Hot Science Cool Talks

UT Environmental Science Institute

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Fighting Deadly Diseases: Strategies for Prediction and Containment

Dr. Lauren Ancel Meyers

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Fighting Deadly Diseases

Strategies for Prediction and Containment

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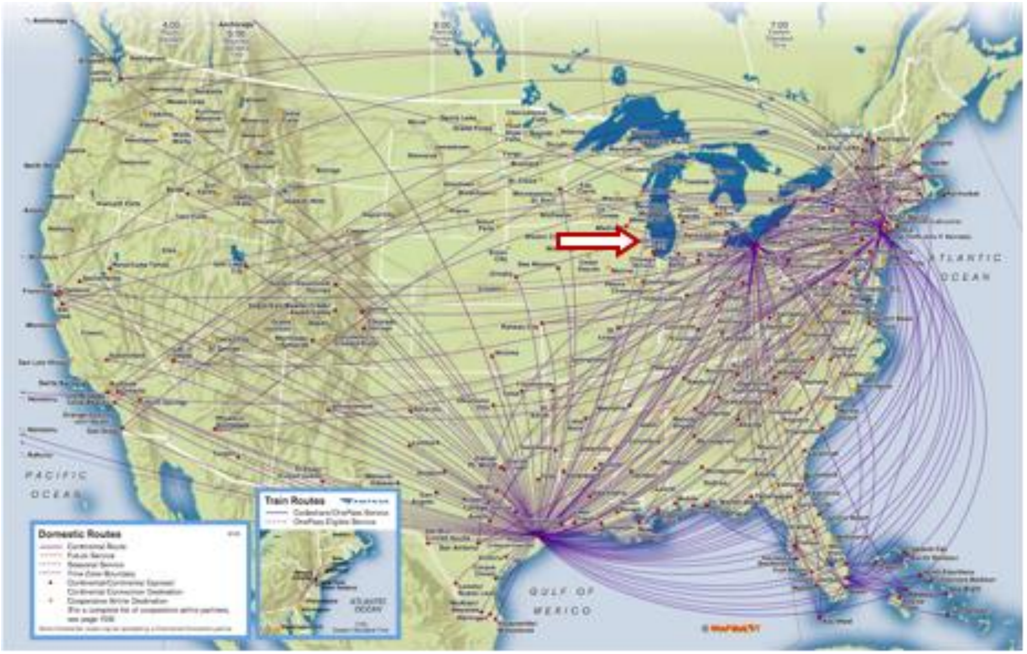
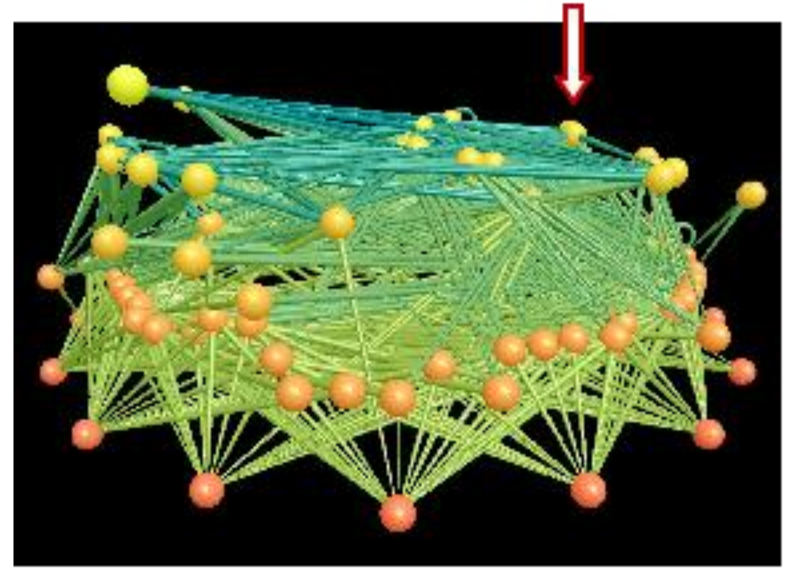
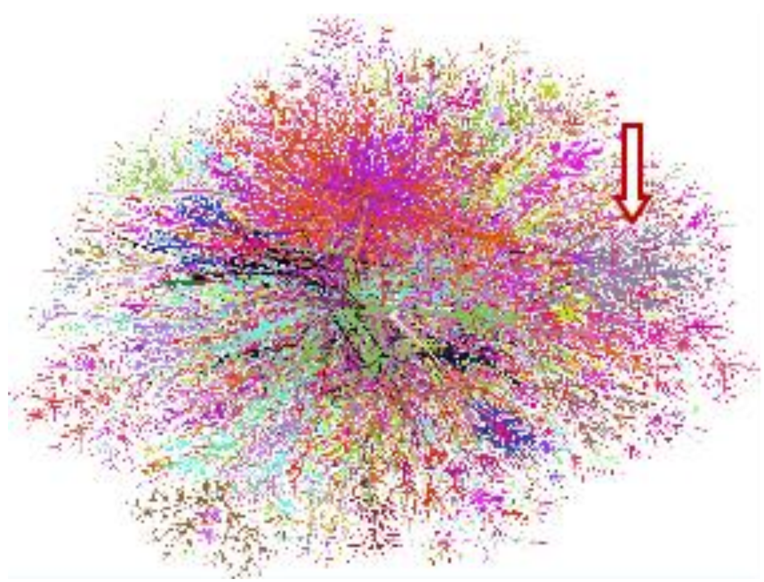
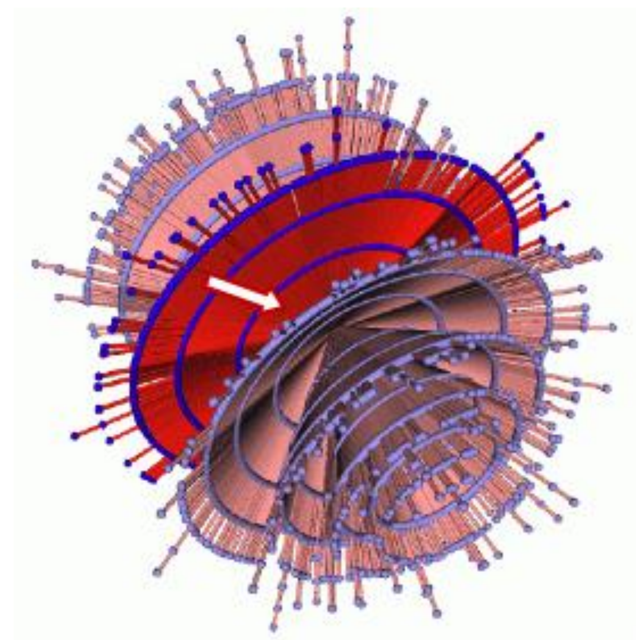
University of Texas at Austin
Santa Fe Institute


ATLANTIC OCEAN
PACIFIC OCEAN
GULF OF MEXICO
Domestic Routes
Train Routes







Tonight …

I. Infectious diseases, past and present

II. How math helps us fight disease

III. Disease transmission networks

IV. Who gets the flu shot?

An **epidemiologist** studies the patterns, causes, and control of disease in groups of people.

