The COVID-19 Pandemic and Colorado:
Epidemiology in Action

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INTRODUCTION

JONATHAN SAMET

The Relevance of Epidemiology

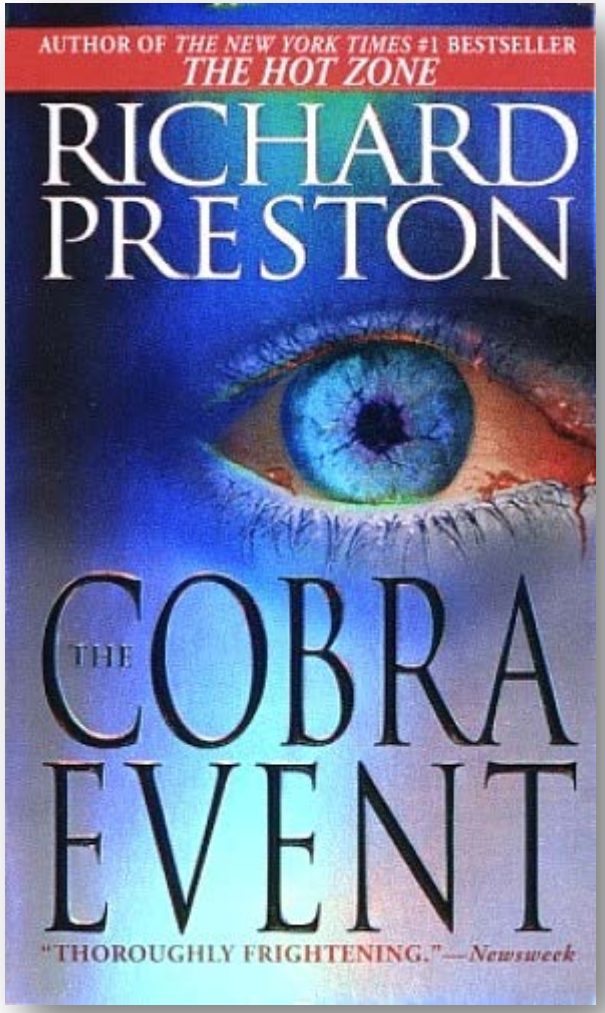
"And it was so typically brilliant of you to have invited an epidemiologist."

The major factors that brought health to mankind were *epidemiology*, sanitation, vaccination, refrigeration, and screen windows.

Richard Lamm, 1986
Former CO Governor

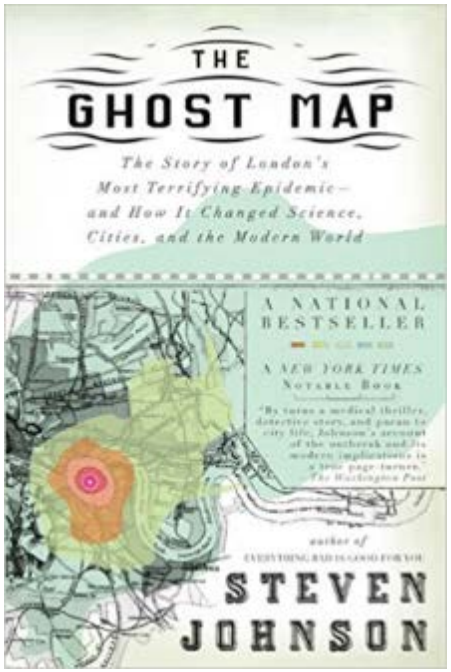
Protecting Health, Saving Lives—*Millions at a Time.*

John Snow and Cholera



"Dr. John Snow was one of the first great disease detectives, a founder of the science of modern epidemiology. …He was a physician in London in 1853 when there was an outbreak of cholera. …He discovered that the sick people had been using the same water pump… Something from the water in that pump was causing the disease. *…he removed the handle from the water pump.* It stopped the outbreak. …This is the classic story of epidemiology."

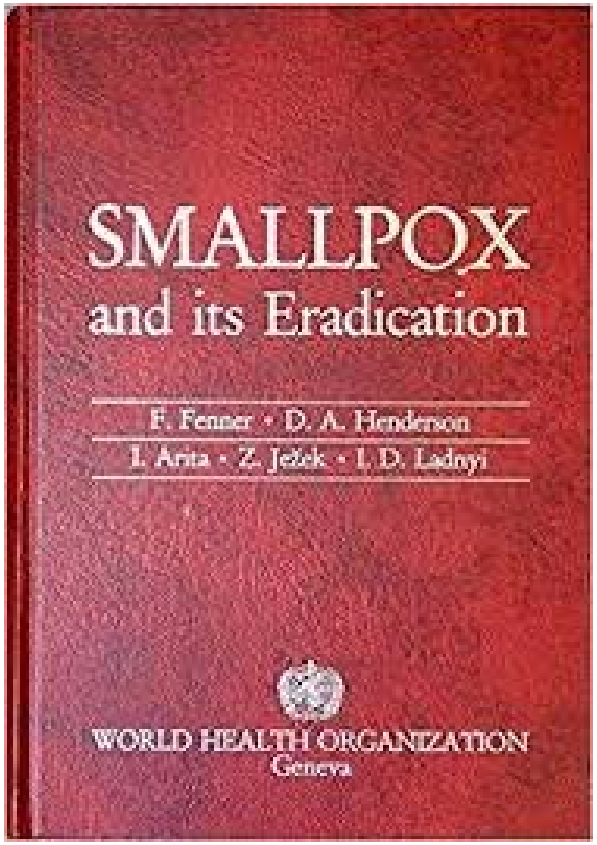
The John Snow Model

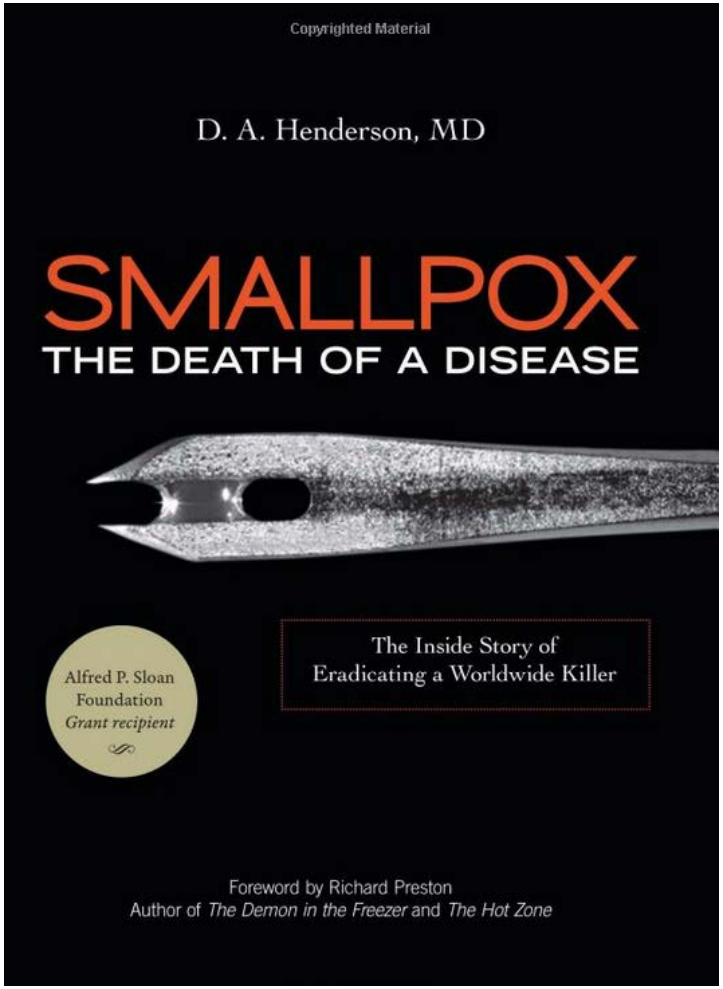


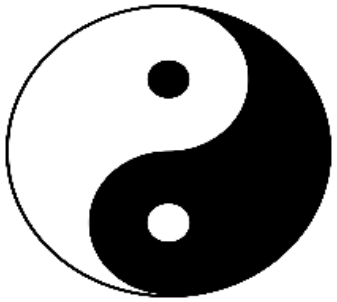
Identify Cholera Outbreak	Identify the Problem
Investigate Broad Street	Gather Data
Infer that Water Transmits Cholera	Analyze and Interpret the Evidence
Recommend Removal of Pump Handle	Translate from Evidence to Action
Continue Tracking	Surveillance

