Reductions in Ebola virus transmission driven by behavioral interventions in Sierra Leone.

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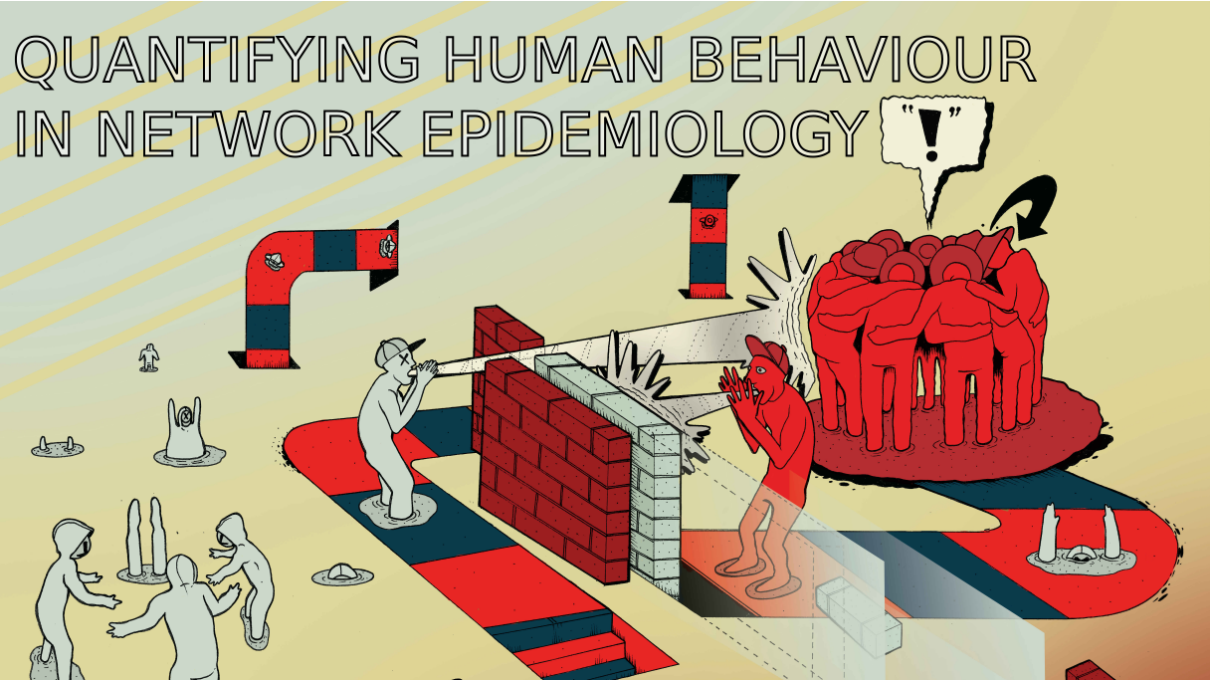
QUANTIFYING HUMAN BEHAVIOUR IN NETWORK EPIDEMIOLOGY



Outline

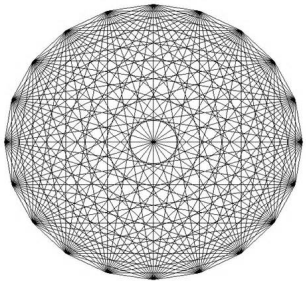
1. Shortcomings of mathematical epidemiology
2. Behavioural mathematical epidemiology

Message

Mathematical epidemiology could be way better with the help of anthropology/social workers.

Classic epidemic models

Everyone is interconnected.
Infected transmit at rate β
and recover at rate α.

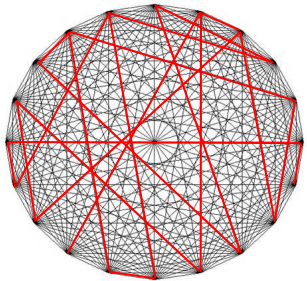


We follow the numbers I and R
of infectious and recovered individuals...

$$\frac{d}{dt}I = \beta(N - I - R)I - \alpha I$$
$$\frac{d}{dt}R = \alpha I$$

Network epidemic models

Not everyone is interconnected!
Infected transmit at rate β
and recover at rate α.