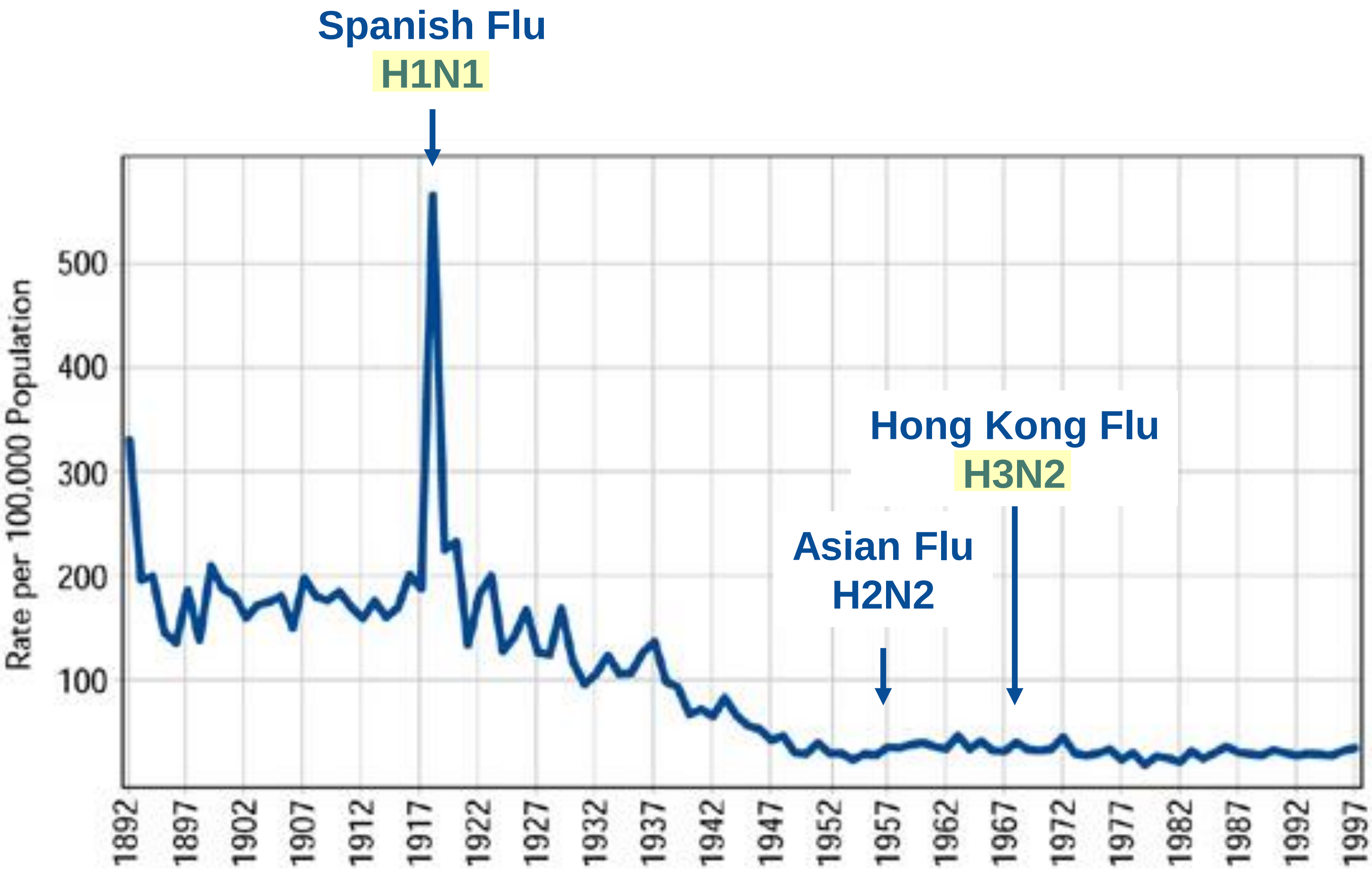
Modes of Transmission

Vector-borne (fleas)

Water-borne

Contact

Sex/Needles



Spanish Flu
H1N1
Hong Kong Flu
H3N2
Asian Flu
H2N2
Rate per 100,000 Population
500
400
300
200
100
1892
1897
1902
1907
1912
1917
1922
1927
1932
1937
1942
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997

Mills (2000)

"I simply wish that, in a matter which so closely concerns the wellbeing of the human race, no decision shall be made without all the knowledge which a little analysis and calculation can provide"

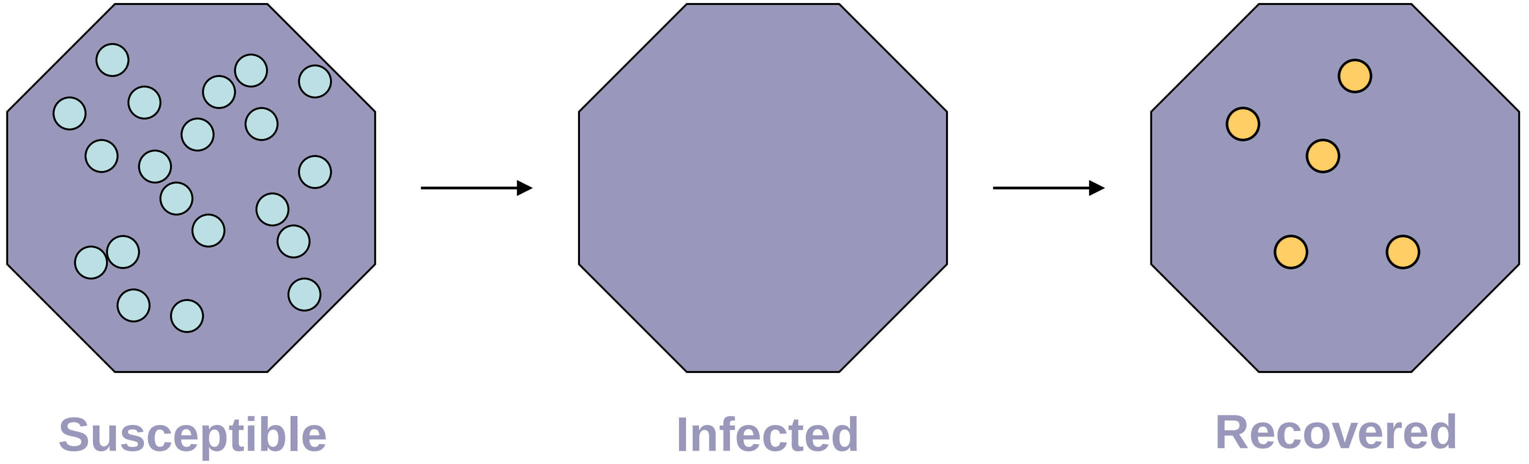
- Daniel Bernoulli 1760

Smallpox in the 18th century …

- 3/4 of all people had been infected
- Typically caught in first 5 years of life
- Killed 20-30% of individuals infected
- 1/10 of all mortality due to smallpox

