

# Spread of disease in networks

Matthew J. Salganik

Social Network (Soc 204)  
Spring 2017  
Princeton University

March 1, 2017



## Logistics:

- ▶ In class midterm in two weeks (March 15), I will discuss more next week

## Questions?

# Using a Probabilistic Model to Assist Merging of Large-scale Administrative Records

Ted Enamorado

Friday, March 3rd, noon - 1:30, Corwin 127

"Since most social science research relies upon multiple data sources, merging data sets is an essential part of workflow for many researchers. In many situations, however, a unique identifier that unambiguously links data sets is unavailable and data sets may contain missing and inaccurate information. As a result, researchers can no longer combine data sets "by hand" without sacrificing the quality of the resulting merged data set. This problem is especially severe when merging large-scale administrative records such as voter files. The existing algorithms to automate the merging process do not scale, result in many fewer matches, and require arbitrary decisions by researchers. To overcome this challenge, . . . . Finally, we use our methodology to merge the campaign contribution data (5 million records), the Cooperative Congressional Election Study data (50 thousand records), and the nationwide voter file (160 million records)."

Vote:

1. Watts, Chapter 6.
2. Bearman, P.S., Moody, J.M., and Stovel, K. (2004). Chains of affection: The structure of adolescent romantic and sexual networks. American Journal of Sociology.

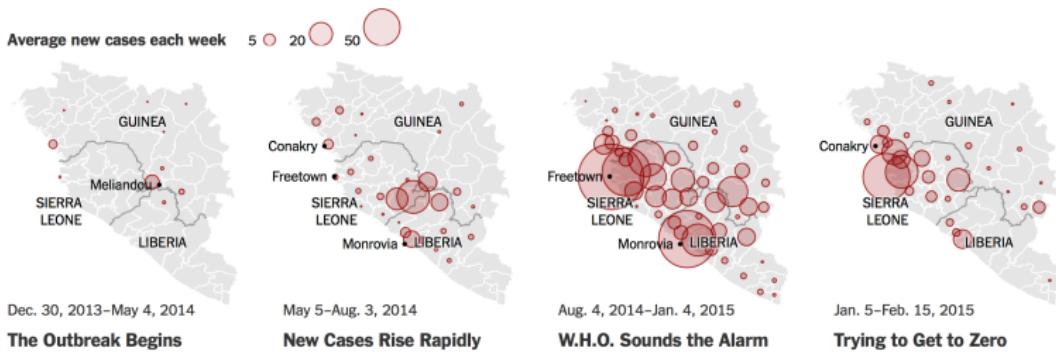
- ▶ directed search and broadcast search

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- ▶ example of directed search: search for an abortionist

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Today: broadcast search because that's what diseases use



<http://www.nytimes.com/interactive/2015/02/24/world/africa/2015-02-24-ebola-outbreak.html>

Chains of transmission and control of Ebola Virus Disease in  
Conakry, Guinea in 2014  
by Simon Cauchemez  
Mathematical Modelling of Infectious Diseases Unit  
Institut Pasteur, Paris

Speaking at Princeton University February 24, 2015

**Matthew J. Salganik**  
To: simon.cauchemez@pasteur.fr  
The Focused Organization of Social Ties

February 24, 2015 2:01 PM  
[Hide Details](#)

Hi Simon,

Here's a link to that paper that I was describing about the important of contexts (he calls them "foci") for the generation of network ties.

[http://emg.media.mit.edu/library/Feld\\_SocialTies.pdf](http://emg.media.mit.edu/library/Feld_SocialTies.pdf)

Matt

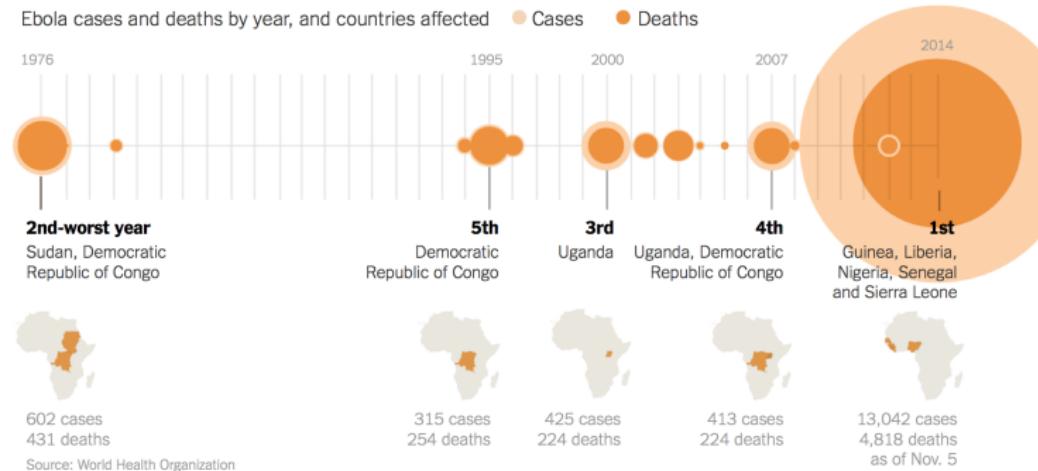
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## How Does This Compare to Past Outbreaks?

