Topic 5: Network Science: Insights for Pandemics

Julia McQuillan & Trish Wonch Hill

Department of Sociology

UGEP 291: The COVID-19 Pandemic: Effects on Industries, People and Society Summer 2020 – 2nd 5-week session – 0 or 1 credit – Pass/No Pass

UNIVERSITY of NEBRASKA–LINCOLN

Topic 5: Network Science: Insights for Pandemics

Part 1 Introduction

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Introduction

Who are we?

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Trish Wonch Hill

RESEARCH COORDINATOR OF THE METHODOLOGY AND EVALUATION RESEARCH CORE (MERC)

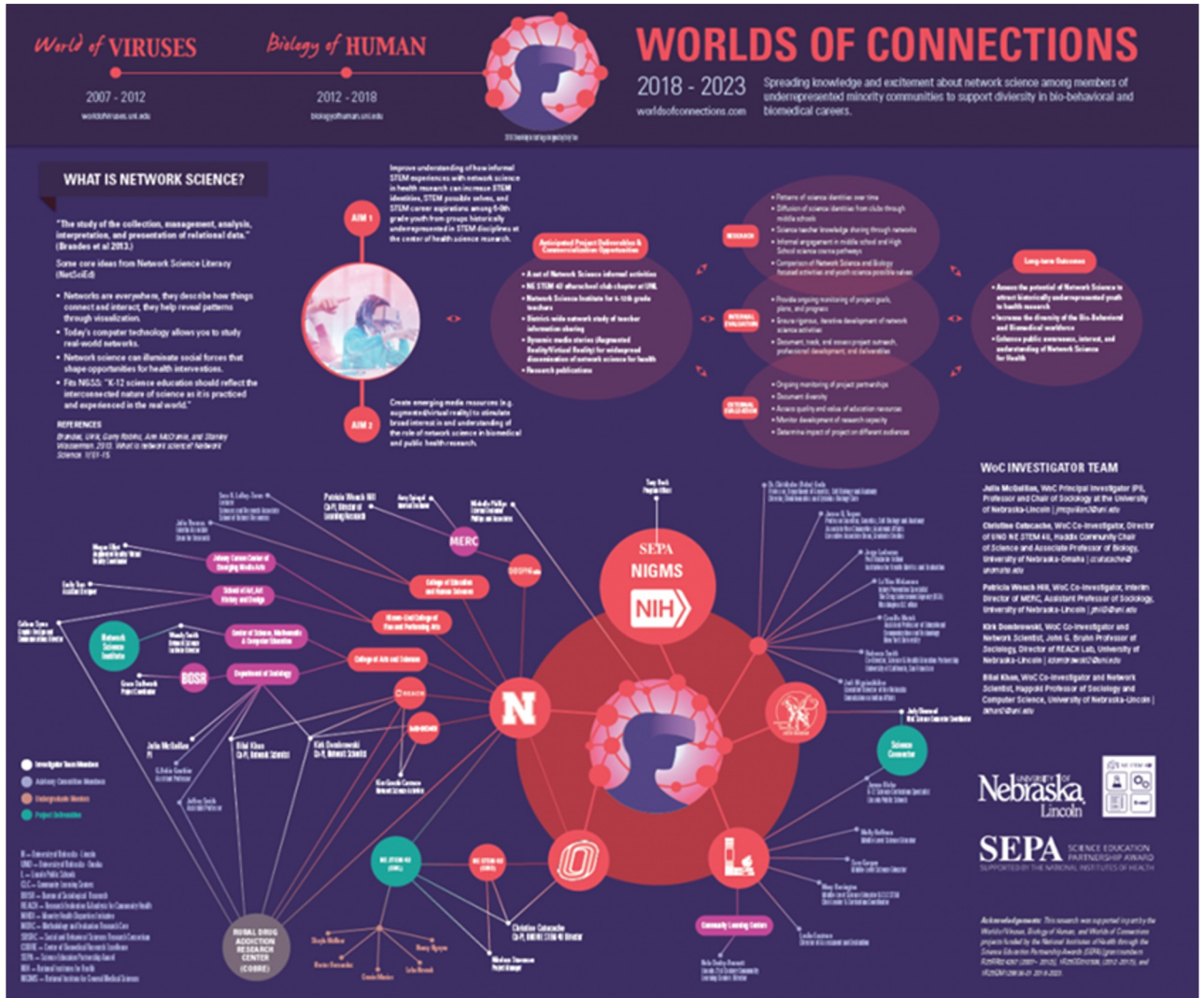
I have a PhD specializing in applied sociology and evaluation with a focus on quantitative methods and broadening participation in Science, Technology, Engineering and Math (STEM). As Research Coordinator of the Methodology and Evaluation Research Core Facility at the Social and Behavioral Sciences Research Consortium, I develop evaluation proposals to support federal, state, and local grants and contracts. I also work on a variety of projects in order to help SBSRC achieve its mission of facilitating the growth and excellence of Social and Behavioral Science research at UNL. I am currently Co-Investigator on an NIH Science Education Partnership Award (Worlds of Connections http://worldsofconnections.com/ and a Broadening Participation in Engineering Award through the National Science Foundation.

https://sbsrc.unl.edu/trish-wonch-hill

Introduction

Why Network Science & Viruses?

worldsofconnections.com



Introduction

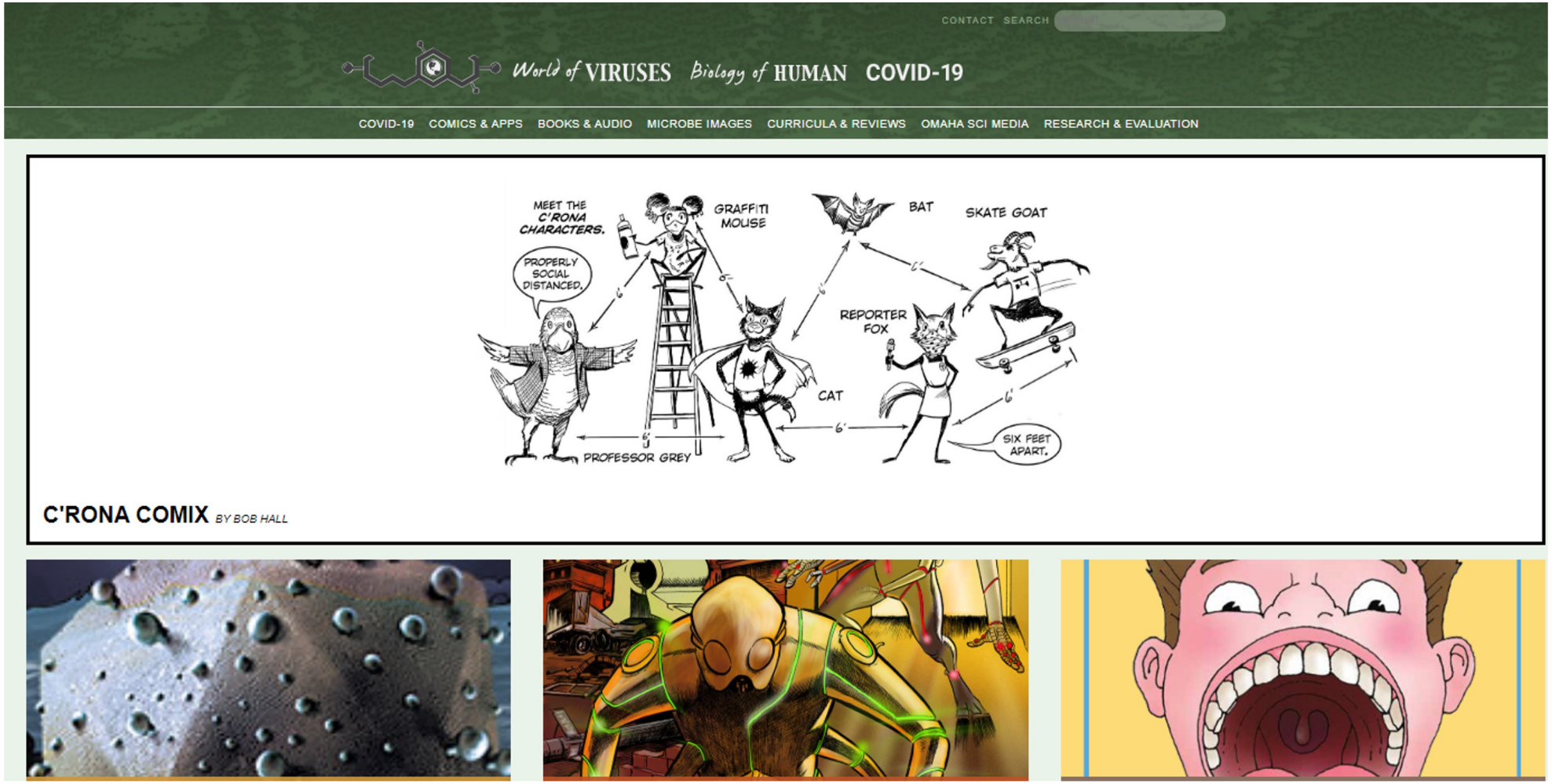
Why Network Science & Viruses?

rdar.unl.edu

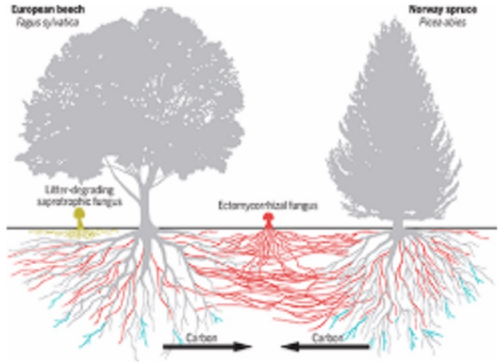
Introduction

Why Network Science & Viruses?

https://worldofviruses.unl.edu/



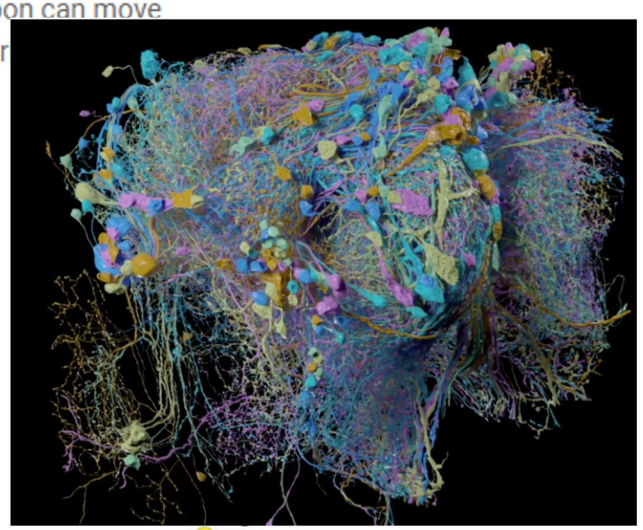
Introduction



Underground networks.

