Modeling SARS-CoV-2 transmission in a shifting landscape

Stephen Kissler
Harvard T.H. Chan School of Public Health

Council of State and Territorial Epidemiologists
June 30th, 2020

Center *for* Communicable Disease Dynamics

HARVARD T.H. CHAN SCHOOL OF PUBLIC HEALTH

Outline

Part I: Projecting the spread of SARS-CoV-2

Part II: Explaining the pandemic's path

Part III: Current outlook

Part I: How many? How long?

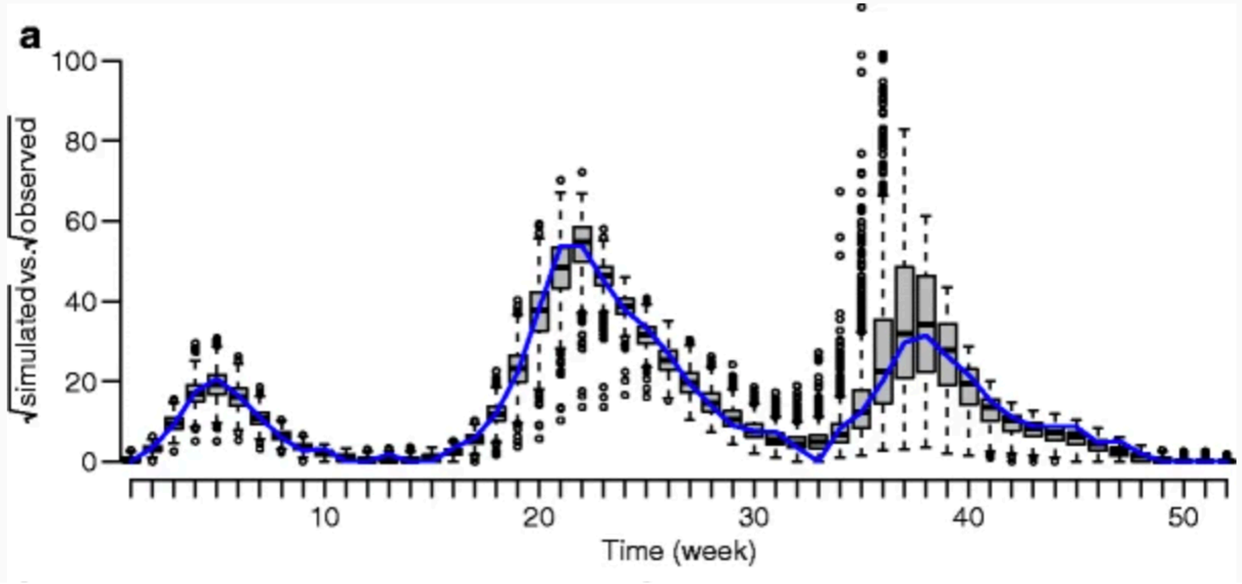
The pandemic that was

Mechanistic modelling of the three waves of the 1918 influenza pandemic

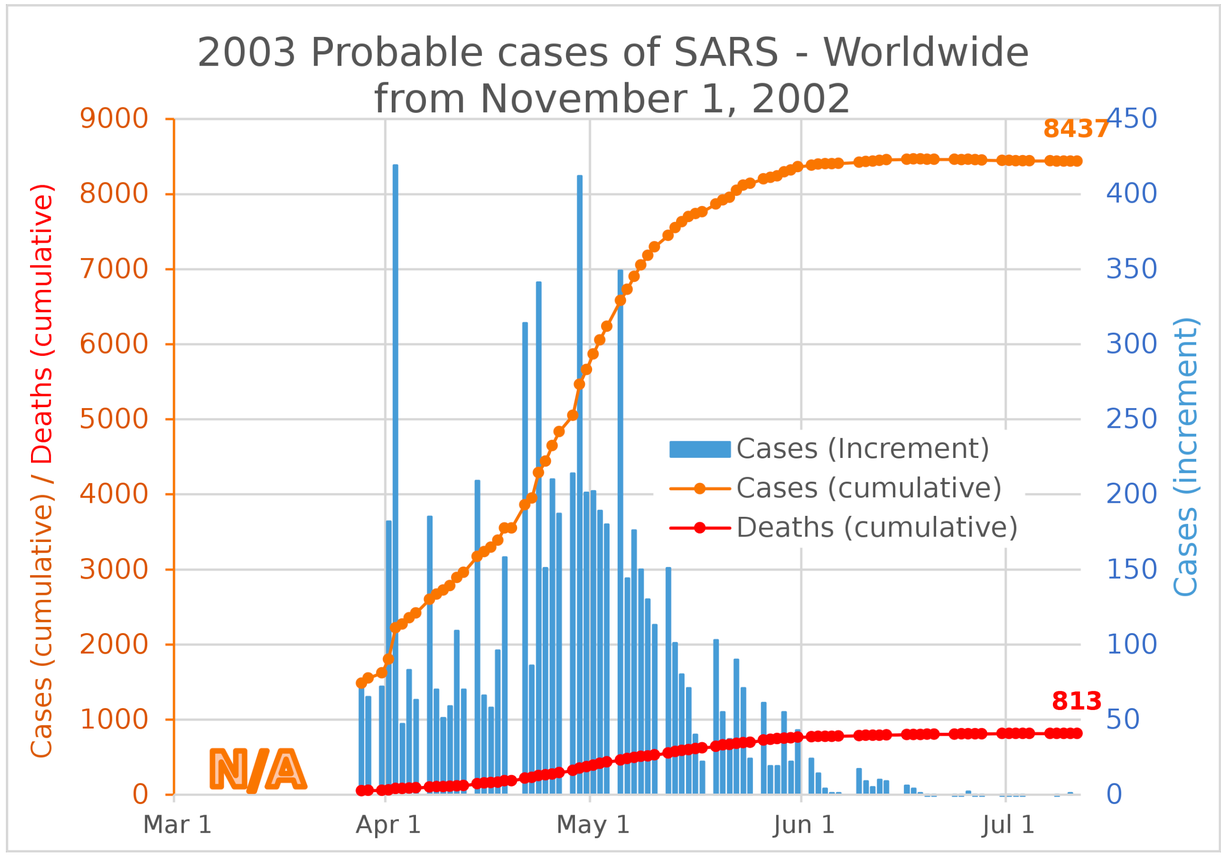
DaiHai He ✉, Jonathan Dushoff, Troy Day, Junling Ma & David J. D. Earn

Theoretical Ecology **4**, 283–288(2011) | Cite this article

Fig. 2



The pandemic that wasn't



https://commons.wikimedia.org/w/index.php?curid=86641069

Timeline of key developments and studies

World Health Organization (WHO) ✓
@WHO

#China has reported to WHO a cluster of #pneumonia cases —with no deaths— in Wuhan, Hubei Province 🇨🇳 . Investigations are underway to identify the cause of this illness.

1:13 PM · Jan 4, 2020 · Twitter for iPhone

JAN. 20

Other countries, including the United States, confirmed cases.

The first confirmed cases outside mainland China occurred in Japan, South Korea and Thailand, according to the W.H.O.'s first situation report. The first confirmed case in the United States cam the next day in Washington State, where a man in his 30s developed symptoms after returning from a trip to Wuhan.
https://www.nytimes.com/article/coronavirus-timeline.html

Novel coronavirus 2019-nCoV: early estimation of epidemiological parameters and epidemic predictions
Version 2. Updated 27 Jan 2020

Jonathan M. Read[1], Jessica R.E. Bridgen[1], Derek A.T. Cummings[2], Antonia Ho[3], Chris P. Jewell[1]

The NEW ENGLAND JOURNAL of MEDICINE
This letter was published on January 30, 2020, and updated on February 6, 2020, at NEJM.org.

CORRESPONDENCE

Transmission of 2019-nCoV Infection from an Asymptomatic Contact in Germany

Monica Gandhi, M.D., M.P.H., Deborah S. Yokoe, M.D., M.P.H., and Diane V. Havlir, M.D.

la Repubblica
23 febbraio 2020

Coronavirus, secondo morto in Lombardia: è una donna a Crema. Chiuso il Duomo di Milano, scuole, musei, cinema, teatri

(agf)

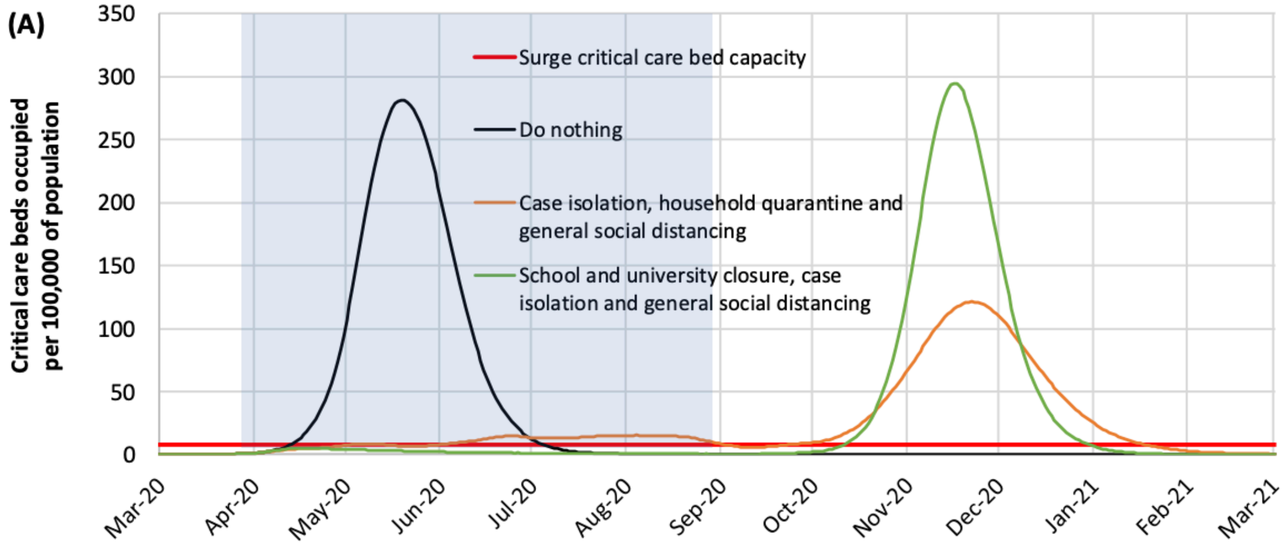
The Imperial College approach

16 March 2020 *Imperial College COVID-19 Response Team*

Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand

Neil M Ferguson, Daniel Laydon, Gemma Nedjati-Gilani, Natsuko Imai, Kylie Ainslie, Marc Baguelin, Sangeeta Bhatia, Adhiratha Boonyasiri, Zulma Cucunubá, Gina Cuomo-Dannenburg, Amy Dighe, Ilaria Dorigatti, Han Fu, Katy Gaythorpe, Will Green, Arran Hamlet, Wes Hinsley, Lucy C Okell, Sabine van Elsland, Hayley Thompson, Robert Verity, Erik Volz, Haowei Wang, Yuanrong Wang, Patrick GT Walker, Caroline Walters, Peter Winskill, Charles Whittaker, Christl A Donnelly, Steven Riley, Azra C Ghani.

