

# 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



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# Topic 5: Network Science: Insights for Pandemics

## Part 1 Introduction



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# Introduction

## Who are we?

### Julia McQuillan



#### Willa Cather Professor and Department Chair

Sociology

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709 Oldfather Hall

<https://soc.unl.edu/julia-mcquillan>

### 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?

*World of VIRUSES*


2007 - 2012

[worldsofconnections.com](http://worldsofconnections.com)

*Biology of HUMAN*

2012 - 2018

[biologyofhuman.unl.edu](http://biologyofhuman.unl.edu)



**WORLDS OF CONNECTIONS**

2018 - 2023

[worldsofconnections.com](http://worldsofconnections.com)

Spreading knowledge and excitement about network science among members of underrepresented minority communities to support diversity in bio-behavioral and biomedical careers.

### WHAT IS NETWORK SCIENCE?

"The study of the collection, management, analysis, interpretation, and presentation of relational data." (Brodie et al 2013)

Some core ideas from Network Science Library (NetSciLib)

- Networks are everywhere. They describe how things connect and interact. They help reveal patterns through visualization.
- Today's computer technology allows you to study real-world networks.
- Network science can illuminate social forces that shape opportunities for health interventions.
- For NGSS, "K-12 science education should reflect the interconnected nature of science as it is practiced and experienced in the real world."

**REFERENCES**

Brodie, L.H.K., Gary Rodin, Ann MCDiarmid, and Zanay Williamson. 2010. *What is network science?* *Nature Science* 331: 41-5.

**AIM 1**

Improve understanding of how informal STEM experiences with network science in health research can increase STEM education, STEM pipeline values, and STEM career aspirations among 5-10th grade youth from diverse historically underrepresented in STEM disciplines at the center of health science research.

**AIM 2**

Create emerging media resources (e.g. e-newsletters) that help to introduce broad interest in and understanding of the role of network science in biomedical and public health research.

**Anticipated Project Outcomes & Communication Opportunities**

- A set of Network Science informed activities
- NE STEM 40 outreach club chapter at UNL
- Network Science Institute for 6-10th grade teachers
- Student wide network study of teacher communication sharing
- Systemic media stories (e-newsletters) that help to introduce broad interest in and understanding of network science for health
- Research publications

**IMPACT**

- Patterns of science decline over time
- Diffusion of science declines from clubs through middle school
- Science teacher knowledge during through networks
- Internal engagement in middle school and high school science coursework
- Comparison of Network Science and Biology teacher education and youth science pipeline values

**Long-term Outcomes**

- Assess the potential of Network Science to attract historically underrepresented youth to health research
- Increase the diversity of the Bio-Behavioral and Biomedical workforces
- Increase public awareness, interest, and understanding of Network Science for Health

**WOC INVESTIGATOR TEAM**

- Jella Michelman, WOC Principal Investigator (PI), Professor and Chair of Sociology at the University of Nebraska-Lincoln | [jmichel@unl.edu](mailto:jmichel@unl.edu)
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- Patrick Weach MB, WOC Co-Investigator, Interim Director of MERC, Assistant Professor of Sociology, University of Nebraska-Lincoln | [pweach@unl.edu](mailto:pweach@unl.edu)
- Rita Guzman, WOC Co-Investigator and Network Scientist, John G. Bruns Professor of Sociology, Director of REACH Lab, University of Nebraska-Lincoln | [rguzman@unl.edu](mailto:rguzman@unl.edu)
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**SEPA** SCIENCE EDUCATION PARTNERSHIP AWARD SUPPORTED BY THE NATIONAL INSTITUTES OF HEALTH

Acknowledgements: This research was supported in part by the World of Connections, Biology of Human, and Worlds of Connections projects funded by the National Institutes of Health through the Science Education Partnership Award (SEPA) program (grant numbers 5R01NS084000-01A1, 5R01NS084000-02A1, 5R01NS084000-03A1, and 5R01NS084000-04A1).




# Introduction

## Why Network Science & Viruses?

The screenshot shows the homepage of the Rural Drug Addiction Research Center (RDAR) at the University of Nebraska-Lincoln. At the top, the university name is displayed in red, along with a 'Log In' button and a search bar. Below this is the RDAR logo, a large red 'N', and the center's name. A red navigation bar contains links for 'About', 'Center Team', 'The LNC Facility', 'Current Projects', 'Research Opportunities', and 'Resources'. The main content area features a background image of a person in a field with a network overlay. A red banner at the bottom left contains the text 'RDAR From Synapse to Society' and a 'JOIN OUR MAILING LIST' button. A small URL '19.unl.edu/2019-novel-coronavirus-covid-19' is visible at the bottom left corner of the page.

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Log In  Search

**N** RURAL DRUG ADDICTION RESEARCH CENTER

≡ About Center Team The LNC Facility Current Projects Research Opportunities Resources

RDAR

**From Synapse to Society**

JOIN OUR MAILING LIST

19.unl.edu/2019-novel-coronavirus-covid-19

# Introduction

## Why Network Science & Viruses?

<https://worldofviruses.unl.edu/>

CONTACT SEARCH

World of VIRUSES Biology of HUMAN COVID-19

COVID-19 COMICS & APPS BOOKS & AUDIO MICROBE IMAGES CURRICULA & REVIEWS OMAHA SCI MEDIA RESEARCH & EVALUATION

MEET THE C'RONA CHARACTERS.

PROPERLY SOCIAL DISTANCED.

GRAFFITI MOUSE

BAT

SKATE GOAT

REPORTER FOX

CAT

SIX FEET APART.

PROFESSOR GREY

**C'RONA COMIX** BY BOB HALL





# Introduction

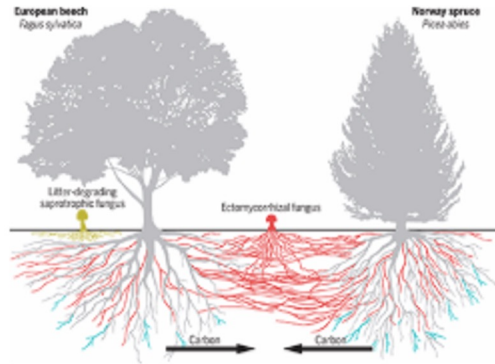
## Where can we find networks?

[Fly brain](#)

[Tree roots](#)

[Transportation maps \(& supply chains\)](#)

