

Class 8: Spread of disease in networks

Matthew J. Salganik

Sociology 204: Social Networks
Princeton University

Wednesday, February 19, 2025



Discussion about the midterm

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*.

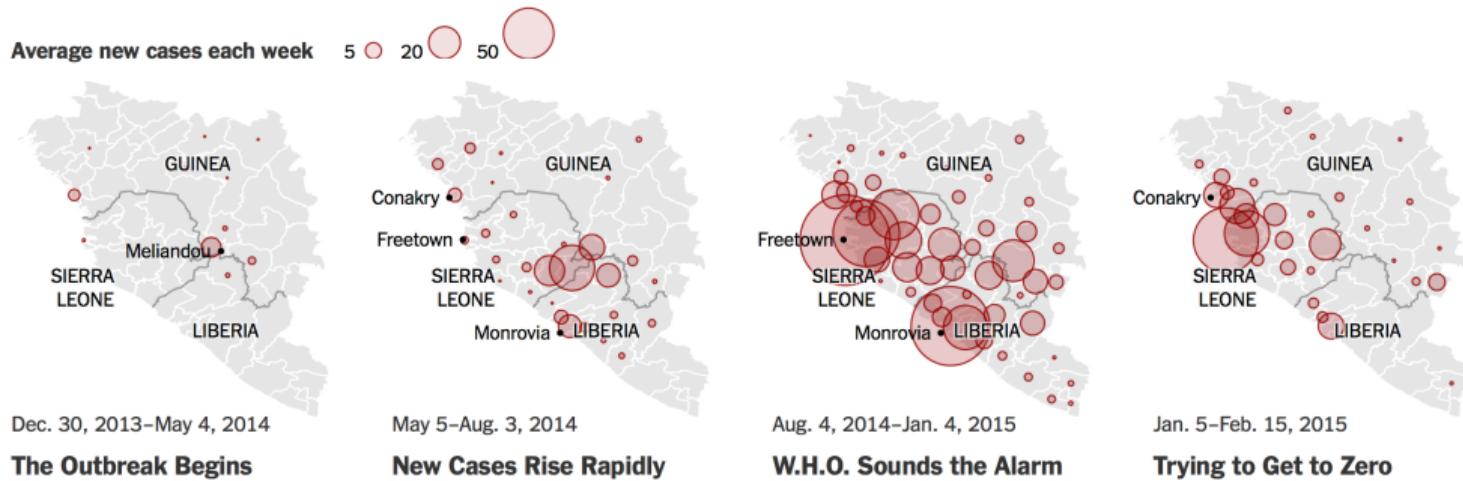
- ▶ directed search and broadcast search

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Today: broadcast search because that's what diseases use

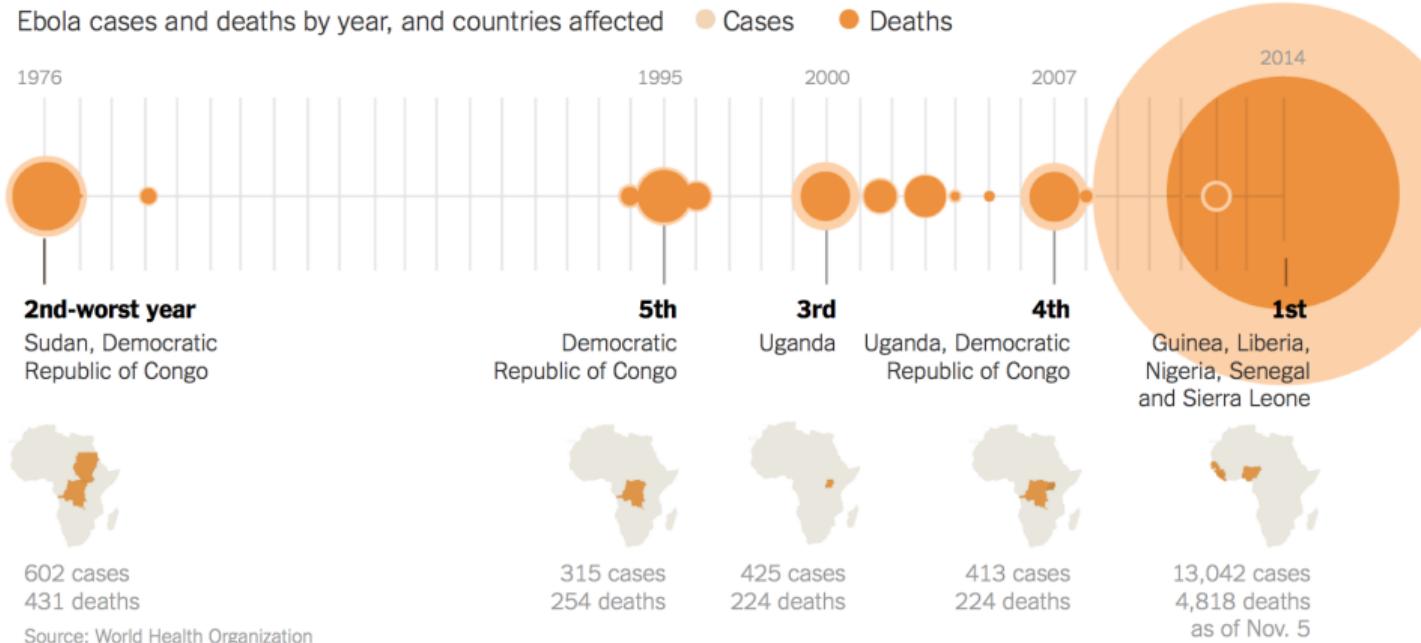


<http://www.nytimes.com/interactive/2015/02/24/world/africa/2015-02-24-ebola-outbreak.html>

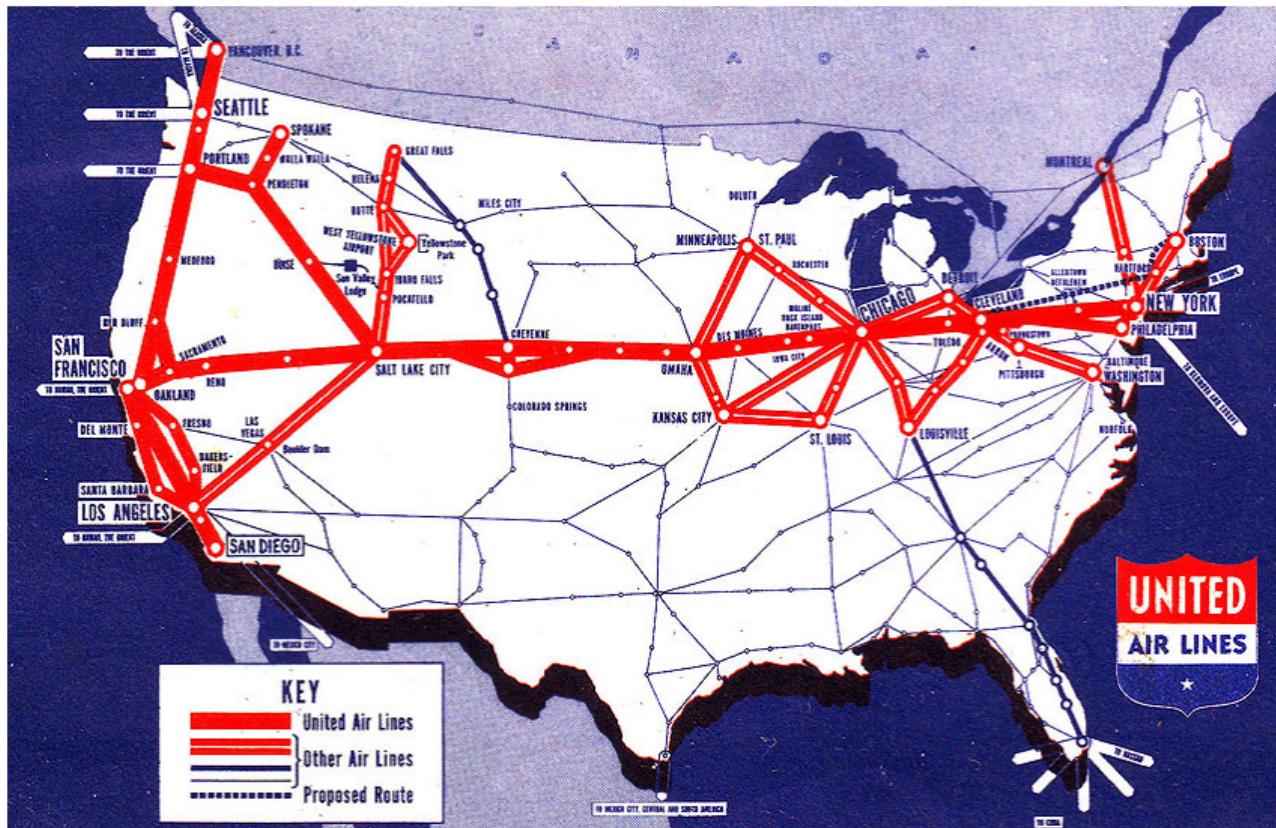
How Does This Compare to Past Outbreaks?