Forest trees are interconnected through extensive mycorrhizal fungal networks that can interlink different tree species. Carbon can move from one three to another through these hyphal networ

ILLUSTRATION: MODIFIED AFTER (2) BY P. HUEY/*SCIENCE*



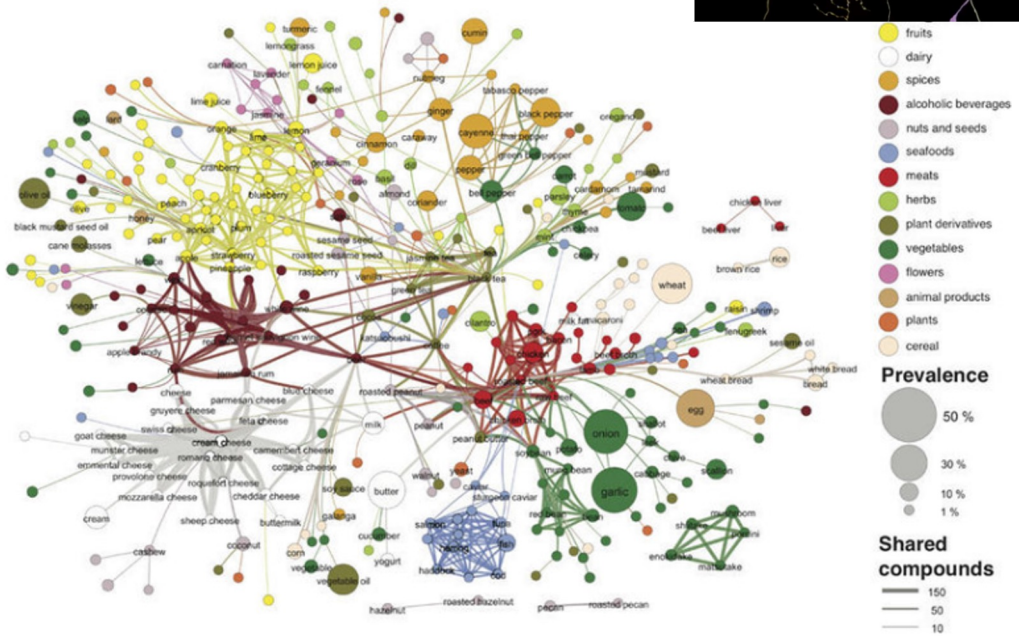
Where can we find networks?

[Fly brain]

[Tree roots]

[Transportation maps (& supply chains)]

[Global flavor map]



Each node in this network denotes an ingredient, the color indicates food category, and node size reflects the ingredient prevalence in recipes. Two ingredients are connected if they share a significant number of flavor compounds, and link thickness representing the number of shared compounds between the two ingredients.

Yong-Yeol Ahn, Sebastian E. Ahnert, James P. Bagrow, and Albert-László Barabási

Introduction

Where can we find networks?

[Adolescent romance/sex]

[Spread of HIV/AIDS]

[Virus Spread]

[Human Disease & Genes]

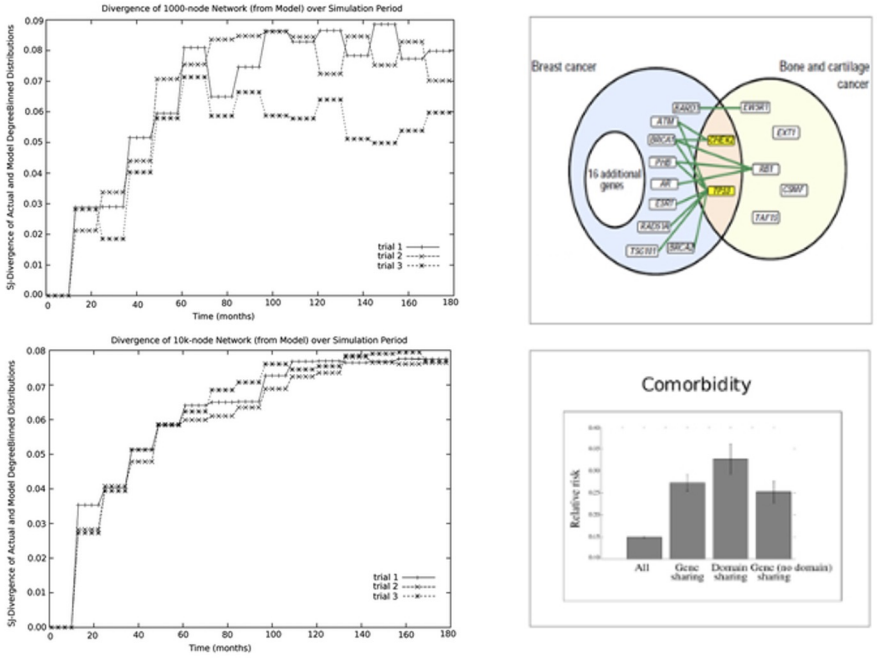
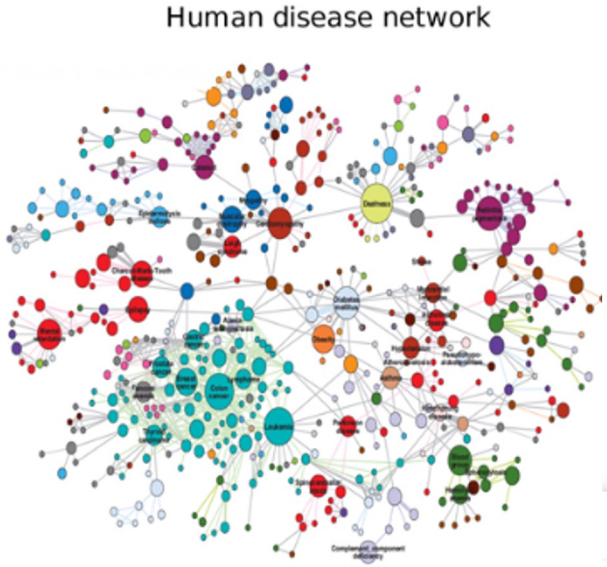


Figure 3. Divergence Δ of $\mathbb{N}$ over 18 months for 1000 (*left*) and 10,000 (*right*) node networks on three trials.



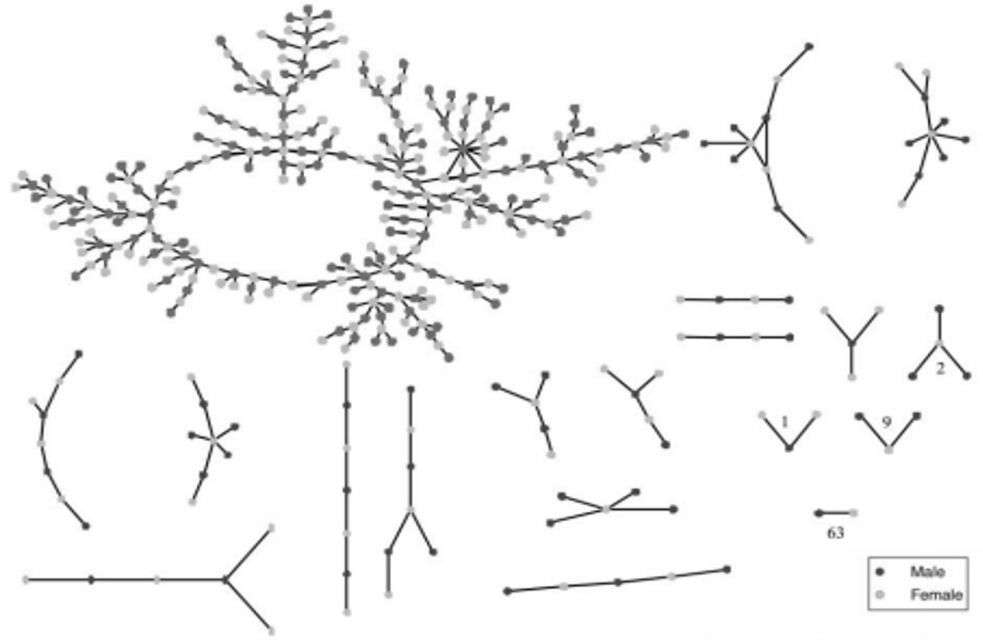


FIG. 2.—The direct relationship structure at Jefferson High

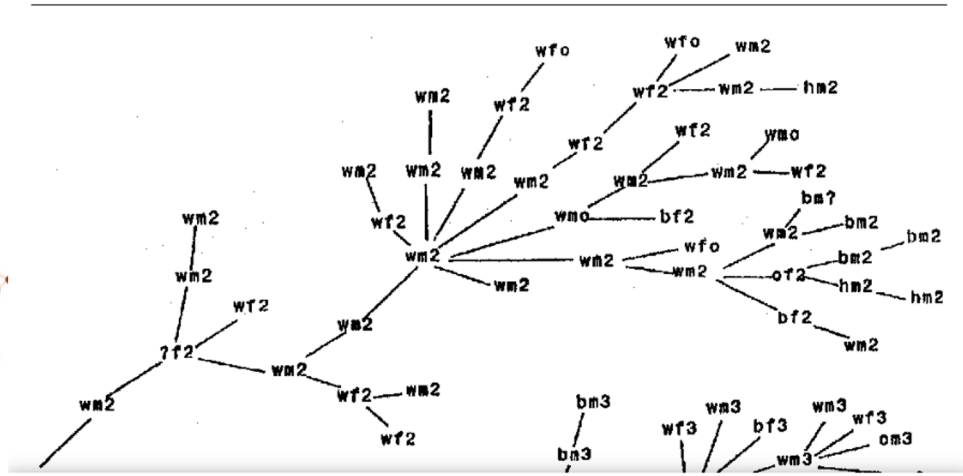


FIGURE 2

Published in 1999

AIDS AND SOCIAL NETWORKS: HIV PREVENTION THROUGH NETWORK MOBILIZATION*

Douglas D. Heckathorn, Robert S. Broadhead, Denise L. Anthony, David L. Weakliem

Introduction

Where can we find networks?