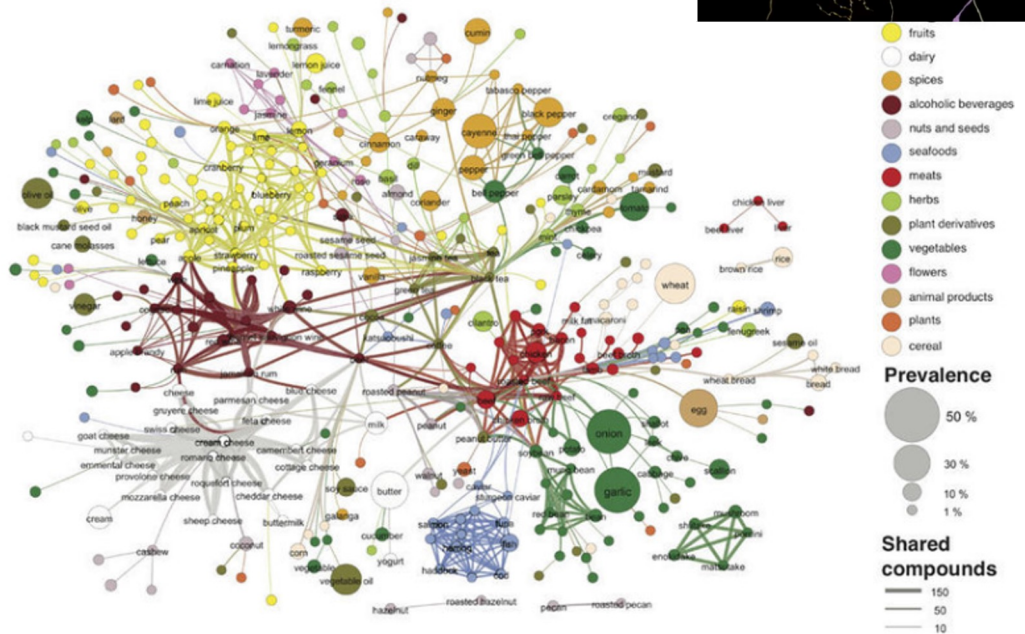
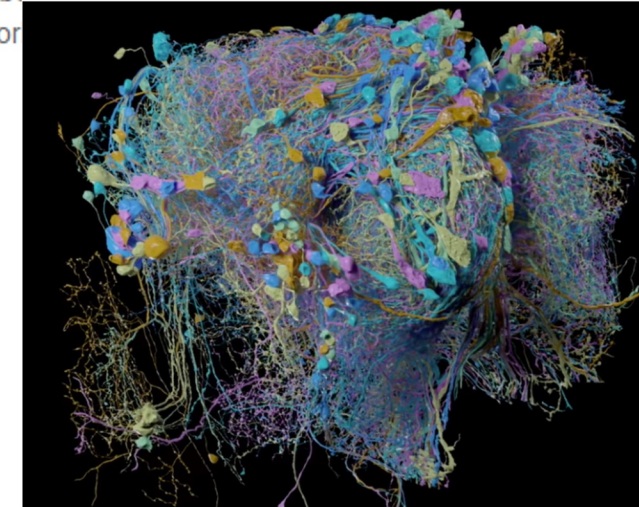
[Global flavor map](#)



## Underground networks.

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

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



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. Ahner, 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](#)

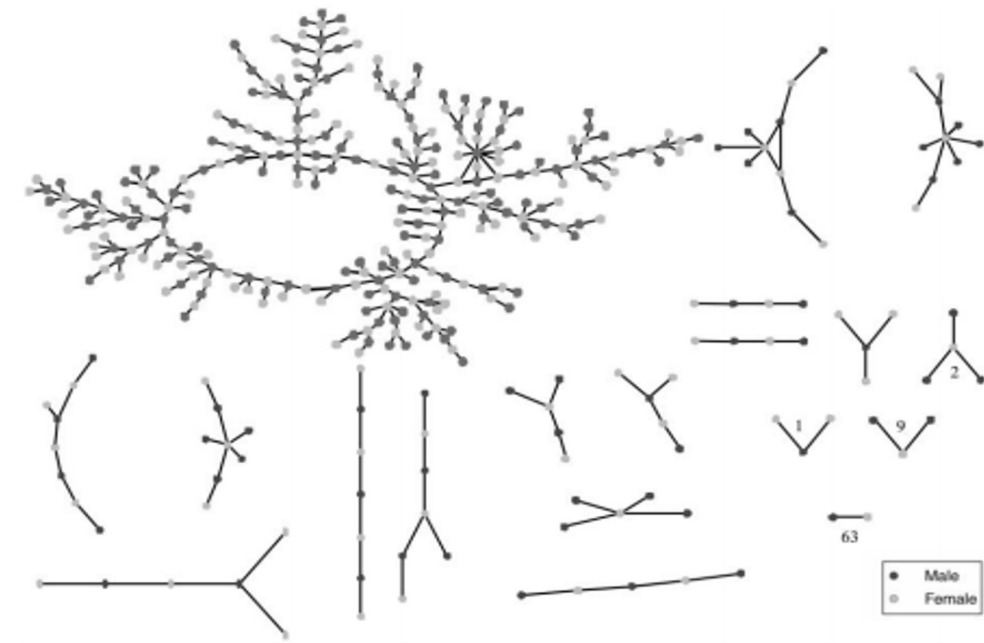
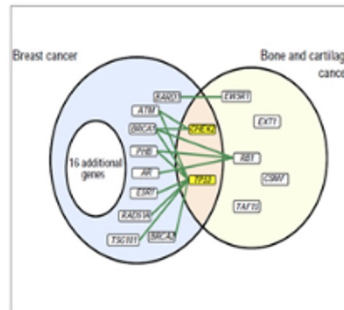
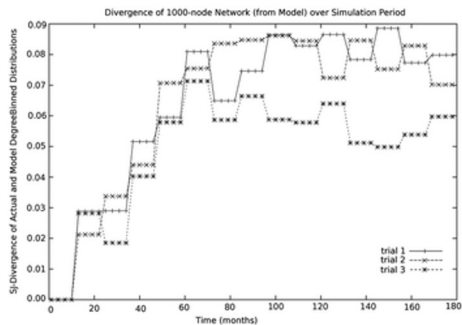


FIG. 2.—The direct relationship structure at Jefferson High



## Human disease network

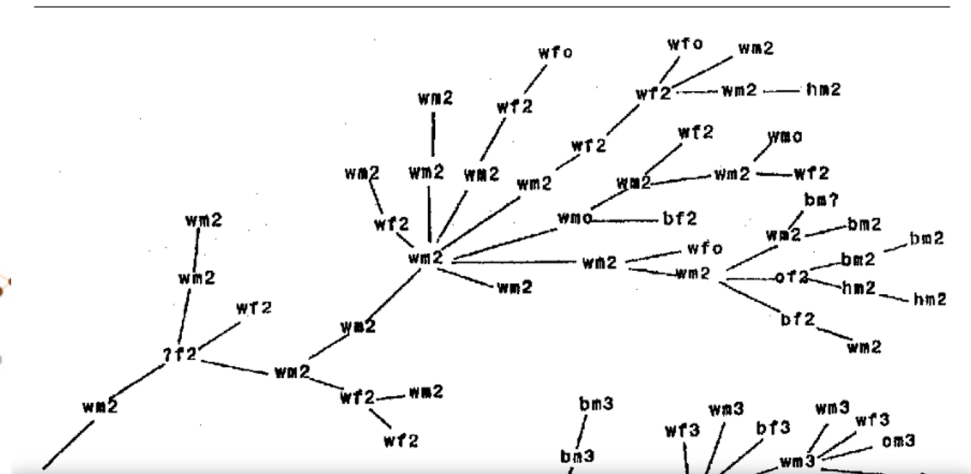
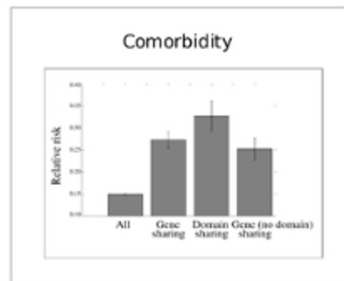
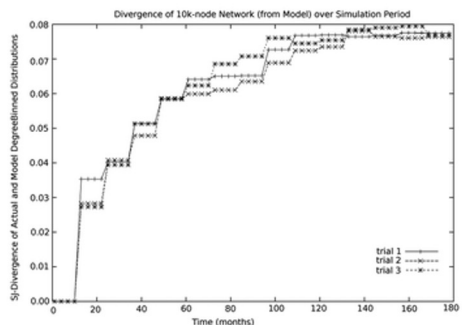
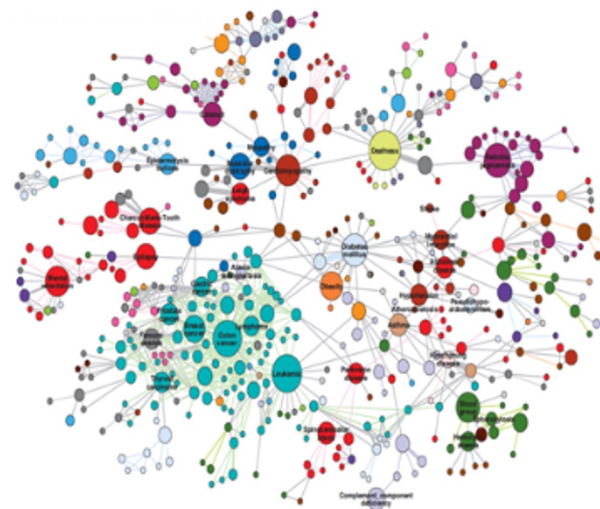