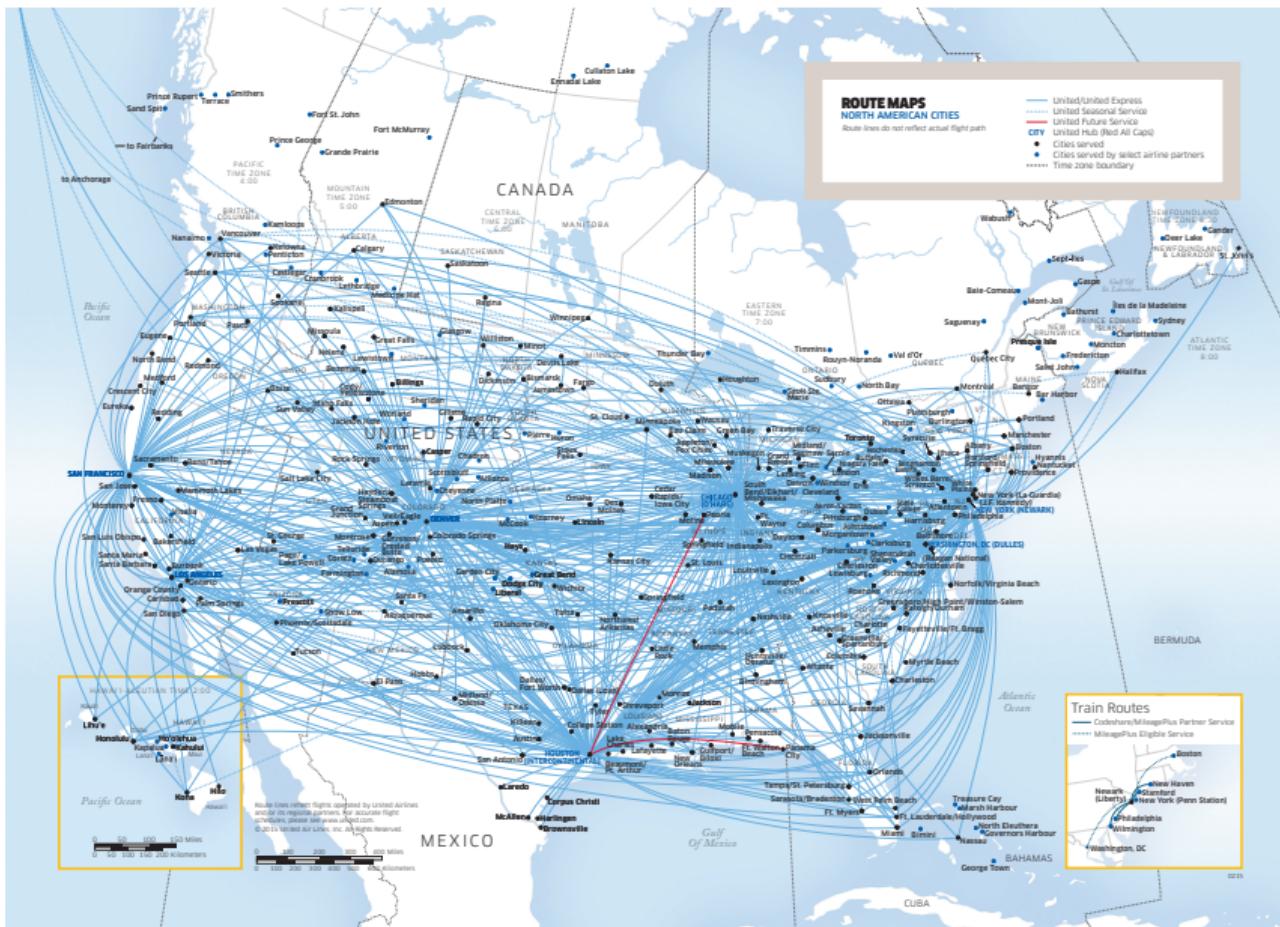
UPDATED NOV. 5

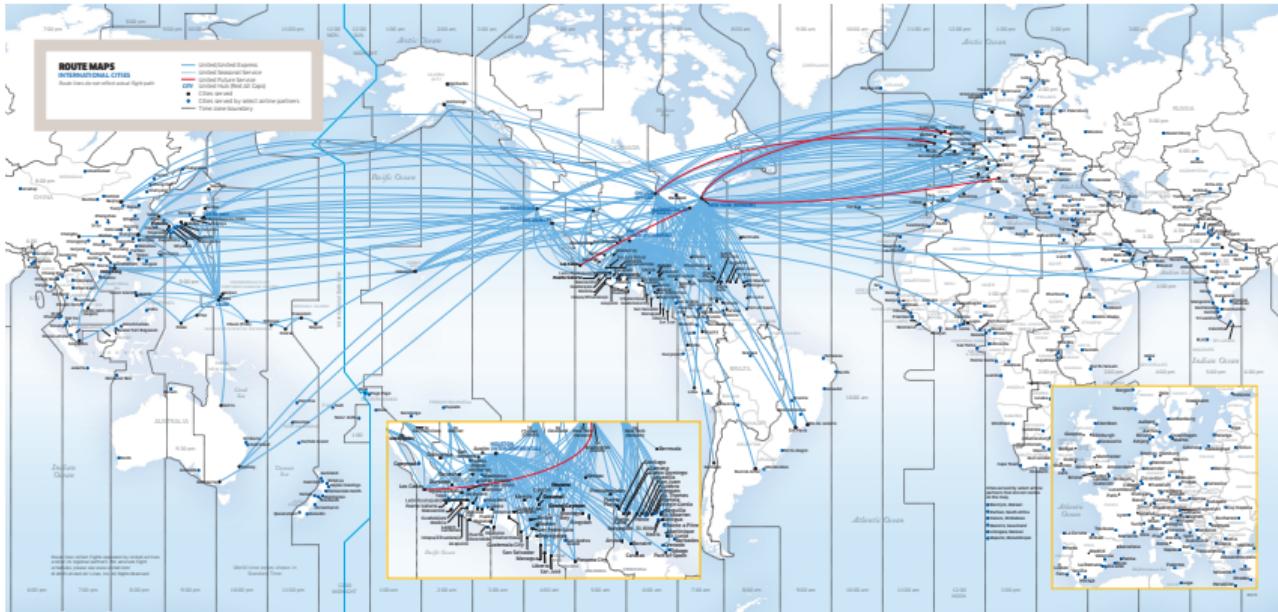
It is the deadliest, eclipsing an outbreak in 1976, the year the virus was discovered.



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







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

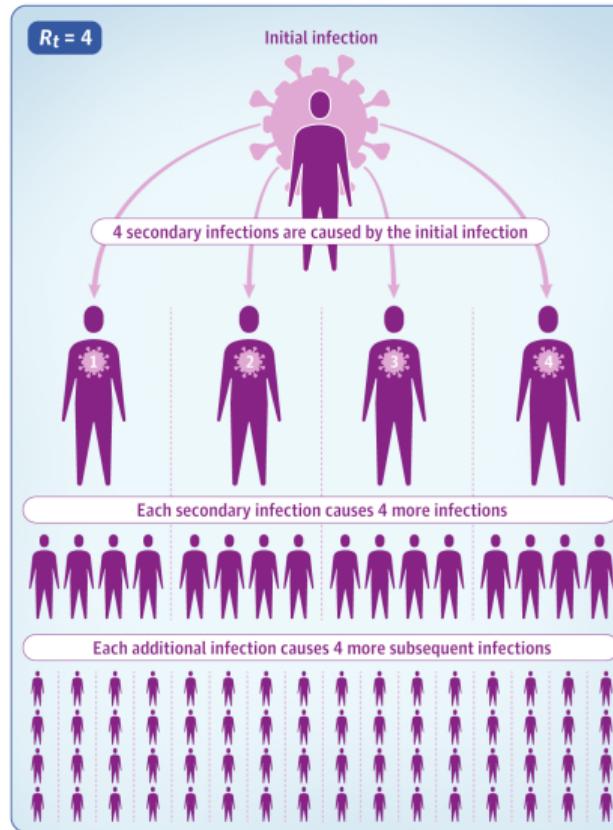
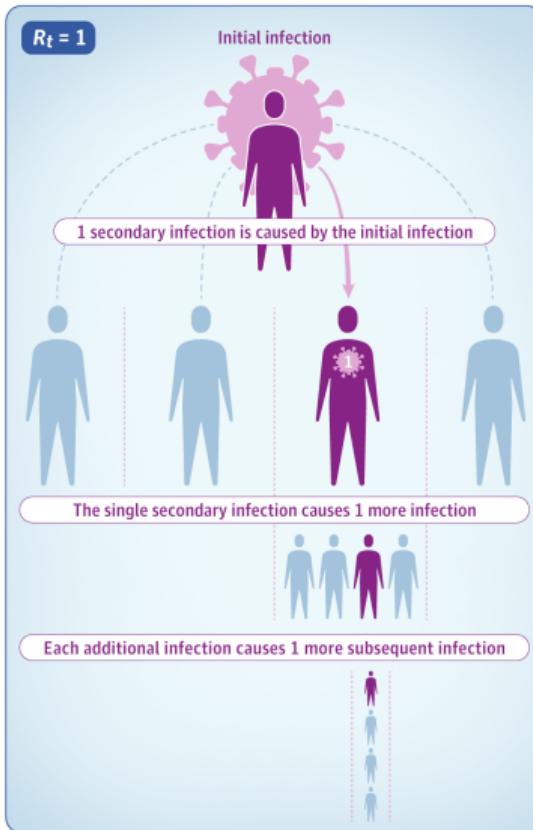
Main tools for thinking about epidemics:

- ▶ R_0
- ▶ R_t
- ▶ SIR model

- ▶ R_0 : Number of new cases when a disease is introduced into a fully susceptible population

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- ▶ R_t : Reproduction rate: the average number of new infections generated by each currently infected individual

The effective reproduction number (R_t) of a viral infection is the mean number of additional infections caused by an initial infection in a population at a specific time.

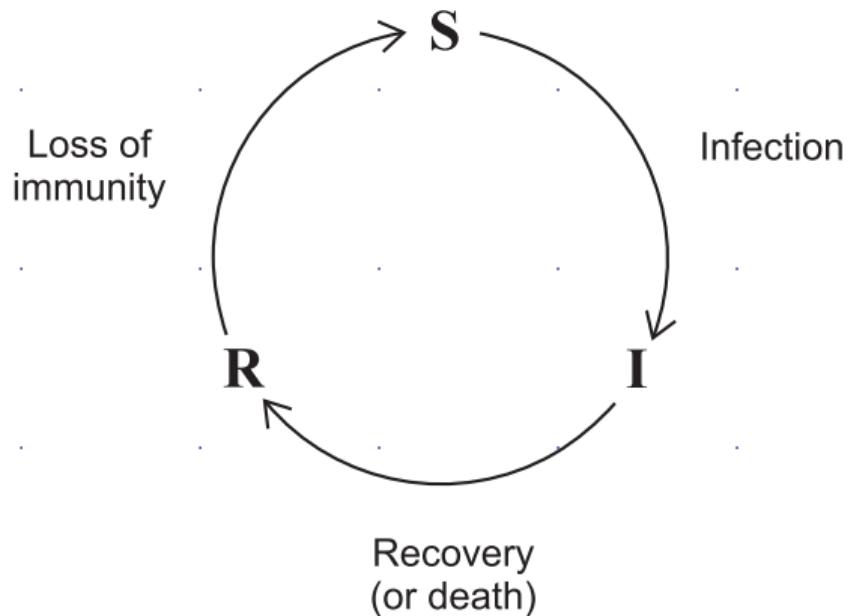


R_t can vary of space and time

Main tools for thinking about epidemics:

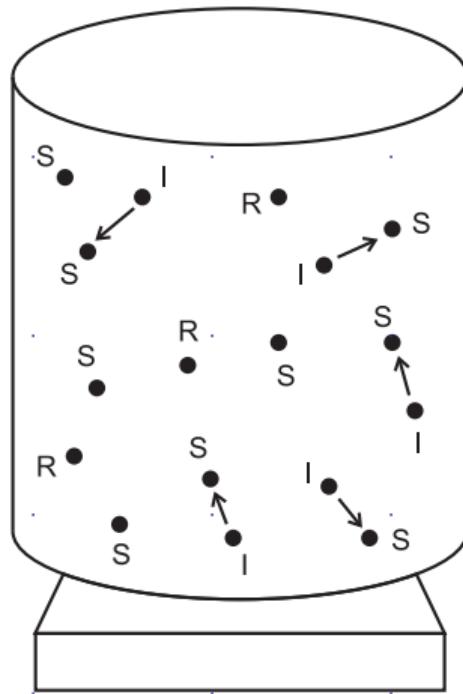
- ▶ R_0
- ▶ R_t
- ▶ SIR model

6.1

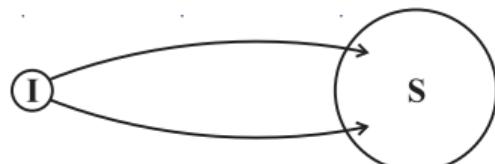


R in SIR model $\neq R_0 \neq R_t$

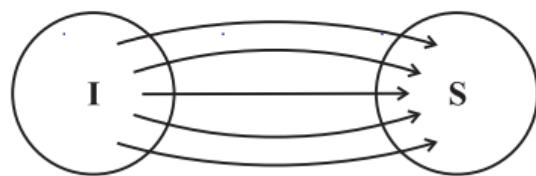
6.2



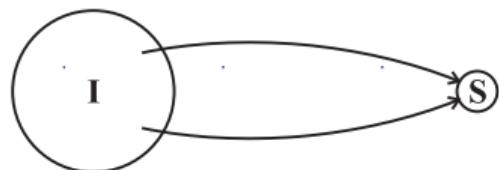
6.3



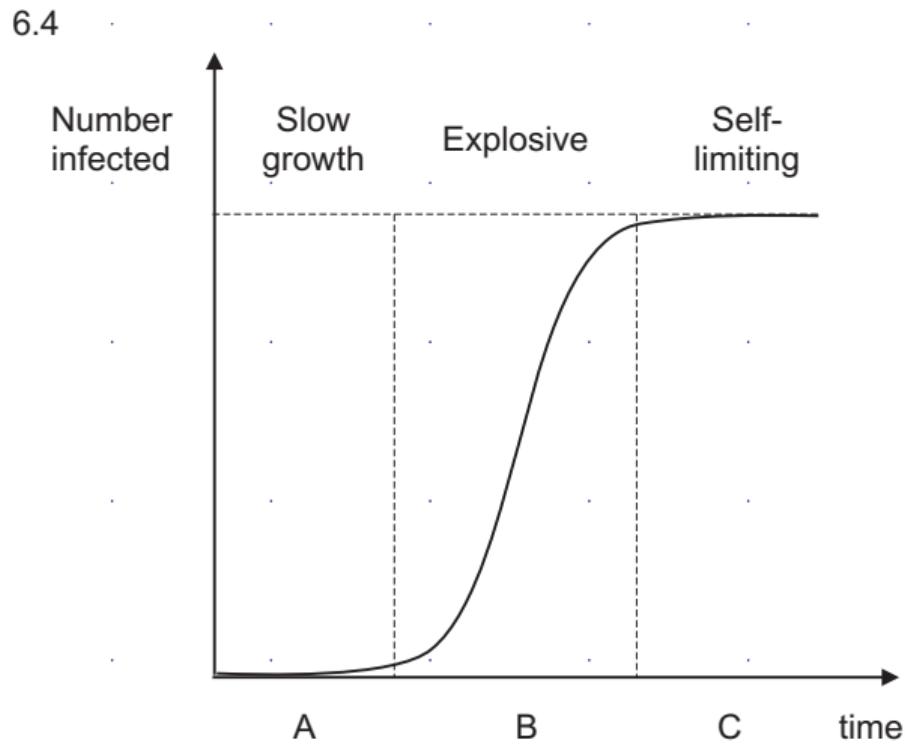
Slow Growth Phase



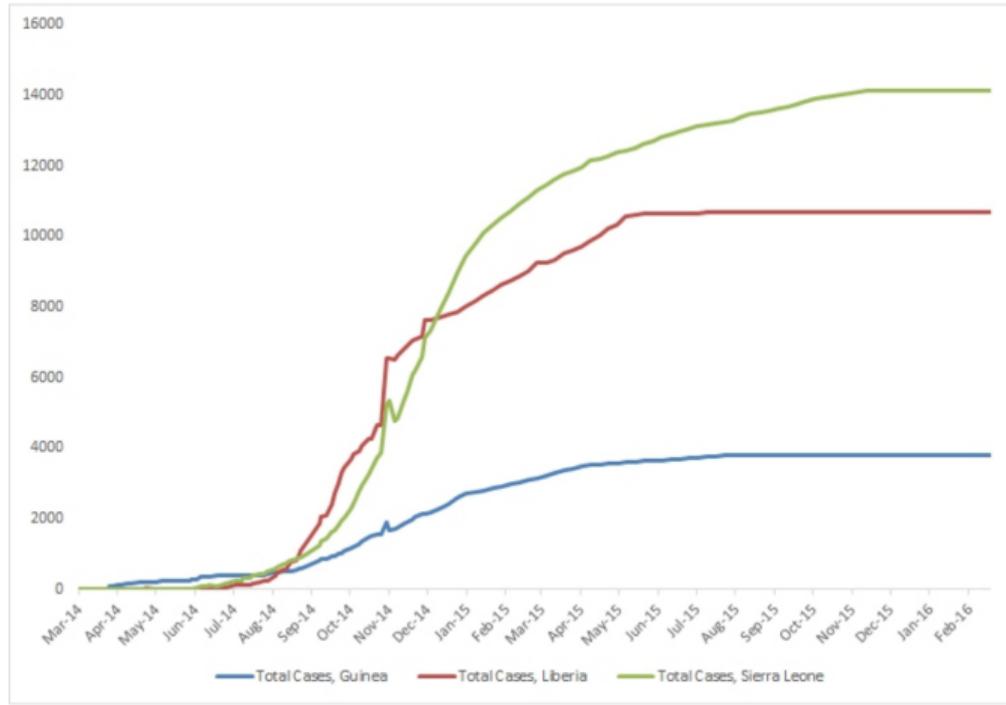
Explosive Phase



Burn Out



What shape will the Ebola time series have?

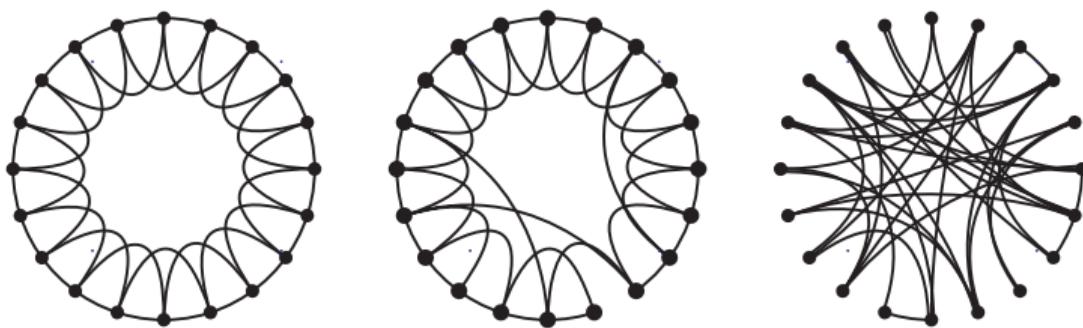


Graph 1 shows the total reported suspected, probable, and confirmed cases in Guinea, Liberia, and Sierra Leone provided in [WHO situation reports](#) beginning on March 25, 2014 through the most recent situation report on February 17, 2016.

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

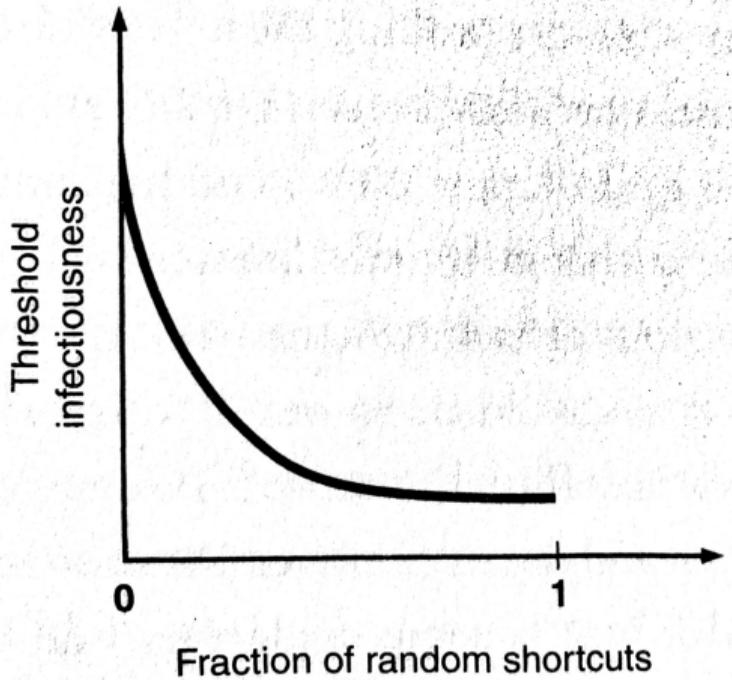
Relationship between networks and disease

3.6



$\beta = 0$ ————— $\beta = 1$

Increasing randomness



The small-world effect is a modern phenomenon

Seth A. Marvel,¹ Travis Martin,² Charles R. Doering,^{1,3} David Lusseau,⁴ and M. E. J. Newman³

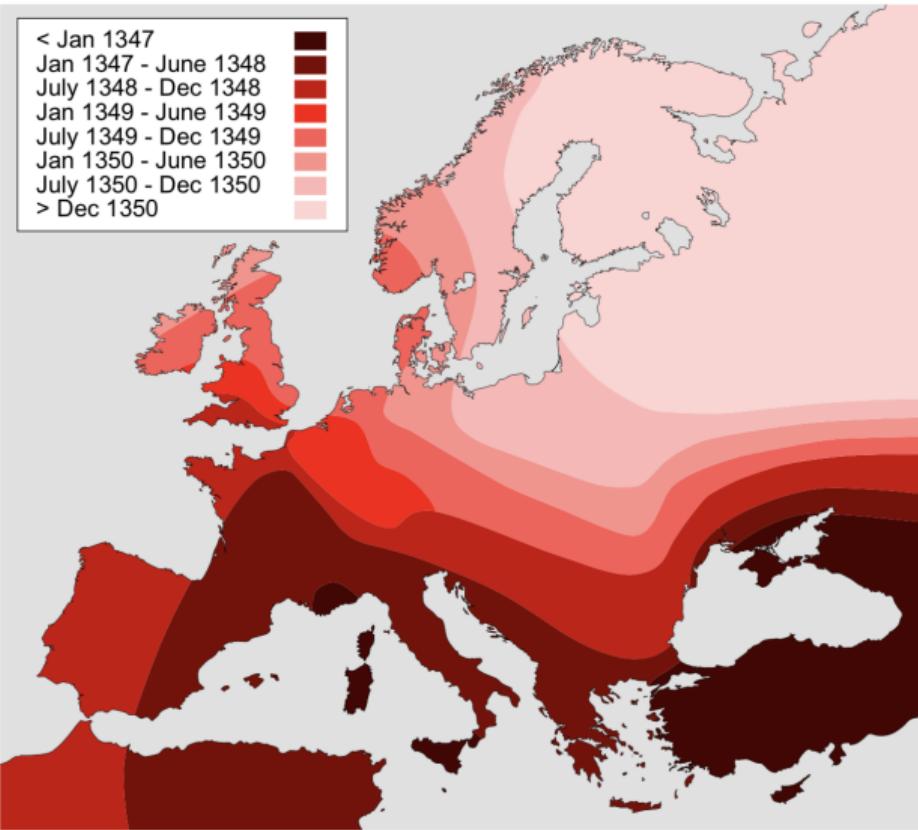
¹*Department of Mathematics, University of Michigan, Ann Arbor, MI 48109, U.S.A.*

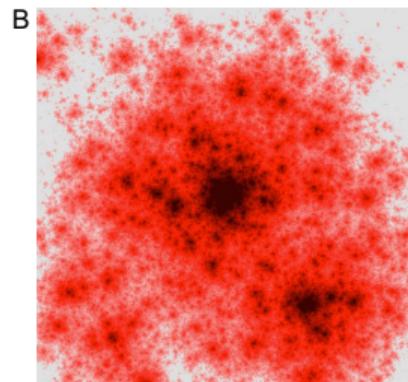
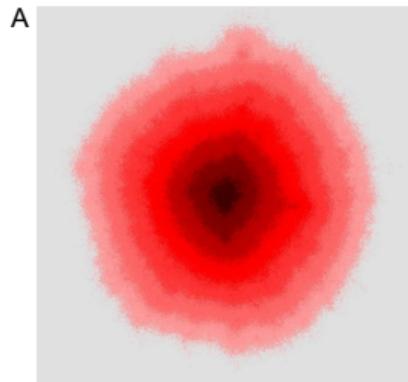
²*Department of Electrical Engineering and Computer Science,
University of Michigan, Ann Arbor, MI 48109, U.S.A.*

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

⁴*Institute of Biological and Environmental Sciences, University of Aberdeen, Aberdeen, U.K.*

