2020

Network Science: Insights for Pandemics

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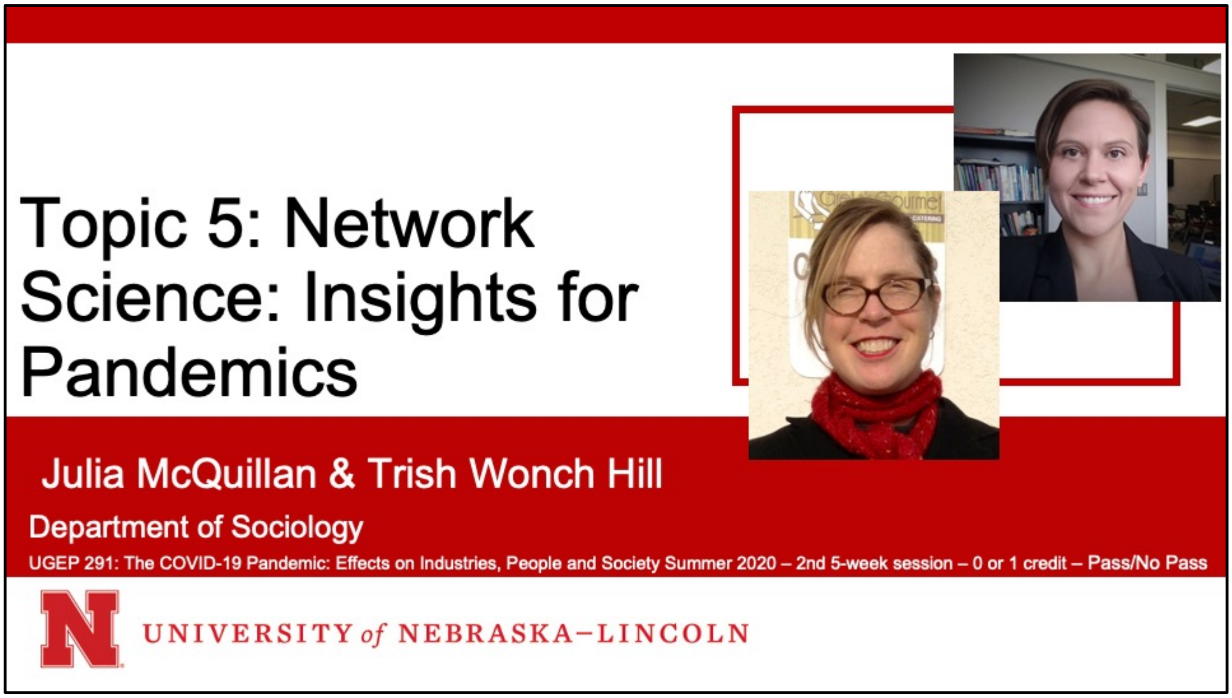
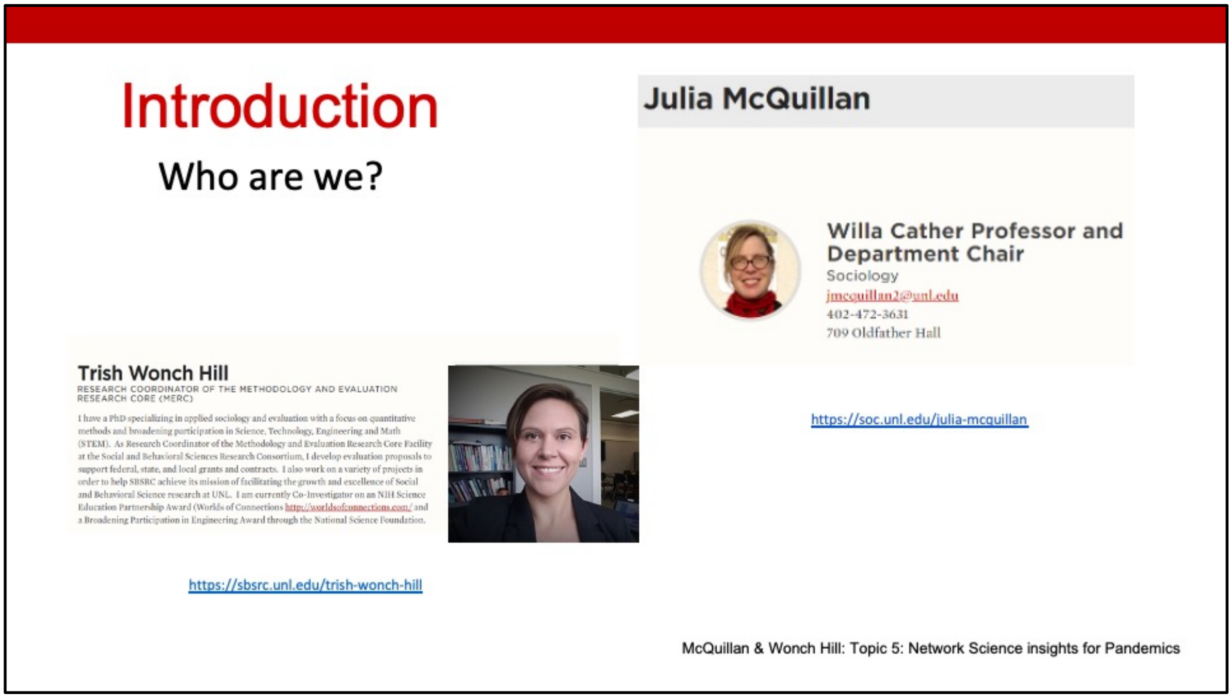


Welcome to Topic 5: Network Science: Insights for Pandemics
Part of the Summer 2020 class UGEP 291; The COVID-19 Pandemic: Effects on Industries, People and Society Summer

This is part 1 of 5. Each part has a separate video if you want to hear the lecture as well as look at the slides and explore the links we have embedded.



I'm Julia McQuillan, and i've been at UNL since 1998 in the Sociology Department.

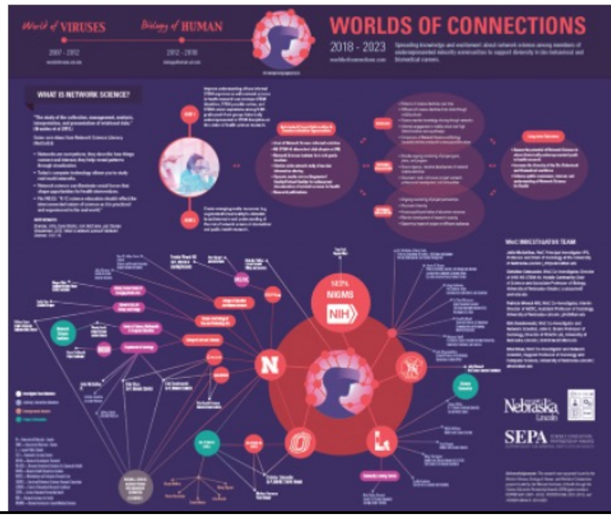
I'm Trish Wonch Hill, a UNL alumna and current professor of practice.