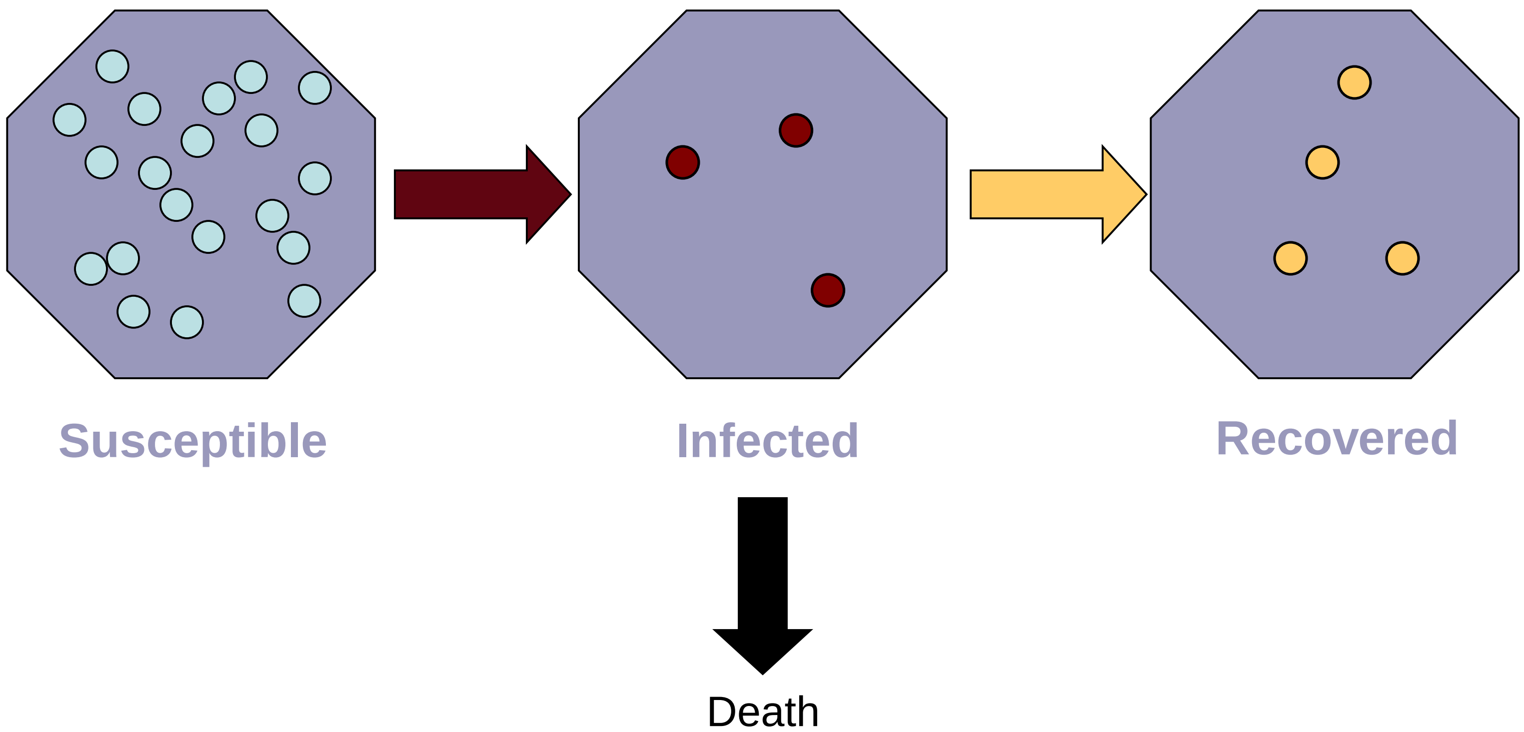
The 20th century …

Compartmental models



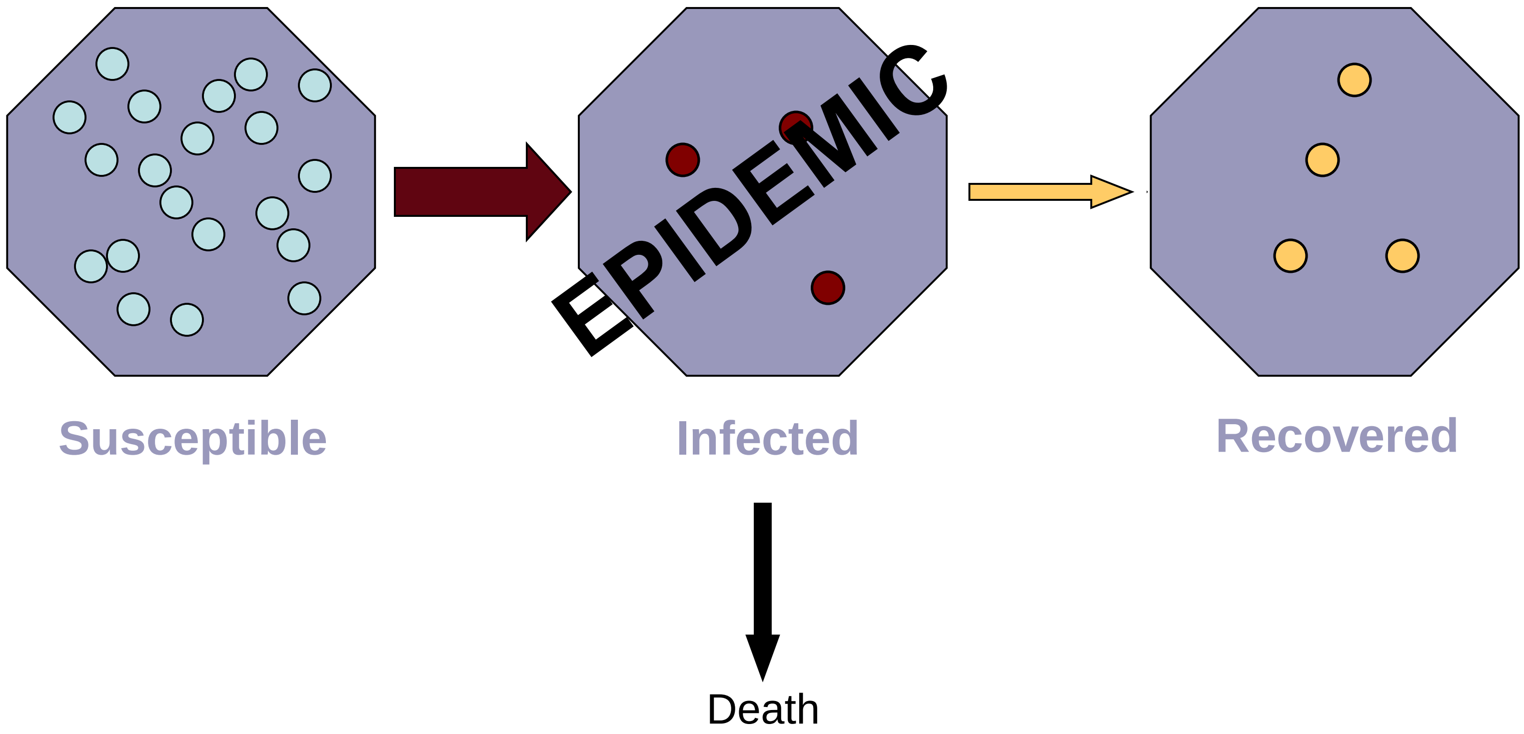
Will an outbreak lead to an epidemic?