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





- ▶ Top: Disease spread with no shortcuts
- ▶ Bottom: Disease spread with long distance connections

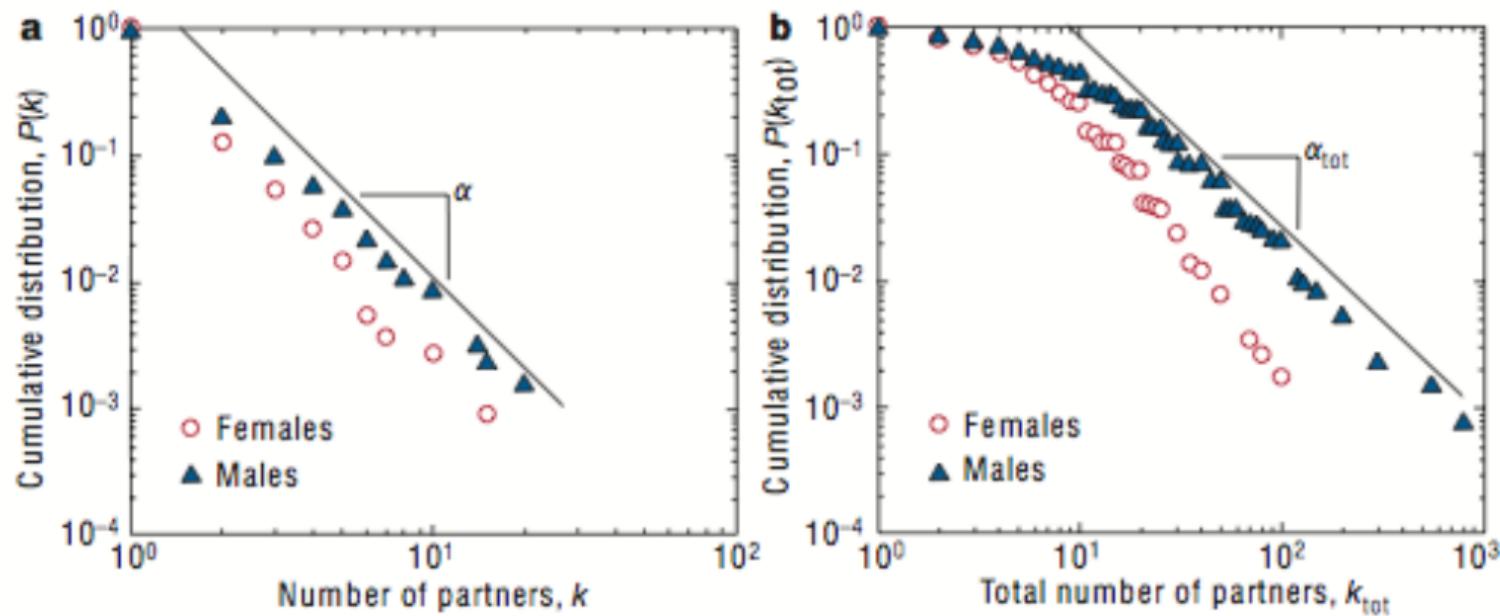
Important to match the disease you are studying to the appropriate contact network.

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- ▶ For STDs, this is the sexual network.
- ▶ COVID seems to mainly spread through close personal contact, which is related to but distinct from, friendship networks.

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 Networks¹

Peter S. Bearman

Columbia University

James Moody

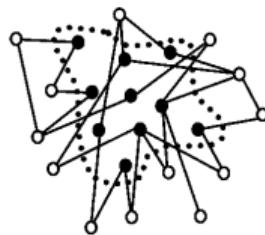
Ohio State University

Katherine Stovel

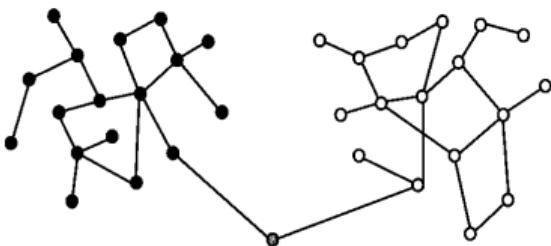
University of Washington



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

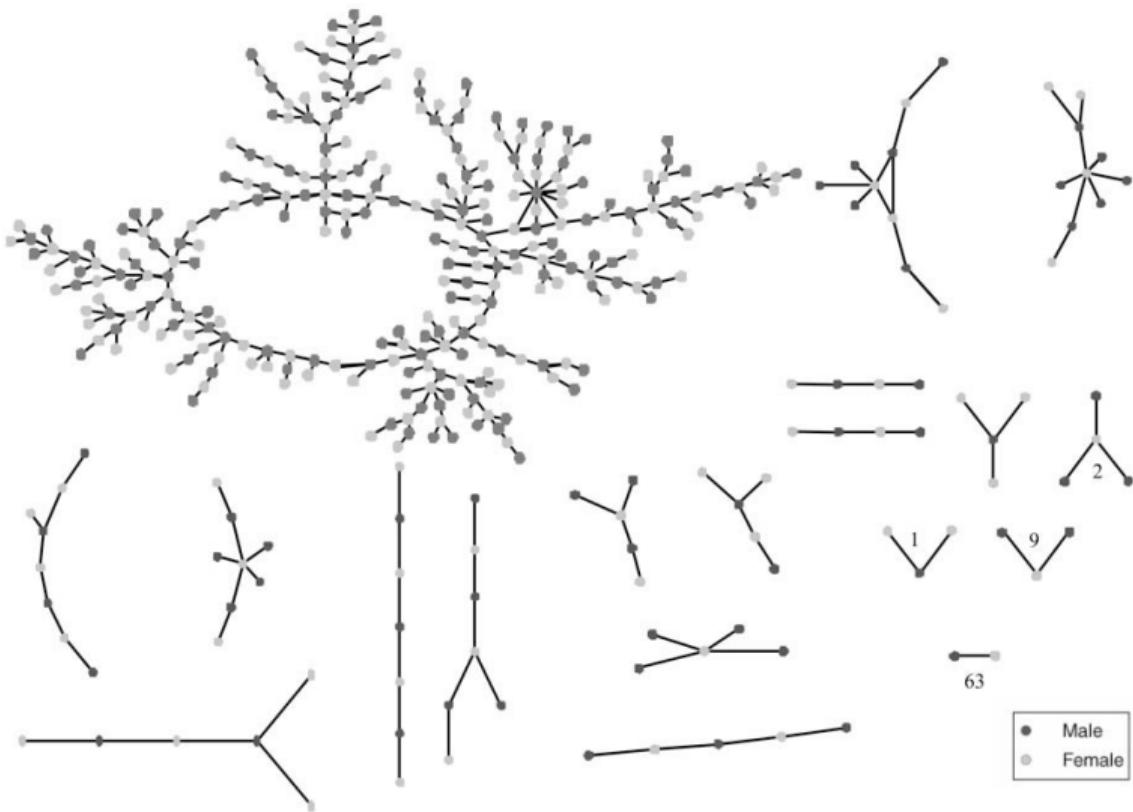


FIG. 2.—The direct relationship structure at Jefferson High

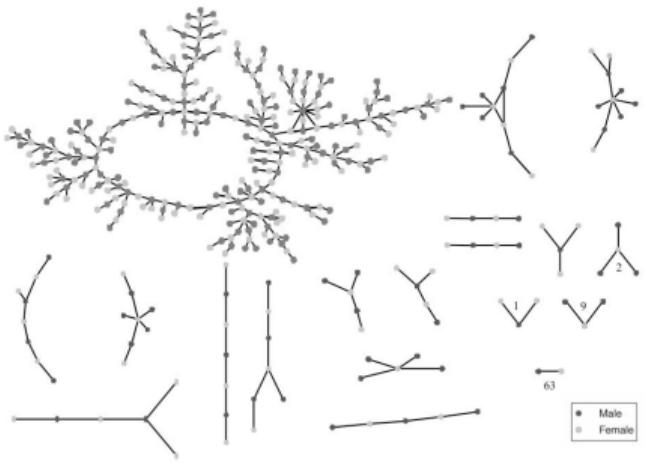
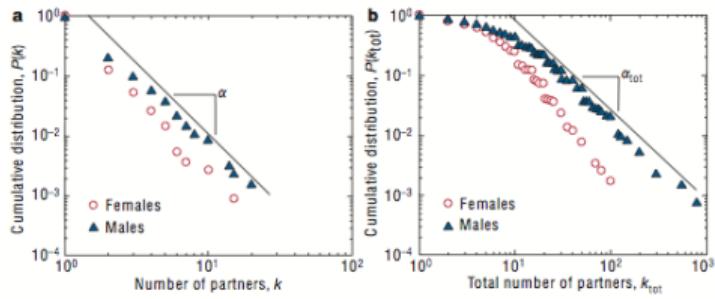


FIG. 2.—The direct relationship structure at Jefferson High

(a) Complete network data



(b) Ego-centric network data

What about time?

