Pacific Northwest
NATIONAL LABORATORY

Model Me This: COVID-19 Scientific Predictions and Where We Go From Here

Tuesday, March 30

Featuring: Tim Scheibe, PhD

Lab Fellow, Earth Scientist
Environmental Dynamics & Simulations

DEMYSTIFYING COVID:

A Special Edition
Seminar Series

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Historical	FY 2019	Historical	FY 2019	Historical	FY 2019
$28.5M	$0.52M	347,000	30,000	>120	56
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DEMYSTIFYING COVID:

A Special Edition Seminar Series

EVERY TUESDAY IN MARCH

5:00-6:00 P.M.

MARCH **02**

Hindsight is 2020: The Science Behind COVID-19

Presented by Steve Wiley

What lessons have we learned over the last few months? What's left for us to uncover? And seriously what is the difference between a cold, a flu, and COVID symptoms?

MARCH **09**

What Do Bats Have to Do with It?

Presented by Amy Sims

Bats, pangolins, and humans—oh my! This talk will explore the role wild animals play in the emergence of new diseases.

MARCH **16**

Behind the Mask: The Science on Stopping the Spread

Presented by Katrina Waters

What measures keep our communities safe? And why do some strange, sometimes serious health effects linger even after COVID-19 has gone, including a loss of taste and smell or COVID toe? Join us to find out.

MARCH **23**

Testing, Testing, 1, 2, 3 (And What's Up With The New Vaccine, Anyways?)

Presented by Kristin Omberg

If you're confused about COVID-19 testing and vaccines, you're not alone. This talk will explore the science behind the 400+ diagnostic tests and 200+ vaccine candidates produced over the last year.

MARCH **30**

Model Me This: COVID-19 Scientific Predictions and Where We Go from Here

Presented by Tim Scheibe

Using mathematical models, scientists across the globe are beginning to arrive at a more complete picture of how and why COVID-19 spread across geographical locations and human populations.

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5:00-6:00 P.M.

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President & CEO
United Way of Benton & Franklin Counties

Kate McAteer
Vice Chancellor | Academic and Student Affairs
WSU Tri-Cities

Justin Raffa
Artistic Director
Mid-Columbia Mastersingers

Martin Valadez
Interim Executive Director
Tri-Cities Hispanic Chamber of Commerce

Regional Director
Tri-Cities Campus Heritage University

TODAY'S SPEAKER

EVERY TUESDAY
IN MARCH
5:00-6:00 P.M.

Tim Scheibe

Lead Scientist
River Corridor Scientific Focus Area Project

When you hear the word "model", what do you think about?

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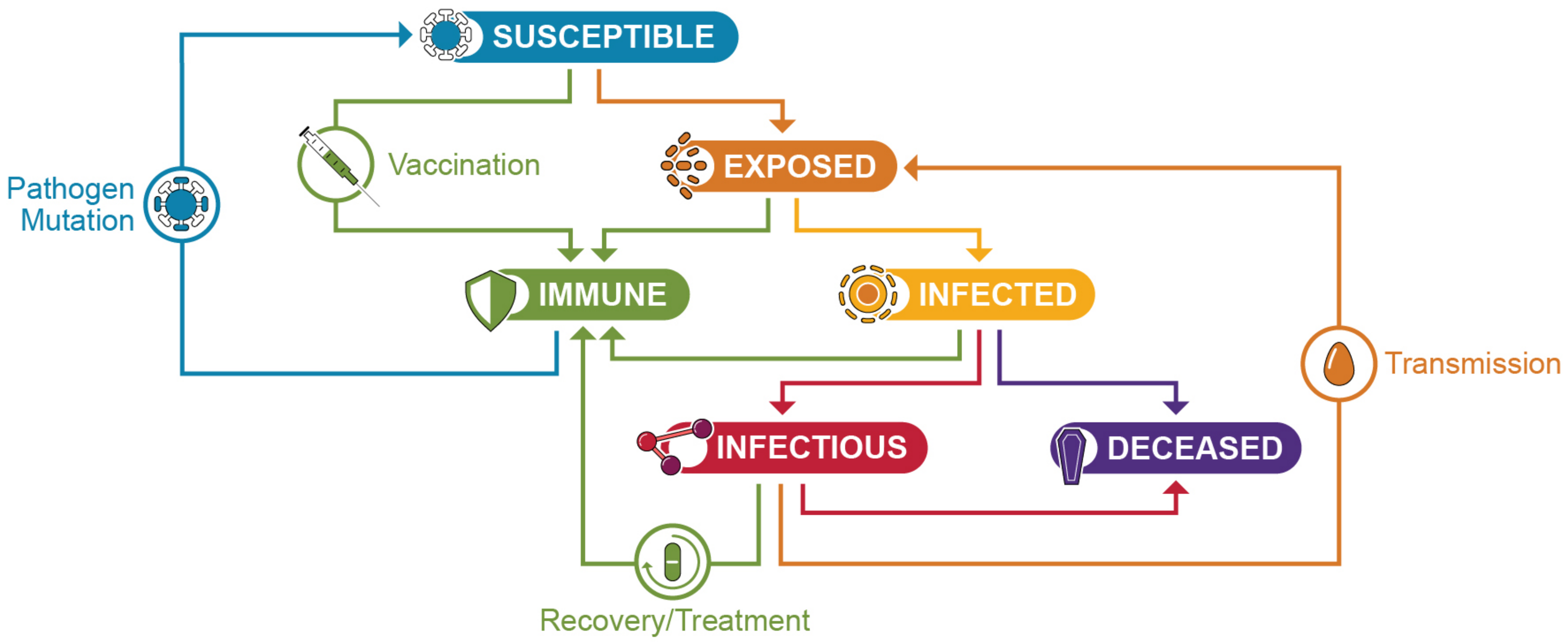
Today's discussion:
models and scientific prediction

VIRAL INFECTION OVERVIEW



Terminology

Pandemic

- An outbreak of a disease that is prevalent over a whole country or world

Transmission

- Spreading a disease

Mutation

- A genetic change in a disease that might or might not impact its transmission, symptoms or prior immunity

Infectious/Contagious

- The state of being able to transmit a disease to another person

Vaccine

- A non-harmful (hopefully) proxy of the disease agent that that can induce a protective immune response

Model

- A representation of a disease or disease process that can recapitulate key aspects

Reservoir

- Any person, animal, plant, soil or substance in which an infectious agent normally lives and multiplies

What is a model?

"An approximate representation of a complex system that we use to learn about, encode knowledge of, and predict the behavior of that system"

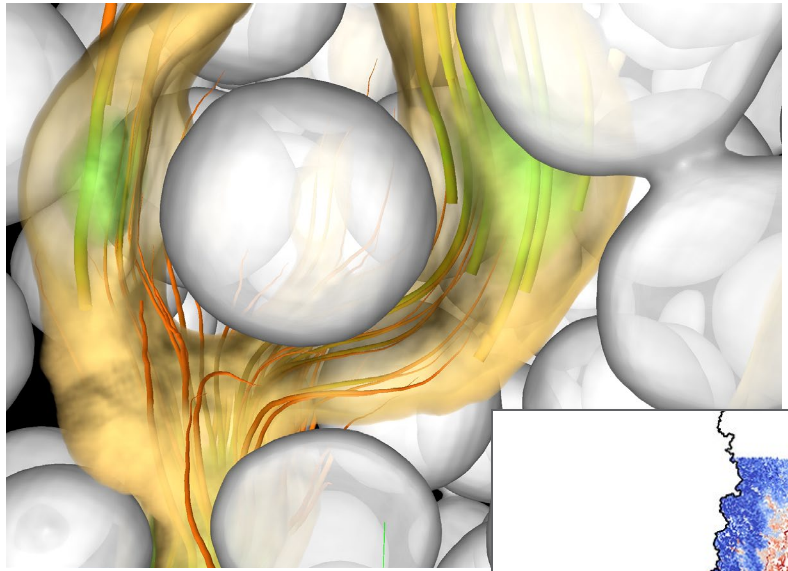
"All models are wrong, some are useful."