The Eradication of Smallpox

DA Henderson

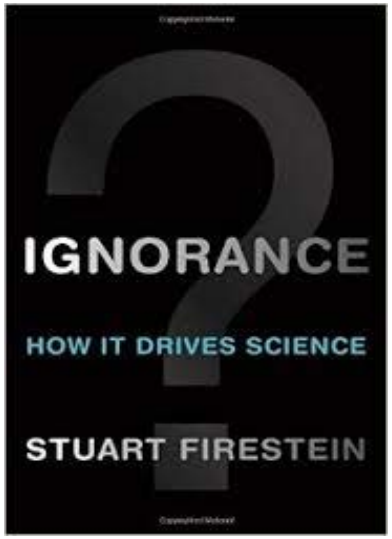


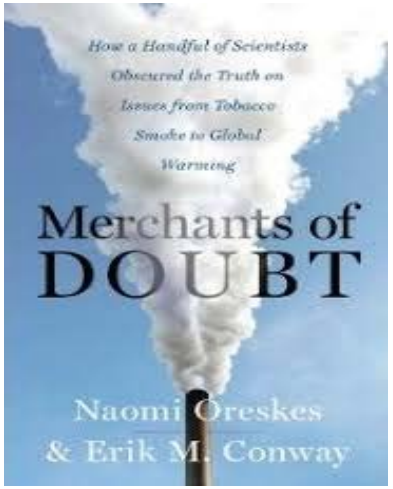




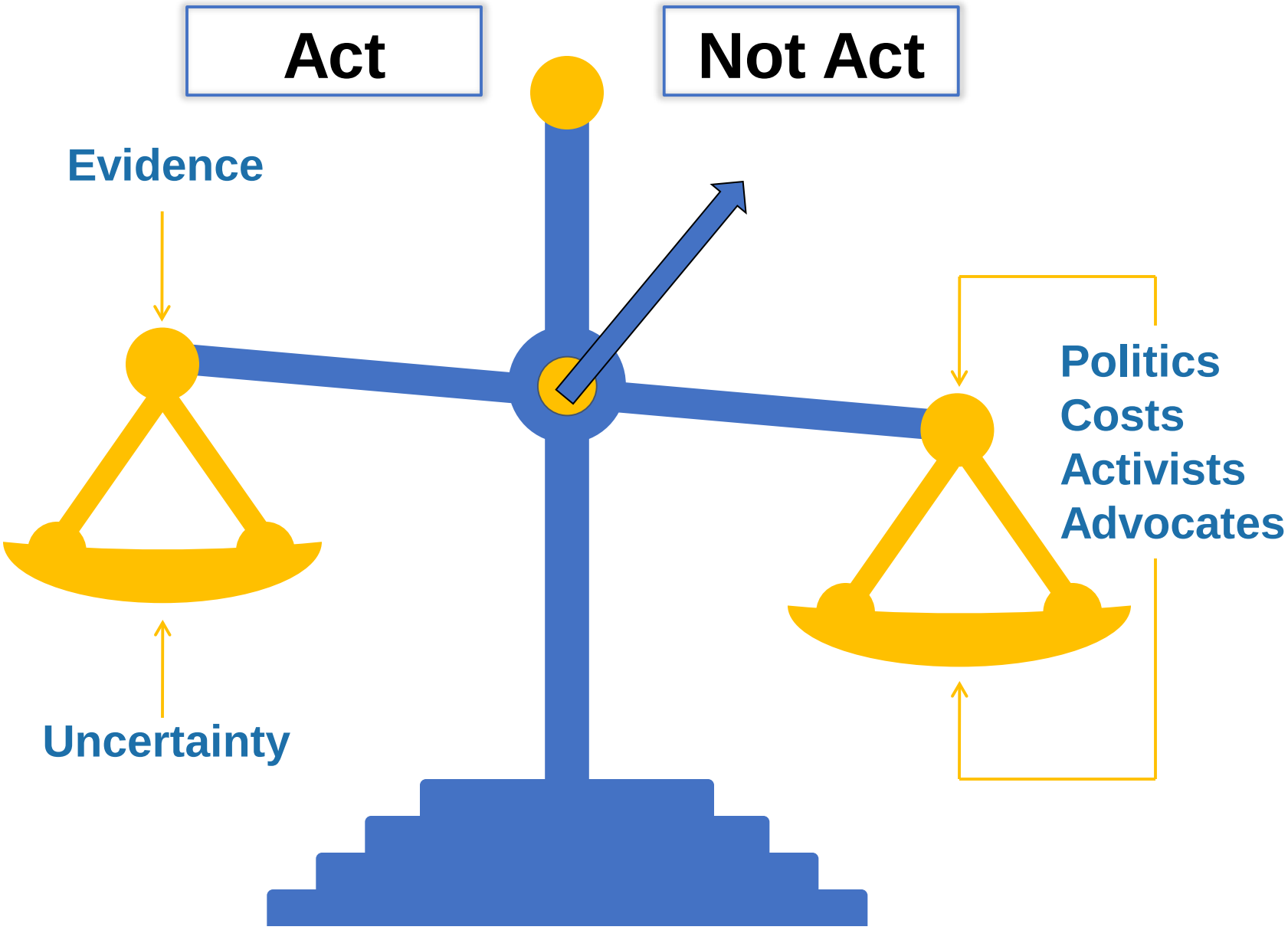
The Yin Yang of Evidence

- Evidence: what we know
- Ignorance: what we do not know
- Uncertainty: the consequence of ignorance
- Doubt: lack of belief/confidence in something
- Manufactured doubt
- And now—post-truth

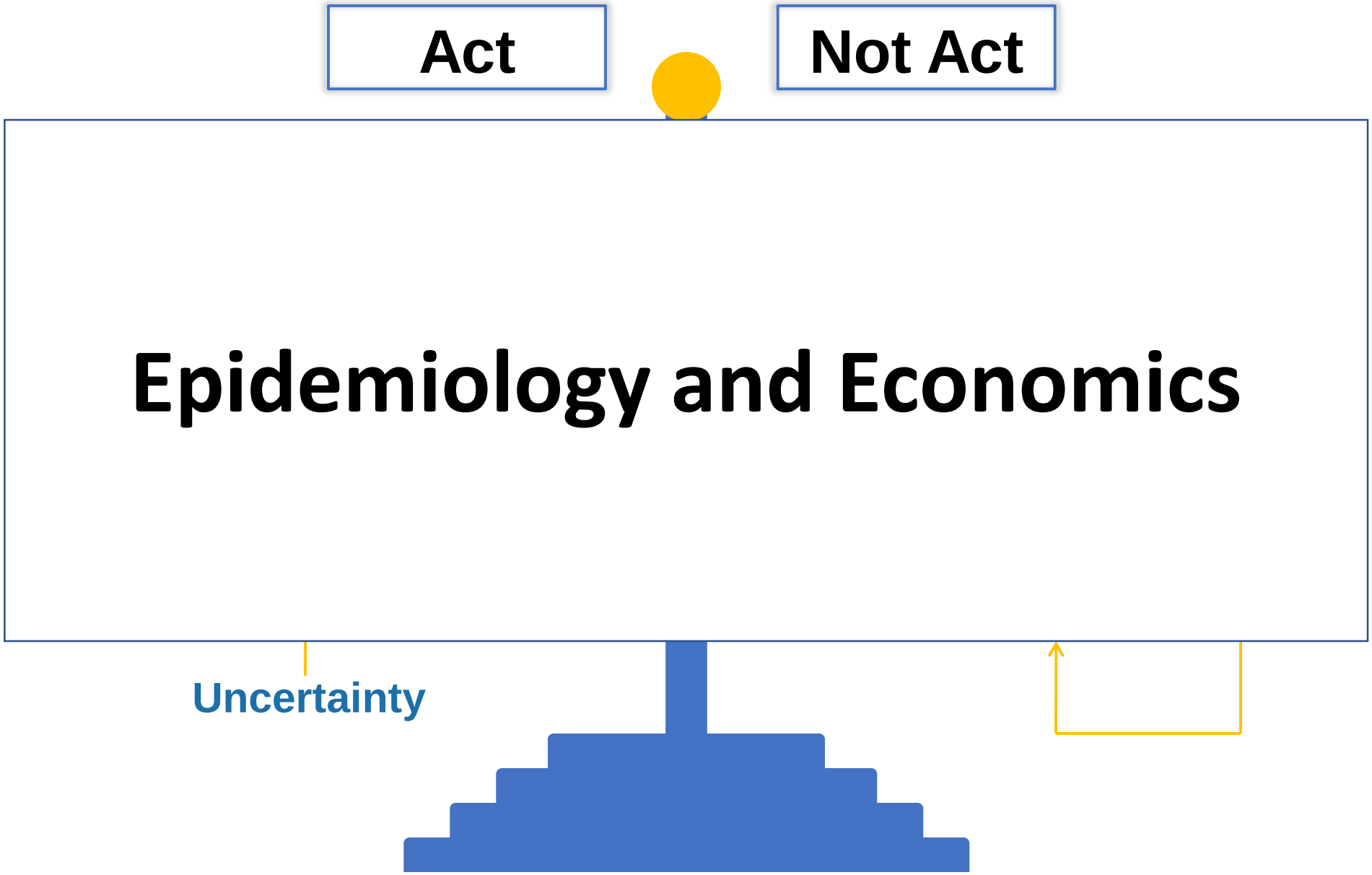




The Evidence Scale



The Evidence Scale



The Role of Models

- Infectious disease models long used to project the course of epidemics and to plan how to end them.
- Mathematical representations of how infections spread within populations.
- Many approaches to modeling and many different modelers.
- But, a fundamental tool for planning strategies for the COVID-19 epidemic.

Models

Fo

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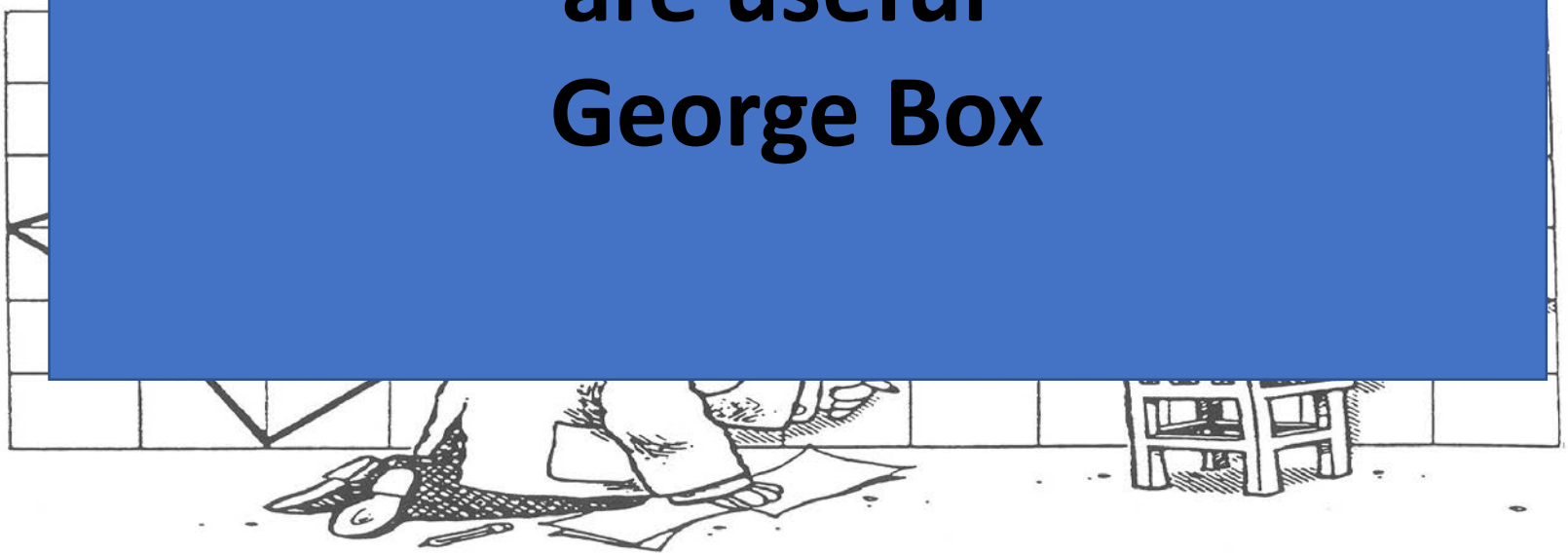
“All models are wrong, but some are useful”
George Box



"HEY, I THOUGHT WE WERE WORKING WITH THE SAME DATA..."

FIGURE 2.3 SOURCE: *National Wildlife Magazine*, August–September, 1984.