FIGURE 2

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](#)

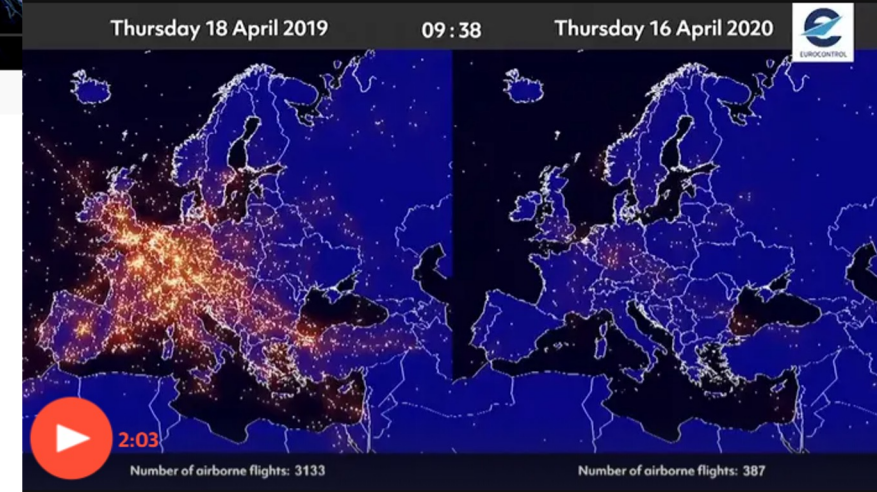
[How the Virus Got Out \(NYT\)](#)

[How the Virus Won \(NYT\)](#)



Air traffic before and after Europe's coronavirus lockdowns - video

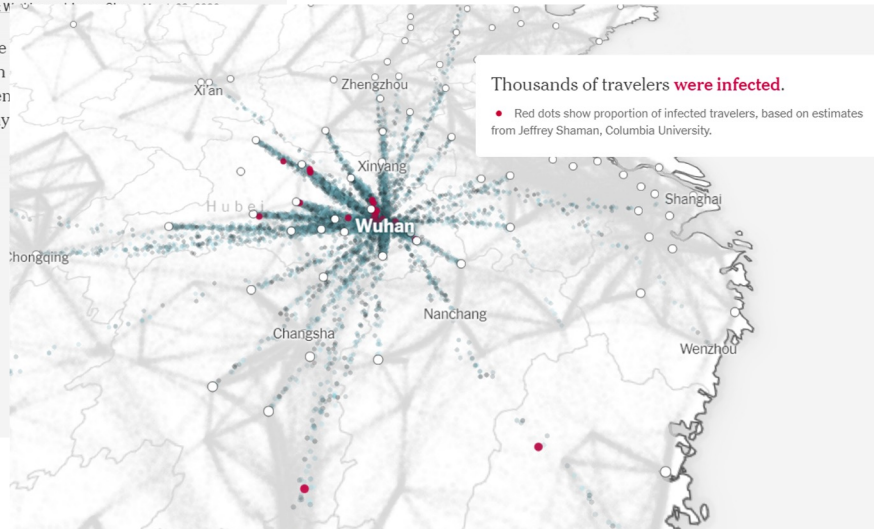
Flight Patterns



## How the Virus Got Out

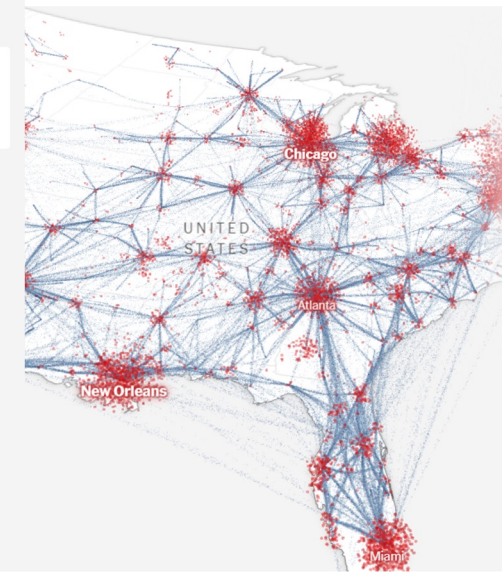
By Jin Wu, Welyi Cai, Derek Watkins

The most extensive outbreak in human history was analyzed to show how the virus spread.



Thousands of travelers were infected.

Red dots show proportion of infected travelers, based on estimates from Jeffrey Shaman, Columbia University.



## How the Virus Won

Invisible outbreaks sprang up everywhere. The United States ignored the warning signs. We analyzed travel patterns, hidden infections and genetic data to show how the epidemic spun out of control.

By Derek Watkins, Josh Holder, James Glanz, Welyi Cai, Benedict Carey and Jeremy White June 25, 2020

# 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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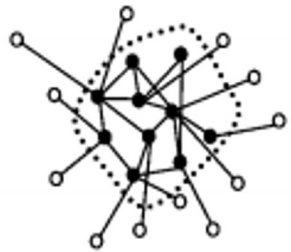
# Which node (circle) is best?

Imagine that the black circles contain...

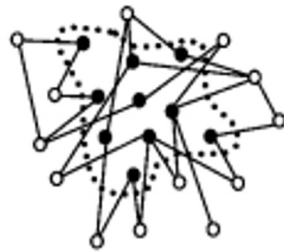
- A valuable secret
- Useful new technology
- A mask wearing habit
- A contagious disease

...and these can spread to the “white” circles

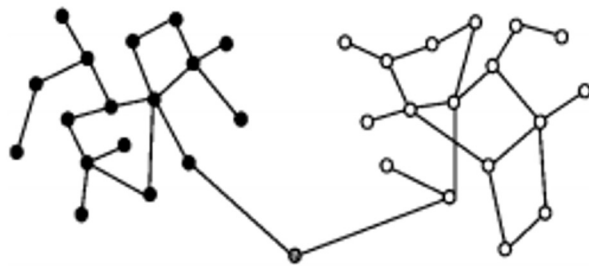
Where would you want to be in each of these networks?



