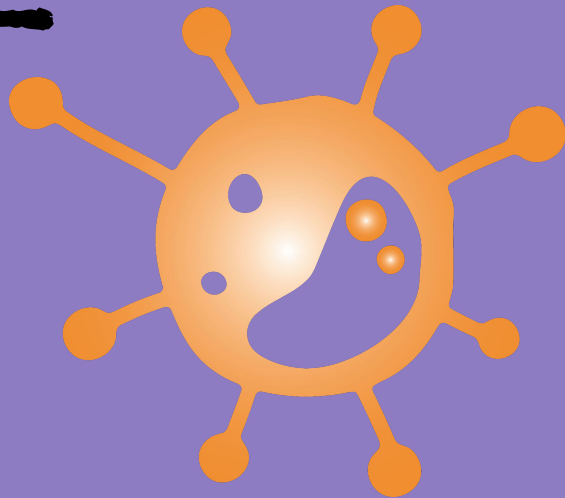
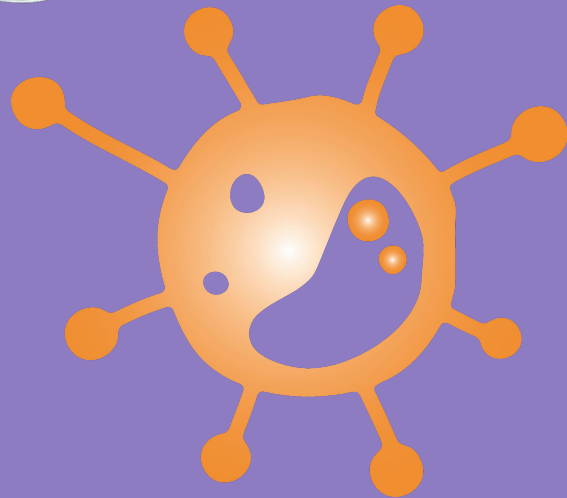
Mathematical Modeling of Disease - COVID19



Presented by Theo N.

Assumptions

"All models are wrong - some are just useful" - George E.P. Box



Knowledge

Bloomberg

World

Jan. 29, 2020

10-Year-Old Boy Raises Fears Wuhan Virus Could Spread Undetected

Business

Mar. 4, 2020

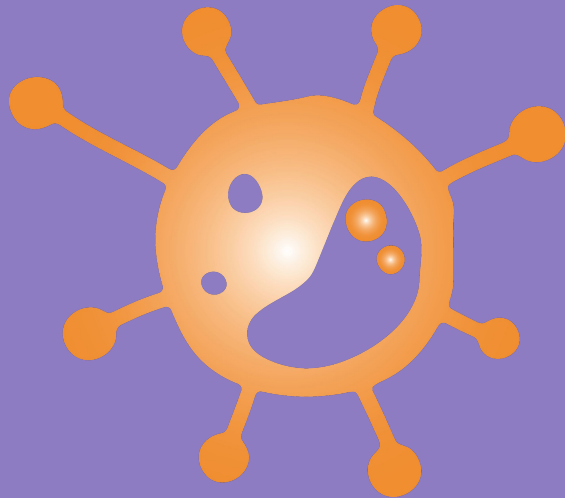
New York Coronavirus Case Spurs Complex Risk Calculus

In South Korea, A Growing Number Of COVID-19 Patients Test Positive After Recovery