On behalf of the Imperial College COVID-19 Response Team



BBC Sign in

Health NEWS

Coronavirus: UK changes course amid death toll fears

By James Gallagher
Health and science correspondent

17 March 2020 Share

Coronavirus pandemic

Boris Johnson flanked by chief medical officer Chris Whitty and chief scientific adviser Sir Patrick Vallance

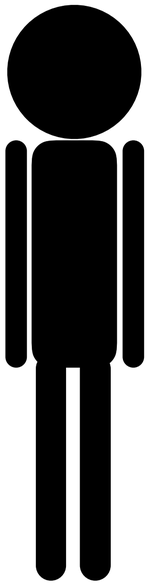
The Imperial College approach

Susceptible

Exposed

Infectious

Recovered



The Imperial College approach

Susceptible

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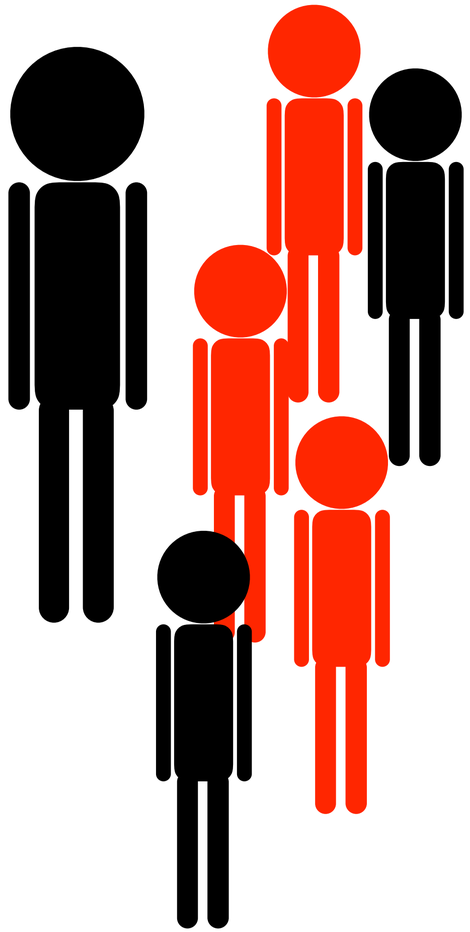
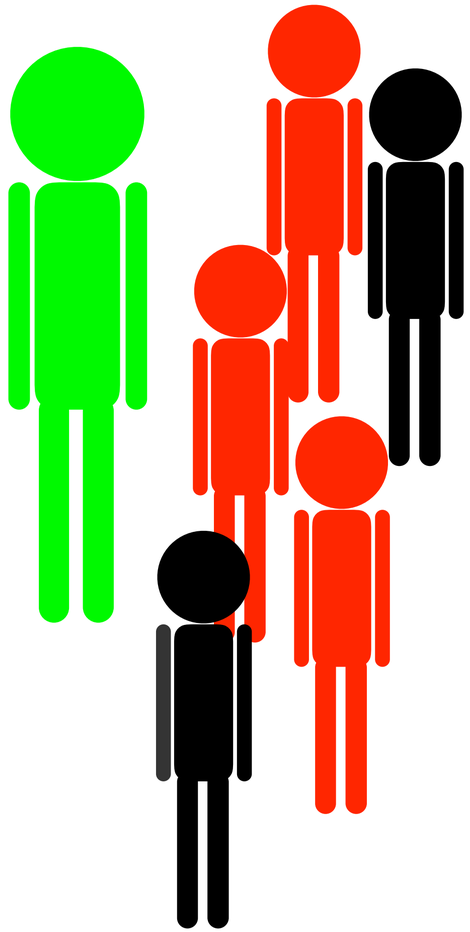
Recovered



The Imperial College approach

Susceptible → **E**xposed **I**nfectious **R**ecovered



The Imperial College approach

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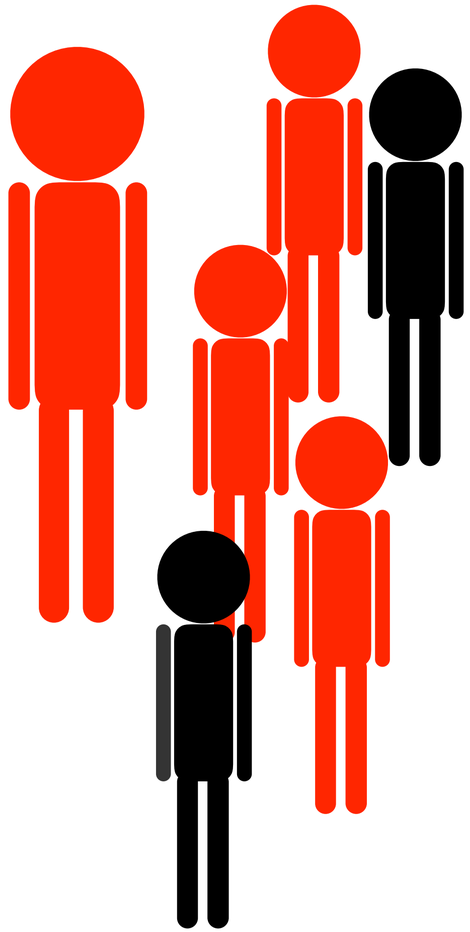
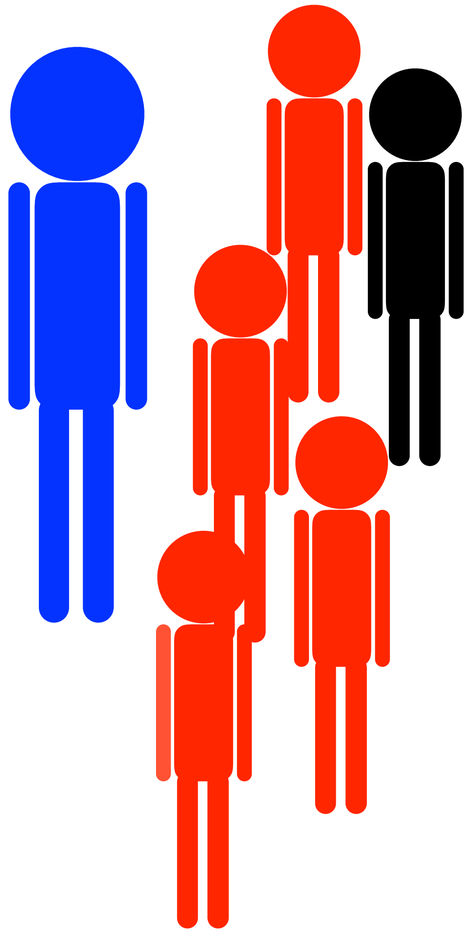


The Imperial College approach

Susceptible → **E**xposed → **I**nfectious → **R**ecovered



The Imperial College approach

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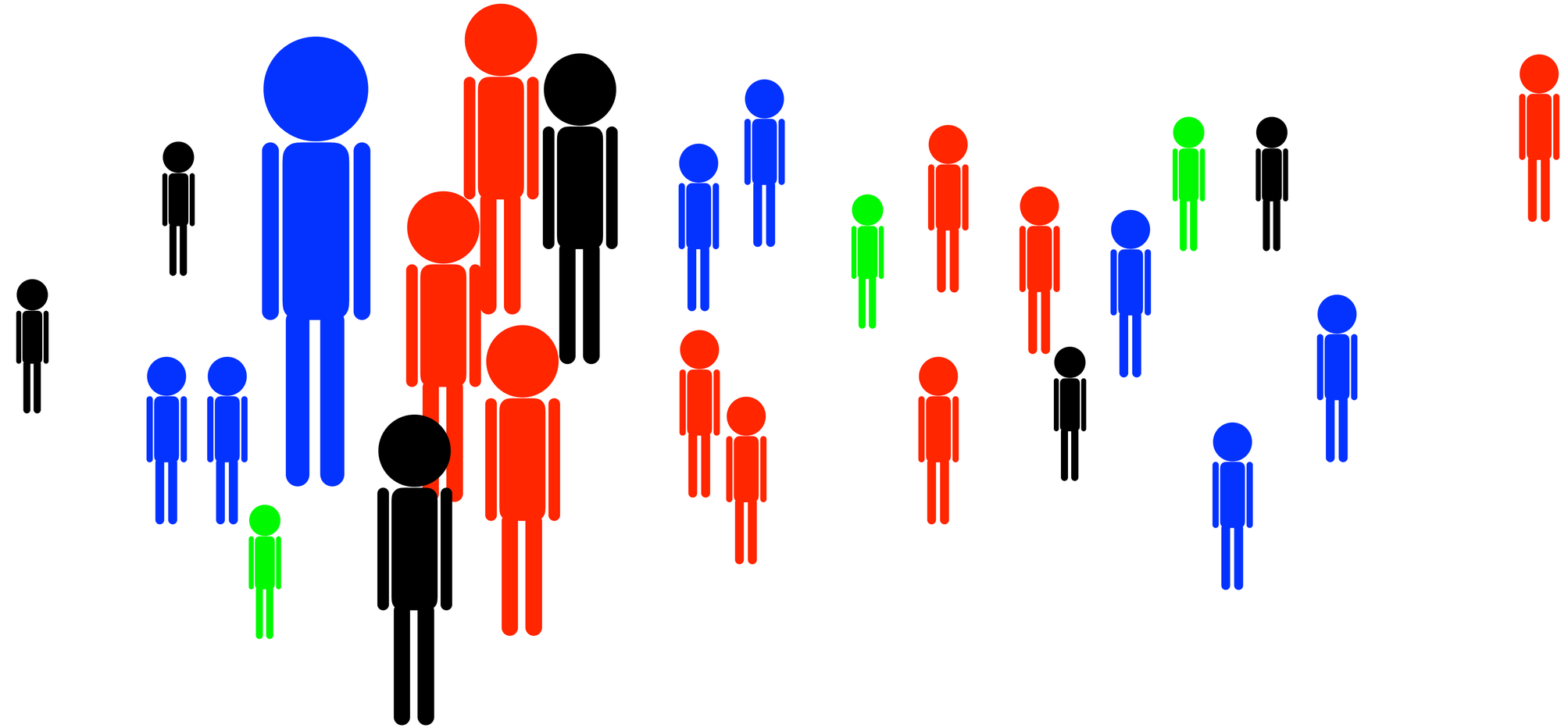
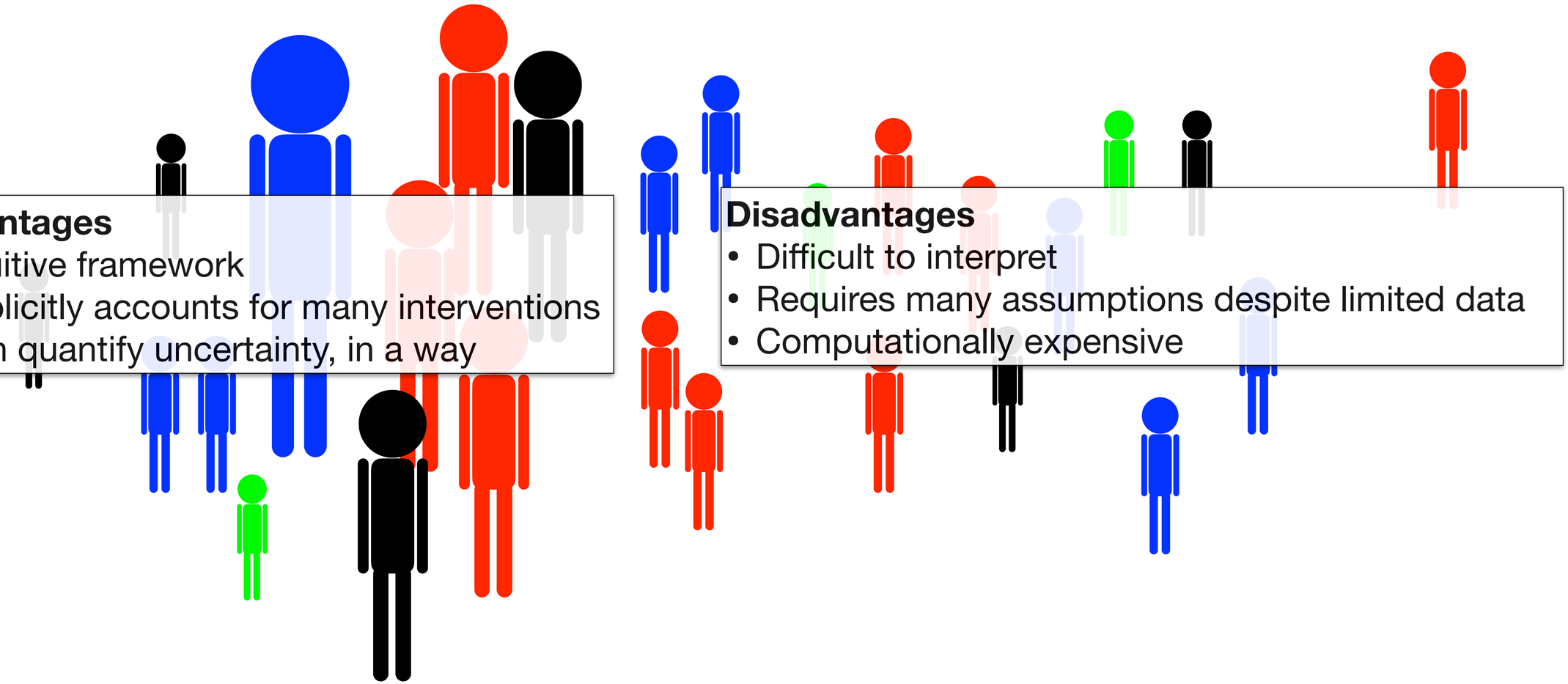