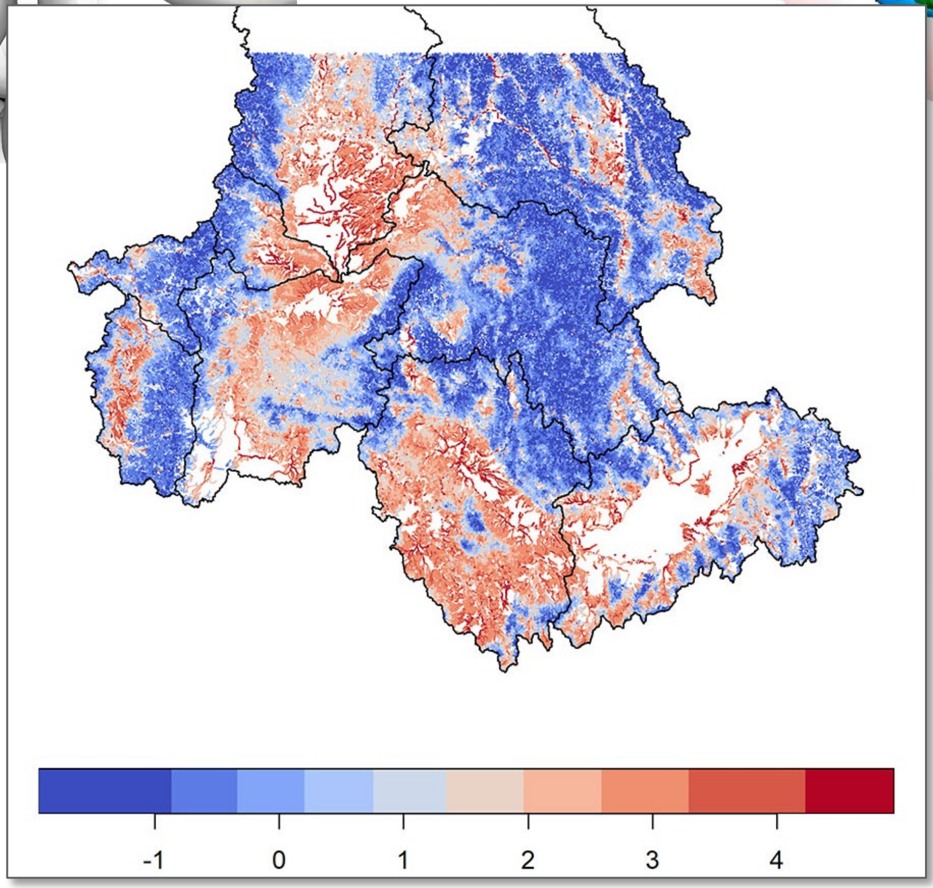
George Box
Statistician

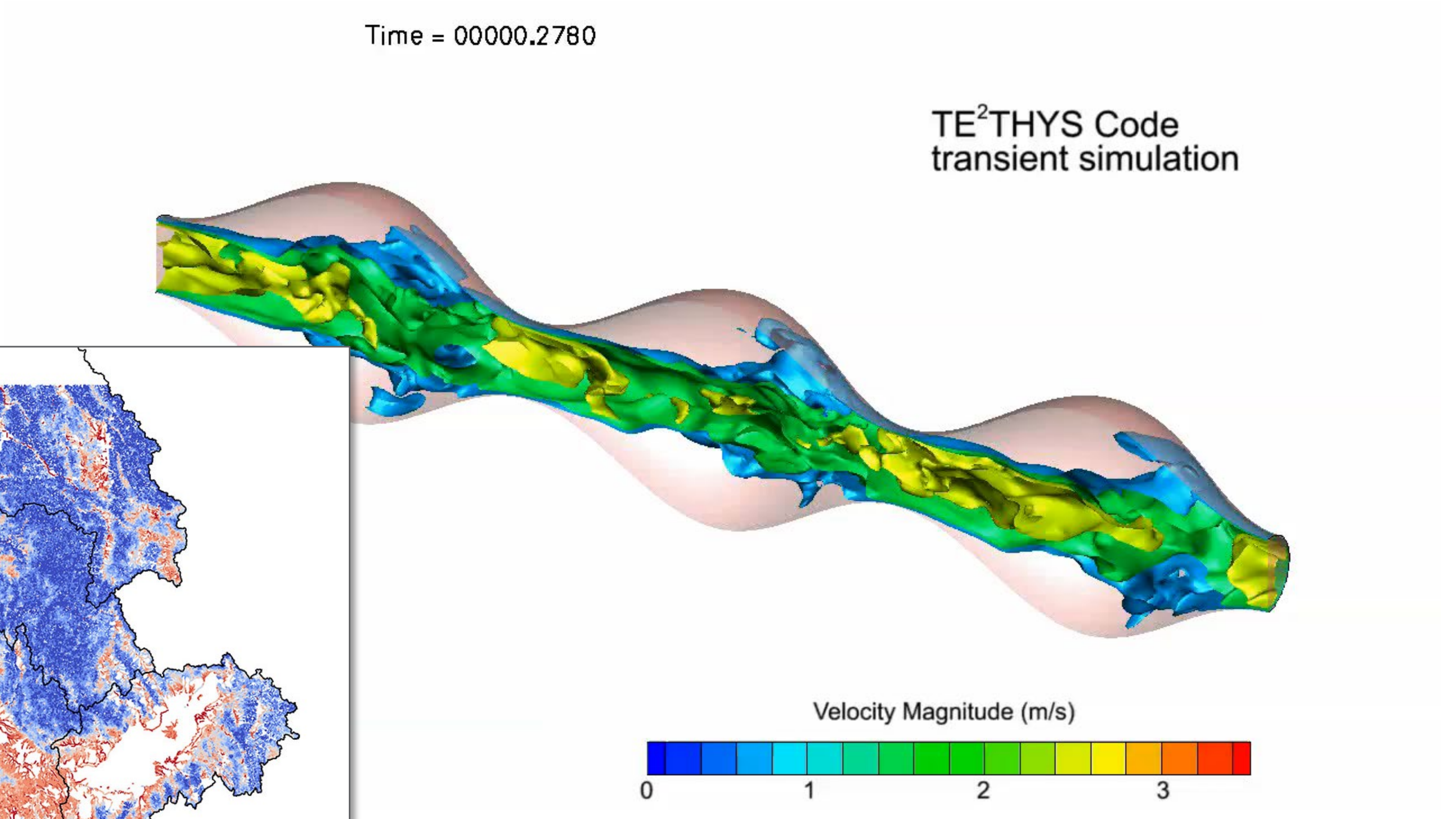
Me – "Reality"	Fashion Model	Anatomical Model	Laboratory Model	Computer Model
				

Descriptive Model: "Tim Scheibe is…
…a nerdy scientist who programs computers"

Some of “my” models



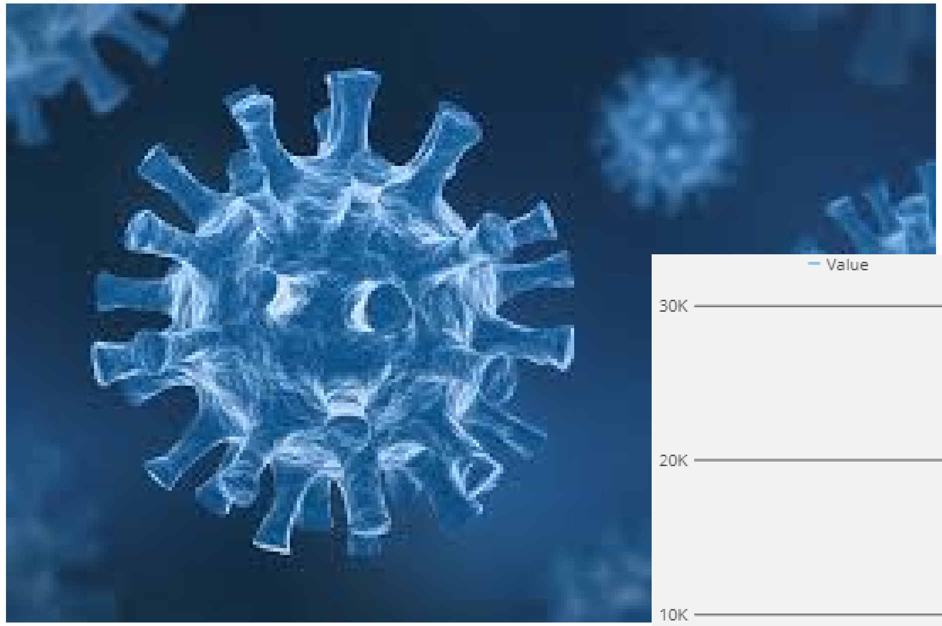


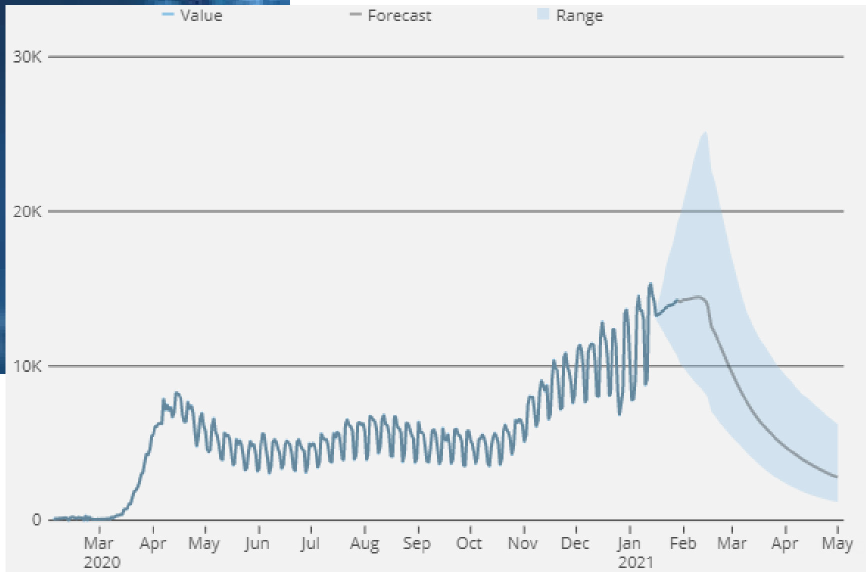


Can we use mathematical models to learn about, encode knowledge of, and predict the spread of diseases like COVID-19?

> **"All models are wrong, some are useful."**
> **George Box**
> Statistician

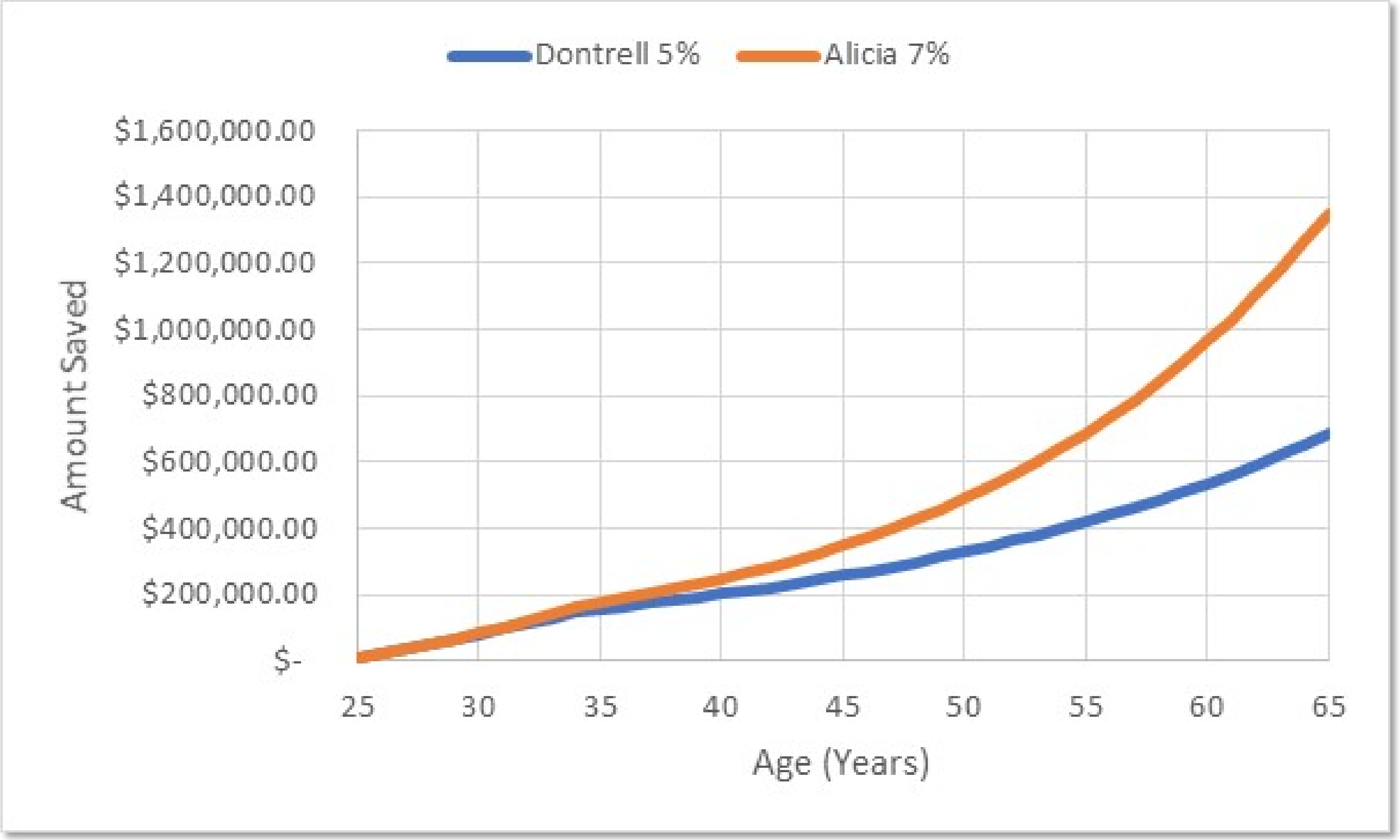
- "An approximate representation of a complex system that we use to learn about, encode knowledge of, and predict the behavior of that system."





A very simple mathematical model – R_0 ("r-zero" or "r-not")

- Have you ever heard about "The Power of Compound Interest?"