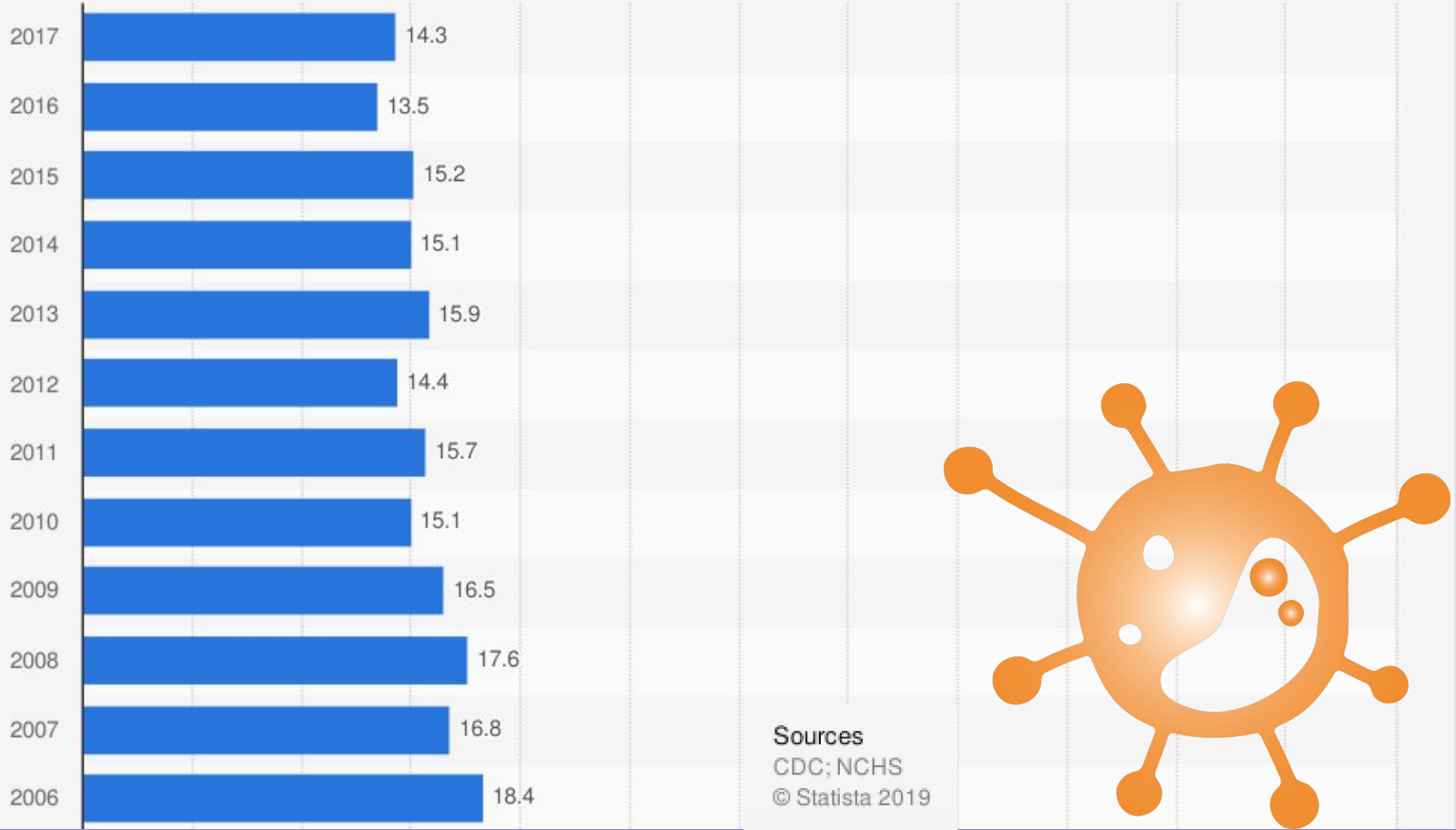
Apr. 17, 2020 - NPR

April 17, 2020 · 11:23 AM ET

April 18, 2020

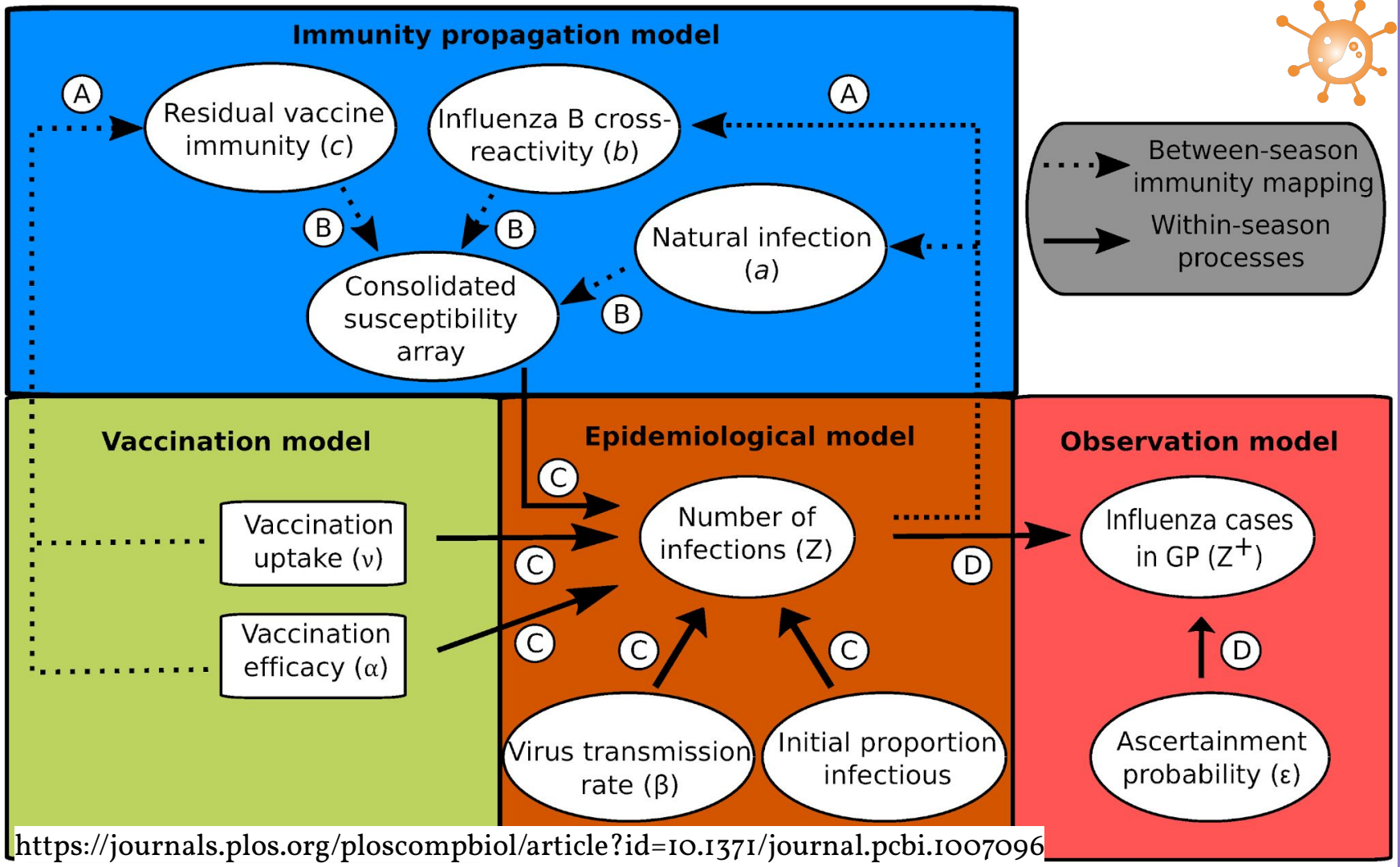


Deaths by influenza and pneumonia in the U.S. from 1950 to 2017 (per 100,000 population)