MODELING THE COVID-19 EPIDEMIC

ELIZABETH CARLTON

Responding to the COVID-19 pandemic

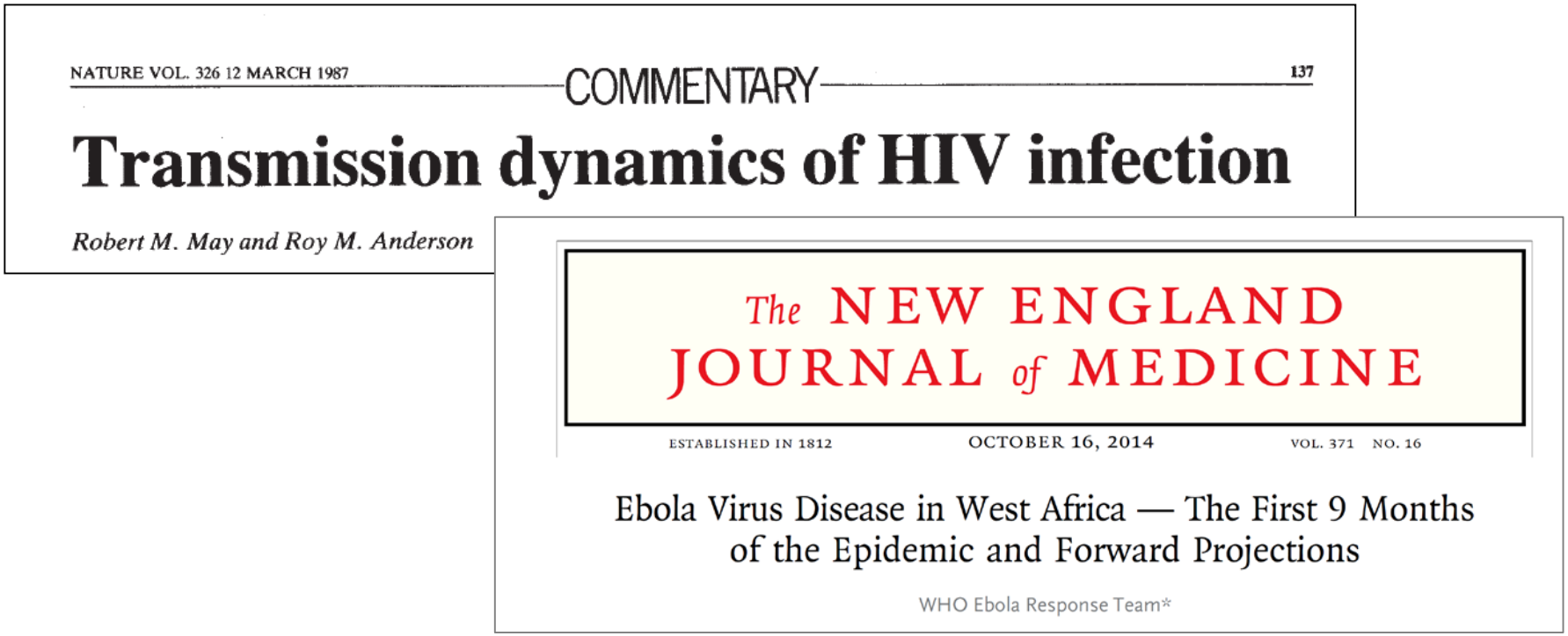
- When will infections peak?
- How soon will we reach ICU bed capacity?
- How many non-ICU and ICU beds will we need at the peak?
- What will the impact of social distancing be? What has been the effect to date?

Need for rapid response in a highly fluid situation

Disease emerged ~4 months ago – scientific evidence is evolving rapidly and certainly incomplete

Modeling the Epidemic: The Team and a Team Meeting

Colorado School of Public Health: Andrea Buchwald, Elizabeth Carlton, Debashis Ghosh, Richard Lindrooth, Jonathan Samet, Tatiane Santos; University of Colorado School of Medicine: Kathryn Colborn; University of Colorado-Boulder: David Bortz; University of Colorado Denver: Jimi Adams



NATURE VOL. 326 12 MARCH 1987 COMMENTARY 137

Transmission dynamics of HIV infection

Robert M. May and Roy M. Anderson

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 OCTOBER 16, 2014 VOL. 371 NO. 16

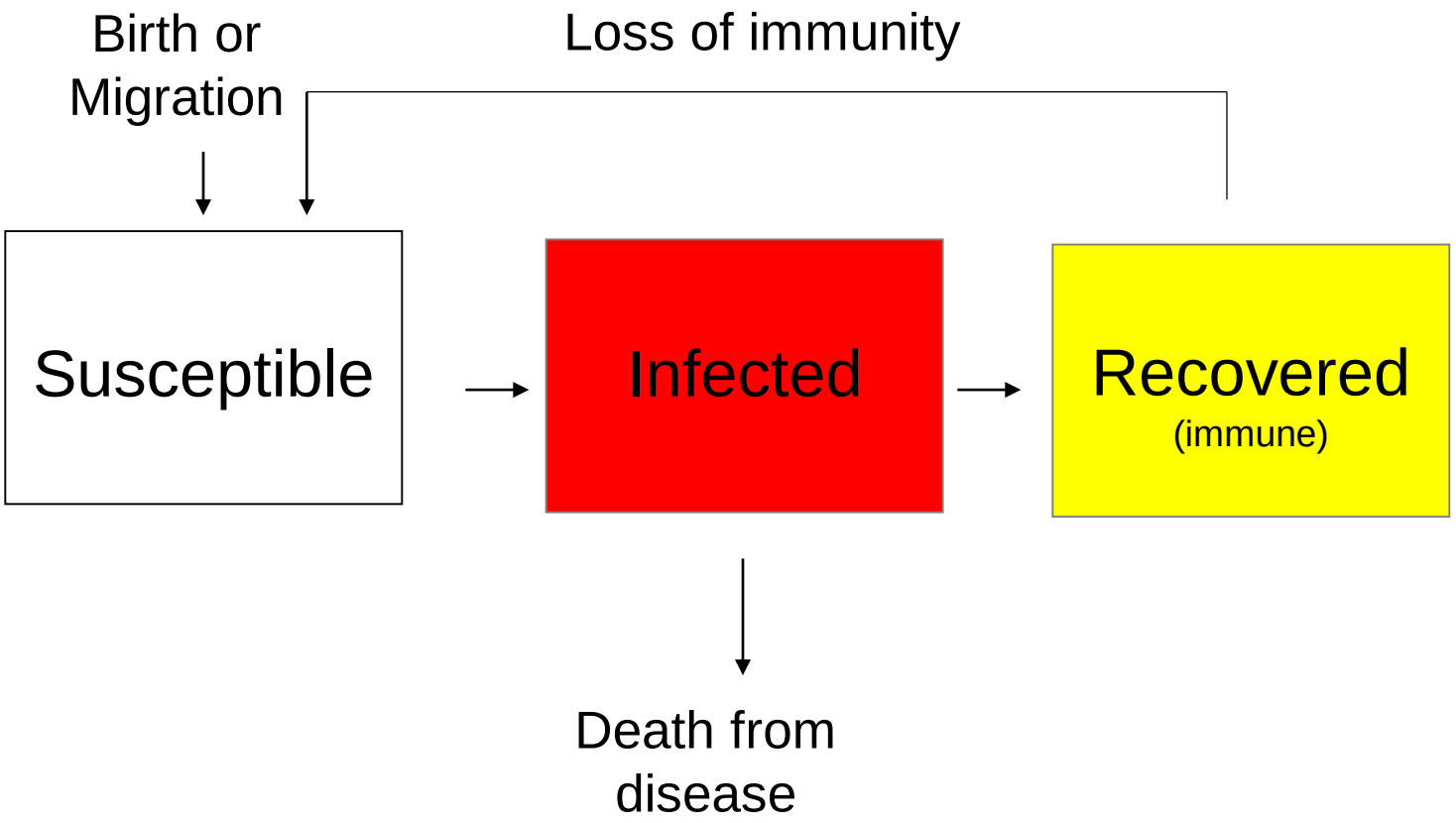
Ebola Virus Disease in West Africa — The First 9 Months of the Epidemic and Forward Projections

WHO Ebola Response Team*

Mathematical models of infectious diseases are a key tool early in epidemics, when data are limited. They can be used to:

- Predict future disease
- Define key features of a disease transmission system (R0, latent period)
- Predict effects of interventions

The SIR Model



Parameters in mathematical models have biological meaning. They can be derived from the literature or by fitting the model estimates to observed data.

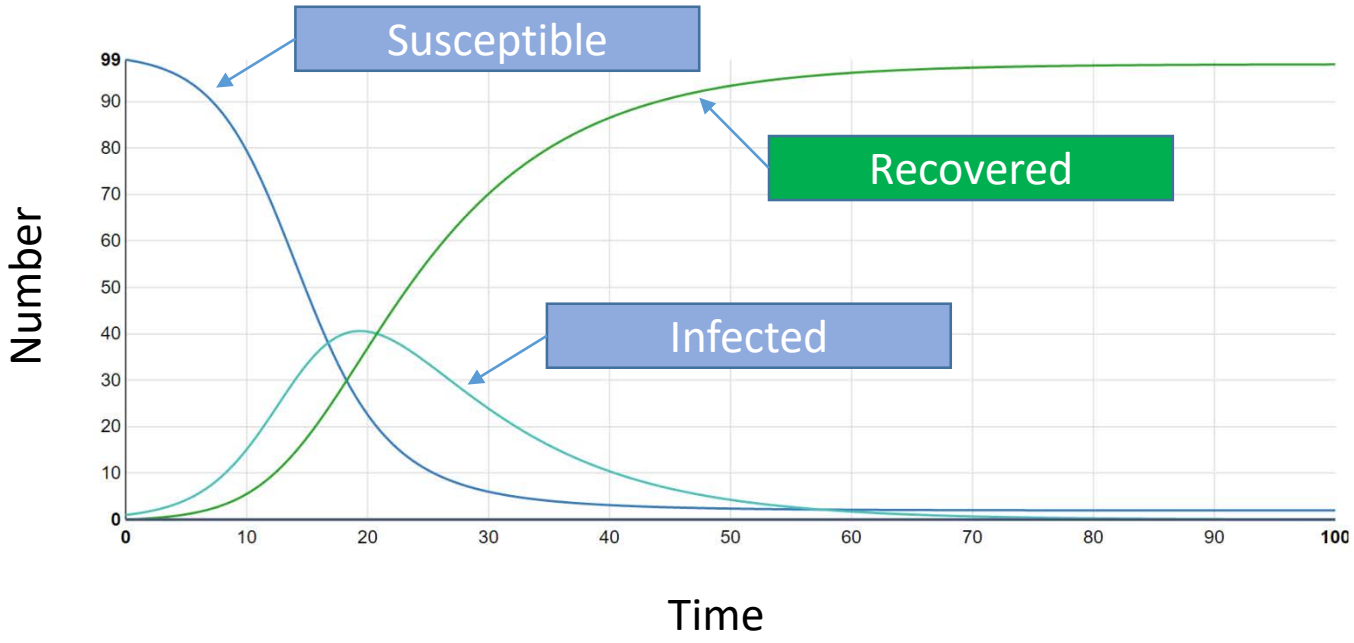
What determines whether a person moves from the susceptible to the infected box?