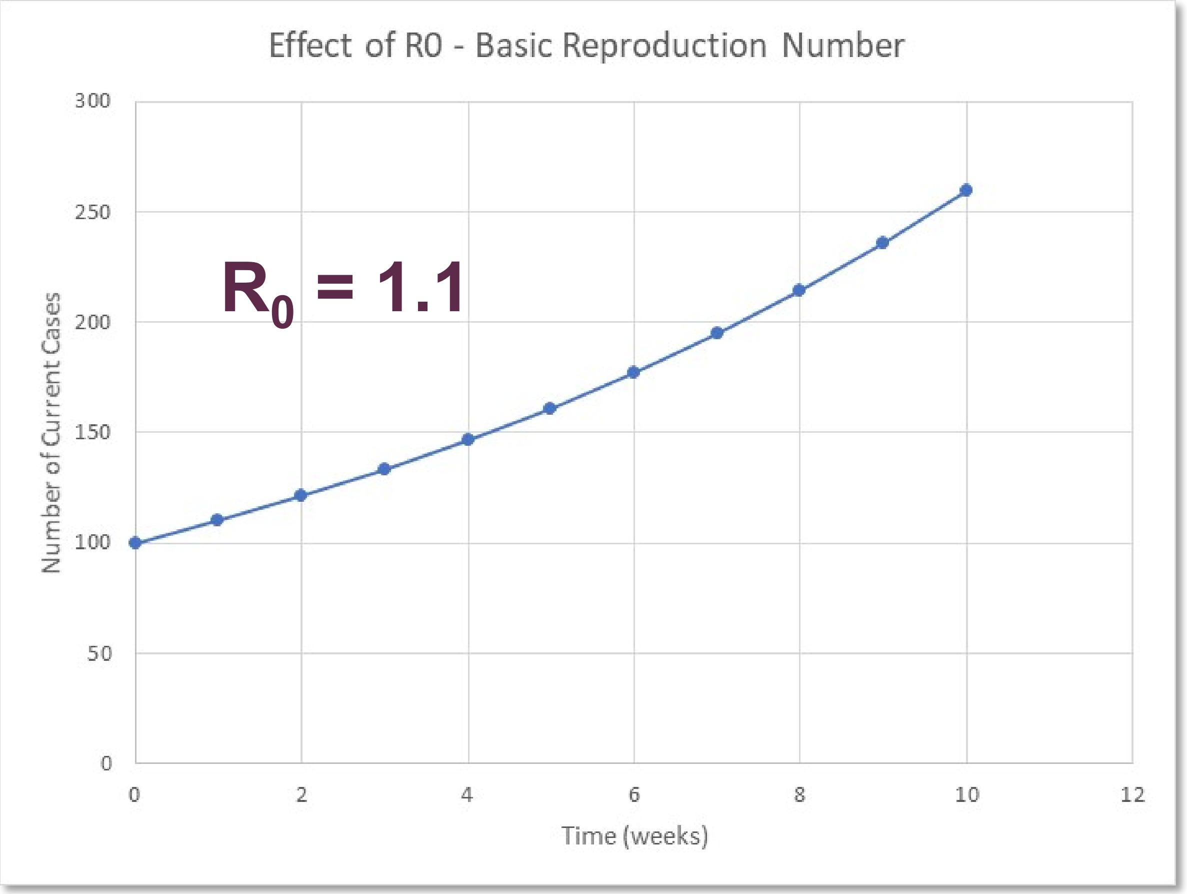
A very simple mathematical model – R_0

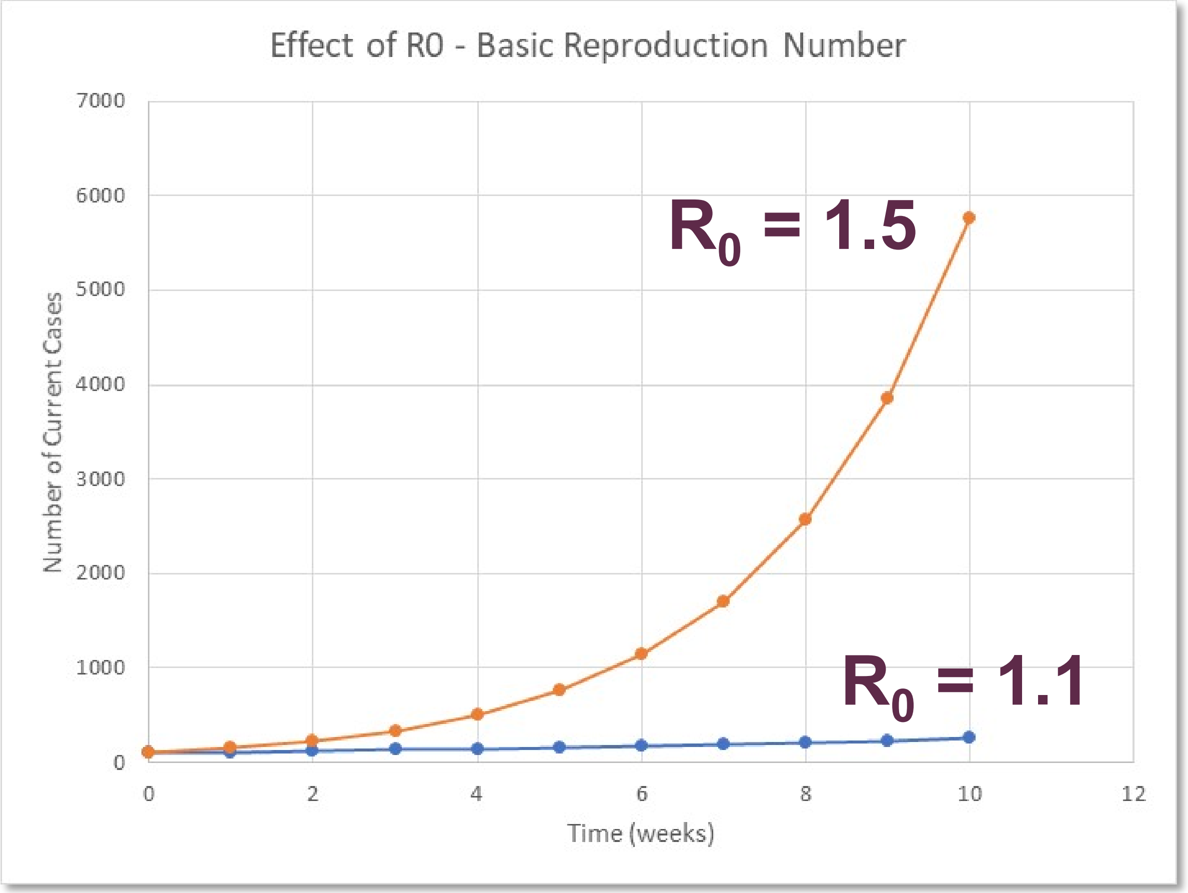
- R_0 is the **basic reproduction number** – the average number of new people infected by one infected person.
  - Dontrell had COVID-19 and spread it to **one** other person in his home
  - Alicia had COVID-19 but quarantined early and did **not** spread it to anyone else
  - Olivia had COVID-19 and spread it to **two** other people before she became symptomatic
  - Brandon had COVID-19 without ever getting symptoms and unknowingly spread it to **six** other people
- The average number of new infections per person for this example is:
  - $R_0 = (1 + 0 + 2 + 6)/4 = 2.25$

$$I_{t+1} = R_o I_t$$

A very simple mathematical model – R_0

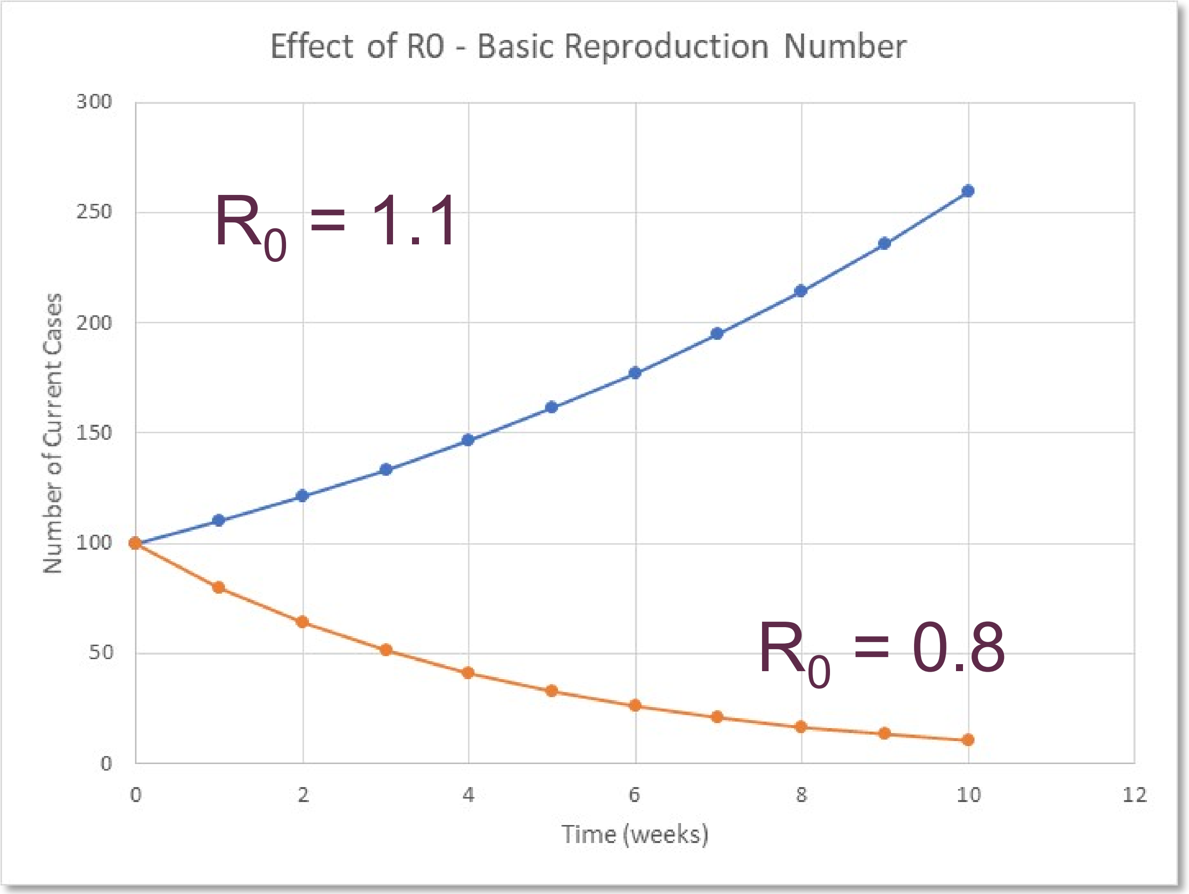
- **What can we learn from this model?**
  - Like compound interest, a small change in R0 leads to a big difference in the number of infections over the same period.