Panel A: Core Infection Model



Panel B: Inverse Core Model



Panel C: Bridge Between Disjoint Populations



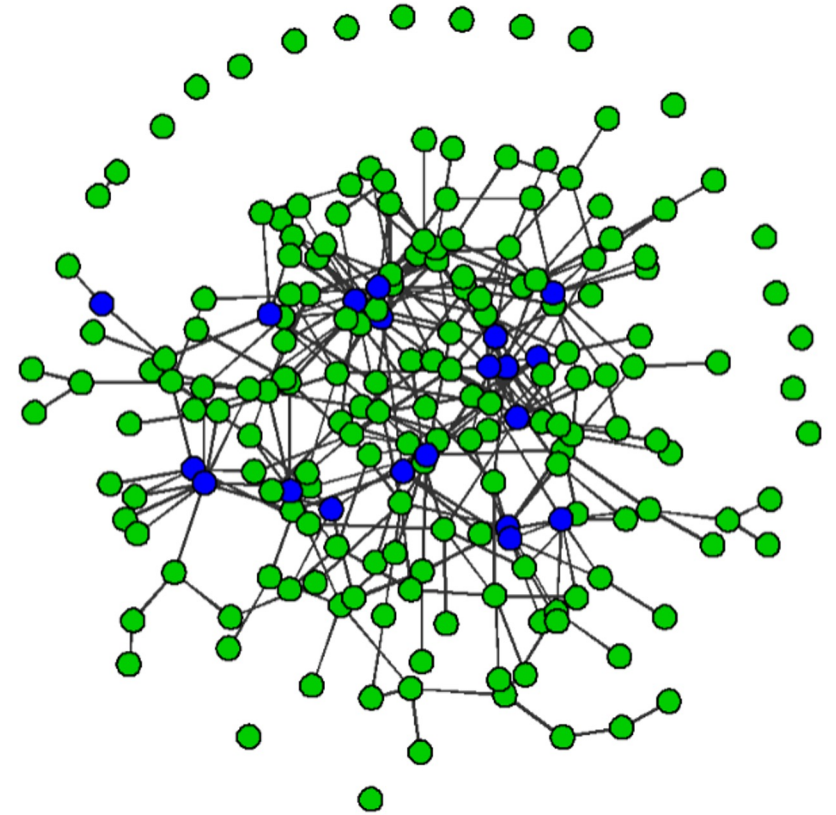
Panel D: Spanning Tree

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



# What are Networks?

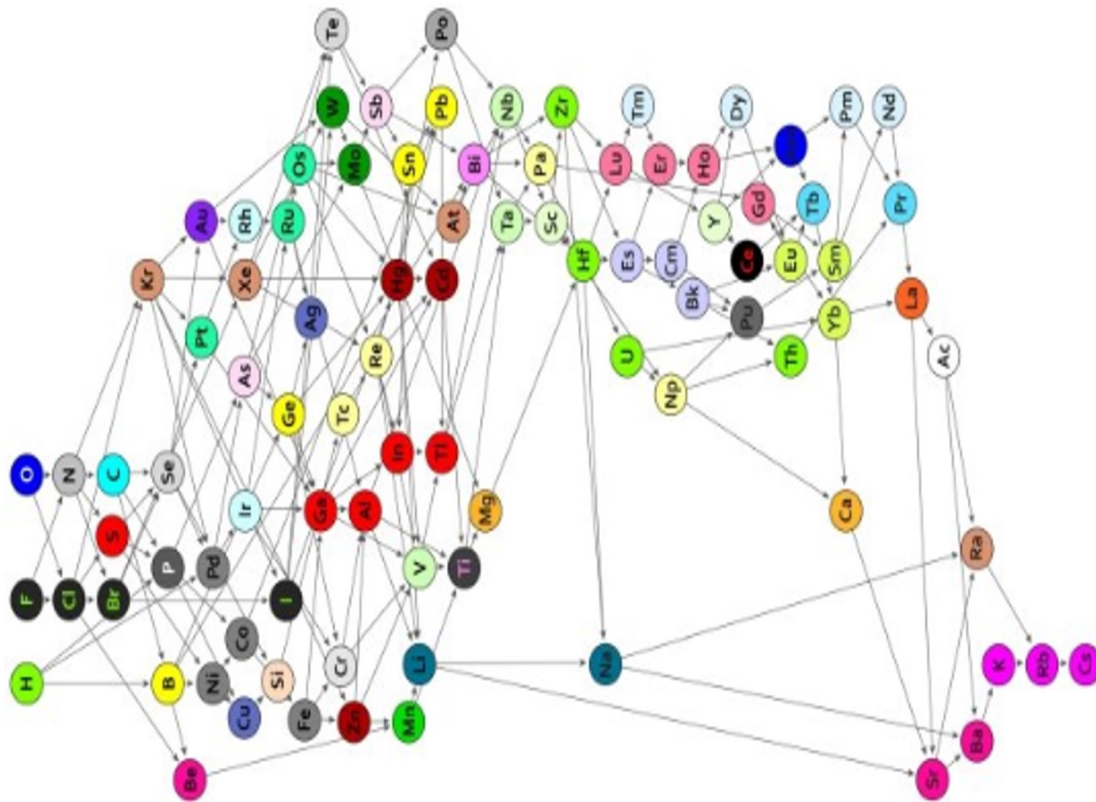
- 1) A set of relationships
- 2) Show how things are connected
- 3) Reveal hidden information
- 4) Provide tools for visualizing & studying complex systems  
illustrated by nodes/vertices  
(circles) & edges (lines)



# What are network visualizations?

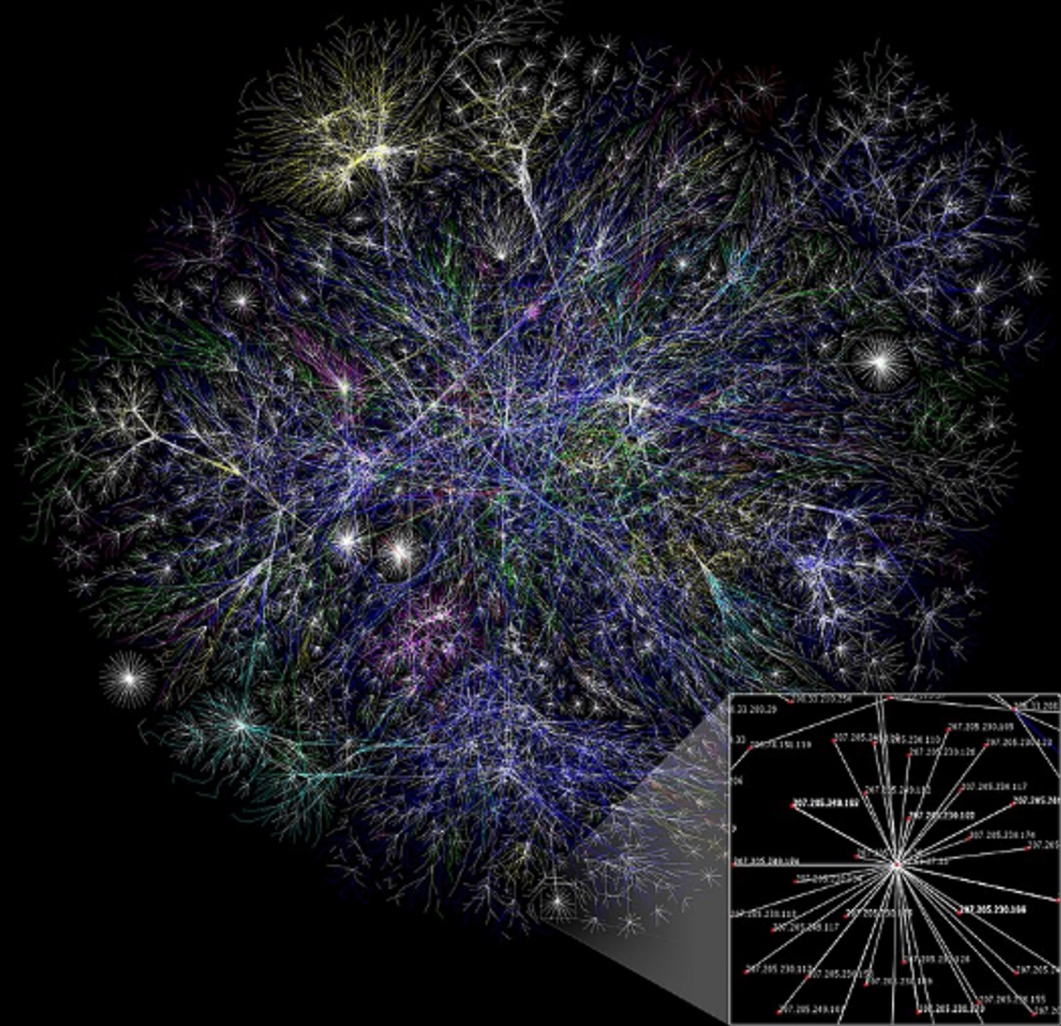
They are graphs used to show connections, often in complex systems that can also be represented by mathematical models.