The Imperial College approach

Susceptible → **E**xposed → **I**nfectious → **R**ecovered



Advantages
- Intuitive framework
- Explicitly accounts for many interventions
- Can quantify uncertainty, in a way

Disadvantages
- Difficult to interpret
- Requires many assumptions despite limited data
- Computationally expensive

Our approach

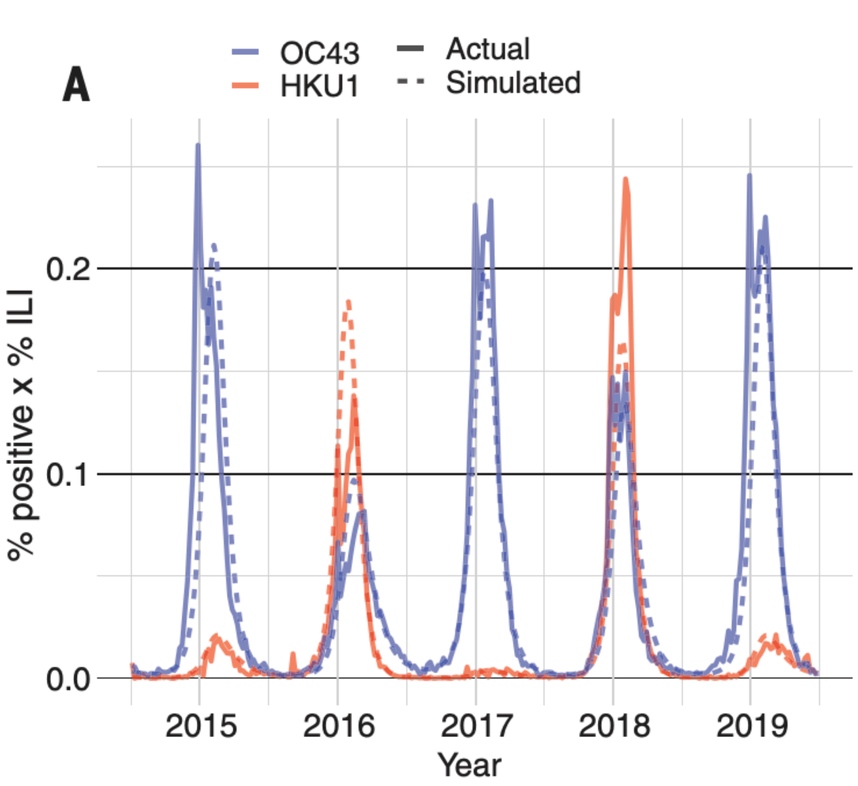
What can we learn from related coronaviruses?

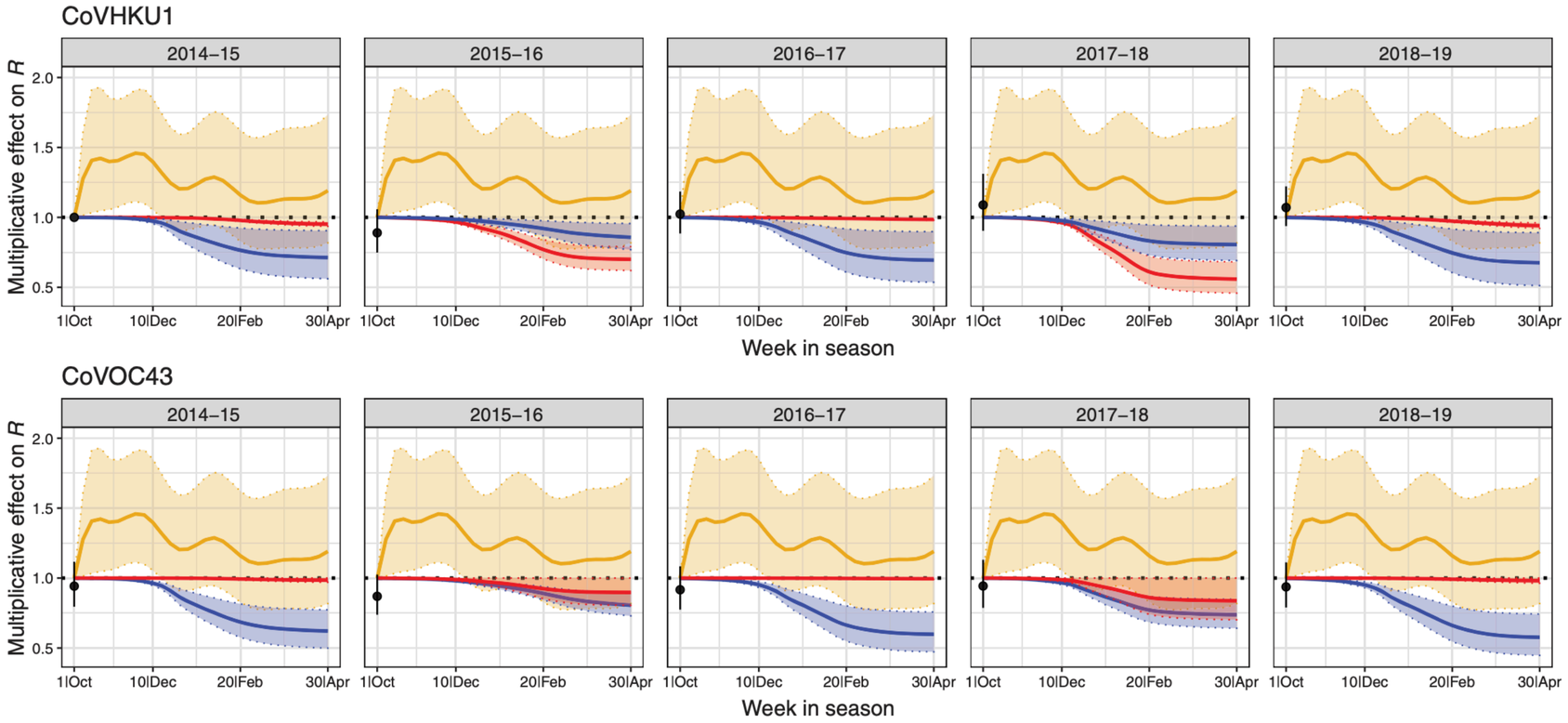
CORONAVIRUS

Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period

Science 22 May 2020:
Vol. 368, Issue 6493, pp. 860-868
DOI: 10.1126/science.abb5793

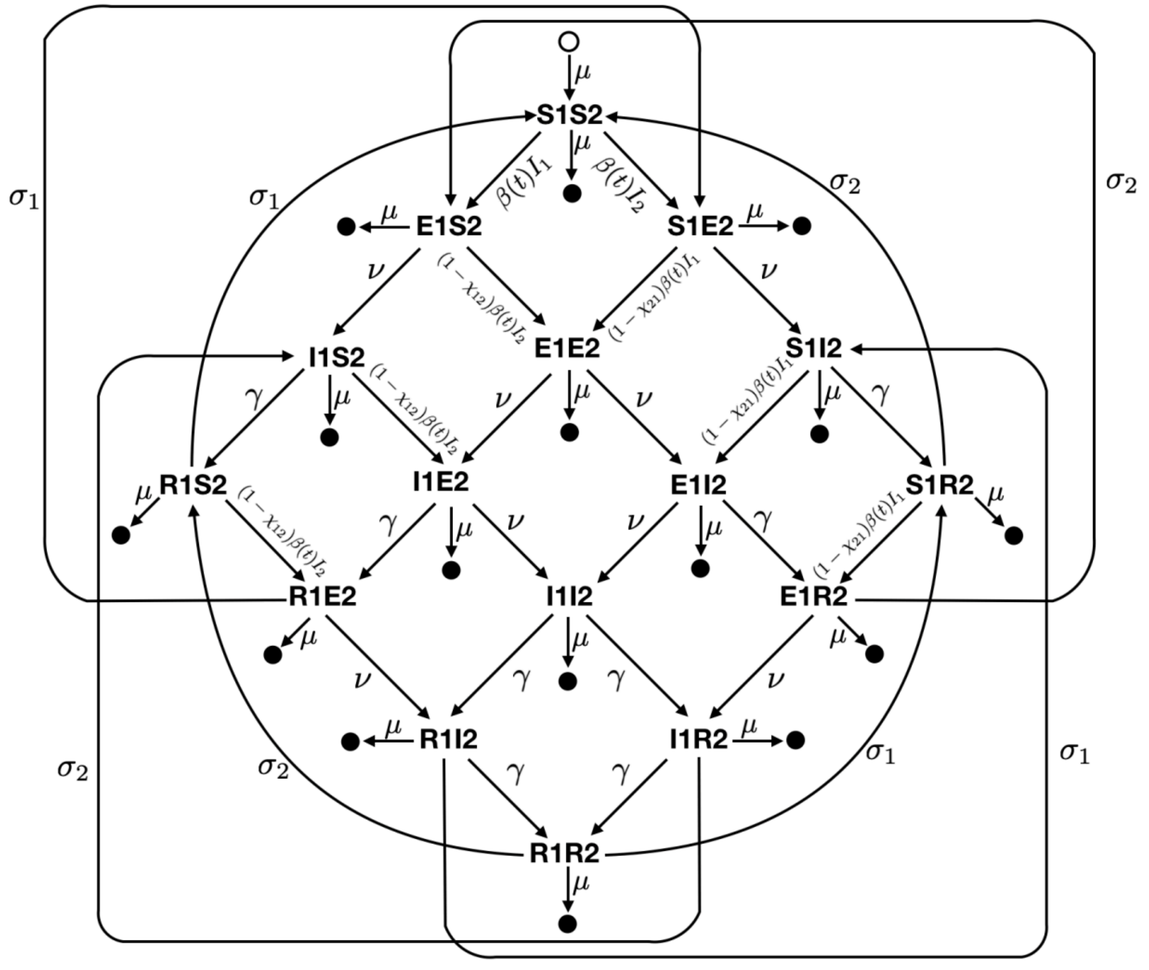
Stephen M. Kissler[1]*, Christine Tedijanto[2]*, Edward Goldstein[2], Yonatan H. Grad[1]†‡, Marc Lipsitch[2]†‡