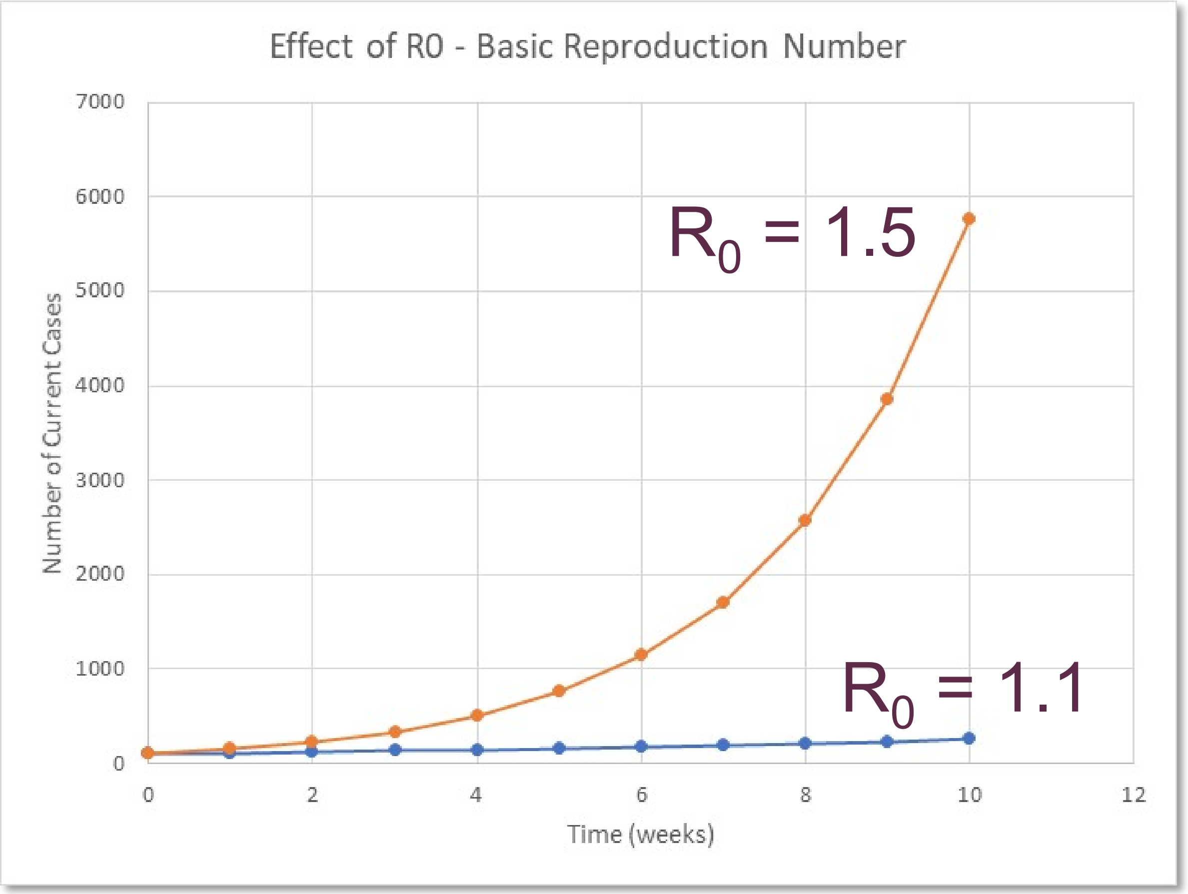




A very simple mathematical model – R_0

- What can we learn from this model?
  - If R_0 is less than 1.0, the pandemic will be controlled





A more complex model – compartment model

Number of susceptible individuals

Number of infected individuals

Number of recovered individuals

r = infection rate parameter

θ = recovery rate parameter

A hypothetical example

Imagine…

- A small city (population 10,000) remotely located, like Sedona, AZ
- One resident went to Phoenix and was exposed to COVID-19 early in the pandemic
- How could that one infection affect the city over one year's time?
- Assume no other COVID-19 brought in from elsewhere

Sedona, Arizona (from Wikipedia)

What can we learn from this model?

Model configuration:

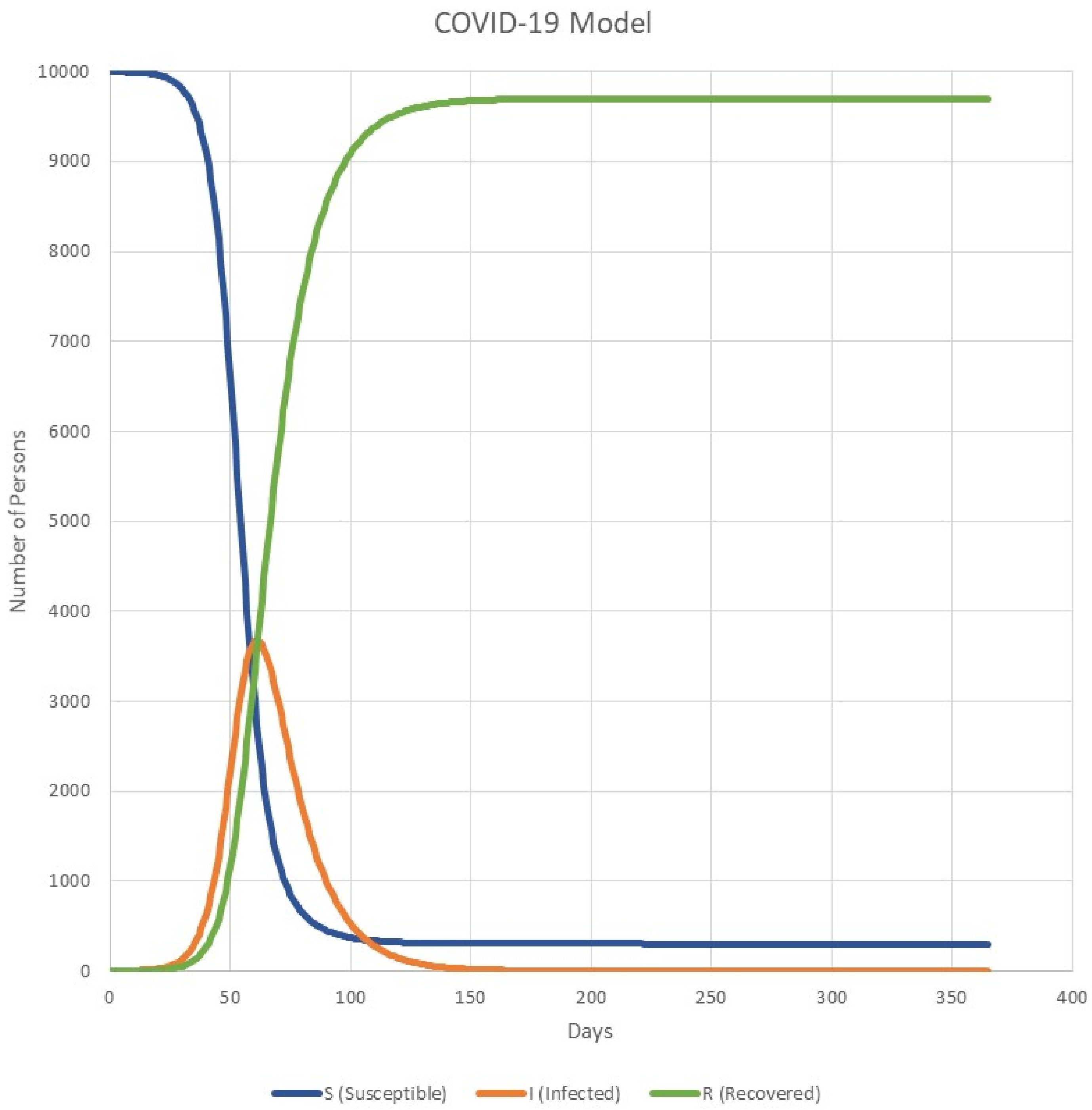
- Total population = 10,000
- Initial infections = 1 at time = 0 days
- Modeled time period = 1 year (365 days)

Parameters:

- Infection rate r = 0.000025
- Recovery rate q = 0.07143

Insights:

- Recovery lags behind infection
- Infection increases until the number of susceptible people decreases sufficiently, then drops
- Number of susceptible people doesn't go to zero (not everyone gets infected) – *herd immunity at ~97% infection*



What else can we learn from this model?

Change infection rate:

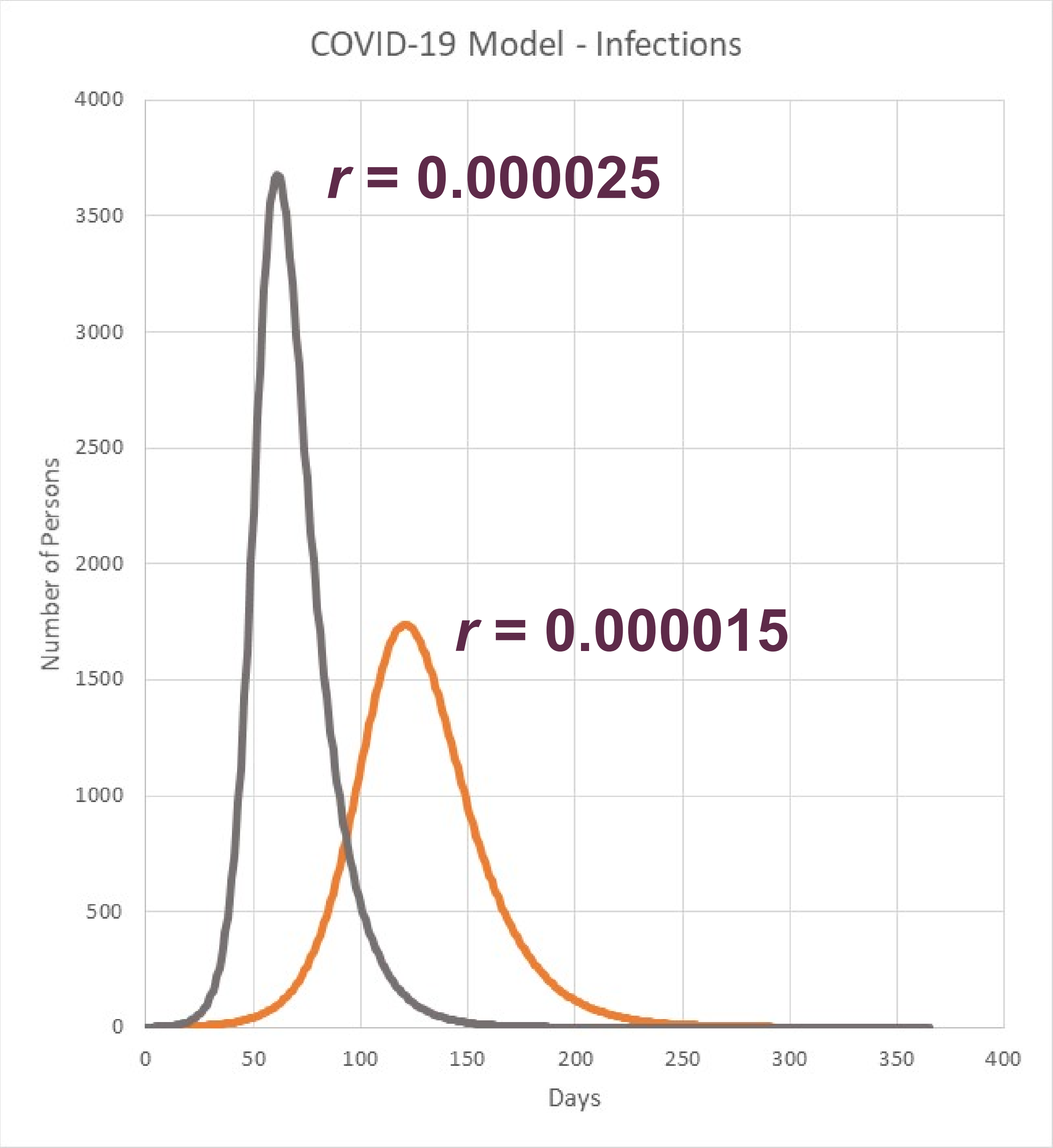
- Old infection rate r = 0.000025
- New infection rate r = 0.000015

Reflects less-contagious conditions:

- Reduced interactions (social distancing)
- Reduced virus spread (mask wearing, personal hygiene)

Insights:

- Flattened the curve – peak is both lower and later
- Herd immunity is reached with less total infections (about 83%)



