DCS 2350
Social and Economic Networks

How does a disease propagate?

Epidemics

Chapter 21 of EK
Optional: Chapter 10 of Barabasi:
http://networksciencebook.com/

Mohammad T. Irfan

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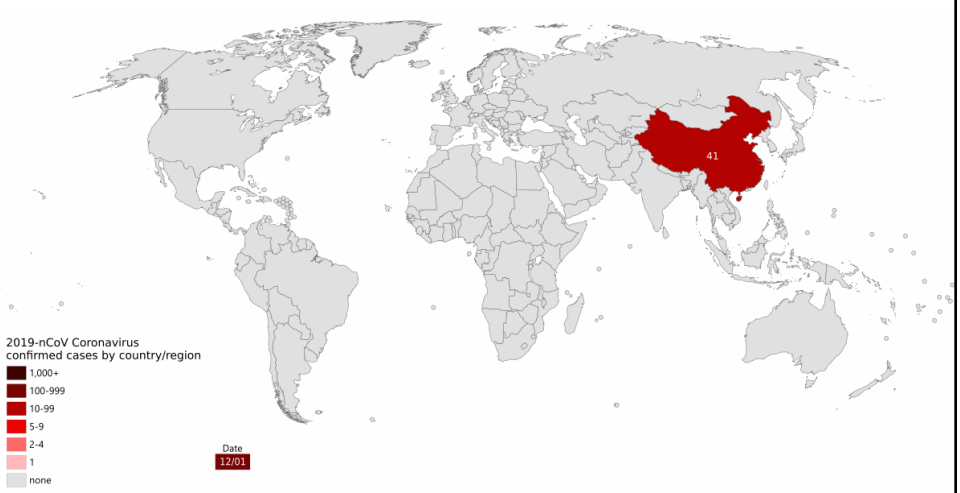
COVID: early timeline (Jan 12 to Feb 10, 2020)



https://en.wikipedia.org/wiki/2019%E2%80%9320_Wuhan_coronavirus_outbreak

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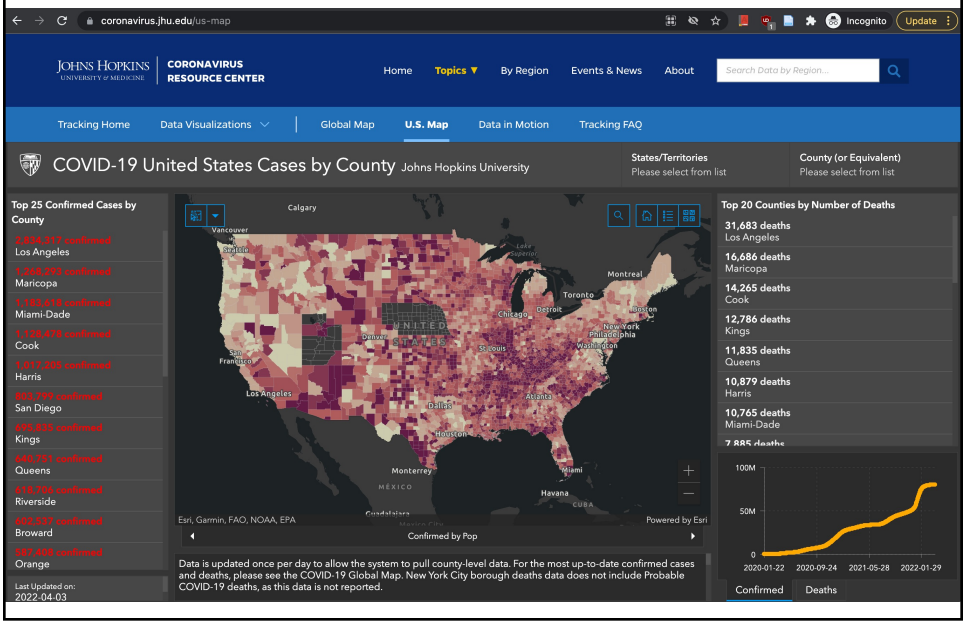
https://coronavirus.jhu.edu/us-map