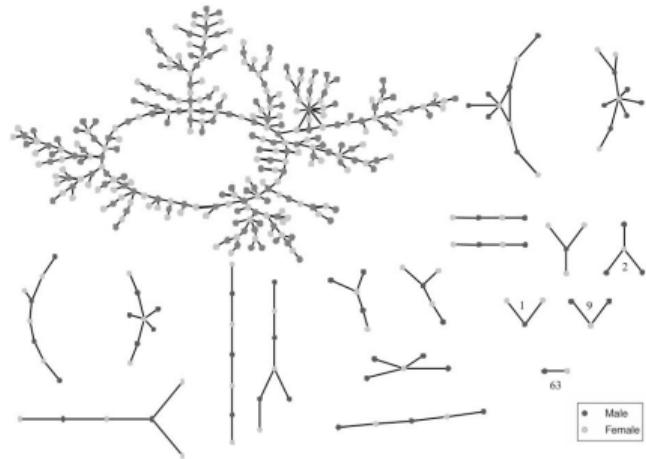
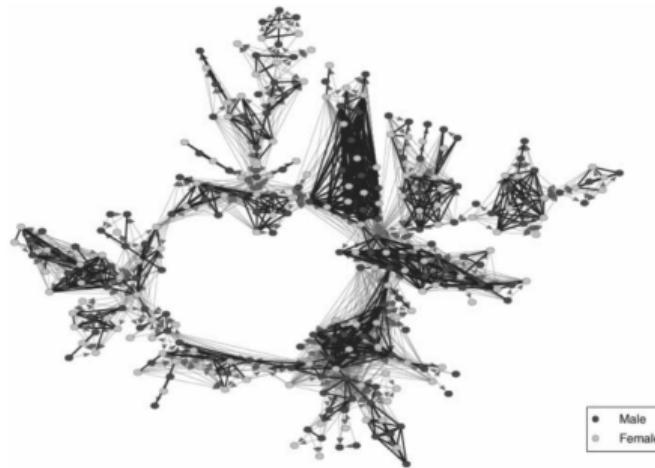


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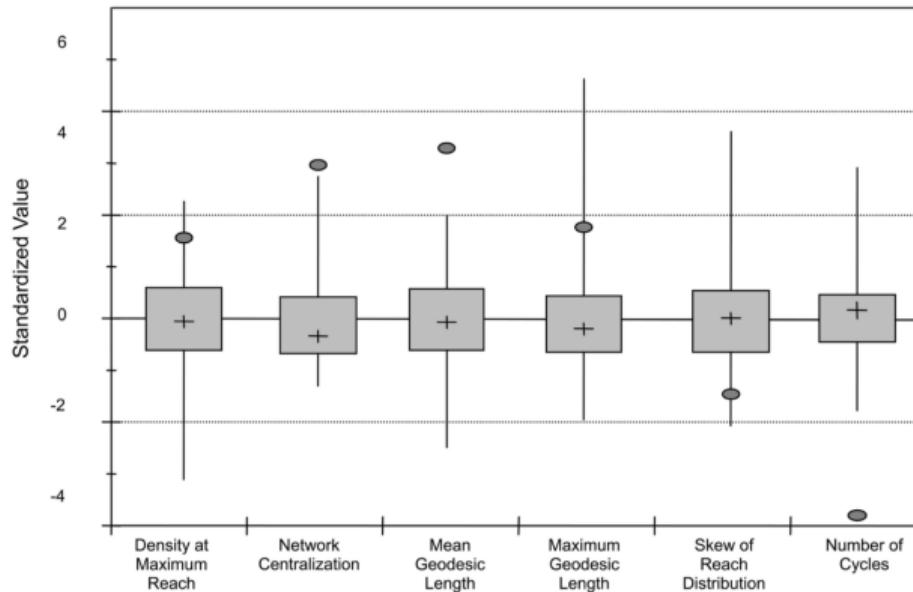
(a) Time flattened



(b) Accounting for time

Generate 1,000 simulated networks with the same number of nodes and degree distribution, but where ties are formed completely randomly. How does these simulated networks compare to the observed network?

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If this pattern did not arise randomly how did it come about?

WE'RE A TERRIBLE MATCH.
BUT IF WE SLEEP TOGETHER,
IT'LL MAKE THE LOCAL
HOOKUP NETWORK A
SYMMETRIC GRAPH.

I CAN'T ARGUE
WITH THAT.