We have worked on projects that use Network Science to answer challenging questions since 2007. Our first project focused on ways to attract, retain, and promote women in Science, Technology, Engineering, and Mathematics (https://advance.unl.edu/advance-nebraska).

Introduction

Why Network Science & Viruses?

worldsofconnections.com



The focus of our current project is on helping members of the public to better understand the role of network science theories and tools for improving public health because often public health is connected to complex systems. We'll focus today on the relevance of network science for understanding how to contain viruses that cause diseases.

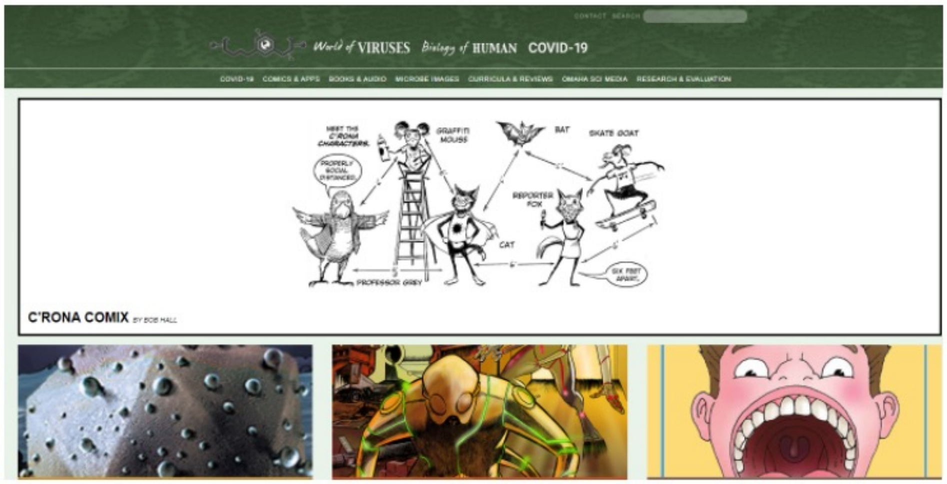
Our project is called Worlds of Connections.

We are affiliated with a large research center that is funded by the National institutes of Health, the Rural Drug Addiction Research (RDAR) Center, that uses network science to understand rural drug addiction.

Introduction

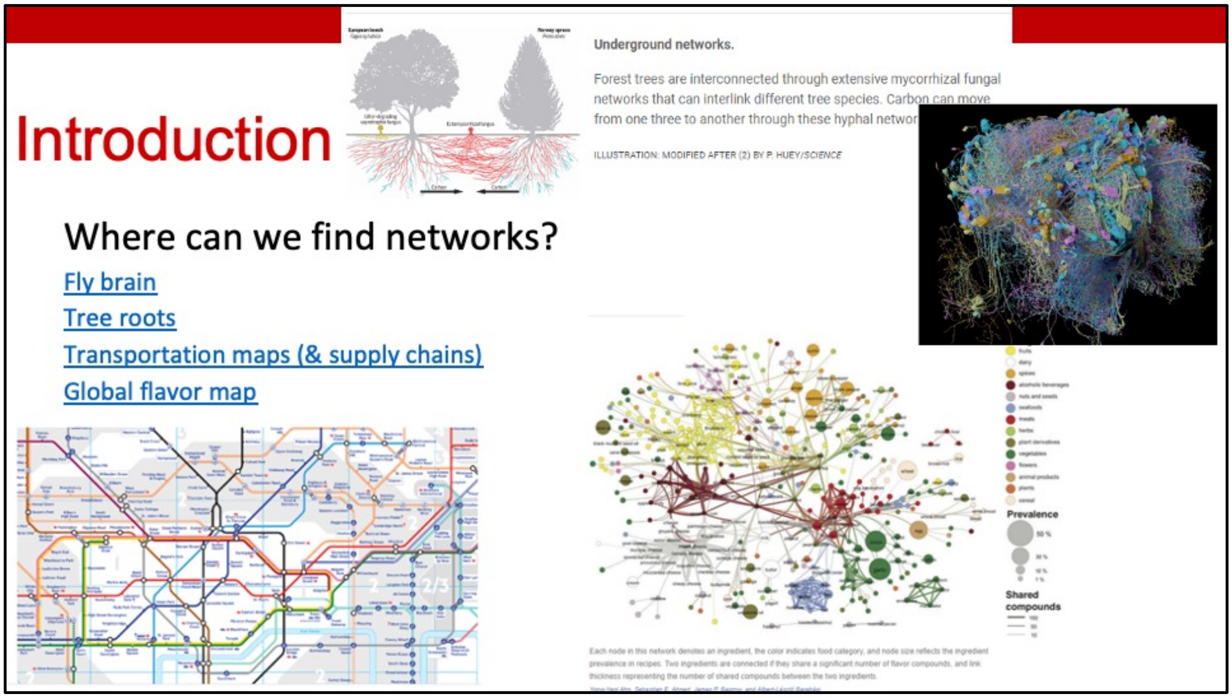
Why Network Science & Viruses?

https://worldofviruses.unl.edu/



Here is a crazy connection – our last project was about human biology, and the one before that was about viruses (Biology of Human and World of Viruses, respectively). Now our Worlds of Connections project is about the role of networks in health, and networks are central to the spread of COVID-19. Disrupting network connections is a vital strategy for stopping the spread. Those two prior projects, led by Dr. Judy Diamond, Curator and Professor of informal science education at the University of Nebraska State Museum and a professor of Libraries, provide perfect background information for understanding COVID-19.

Another interesting connection—we are now working on a new NSF project to quickly educate the public about COVID-19 virus through comics. You can go to the webpage linked on the screen to see the comics.