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).

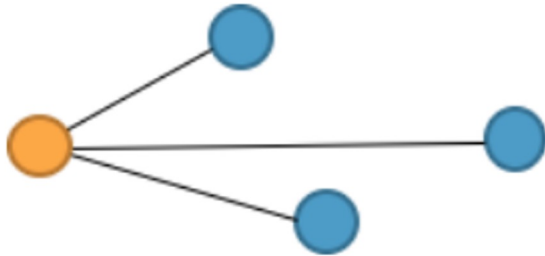


Partial map of the Internet based on the January 15, 2005 data found on [opte.org](http://opte.org). Each line is drawn between two nodes, representing two IP addresses. The length of the lines are indicative of the delay between those two nodes. This graph represents less than 30% of the Class C networks 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](#) highlights:

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

<https://ncase.me/crowds/>



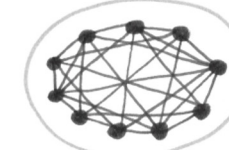
"Unity without uniformity". "Diversity without division". "E Pluribus Unum: out of many, one".

No matter how it's phrased, people across times and cultures often arrive at the same piece of wisdom: **a healthy society needs a sweet spot of bonds *within* groups and bridges *between* groups.** That is:

Not this...  
(because ideas can't spread)



nor this...  
(because you'll get groupthink)



...but **THIS:**



Network scientists now have a mathematical definition for this ancient wisdom: the **small world network** \*. This optimal mix of bonding+bridging describes how our neurons are connected \*, fosters collective creativity \* and problem-solving \*, and even once helped US President John F. Kennedy (barely) avoid nuclear war! \* So, yeah, small worlds are a big deal.

ok, let's wrap this up... →

# Part 2: Overview of Network Science & Pandemics

## “Can’t I please just visit one friend?”

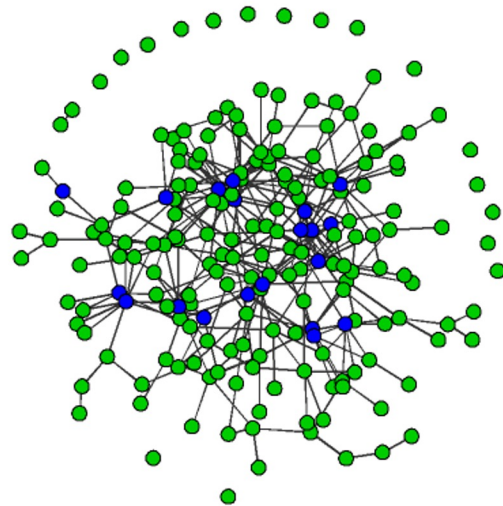
### 6 Visiting just one friend

But, we all know now: strict social distancing starts to get boring after a while. And meeting up to hang out with just one person outside your household—a friend especially—is pretty tempting. And it just doesn’t seem like such a big deal when these other connections are already happening, right?

What happens if an average of two people in each household each decide to maintain an in-person social connection with one person from another household?

6.1 The Network

6.2 What’s going on?



### Key concepts:

Nodes & Links (relationships)

Clusters/Components (“reachability”)

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

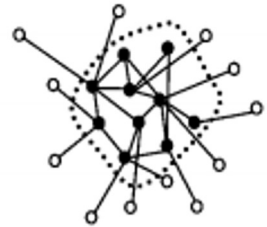
Density (# of ties)

exponential growth

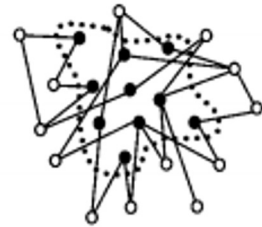
externality

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/>

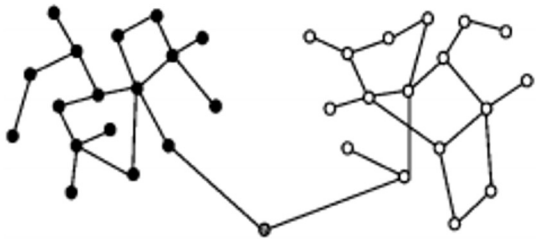
# Why is understanding networks helpful for understanding the spread of COVID-19?



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

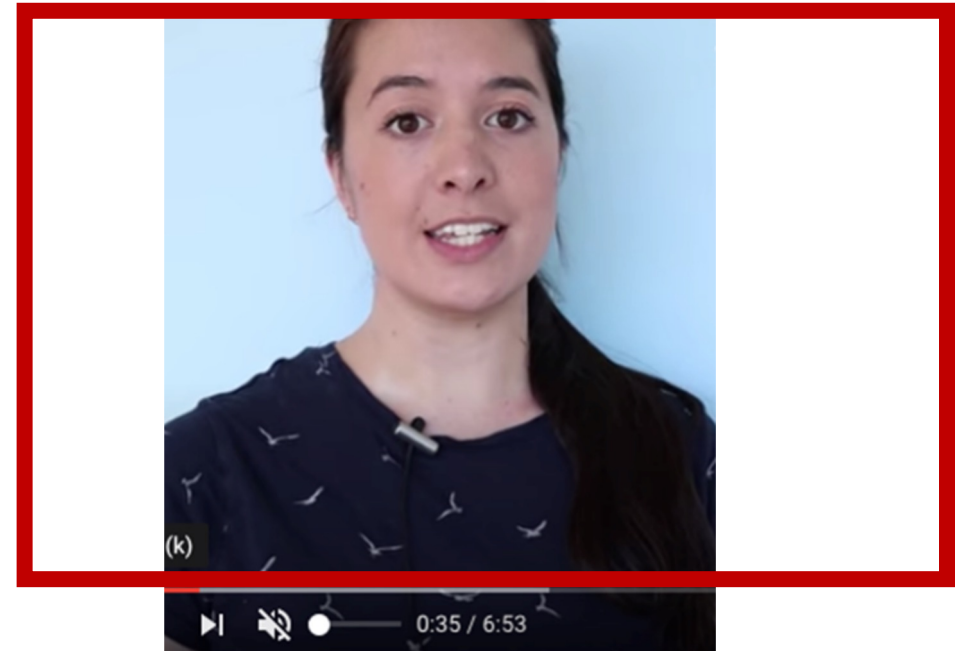
The disease spreads person to person. It depend upon relationships (connections).