$$\frac{\text{Infection rate}}{\text{Mortality + Recovery rate}}$$



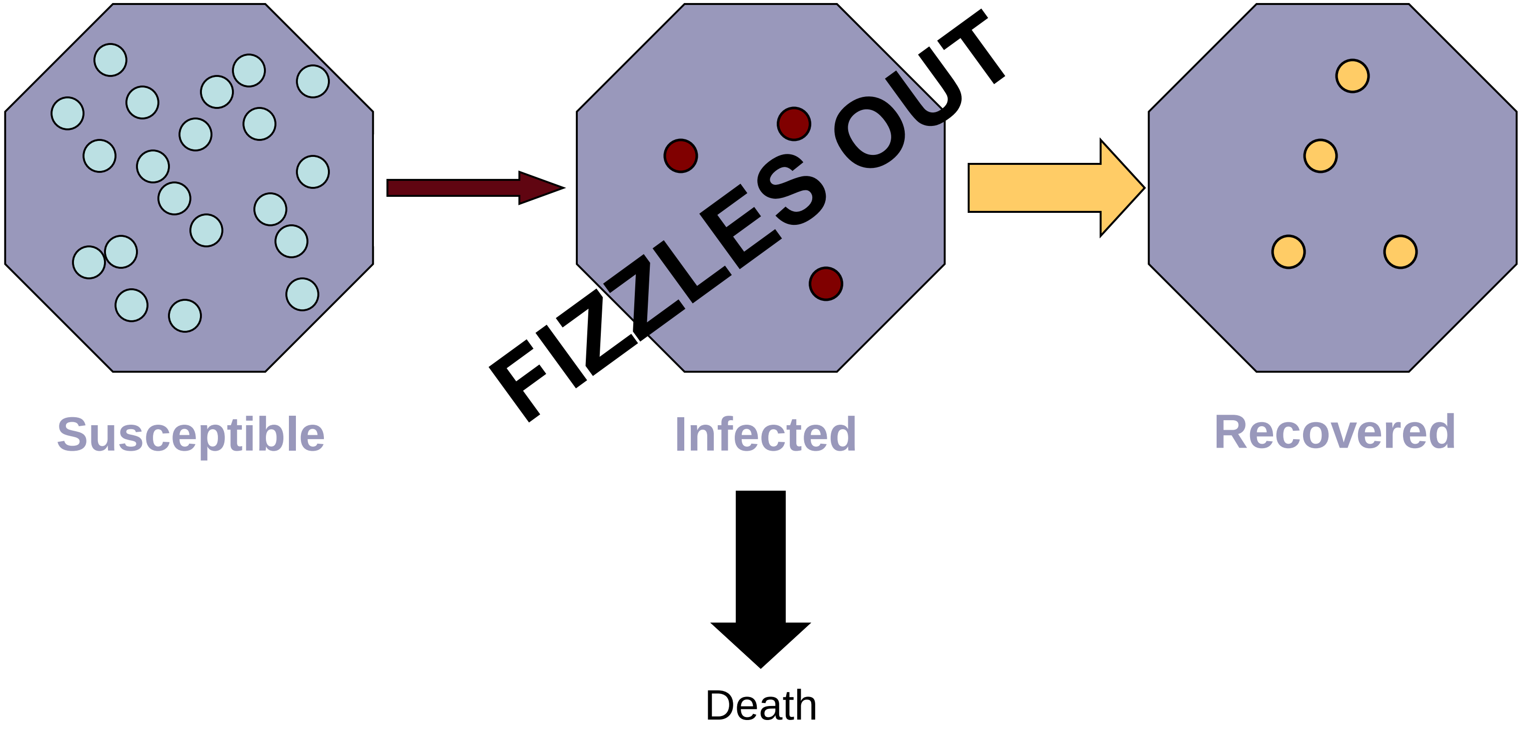
Reproductive ratio of the disease

$$R_0 = \frac{\text{Infection rate}}{\text{Mortality + Recovery rate}} > 1$$

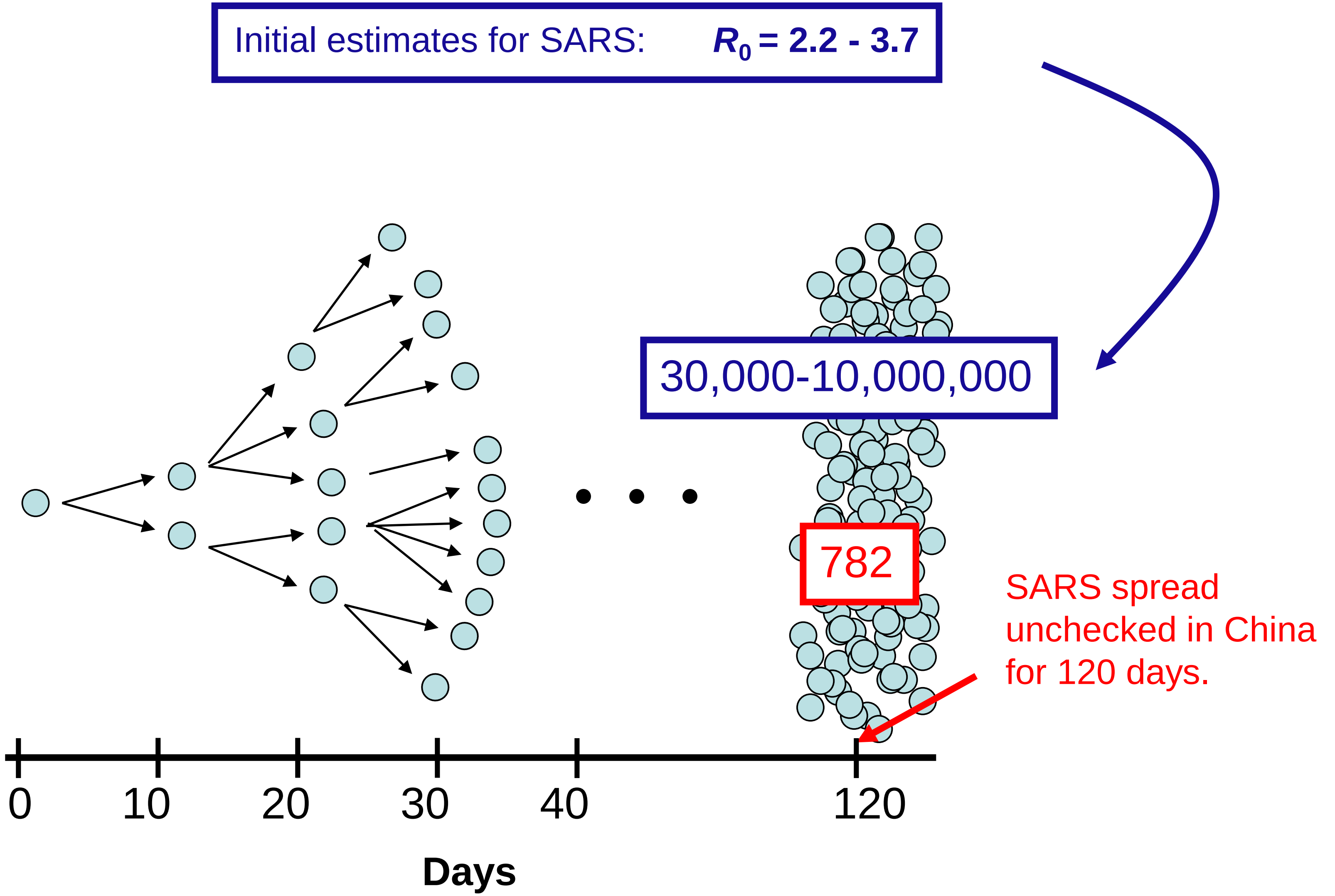


Reproductive ratio of the disease

$$R_0 = \frac{\text{Infection rate}}{\text{Mortality + Recovery rate}} < 1$$



SARS and its Reproductive Ratio (R_0)



What's wrong with these estimates?

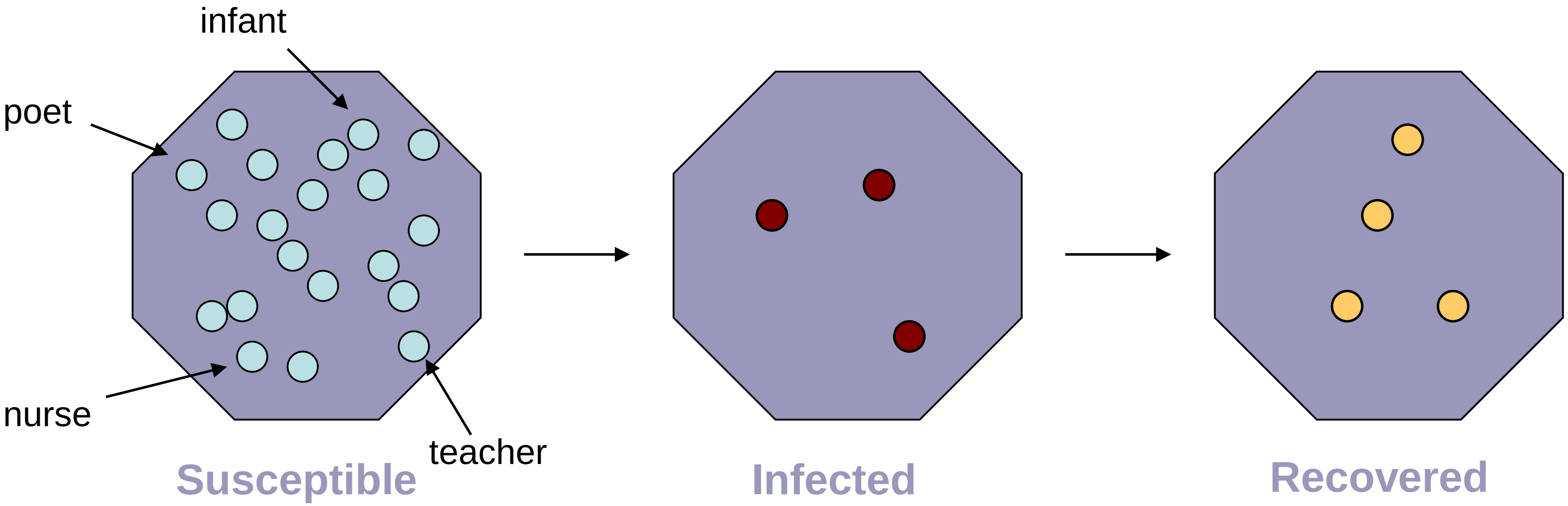
They are based on data from **hospitals** and **crowded apartment buildings** where people have **unusually high rates of contact** with each other.