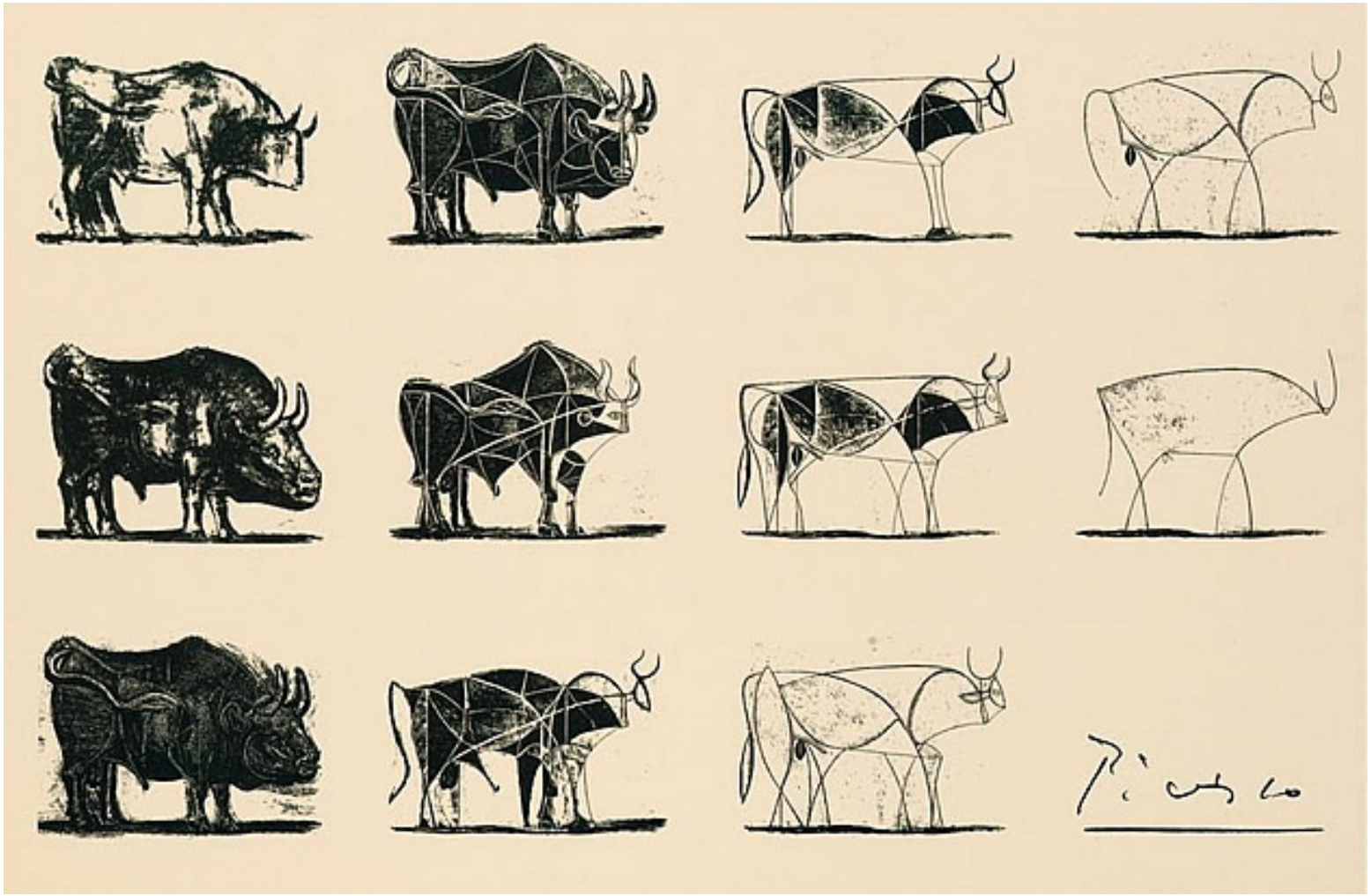
- **Contact rate:** the rate at which susceptible individuals contact infected individuals
- **Transmission probability:** the probability that, given a contact between an infective source and a susceptible host, the susceptible host will become infected

R_0 basic reproductive number: R_0 is the number of secondary infections produced by an infected individual in a population where everyone is susceptible and in the absence of controls

The reproductive number depends on:

- **Contact rate:** the rate at which susceptible individuals contact infected individuals
- **Transmission probability:** the probability that, given a contact between an infective source and a susceptible host, the susceptible host will become infected
- **Duration of infectiousness**

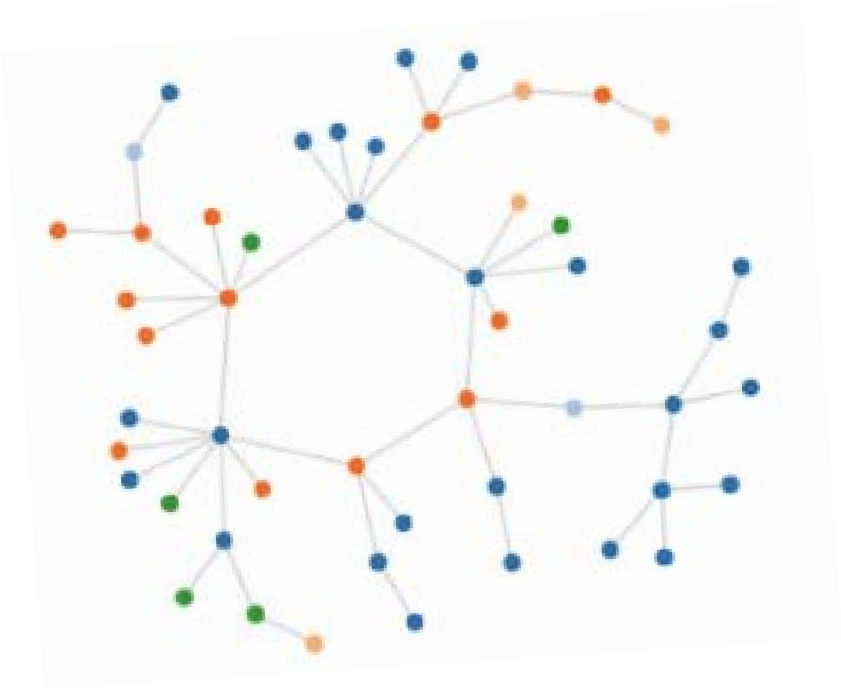




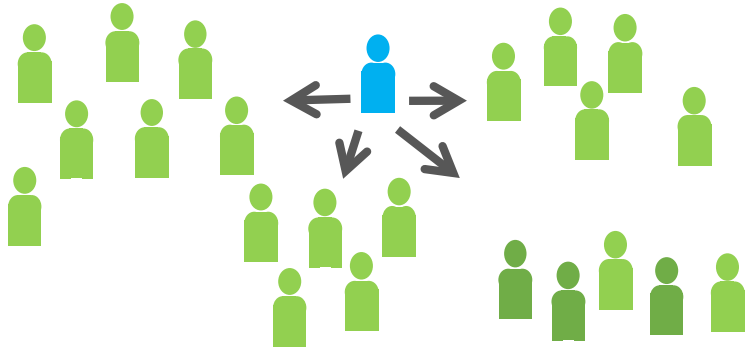
Parsimony vs. complexity

Mathematical models of infectious disease are based on a set of assumed relationships (equations). The goal is to pick the simplest model that allows you to answer your question.

There are more complex infectious disease model frameworks, but they share the same basic principles

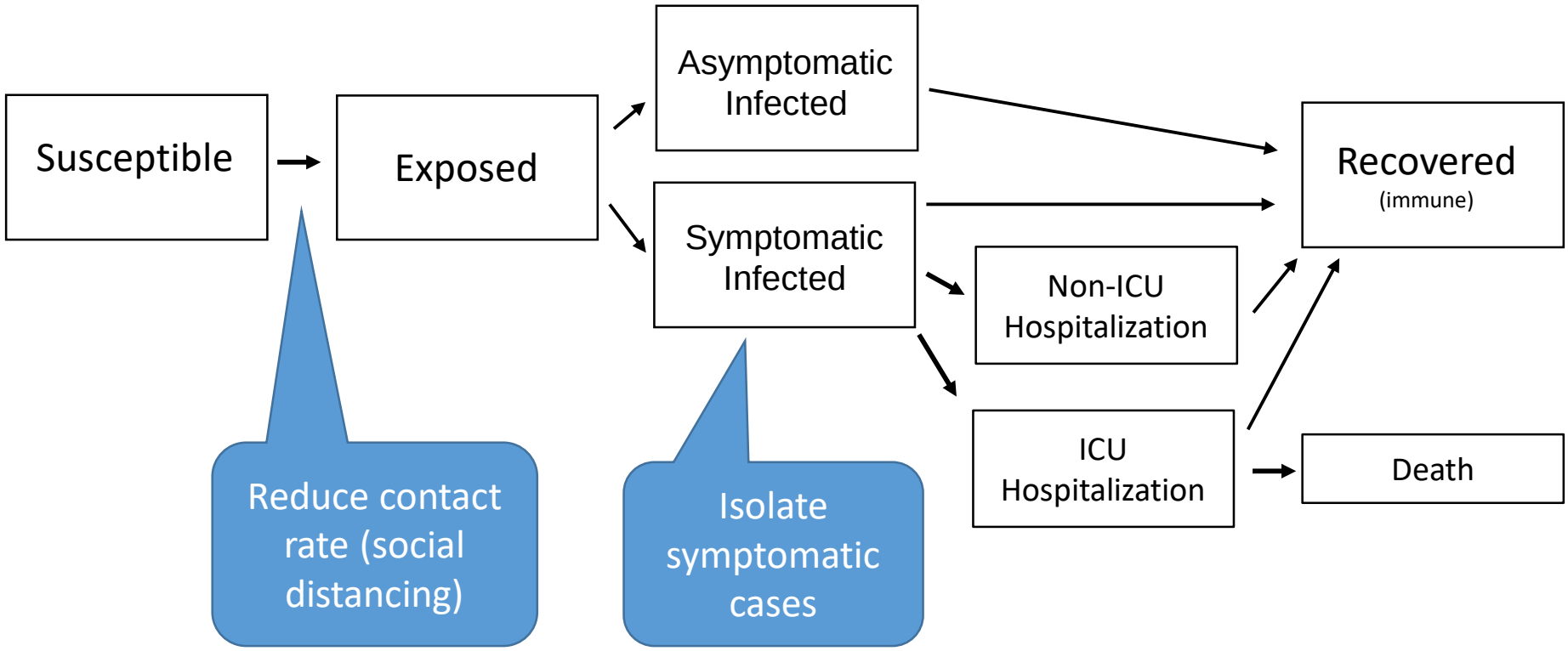


Meta-population models can look at disease spread over a network



Individual-based models can model complex interactions between hosts

The Colorado Model



Key assumptions

- Once a person is infected, their probability of developing symptoms and the severity of symptoms is age-dependent
- An individual acquires at least short-term immunity following infection
- The reported cases in Colorado do not represent all COVID-19 cases in Colorado
- Individuals needing ICU care in excess of capacity die
- No further transmission occurs once a patient enters a hospital

Model parameters estimated by fitting our model to Colorado COVID-19 surveillance data

	Range of possible values and sources	Fitted value
The rate of infection (beta)	0.2 - 0.6 (MIDAS COVID-19 Portal)	0.413
Proportion of symptomatic individuals that self-isolate after March 5 (sil)	0.3 - 0.8 (Ferguson et al)	0.379
Ratio of infectiousness for symptomatic vs. asymptomatic individuals (lambda)	1.0 - 4.0 (Li et al, Zou et al)	2.268
Probability symptomatic cases are identified by state surveillance (pID)	0.05 - 0.6 (MIDAS COVID-19 Portal)	0.277
Date the first infection was introduced in Colorado	Jan 17 – Jan 29 (based on case reports)	Jan 24
Effectiveness of social distancing interventions implemented March 17	0.1 - 0.6	0.45

Best-fitting parameter estimates were identified via a least squares cost function minimizing the comparison between the estimated cases that would be detected based on the model and the number of confirmed COVID-19 cases reported in Colorado through March 31.