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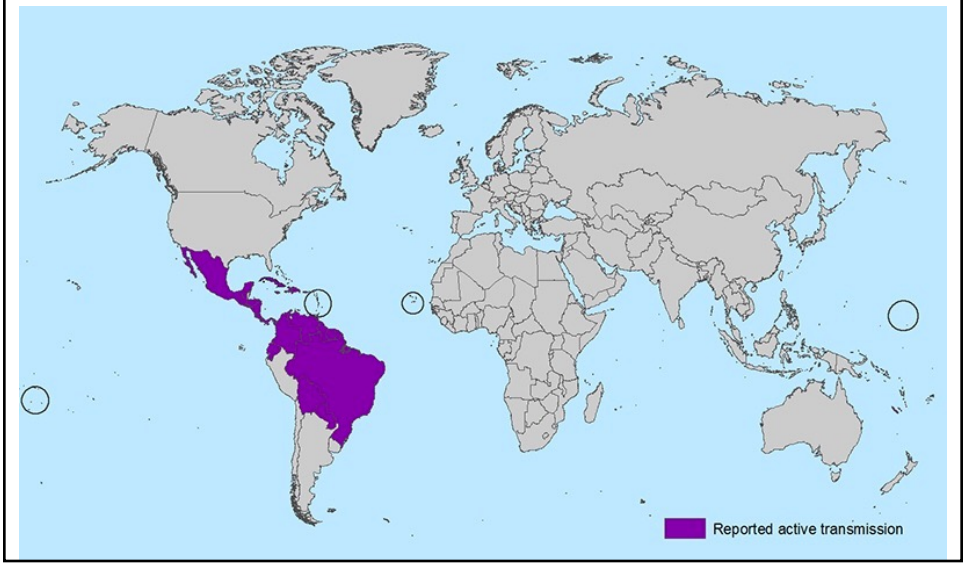
Zika outbreak (2015—2016)

March 2016



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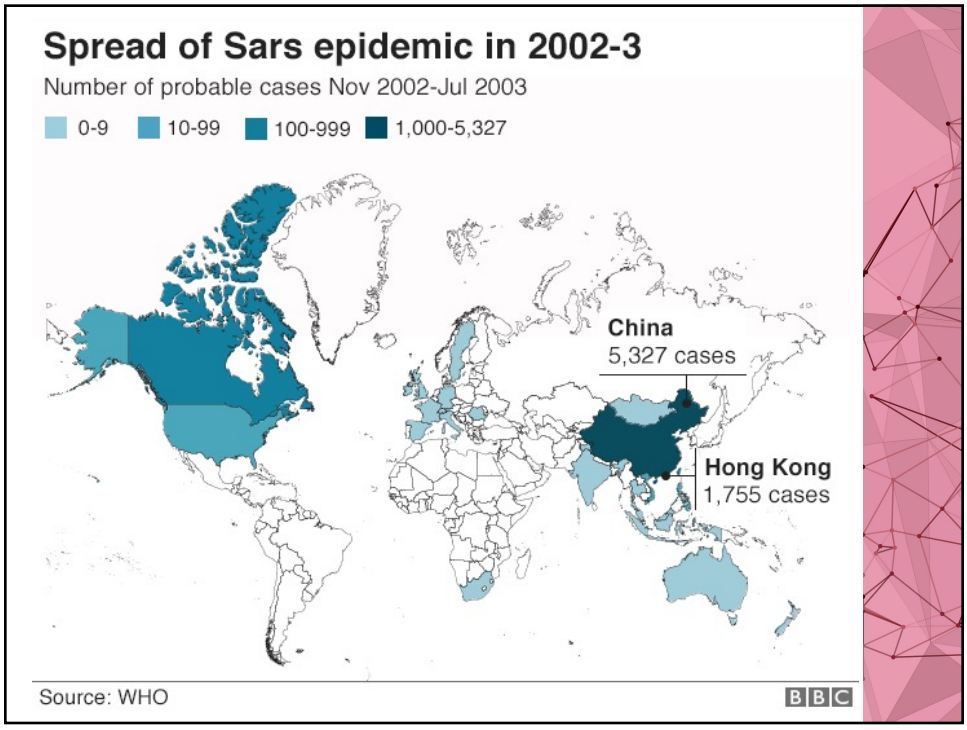
Zika outbreak (2015—2016)

