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Social Networking for Zebras

Scientists are developing a new branch of network theory to understand zebra communities

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Facebook hasn't yet opened up a site for zebras. Even so, social networking is taking off for them, too. By using social network theory to understand how zebras interact, scientists hope to explain why the plains zebra is thriving while the Grevy's zebra is endangered.

But to apply network theory to that problem, researchers need to develop wide-ranging new theoretical tools. The same concepts that can explain the zebra problem are also useful for tackling problems as wide-ranging as tracking terrorists, controlling the spread of diseases, and recommending products to consumers.

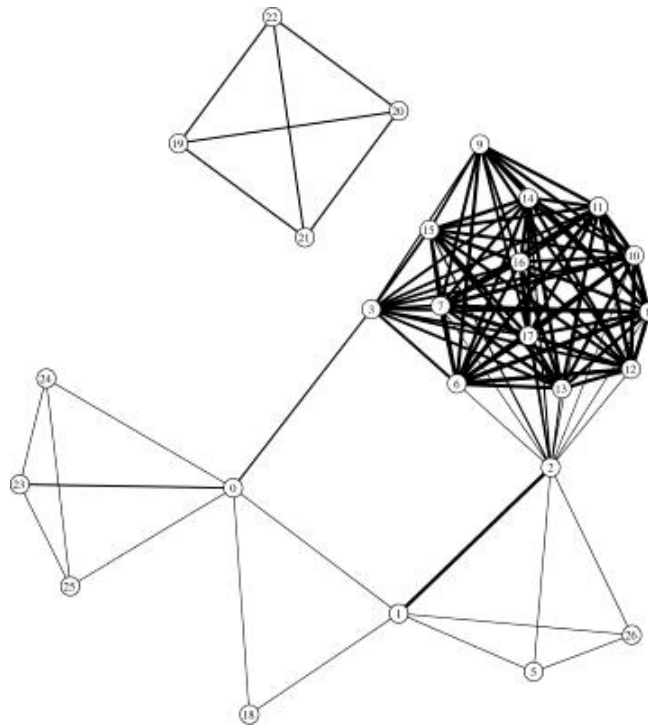
Grevy's and plains zebras look and act very much alike, but their social structures are quite different. Plains zebras organize themselves into stable "harems," with a single stallion keeping watch over a group of mares and babies. The Grevy's zebra, on the other hand, has a "fission-fusion society," with groups that form and dissolve.



All zebras are social animals, but the social structures of different species vary substantially.
Photodisc

Dan Rubenstein of Princeton University is an ecologist who has studied zebras and other horse-like animals for 20 years. To understand their social structure, he makes graphs of their interactions, with a separate graph for each season. Each zebra corresponds to a node on a graph (drawn as a dot), and two zebras are connected by a line if they've come within a few feet of each other during a given season.

Rubenstein first graphed data showing the interactions among Grevy's zebras and among onagers, a closely related horse-like species. Both are fission-fusion societies without stable harems, so he expected the graphs to look similar. But in fact, the zebra graph had masses of tightly connected clumps, whereas the onager graph sprawled across the page, with looser and more random connections. The difference showed that the Grevy's zebras tended to hang out in cliques, whereas the onagers spent time with different buddies on different days.



This graph depicts the social relationships among zebras in a group. Each circle represents a zebra, and the lines connect zebras that spent time together. The graph reveals that many of the zebras hang out together in a single group, while a few of the zebras form smaller communities.