Sources
CDC; NCHS

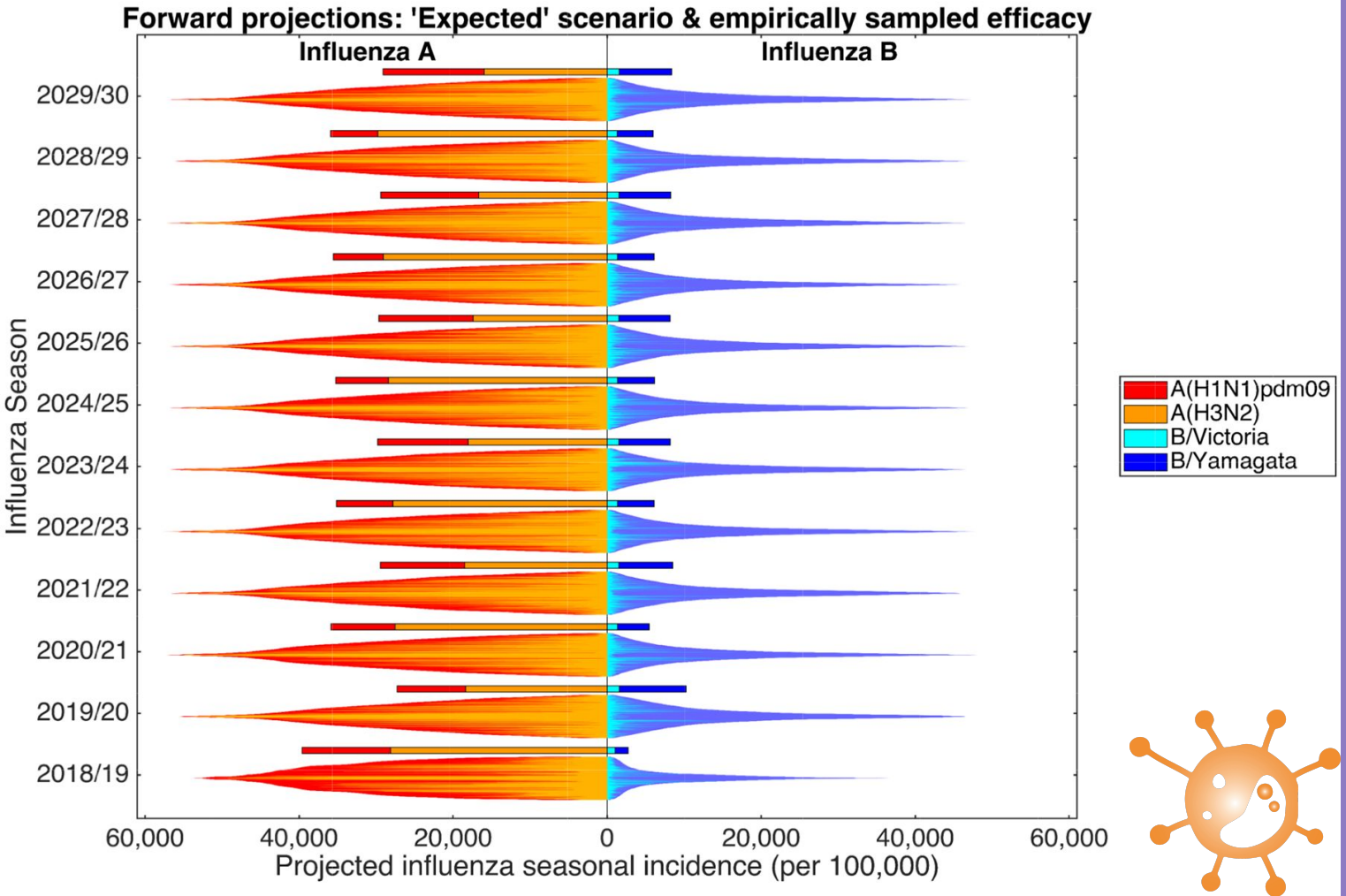
INFLUENZA



https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1007096

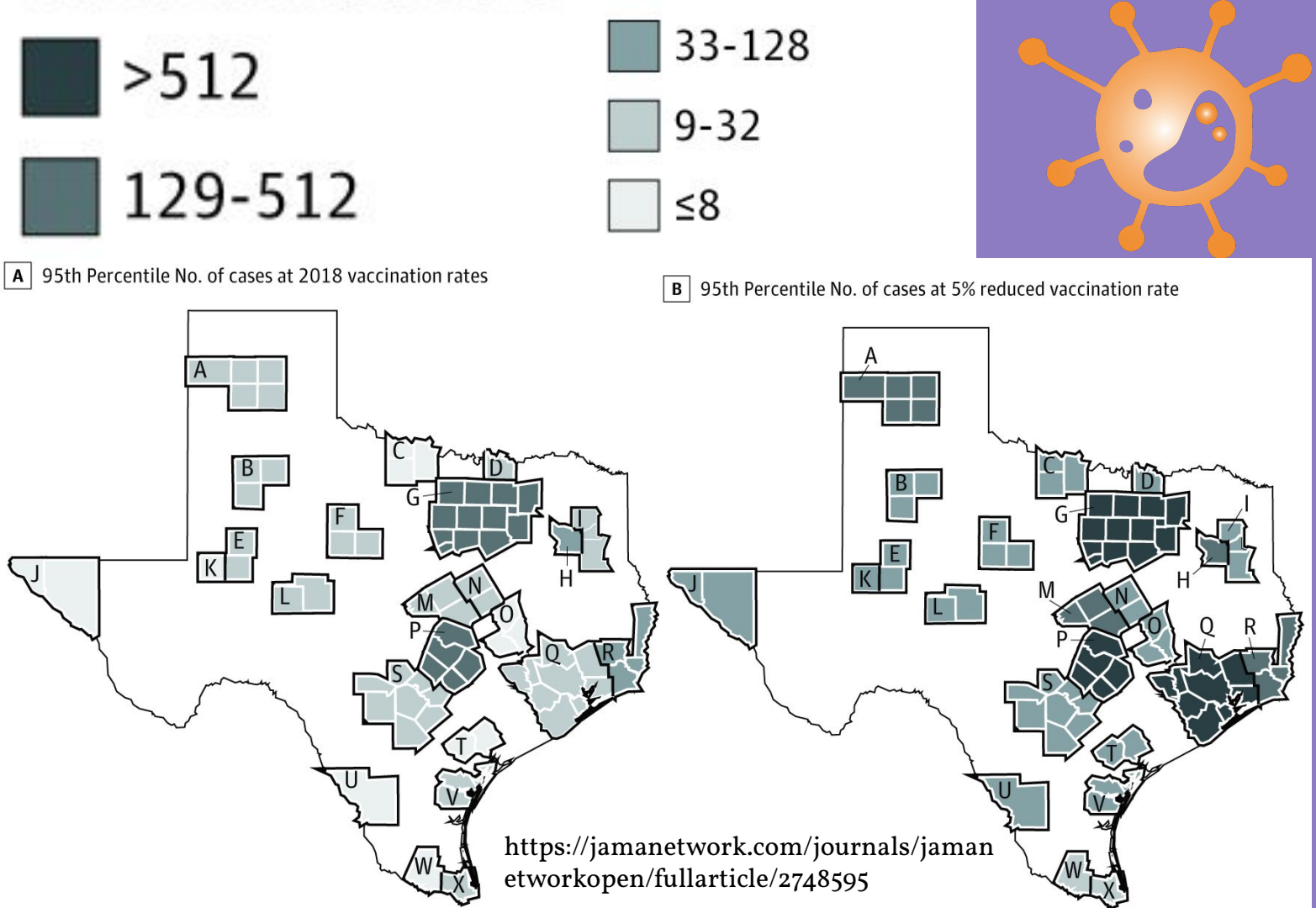
INFLUENZA

(a) https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1007096



INFLUENZA

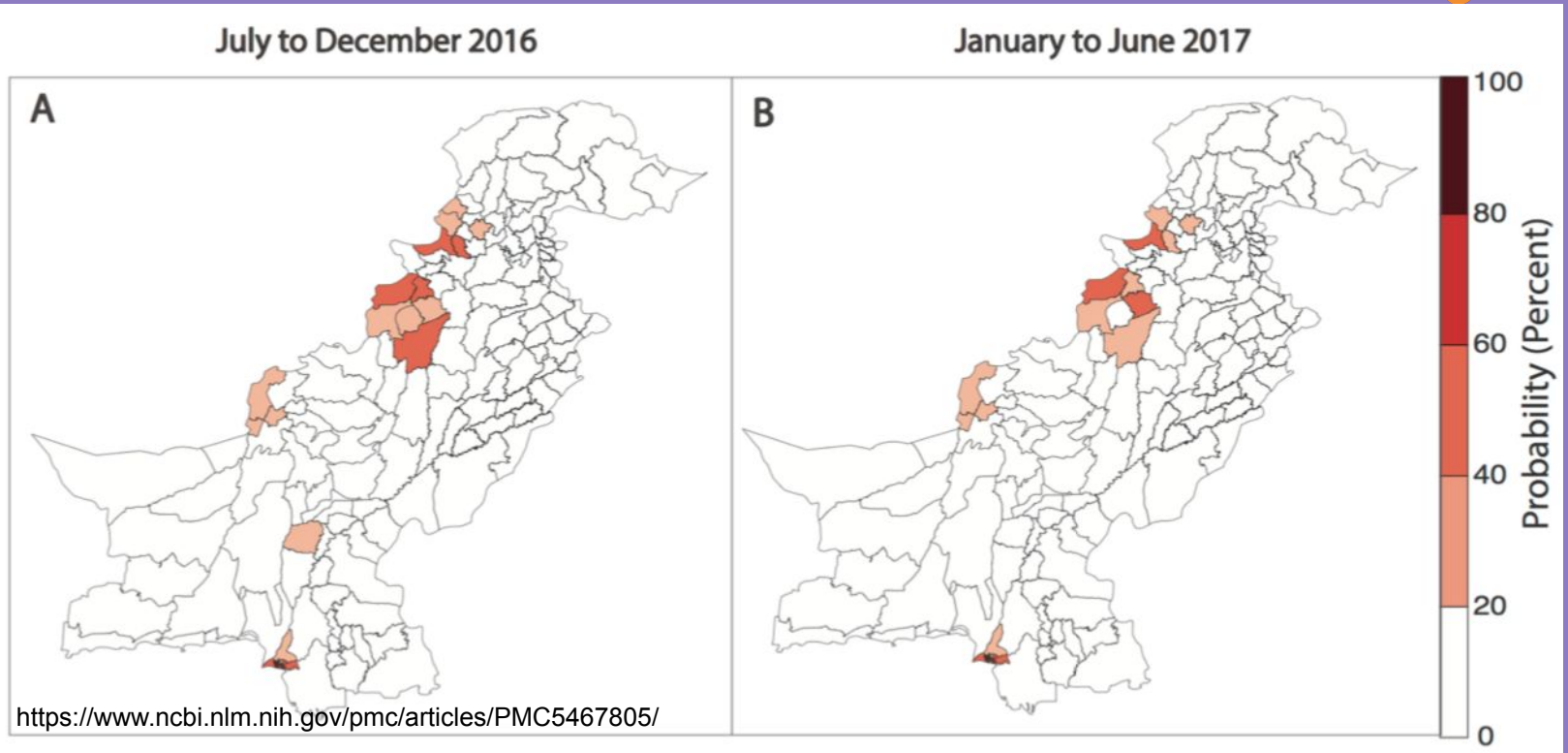
Measles



https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2748595

Pakistan

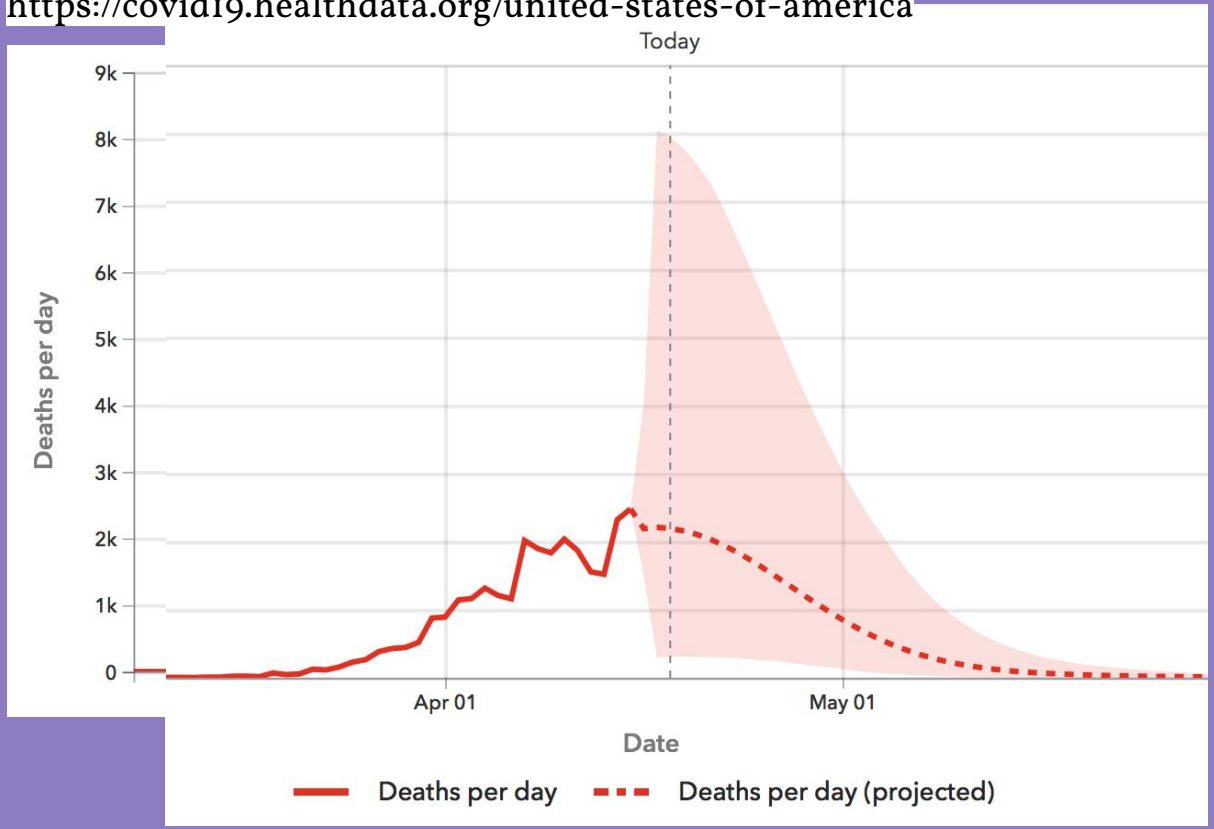
POLIO



https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5467805/

COVID-19

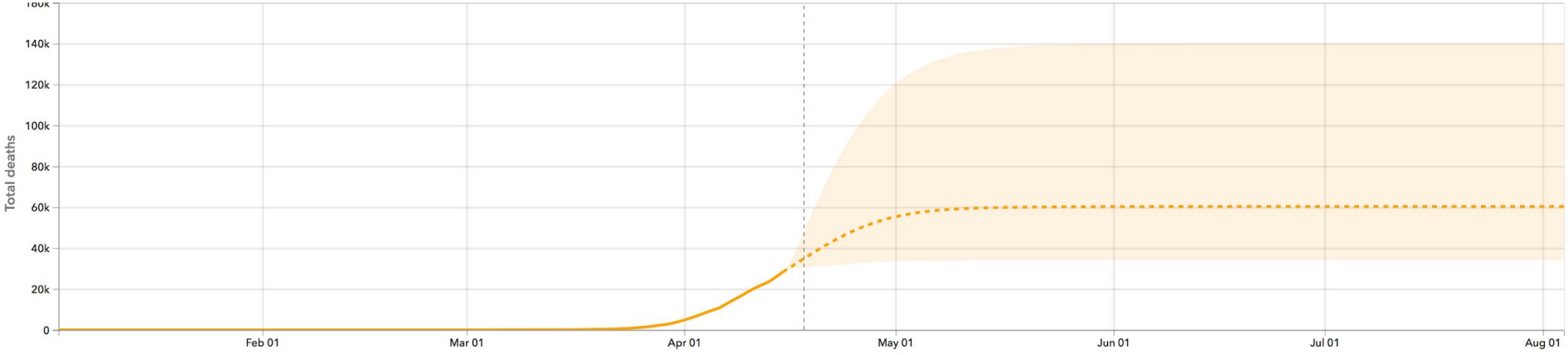
https://covid19.healthdata.org/united-states-of-america



COVID-19

$$D(t;\alpha,\beta,p) = \frac{p}{2}\left(\Psi(\alpha(t-\beta)) = \frac{p}{2}\left(1 + \frac{2}{\sqrt{\pi}}\int_0^{\alpha(t-\beta)} \exp\left(-\tau^2\right) d\tau\right)\right.$$

where the function Ψ is the Gaussian error function (written explicitly above), *p* controls the maximum death rate at each location, *t* is the time since death rate exceeded 1e-15, *β* (beta) is a location-specific inflection point (time at which rate of increase of the death rate is maximum), and α (alpha) is a location-specific growth parameter. Other sigmoidal functional forms (alternatives to Ψ) were considered but did not fit the data as well. Data were fit to the log of the death rate in the available data, using an optimization framework described in the appendix.