November 21, 2016

5



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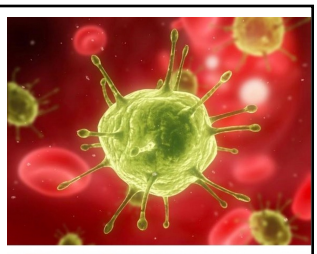
Modeling epidemics

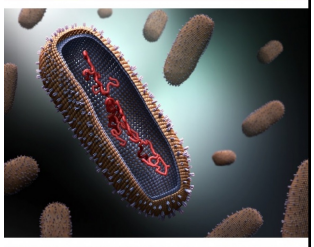
Pathogen

- How contagious is it?
- How long is the infectious period?
- How severe is it?

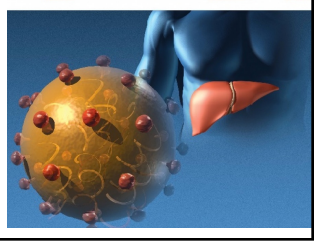
HIV



Flu



Hepatitis C



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Modeling epidemics

- Contact network
  - Depends on pathogen: flu vs. STI
- Examples
  - Human diseases– travel pattern
  - Animal diseases (e.g., 2001 F&M disease in the UK)
  - Plant diseases– spatial footprint

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Modeling epidemics

- Branching model
  - Network is a tree
- SIR model
  - No multiple infections
  - General network structure (directed graph)
- SIS model
  - One *can be* infected multiple times

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Branching model

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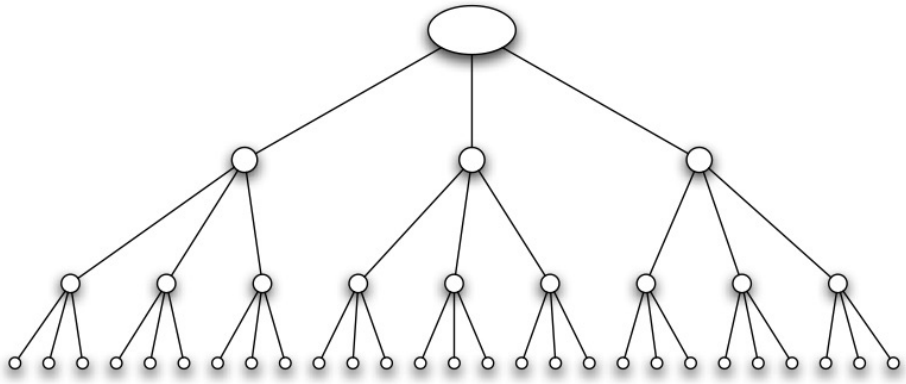
Branching model (p, k)