When will we see the impact of social distancing?

The expected dates when the first impacts of different social distancing measures will be observed in reported COVID-19 cases and deaths.

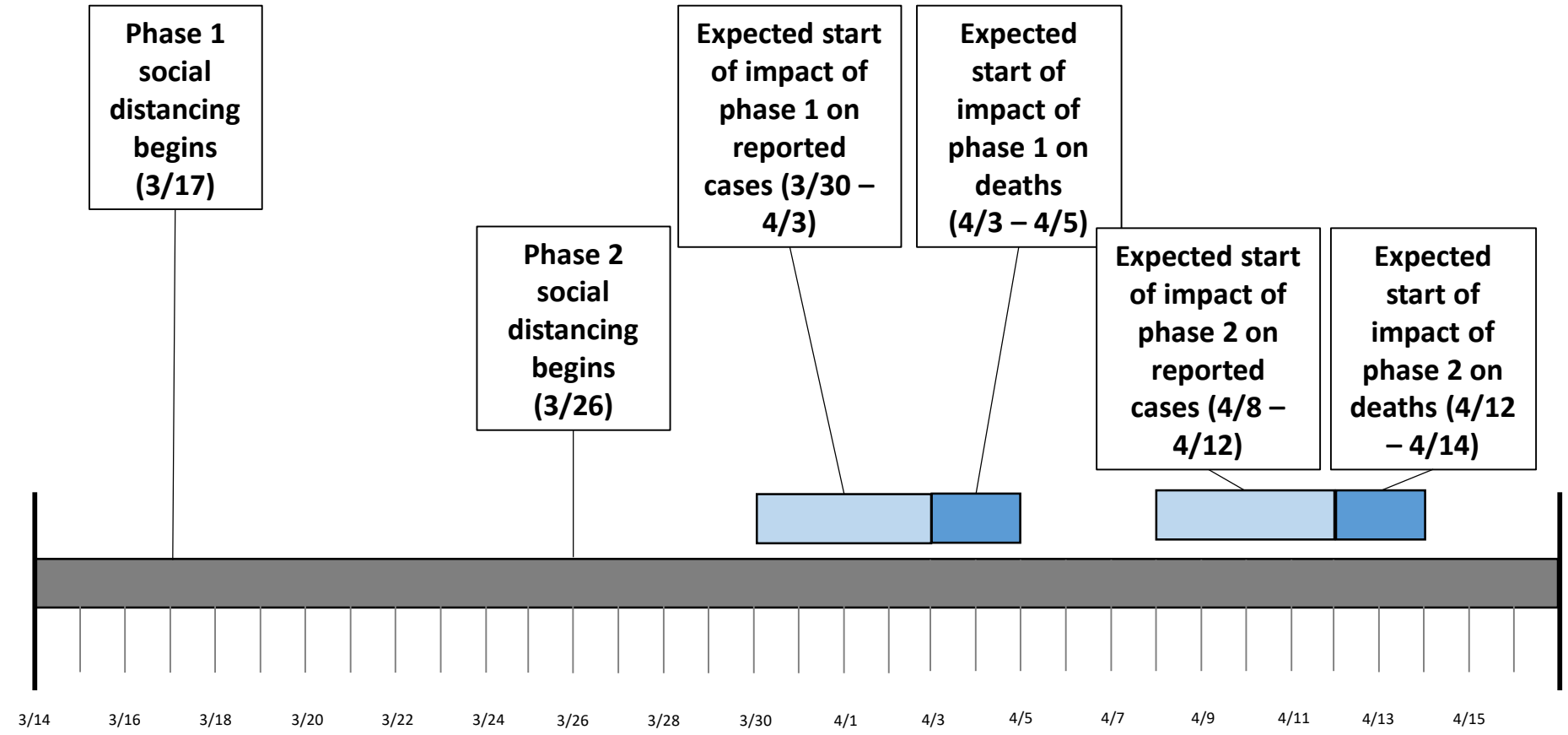
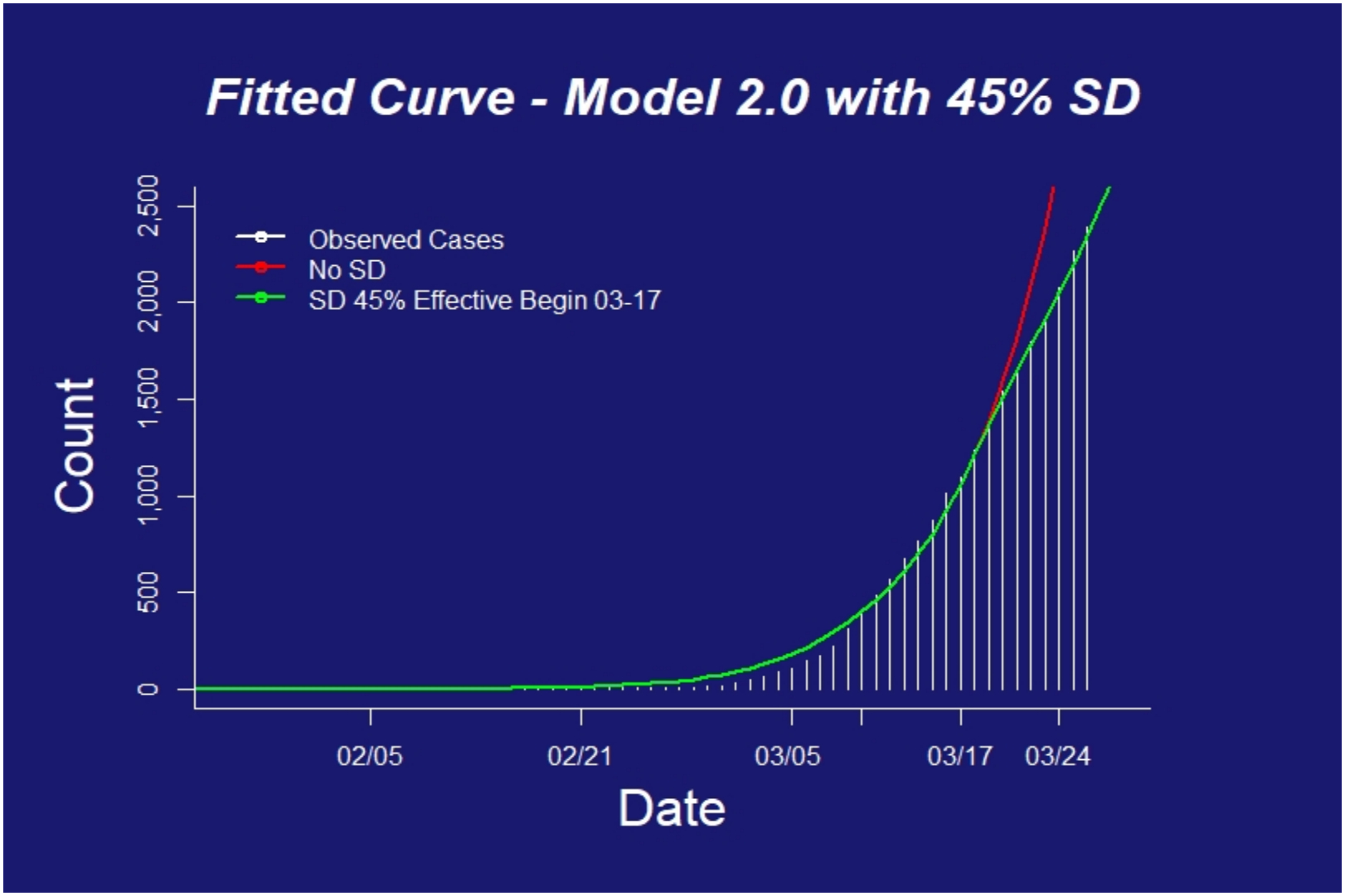