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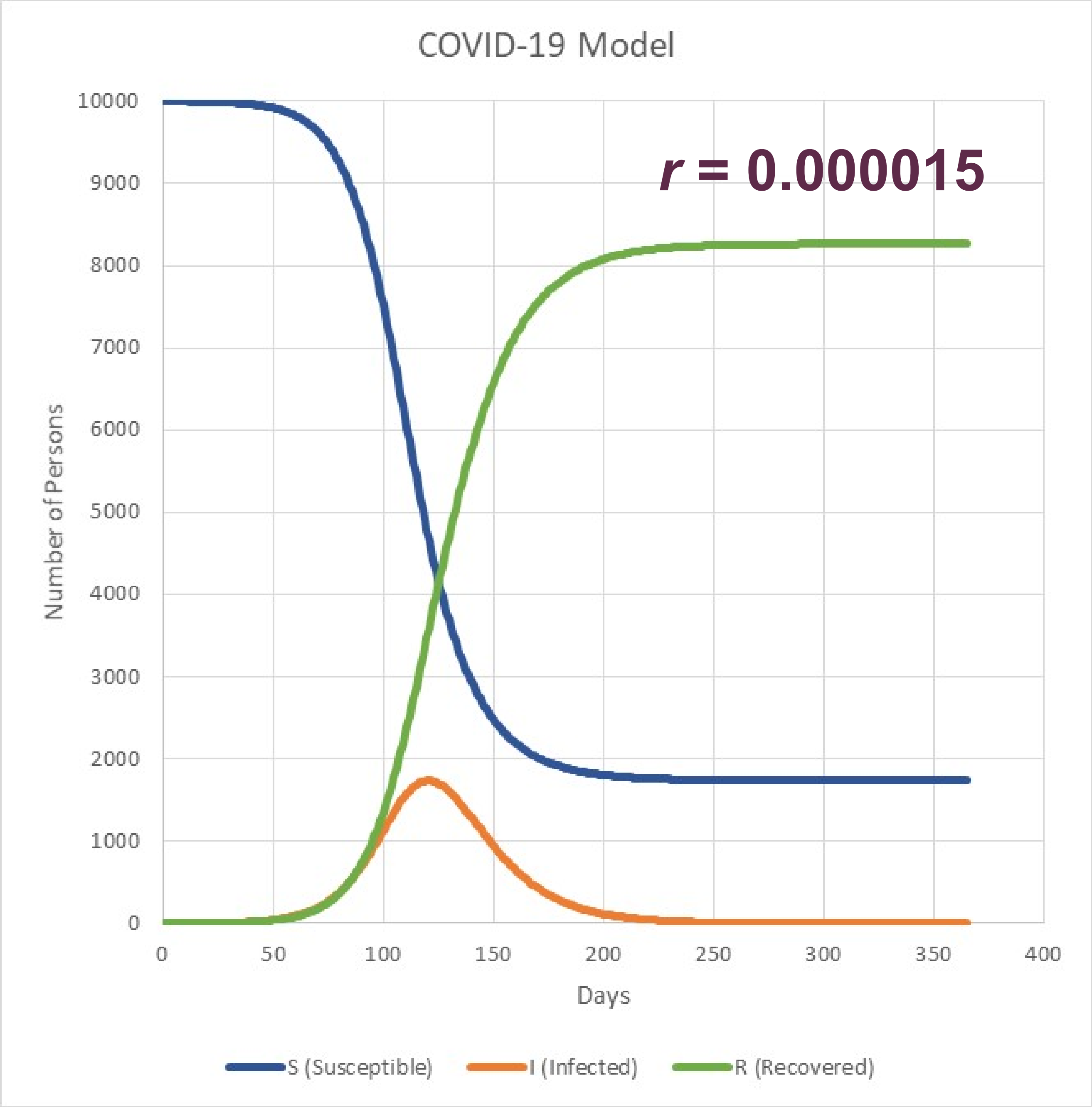


So… what are the “correct” parameters?

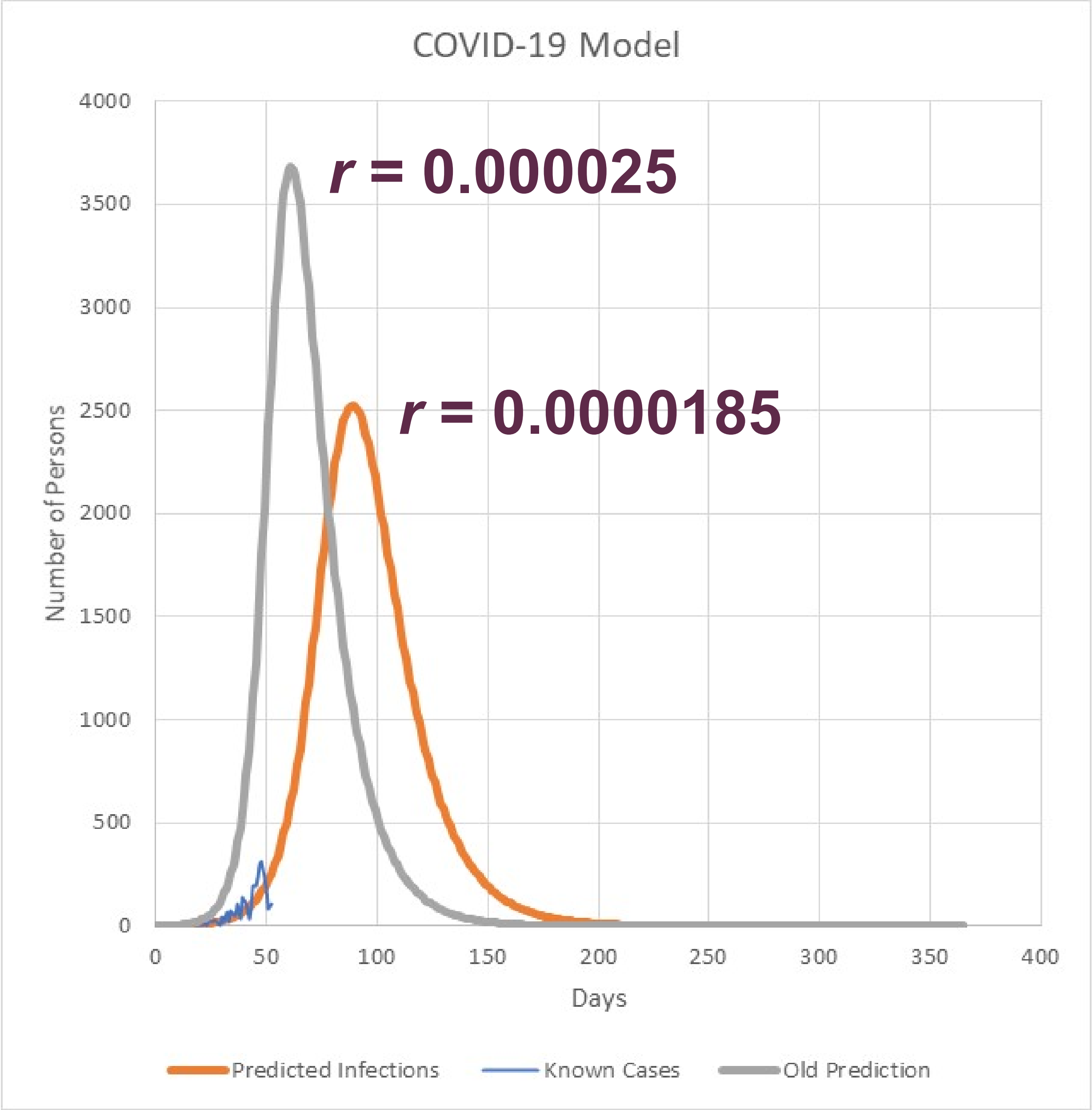
Initial estimates:

- Based on “prior knowledge” (from experience with other diseases)
- If recovery takes 14 days on average, then q = 1/14 = 0.07143
- R_o = the “basic reproduction number,” or the expected number of new infections from a single infection in a fully susceptible population. If this number is 3.5 in a population of 10,000, then r = 0.000025

$$R_0 = \frac{rN}{\theta}$$

“Fitting” the model to early data:

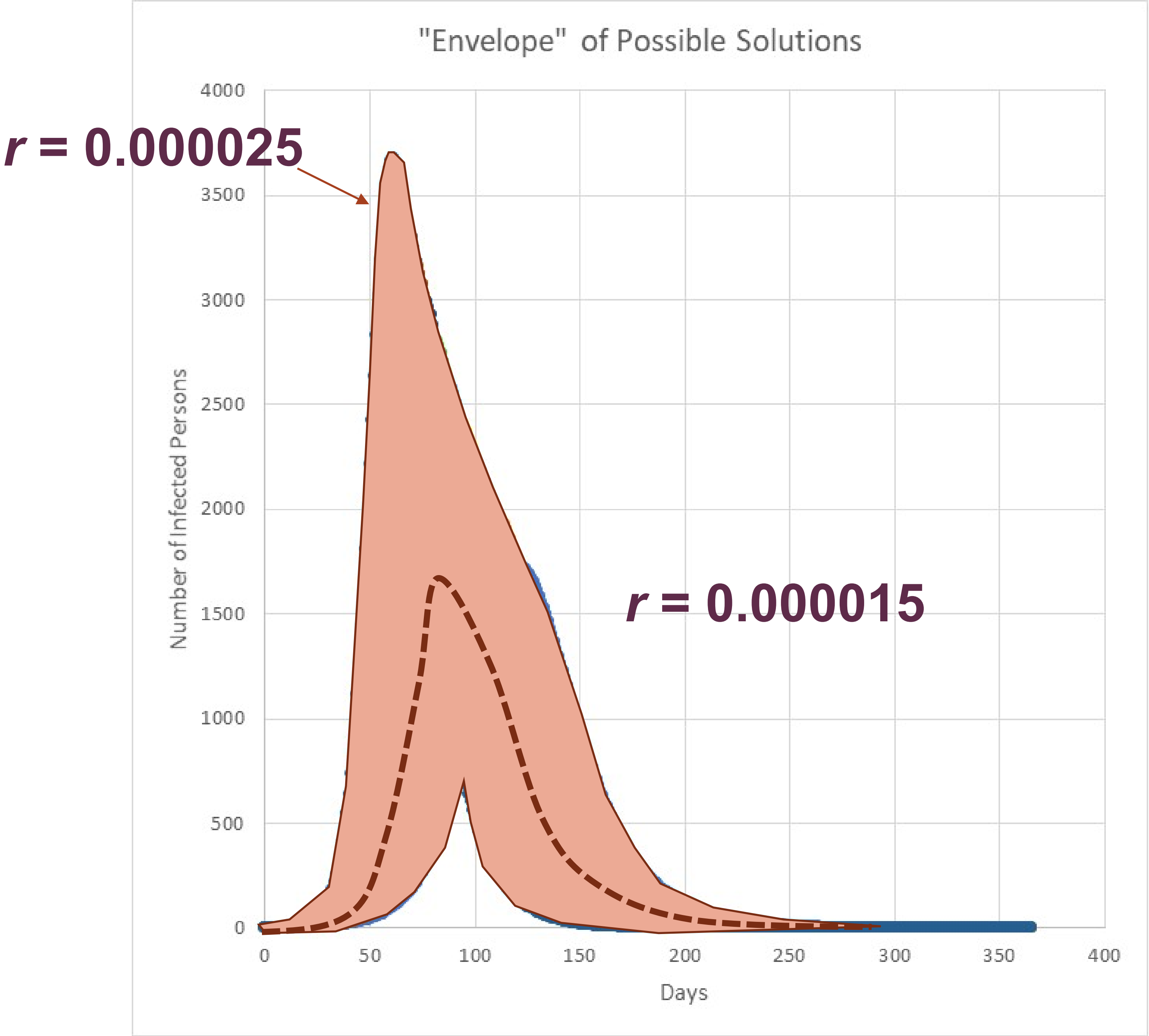
- Once we start measuring the number of cases (testing), we can use those data to modify our model parameters so that the model better matches the observations
- Calibration or Parameter Estimation



So… what are the “correct” parameters?