We follow individuals by state and # of connections,
or we follow pairwise interactions...

$$\frac{d}{dt}I_k = \beta k S_k P(\text{neighbor is infected}) - \alpha I_k$$

$$\frac{d}{dt}[SI] = -\alpha[SI] - \beta[SI] + \beta[SSI] - \beta[ISI]$$


2014: Santa Fe, NM

Two very serious epidemiologists

Ben Althouse

Sam Scarpino


PASCAL GUYOT/AFP/GETTY IMAGES

How the Fight Against Ebola Tested a Culture's Traditions

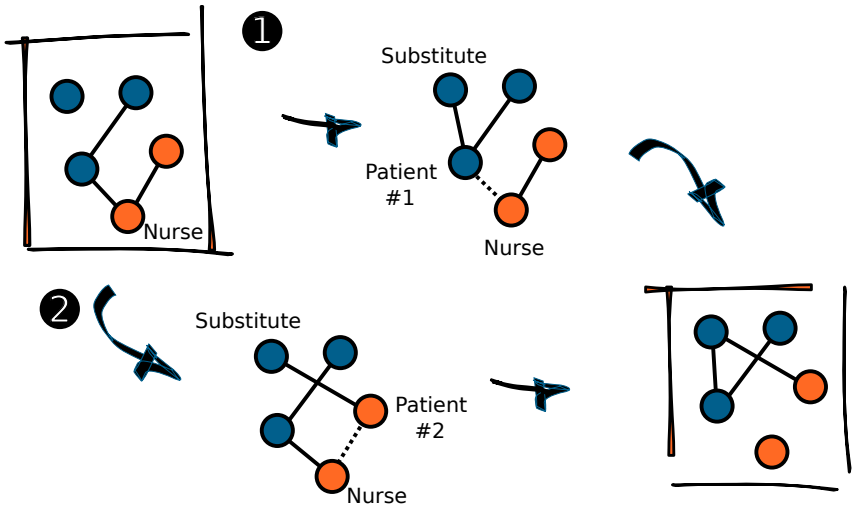
To stop infected bodies from spreading the disease in Sierra Leone, health officials persuaded local leaders to change how villagers mourned.

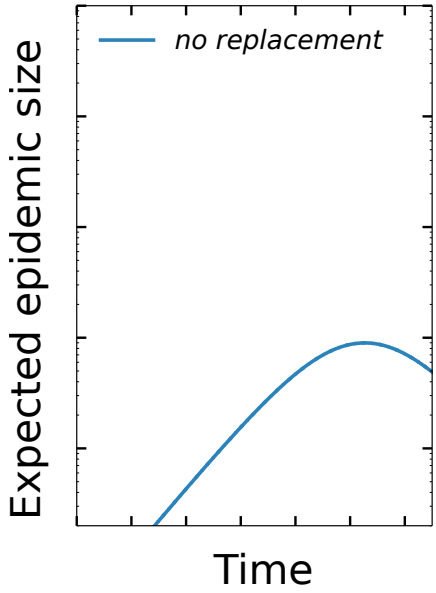
By **Amy Maxmen**, for National Geographic
Photographs by **Pete Muller**, for National Geographic

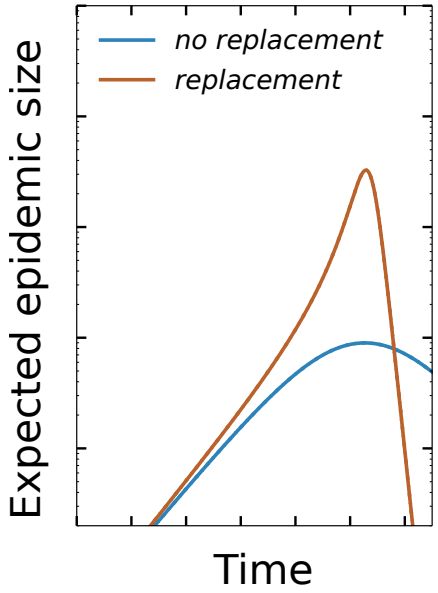
PUBLISHED JANUARY 30, 2015

We don't really know what we're doing.

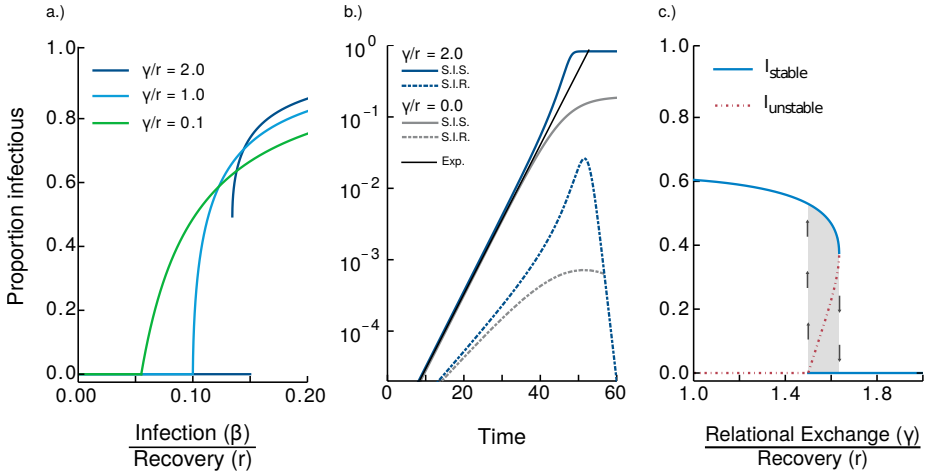
Epidemics on adaptive network




no replacement
Expected epidemic size
Time


no replacement
replacement
Expected epidemic size
Time

This is a fully solvable model



[Scarpino, Allard & Hébert-Dufresne, Nature Physics, 2016]