SIRS Mathematics

$$\frac{dS}{dt} = -\frac{\beta SI}{N}$$

$$\frac{dI}{dt} = \frac{\beta SI}{N} - \gamma I$$

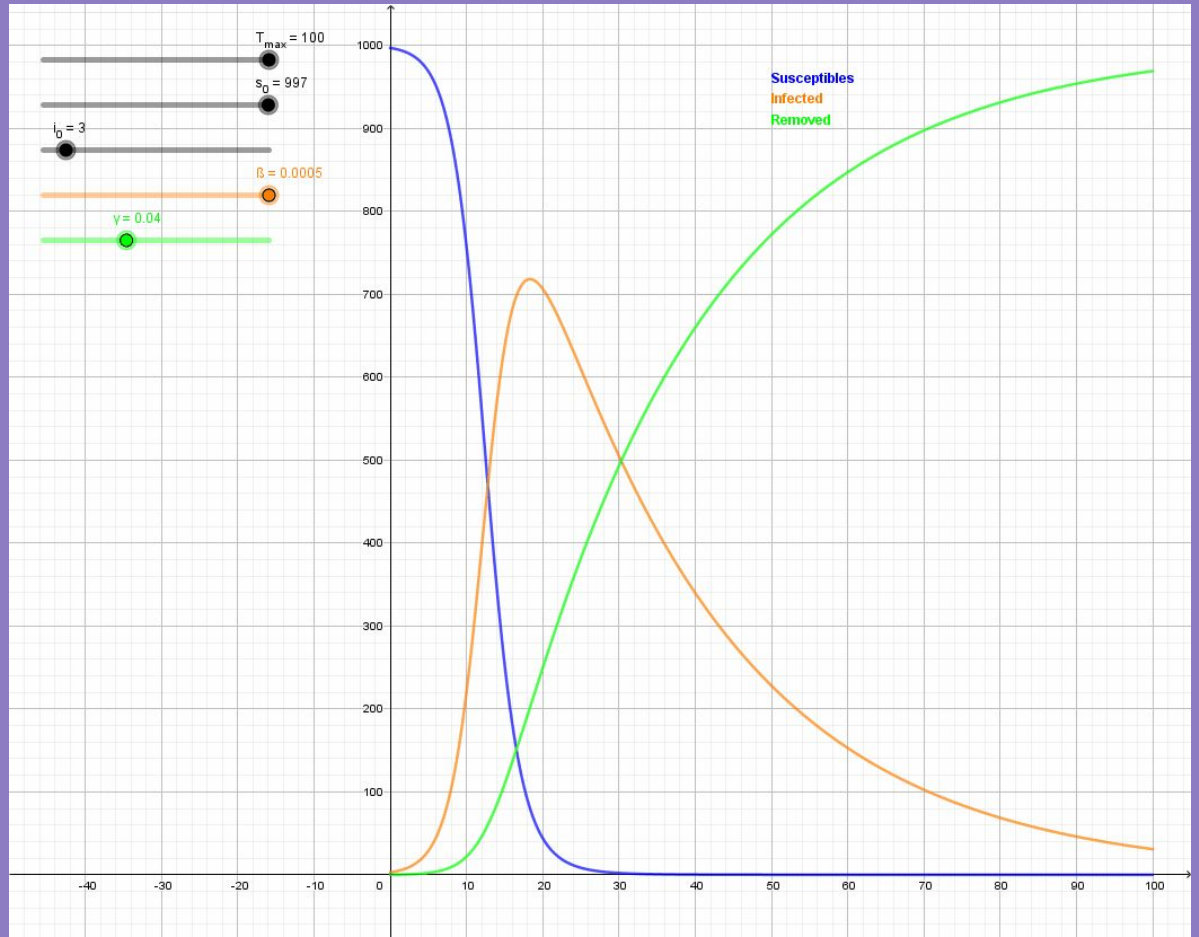
$$\frac{dR}{dt} = \gamma I$$

β = contact rate

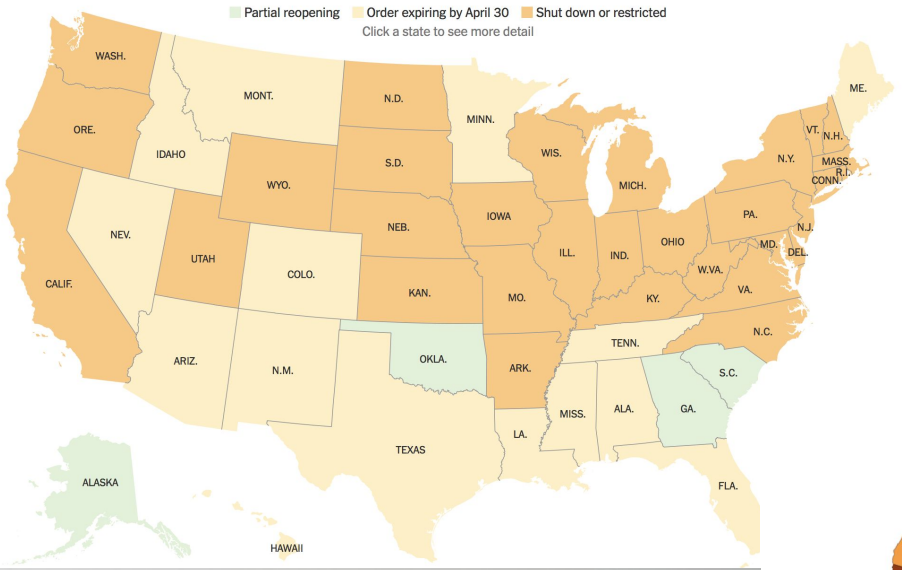
γ = “recovery” rate

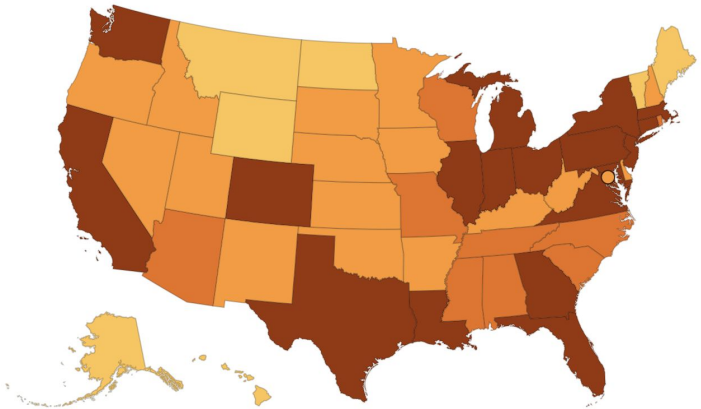
S → I → R

SIR's Animation



Allocation of Resources





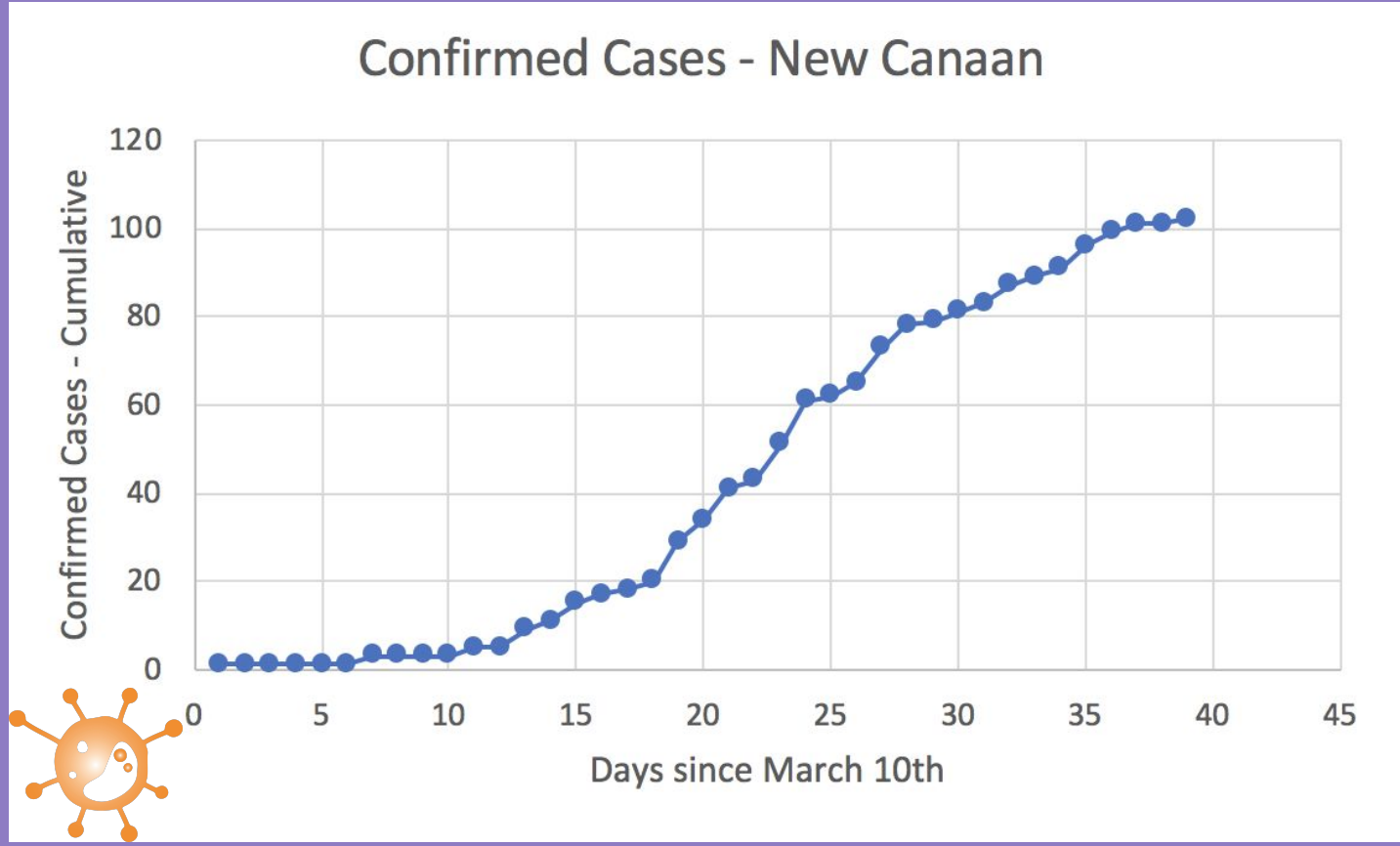
Reported Cases

- None
- 1 to 100
- 101 to 1000
- 1001 to 5000
- 5001 to 10000
- 10001 or more

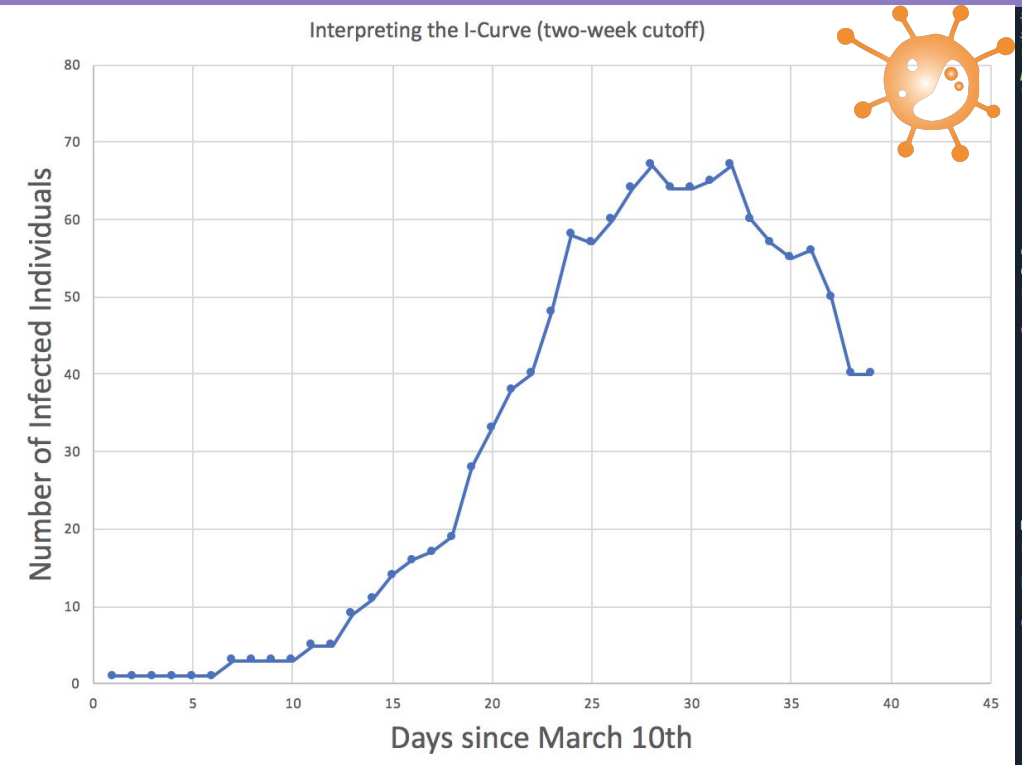
Territories AS GU MH FM MP PW PR VI

New Canaan Coronavirus Modeling

CT State Gov. Report: March 11th - April 18th, 2020



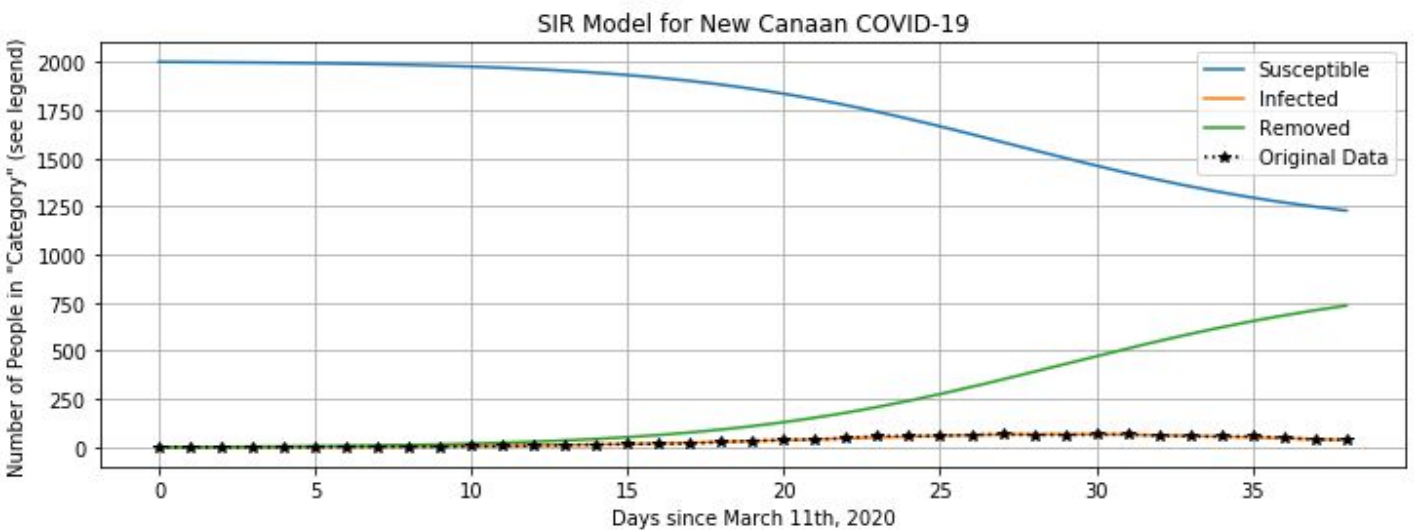
New Canaan Coronavirus Modeling

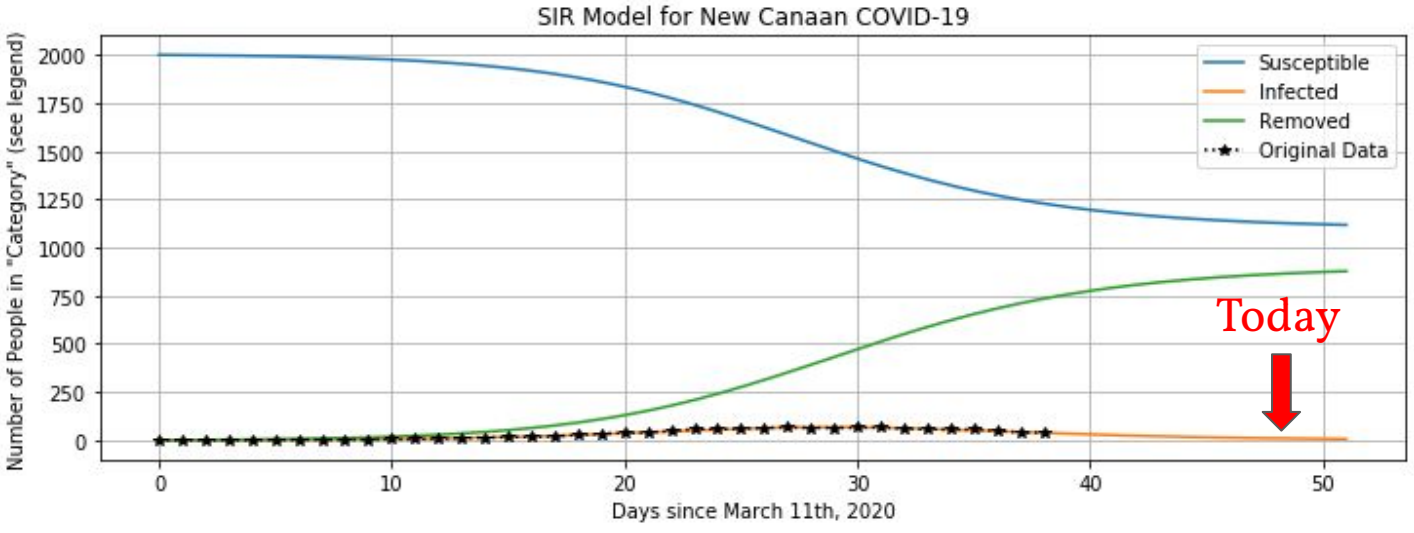


Apr. 11th	32	67