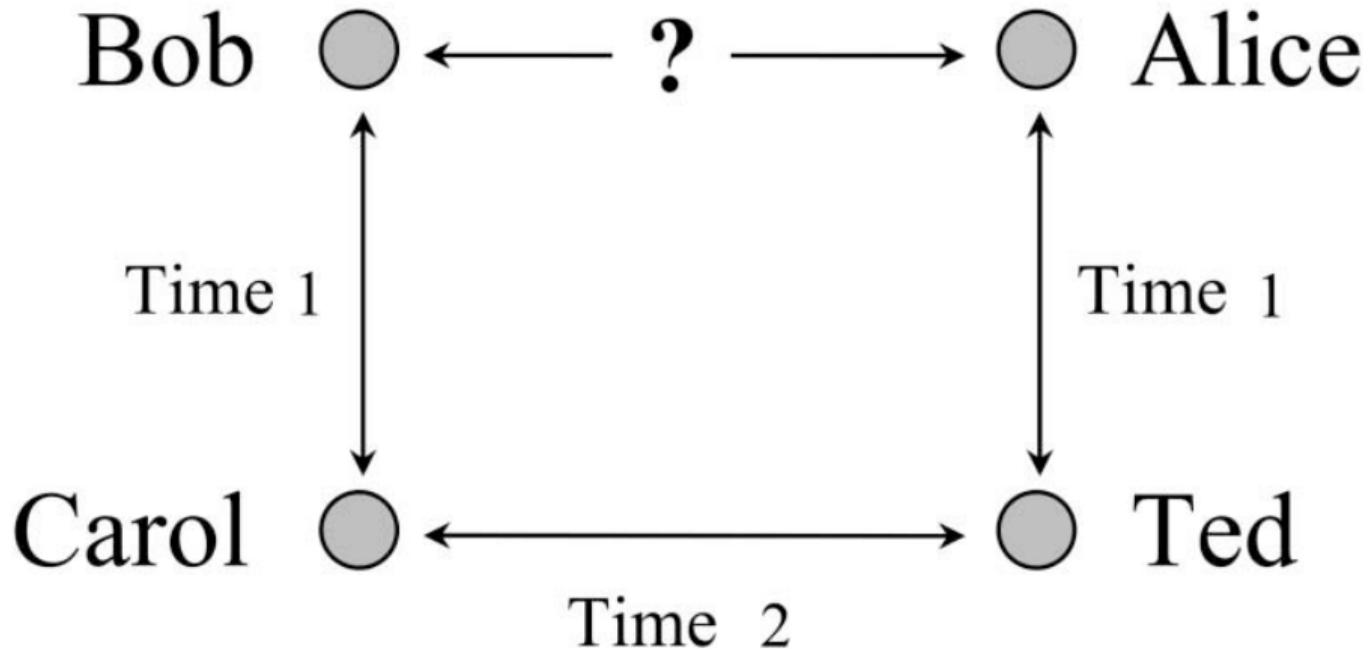
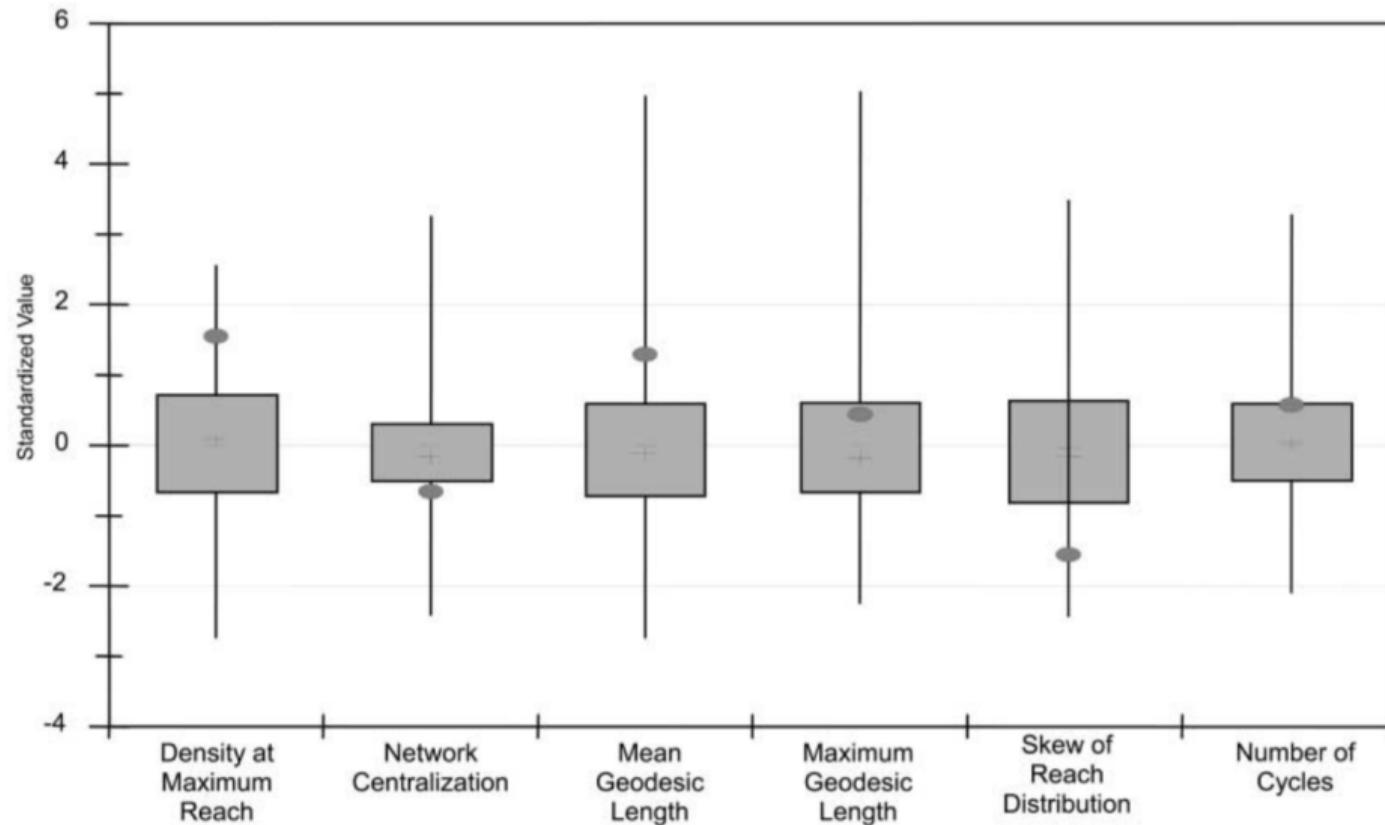
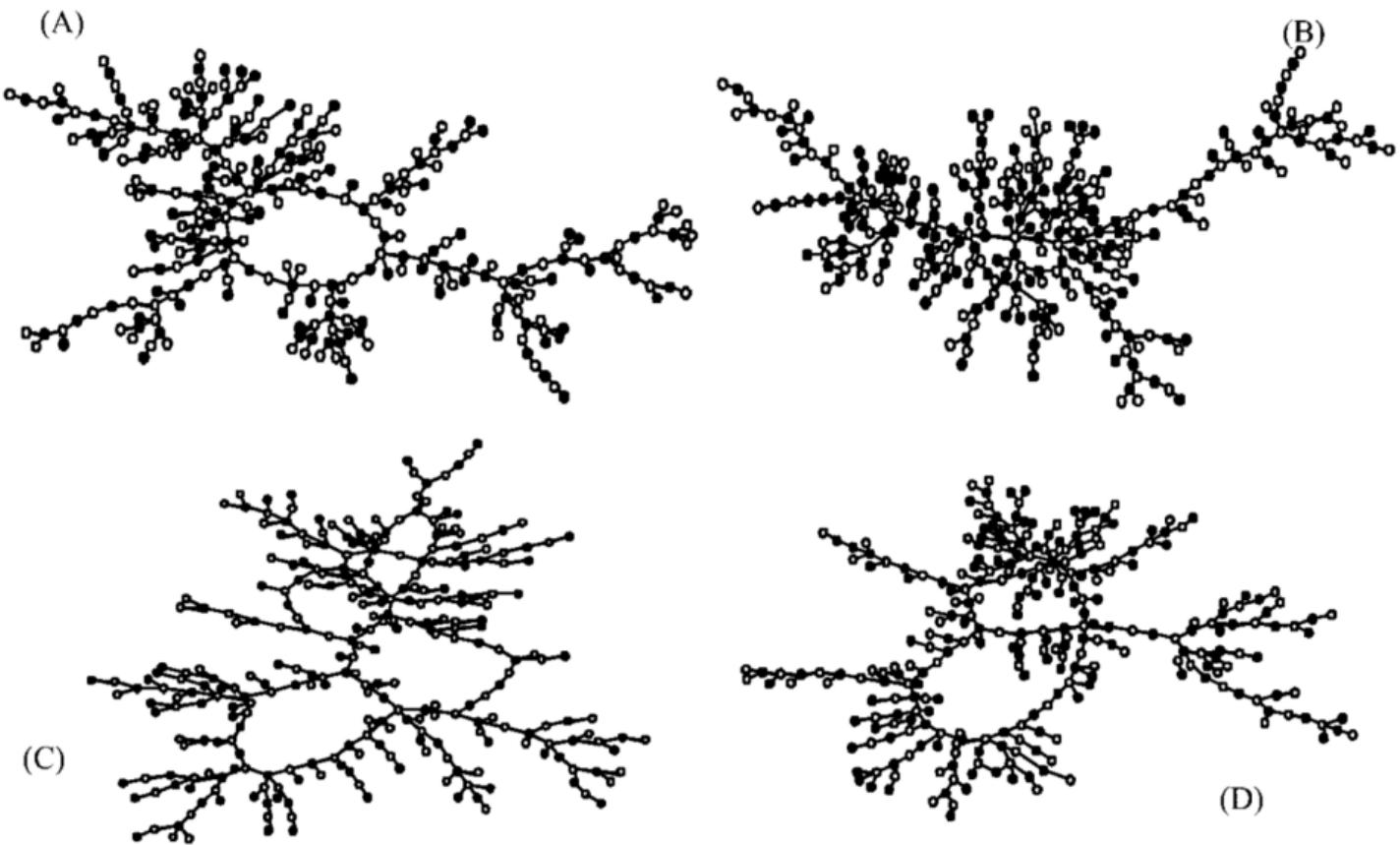


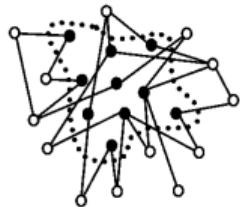
FIG. 8.—Hypothetical cycle of length 4



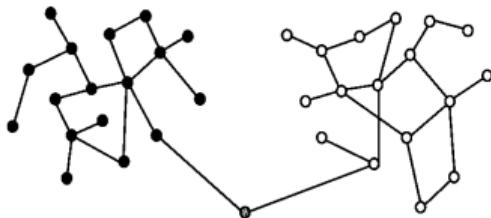




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Panel C: Bridge Between Disjoint Populations



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Policy implication: targeting might be important in a core network, but not as important in a spanning tree