- k = # of branches from each internal node
- p = Probability of infection



(a) *The contact network for a branching process*

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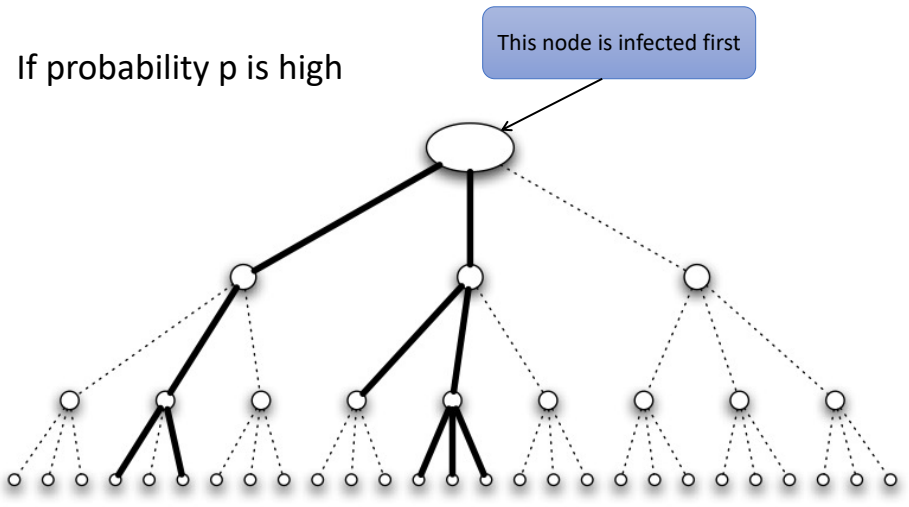
If probability p is high



(b) *With high contagion probability, the infection spreads widely*

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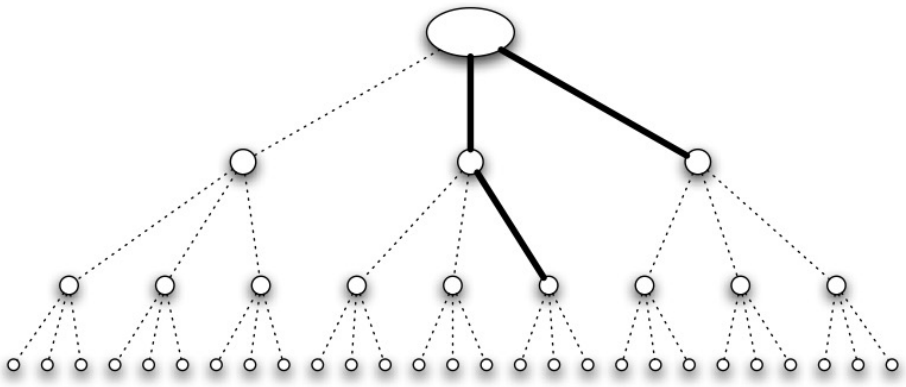
If probability p is low



(c) *With low contagion probability, the infection is likely to die out quickly*

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Will the disease become an epidemic?

- Basic reproductive number, R_0
  = Expected # of new cases of the disease caused by a single person

- $R_0 = p\ k$

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Will disease become an epidemic?

- Dichotomy result
  - $R_0 < 1$ => disease will die out for sure
  - $R_0 > 1$ => disease will persist with positive prob.
- "Knife-edge" situation
  - $R_0 = 1$: critical value

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Insights from the branching model

- $R_0 = p\ k$
- How to prevent an epidemic?
  - Reduce the value of p – masking, sanitary practice
  - Reduce the value of k – isolation, quarantine

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R_0 values

Disease	Transmission	R_0
Measles	Airborne	12-18
Pertussis	Airborne droplet	12-17
Diptheria	Saliva	6-7
Smallpox	Social contact	5-7
Polio	Fecal-oral route	5-7
Rubella	Airborne droplet	5-7
Mumps	Airborne droplet	4-7
HIV/AIDS	Sexual contact	2-5
SARS	Airborne droplet	2-5
Influenza (1918 strain)	Airborne droplet	2-3