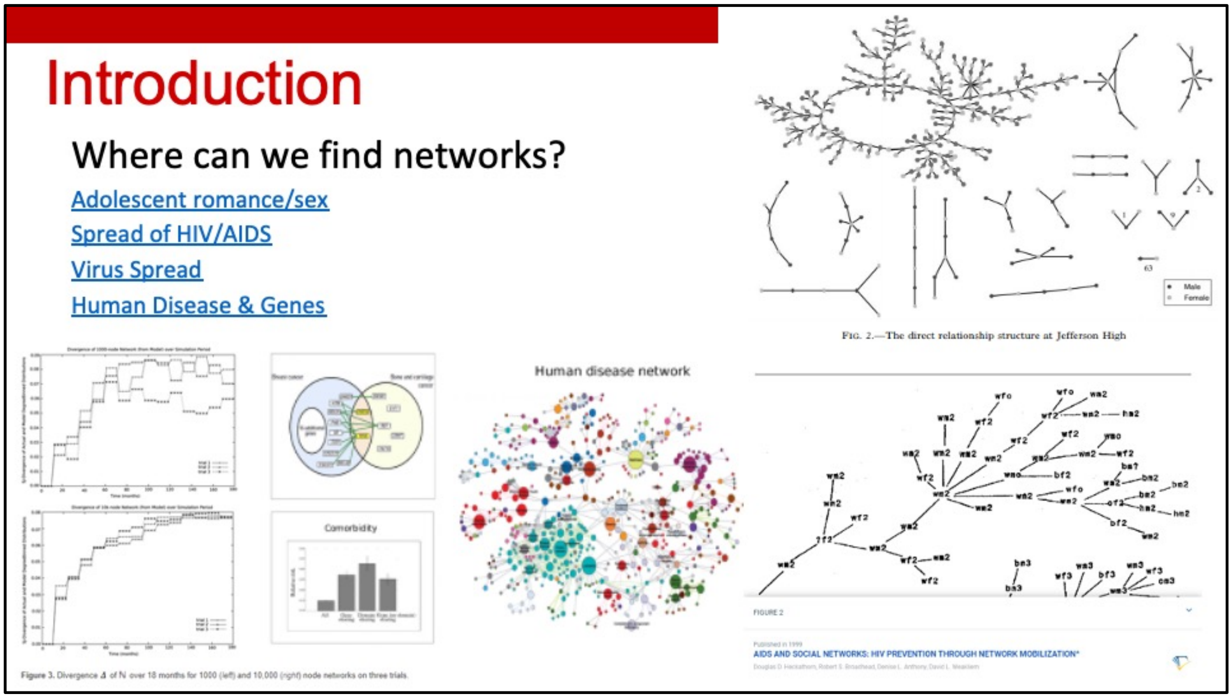


You've already done some reading, watching, and exploring with networks if you are keeping up with the assignments. Once you start to think about connections, it becomes easier to notice how using a network science framework can make visible what is often hidden to us—how what we see in front of us is often connected beyond what we can see. Networks are everywhere—and network models are helpful for understanding complex systems such as the spread of a disease-causing virus.

Here are a few examples:

- A 3D model of the brain of a fly shows vertices (nodes) and edges (connections): [Google's 3D Map of a Fly Brain Is Beautiful](#).
- We can think of the roots of trees as forming networks for nutrition and for connections among plants that are hidden underground: (https://science.sciencemag.org/content/352/6283/290?rss=1.
- We can think of maps as a simplification of information and of network maps as even more simplifying—building on Professor Bitterman's work last week: [24 awesome alternative London tube maps](#).
- It is fun to be surprised by what flavors might go together in a recipe that people like—and how flavor pairings might differ by cluster—as the report

says, “which foods are chemical cousins, and which are flavor outliers”: What A Global Flavor Map Can Tell Us About How We Pair Foods : The Salt : NPR.



Social network analysis has been important to understanding disease spread in epidemiology and sociology for decades, from discovering the importance of an infected water well to tracing the complexities of the spread (and lack of spread) of HIV ([PDF] AIDS AND SOCIAL NETWORKS: HIV PREVENTION THROUGH NETWORK MOBILIZATION).

In 2004 Sociologists, led by James Moody, showed the spread of an STD through an adolescent friendship network and discovered that one reason the virus spread as far as it did was because of a social norm: it was NOT okay to have sex with a friend's ex-partner. Therefore, no one had to have many partners to spread the virus: they just had to have two, and their friends had to have two (or more than 1, the reproduction number) (Chains of Affection: The Structure of Adolescent Romantic and Sexual Networks).

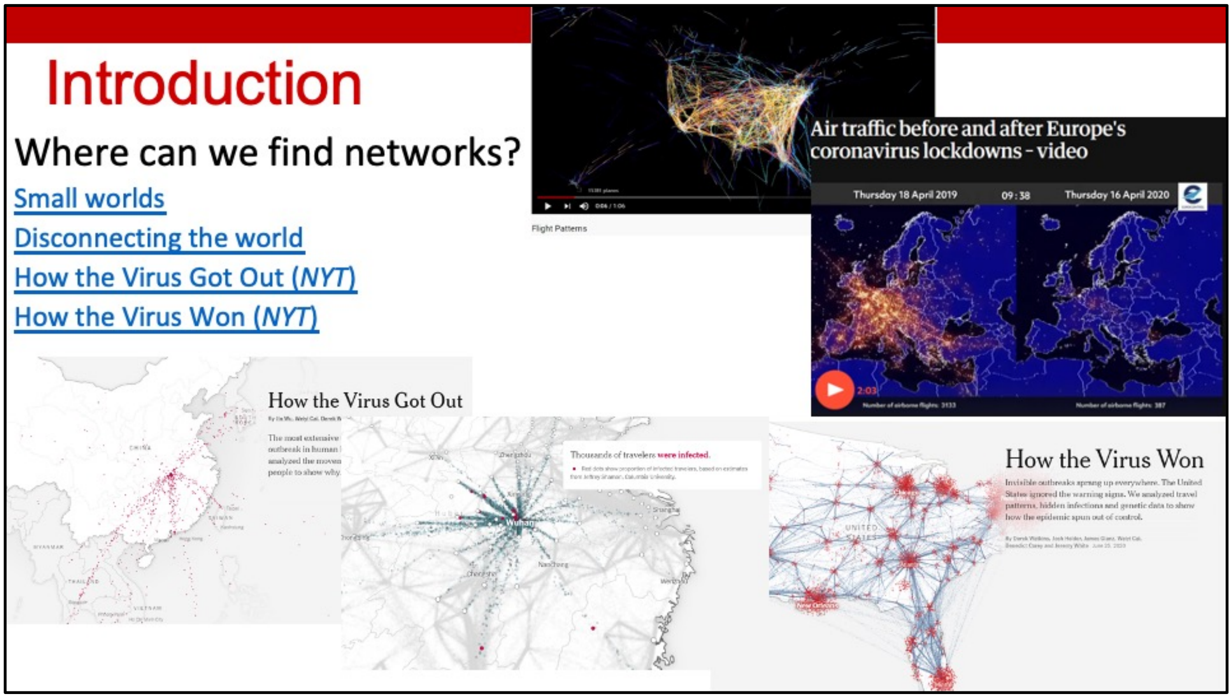
Barabási and colleagues used network science methods to examine clusters of disease and genes (The human disease network | PNAS).

Our colleagues in the RDAR Center have used a combination of "real-world" data and computer simulations to understand how network and viral properties combined to facilitate the spread of HIV to some people and not others (A stochastic agent-based model of pathogen propagation in dynamic multi-relational social networks - Bilal Khan, Kirk Dombrowski, Mohamed Saad, 2014).