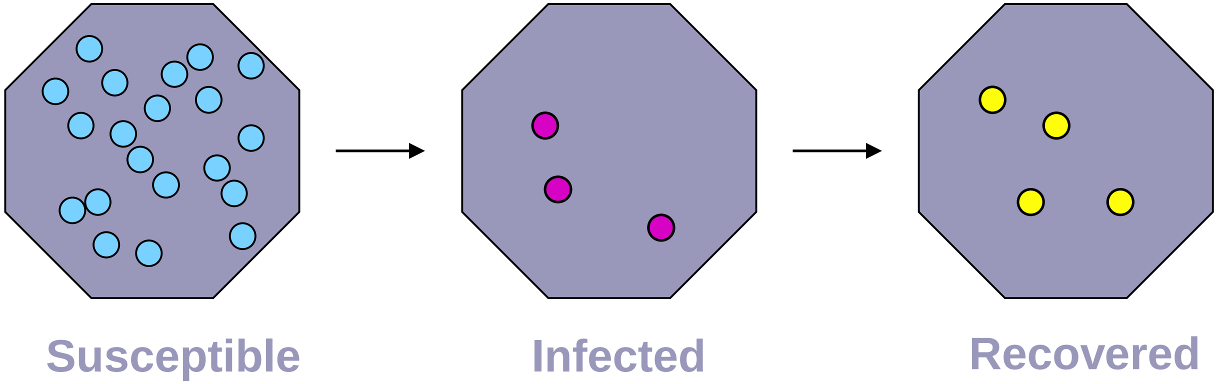


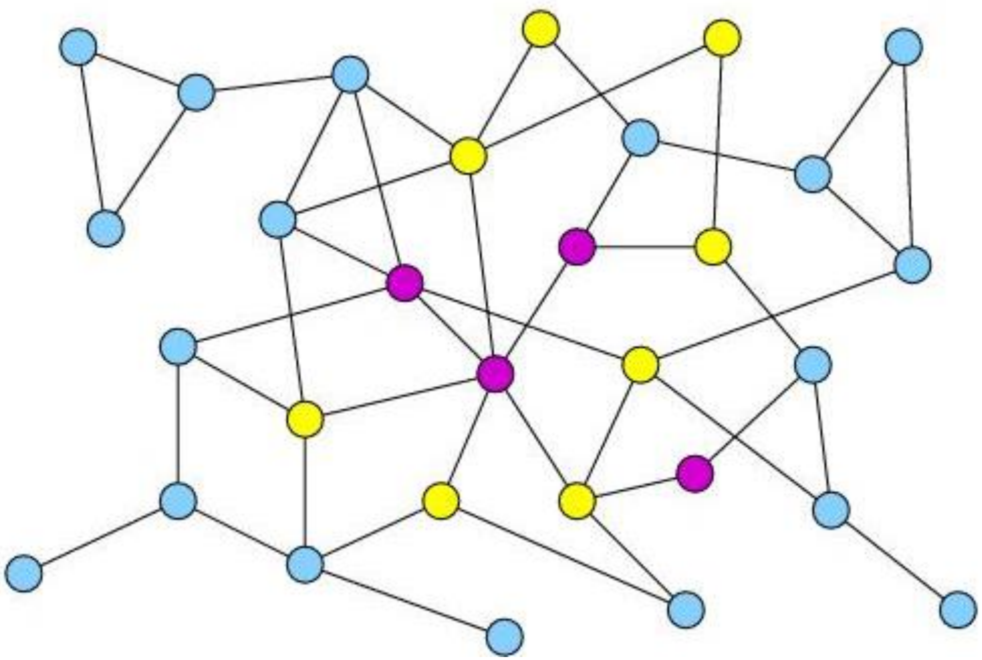





What's missing in traditional models?

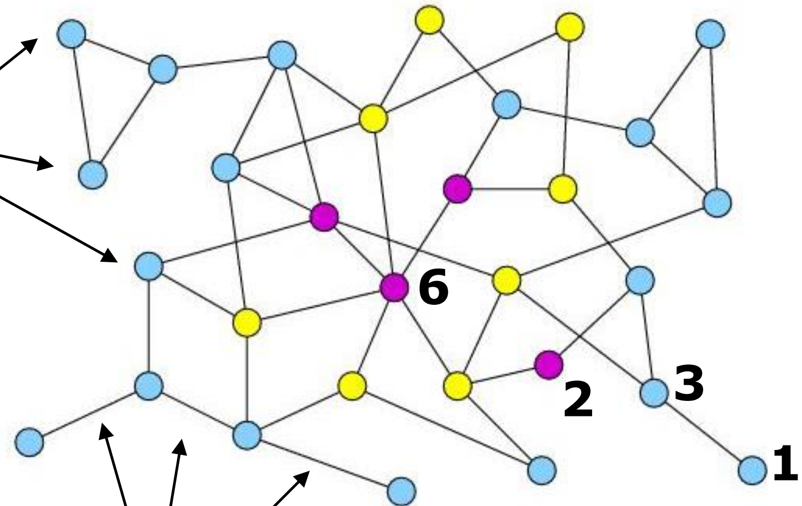



Susceptible
Infected
Recovered



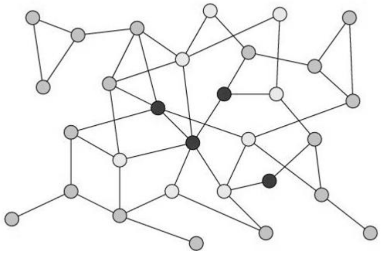
Terminology

Node:
These represent people or places that can become infected

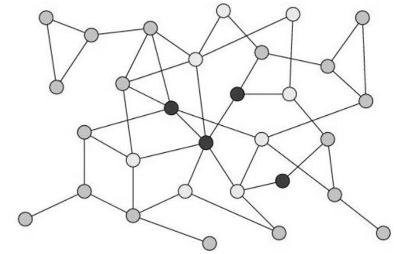


Degree: The number of edges coming out of a node

Edge: contacts between nodes (people) that can lead to disease transmission



What do we do with these networks?



