they can explore the marine lives of Adélie penguins (these birds spend less than 10% of their lives on land) and further improve our understanding of oceanic ecosystems. ■

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Networks untangled

Six Degrees: The Science of a Connected Age
by Duncan J. Watts
W. W. Norton/Heinemann: 2003. 448 pp. $27.95/£17.99

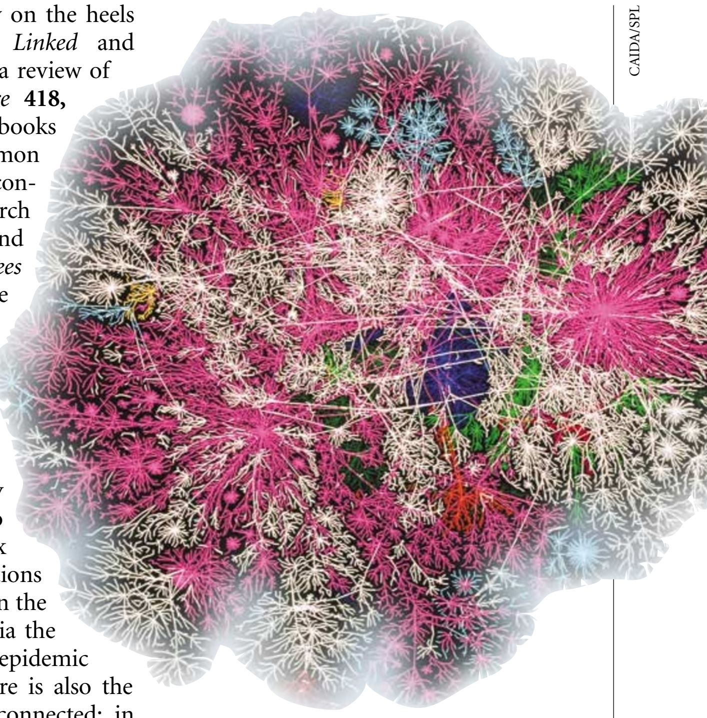
Lada Adamic

Advances in computing over the past decade have not only improved the world's networks, they have made it easier for scientists to study networks, both new (the Internet) and old (metabolic and other biological networks that have been evolving for billions of years). The recent avalanche of research on networks was set off by Duncan Watts, who, while working on his PhD thesis with Steve Strogatz at Cornell University, wrote the seminal article "Collective dynamics of 'small-world' networks" (*Nature* **393,** 440–442; 1998). Five years and hundreds of articles later, the research community is making progress in understanding the structure of networks. But working out how network structure affects dynamics, which was Watts' original interest, has proven to be a much harder problem. Undeterred, Watts has continued this vein of research, with several interesting and rewarding results. This book is a narrative of his research and of the many connections that have led him down this path.

Six Degrees follows closely on the heels of Albert-László Barabási's *Linked* and Mark Buchanan's *Nexus* (for a review of these two books, see *Nature* **418,** 127–128; 2002). All three books cover quite a bit of common ground, including the major contributions to network research made by both Watts and Barabási. In addition, *Six Degrees* and *Linked* use many of the same examples to illustrate the role of networks. There is the groundbreaking experiment in the 1960s by Stanley Milgram showing that any two people in the United States (and probably the world) are connected to each other through a mere 'six degrees'. There are the observations that networks are important in the spread of computer viruses via the Internet, and the AIDS epidemic through sexual contacts. There is also the certainty that everything is connected: in 1996, the failure of a single transmission line in the US electrical grid caused major power outages across the western United States; and the 1997 currency-exchange crisis in Thailand was felt not only in Southeast Asia, but worldwide.

Six Degrees and *Linked* differ in their focus, however. Barabási tells a simple and convincing story: that networks in many systems arise through a rich-get-richer phenomenon, yielding many poorly connected nodes and a few hubs, or extremely well-connected nodes. These hubs affect properties of the network, such as susceptibility to computer-virus epidemics. Watts' book presents a broader view: that the distribution of connections among the nodes is just one of the factors that influence the dynamics of networks. In the context of social networks, some individuals may be better connected than others, but who we know also depends on who our friends know, and where we live and work, and this leads to a network property called 'clustering'. Watts' original *Nature* article showed that networks can be clustered, but as long as there are a few random connections, the network is a 'small world', with only a few hops separating any two nodes.

But the existence of short paths does not, in itself, explain how people can find their targets. If you are trying to reach someone, but know only your friends, and some of your friend's friends, six degrees can seem quite distant. Watts has developed a mathematical model to show why individuals succeed in finding short paths simply by choosing for each link in the chain a friend who is most like the target. In addition to presenting a solution to the small-world problem, Watts has studied information cascades and the spread of disease in networks. The insights presented, though quite general, are based on the results of analysis and simulation, and would benefit from empirical validation.



CAIDA/SPL

An understanding of networks can show us how computer viruses spread on the Internet.

Watts' casual style of writing, dotted with humorous introspection and observations about his collaborators, is accessible and engaging. The more involved models covered in the later chapters require a bit of effort to follow, even in the absence of equations. For further reading, Watts provides a list of resources, grouped by topic.

Six Degrees primarily covers Watts' own work, so it is not a comprehensive overview of recent developments in the field (the books by Buchanan and Barabási are somewhat broader). But it does provide a good introduction to the topic, including many interesting real-world examples of network dynamics. It also offers historical background and several new results relevant to the social sciences. If you haven't yet had time to learn about the latest intriguing research on networks, reading this book could help you see why people increasingly believe that understanding networks is the key to such seemingly disparate problems as securing the Internet, fighting epidemics, curbing terrorism and deciphering genetics. ■

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Correction In his review of *Cassell's Laws of Nature* by James Trefil (*Nature* **421,** 578–579, 2003), Walter Gratzer imputed to the author an error that he did not make: it is blue-eyed parents who do not have brown-eyed children, brown being dominant, and not the other way around. We apologise to James Trefil.