I hope you are thinking, *I wonder if there is a network map of which genes are associated with which diseases, and if there are any clusters of diseases?* Your curiosity is correct, and an emerging field of network medicine helps us to see these connections: Network Medicine: A Network-based Approach to Human Disease - PMC.

Social network analysis has been important to understanding disease spread in epidemiology and sociology for decades, from discovering the importance of an infected water well to tracing the complexities of the spread (and lack of spread) of HIV ([PDF] AIDS AND SOCIAL NETWORKS: HIV PREVENTION THROUGH NETWORK MOBILIZATION* | Semantic Scholar).

You already know about networks a little bit because maps can be considered a model of a network and geographers do spatial analysis (Patrick Bitterman's module).



International travel has helped to make the world very small. As you learned when you did the homework, “small worlds” are kinds of networks with high internal clustering and bridges between clusters or components. Airports can literally be hubs – and can be represented in network terms as hubs that help spread human disease.

This video shows air travel in the USA before COVID. This next video shows Europe before and after COVID lockdowns to slow the spread. Network models and analyses of the virus spread have been in the news (“How the Virus Got Out” - *The New York Times*, “How the Virus Won” - *The New York Times*), and we want you to know some of the fundamental concepts behind the brief mentions in the news.

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

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Big Ideas:

- People we do not know can have an impact on our health through people we do know.
- It can be hard to see the larger structure of network components (i.e. all the people we are connected to beyond our immediate connections).
- Using a variety of data sources (e.g. contact tracing, cellphones) to visualize the degree of connections among people and how viruses have and can spread improves efforts to stop the spread.
- Reducing physical connections among people (e.g. physical distance, sheltering in place, handwashing, face masks) helps prevent the spread of viruses, and it is important to still stay connected socially
- Humans need social connections for their well-being. Therefore, think of physical distancing and social connections—from a distance—check in on people, talk to them, listen, support.

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

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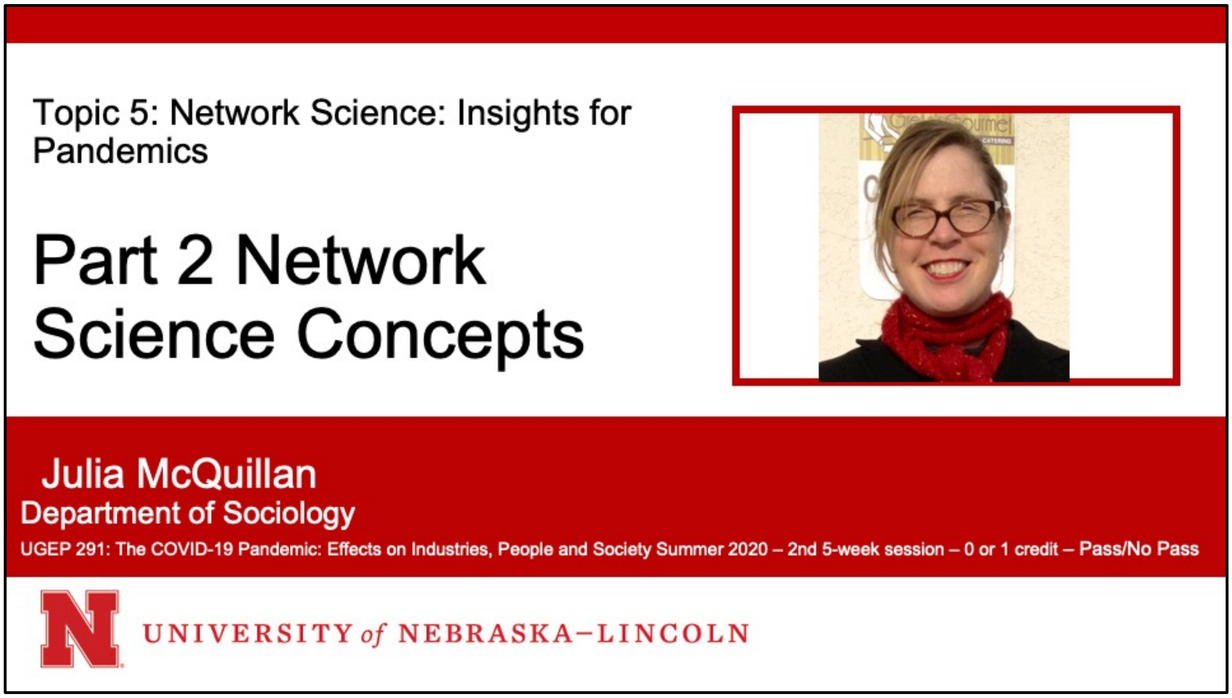
This module has five parts. You've just completed Part 1, the introduction. You'll learn more about key concepts in Part 2, watch a video on how to predict the spread of epidemics using network science in Part 3, explore how network science helps to contain contagious disease in Part 4, and we'll wrap up with an emphasis on staying physically distant and socially connected in Part 5.



In this part we will highlight some key concepts from the "Wisdom and/or Madness of Crowds" webpage and "Can't I *please* just visit one friend?"

Which node (circle) is best?

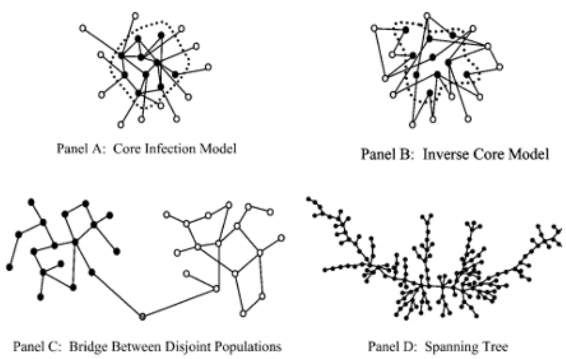


FIG. 1.—The network structure of four models of infection

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

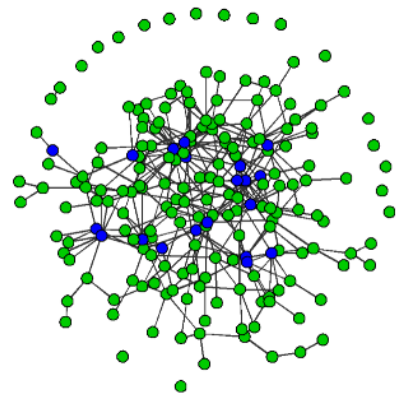
Where would you want to be in each of these networks?

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

These are actual disease networks. We can imagine that they “spread” more than disease.