LETTERS
PUBLISHED ONLINE: 1 AUGUST 2016 | DOI: 10.1038/NPHYS3832
nature physics

The effect of a prudent adaptive behaviour on disease transmission

Samuel V. Scarpino[1,2]*, Antoine Allard[3] and Laurent Hébert-Dufresne[1]

The spread of disease can be slowed by certain aspects of real-world social networks, such as clustering[1,2] and community structure[3], and of human behaviour, including social distancing[4] and increased hygiene[5], many of which have already been studied. Here, we consider a model in which individuals with essential societal roles—be they teachers, first responders or health-care workers—fall ill, and are replaced with healthy individuals. We refer to this process as relational exchange, and incorporate it into a dynamic network model to demonstrate that replacing individuals can accelerate disease transmission. We find that the effects of this process are trivial in the context of a standard mass-action model, but dramatic when considering network structure, featuring accelerating spread,

custodians, health workers, and even children on a hockey team) will be replaced by susceptible individuals if they are ever infected. This replacement process occurs at some rate, termed γ in our equations, to account for a potential delay between when individuals become infectious and when they are diagnosed. Once replaced, a new susceptible individual is given some of the connections of the essential individual (such as students or patients). This relational exchange is important because: the new susceptible node is introduced into what is most probably a more dangerous situation with respect to disease risk; and bringing susceptible nodes from a different region of the contact network reduces the diameter of the population.

To begin, we investigated a standard mass-action model where

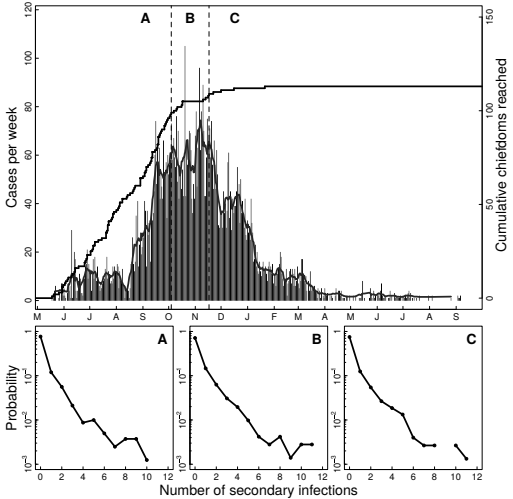
Lessons

1. Epidemic models are sensitive to behaviour.
2. We have no general models of behaviour.
3. And no parametrization of behaviour.

We need a different approach and different data.

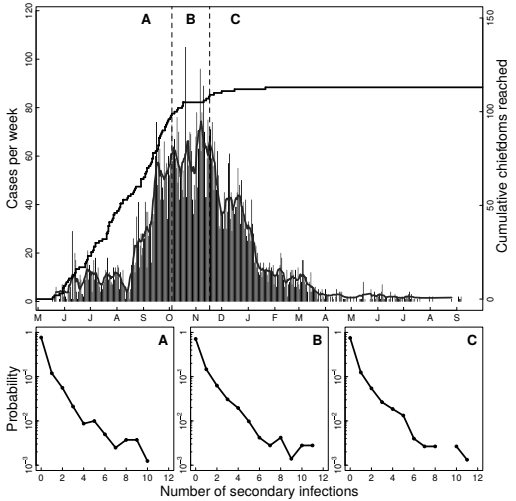
2016: Seattle, WA

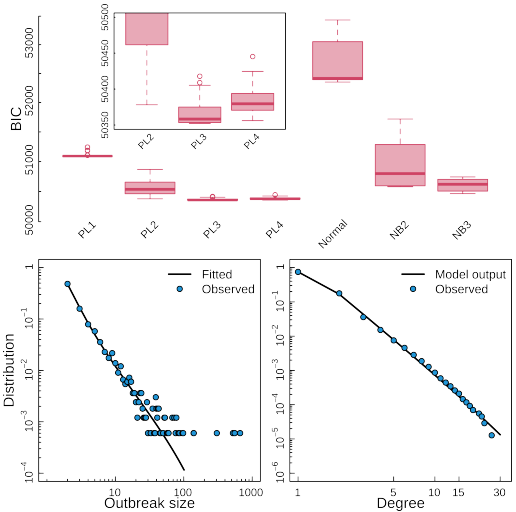
Timeline of Ebola and its contact tracing efforts



[Hébert-Dufresne et al., *in preparation*]