Three step process

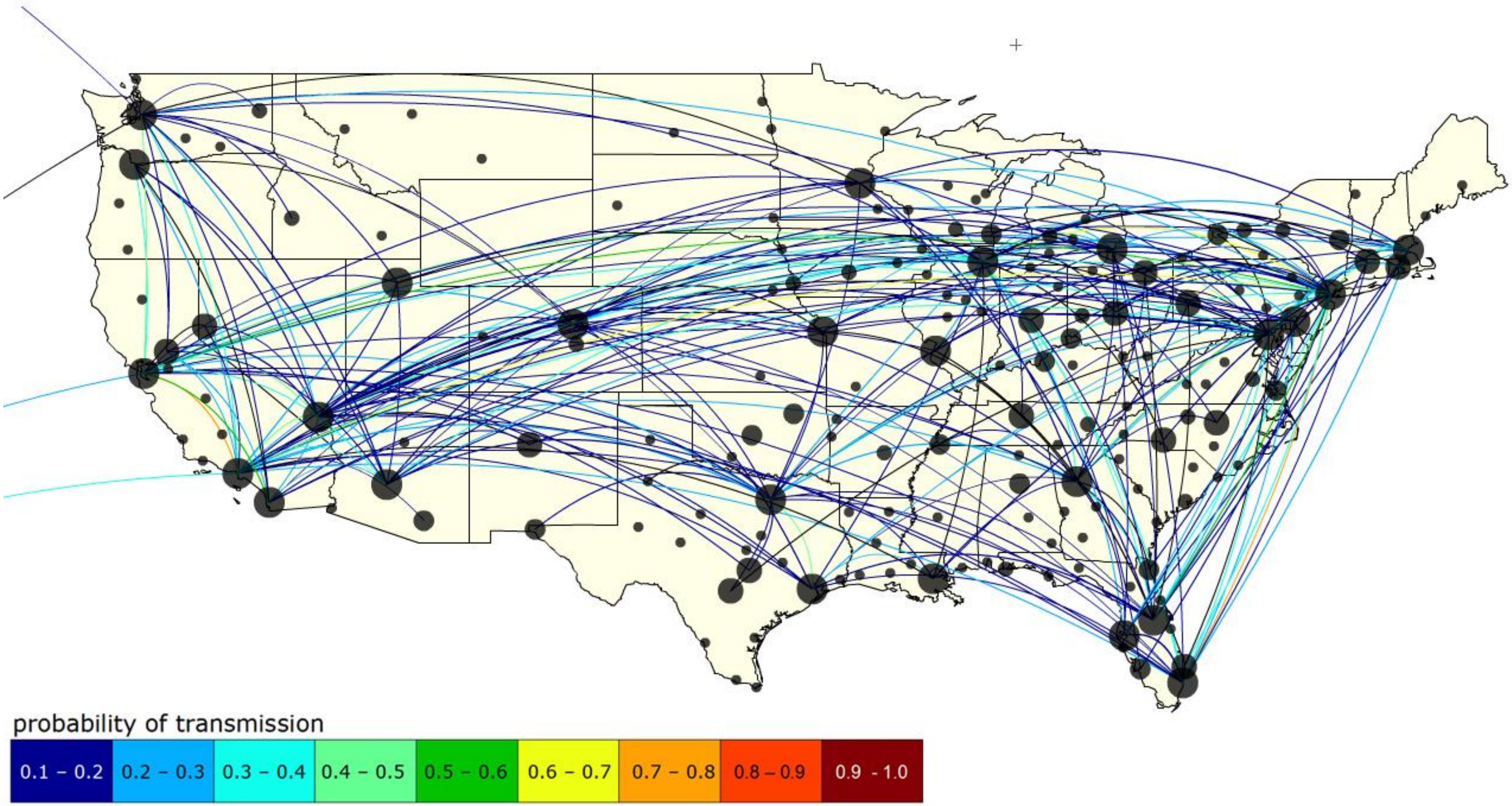
1. Build a realistic contact network

2. Predict the spread of disease through the network

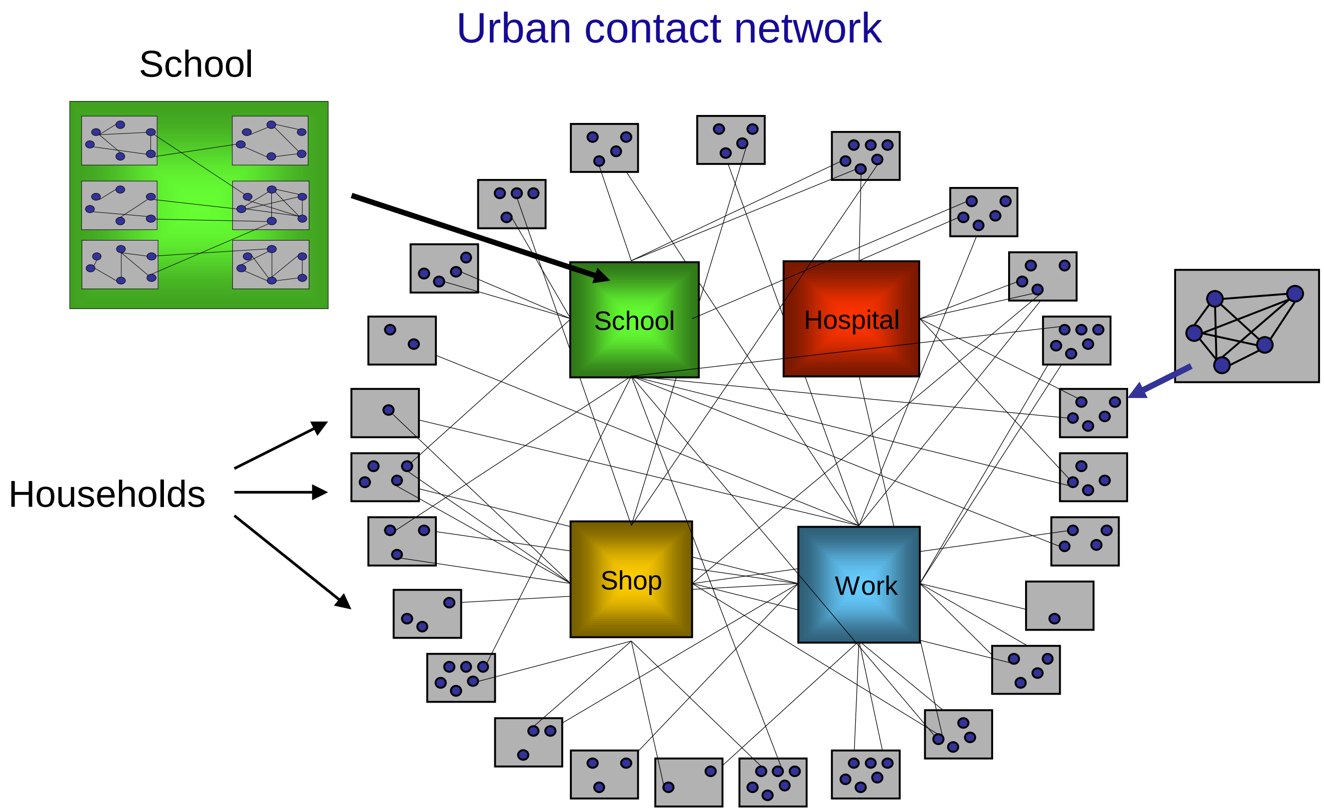
3. Quantify the impact of intervention

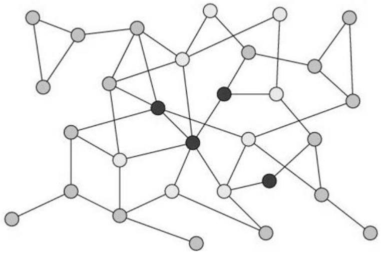
I. Building realistic networks

globe, **country**, state, **metropolitan area**, community, **hospital**, nursing home, **school**, military facility, **prison**, cruise ship, …



I. Building realistic networks





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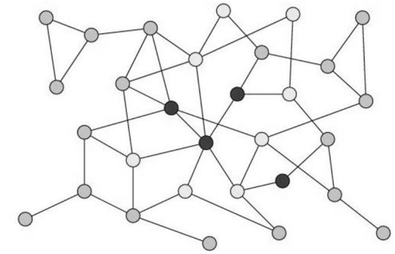

<u>Three step process</u>

1. Build a realistic contact network

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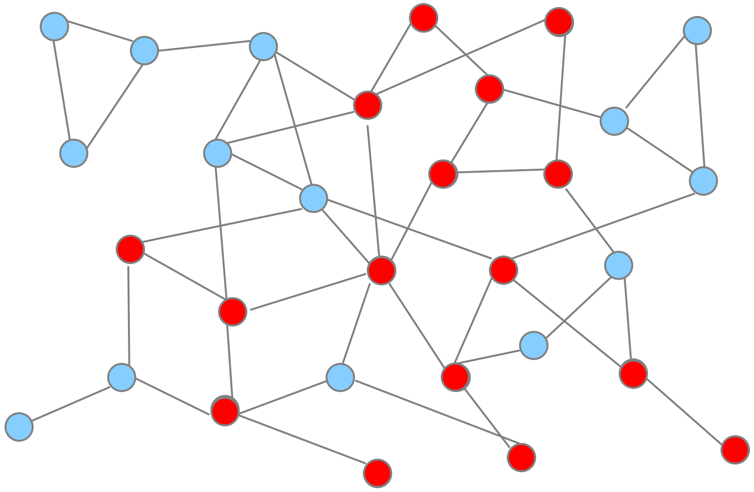
II. Predicting epidemics: The idea



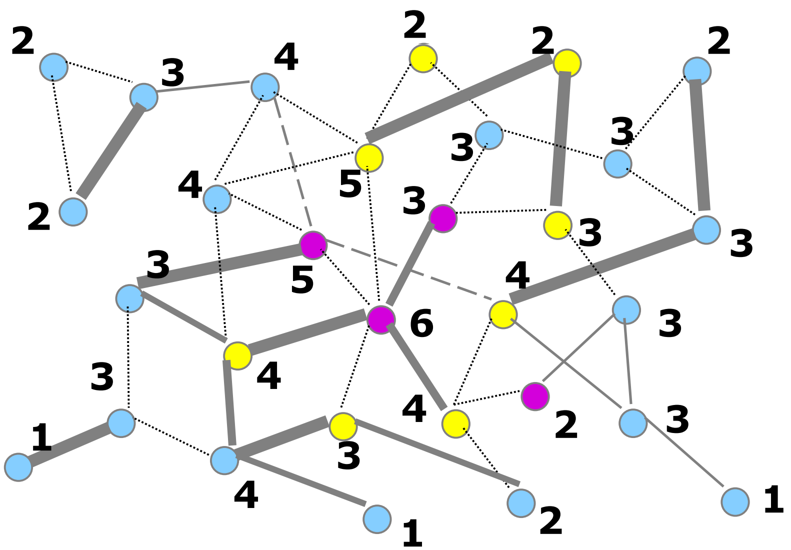
Percolation theory

II. Predicting epidemics: The math

The Two Basic Ingredients

1. Degree distribution: The frequency of each degree in the population

Degree	Frequency
1	3/30 = 0.1
2	7/30 = 0.23
3	11/30 = .37
4	6/30 = 0.2
5	2/30 = 0.07
6	1/30 = 0.03