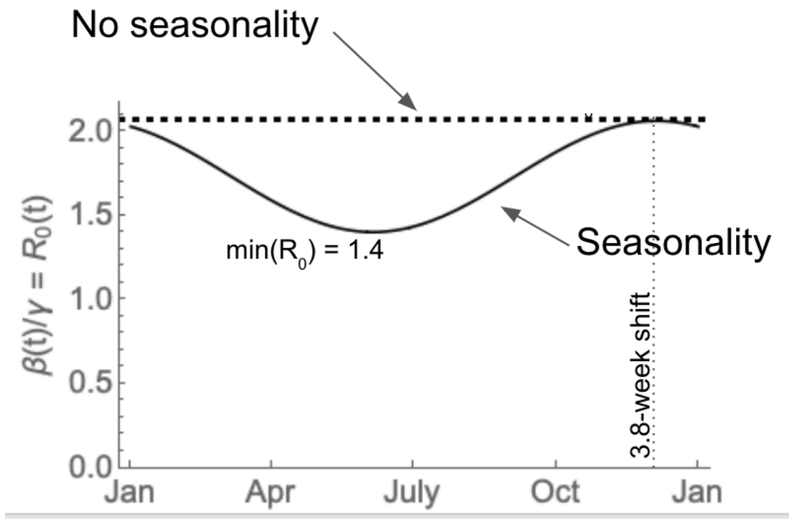




Cross-immunity and seasonality could influence long-term dynamics

Our approach



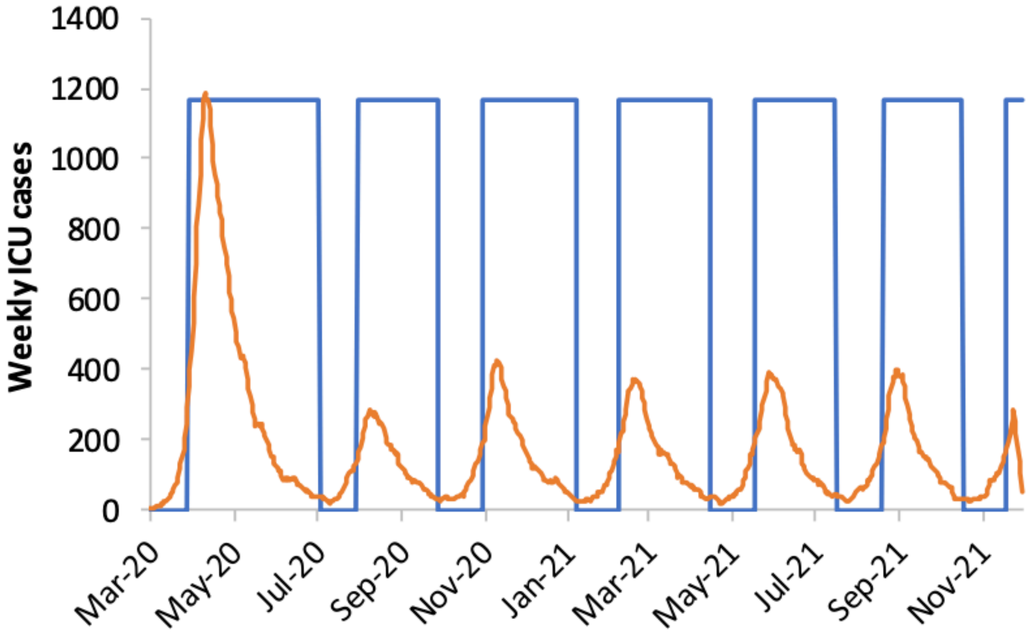


Advantages
- More interpretable
- Requires fewer assumptions
- More computationally efficient

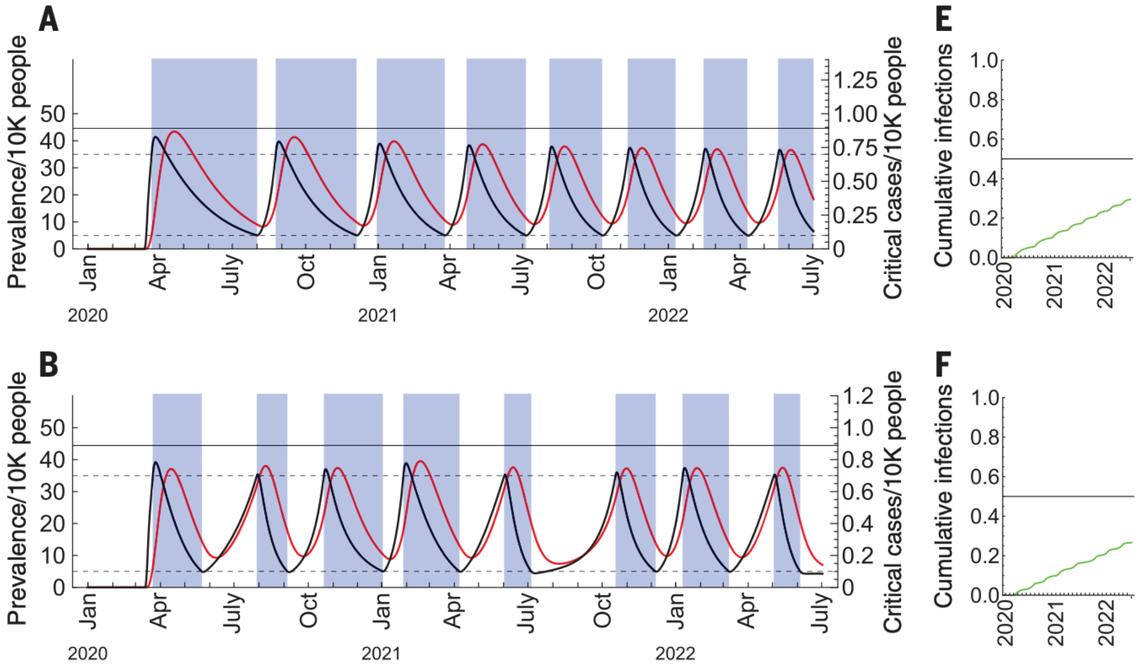
Disadvantages
- Machinery is less intuitive
- No sense of population heterogeneity
- Difficult to measure uncertainty

Still, they agree pretty well

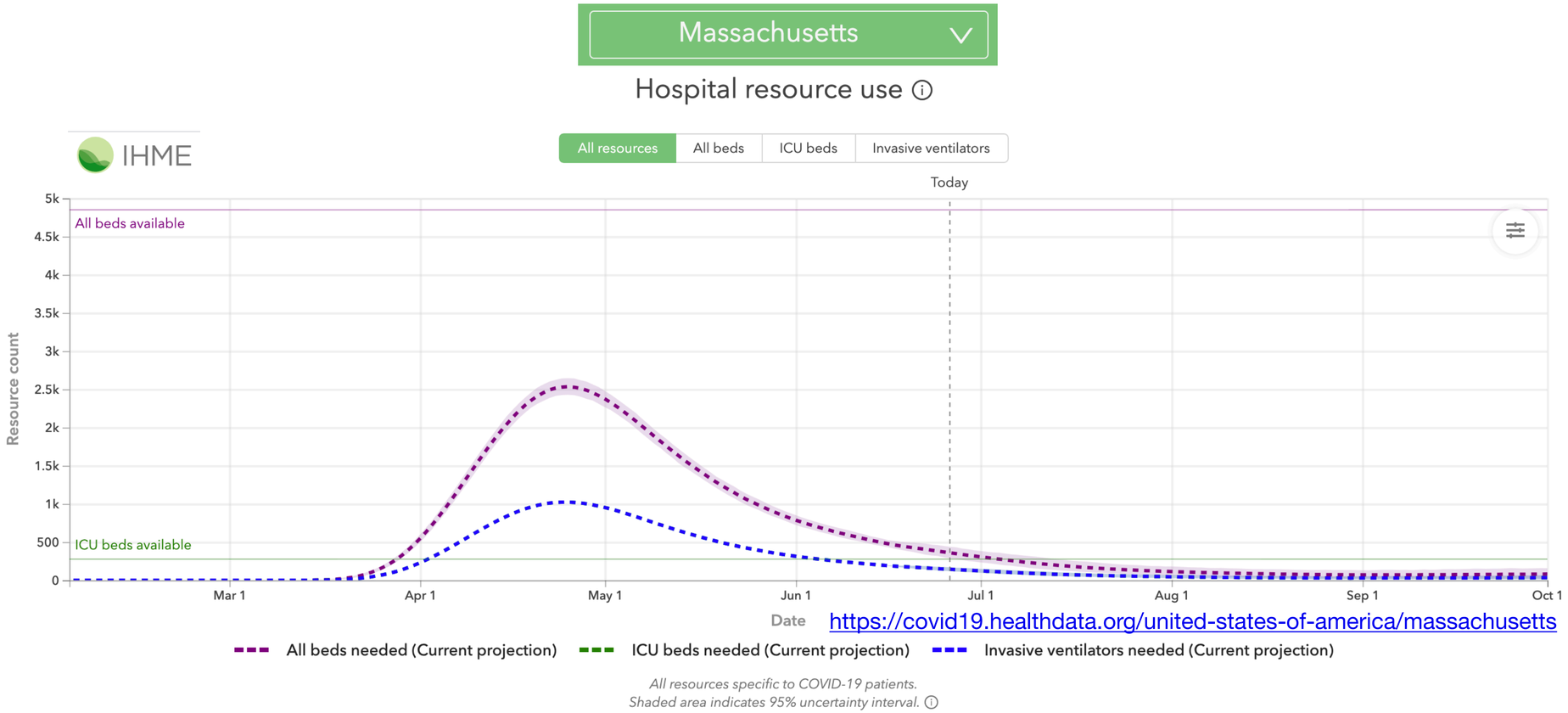
Imperial model



Harvard model

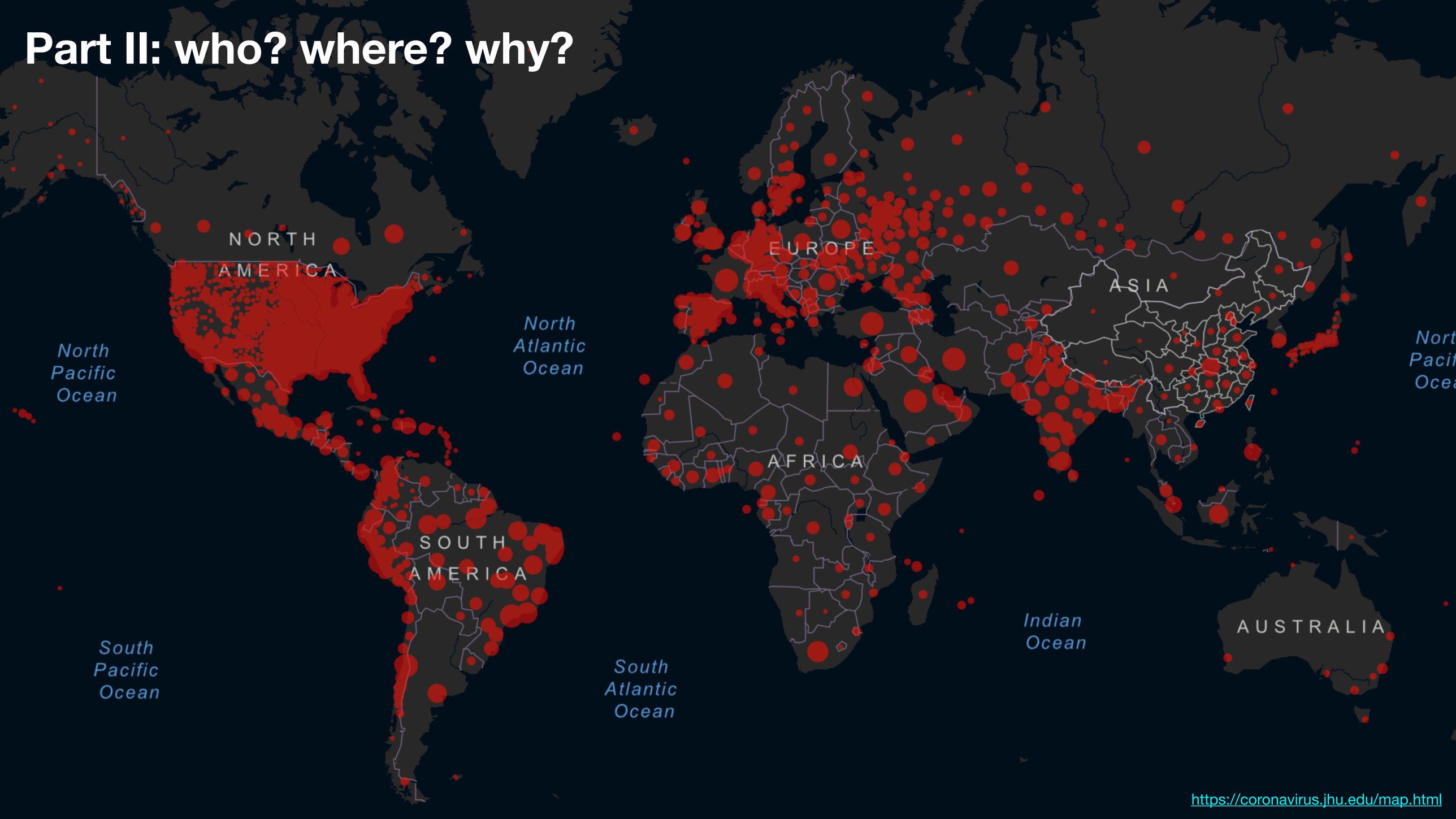


Other notable alternatives



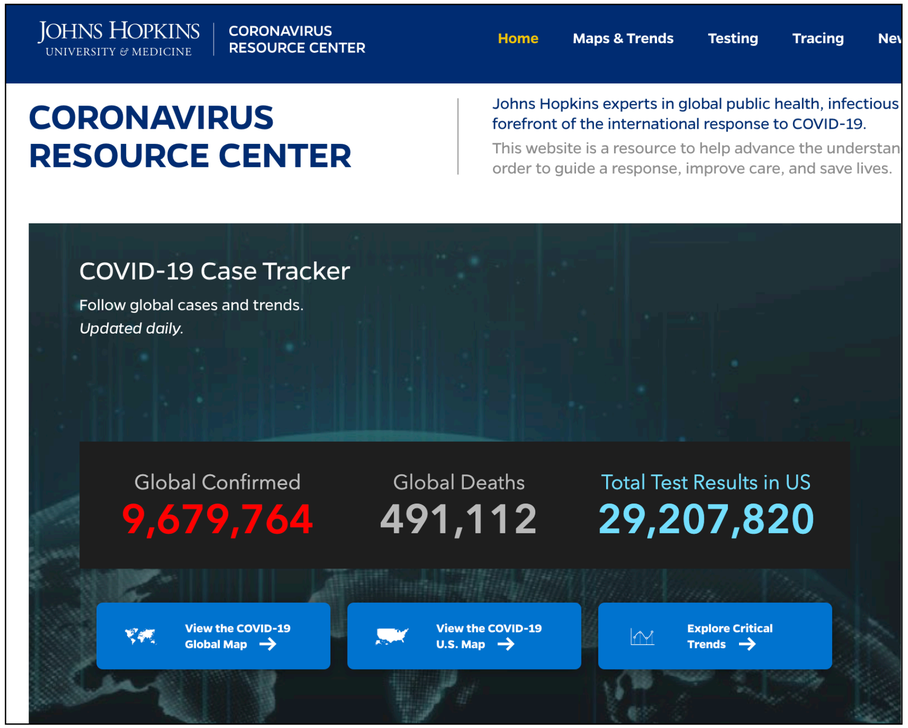
- **Has had a big influence, but based on very different principles**