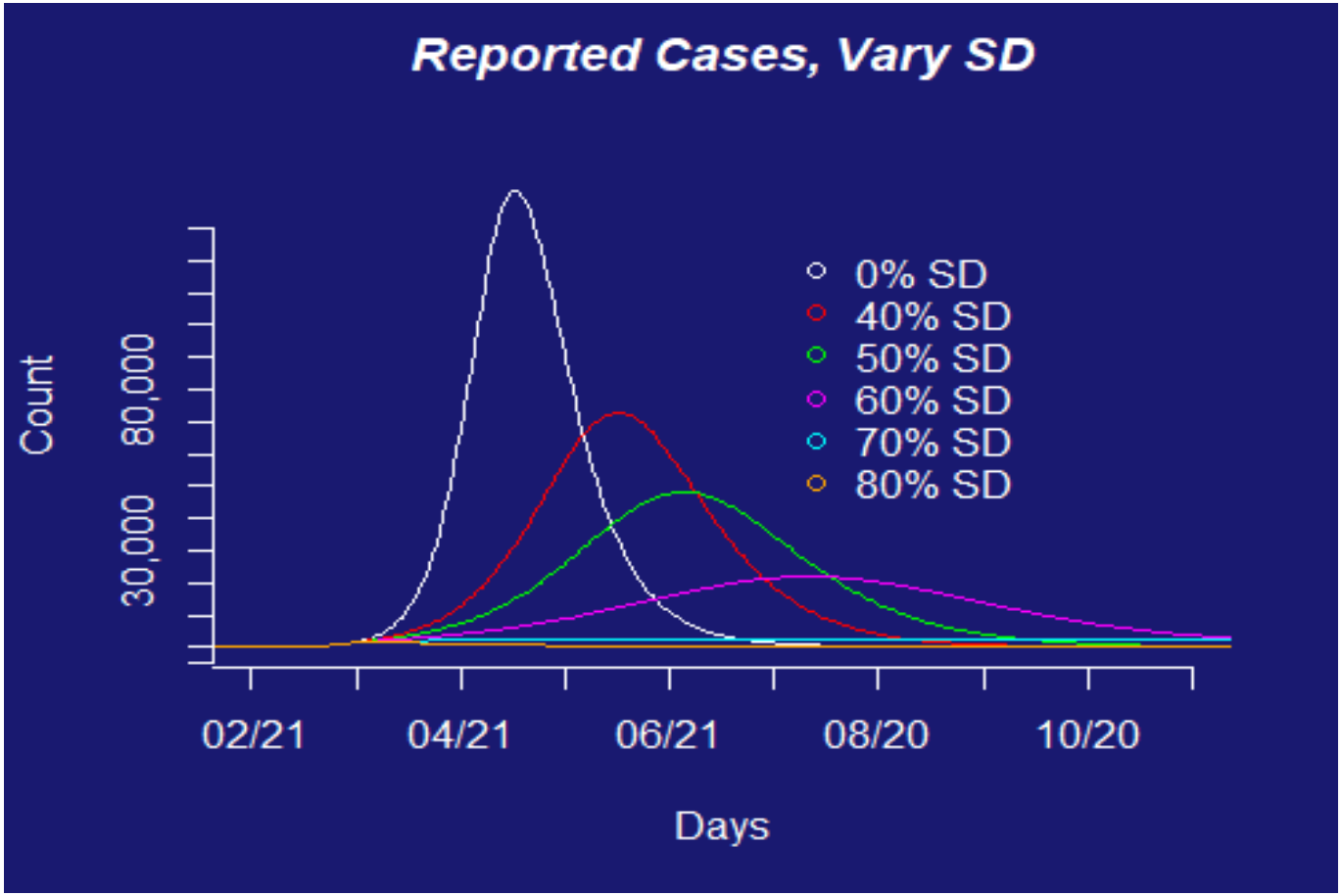
Figure 4

Estimated impact of phase 1 (March 17th) social distancing



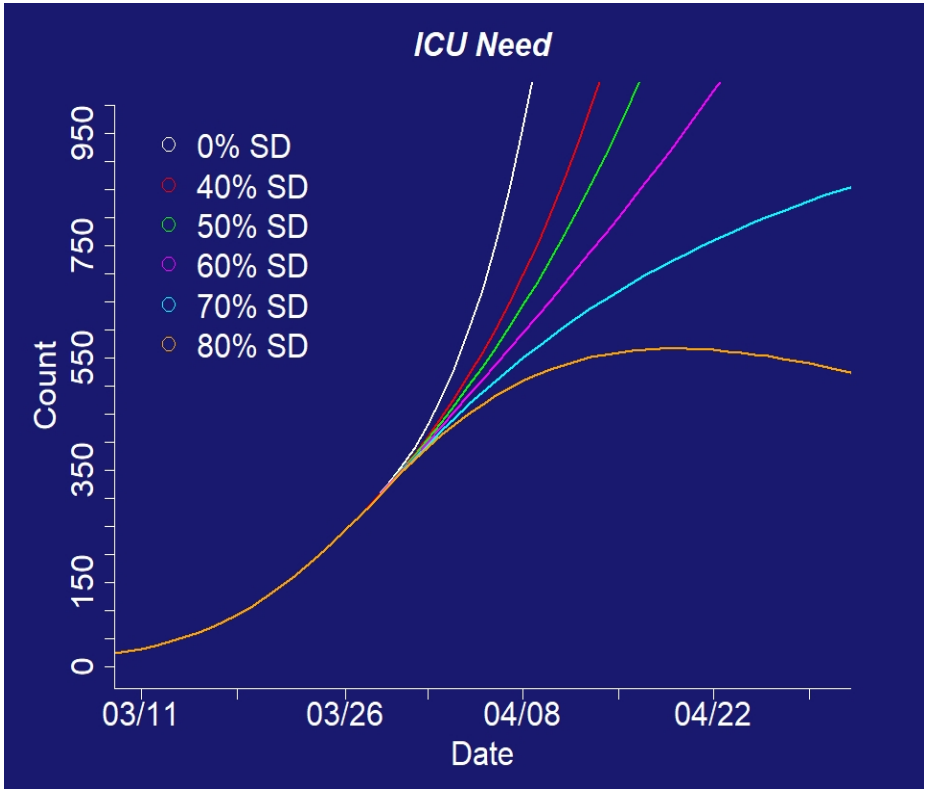
The fit of the age-structured SEIR model to reported COVID-19 cases through March 31. The best-fit curve, showing social distancing efficacy of 45% starting March 17 (green line) and a curve showing no social distancing (red line) are shown.

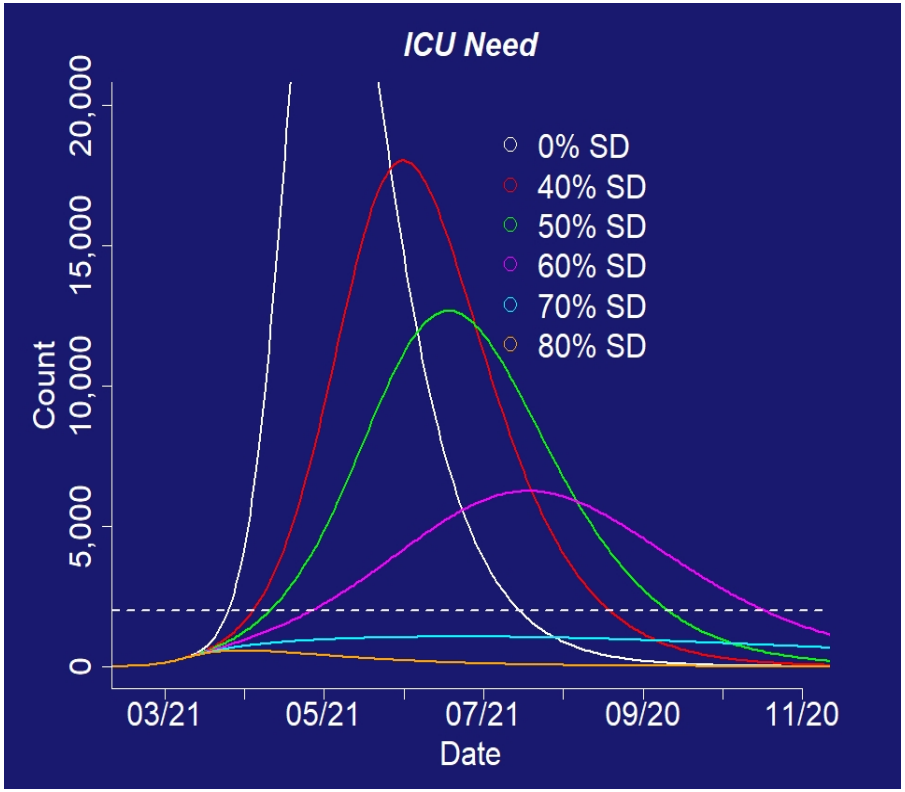
Projected impacts of phase 2 social distancing starting March 26 on reported cases, assuming social distancing implemented indefinitely



Projected number of observed cases under different social distancing scenarios, starting March 26. All scenarios include phase 1 social distancing starting March 17 modeled as a 45% reduction in the contact rate.

Projected impacts of phase 2 social distancing starting March 26 on ICU need, assuming social distancing implemented indefinitely





Projected COVID-19 ICU demand in the short-term (left) and long-term (right) under different levels of phase 2 social distancing, starting March 26. Dashed line in the bottom panel indicates Colorado's estimated COVID-19 ICU capacity of 2,000 beds, reflecting an estimated 2700 ICU beds, 700 of which are occupied by non-COVID-19 patients. All scenarios include phase 1 social distancing starting March 17 modeled as a 45% reduction in the contact rate.

Estimated timing and magnitude of peak under different social distancing scenarios

	Peak Infections		Peak non-ICU hospitalizations***		Peak ICU hospitalizations	
Phase 2 Social Distancing Scenarios	Num.*	Date	Num.*	Date	Num*	Date
0% Efficacy	223,000	5/8/2020	49,900	5/11/2020	29,900	5/16/2020
40% Efficacy	138,000	6/13/2020	26,900	6/09/2020	18,000	6/17/2020
50% Efficacy	105,000	7/9/2020	18,00	6/28/2020	12,600	7/06/2020
60% Efficacy	65,600	9/14/2020	8,250	8/03/2020	6,130	8/13/2020
80% Efficacy	2,390	4/01/2020	557	4/03/2020	339	4/13/2020

*Number of infections, non-ICU hospitalizations and ICU hospitalizations at the peak date indicated. **Note: Infections and medical needs based on model estimates**

***Peak and cumulative ICU hospitalizations is the estimated number of needed ICU beds. These may be in excess of capacity at peak times. The 0% efficacy is used to determine the consequences of distancing.

Table 4

Estimated cumulative deaths under different social distancing scenarios

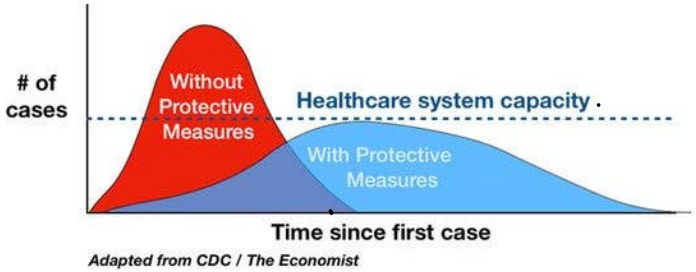
	Cumulative deaths*		Cumulative ICU bed need**	
	As of 6/1/2020	As of 1/1/2021	As of 6/1/2020	As of 1/1/2021
0% Efficacy	73,000	80,300	127,200	161,000
40% Efficacy	29,800	68,800	48,300	138,000
50% Efficacy	13,800	60,100	24,200	120,000
60% Efficacy	4,520	43,200	10,400	86,800
80% Efficacy	1,030	1,410	2,230	2,810

*We assume 50% of cases in the ICU die, a figure which is consistent with Ferguson et al and roughly the mortality of ARDS cases, generally. Additionally, we assume that once available ICU beds are full, all cases requiring ICU in excess of availability result in deaths. Cumulative death estimate assumes the number of available beds with ventilator-capacity in the ICU is 2000.

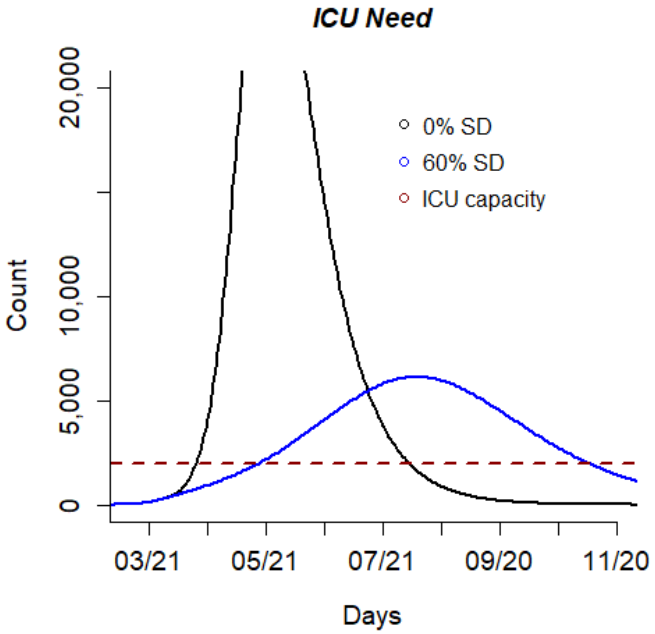
**Peak and cumulative ICU hospitalizations is the estimated number of needed ICU beds. These may be in excess of capacity at peak times.