UPDATED NOV. 5

It is the deadliest, eclipsing an outbreak in 1976, the year the virus was discovered.



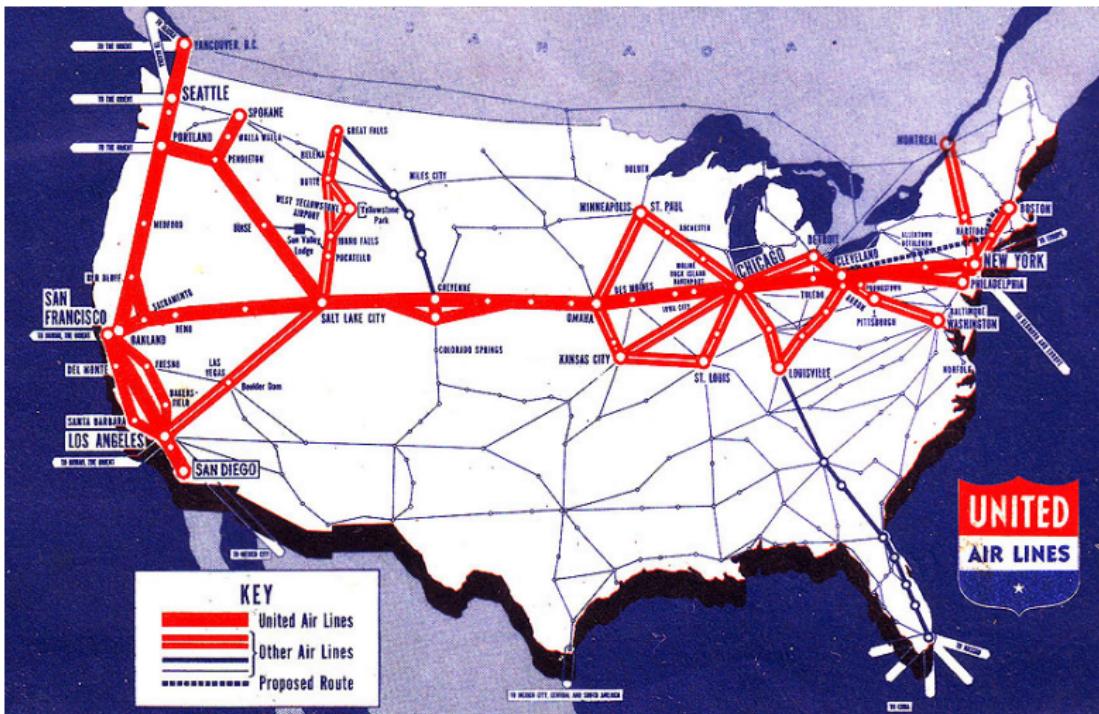
<http://www.nytimes.com/interactive/2014/07/31/world/africa/ebola-virus-outbreak-qa.html>