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



Topic 5: Network Science: Insights  
for Pandemics

# Part 3: Up & Atom Video



Up & Atom

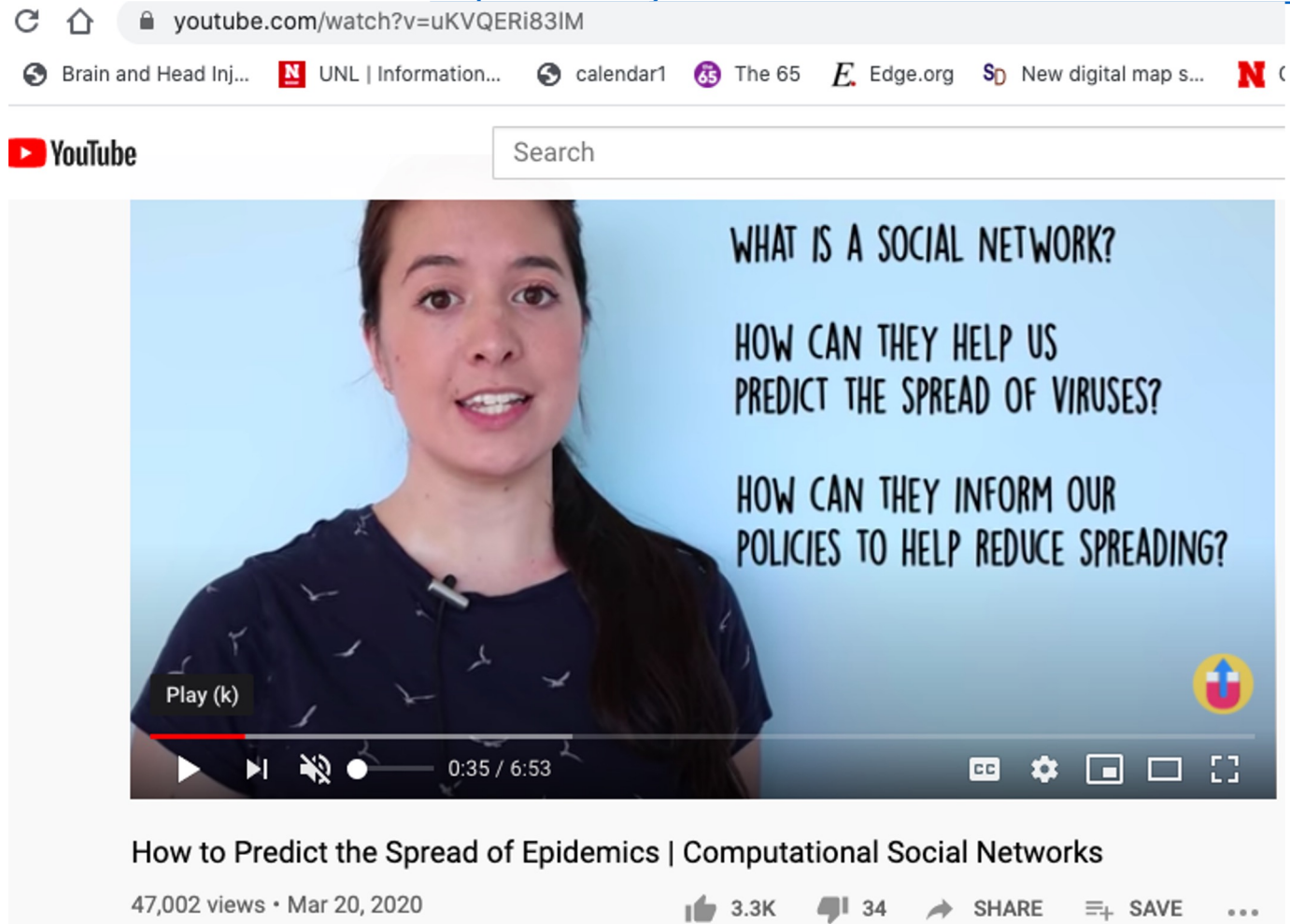
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# How to Predict the Spread of Viruses Using Social Networks

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



Brain and Head Inj... UNL | Information... calendar1 The 65 Edge.org New digital map s... N C

YouTube Search

WHAT IS A SOCIAL NETWORK?  
HOW CAN THEY HELP US PREDICT THE SPREAD OF VIRUSES?  
HOW CAN THEY INFORM OUR POLICIES TO HELP REDUCE SPREADING?

Play (k) 0:35 / 6:53

How to Predict the Spread of Epidemics | Computational Social Networks

47,002 views · Mar 20, 2020

3.3K 34 SHARE SAVE ...

Topic 5: Network Science: Insights for  
Pandemics

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



Trish Wonch Hill

Department of Sociology

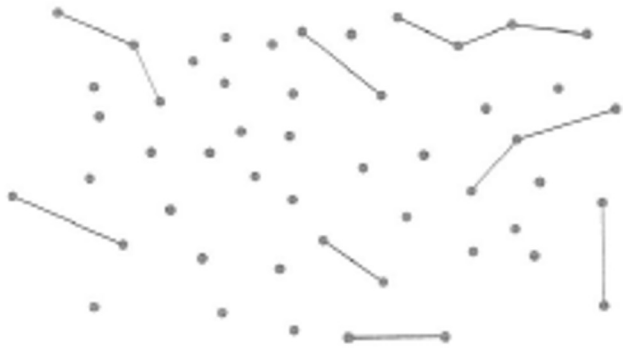
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# Phase Transition

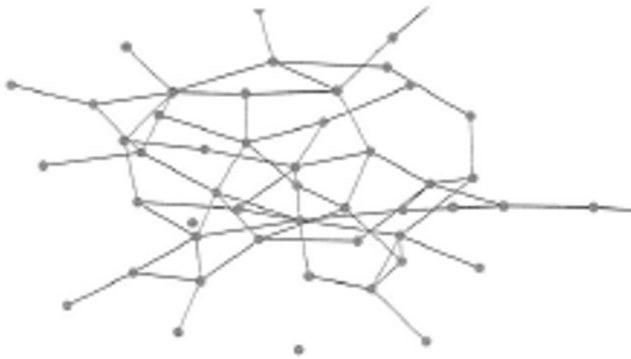
- Phase Transitions and Reproduction Rate – (Jackson, 2019, pg. 48-49)



(a) A network with average degree .5.



(b) A network with average degré 1.5.



(c) A network with average degree 2.5.