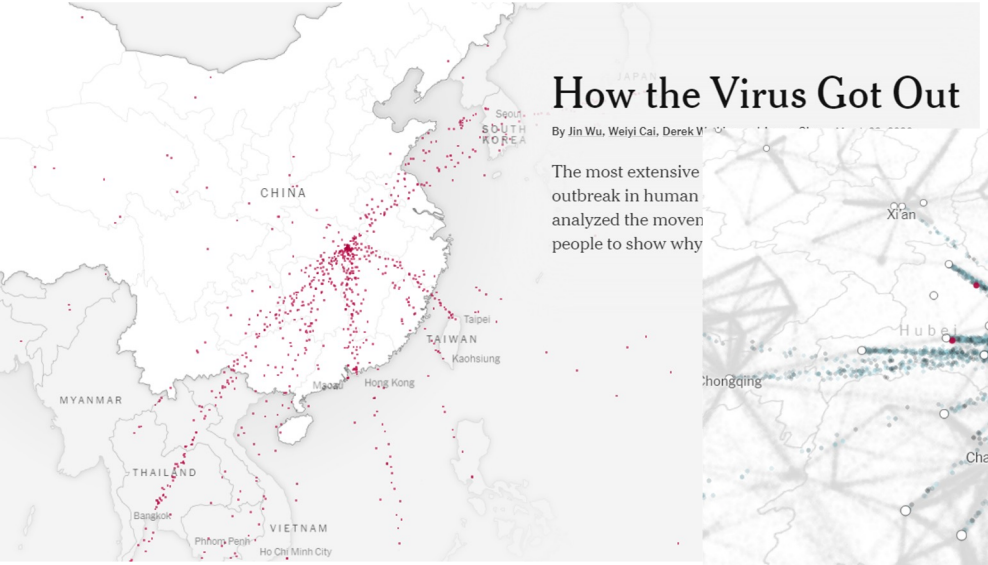
[Small worlds]

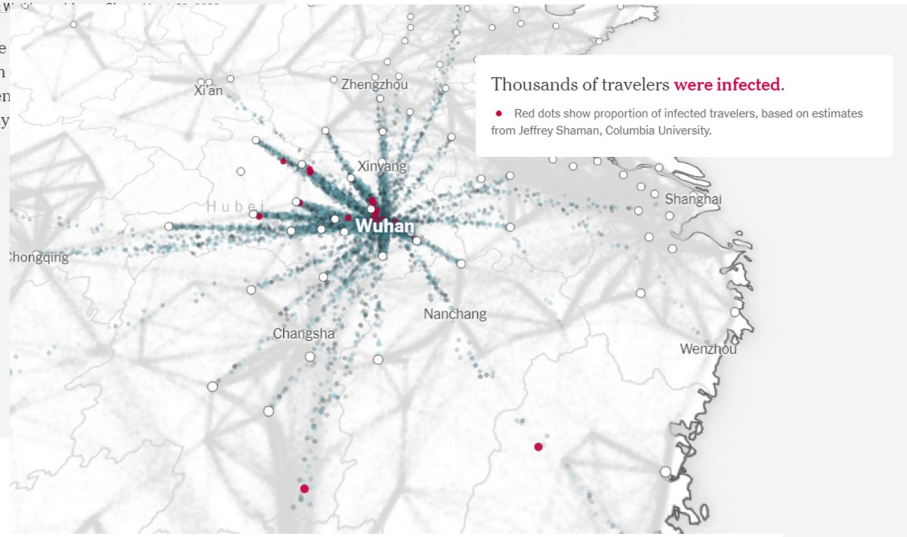
[Disconnecting the world]

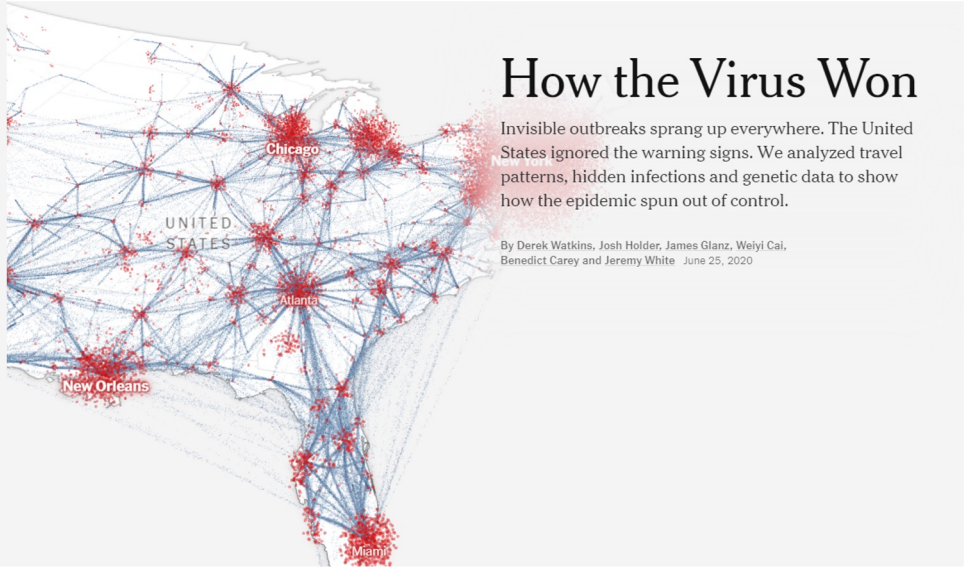
[How the Virus Got Out (*NYT*)]

[How the Virus Won (*NYT*)]

Flight Patterns







Introduction

What are the course objectives?

1) Recognize that diseases can spread through populations because of human connections and that even people we do not directly know can influence our health
2) Understand how network science helps reveal how risk of getting a disease can depend upon the pattern of connections in the network
3) Identify ways to help reduce the spread of infectious diseases based upon information on the size and structure of networks because the number of connections a person has increases both the social support available and the risk of exposure to infectious disease

Overview

Part 1: Introduction

a) Who are we?
b) Why Network Science & Viruses?
c) Where can we find networks?
d) What are the course objectives?

Part 2: Key concepts in network science relevant to contagious disease

a) *Nicky Case – The Wisdom and/or Madness of Crowds highlights:* connections, structures, visualization, mathematics, majority illusion & friendship paradox, thresholds, cascades, bonding and bridging, hubs, small worlds

b) *Can't I* please *just visit just one friend?:* nodes, links, cluster/components (<1,1,>1), degrees of separation (friends of friends of friends….), density, each visit 1 – rapid increase in how "reachable" everyone is (exponential so externality)

c) *The Small-World Network of College Classes:* Implications for Epidemic Spread on a University Campus: high clustering, short average path lengths, hubs and bridges

Part 3: Overview of Network Science & Pandemics

a) *Up & Atom video – "How to Predict the Spread of Epidemics | Computational Social Networks":* # nodes, # connections, density, clustering (components), centrality, small worlds, data & imperfect models, simulations, change as learn, policies to fit networks structures balance health & economy

Part 4: Knowing network science helps efforts to contain contagious disease

a) The Human Network *Ch. 3 Diffusion & Contagion:* basic reproduction number & average degree, phase transitions, giant components, externalities, well connected but sparse, small worlds, popularity – exposure, mathematics of small worlds, density, distances, hubs (super spreaders) & speed of spread, networks as dynamic entities

b) *VAX!* How vaccines help stop the spread by "taking out" connections and making smaller components

Part 5: Conclusion

a) Humans need social connection – stay socially connected and physically distant

Topic 5: Network Science: Insights for Pandemics

Part 2 Network Science Concepts

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Which node (circle) is best?

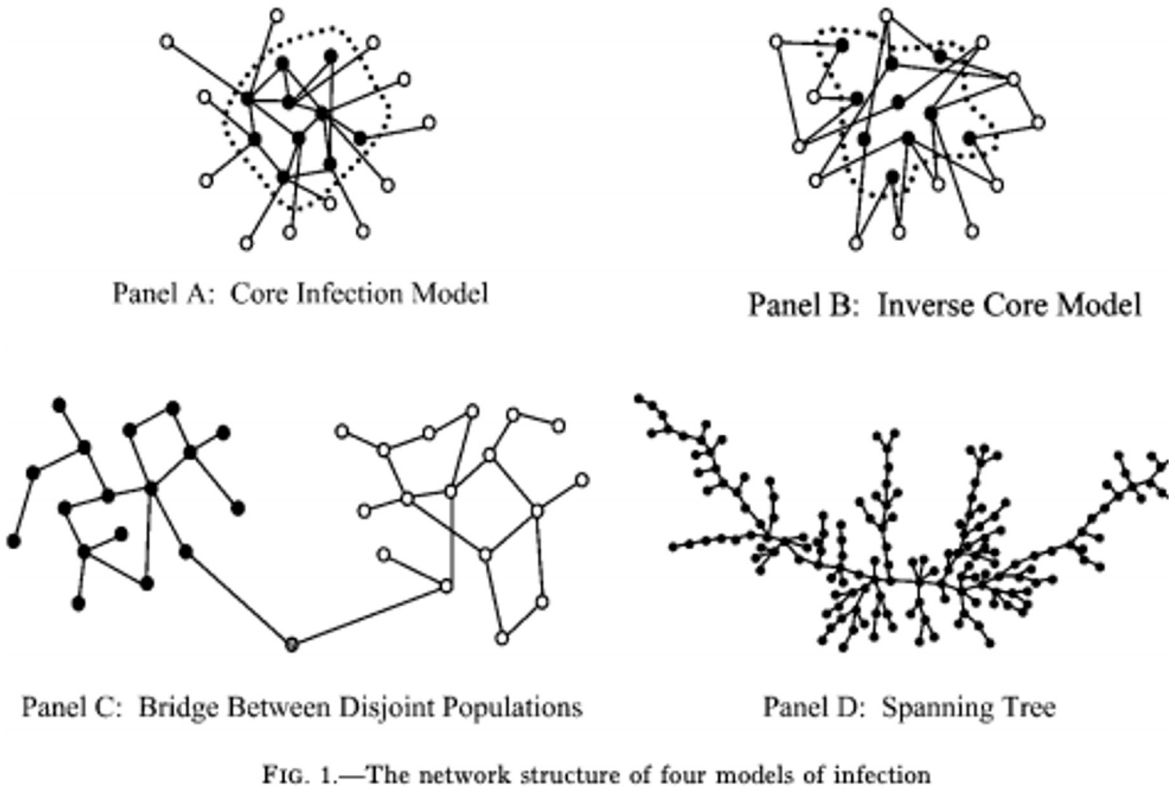


FIG. 1.—The network structure of four models of infection

Imagine that the black circles contain…

- A valuable secret
- Useful new technology
- A mask wearing habit
- A contagious disease