# Reduced vaccination and the risk of measles and other childhood infections post-Ebola

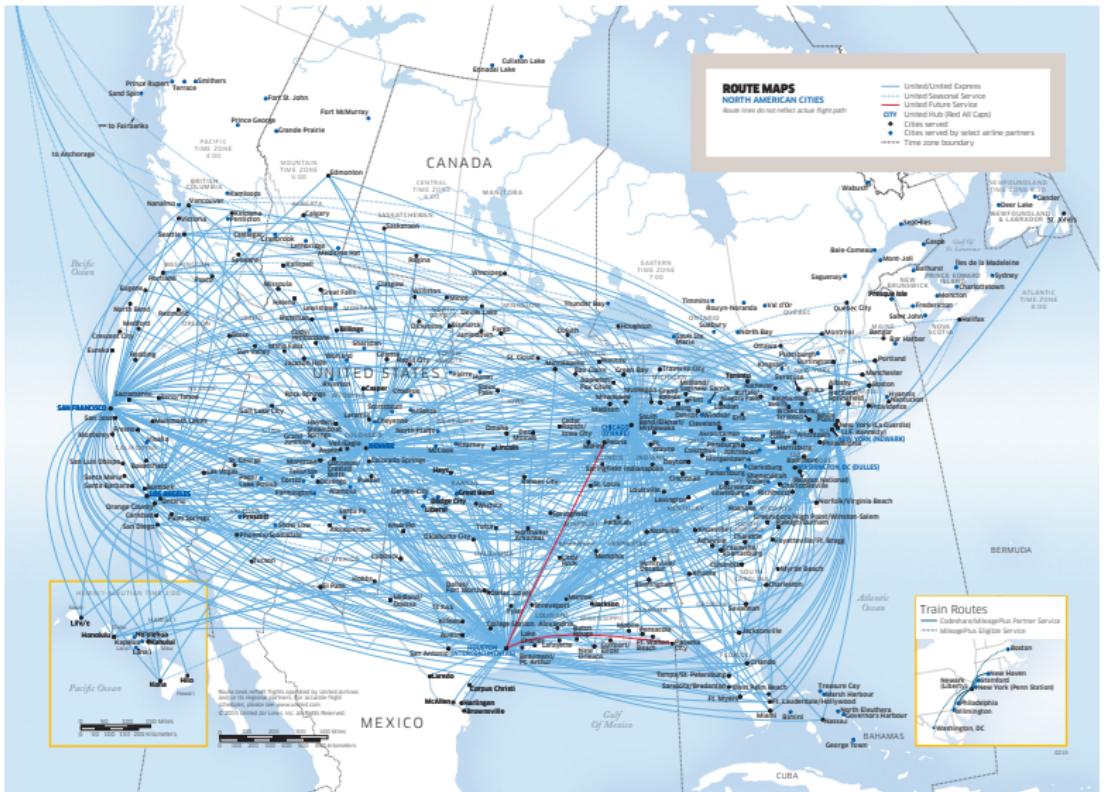
Saki Takahashi,<sup>1</sup> C. Jessica E. Metcalf,<sup>1,2</sup> Matthew J. Ferrari,<sup>3</sup> William J. Moss,<sup>4</sup>  
Shaun A. Truelove,<sup>4</sup> Andrew J. Tatem,<sup>5,6,7</sup> Bryan T. Grenfell,<sup>1,6</sup> Justin Lessler<sup>4\*</sup>

<http://dx.doi.org/10.1126/science.aaa3438>

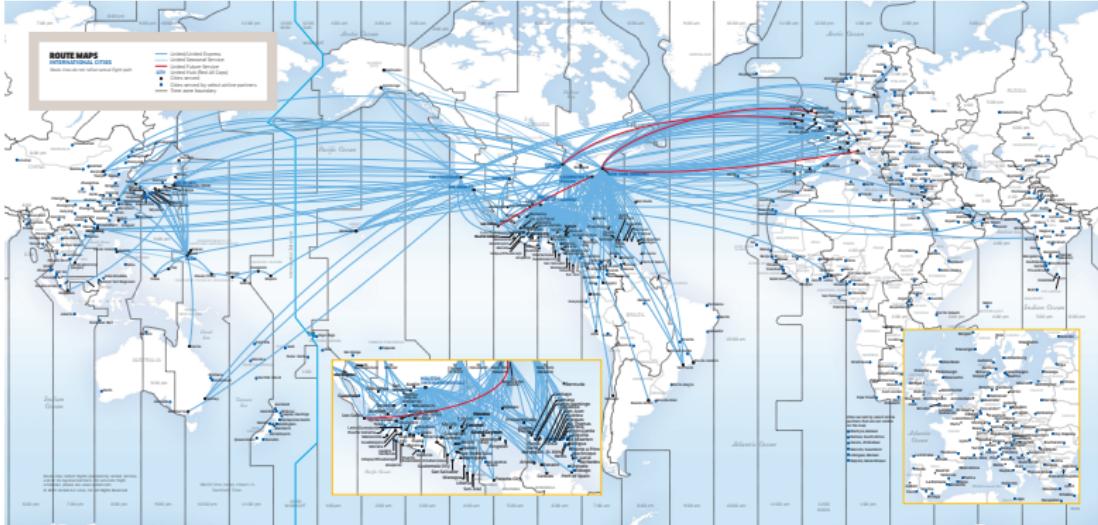
What does the future of global pandemics look like? Is technology going to help us or hurt us?



[http://en.wikipedia.org/wiki/United\\_Airlines#mediaviewer/File:UAL\\_Route\\_Map\\_1940.jpg](http://en.wikipedia.org/wiki/United_Airlines#mediaviewer/File:UAL_Route_Map_1940.jpg)



[http://www.united.com/CMS/Documents/pdfs/route-maps/UAL\\_NA\\_Map\\_2015\\_02\\_01.pdf](http://www.united.com/CMS/Documents/pdfs/route-maps/UAL_NA_Map_2015_02_01.pdf)



[http://www.united.com/CMS/Documents/pdfs/route-maps/UAL\\_WORLD\\_Map\\_2015\\_02\\_01.pdf](http://www.united.com/CMS/Documents/pdfs/route-maps/UAL_WORLD_Map_2015_02_01.pdf)