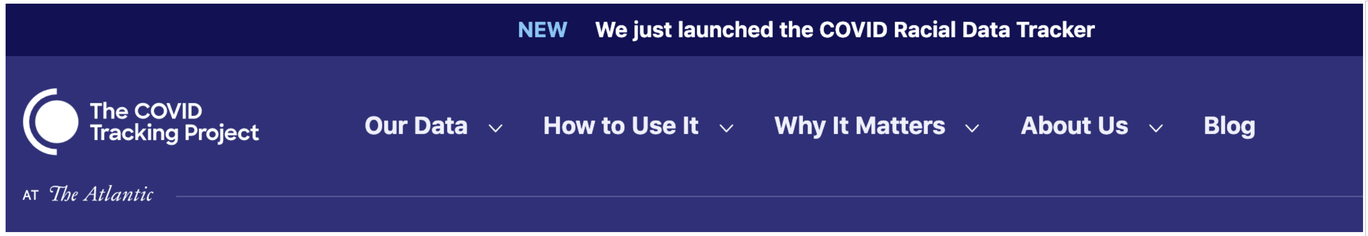
Part II: who? where? why?

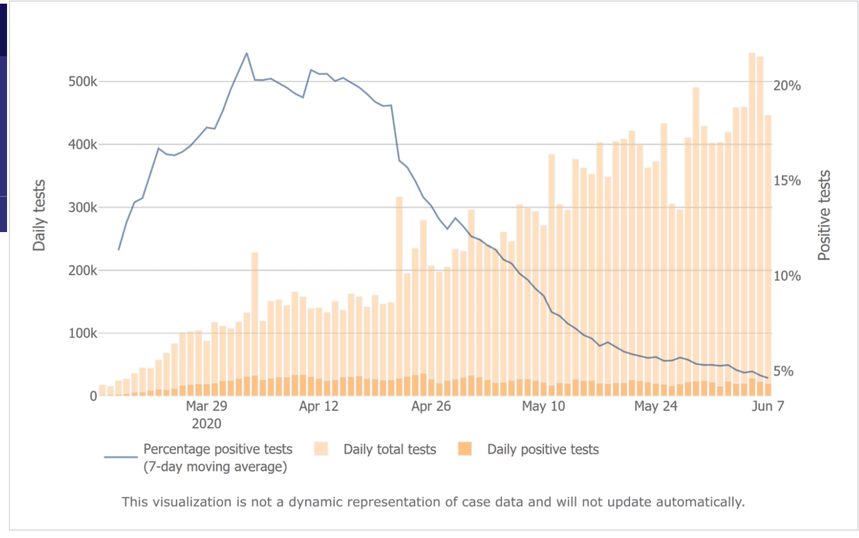


https://coronavirus.jhu.edu/map.html

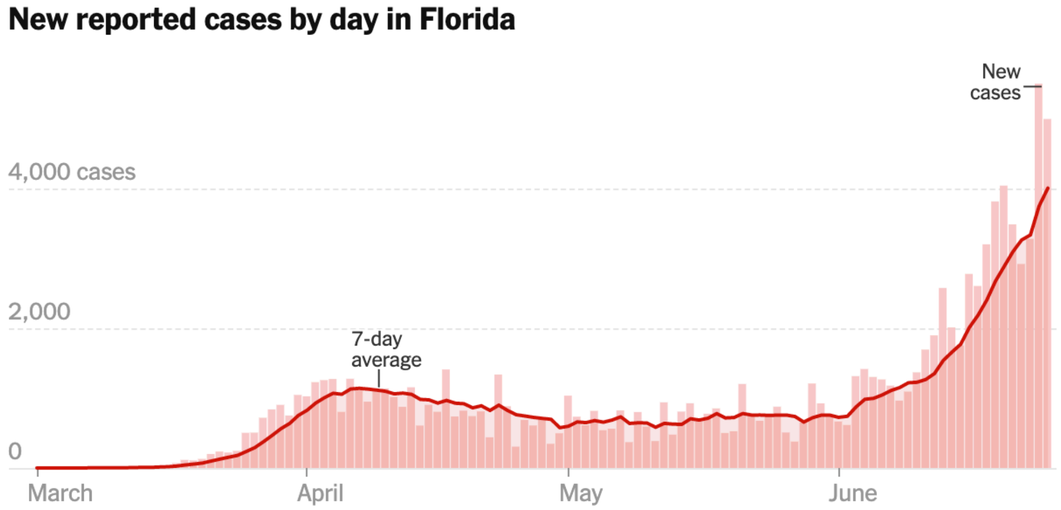
COVID-19 dashboards



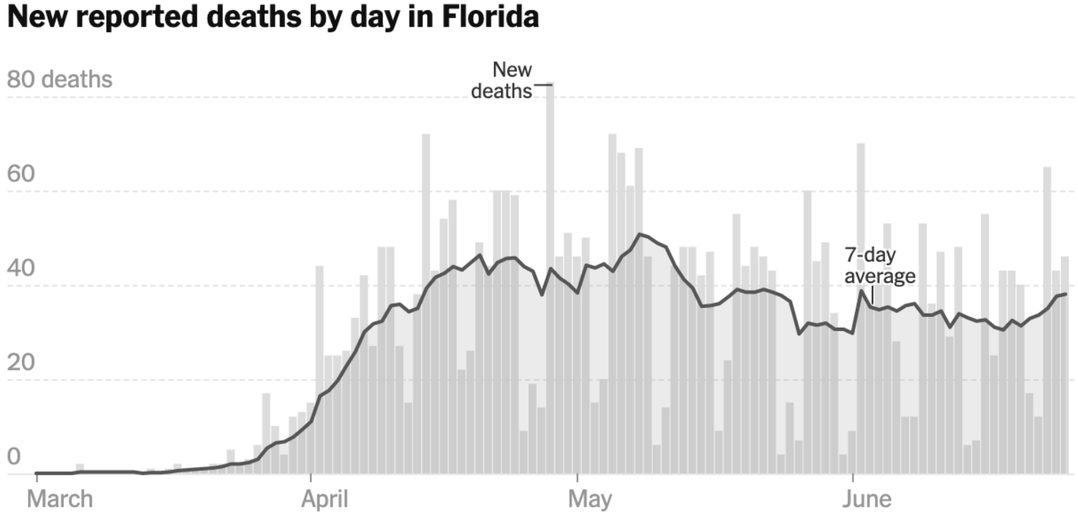




Contrasting data streams



https://www.nytimes.com/interactive/2020/us/florida-coronavirus-cases.html



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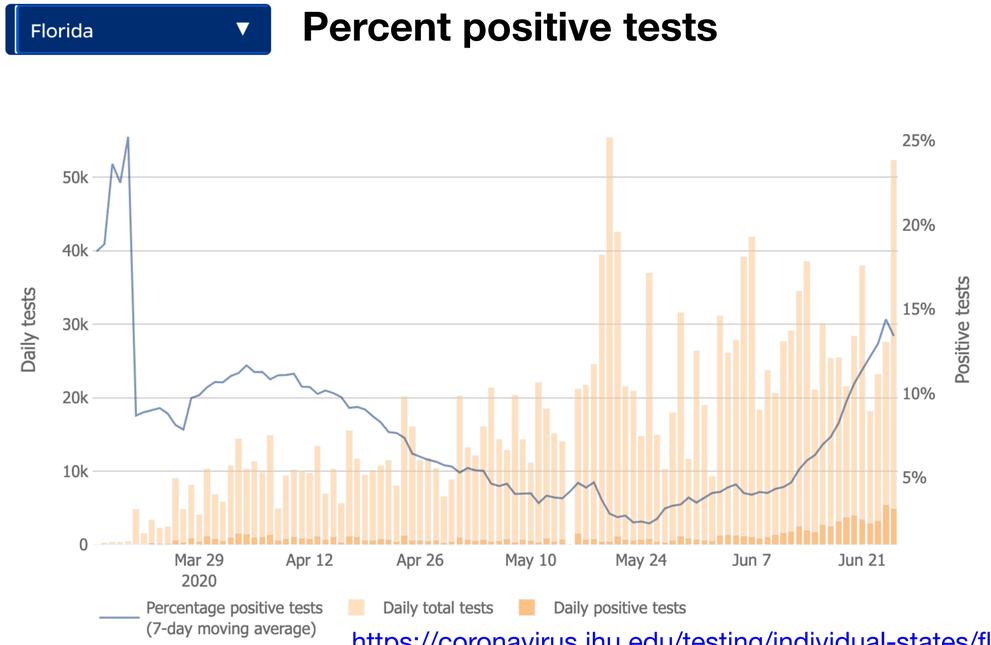
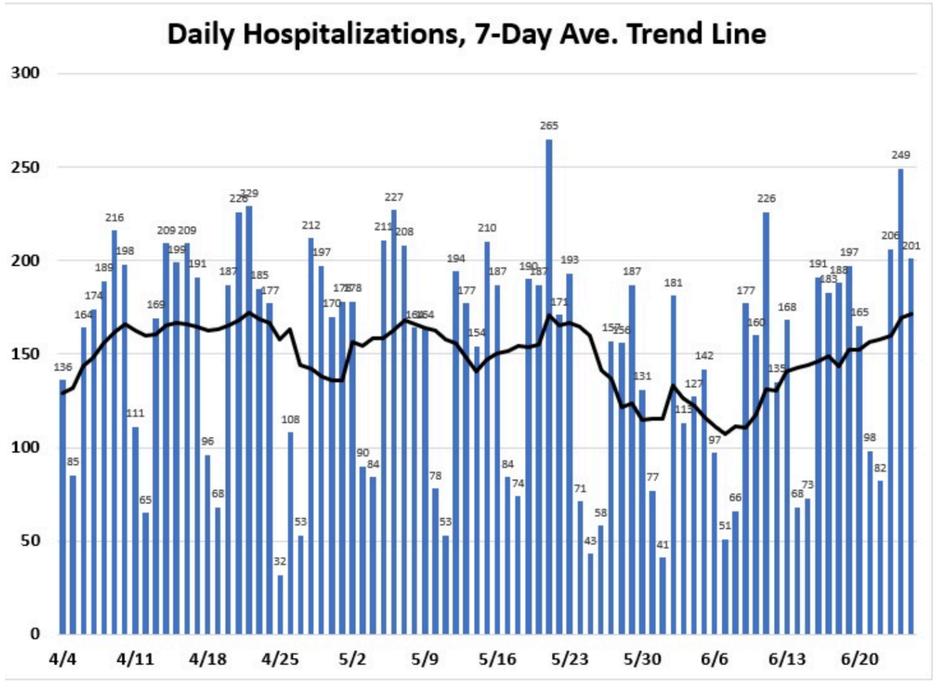


https://coronavirus.jhu.edu/testing/individual-states/florida



https://tallahasseereports.com/2020/06/24/two-charts-show-positive-trends-for-florida-in-coronavirus-battle/