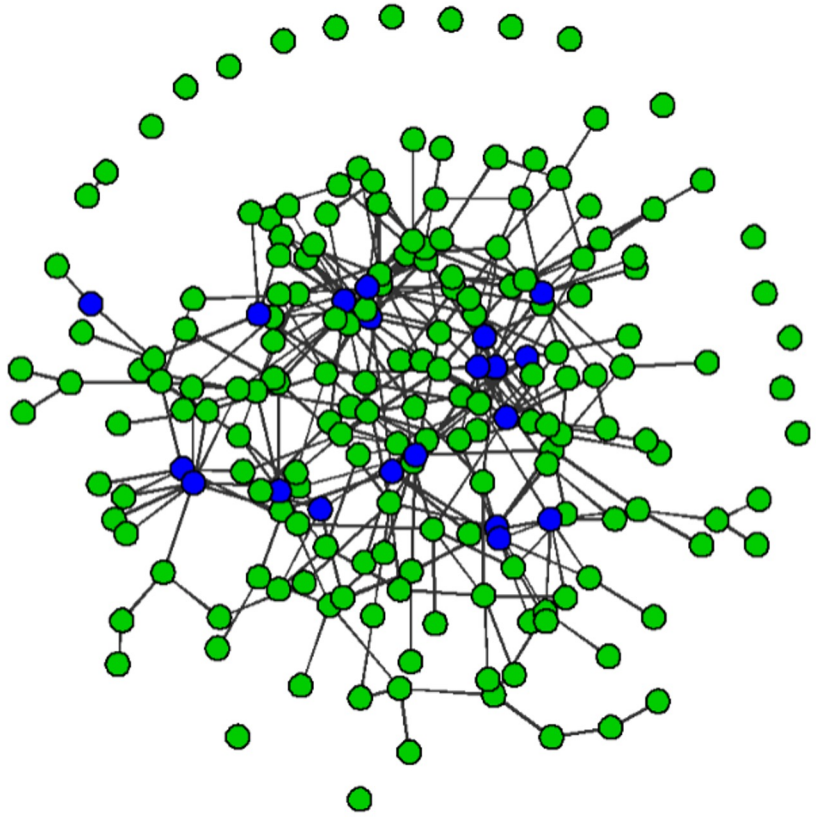
…and these can spread to the "white" circles

Where would you want to be in each of these networks?

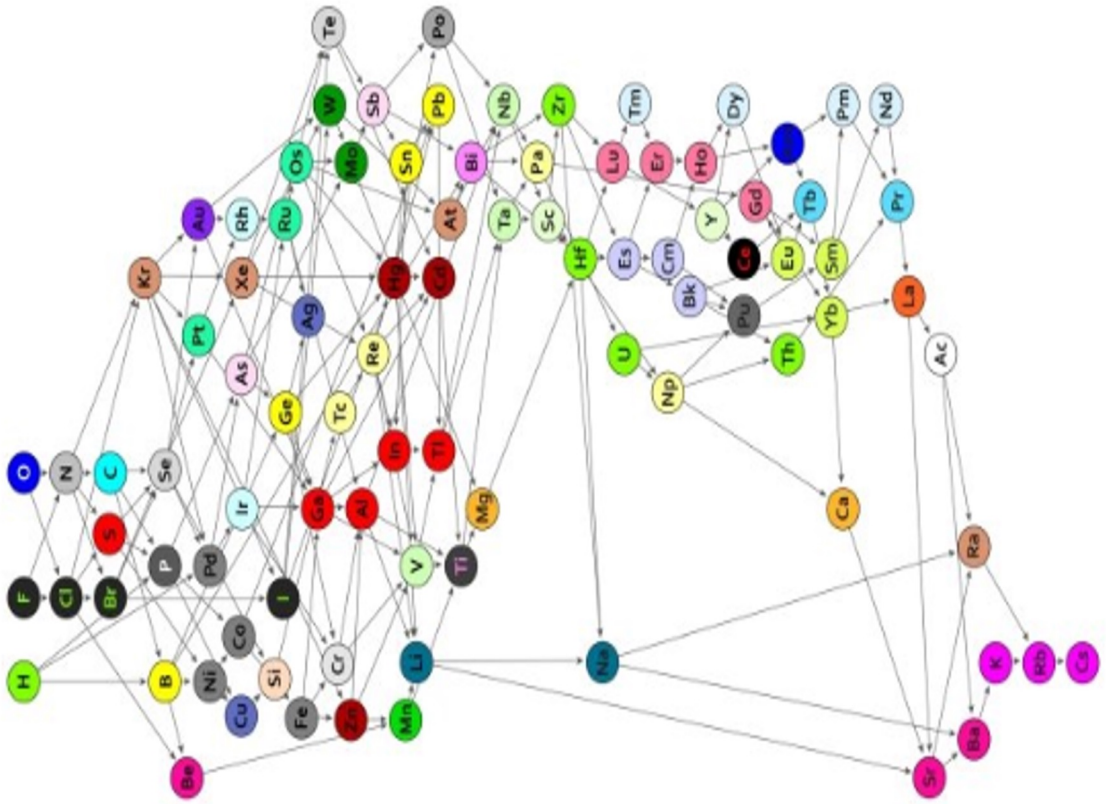
Bearman, Moody, Stovel 2004. Chains of Affection: The Structure of Adolescent Romantic and Sexual Networks. American Sociological Review. 101:44-91

What are Networks?

1) A set of relationships
2) Show how things are connected
3) Reveal hidden information
4) Provide tools for visualizing & studying complex systems illustrated by nodes/vertices (circles) & edges (lines)



What are network visualizations?



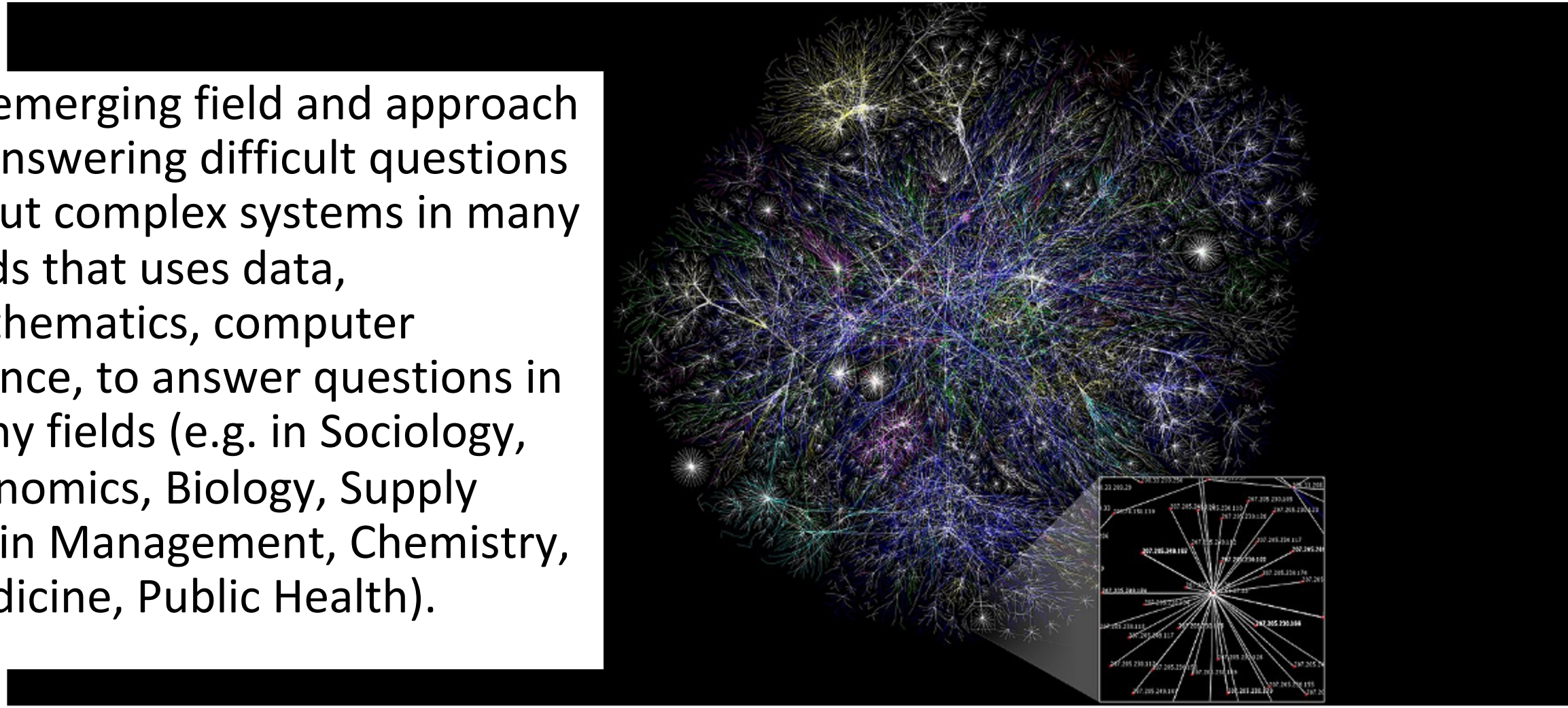
A periodic table grouped according to chemical bonds. (Guillermo Restrepo, MPI for Mathematics in the Sciences)

They are graphs used to show connections, often in complex systems that can also be represented by mathematical models.

They can often reveal hidden information that is hard to see from the perspective of any one node.

What is network science?

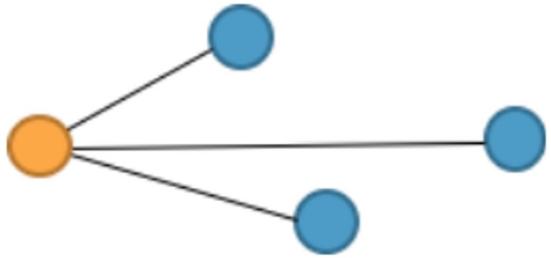
An emerging field and approach to answering difficult questions about complex systems in many fields that uses data, mathematics, computer science, to answer questions in many fields (e.g. in Sociology, Economics, Biology, Supply Chain Management, Chemistry, Medicine, Public Health).