Model uncertainty

- Maybe we don’t know the correct value, but we think we know likely minimum and maximum
- A range of unknown model parameters can be used to give an “envelope” of predictions



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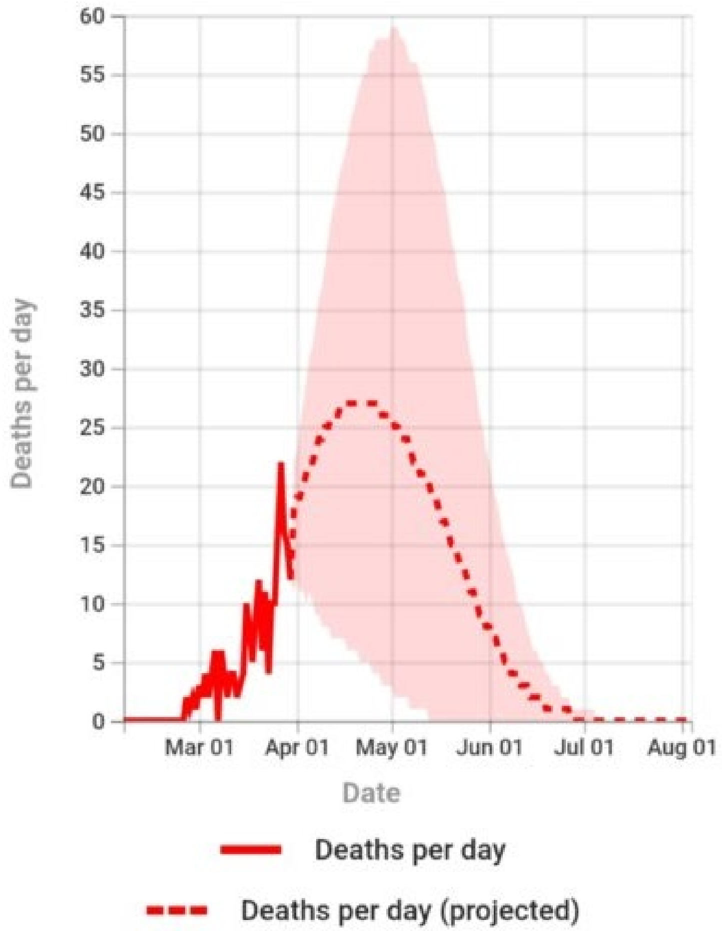
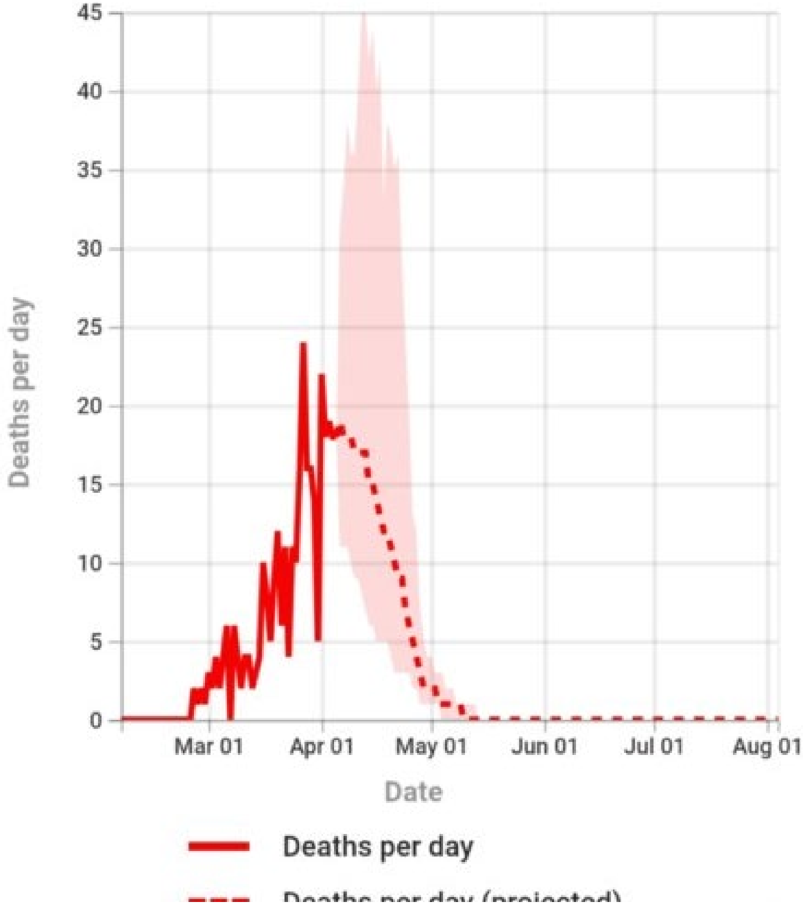
Some real model predictions

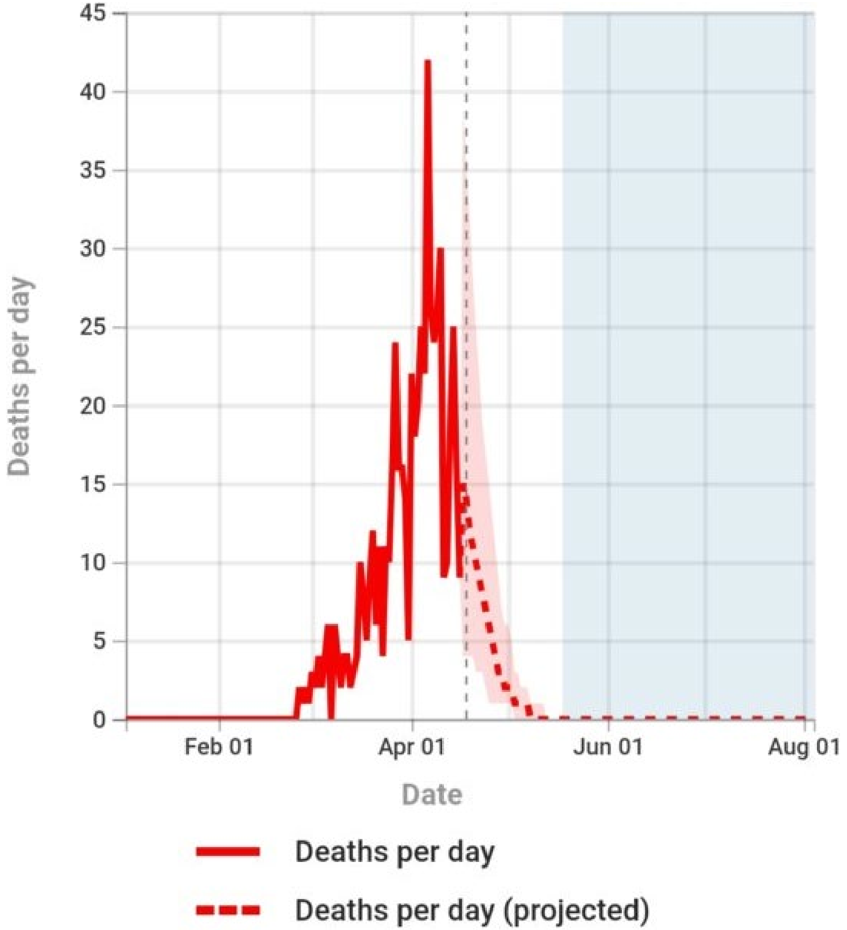
April 1, 2020



April 7, 2020

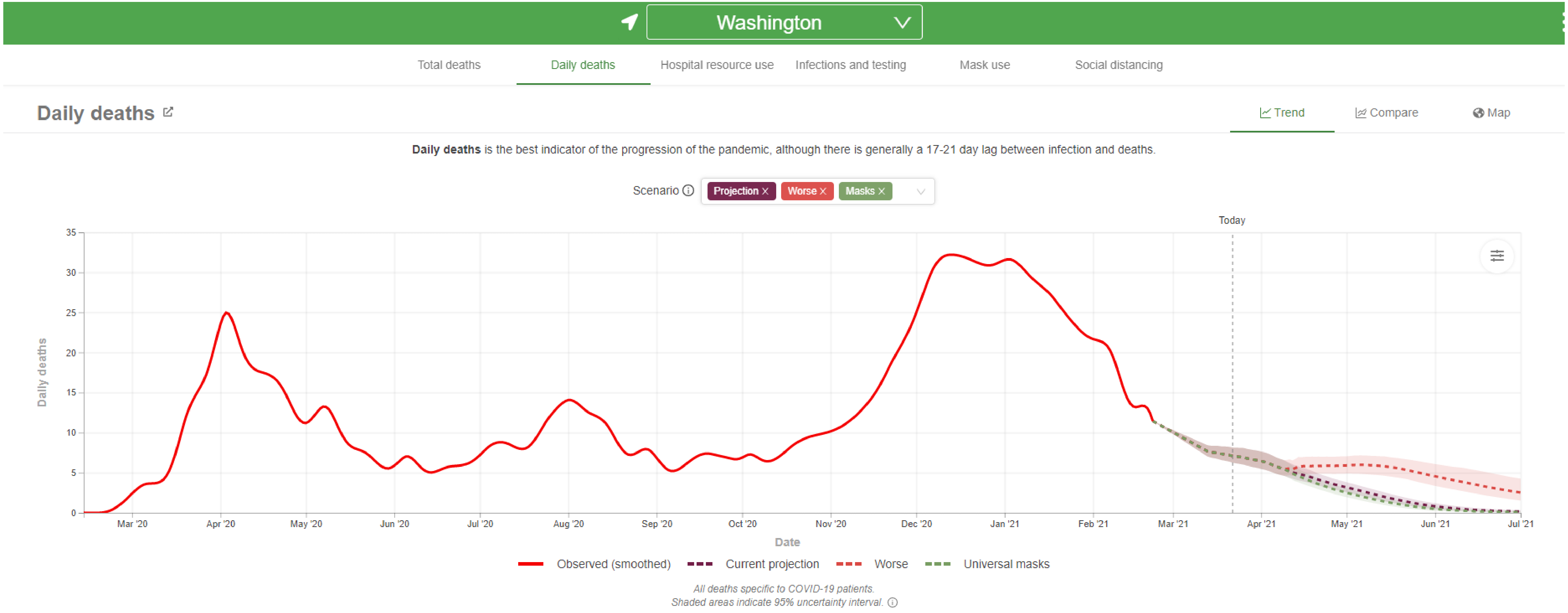


April 19, 2020



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

Some real model predictions

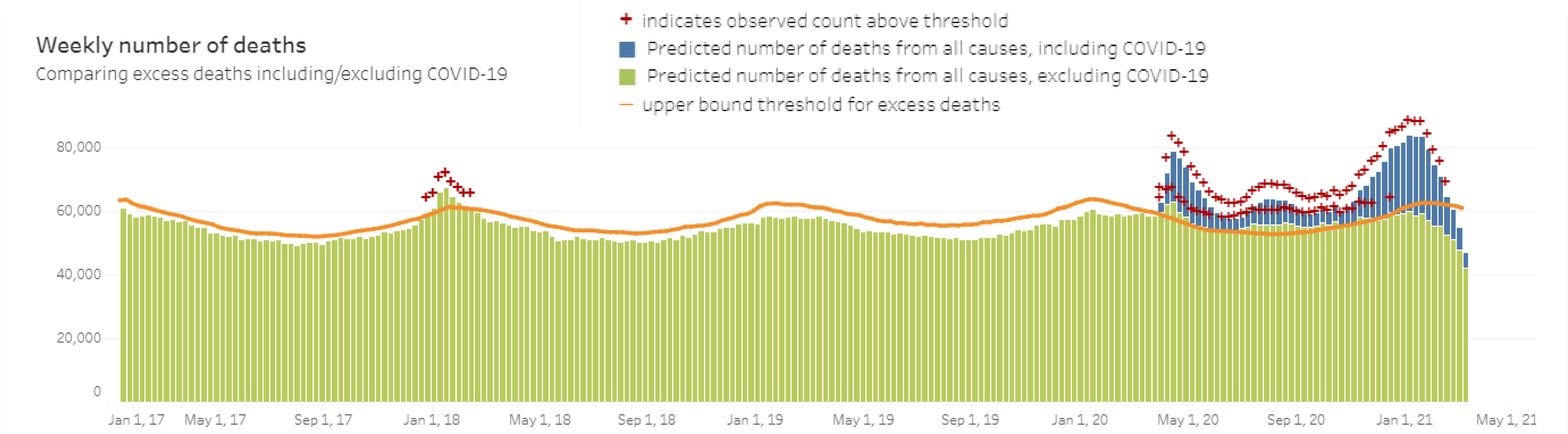


Source: https://covid19.healthdata.org/united-states-of-america/washington

Statistical model – excess deaths

Excess deaths: The difference between the **observed** numbers of deaths in specific time periods and **expected** numbers of deaths in the same time periods (based on historical trends from 2013 to present)