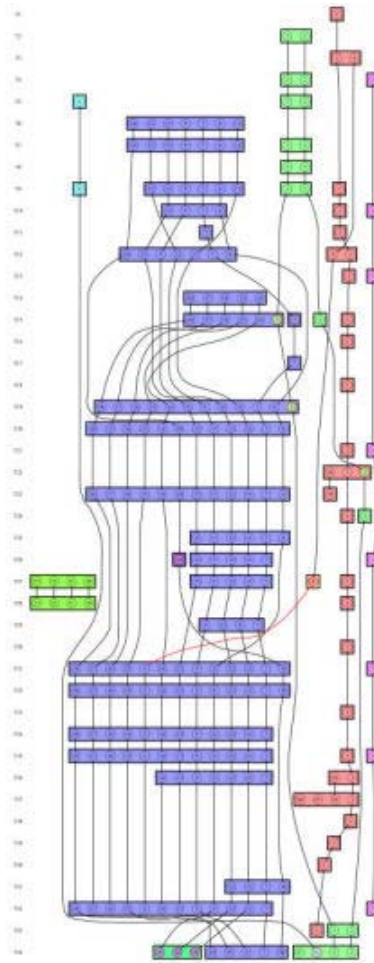
Berger-Wolf

Rubenstein was thrilled to see that network theory revealed patterns he wouldn't have seen otherwise, and he started thinking of all the other questions network theory might help him answer. In a harem society, is there a change in the zebras' interactions just before a bachelor overthrows a stallion in a coup? When zebras flee a lion, how do they decide which zebra will lead the stampede? Do different zebras play different roles in society?

He rapidly hit a roadblock, however. Answering these questions required seeing how the interactions changed over time, but two zebras were connected in a graph if they had interacted at any time over a three-month season. The graphs didn't depict any of the changes in interactions within a season, so they couldn't answer the questions that most interested him. "It was like looking at the data with a very cloudy lens," Rubenstein says. "We were throwing away a lot of information, which was really frustrating."

So he turned to Tanya Berger-Wolf, a computer scientist at the University of Illinois in Chicago, to find out how to analyze changing networks. She told him that the methods hadn't been developed yet. "If there's nothing else out there," she said, "I guess we'll have to do it." In August, Berger-Wolf and her collaborators received a \$900,000 grant from the National Science Foundation for the project.

First, Berger-Wolf is redefining the most basic concepts of network theory to make them work in a graph that reflects changes over time. Even the definition of a community has to be changed for dynamic networks. To take a very simple example, suppose that two zebras always hang out together, while a third is with them half the time. Is the third zebra a part of the group or not? If the third zebra joins the first two halfway through the study period, and then spends time with them consistently, we'd probably want to say yes. If the third zebra comes and goes, we might say no. She presented her new methods in August at the International Conference on Knowledge Discovery and Data Mining in San Jose, Calif.



This graph shows a dynamic version of the network graphed in the first image. Each row shows all the zebras that have been detected at a particular moment, with each circle representing an individual zebra. The vertical lines connect an individual zebra to itself over time. Zebras in the same community appear in the same color.
Berger-Wolf

Using all the techniques that Berger-Wolf is devising will require that Rubenstein collect more detailed data about the zebras' movements. In the past, he relied mostly on visual observations. But if his workers didn't see a zebra on a particular day, he didn't know whether the zebra was alone or hanging out with a different group of zebras. And he couldn't get any information during the night hours.

This summer, he and his students put collars on 12 zebras in Kenya that use the Global Positioning System (GPS) to track their movements hourly throughout the day and night. He's now in the process of gathering data from those collars.



This zebra is wearing a wireless GPS tracking collar.
Rubenstein

In the meantime, Berger-Wolf is testing her methods on other datasets, including the records of e-mails exchanged at Enron that became available after they were subpoenaed. She has found some surprising connections between the two kinds of networks. "We can see that our method to detect when a lion was in the area of zebras detects very well when the subpoena was issued at Enron," she says. When faced with a lion, the zebras flee and follow one lead zebra. Similarly, after the subpoena was issued, e-mail traffic to the lawyers increased dramatically.

Berger-Wolf says that as she and others develop new computational methods, their work will allow biologists to ask entirely new questions. "This is a beautiful example of computer science," she says, "because there are some questions biologists cannot even ask before we do the computational analysis."

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References:

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To see the movements of Rubenstein's zebras, go to <http://www.princeton.edu/~equids/multimedia.html> and click "Display Data."

<http://www.sciencenews.org/articles/20071201/mathtrek.asp>

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