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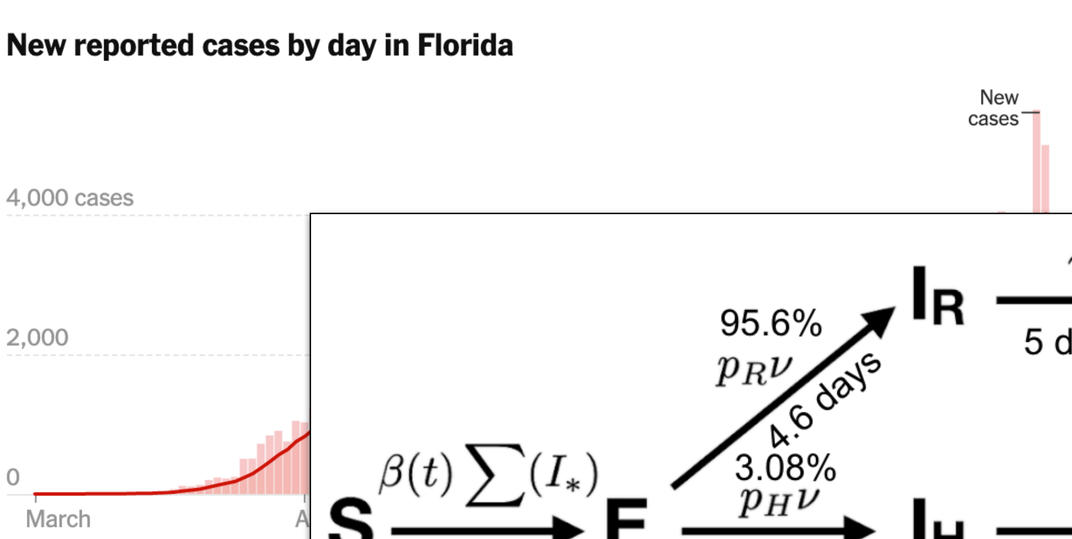
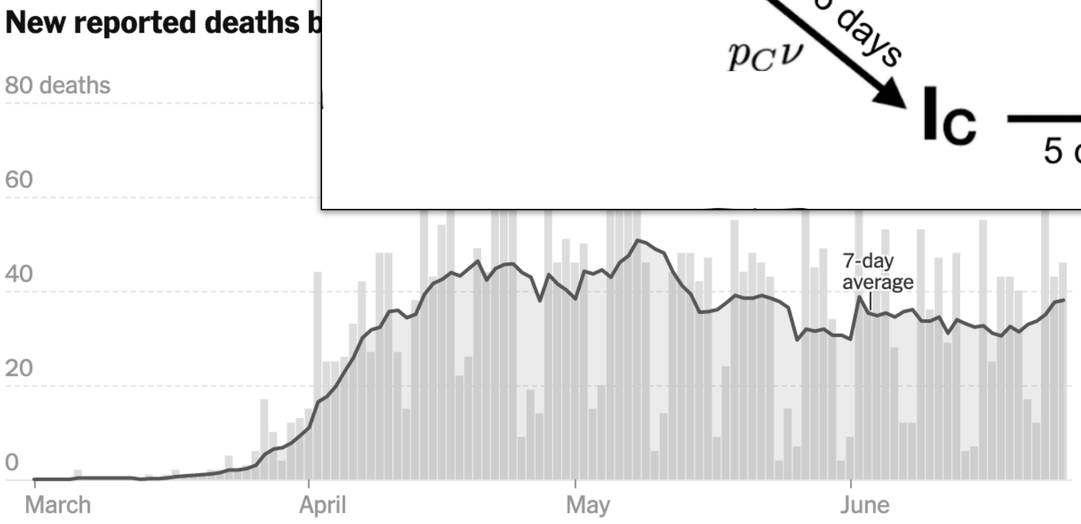
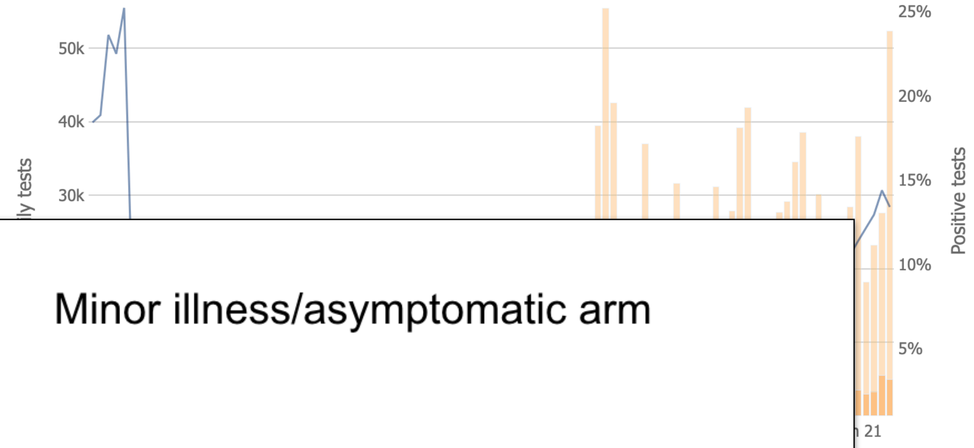


https://www.nyt

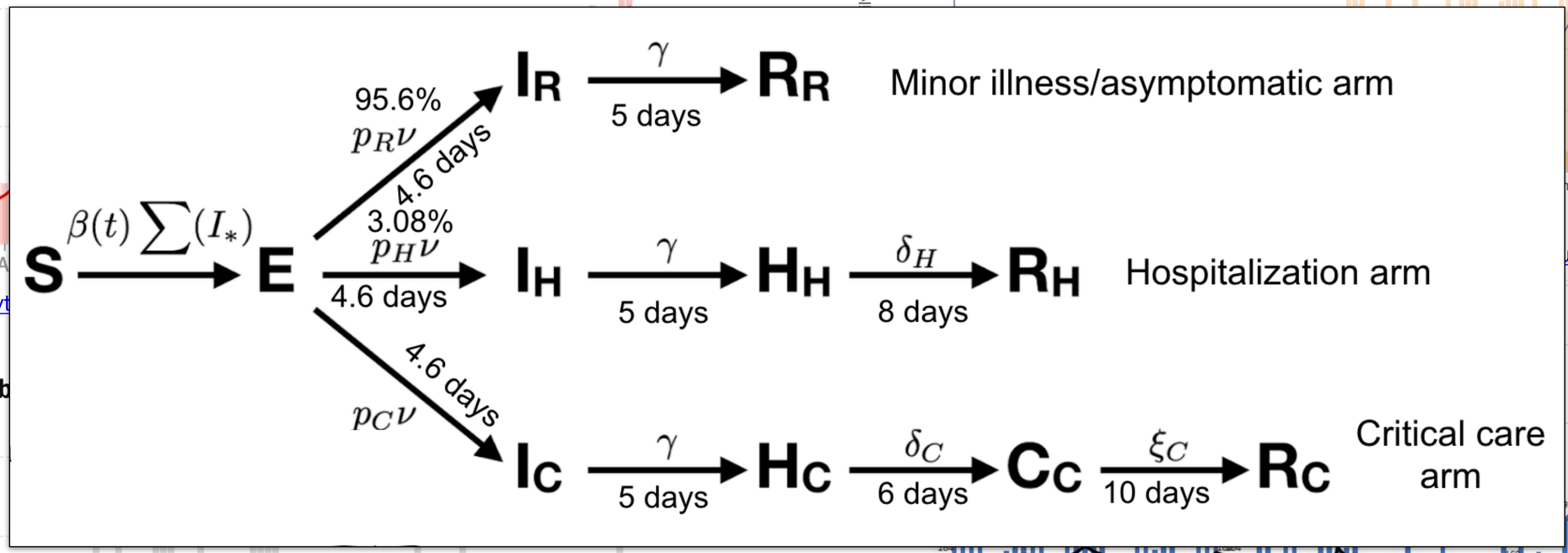


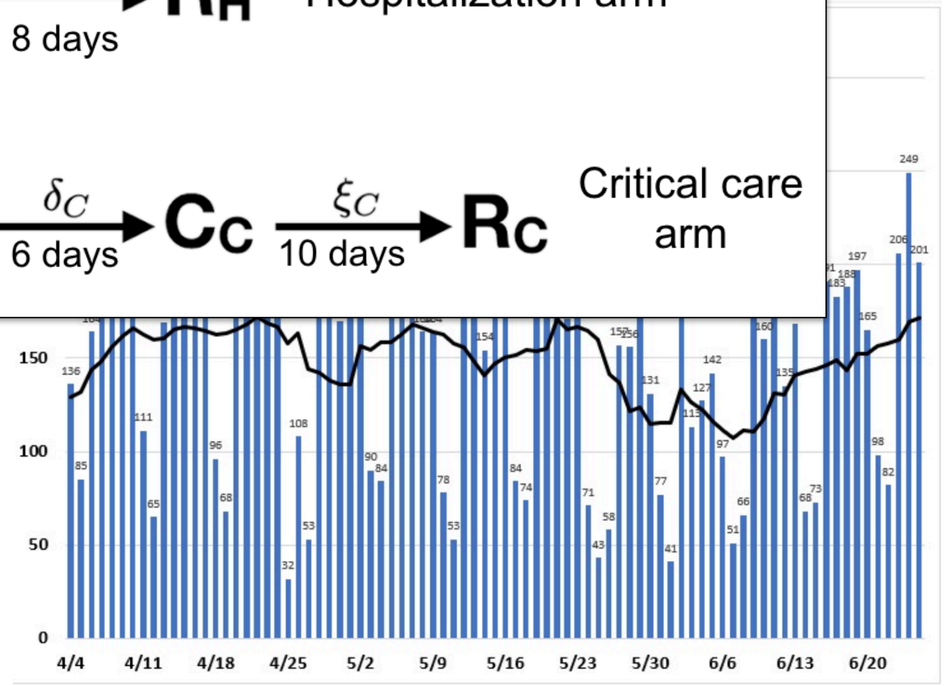
https://www.nytimes.com/interactive/2020/us/florida-coronavirus-cases.html

Percent positive tests



ual-states/florida





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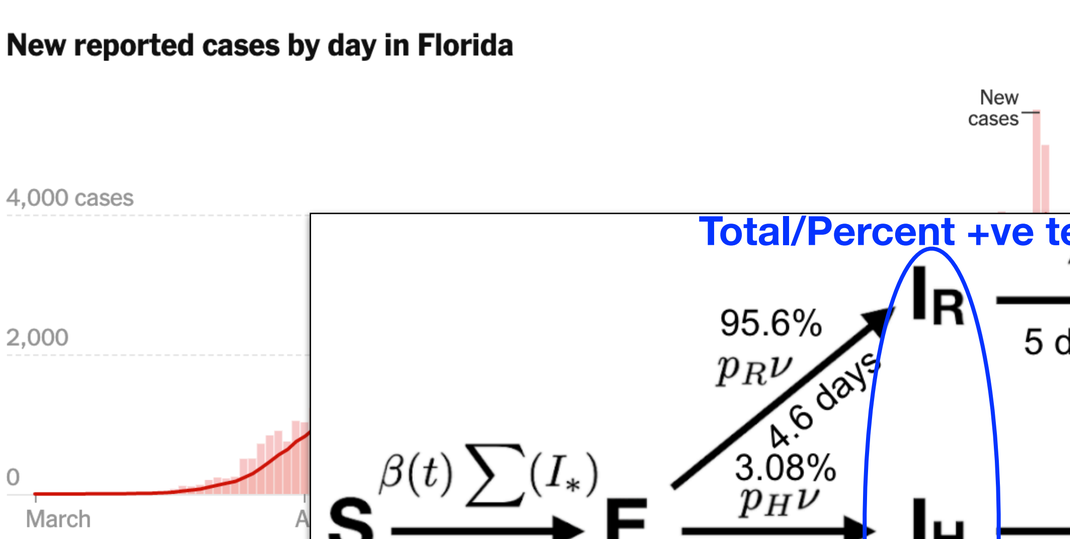