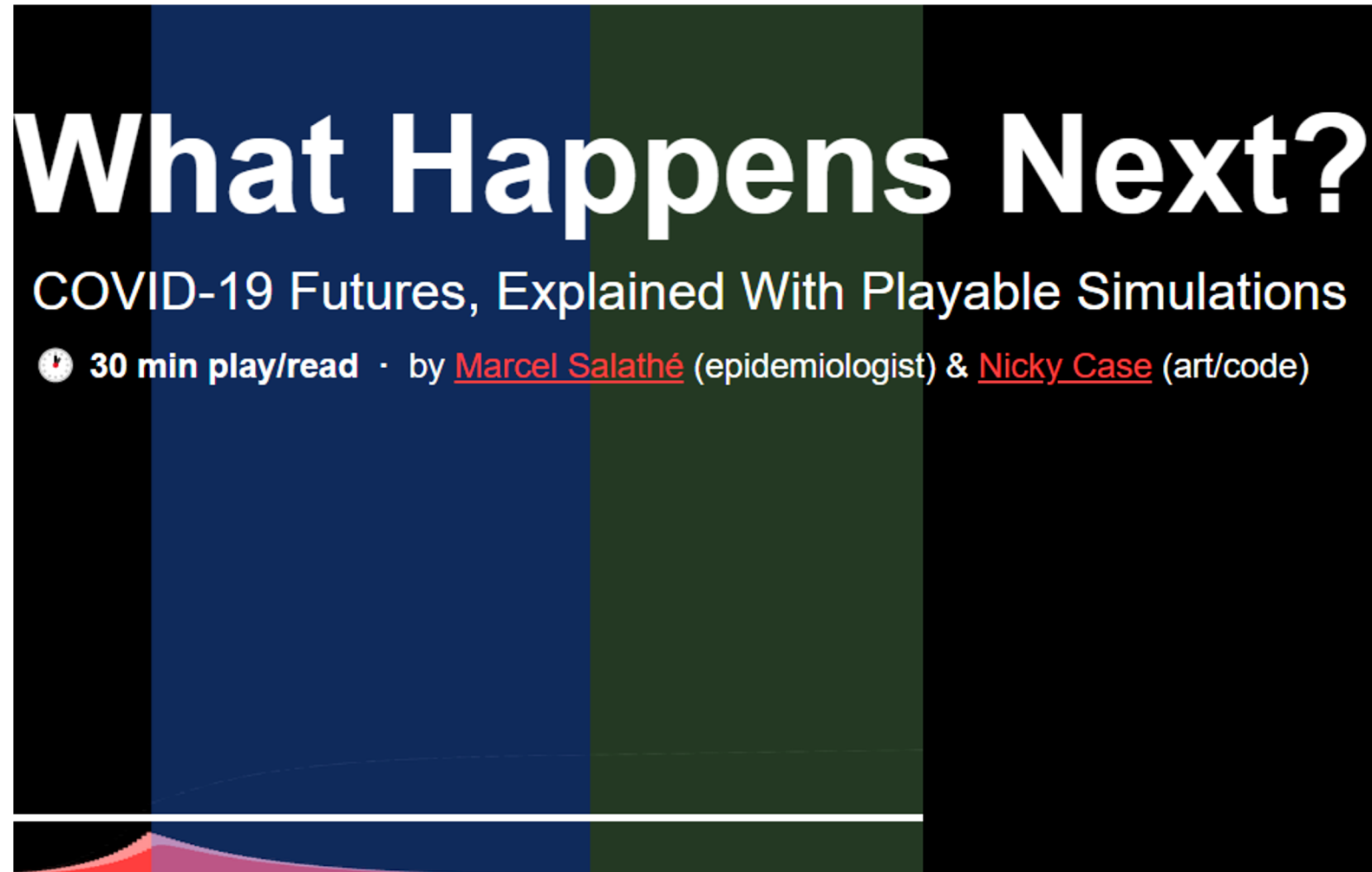


(d) A network with average degree 5.