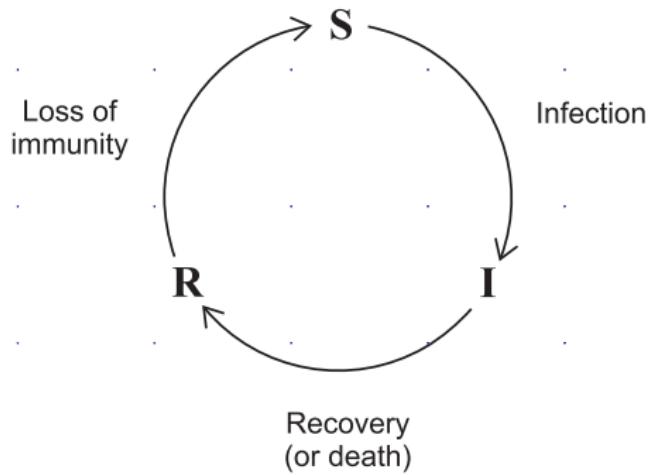
Is technology going to help or hurt with the next global pandemic?

1. help
2. hurt

Main tools for thinking about epidemics:

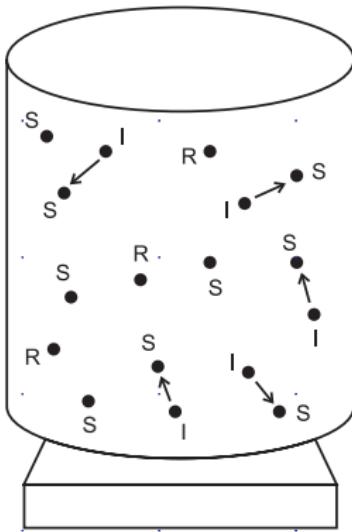
- ▶  $R_0$
- ▶ SIR model

6.1

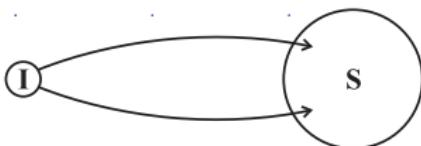


$R \neq R_0$

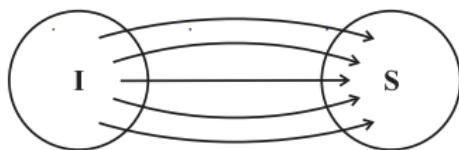
6.2



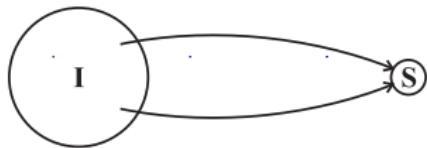
6.3



Slow Growth Phase

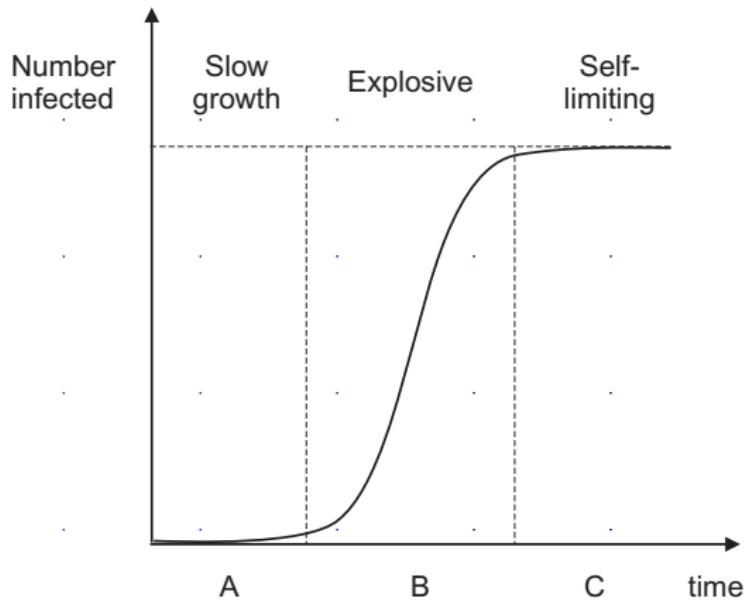


Explosive Phase

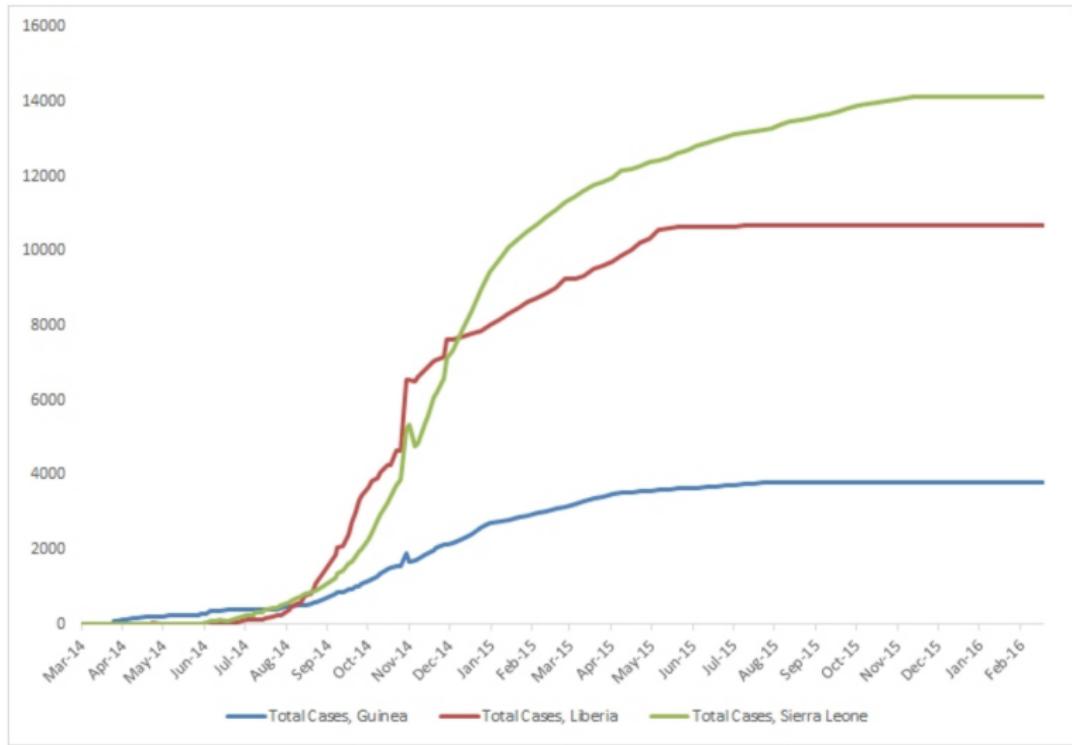


Burn Out

6.4



What shape will the Ebola time series have?

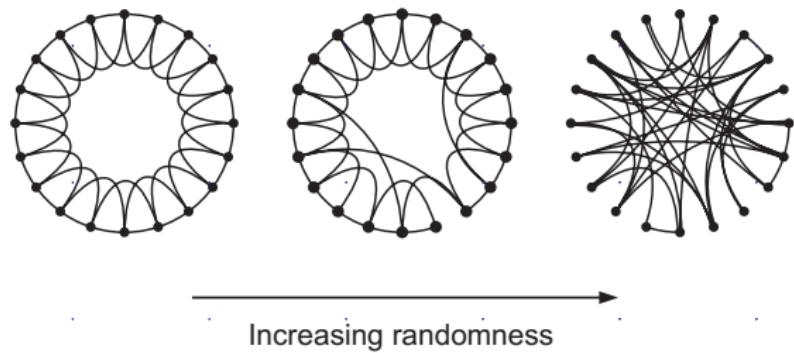


Graph 1 shows the total reported suspected, probable, and confirmed cases in Guinea, Liberia, and Sierra Leone provided in [WHO situation reports](#) beginning on March 25, 2014 through the most recent situation report on February 17, 2016.

<https://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/cumulative-cases-graphs.html>

## Relationship between networks and disease

3.6



# The small-world effect is a modern phenomenon

Seth A. Marvel,<sup>1</sup> Travis Martin,<sup>2</sup> Charles R. Doering,<sup>1,3</sup> David Lusseau,<sup>4</sup> and M. E. J. Newman<sup>3</sup>

<sup>1</sup>*Department of Mathematics, University of Michigan, Ann Arbor, MI 48109, U.S.A.*

<sup>2</sup>*Department of Electrical Engineering and Computer Science,  
University of Michigan, Ann Arbor, MI 48109, U.S.A.*

<sup>3</sup>*Department of Physics and Center for the Study of Complex Systems,  
University of Michigan, Ann Arbor, MI 48109, U.S.A.*

<sup>4</sup>*Institute of Biological and Environmental Sciences, University of Aberdeen, Aberdeen, U.K.*