Partial map of the Internet based on the January 15, 2005 data found on opte.org. Each line is drawn between two nodes, representing two IP addresses. The length of the lines are indicative of the delay between those two nodes. This graph represents less than 30% of the Class C networks reachable by the data

Degree:

The number of edges a vertex has connected to it. The leftmost (orange) vertex pictured below has a **degree of three:**



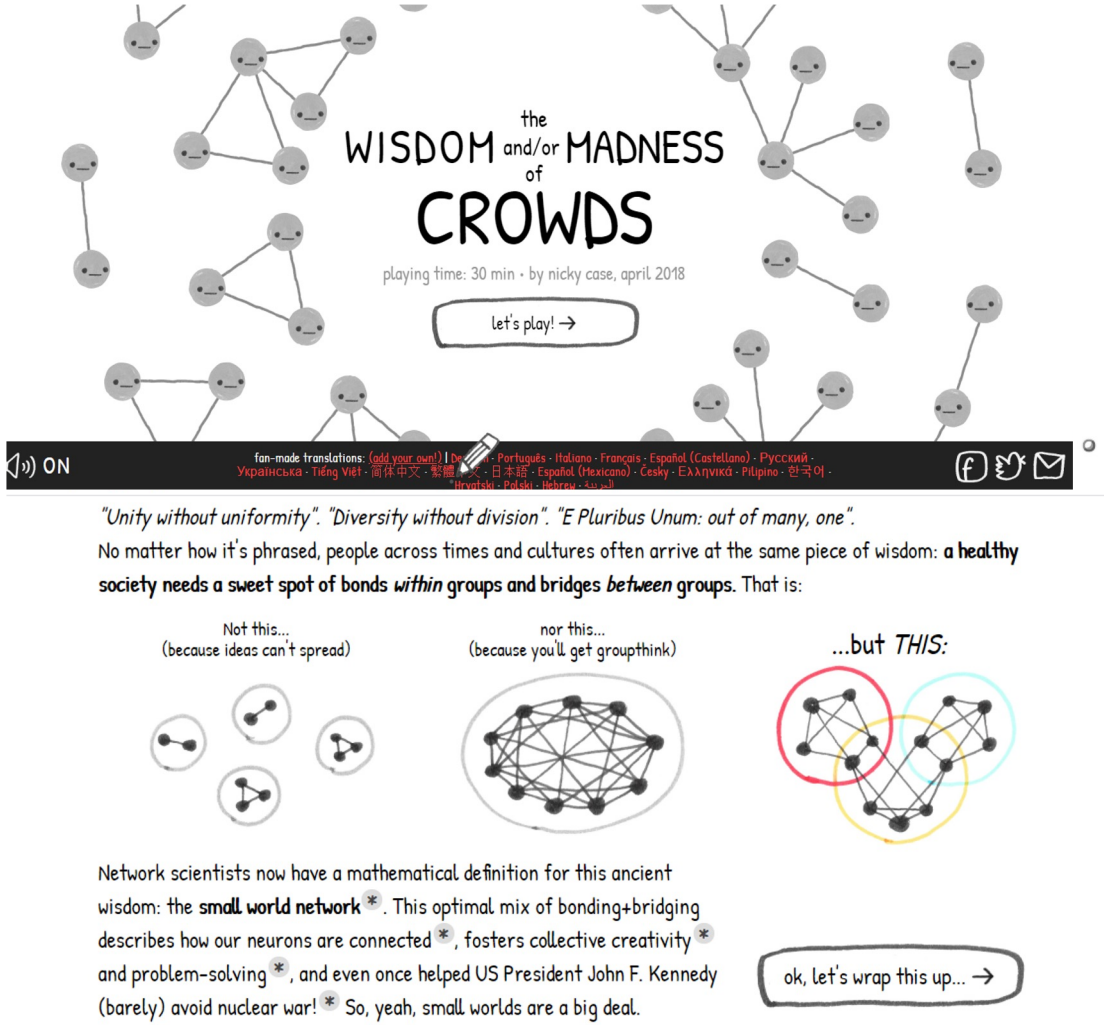
Hub:

A node/vertex that has a lot more connections than the rest. In other words, it has a much higher degree compared to the other vertices. The center (orange) vertex pictured below is a hub:

Part 2: Overview of Network Science & Pandemics

Nicky Case – [The Wisdom and/or Madness of Crowds](https://ncase.me/crowds/) highlights:

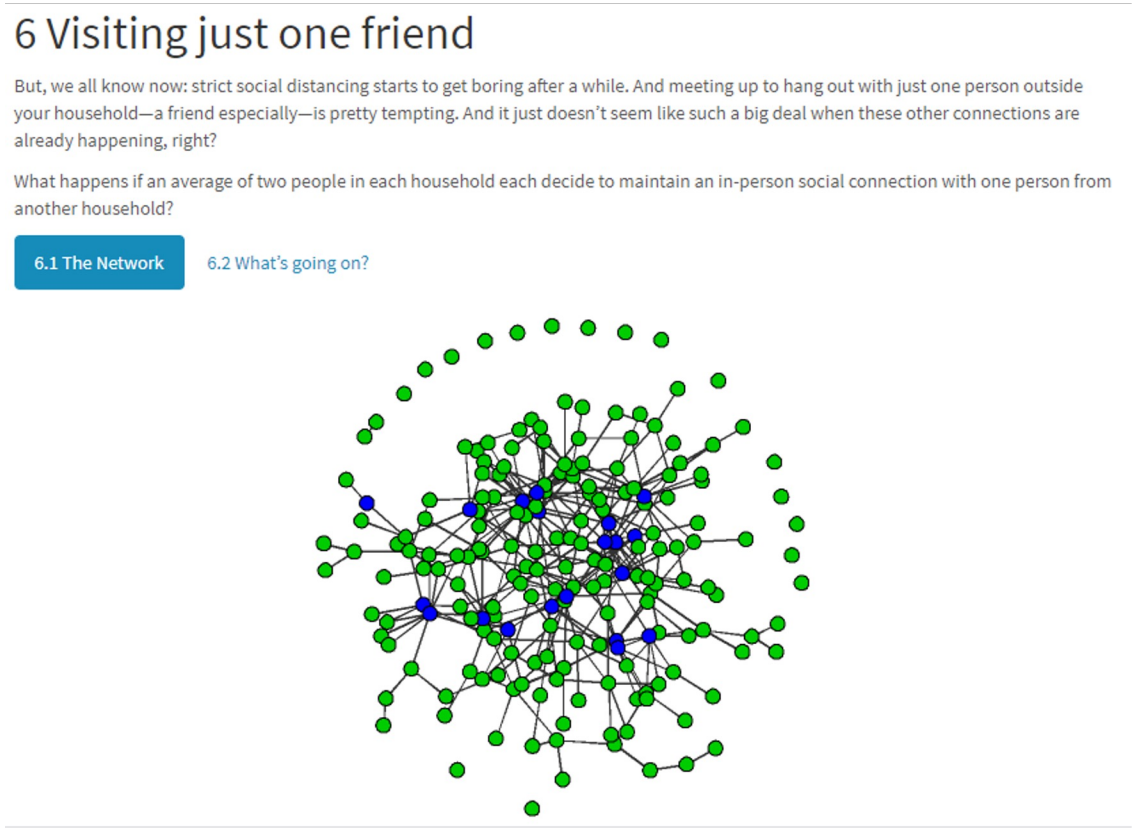
- Connections
- Structures
- Visualization
- Mathematics
- Majority illusion & friendship paradox
- Thresholds
- Cascades
- Bonding and bridging
- Hubs
- Small worlds



https://ncase.me/crowds/

Part 2: Overview of Network Science & Pandemics

"Can't I please *just visit one friend?"*



Goodreau SM, Pollock ED, Birnbaum JK, Hamilton DT, Morris M, on behalf of the Statnet Development Team. 2020. *Can't I please just visit one friend?: Visualizing social distancing networks in the era of COVID-19*. http://statnet.org/COVID-JustOneFriend/

Key concepts:

Nodes & Links (relationships)

Clusters/Components ("reachability")

Average Degrees of separation (<1,1,>1)

friends of friends of friends….)

Density (# of ties)

exponential growth

externality

Why is understanding networks helpful for understanding the spread of COVID-19?