Total excess deaths since 2/1/2020 across the United States: 529,900–647,117
(61,713–160,437 non-COVID excess deaths)

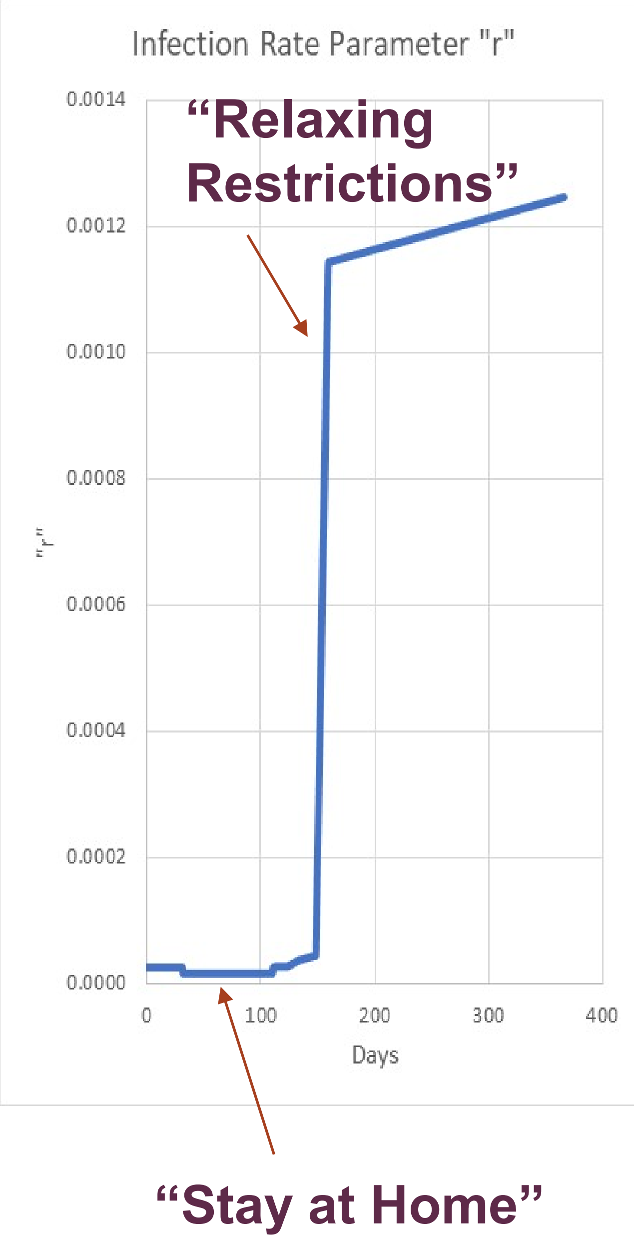


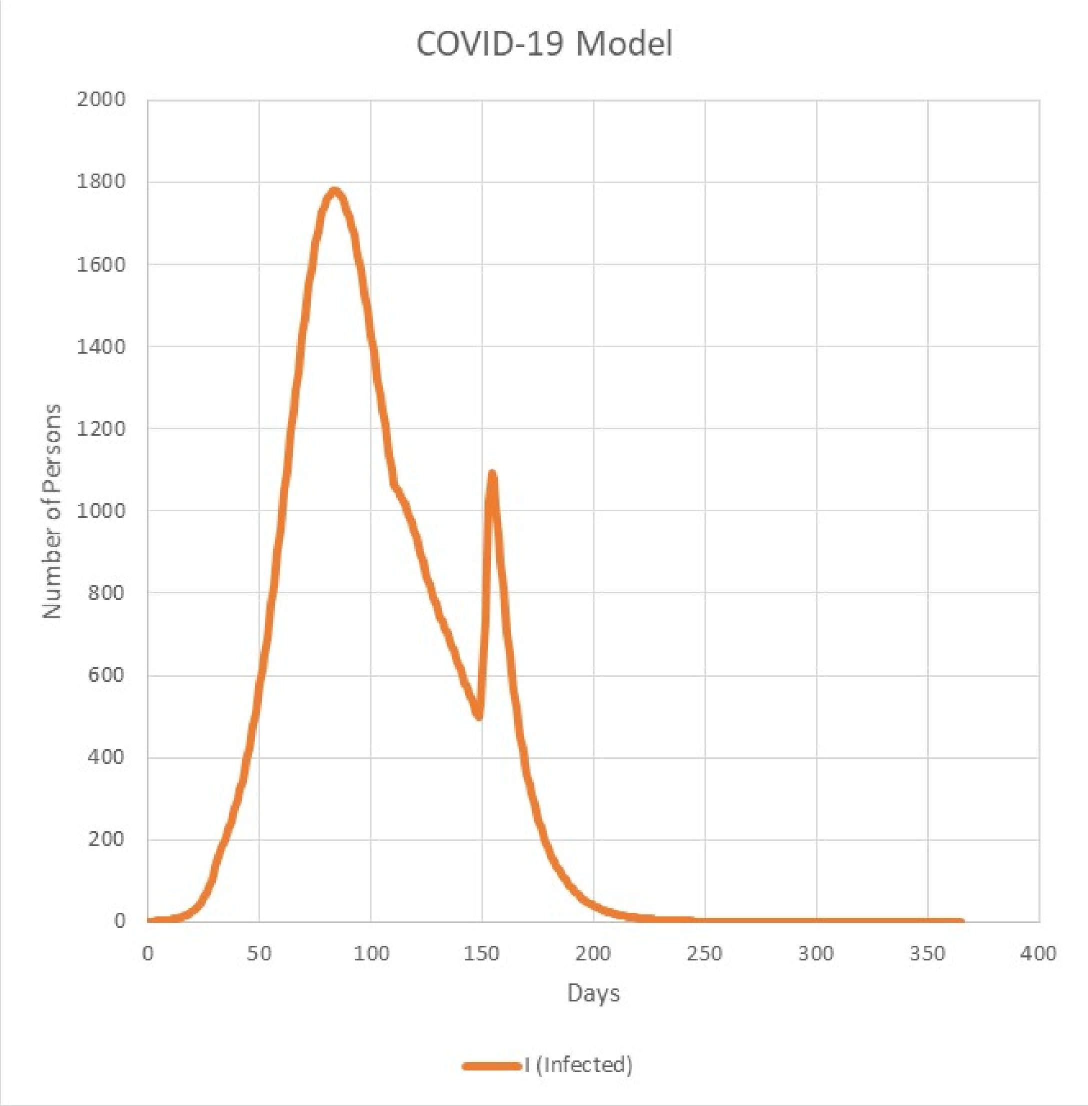
https://www.cdc.gov/nchs/nvss/vsrr/covid19/excess_deaths.htm

Let’s explore our assumptions!

Assumption: The rate of infection (our parameter “r”) is a single number

- It could vary over time because of public policies and behaviors, because of mutations in the virus, or because of environment (temperature, humidity)
- It could vary between sub-populations (large families, people in assisted living, health care workers, children in schools)

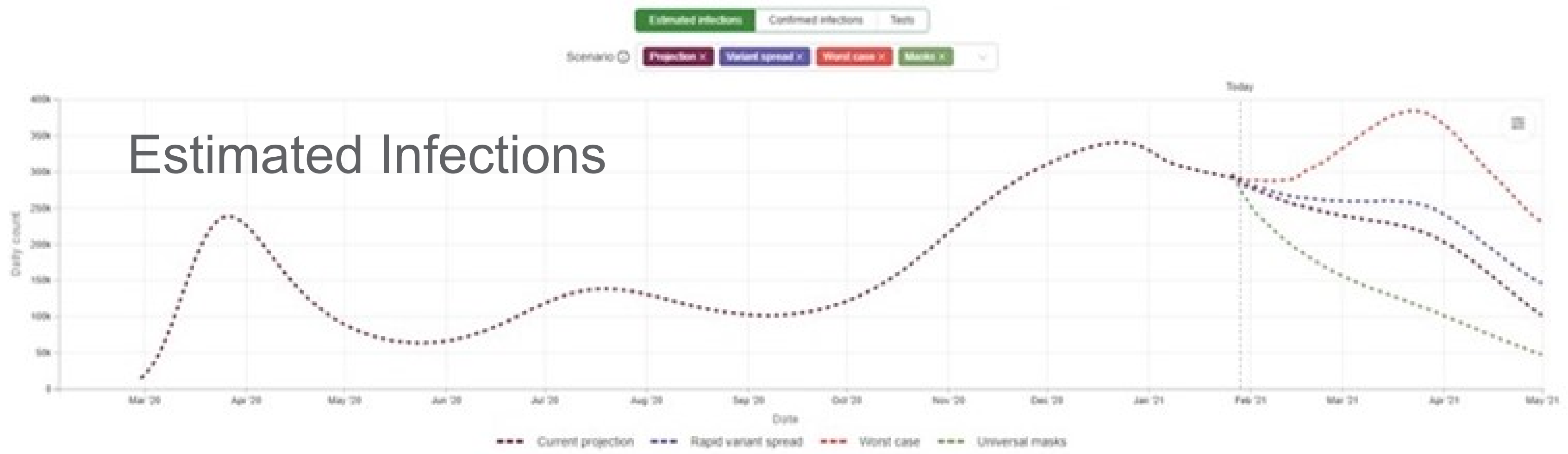


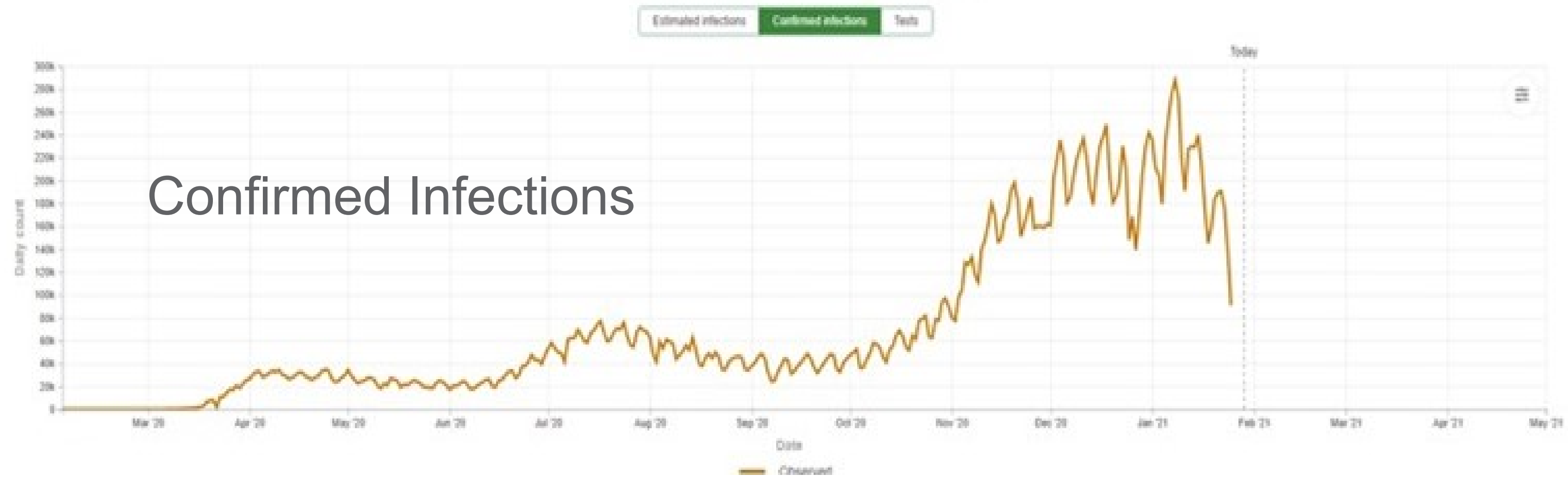


Let’s explore our assumptions!