<http://arxiv.org/pdf/1310.2636v1.pdf>

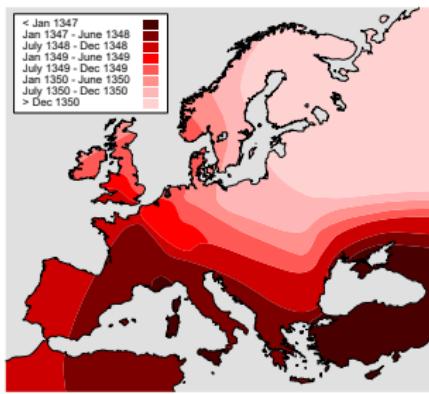
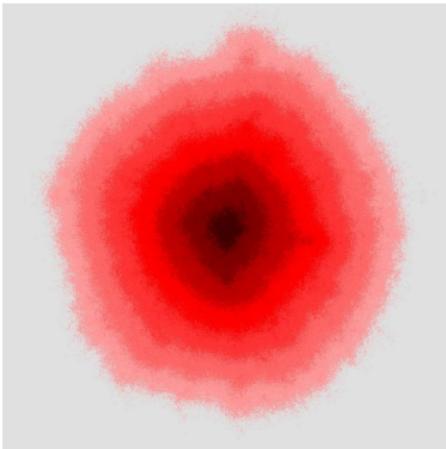
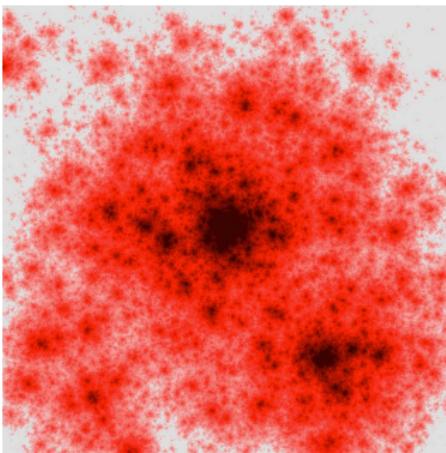


FIG. 1: The spread of the Black Death across Europe in the 14th century, after Sherman and Salisbury [18]. Observe that the disease advanced as a wave of infection across the continent at a more or less constant speed for over three years.

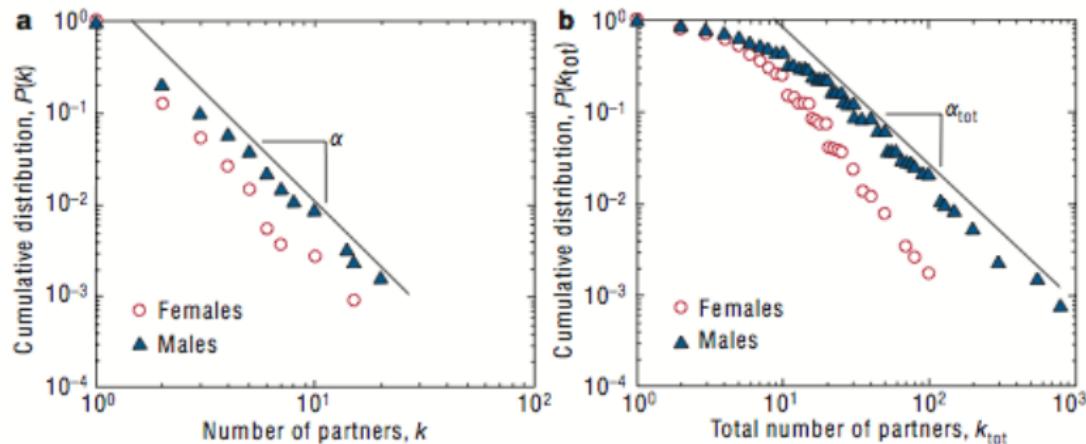
A



B



Important to match the disease you are studying to the appropriate contact network. For STDs, this is the sexual network.  
Recall, this image of the sexual networks in Sweden.



But what is the structure of sexual networks?