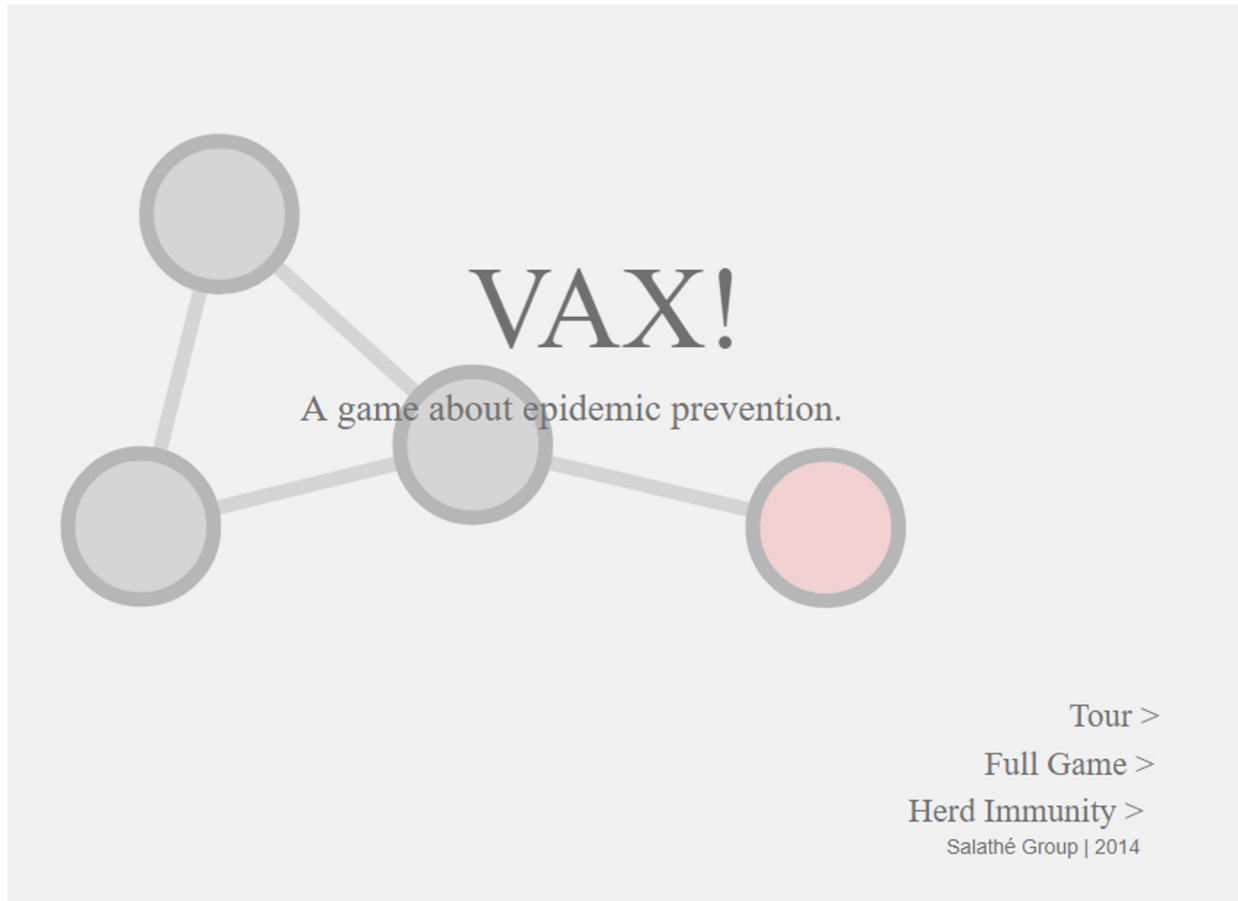
# Reproduction Rate and Externalities

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



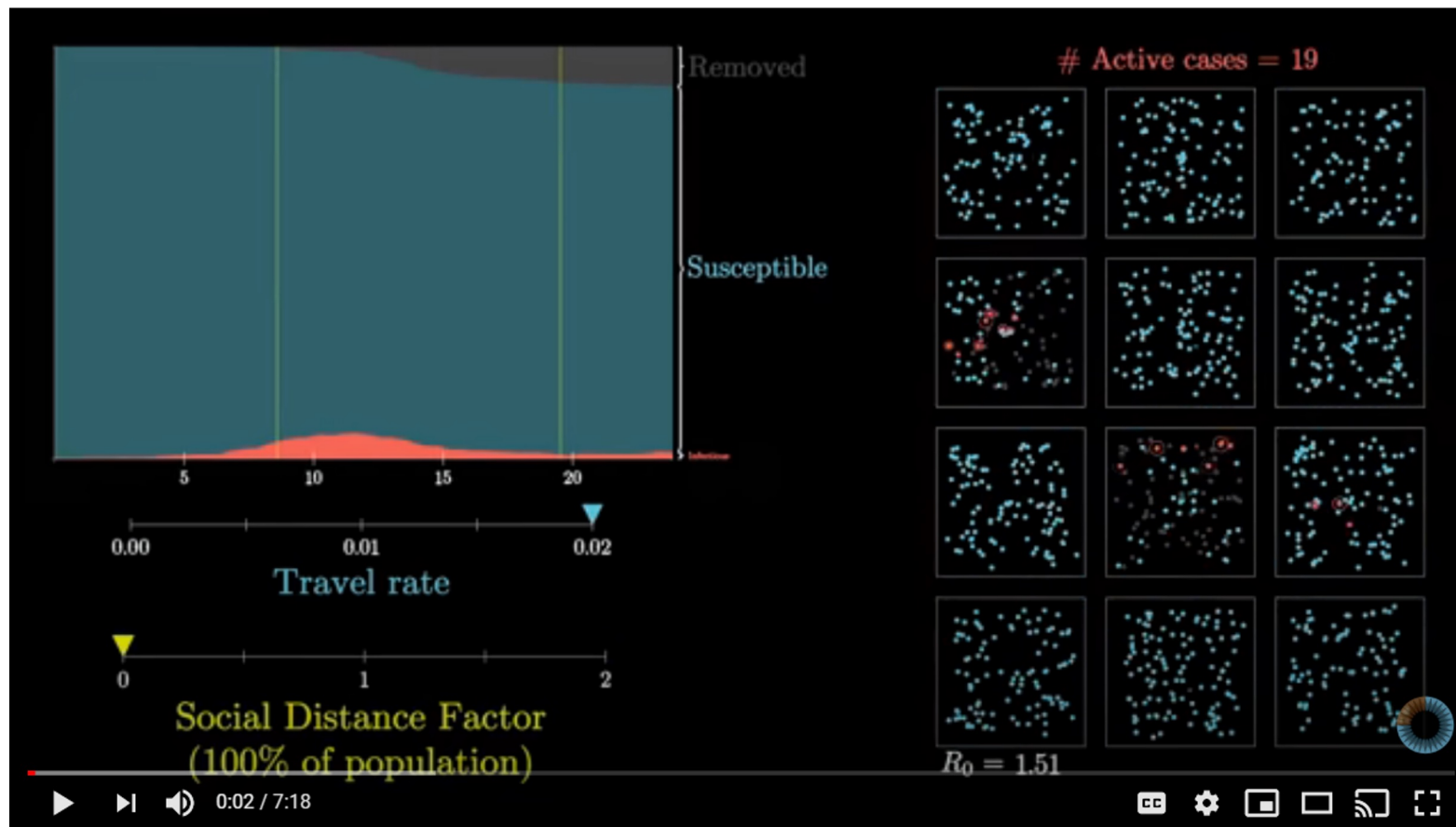
# Externalities and VAX!

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



# (Optional) Video on Contact Tracing and Privacy

[https://www.youtube.com/watch?v=D\\_UaR5MQao](https://www.youtube.com/watch?v=D_UaR5MQao)



# Topic 5: Network Science: Insights for Pandemics

## Part 5: Conclusion

Julia McQuillan & Trish Wonch Hill  
Department of Sociology

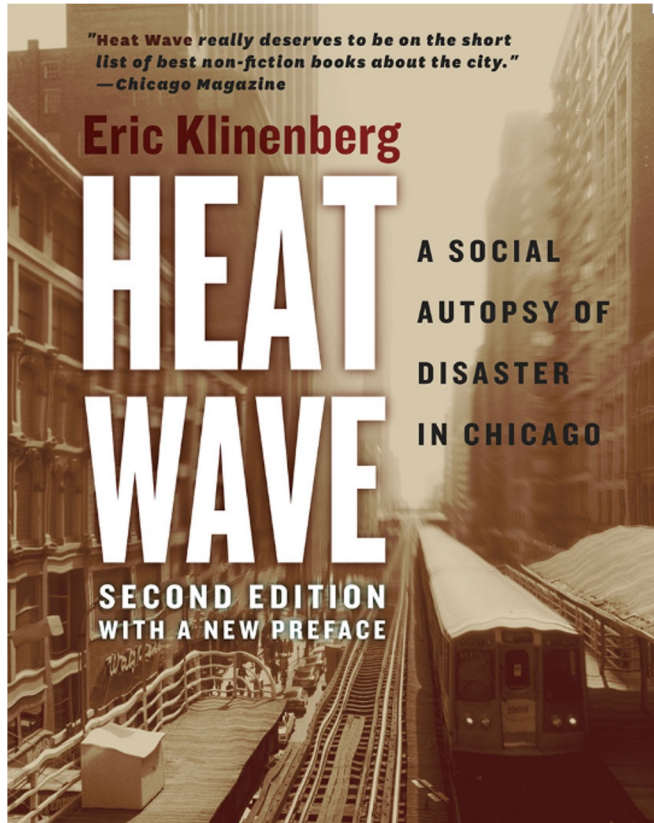
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# Part 5: Conclusion – physically distant, socially connected



“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.**”

# 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>

Opinion Political Op-Eds Social Commentary

## Don't call it 'social distancing'

Opinion by Cecilia Menjivar, Jacob G. Foster and Jennie E. Brand

Updated 9:20 AM ET, Sat March 21, 2020



What seniors really need during the coronavirus pandemic 01:37

*Editor's Note: Cecilia Menjivar is Professor of Sociology and Dorothy L. Meier Social Equities Chair, Jacob G. Foster is Assistant Professor of Sociology, and Jennie E. Brand is Professor of Sociology and Statistics, all at the University of California at Los Angeles. The opinions expressed in this commentary belong to the authors. View more [opinion](#) on CNN.*

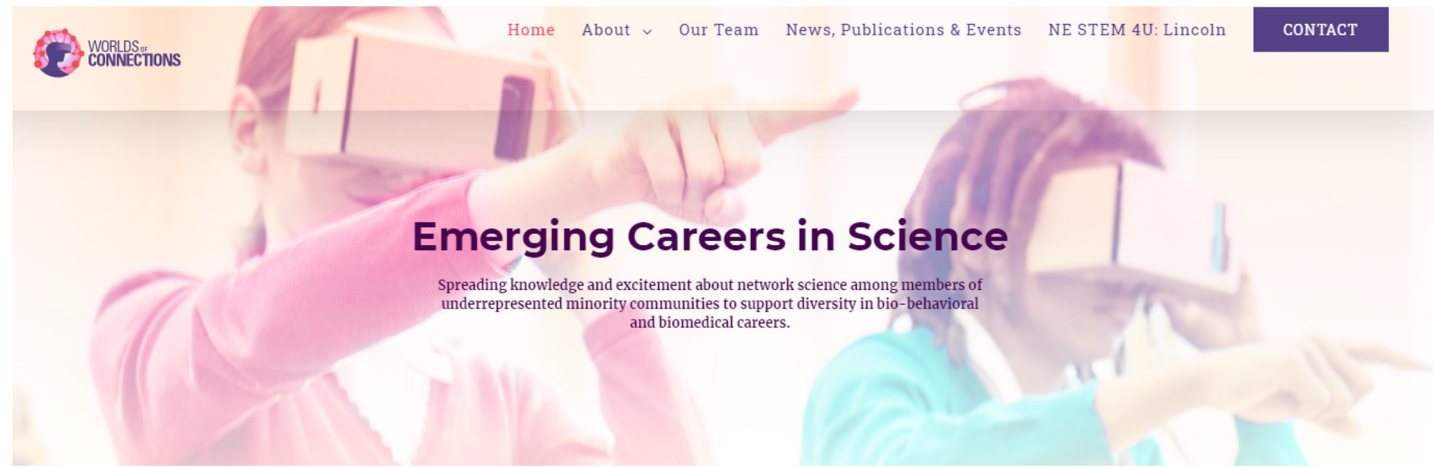
[Don't call it 'social distancing' \(opinion\) | CNN](#)

# 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?



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# 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