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

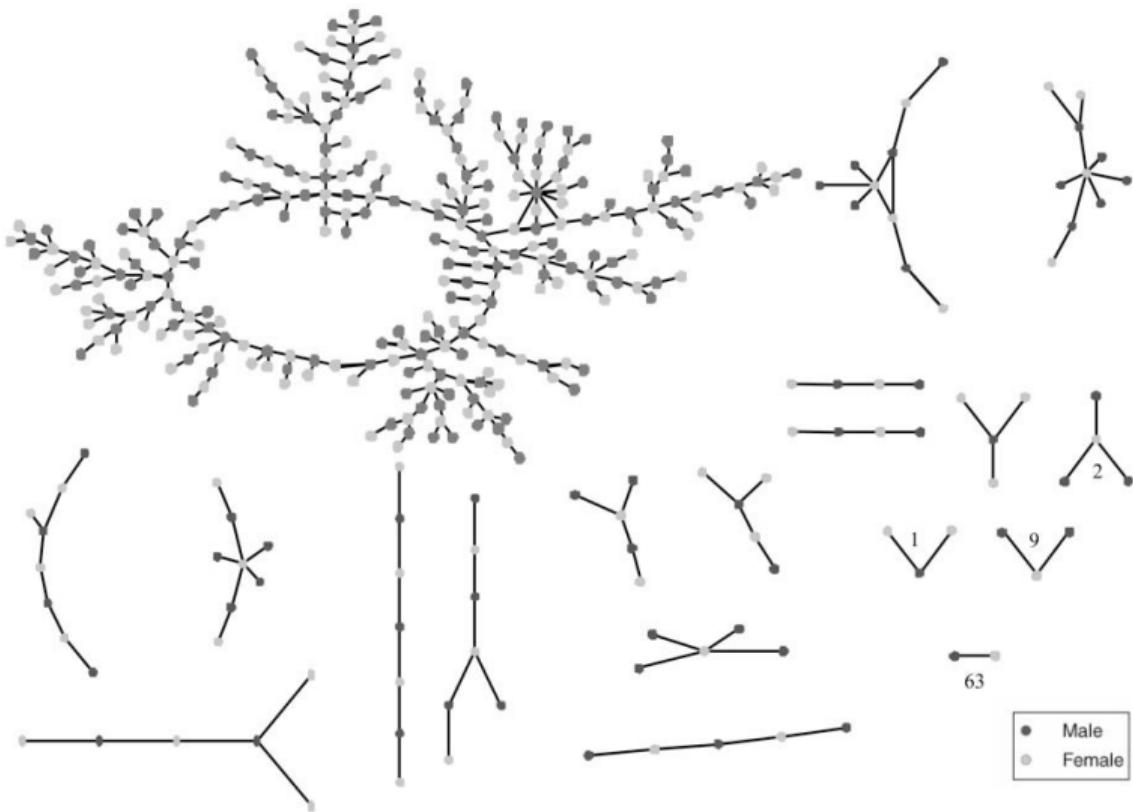


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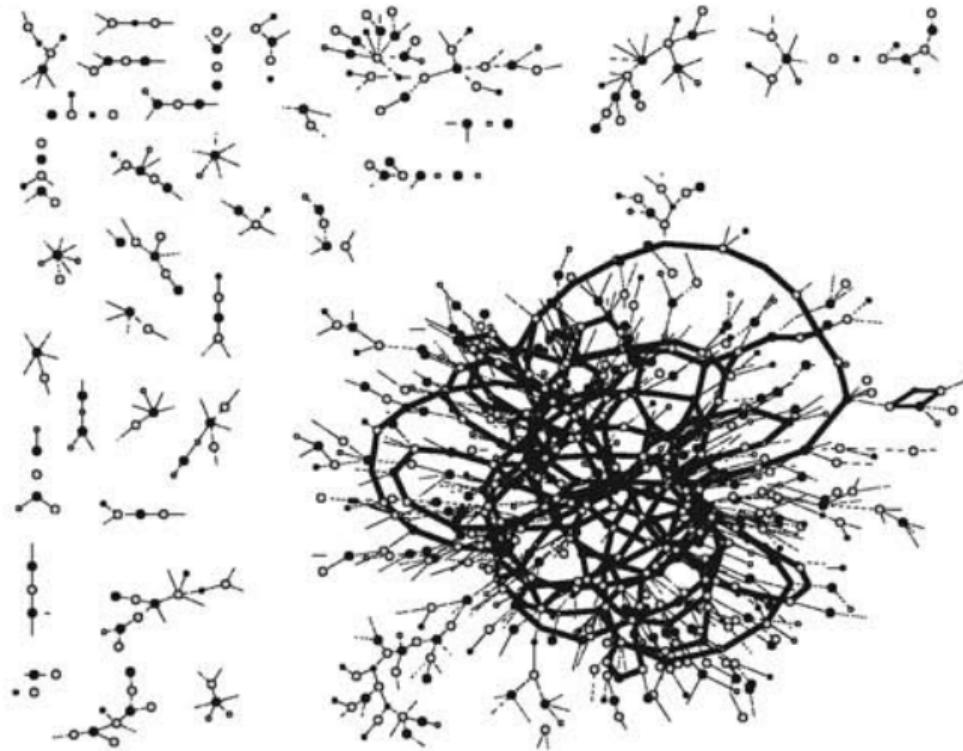
Sexual network structure and the spread of HIV in Africa: evidence from Likoma Island, Malawi

Stéphane Helleringer and Hans-Peter Kohler

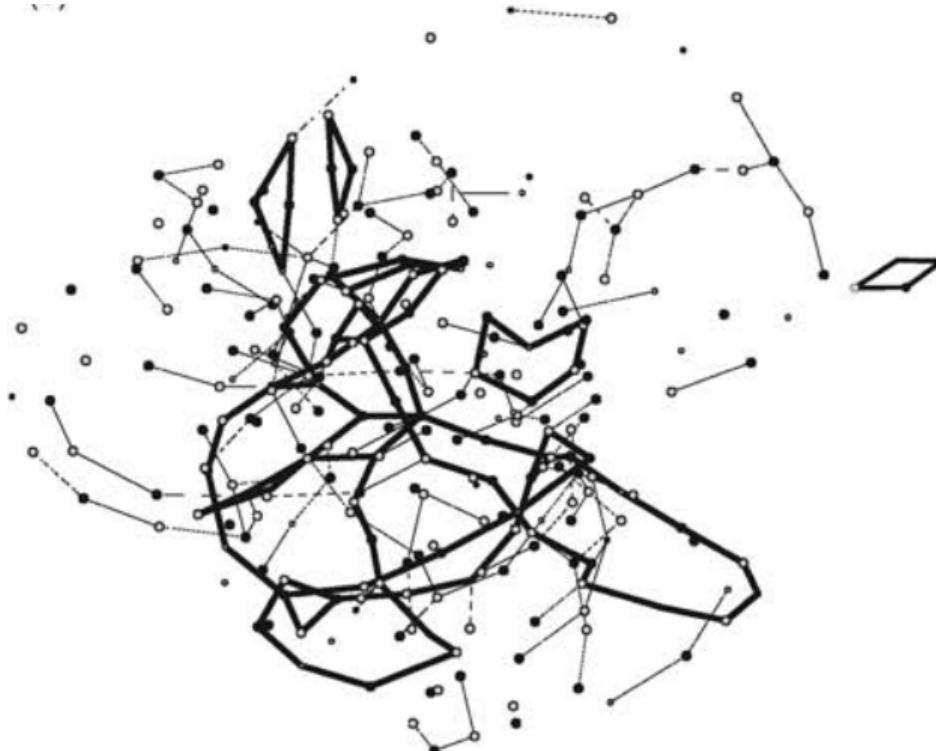
<http://www.ncbi.nlm.nih.gov/pubmed/18090281>



How to get to zero:
Faster.
Smarter.
Better.

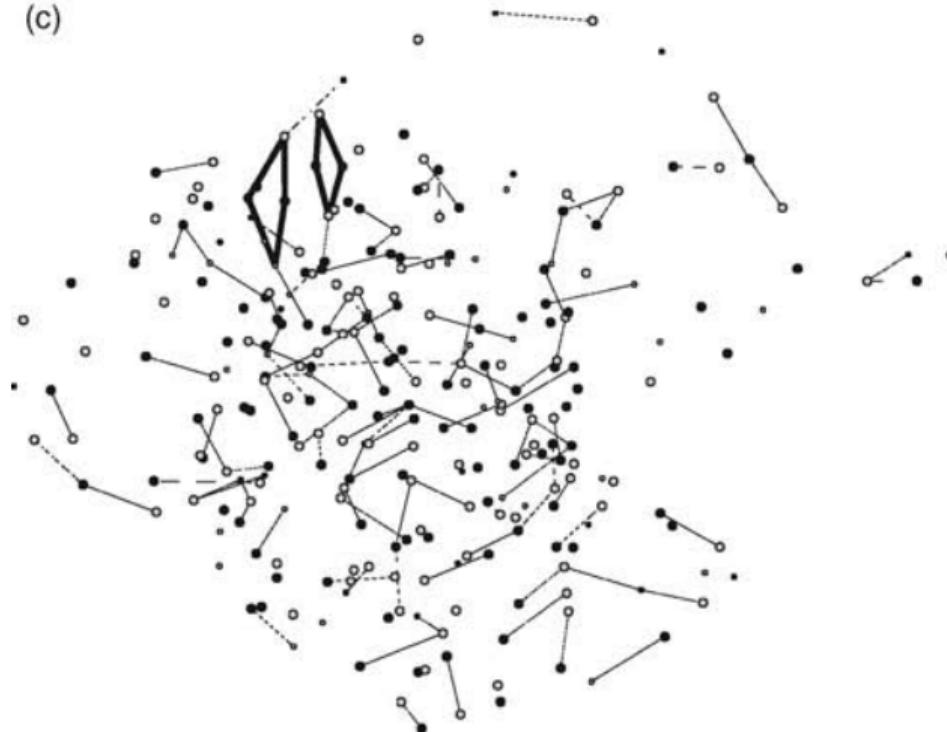


Last 3 years



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

Reflection and feedback: <https://rb.gy/wl08de>

Next class: Madness of Crowds

- ▶ Watts, Chapter 7.
- ▶ Asch, S.E. (1955). Opinions and social pressure. *Scientific American*, 193(5):31-35. (Available on Canvas)
- ▶ 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*