# **Chains of Affection: The Structure of Adolescent Romantic and Sexual Networks<sup>1</sup>**

Peter S. Bearman

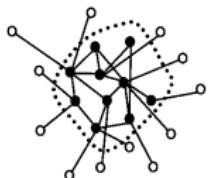
*Columbia University*

James Moody

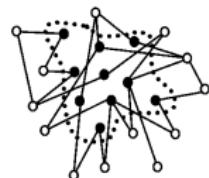
*Ohio State University*

Katherine Stovel

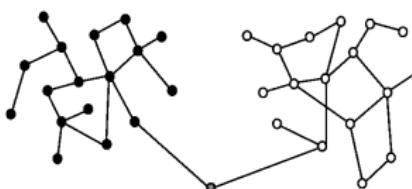
*University of Washington*



Panel A: Core Infection Model



Panel B: Inverse Core Model



Panel C: Bridge Between Disjoint Populations



Panel D: Spanning Tree

FIG. 1.—The network structure of four models of infection

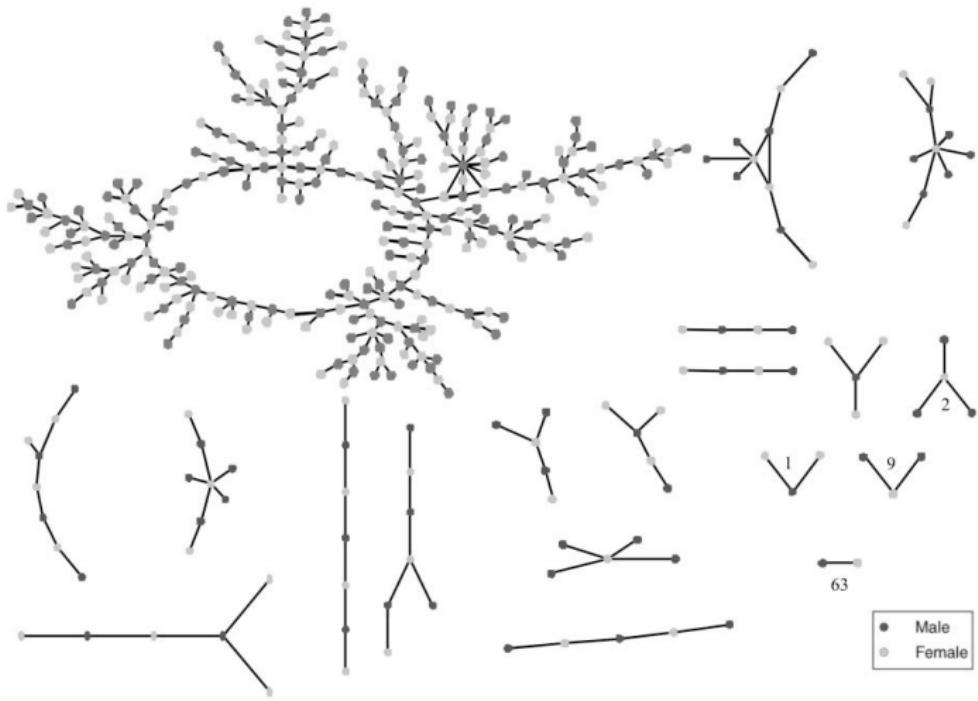


FIG. 2.—The direct relationship structure at Jefferson High

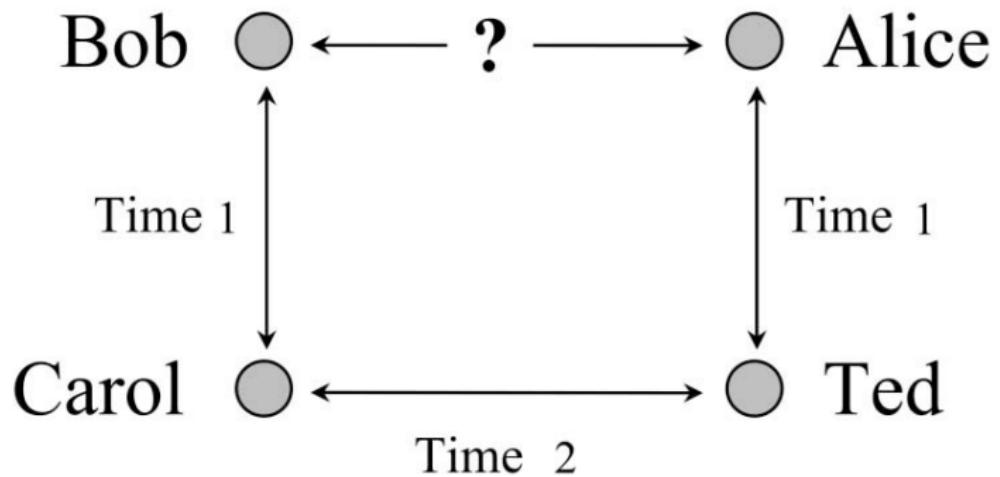


FIG. 8.—Hypothetical cycle of length 4

Is this the same everywhere? In other words, what are the *scope conditions* for this pattern?

If we were able ethically and accurately measure the entire sexual network of Princeton students, do you think we would find a spanning tree?

1. yes
2. no

# **Sexual network structure and the spread of HIV in Africa: evidence from Likoma Island, Malawi**

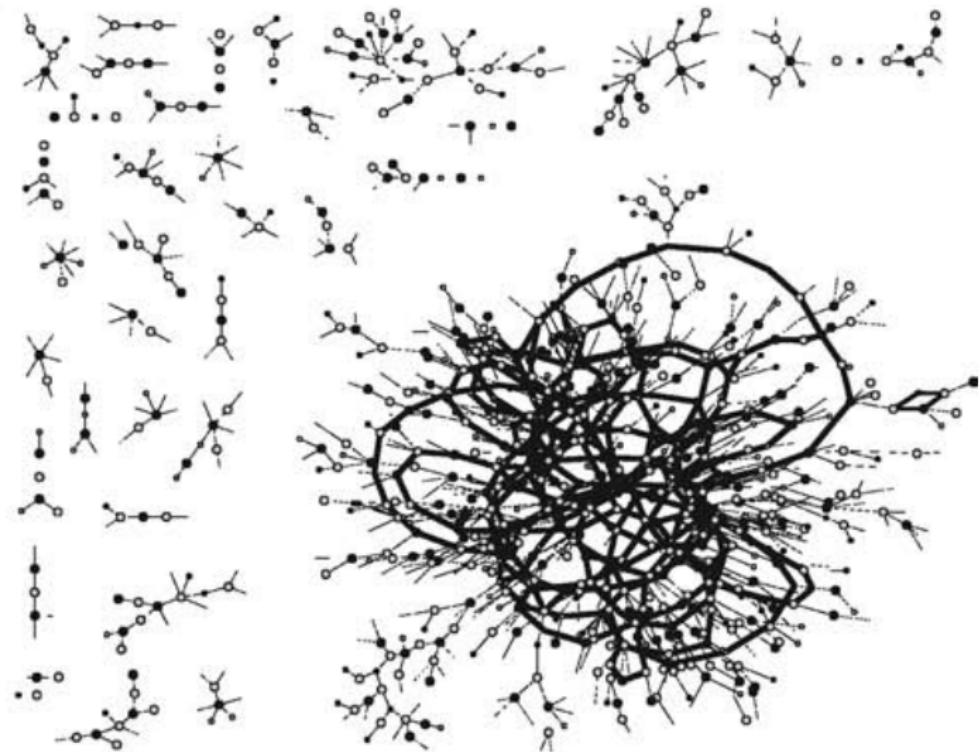
**Stéphane Helleringer and Hans-Peter Kohler**

