupid: Why Everything in Medicine Is Connected

The *PLoS Medicine* Editors

One need look no further than Facebook to appreciate the significance and power of social networking. (Even PLoS has its own thriving Facebook community, which you can join at http://www.facebook.com/group.php?gid=2401713690.) But social networking is about more than just friends reunited; it's a framework for understanding even the most basic of biological processes. Two papers in this month's *PLoS Medicine* illustrate the insight that network theory brings to basic science, and the valuable interdisciplinarity that social network analysis can inspire.

Once the domain of social scientists—who have used social network analysis to study such diverse phenomena as kinship ties, organizational behavior, rumor spreading, and global air traffic—network theory has now entered the purview of health scientists. Network theory is concerned with mapping the links between entities, and social network analysis is the application of that theory to the social sciences. Searching for more social and environmental explanations for the obesity epidemic in America, for example, Christakis and Fowler [1] showed that obesity can spread from person to person, and that this spread depends on the nature of social ties: a person's chance of becoming obese increased by 171% if he or she had a mutual friend who had become obese (even if they lived far away). Their risk increased by 40% if it was their sibling or spouse who became obese. Christakis and Fowler concluded that the social network is a crucial component—perhaps more so than genetics—in explaining obesity, a problem normally thought of as solely biological and behavioral.

Similarly, a major advance in stemming an outbreak of early syphilis in San Francisco was accomplished through understanding social networks. Klausner and colleagues found that the outbreak was tied to a network of sexual contacts who were meeting through Internet chat rooms [2]. The public health department was then able to initiate an electronic awareness and partner notification campaign using the same Web-based sexual network; 42% of named partners were identified and evaluated.

The observation that social relations and interdependency play a part in health is not surprising. But what network theory teaches us is that connections, even within the most complex systems, are not random (that is, they are not unpredictable). Instead, networks behave in ways that we can theorize, model, and predict.

In network analysis, the network becomes more important than the individual entity.

In its simplest form, network analysis can map ties between entities (whether elephants, humans, or genes).The same principles that allowed researchers to characterize the role of matriarchs in the social organization of the endangered African elephant species [3] also illuminated the collective dynamics fueling individual donations to the 2004 tsunami relief fund [4], and provided the techniques to model the gene network that controls T cell activation in humans [5].

But beyond identifying simple links, network analysis also helps to illustrate the structure of those ties—the nature of the relationships, the rules that govern them, and how we might predict various relationships or outcomes under various conditions. The network becomes more important than the individual entity. In this month's *PLoS Medicine* paper by Lewis and colleagues [6], for example, investigating the transmission network (and its episodic nature) provides insights into HIV prevention that would not emerge from studying individual behavior.

Lewis and colleagues conducted their study because of a seeming contradiction. Genetic studies of HIV transmission networks have not corresponded well with the social contact networks revealed through interview data. The authors' use of phylodynamics—a mix of genetics, epidemiology, and evolutionary biology—allowed a more sophisticated look. By examining and dating the genetic sequences of men attending an HIV clinic in central London, Lewis and colleagues found large clusters comprising ten or more individuals, a quarter of whom had transmitted the virus within several months of being infected. This information is valuable for understanding HIV transmission dynamics, not least because rapid transmission within clusters may result in the spread of drug-resistant strains.

Network analysis is also used in Mossong and colleagues' study on the dynamics of influenza transmission, reported in this month's *PLoS Medicine* [7]. Using paper diaries completed by over 7,000 Europeans documenting their daily physical and nonphysical contacts, Mossong and colleagues found varied mixing patterns, duration of contacts, and types of contacts. This information allowed the researchers to produce a mathematical model that suggests that 5-19-year-olds will suffer the highest burden of respiratory infection during any initial spread.

Citation: The *PLoS Medicine* Editors (2008) It's the network, stupid: Why everything in medicine is connected. PLoS Med 5(3): e71. doi:10.1371/journal.pmed.0050071

E-mail: medicine_editors@plos.org

The *PLoS Medicine* Editors are Virginia Barbour, Jocalyn Clark, Larry Peiperl, Emma Veitch, and Gavin Yamey.

Mossong and colleagues' work illustrates how the patterning of social contacts—between and within groups, and in different social settings—and not just contact rates can influence how new emerging diseases spread. Physical exposure to an infectious agent, the authors conclude, is thus best modeled by taking into account the social network of close contacts and its patterning.

The physicist Albert-László Barabási argues in his book, *Linked*, that "there is a path between any two neurons in our brain, between any two companies in the world, between any two chemicals in our body. Nothing is excluded from this highly interconnected web of life" [8]. As health professionals, we might find network analysis useful in helping us describe and explain the connections in matters of health, whether they be at the cellular or population level. But we will also want to act.

Indeed, the greatest value in understanding networks lies in what they can tell us about taking action. The same insights generated from social network analysis about the spread of disease hold the key to developing effective interventions to halt that spread. The nature of social networks that drive transmission of syphilis and other sexually transmitted infections, for example, demonstrate that the Internet is an appropriate place to deliver safe sex education [9–11]. Exploiting the peer influences that feed the social network of obesity (or smoking, or substance abuse) could be a meaningful way to spread healthy behaviors. Even in diseases that appear intractable to our campaigns and controls, we might best inform policy makers and health promoters by considering: It's the network, stupid. ■

References

1. Christakis NA, Fowler JH (2007) The spread of obesity in a large social network over 32 years. N Engl J Med 357: 370–379.
2. Klausner JD, Wolf W, Fischer-Ponce L, Zolt I, Katz MH (2000) Tracing a syphilis outbreak through cyberspace. JAMA 284: 447–449.
3. McComb K, Moss C, Durant SM, Baker L, Sayialel S (2001) Matriarchs as repositories of social knowledge in African elephants. Science 292: 491–494.
4. Schweitzer F, Mach R (2008) The epidemics of donations: Logistic growth and power-laws. PLoS ONE 3: e1458. doi:10.1371/journal.pone.0001458
5. Palacios R, Goni J, Martinez-Forero I, Iranzo J, Sepulcre J, et al. (2007) A network analysis of the human t-cell activation gene network identifies jagged1 as a therapeutic target for autoimmune diseases. PLoS ONE 2: e1222. doi:10.1371/journal.pone.0001222
6. Lewis F, Hughes GJ, Rambaut A, Pozniak A, Leigh Brown AJ (2008) Episodic sexual transmission of HIV revealed by molecular phylodynamics. PLoS Med 5: e50. doi:10.1371/journal.pmed.0050050
7. Mossong J, Hens N, Jit M, Beutels P, Auranen K, et al. (2008) Social contacts and mixing patterns relevant to the spread of infectious diseases. PLoS Med 5: e74. doi:10.1371/journal.pmed.0050074
8. Barabási A-L (2003) Linked: How everything is connected to everything else and what it means. New York: Plume. 304 p.
9. Benotsch EG, Kalichman S, Cage M (2002) Men who have met sex partners via the Internet: Prevalence, predictors, and implications for HIV prevention. Arch Sex Behav 31: 177–183.
10. Bolding G, Davis M, Hart G, Sherr L, Elford J (2005) Gay men who look for sex on the Internet: Is there more HIV/STI risk with online partners? AIDS 19: 961–968.
11. Curioso WH, Blas MM, Nodell B, Alva IE, Kurth AE (2007) Opportunities for providing web-based interventions to prevent sexually transmitted infections in Peru. PLoS Med 4: e11. doi:10.1371/journal.pmed.0040011