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)



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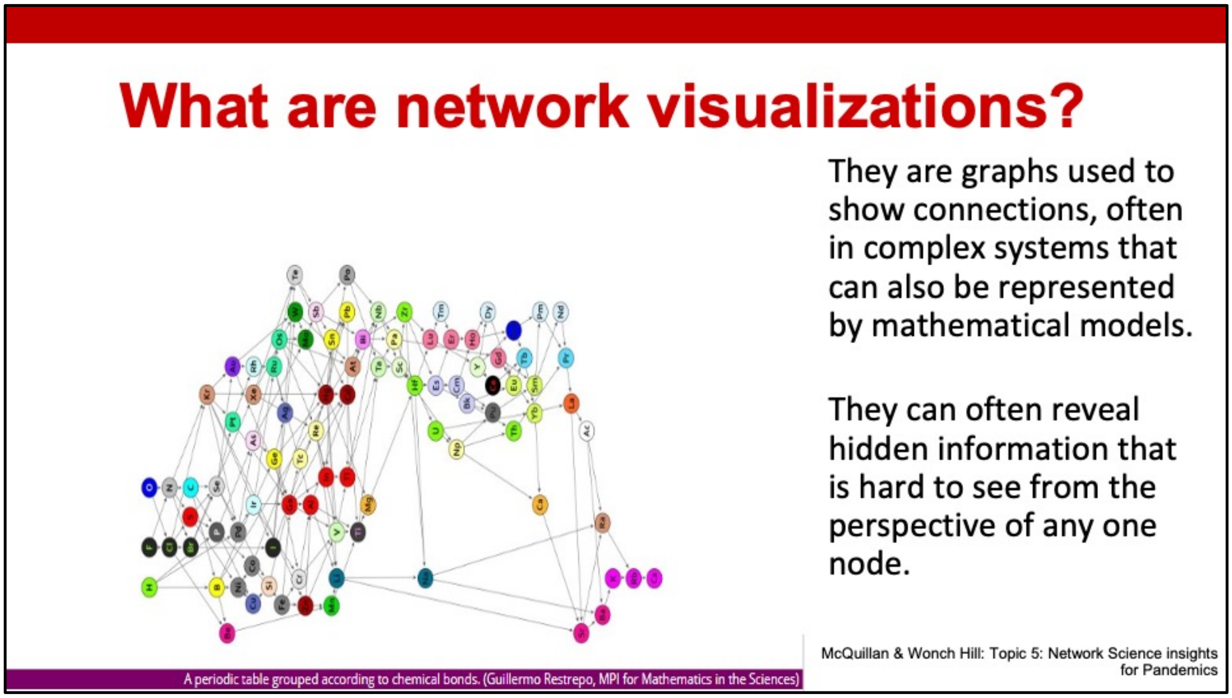
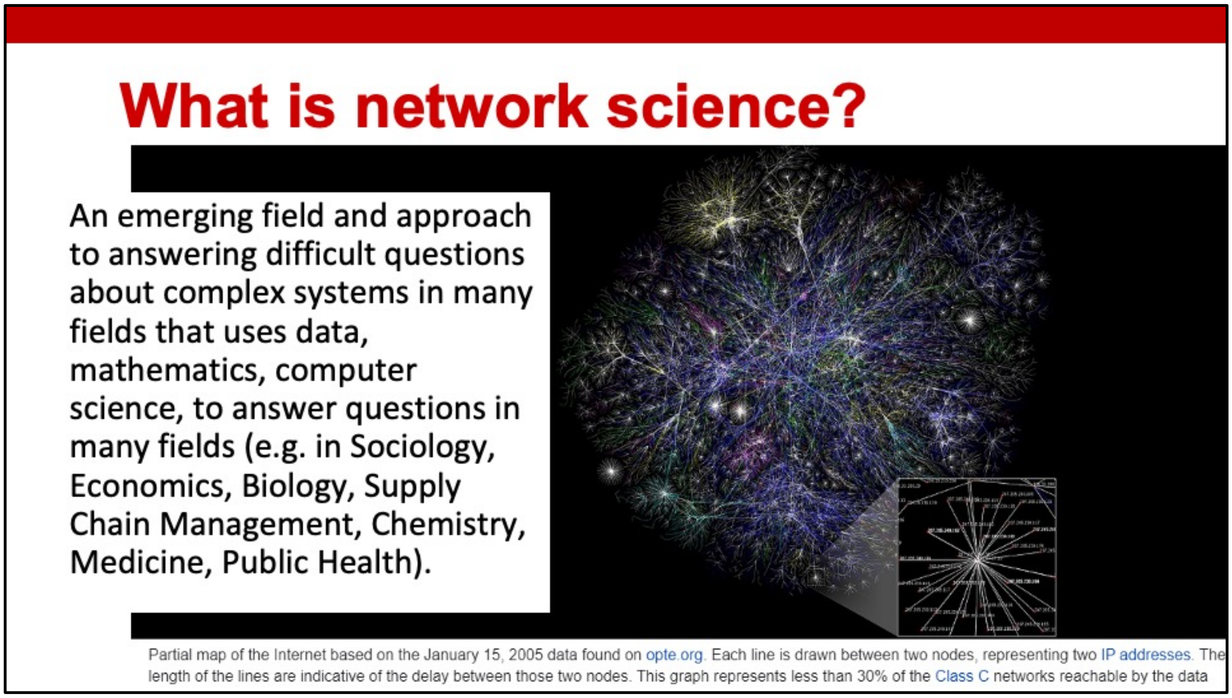
It is surprisingly hard to define networks. Fundamentally, they are about connections. It is useful to think about networks existing "out there" and how network scientists model/graph/draw and quantify networks to gain information and insights.



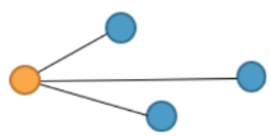
The image on this slide comes from an article about using network science to create a new way to visualize the periodic table of elements.



The image above is a representation of connections among web pages on the internet in 2005 (Erdős–Rényi model - Wikipedia).

Degree:

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



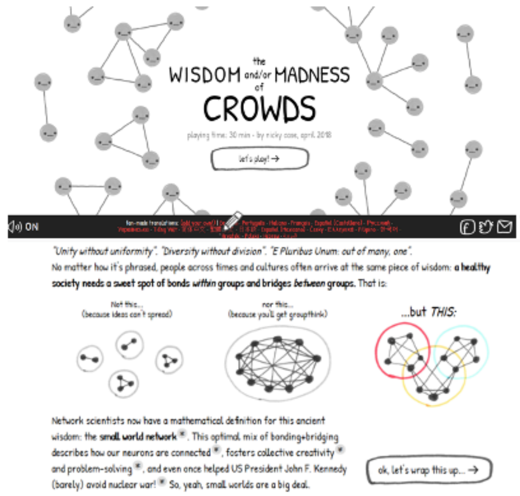
Hub:

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

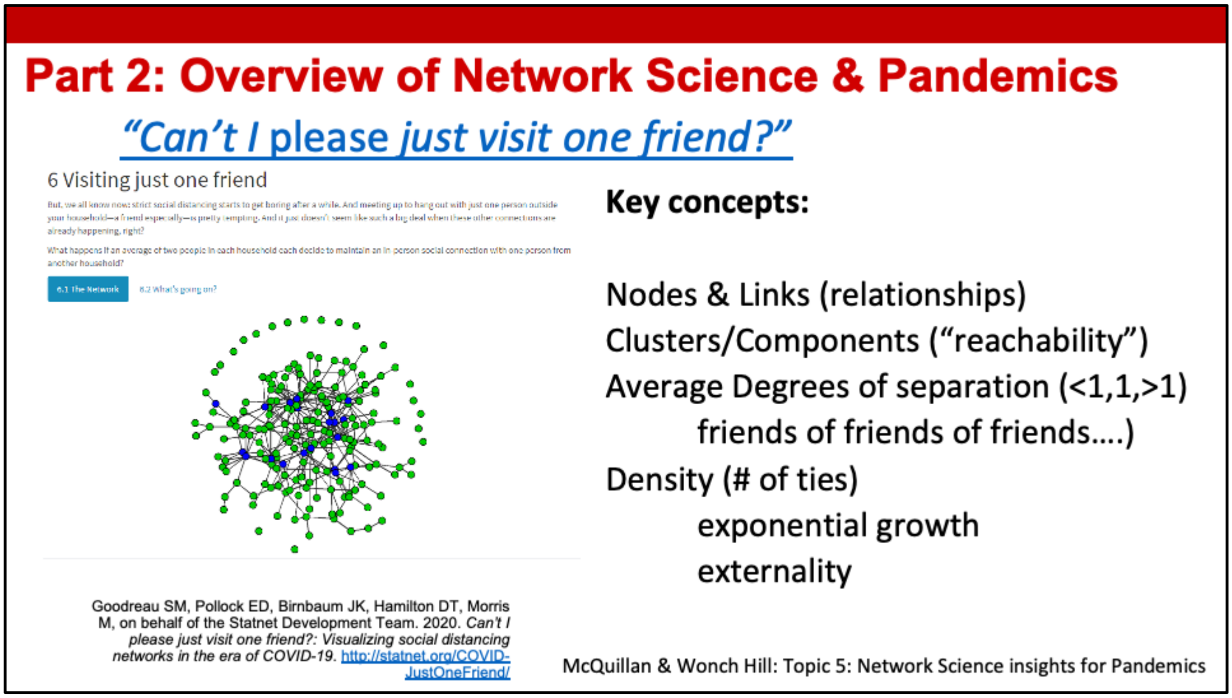
Nicky Case – [The Wisdom and/or Madness of Crowds](https://ncase.me/crowds/) highlights:

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

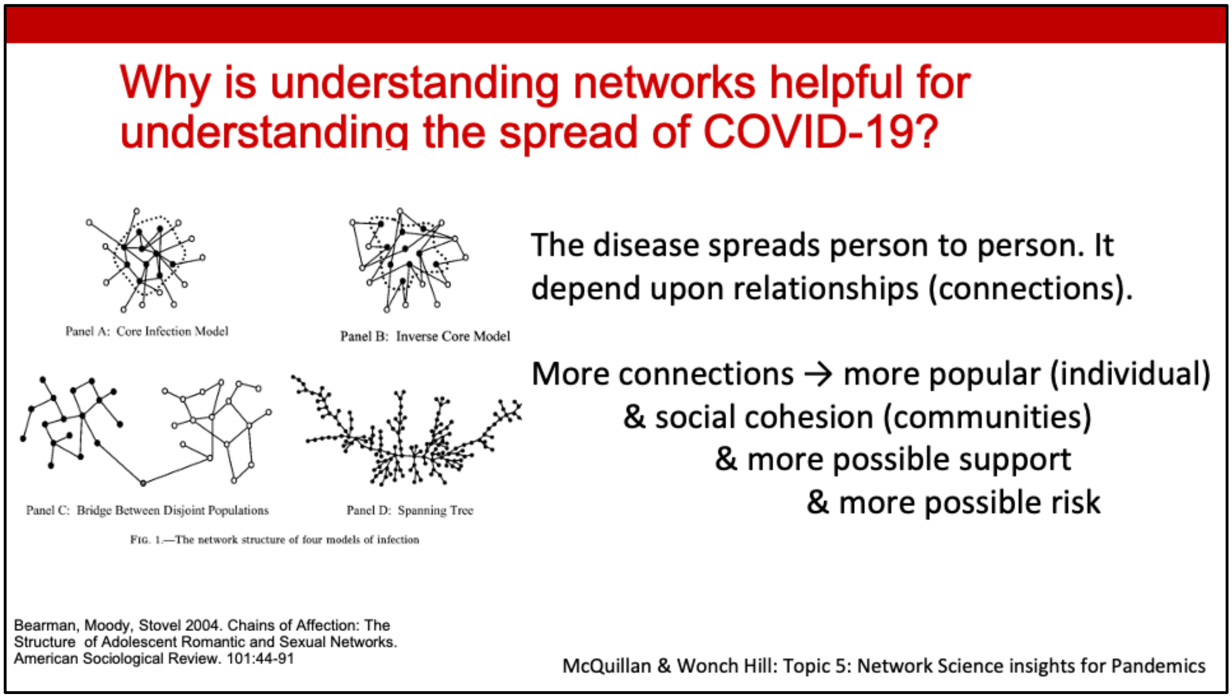


https://ncase.me/crowds/

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



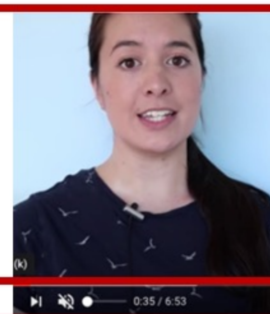
[Can't I please just visit one friend?](http://statnet.org/COVID-JustOneFriend/)



After doing the activities in the "Wisdom/Madness of Crowds" and reading "Can't I *please* just visit one friend?", answering the questions about the networks above should be easier. In the video for Part 3, the Youtube channel Up & Atom provides a quick and useful overview of the value of network science (and computation) for predicting why COVID-19 reaches more people in some communities compared to others, even when they have the same population size.