2. Transmissibility: The probability that an infected individual will transmit the disease to another individual on the opposite side of an edge

$$T_c = \left(\frac{\sum k p_k}{\sum k(k-1) p_k} \right)$$

II. Predicting epidemics

Basic epidemiological quantities:

$$R_0 = T \frac{\sum_{jkm} (j(k+m) + m(k+m-1)) p_{jkm}}{< k_{in} > + < k_{un} >}$$

Epidemic threshold - *how contagious a pathogen must be to cause a large-scale epidemic*

Size of a small outbreak

Probability of a large-scale epidemic

Size of a large-scale epidemic (should one occur)

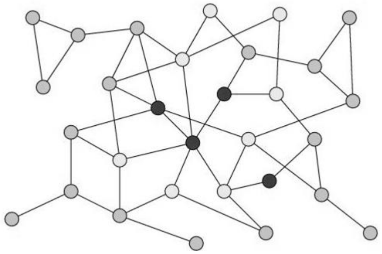
Who gets infected?

$$\langle s \rangle = 1 + \frac{T \sum k p_k}{1 - T \left(\frac{\sum k(k-1) p_k}{\sum k p_k} \right)}$$

Does it matter who gets sick first?

The changing structure of the network

$$P_e = 1 - \sum_{jkm} p_{jkm} (1 + (\alpha - 1)T)^k (1 - (\beta - 1)T)^m$$



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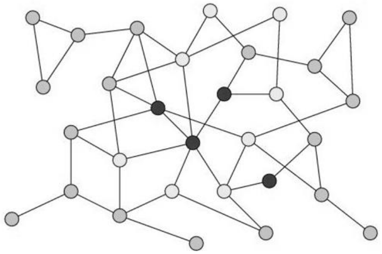


Three step process

1. Build a realistic contact network

2. Predict the spread of disease through the network

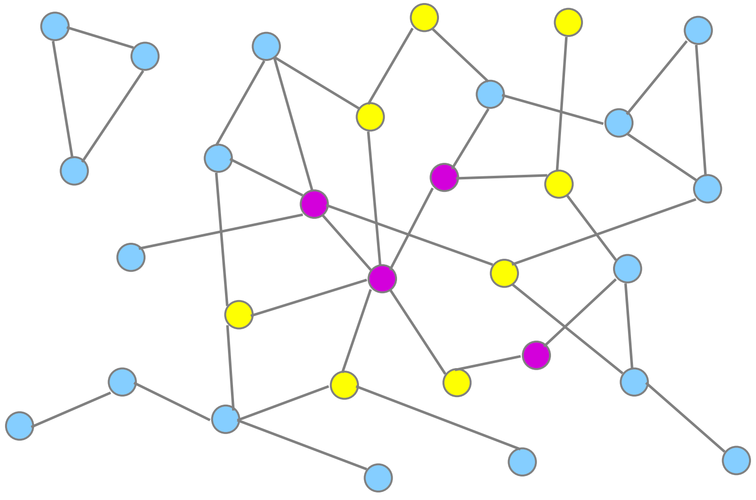
3. Quantify the impact of intervention

III. Assessing control strategies

Three categories of intervention

Contact reducing interventions
Quarantine, cohorting, travel restrictions, etc.

Degree	Old	New
1	0.10	0.23
2	0.23	0.23
3	0.37	0.43
4	0.20	0.03
5	0.07	0.07
6	0.03	0



III. Assessing control strategies

Three categories of intervention

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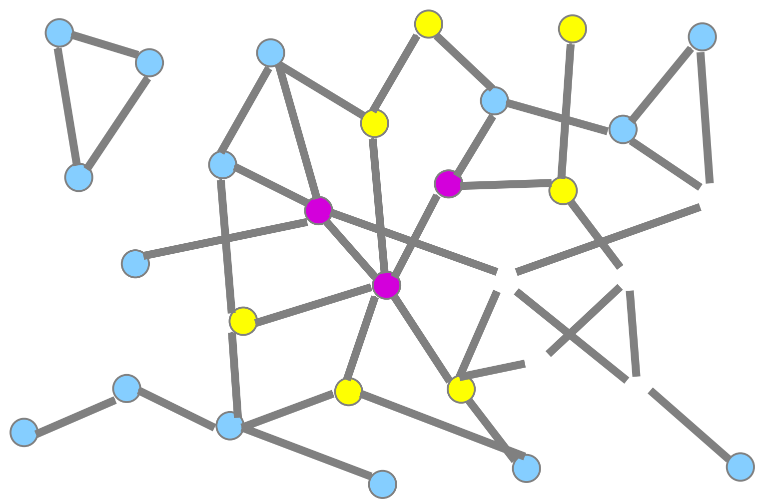
6	0.03	0

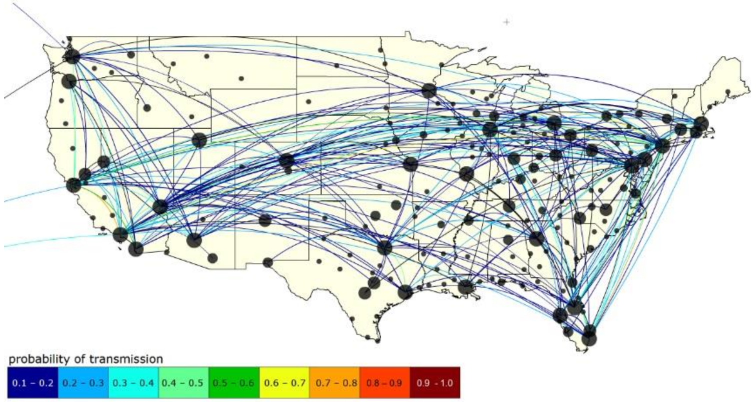


Vaccination
Targeted, general, ring, etc.

Degree	Old	New
1	0.23	0.26
2	0.23	0.30
3	0.43	0.30
4	0.03	0.09
5	0.07	0.04
6	0	0

Transmission reducing interventions
Face masks, hand washing, etc.

III. Evaluating Travel Restrictions



Airport closures - ring strategy

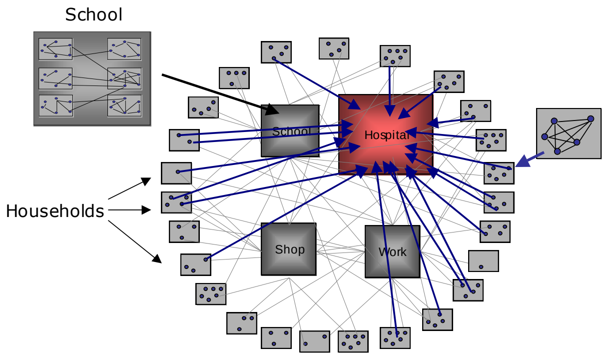
Restricting nonessential travel

Airport screening

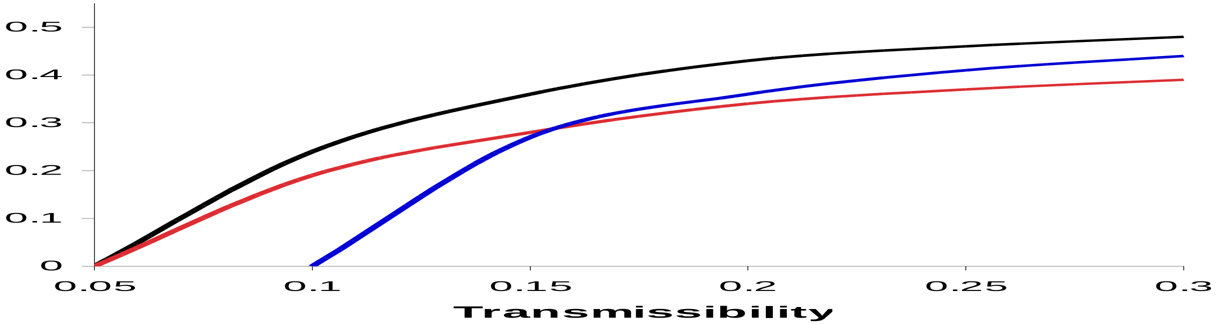
III. Evaluating Flu Vaccination Programs