Table 5

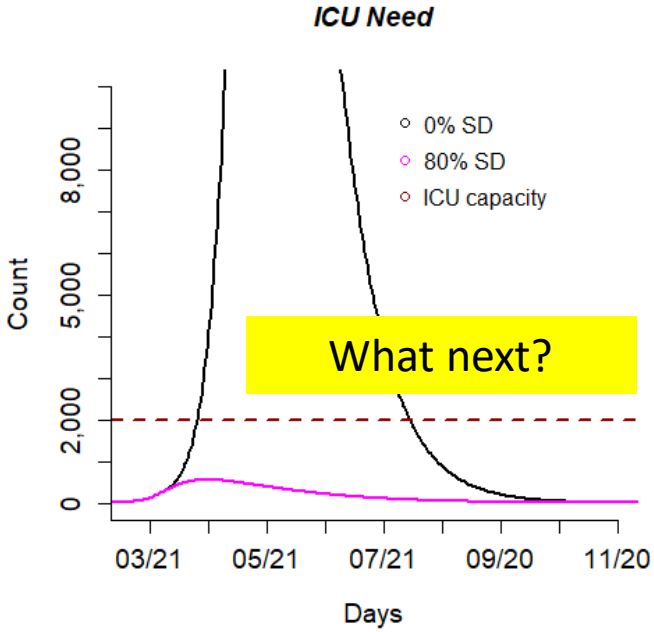
Flattening the curve vs. bending the curve



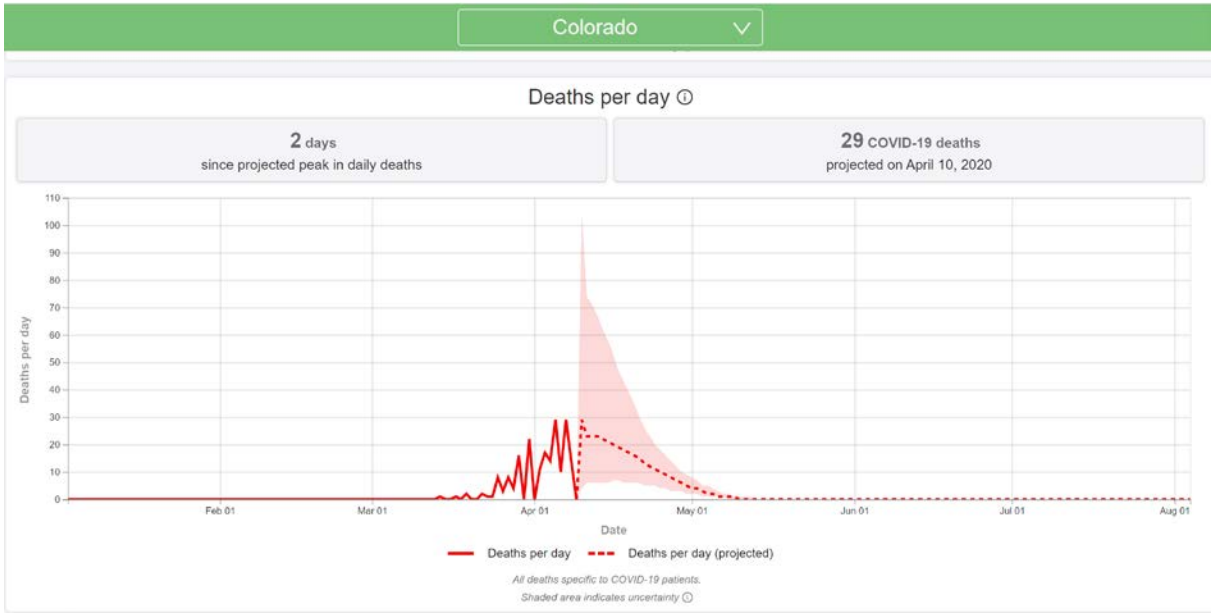
Flattening the curve, but exceeding ICU capacity



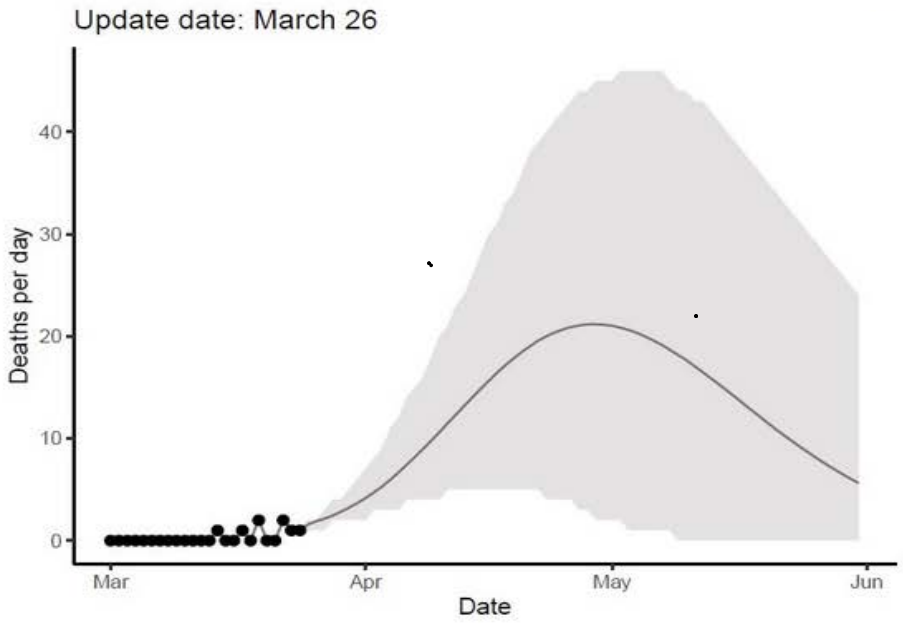
Bending the curve at high levels of social distancing

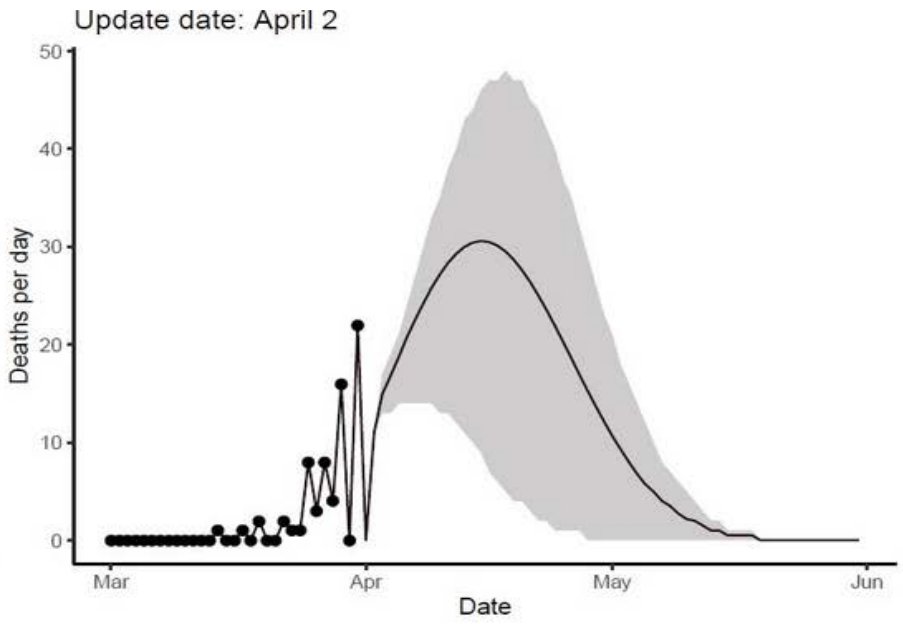


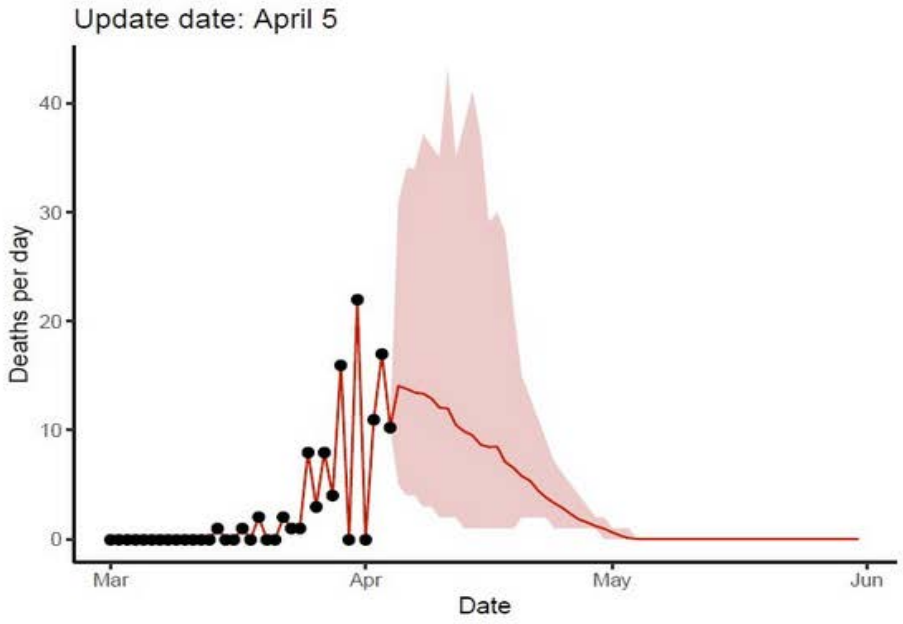
The IHME Model

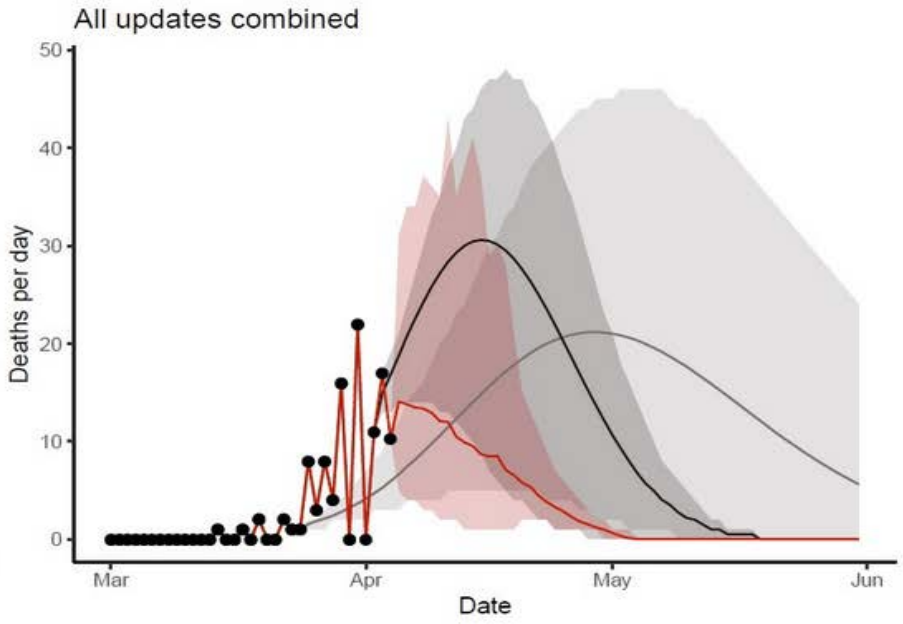


IHME Models for Colorado









Key findings to date

- Social distancing implemented in mid-March appears to be slowing the growth of COVID-19 in Colorado
- We anticipate seeing the impact of the statewide stay at home order around now
- The trajectory of the outbreak and the number of deaths depends, in large part, on how well we reduce contact now and in coming weeks
- High levels of social distancing have the potential to bend the curve leading to an early, and low peak. Disease control measures will be needed to prevent additional peaks.