Topic 5: Network Science: Insights for Pandemics

Part 3: Up & Atom Video



Up & Atom

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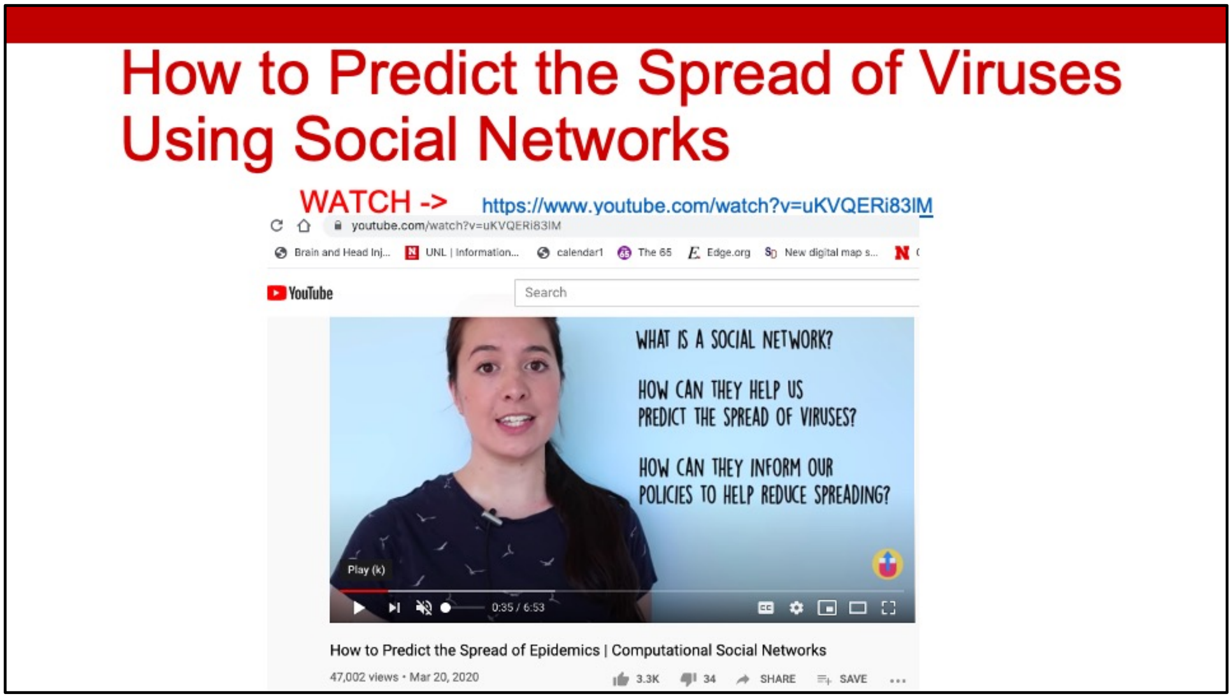
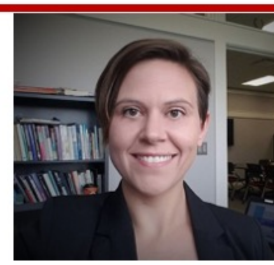


[How to Predict the Spread of Epidemics | Computational Social Networks](https://www.youtube.com/watch?v=uKVQERi83IM)

Topic 5: Network Science: Insights for Pandemics

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



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

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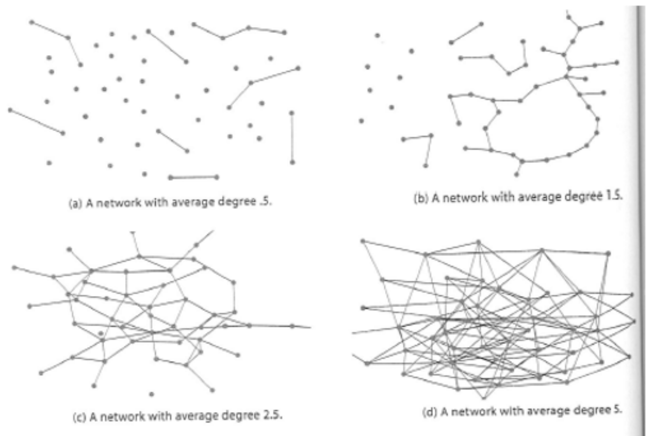
Phase Transition

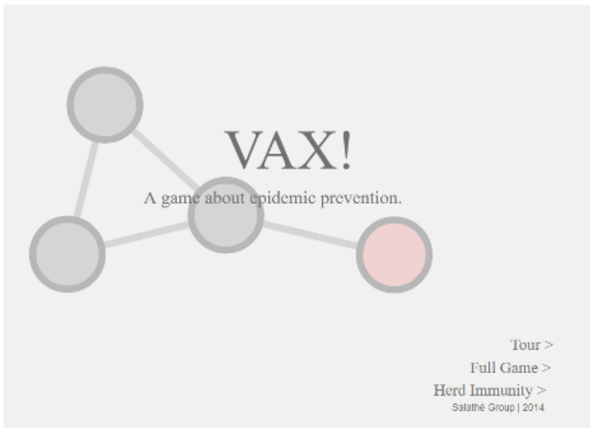
- Phase Transitions and Reproduction Rate – (Jackson, 2019, pg. 48-49)



[What Happens Next? COVID-19 Futures, Explained With Playable Simulations](https://ncase.me/covid-19/)

Externalities and VAX!

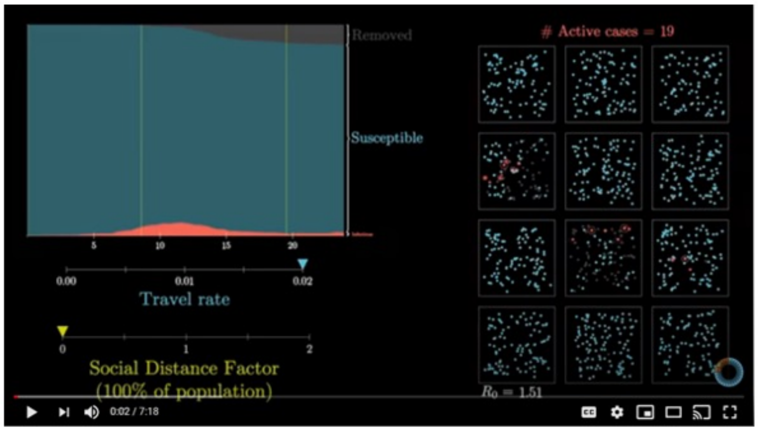
Link to game: https://vax.herokuapp.com/



https://vax.herokuapp.com/

(Optional) Video on Contact Tracing and Privacy

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



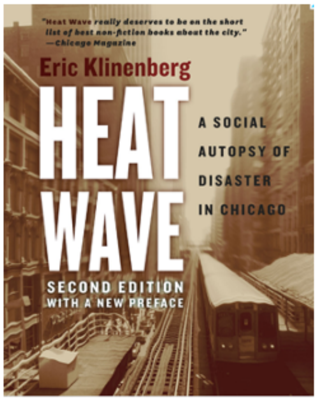
The DP-3T algorithm for contact tracing (via Nicky Case)

We hope you a have better understanding of how network science provides vital tools for containing contagious disease spread.