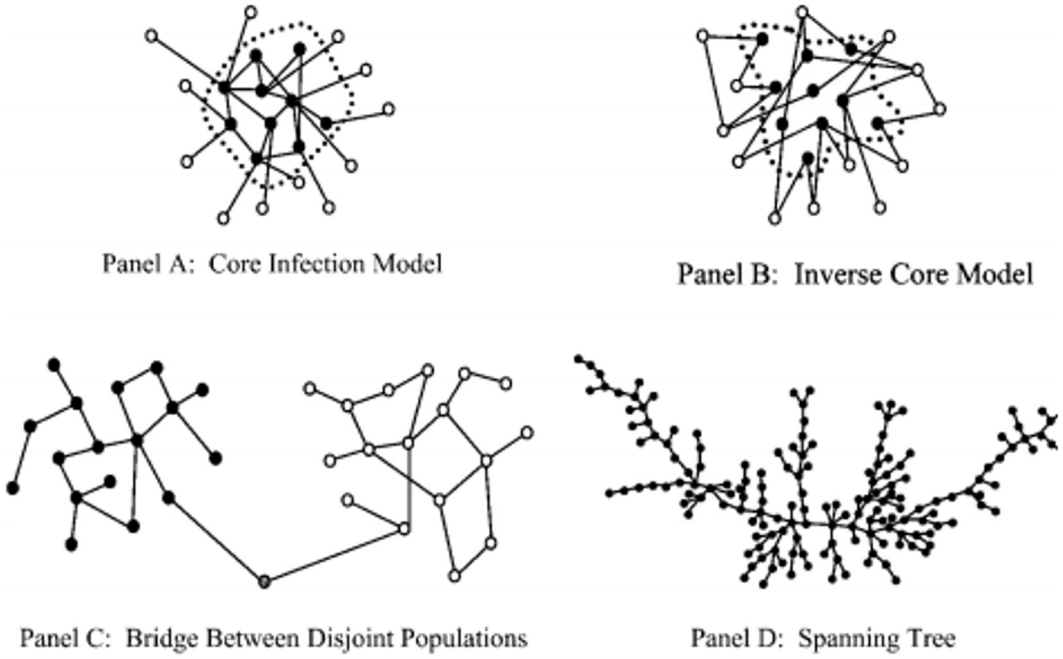


FIG. 1.—The network structure of four models of infection

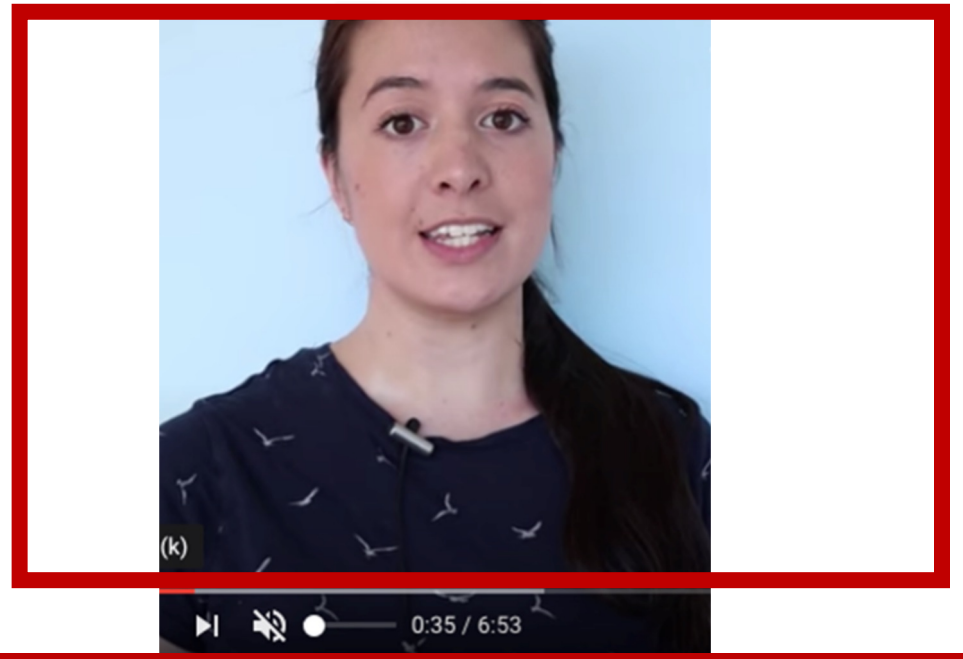
The disease spreads person to person. It depend upon relationships (connections).

More connections → more popular (individual)
& social cohesion (communities)
& more possible support
& more possible risk

Bearman, Moody, Stovel 2004. Chains of Affection: The Structure of Adolescent Romantic and Sexual Networks. American Sociological Review. 101:44-91

Topic 5: Network Science: Insights for Pandemics

Part 3: Up & Atom Video



Up & Atom

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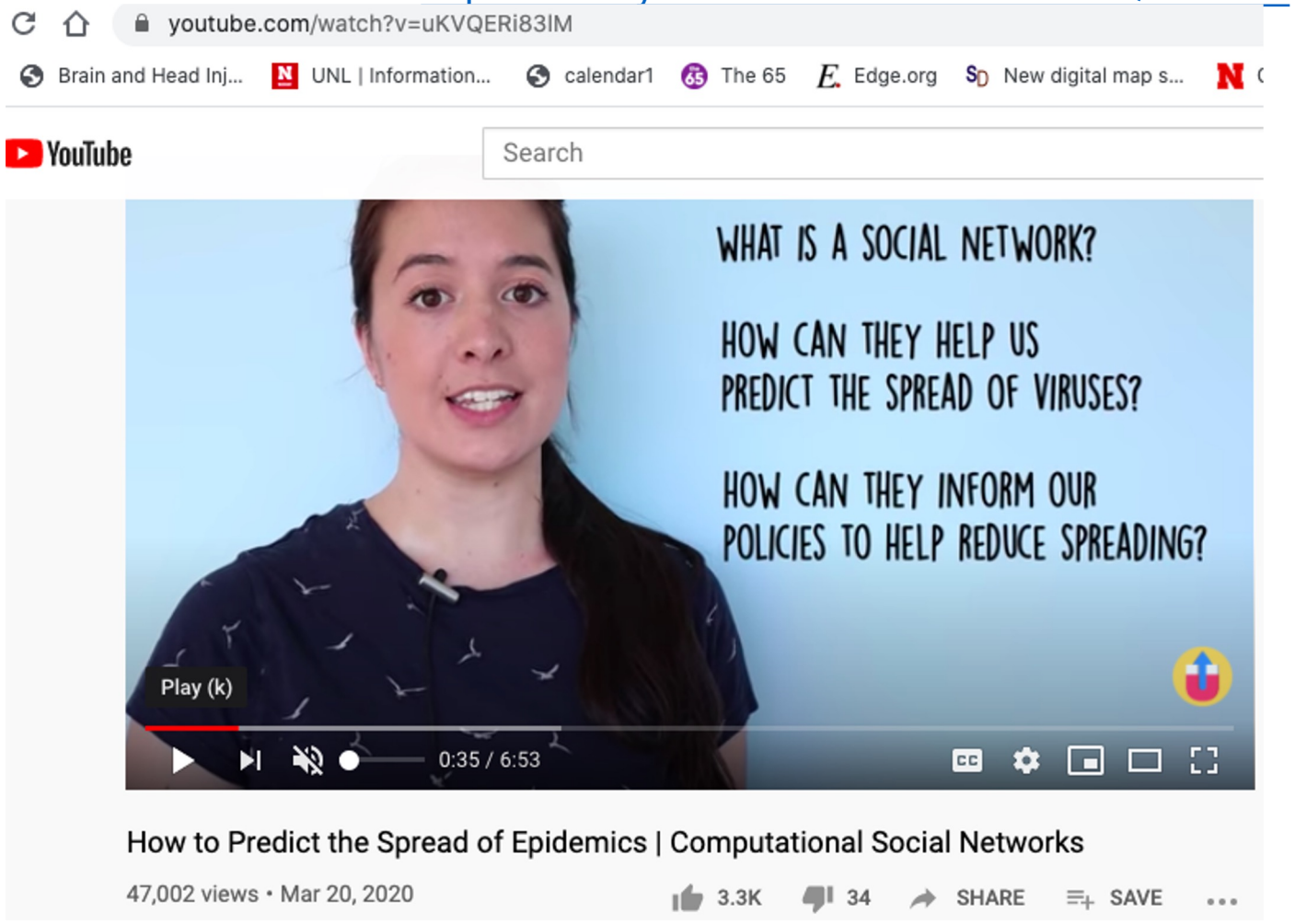
How to Predict the Spread of Viruses Using Social Networks

WATCH -> https://www.youtube.com/watch?v=uKVQERi83IM



Topic 5: Network Science: Insights for Pandemics

Part 4: Knowing network science helps efforts to contain contagious disease

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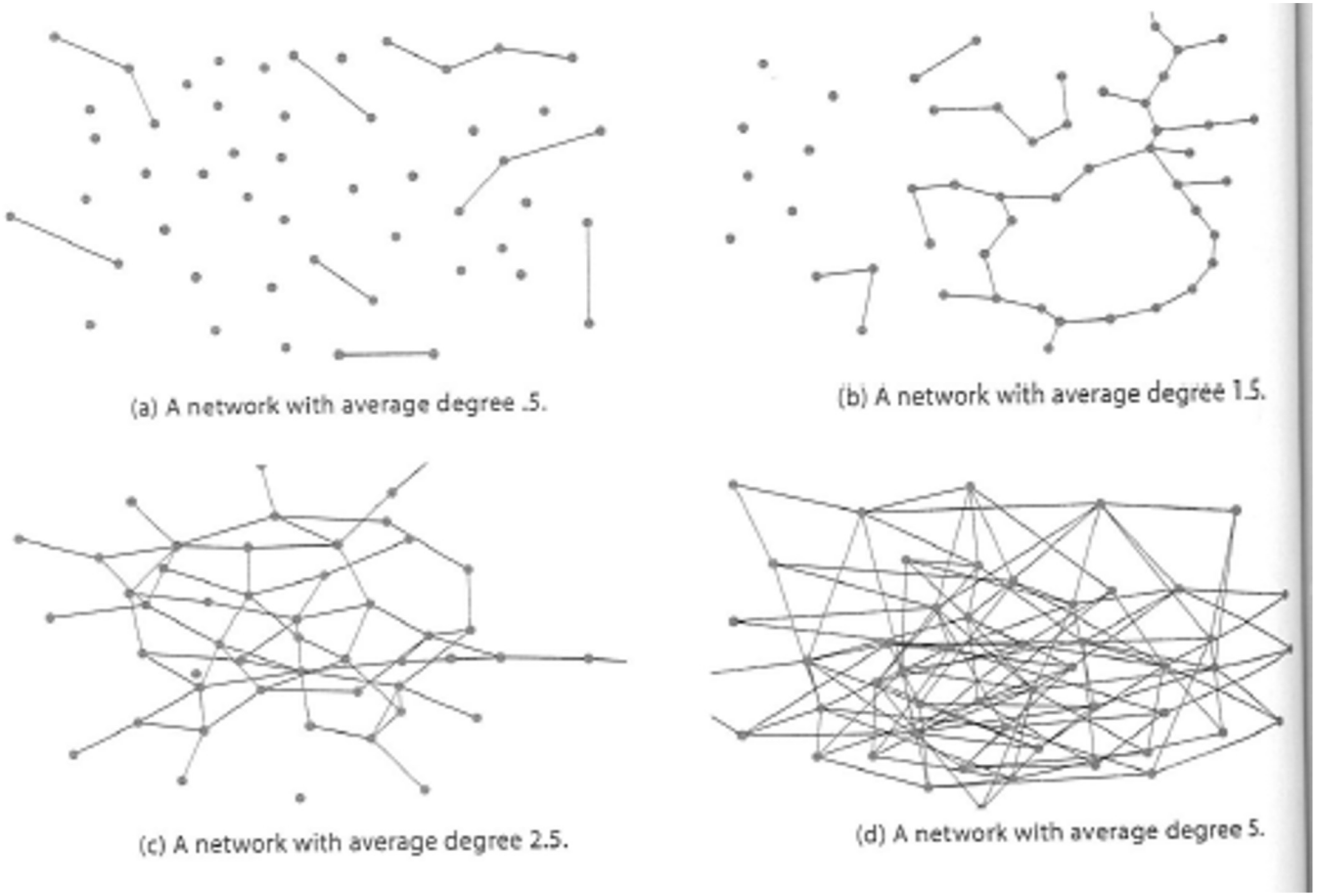
Phase Transition

- Phase Transitions and Reproduction Rate – (Jackson, 2019, pg. 48-49)



(a) A network with average degree .5.