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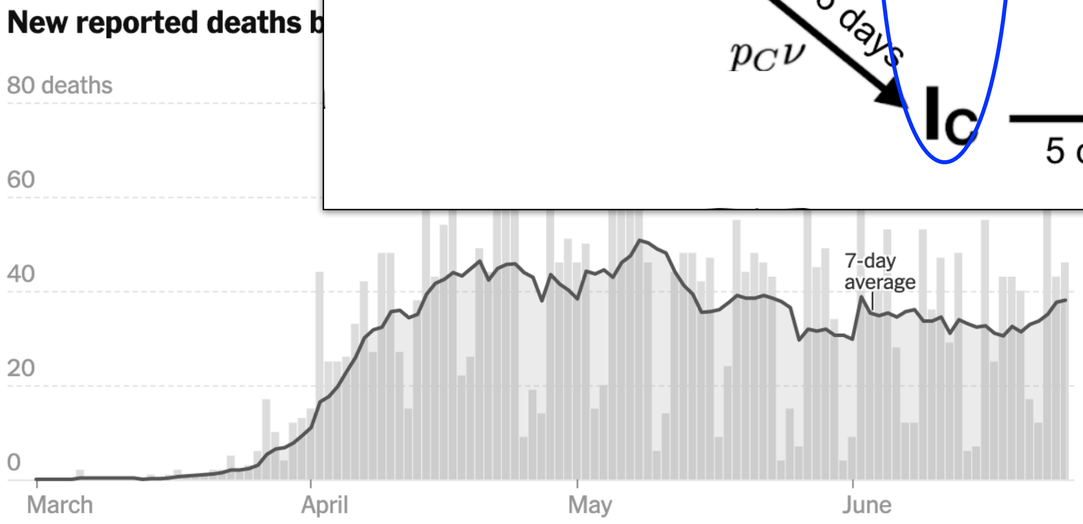

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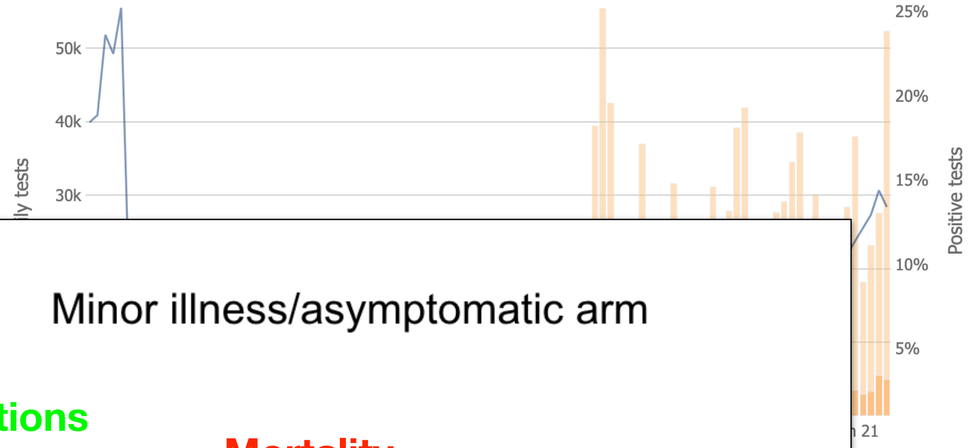

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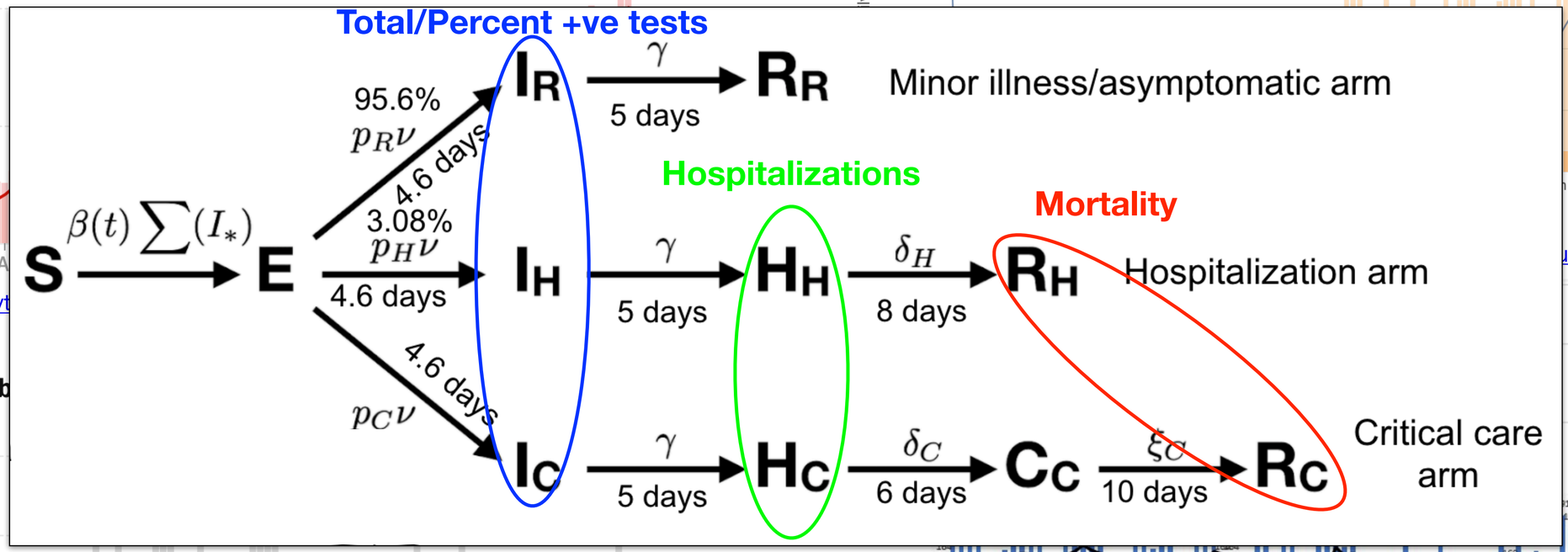
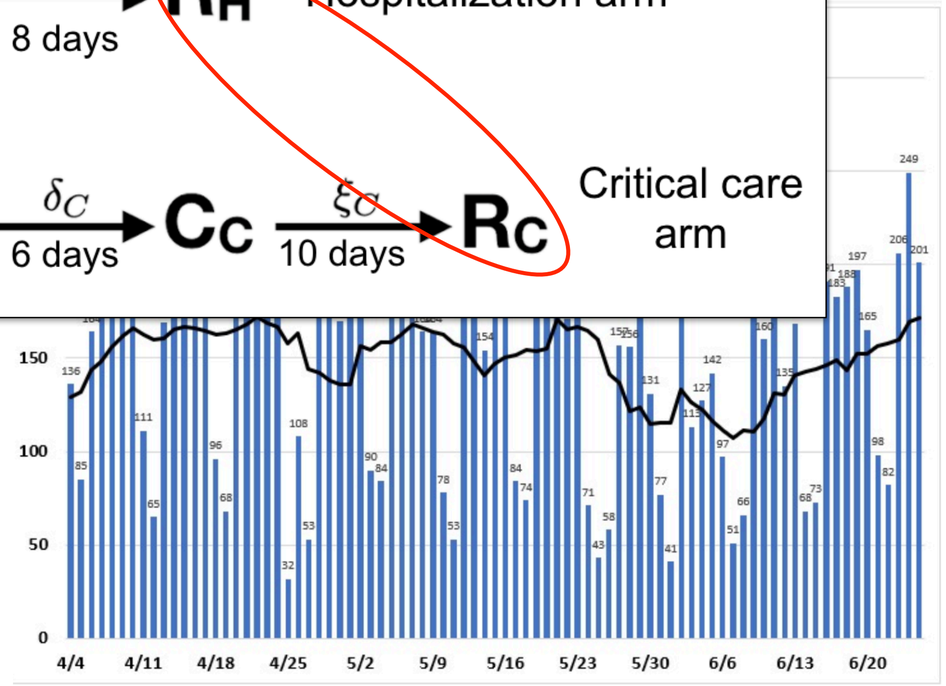


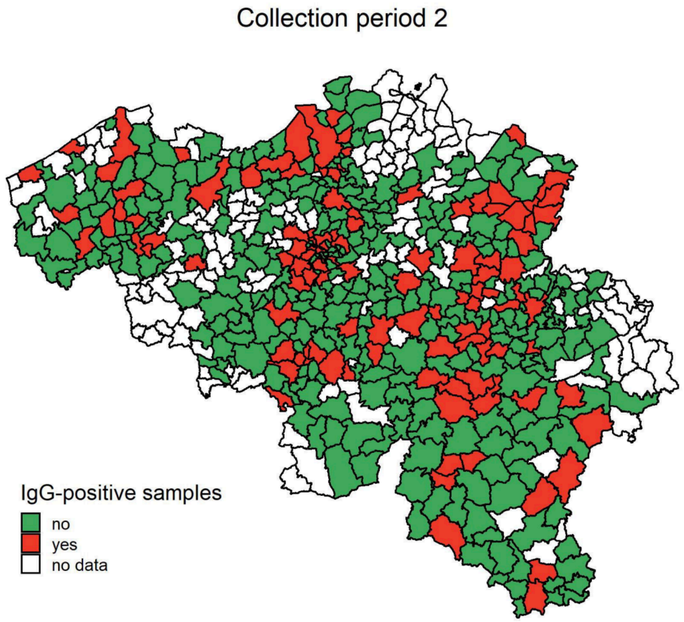


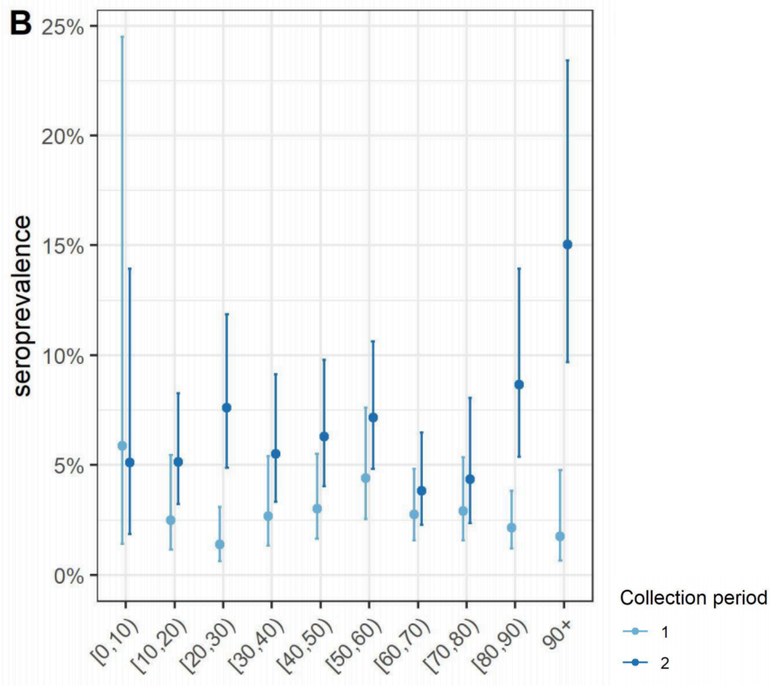
https://tallahasseereports.com/2020/06/24/two-charts-show-positive-trends-for-florida-in-coronavirus-battle/

Contrasting data streams

Seroprevalence of IgG antibodies against SARS coronavirus 2 in Belgium – a prospective cross-sectional study of residual samples

Herzog Sereina, PhD [1 *], De Bie Jessie, PhD [2, 3 *], Abrams Steven, Prof [3, 4], Wouters Ine, PhD [2], Ekinci Esra, MSc [2], Patteet Lisbeth, PhD [5], Coppens Astrid, MSc [5], De Spiegeleer Sandy, MSc [6], Beutels Philippe, Prof [1], Van Damme Pierre, Prof [2], Hens Niel, Prof [1, 4], Theeten Heidi, Prof [2]