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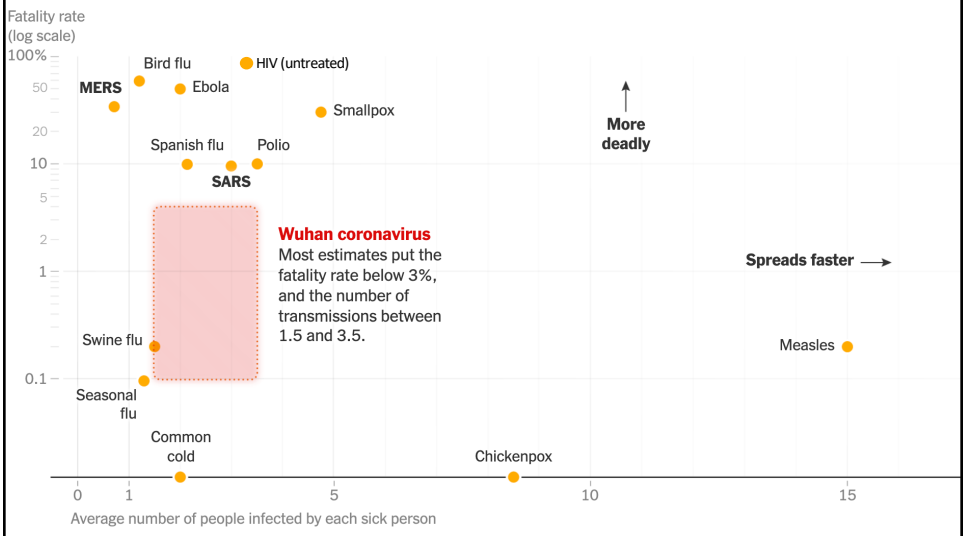
R_0 value & deadliness



https://www.nytimes.com/interactive/2020/world/asia/china-coronavirus-contain.html
February 2020

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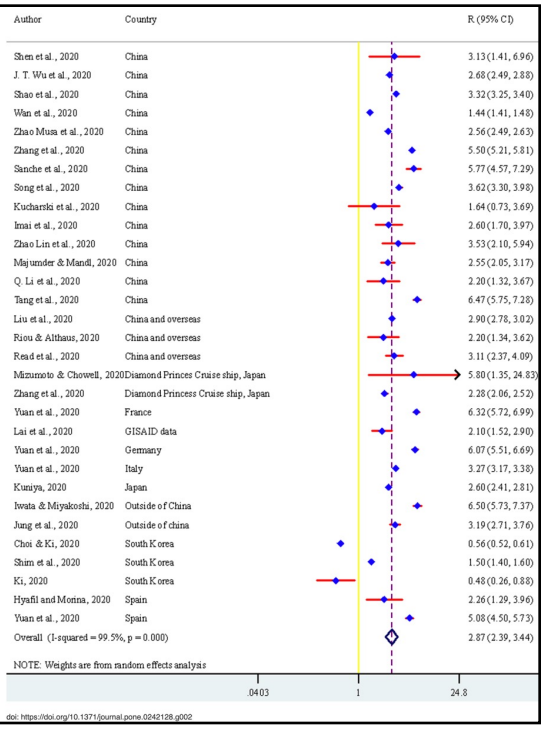
R0 of SARS-CoV-2

Meta study by
Billah et al. (Nov 2020)