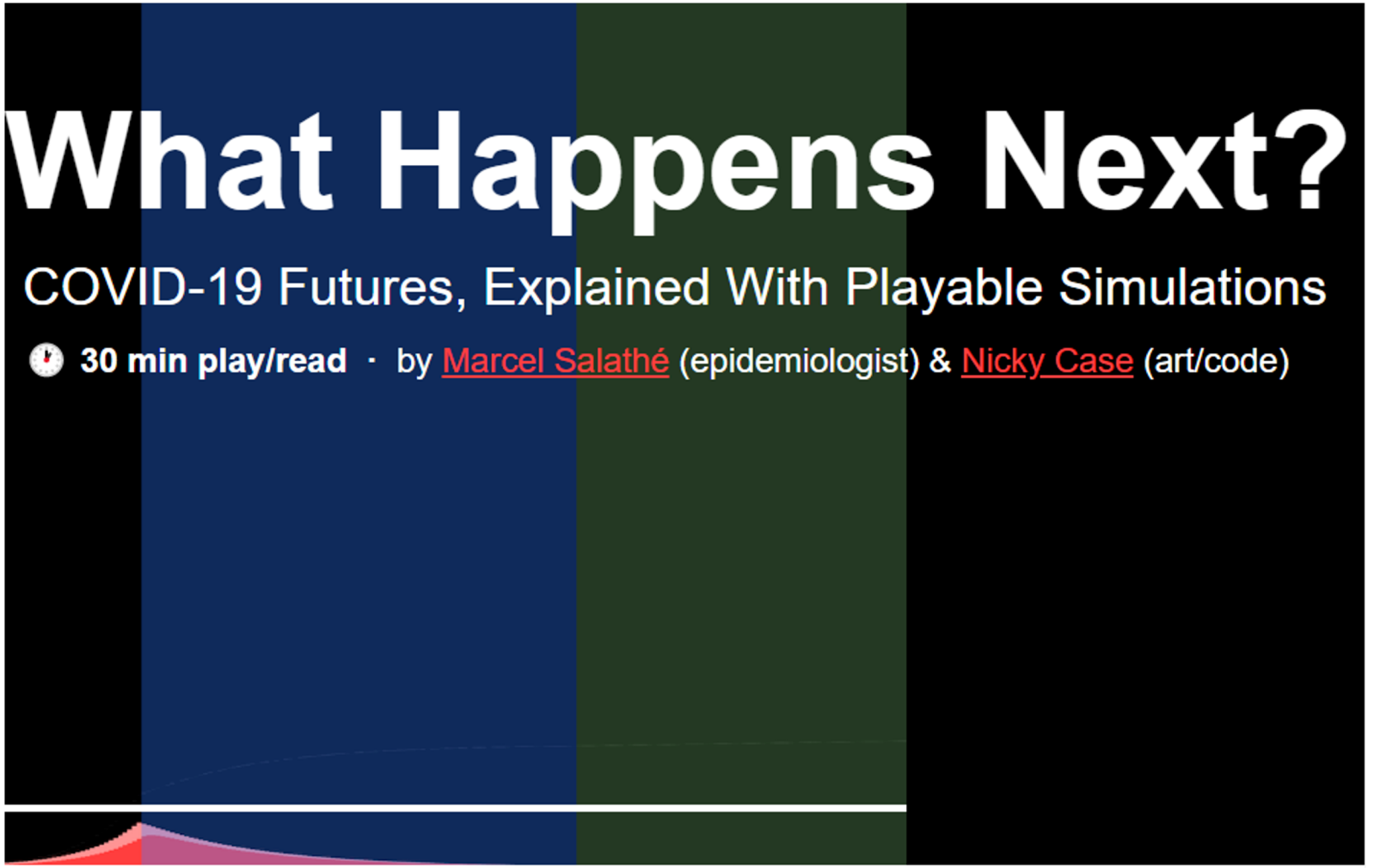
(b) A network with average degree 1.5.

(c) A network with average degree 2.5.

(d) A network with average degree 5.

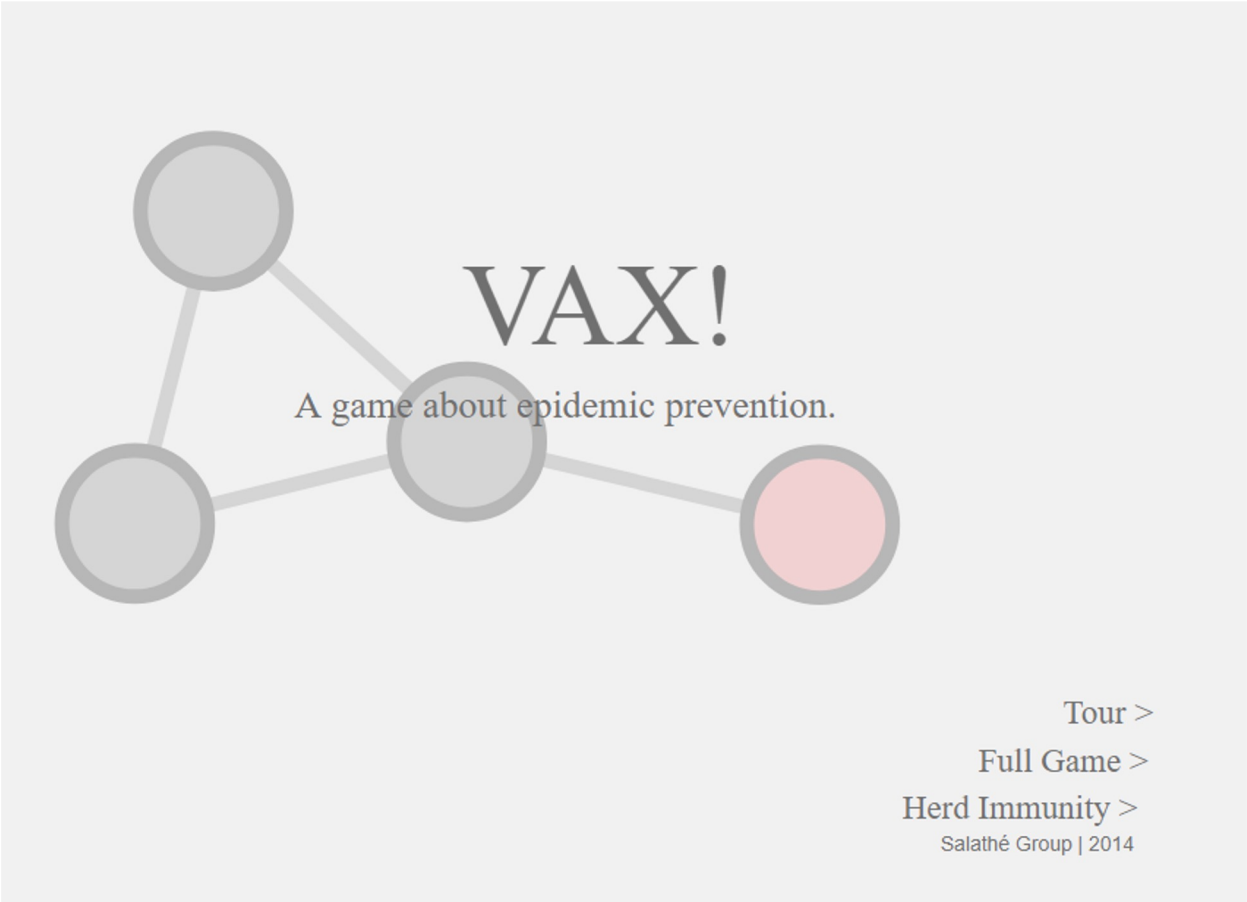
Reproduction Rate and Externalities

Links from video: https://ncase.me/covid-19/



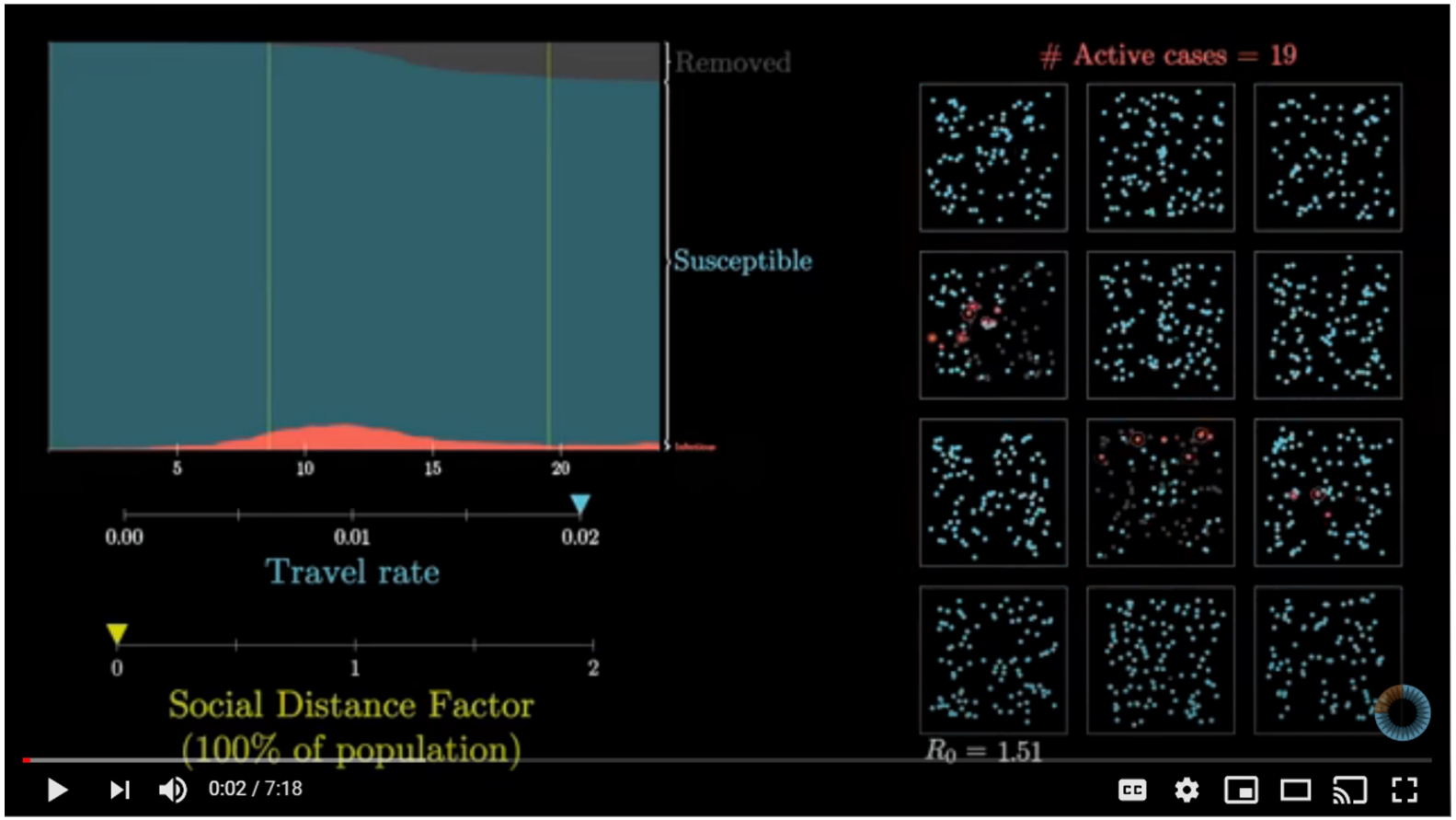
Externalities and VAX!