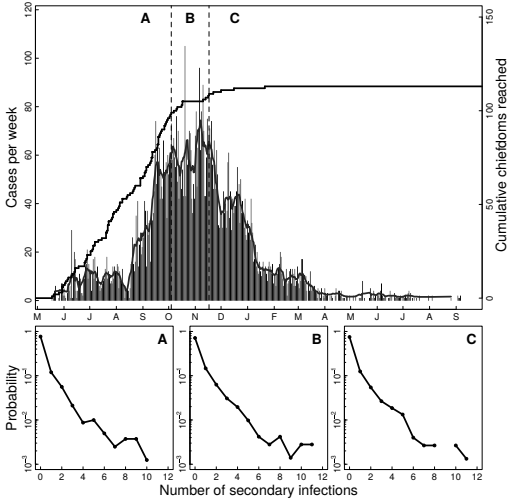
Timeline of Ebola as a branching process





[Hébert-Dufresne et al., *in preparation*]

What stopped Ebola?



[Hébert-Dufresne et al., *in preparation*]

Social Mobilization Action Consortium (SMAC)

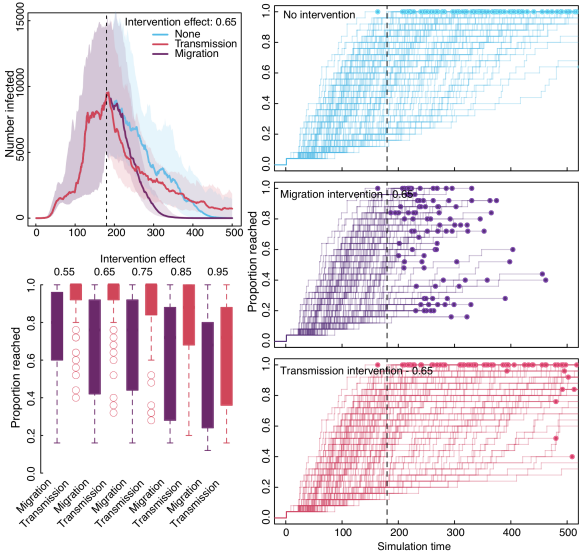
Social Mobilisation Action Consortium:
Standards and lessons from the 2014-15 Ebola Outbreak in Sierra Leone

Mohamed F. Jalloh,[1] Jamie Bedson,[2] Danielle Pedi,[3] Saiku M. Bah,[2] Nyuma E. James,[1] Katharine Owen,[3] Allan Oniba,[3] Musa Sangarie,[4] Laura Hucks,[4] Paul Sengeh,[1] James Fofanah,[2] Mohammad B. Jalloh,[1] Else Kirk,[5] Benjamin M. Althouse[†,6,7,8] and Laurent Hébert-Dufresne[†9,10]

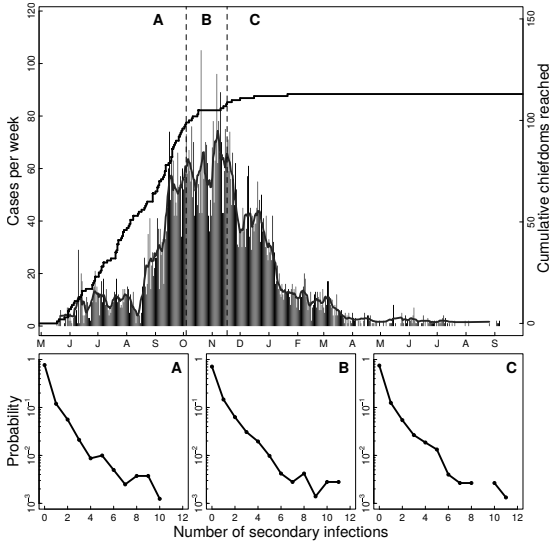
[1]*FOCUS 1000*
[2]*Restless Development*
[3]*Bill and Melinda Gates Foundation*
[4]*BBC Media Action*
[5]*GOAL*
[6]*Institute for Disease Modeling, Bellevue, WA*
[7]*Information School, University of Washington, WA*
[8]*Department of Biology, New Mexico State University, Las Cruses, NM*
[9]*Vermont Complex Systems Center, University of Vermont, Burlington, VT*
[10]*Département de Physique, de Génie Physique, et d'Optique, Université Laval, Québec (Québec), Canada*

- 2,466 mobilizers for 12,505 communities (60% coverage)
- 2+ million interviewed ($\lesssim 25\%$)
- Goal: Bottom-up self-motivated action plans

Agent-based metapopulation model



Importance of preventive self-motivated intervention




2018: Burlington, VT

Future work

1. Parametrization of behavioural model possible through anthropological data.

Future work

1. Parametrization of behavioural model possible through anthropological data.
2. Data collection in tandem with community engagement / bottom-up interventions.

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ANY QUESTIONS?

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