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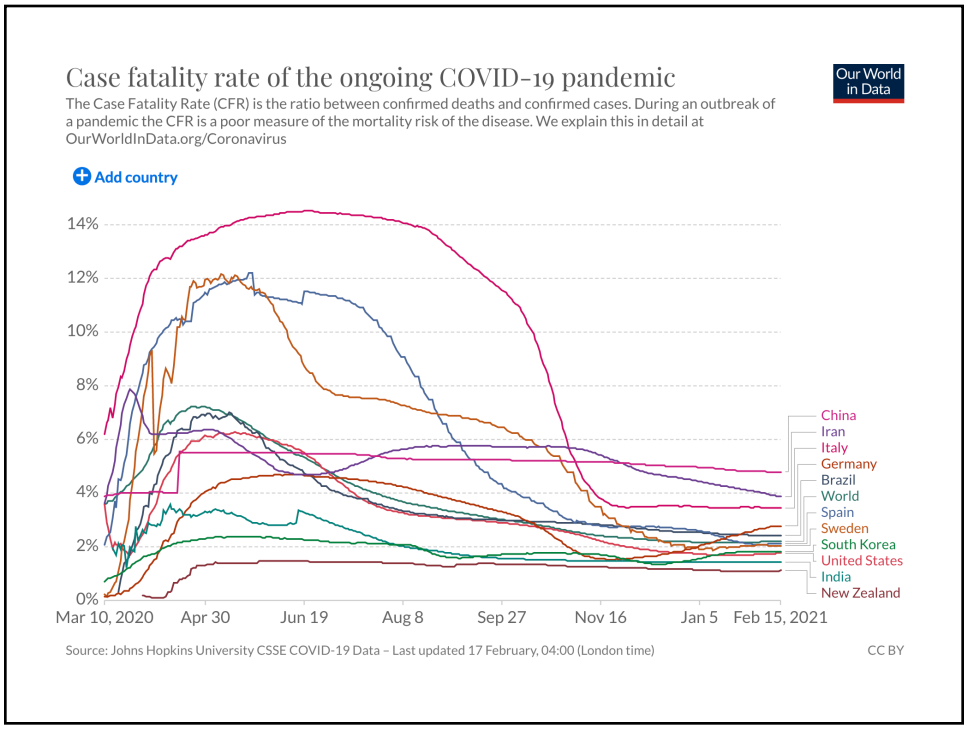
Case fatality rate of the ongoing COVID-19 pandemic
The Case Fatality Rate (CFR) is the ratio between confirmed deaths and confirmed cases. During an outbreak of a pandemic the CFR is a poor measure of the mortality risk of the disease. We explain this in detail at OurWorldInData.org/Coronavirus
Our World in Data
Add country
14%
12%
10%
8%
6%
4%
2%
0%
Mar 10, 2020
Apr 30
Jun 19
Aug 8
Sep 27
Nov 16
Jan 5
Feb 15, 2021
China
Iran
Italy
Germany
Brazil
World
Spain
Sweden
South Korea
United States
India
New Zealand
Source: Johns Hopkins University CSSE COVID-19 Data – Last updated 17 February, 04:00 (London time)
CC BY

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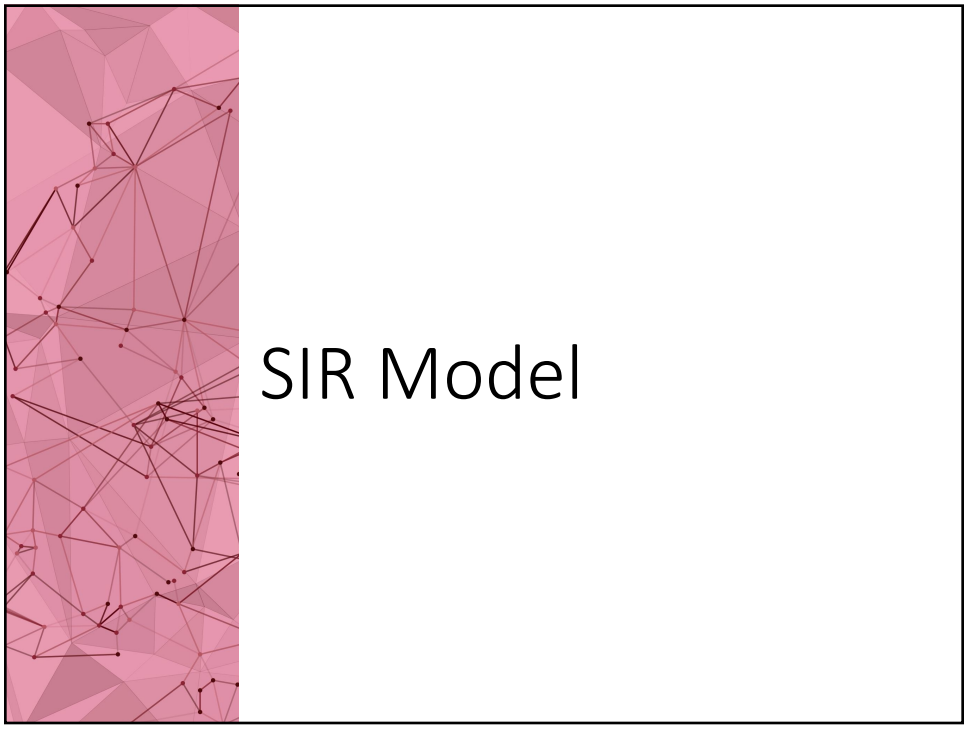
SIR Model