Brian: Please replace this pict
people waiting in line for a flu

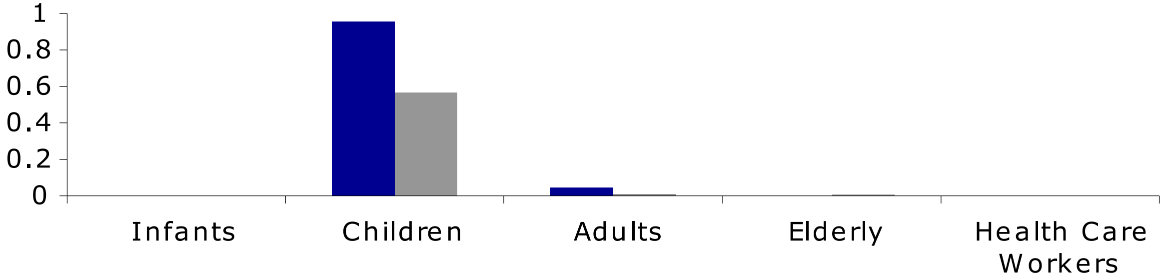
III. Evaluating Flu Vaccination Programs



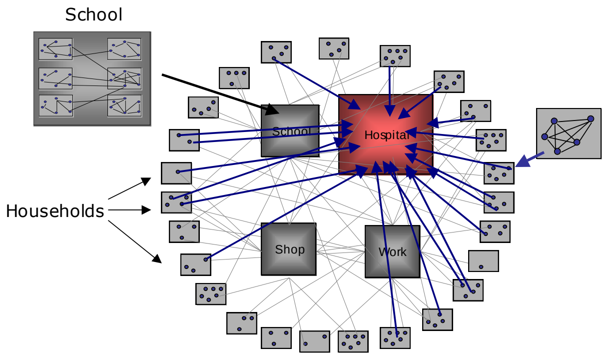
High-risk



School-based

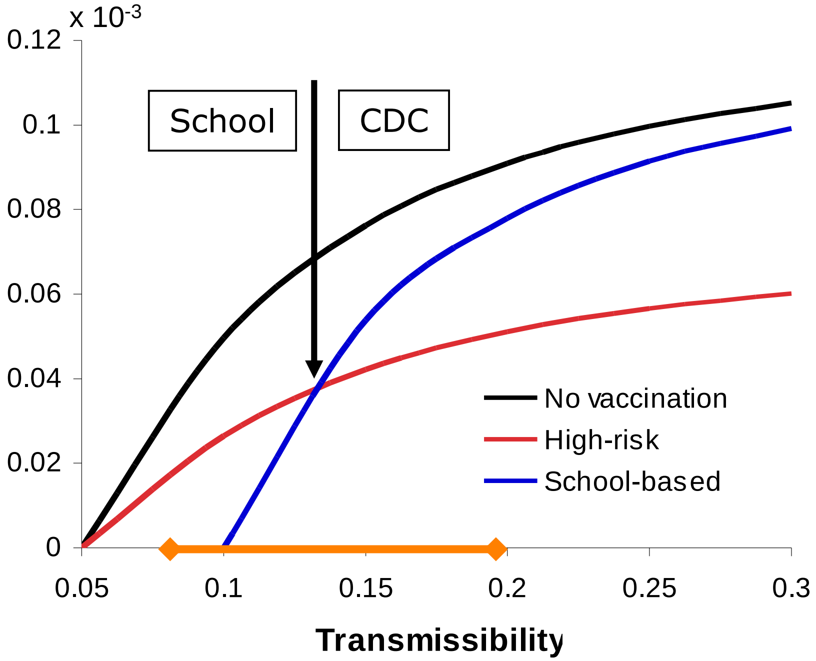


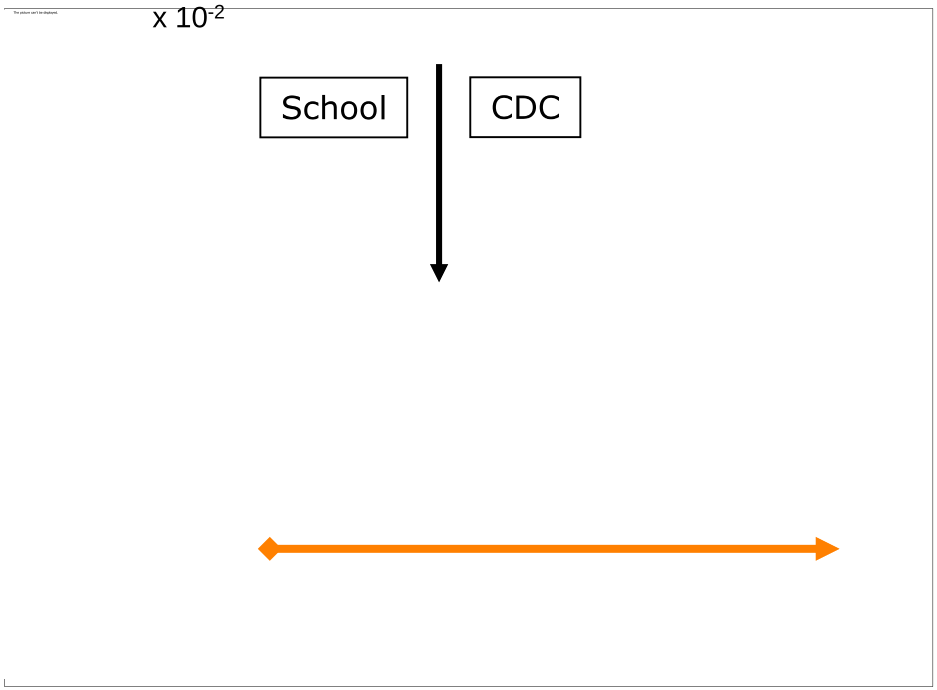
III. Evaluating Flu Vaccination Programs



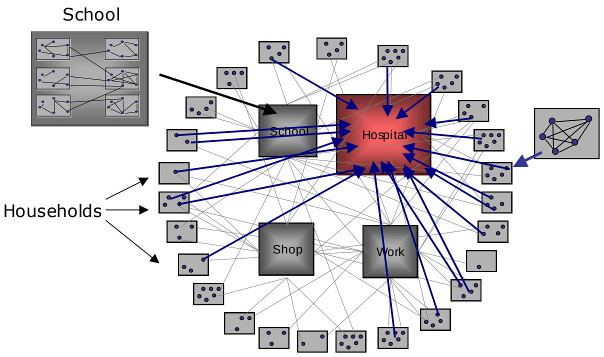
Seasonal flu

Pandemic (1918) flu





III. Evaluating Flu Vaccination Programs



What should the CDC and other health agencies do?

- If the contagiousness of the strain is known, select the best strategy
- If not, target high-risk individuals first

There's no reason to rely on intuition alone.

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British Columbia CDC

Shweta Bansal
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Mark Newman
University of Michigan

Dr. Lauren Ancel Meyers

Lauren Ancel Meyers is an assistant professor in integrative biology at UT Austin. She was named as one of the Top 100 Global Innovators under the age of 35 in 2004 in the MIT Technology Review. Recent awards and honors from UT include the 2005-2006 Institute for Cellular and Molecular Biology Fellowship and the 2005 College of Natural Sciences Teaching Excellence Award.

Her research involves using a combination of theory, simulation, and microbial experimentation, to work on problems at the interface of evolution and epidemiology. The Lauren Ancel Meyers Research Group applies network theory, agent-based simulation, and other quantitative tools to study the interplay between infectious disease transmission dynamics and the evolution of pathogens. In May 2003, she began collaborating with researchers at the British Columbia Centre for Disease Control to develop mathematical models of the transmission of SARS coronovirus, and to use these models to predict its spread and determine effective interventions strategies in urban settings and hospitals, as well as across larger geographic scales.