Link to game: https://vax.herokuapp.com/



(Optional) Video on Contact Tracing and Privacy

https://www.youtube.com/watch?v=D__UaR5MQao



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Part 5: Conclusion

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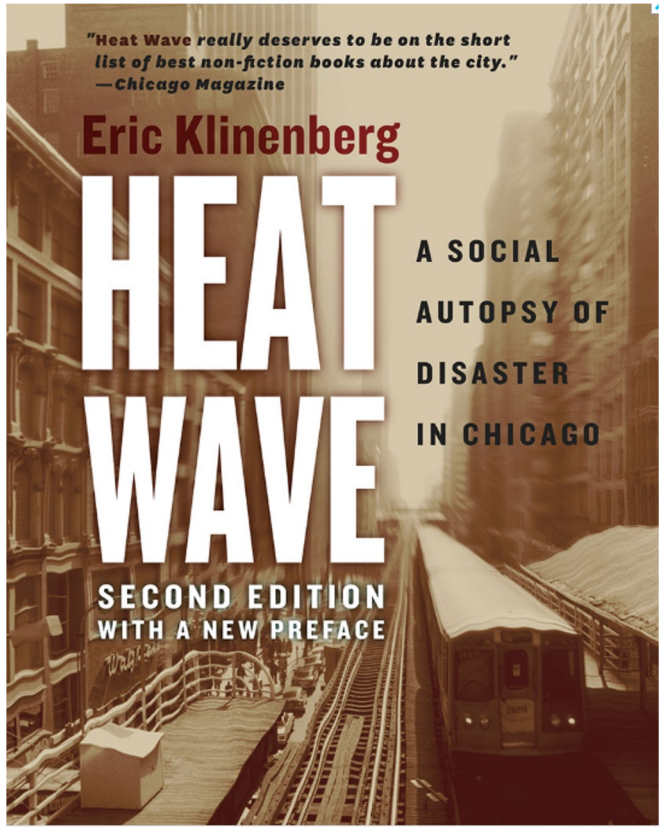
Part 5: Conclusion – physically distant, socially connected



"Heat waves in the United States kill more people during a typical year than all other natural disasters combined. Until now, no one could explain either the overwhelming number or the heartbreaking manner of the deaths resulting from the 1995 Chicago heat wave. Meteorologists and medical scientists have been unable to account for the scale of the trauma, and political officials have puzzled over the sources of the city's vulnerability. In *Heat Wave*, Eric Klinenberg takes us inside the anatomy of the metropolis to conduct what he calls a "social autopsy," examining the social, political, and institutional organs of the city that made this urban disaster so much worse than it ought to have been."

"Starting with the question of **why so many people died at home alone**, Klinenberg investigates **why some neighborhoods experienced greater mortality than others**, how the city government responded to the crisis, and how journalists, scientists, and public officials reported on and explained these events. Through a combination of years of fieldwork, extensive interviews, and archival research, Klinenberg uncovers how a number of surprising and unsettling forms of **social breakdown—including the literal and social isolation of seniors, the institutional abandonment of poor neighborhoods, and the retrenchment of public assistance programs—contributed** to **the high fatality rates.** The human catastrophe, he argues, cannot simply be blamed on the failures of any particular individuals or organizations. **For when hundreds of people die behind locked doors and sealed windows, out of contact with friends, family, community groups, and public agencies, everyone is implicated in their demise."**

https://as.nyu.edu/content/nyu-as/as/faculty/eric-klinenberg.html

Part 4: Conclusion – physically distant, socially connected

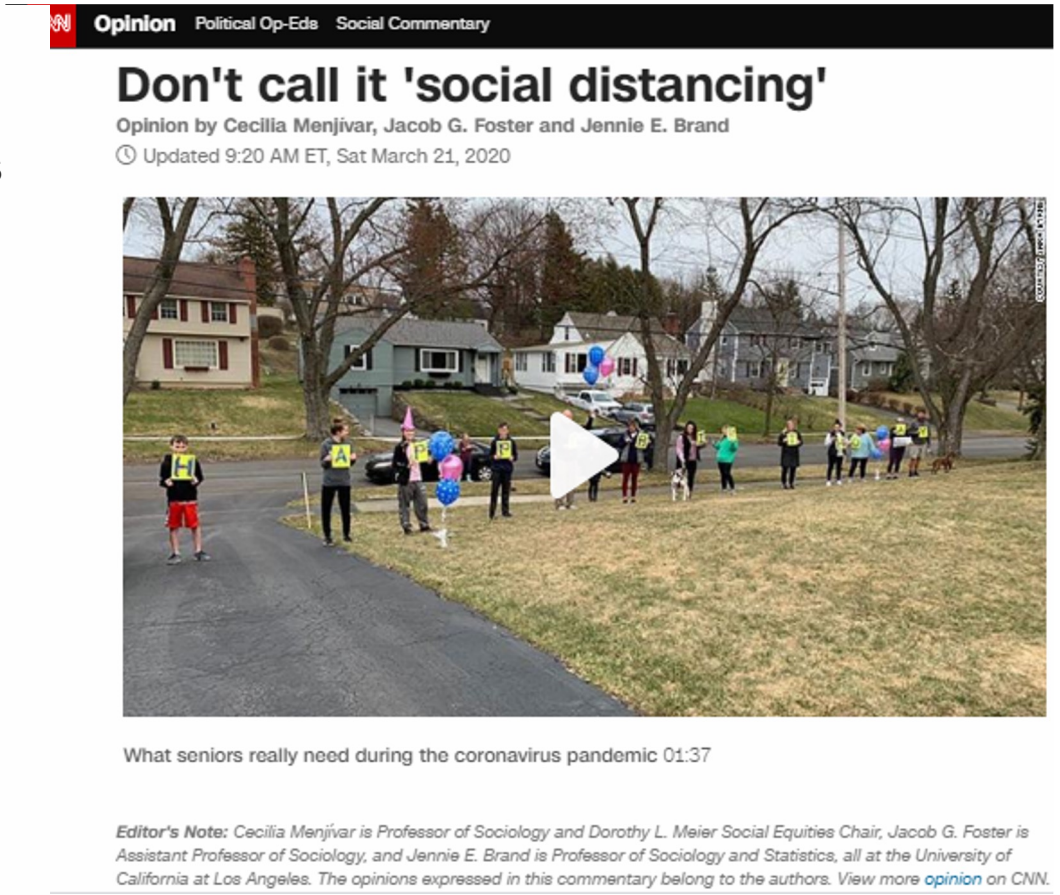
"Public health officials tell us to minimize physical contact in order to combat the Covid-19 pandemic. While the public, thankfully, is hearing the message, there is a hidden danger: As we retreat into our homes, we can lose sight of our essential connections to one another and forget about the plight of those most vulnerable to the fraying of social bonds."

Read the opinion piece by sociologists at UCLA.
They argue we need to be creative and keep:

- Stay socially connected
- Maintain social inclusion
- Focus on the collective good

Social connections are important for health:
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3150158/pdf/nihms300162.pdf

There are health risk of social isolation for older adults:
https://www.nia.nih.gov/news/social-isolation-loneliness-older-people-pose-health-risks

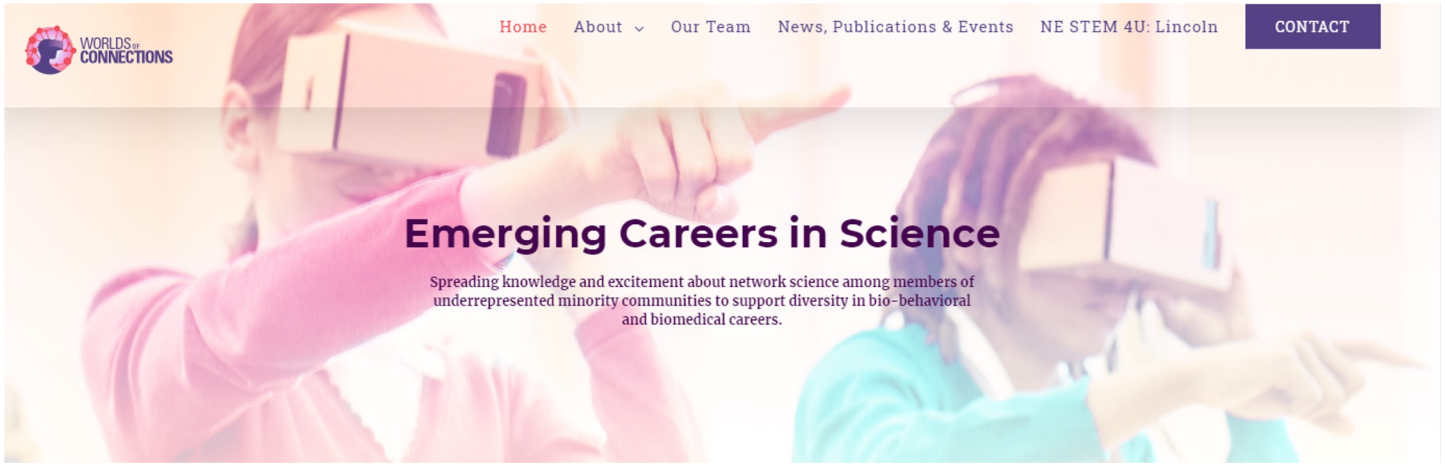


Don't call it 'social distancing' (opinion) | CNN

Part 5: Reflection – do you think…

- Visiting just one friend during a pandemic can spread the virus to many people?
- My behavior can protect the health of the people in my community even those I cannot see?
- The structure of a network (how dense it is, or if it has a hub) can influence how quickly or slowly a disease spreads?
- Health behaviors, like wearing a mask, spread through social networks similar to diseases?

http://worldsofconnections.com/



If you want to explore more!

- Take graph theory courses in the math department
- Explore supply chain management methods courses
- Take SOCI 198 Introduction to Network Science, SOCI 4/898 Agent Based Modeling, SOCI 4/898 Machine Learning
- Read *Connected* by Nicholas Christakis and James H. Fowler (and watch their TED Talks)
- And so much more!

Thanks for participating in:

Network Science: insights for Pandemics

We hope you enjoy the rest of the class.

The End