Fitting the SIR model of disease to data in Python

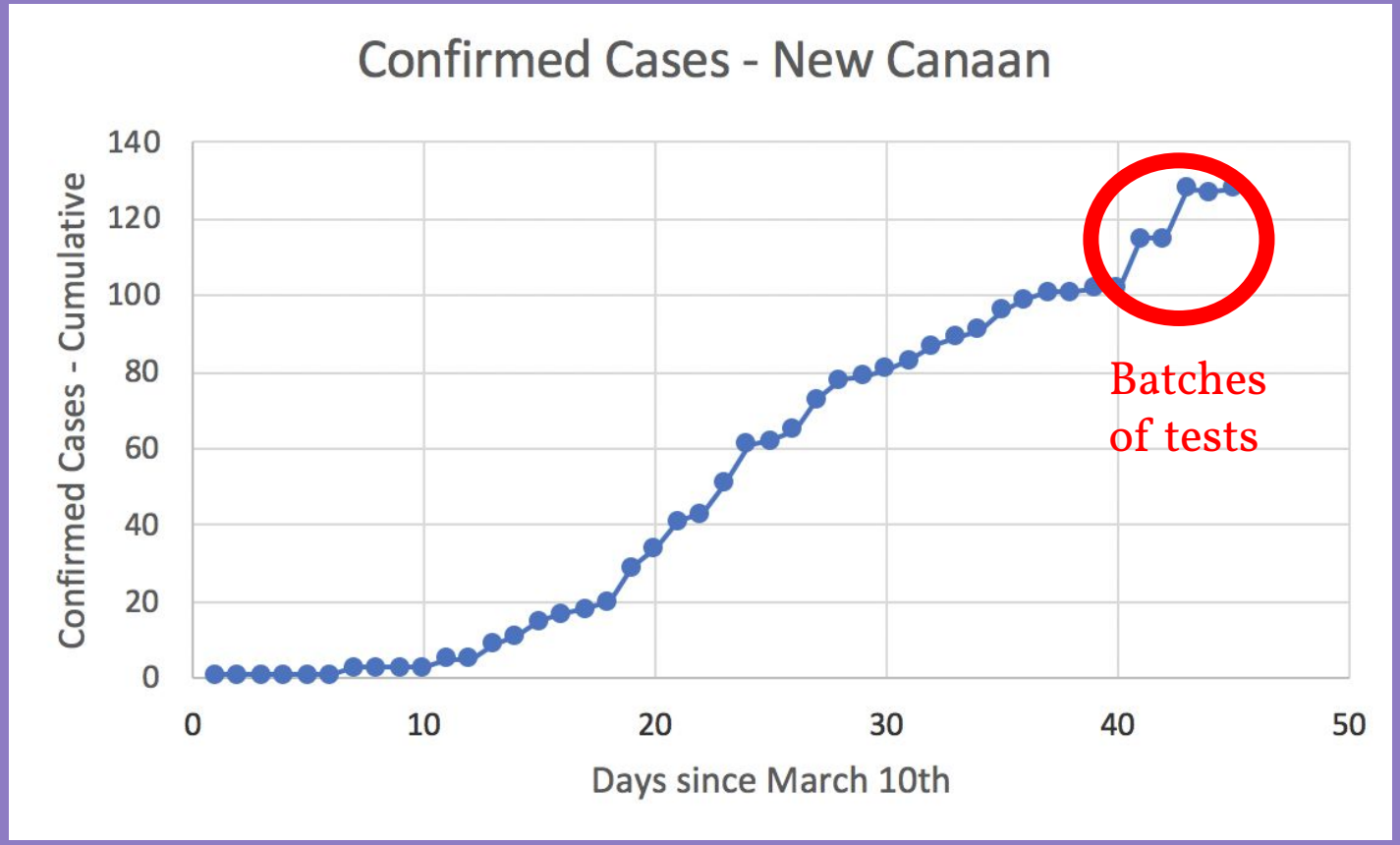
```
#!/usr/bin/env python3
# -*- coding: utf-8 -*-
"""
Description: Python program to fit SIR Curve to availiable NC Coronavirus Data
"""

import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
from scipy.integrate import solve_ivp
from scipy.optimize import minimize

originalData = pd.read_csv("coronaVirusData.csv")
data = originalData[" # of Infected Individuals "]
print(len(data))

def sumsq(p):
    beta, gamma = p
    def SIR(t,y):
        S = y[0]
        I = y[1]
        R = y[2]
        return([-beta*S*I, beta*S*I-gamma*I, gamma*I])
    sol = solve_ivp(SIR,[0,len(data)-1],[2000,1,0],t_eval=np.arange(0,len(data)+.2-1,0.2))
    return(sum((sol.y[1][::5]-data)**2))

msol = minimize(sumsq,[0.001,1],method='Nelder-Mead')
print(msol.x)

beta,gamma = msol.x

def SIR(t,y):
    S = y[0]
    I = y[1]
    R = y[2]
    return([-beta*S*I, beta*S*I-gamma*I, gamma*I])

sol = solve_ivp(SIR,[0,len(data)-1],[2000,1,0],t_eval=np.arange(0,len(data)+.2-1,0.2))

fig = plt.figure(figsize=(12,4))
plt.plot(sol.t,sol.y[0])
plt.plot(sol.t,sol.y[1])
plt.plot(sol.t,sol.y[2])
plt.plot(np.arange(0,len(data)),data,"k*:")
plt.grid("True")
plt.legend(["Susceptible","Infected","Removed","Original Data"])
plt.show()
```


SIR Model for New Canaan COVID-19
Number of People in "Category" (see legend)
Days since March 11th, 2020
Susceptible
Infected
Removed
Original Data


SIR Model for New Canaan COVID-19
Number of People in "Category" (see legend)
Days since March 11th, 2020
Susceptible
Infected
Removed
Original Data
Today