<http://www.ncbi.nlm.nih.gov/pubmed/18090281>



*How to get to zero:*

**Faster.  
Smarter.  
Better.**

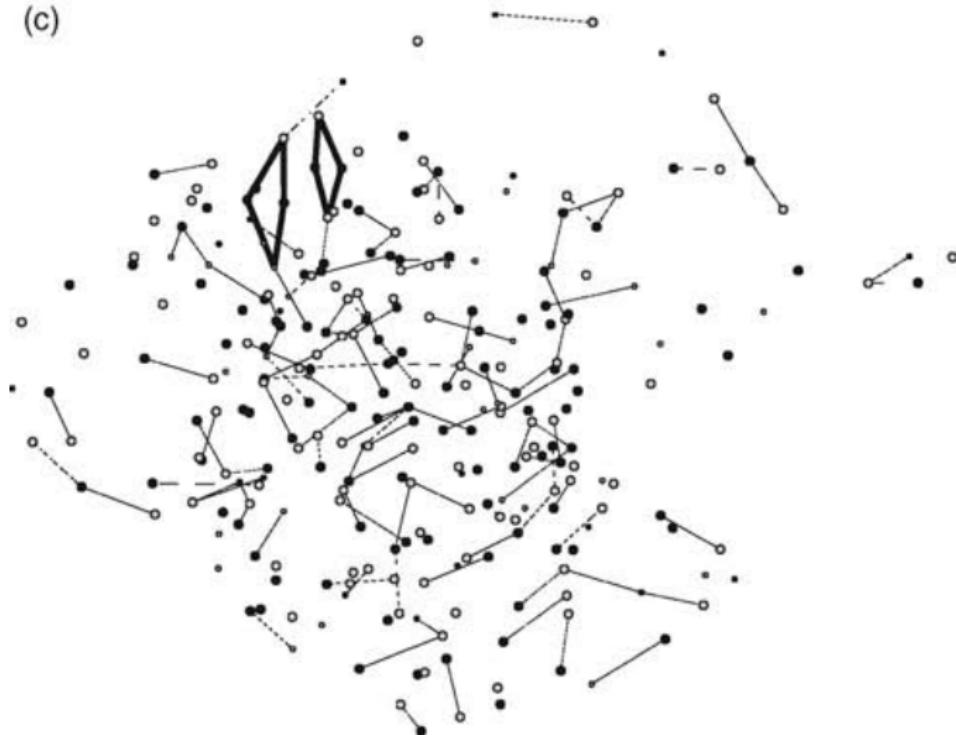


Last 3 years



Last year

(c)



Right now

members (Fig. 2b). Short-length cycles (i.e. two individuals having two partners in common) are also present within the network of relationships that were ongoing at the time of the survey (Fig. 2c). For comparison, Bearman *et al.* [25] did not find any short-length cycles among students of a US high school over an 18 month period.

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- ▶ contact patterns are important for the spread of disease

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- ▶ sometimes detailed structure matters
- ▶ simple rules by individuals can aggregate to complex network patterns

If you are interested in disease modeling, check out Jess Metcalf's and Brian Grenfell's classes

<http://bit.ly/socnet204>

<http://bit.ly/socnet204>

Next class: Madness of Crowds

- ▶ Watts, Chapter 7.
- ▶ Asch, S.E. (1955). Opinions and social pressure. *Scientific American*, 193(5):31-35. (Available on Blackboard)
- ▶ Easley D. and Kleinberg, J. (2010). Networks, Crowds, and Markets: Chapter 16. (skim mathematical model in Sections 16.3-16.6)
- ▶ Tierney, J. (2007). Diet and fat: A severe case of mistaken consensus. *New York Times*