Priority questions for COVID-19 in Colorado and beyond

- How long will people comply with social distancing orders? Will compliance wane after a “peak”?
- Who are the most vulnerable populations and what is driving that vulnerability?
- What measures are needed to prevent a second peak when social distancing is relaxed? And what is the best way to relax social distancing?
- How many people have been infected and are now immune?
- What is the role of children in the transmission of COVID-19?

Epidemiology in action

- Timely response a priority. To minimize potential coding errors run two models on two platforms in parallel.
- Focus on being transparent about assumptions – and revisit often. Science and data are changing rapidly.
- Underestimating and overestimating impacts both have costs – used social distancing “scenarios” to give range of potential outcomes.
- Draw on the strengths (and diverse work schedules) of your team.
- This is an unprecedented time. There is an amazing sense of collaboration and willingness to help within the scientific community.

USING MODELS TO MAKE DECISIONS

RACHEL HERLIHY

Colorado Gov. Jared Polis' handling of coronavirus crisis earns mostly praise so far

Governor "threading the needle" with decisions to close businesses, cancel events

Hyoung Chang, The Denver Post

Gov. Jared Polis declared a state of emergency on March 10 as Colorado faced a growing outbreak of the new coronavirus, which has already caused havoc around the globe.

By **JOHN AGUILAR** | jaguilar@denverpost.com | The Denver Post

March 17, 2020 at 6:00 a.m.

Stakeholders for Policy for COVID-10

Stakeholders

- National level
- State and local public health agencies
- General population
- Health care systems
- Social welfare systems
- Business owners

Evidence

- Case counts
- Hospitalizations
- Deaths
- Testing
- Modeling

Decision-Makers

- CDPHE
- Governor's Office
- The Governor
- The people

COLORADO
Department of Public Health & Environment

Strategic Plan, 2019-2023

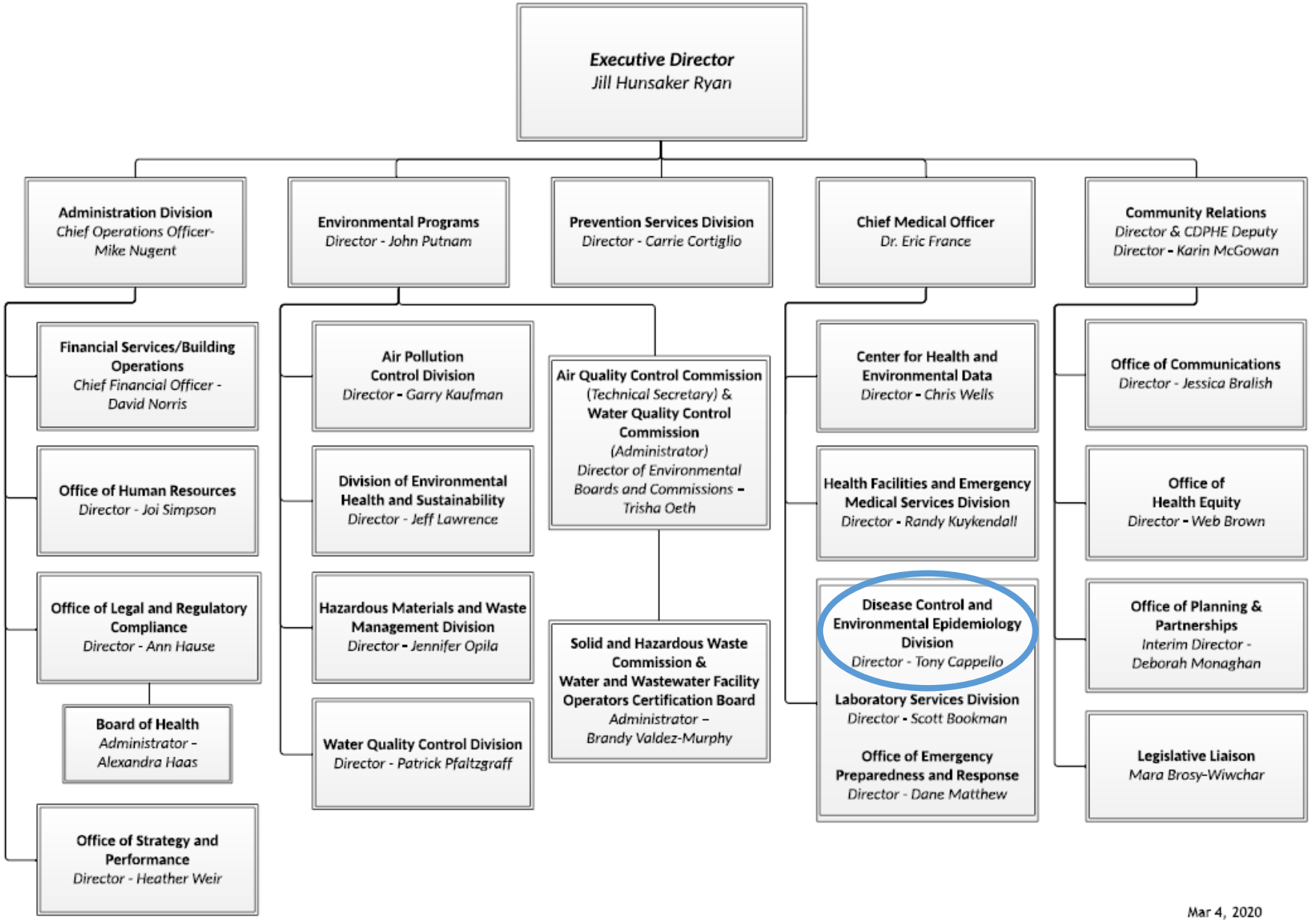
These are our wildly important goals, along with ensuring we are prepared for any public health emergency that may come our way

Director Jill Ryan

continues to identify and respond to emerging issues affecting Colorado's public and environmental health.

The Architecture of Decision-Making

CDPHE Organization Chart



Mar 4, 2020

State Epidemiologist

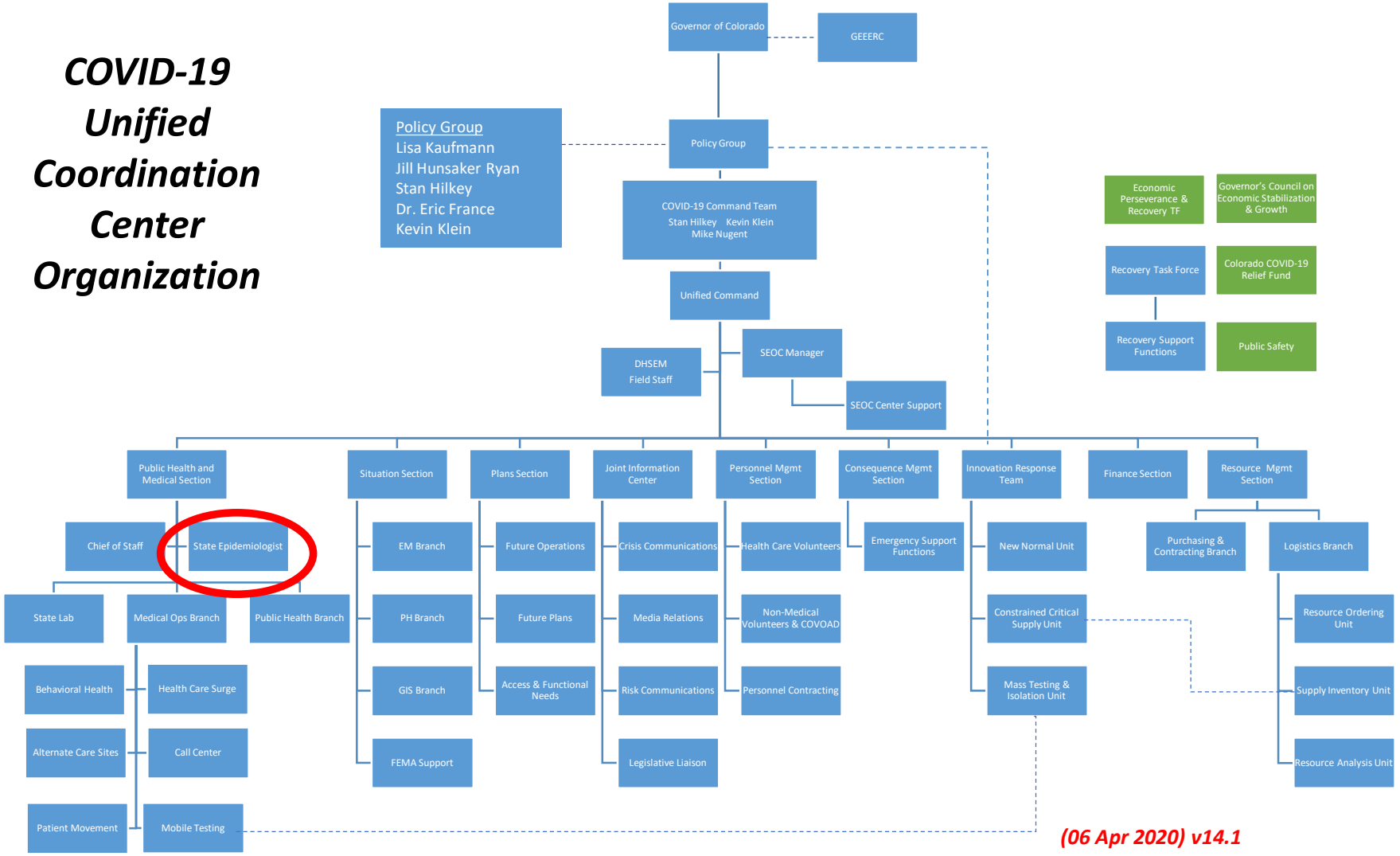
A State Epidemiologist is a manager, health expert, disease investigator, emergency responder, public speaker, educator, convener, and public health advocate.

Council of State and Territorial Epidemiologists (CSTE)

COLORADO
State Emergency Operations Center

COLORADO
Department of Public Health & Environment

COVID-19 Unified Coordination Center Organization



(06 Apr 2020) v14.1

Making Decisions

- Model estimates of the epidemic and its course
- Inherent uncertainties
- Costs and consequences of interventions and non-interventions
- The epidemic models consider infections and not everything else
- Balancing disease control and economic priorities

The Elegant Solution

- Interventions that suppress disease transmission without suppressing the economy
- The menu:
  - Social distancing
  - Rapid case identification, testing
  - Isolation, contact tracing, quarantine
  - Symptom screening in schools and businesses
  - Community use of masks
- What combination and how do they add up to be enough?
- Simultaneously increasing health care capacity

colorado school of public health

UNIVERSITY OF COLORADO
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- Dean's Weekly Updates
- Operations
- Health
- Travel
- Give Back

Coronavirus (COVID-19)

Information and resources

Linked from the top of our homepage: ColoradoSPH.ucdenver.edu
www.ucdenver.edu/academics/colleges/PublicHealth/coronavirus/Pages/coronavirus.aspx