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SIR model

At each step, an infectious node infects its susceptible neighbors with probability p

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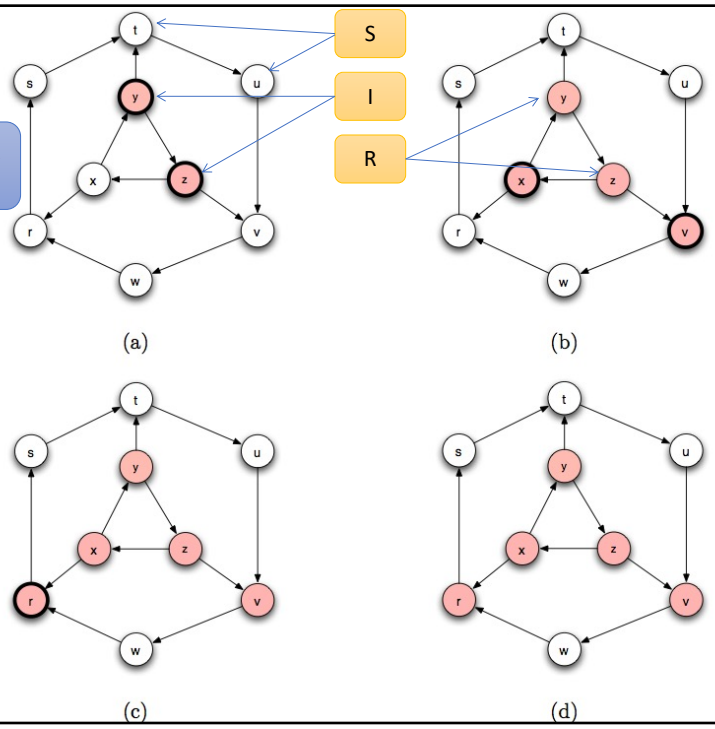
SIR Network Model

- Infection period = 1
- p = 0.5

S
I
R



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Basic reproductive number

- R_0 = expected number of new infections caused by a node
- Dichotomy does not hold for SIR model on
  - R_0 can be > 1, but the disease may still die out

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COVID-19: SEIR model

- S-Exposed-I-R
- Exposed: incubation before becoming infectious

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SIS Model

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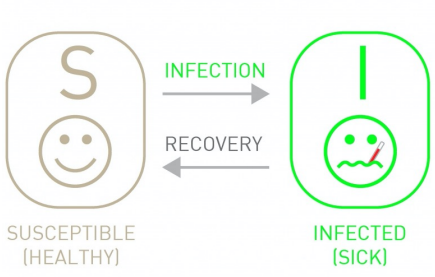
SIS model



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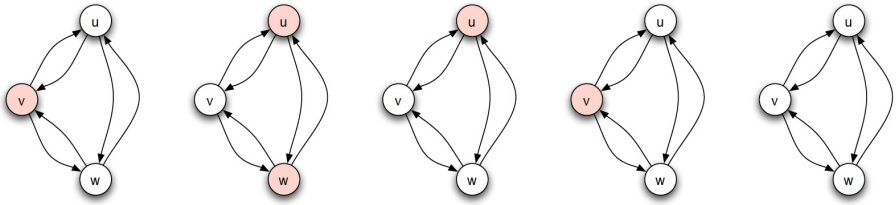
SIS Model

- SIS model
  - S: Susceptible
  - I: Infectious
- A node can become infected multiple times
- Dichotomy result exists



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NetLogo experiment on SIR

- Models Library → Networks → Virus on a network
- Edit the "go" button and uncheck "Forever"
- Edit the max to 100% for the following:
  - virus-spread-chance (p)
  - recovery-chance [proxy for infectious period t_i]

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