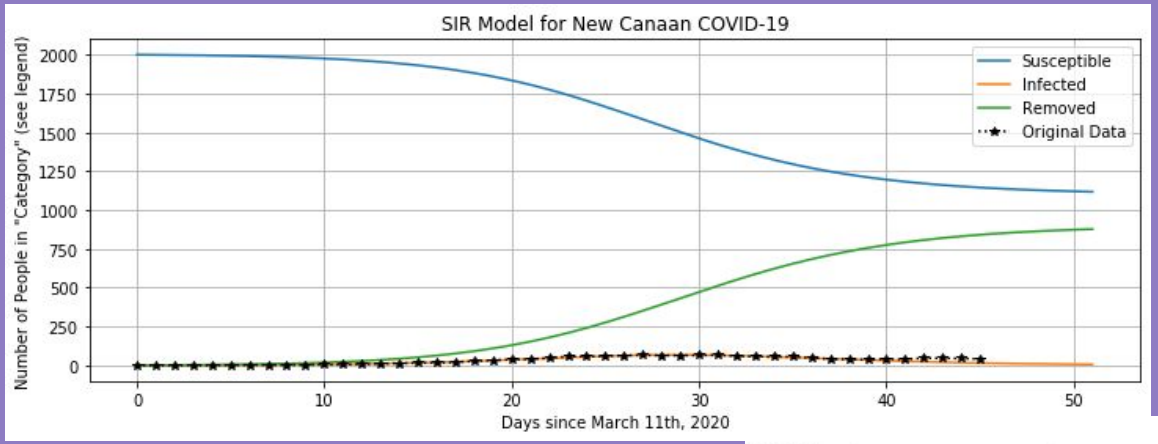
New Canaan Coronavirus Modeling

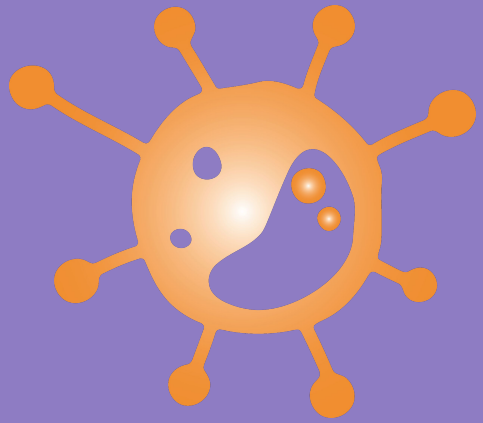
Apr. 25th Update

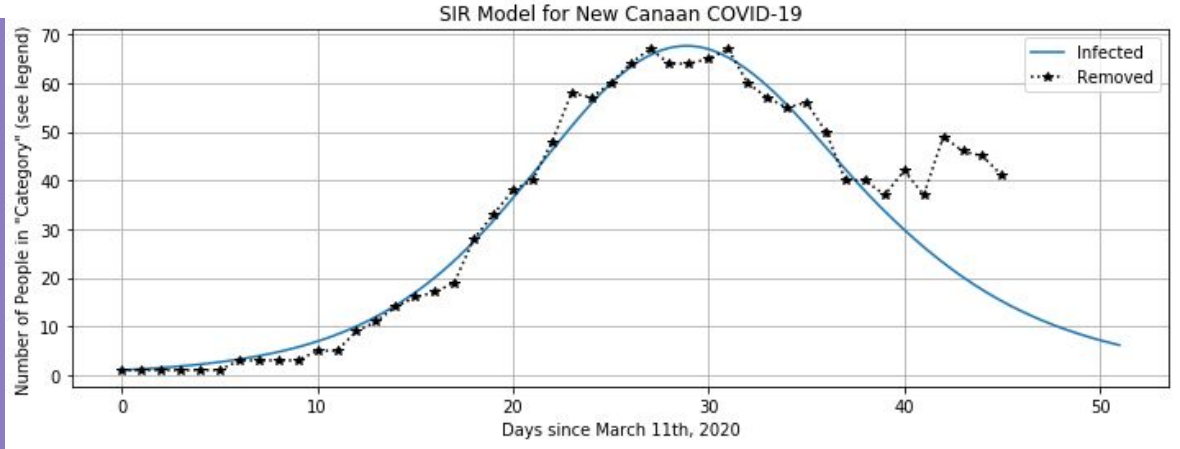


New Canaan Coronavirus Modeling

Apr. 25th Update

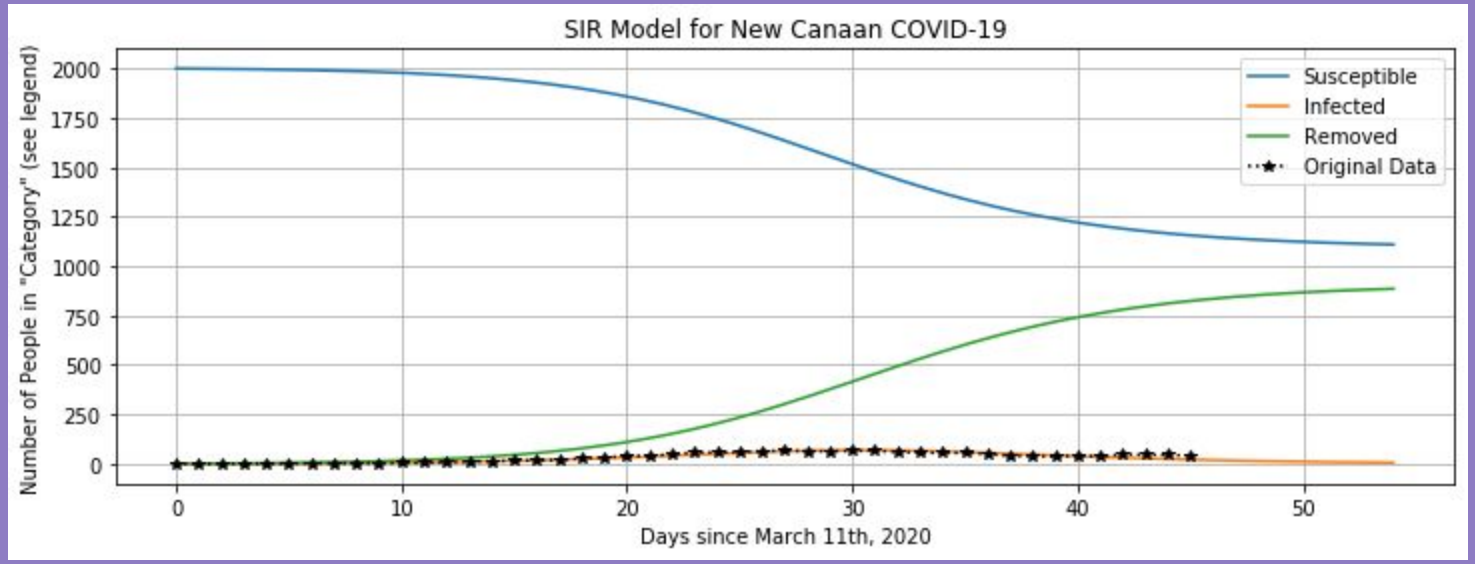






New Canaan Coronavirus Modeling

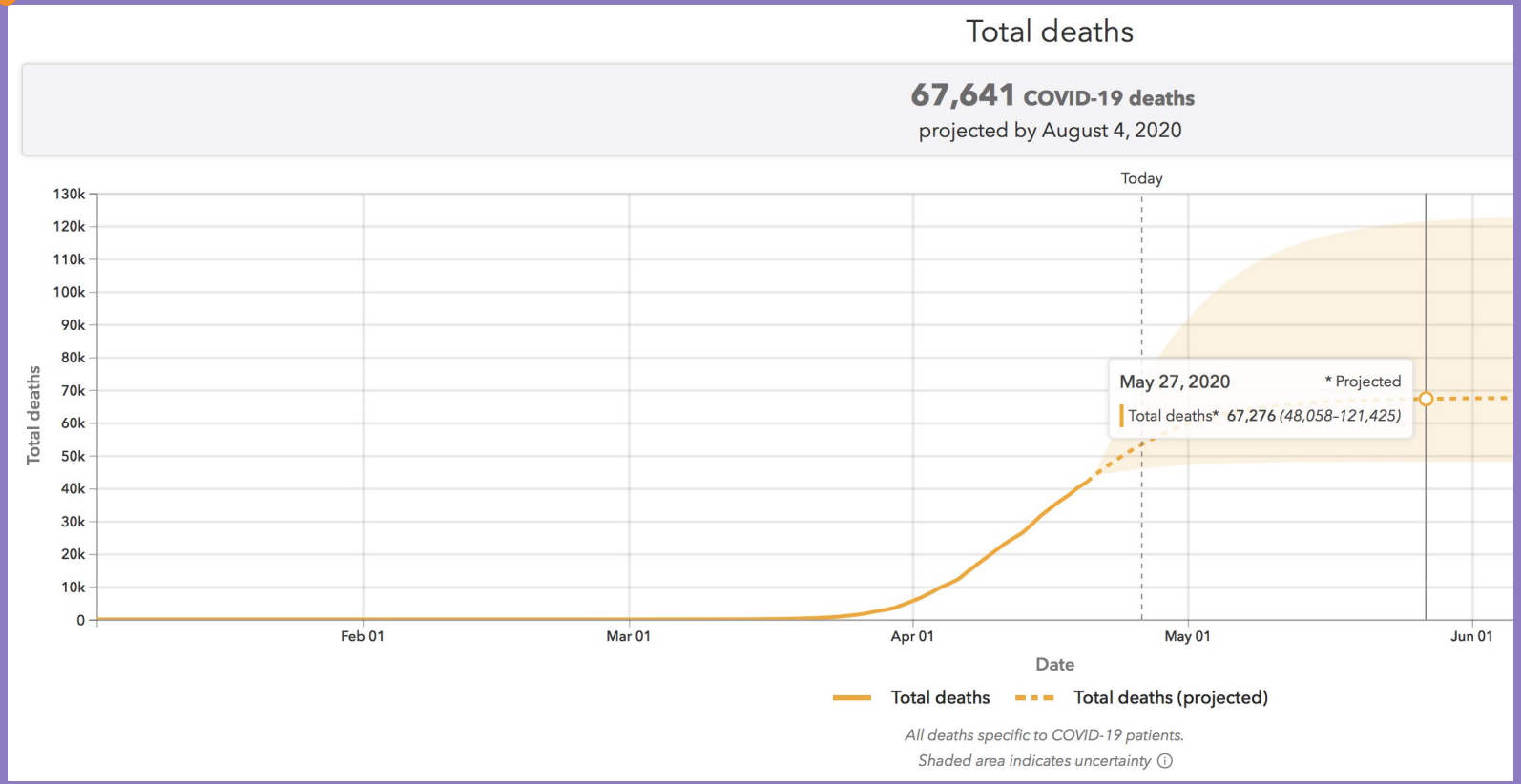
Apr. 25th Update



Similar Projections as Before!

Coronavirus Modeling

Apr. 25th Update



Epidemics Modeling - Data Science

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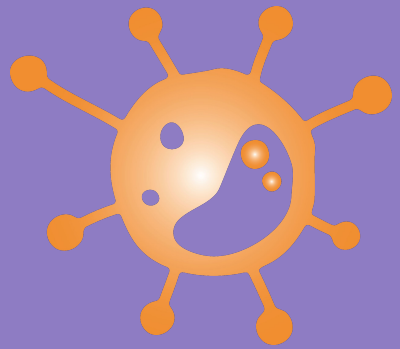
For more info about the coronavirus, see cdc.gov.

Modelling the coronavirus epidemic in a city with Python

Are cities prepared for epidemics?



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Infectious Disease Modelling: Beyond the Basic SIR Model

Sources