Assumption: Our testing data represent all infections

- People with mild symptoms may choose not to be tested
- Tests may not be available (especially early in the pandemic)
- Some people could be infected and never show symptoms (asymptomatic) – less likely to be tested





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

Let's explore our assumptions!

Assumption: Recovered persons are immune

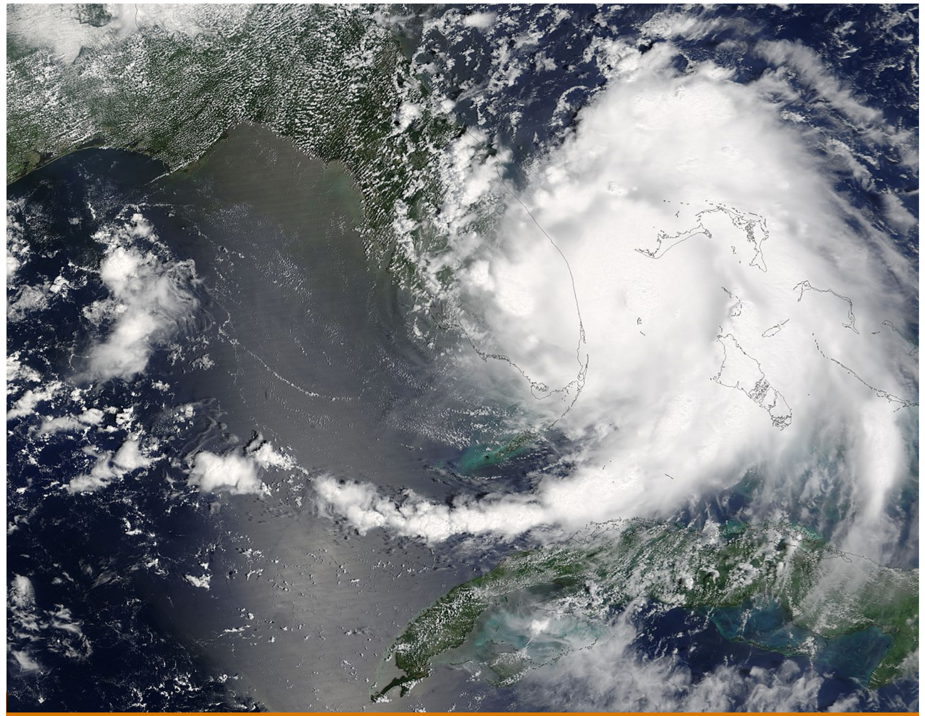
- Immunity may be weak, allowing re-infection of a recovered person
- Immunity may only last for a period of time (Months? Years?)
- New mutations/strains may not be susceptible to antibodies

Can models predict the future?

That depends…

- How well are the underlying processes known? Are the assumptions valid? Are the important factors represented?
- How well are the parameters known? What supporting data/information do we have available? How uncertain are the data?
- Can the model reflect changes in future conditions?

SpaceX Crew Dragon



Hurricane Katrina

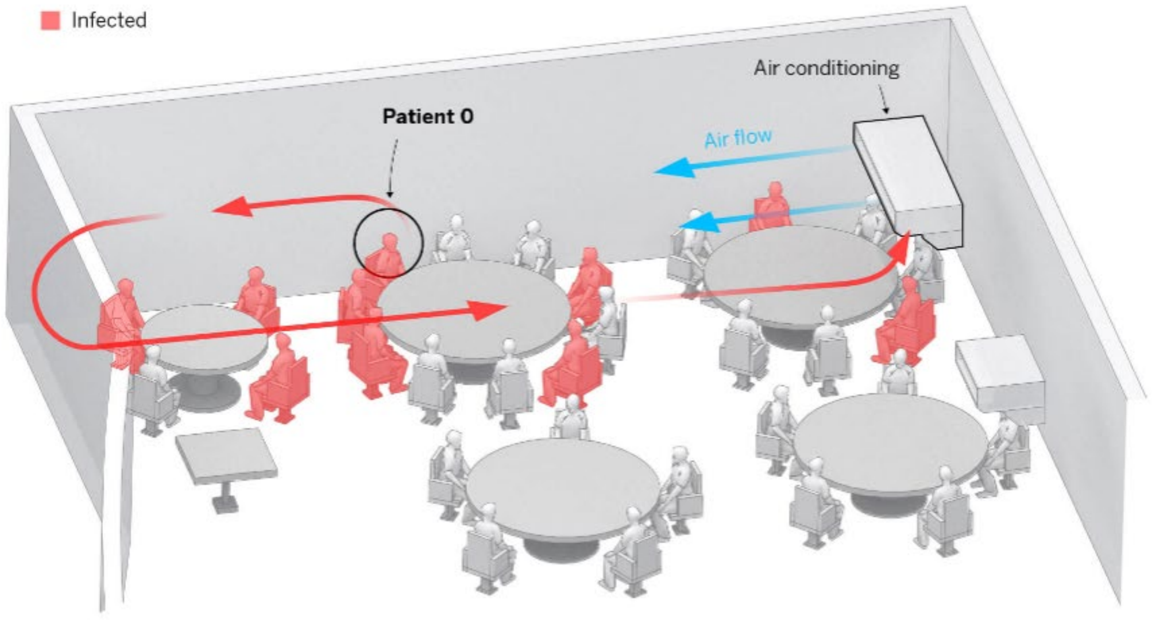
Can models predict the future?

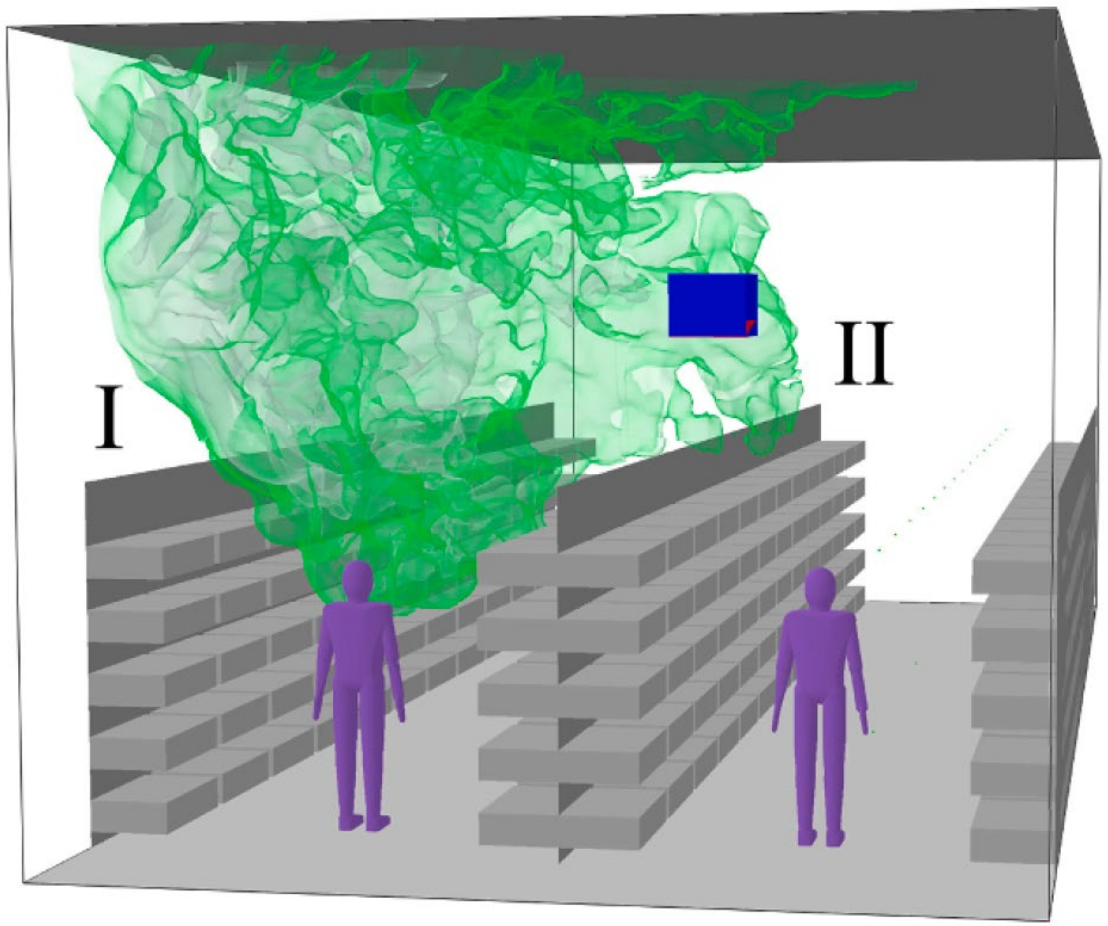
A better question is: Can models help us learn and support policy decisions?

- Flattening the curve – applying social distancing and masks to reduce “r”
  - Reduce total infections (and deaths)
  - Achieve herd immunity at lower level of infection
  - Reduce impacts on health care infrastructure
  - Limit infections and deaths while developing vaccines
- Vaccines: Reduce S without increasing I
- Asking the right questions of our models may reveal new data or information we need to collect (example: asymptomatic spread, possibility of reinfection, impact of new variants)

Other models relevant to COVID-19

Hydrodynamics and aerosol transport (computational fluid dynamics)





- Avoid internal air recirculation
- Use filters
- Increase external air flow
- Reduce background music
- Hold events outdoors

Vuorinen et al. (2020) *Safety Science*, doi:10.1016/j.ssci.2020.104866

https://english.elpais.com/spanish_news/2020-06-17/an-analysis-of-three-covid-19-outbreaks-how-they-happened-and-how-they-can-be-avoided.html?rel=mas

Summary:
some modeling best practices

> **"All models are wrong, some are useful."**
>
> **George Box**
> Statistician

1. Understand your assumptions and how they affect the model outputs.
2. Test your model solutions and verify your code.
3. Realize that model predictions are inherently uncertain. Consider alternatives and interpret the results accordingly.
4. Understand that data may also have errors or assumptions.
5. Update the model and parameters as new information and data become available – predictions *should* change over time.
6. Use the model to learn and guide additional research/data collection.
7. Work in teams to assure the best information and methods are used. Openness is essential!

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SUBMIT YOUR QUESTIONS VIA THE DISCUSSION CHAT

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THANK YOU FOR ATTENDING!

Malin Young

Associate Laboratory Director
Earth & Biological Sciences

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Thank you

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