Takeaways:

- **People we do not know can have an impact on our health through people we do know.**
- **It can be hard to see the larger structure of network components (i.e. all the people we are connected to beyond our immediate connections).**
- **Using a variety of data sources (e.g. contact tracing, cellphones) to visualize the degree of connections among people improves efforts to stop the spread of infectious disease.**

Part 5: Conclusion – physically distant, socially connected



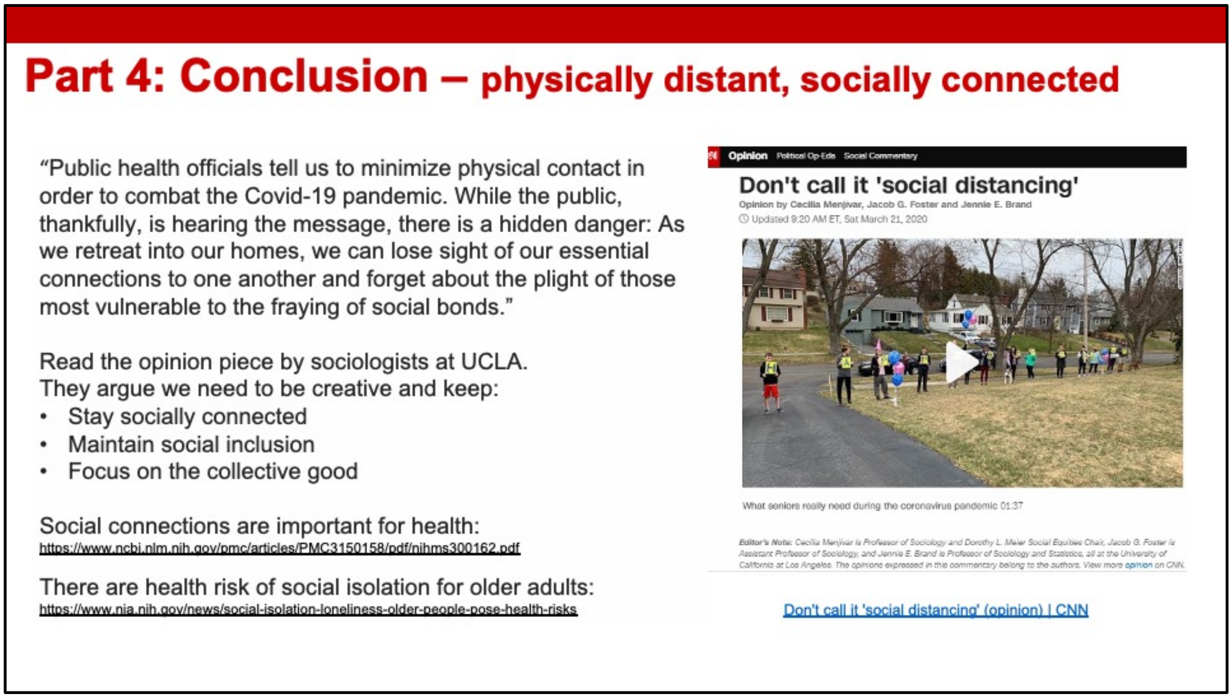
"Heat waves in the United States kill more people during a typical year than all other natural disasters combined. Until now, no one could explain either the overwhelming number or the heartbreaking manner of the deaths resulting from the 1995 Chicago heat wave. Meteorologists and medical scientists 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

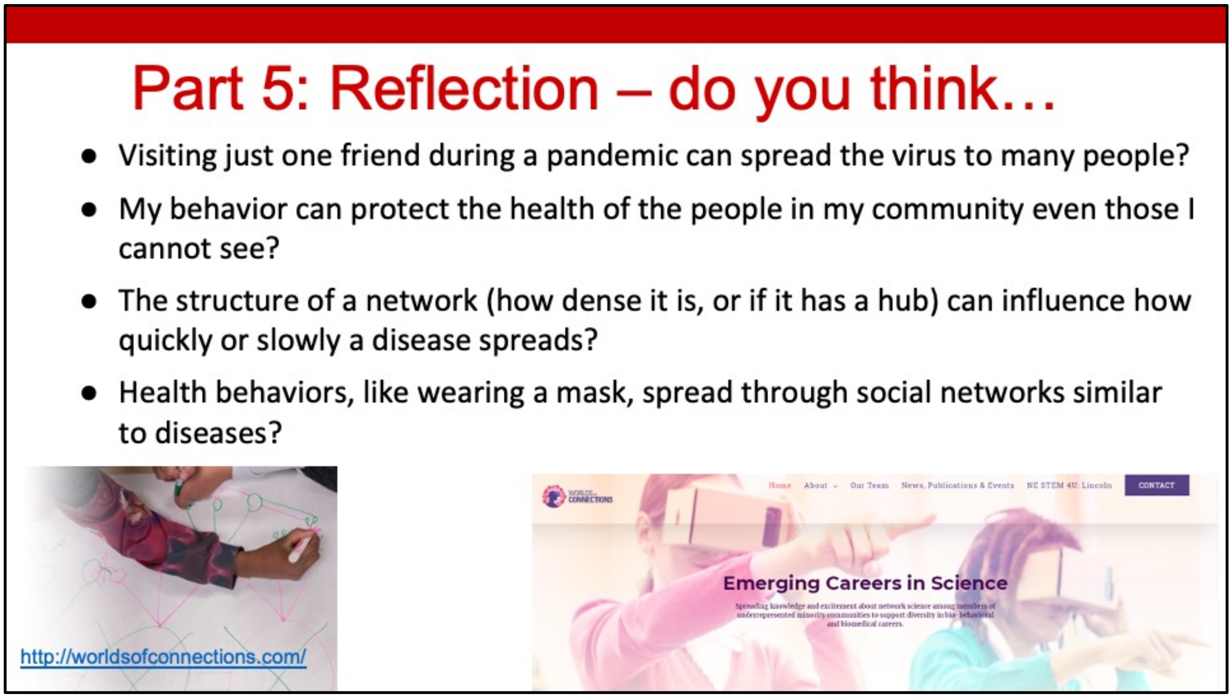
Much of the focus of network science is on modeling and analysis. The goal is to figure out how to break apart components. We are trying to slow the reachability from our contacts, our contacts' contacts, and so on (our friends' friends' friends). However, sociologists have also discovered how very important social connections are to health and and life. This slide provides brief quotes from Eric Klinenberg's exploration of why many more people died during a Chicago heat wave in some neighborhoods compared to others. We've bolded some key phrases – the idea is that people who others are connected to and have checking in on them were more likely to survive.

Humans need social connections for their well-being. Therefore, think of physical distancing and social connections—from a distance—check in on people, talk to them, listen, and support.



As we argued in the prior slide, staying socially connected is important for human health. You can learn more by reading the essay in the link from this slide about maintaining social connections.

<u>Reducing physical connections among people (e.g. physical distance, sheltering in place, handwashing, face masks) helps prevent the spread of viruses and it is important to still stay connected socially</u>



Based upon the knowledge that you gained about the virus from other sections and what you have learned about network science, we expect that you have information to help you reflect upon the questions on the slide.

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!

http://www.connectedthebook.com/

Thanks for participating in:

Network Science: insights for Pandemics

We hope you enjoy the rest of the class.

The End