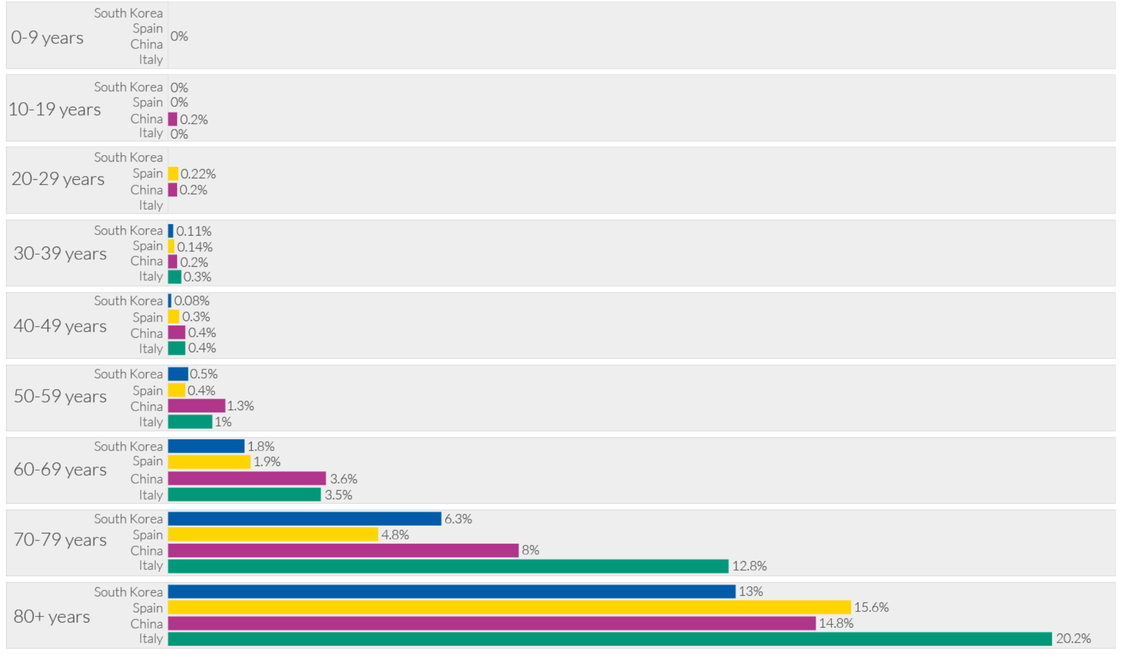
Studies on age

Coronavirus: case fatality rates by age

Our World in Data

Case fatality rate (CFR) is calculated by dividing the total number of confirmed deaths due to COVID-19 by the number of *confirmed* cases.

Two of the main limitations to keep in mind when interpreting the CFR:
(1) many cases within the population are unconfirmed due to a lack of testing.
(2) some individuals who are infected will eventually die from the disease, but are still alive at time of recording.



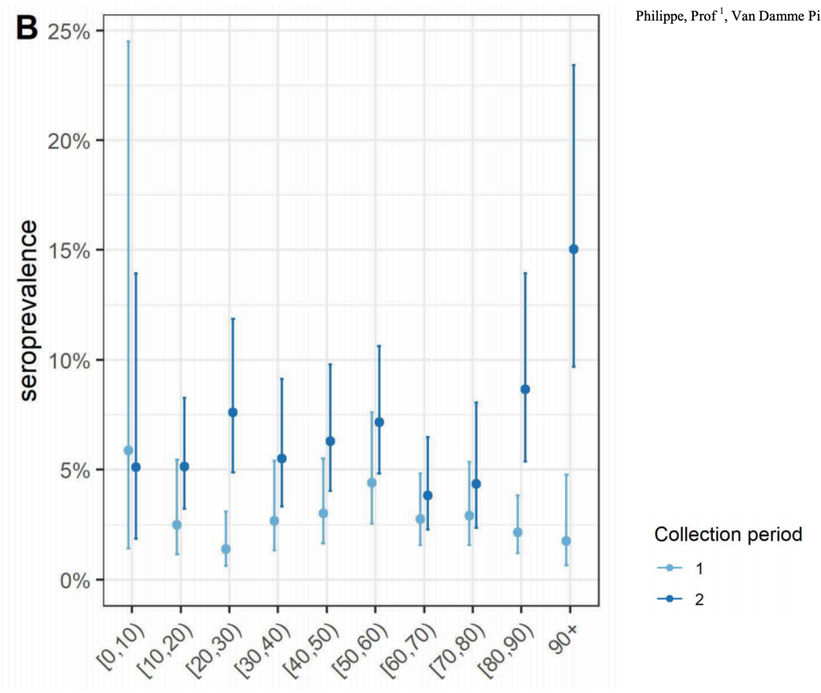
Note: Case fatality rates are based on confirmed cases and deaths from COVID-19 as of: 17th February (China); 24th March (Spain); 24th March (South Korea); 17th March (Italy).

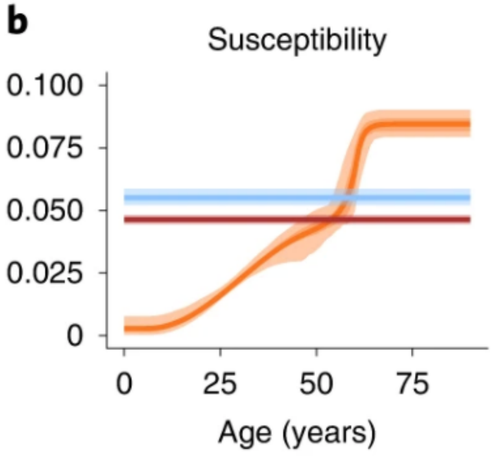
Data sources: Chinese Center for Disease Control and Prevention (CDC); Spanish Ministry of Health; Korea Centers for Disease Control and Prevention (KCDC).
Onder G, Rezza G, Brusaferro S. Case-Fatality Rate and Characteristics of Patients Dying in Relation to COVID-19 in Italy. *JAMA*.

OurWorldinData.org – Research and data to make progress against the world's largest problems.

Seroprevalence of IgG antibodies against SARS coronavirus 2 in Belgium – a prospective cross-sectional study of residual samples

Herzog Sereina, PhD [1*], De Bie Jessie, PhD [2,3*], Abrams Steven, Prof [3,4], Wouters Ine, PhD [2], Ekinci Esra, MSc [2], Patteet Lisbeth, PhD [5], Coppens Astrid, MSc [5], De Spiegeleer Sandy, MSc [6], Beutels Philippe, Prof [1], Van Damme Pierre, Prof [2], Hens Niel, Prof [1,4], Theeten Heidi, Prof [2]





Letter | Published: 16 June 2020

Age-dependent effects in the transmission and control of COVID-19 epidemics

Nicholas G. Davies ✉, Petra Klepac, Yang Liu, Kiesha Prem, Mark Jit, CMMID COVID-19 working group & Rosalind M. Eggo ✉

Nature Medicine (2020) | Cite this article

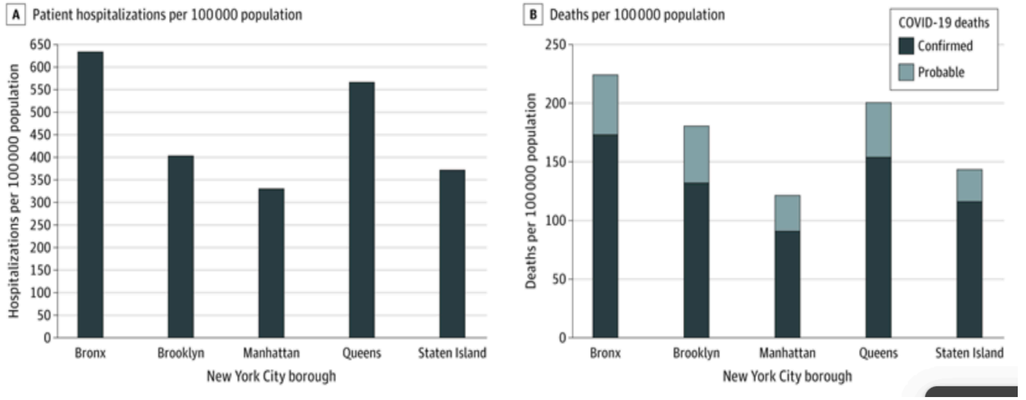
Studies on geography, socioeconomic status, and race/ethnicity

April 29, 2020

Variation in COVID-19 Hospitalizations and Deaths Across New York City Boroughs

Rishi K. Wadhera, MD, MPP, MPhil[1]; Priya Wadhera, MD, MS[2]; Prakriti Gaba, MD[3]; et al

Figure. Rates of Coronavirus Disease 2019 (COVID-19) Hospitalizations and Deaths by New York City Borough

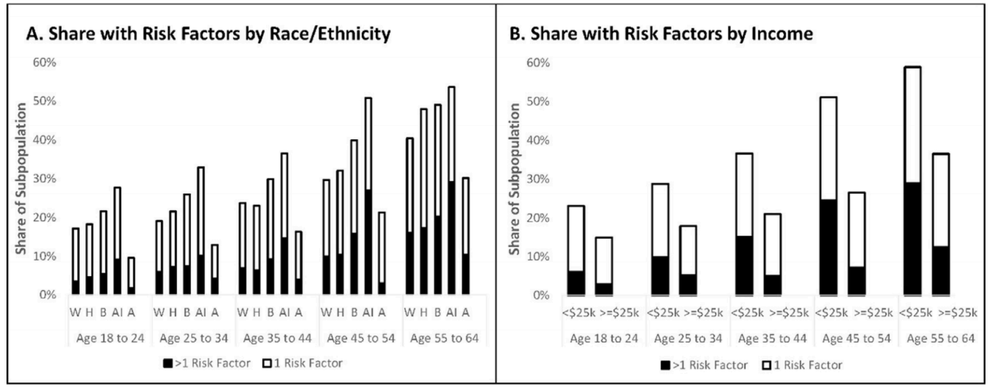


American Journal of
Preventive Medicine

RESEARCH LETTER

Disparities in the Population at Risk of Severe Illness From COVID-19 by Race/Ethnicity and Income

Matthew A. Raifman, MPP,[1] Julia R. Raifman, ScD[2]



Viewpoint

April 15, 2020

COVID-19 and African Americans

Clyde W. Yancy, MD, MSc[1]

» Author Affiliations | Article Information

JAMA. 2020;323(19):1891-1892. doi:10.1001/jama.2020.6548

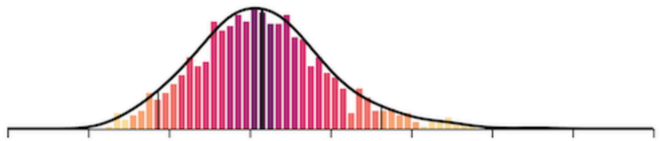
"A 6-fold increase in the rate of death for African Americans due to a now ubiquitous virus should be deemed unconscionable."

Studies on geography, socioeconomic status, and race/ethnicity

Reductions in commuting mobility predict geographic differences in SARS-CoV-2 prevalence in New York City

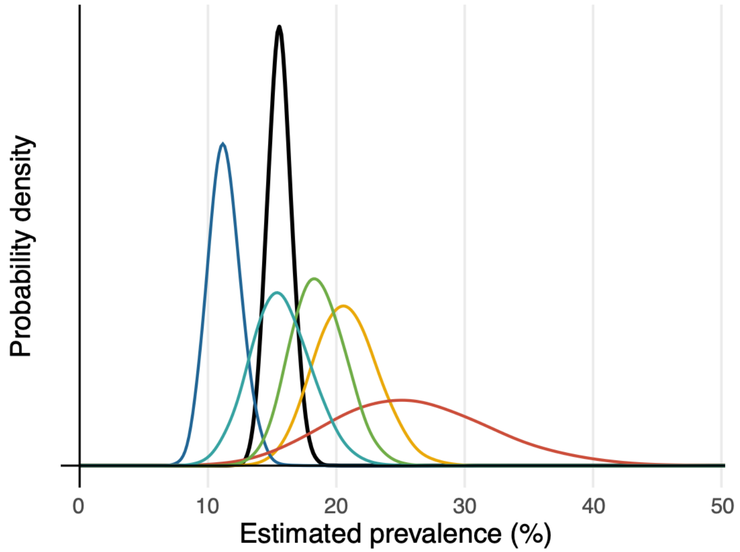
Stephen M. Kissler[1*], Nishant Kishore[2*], Malavika Prabhu[4*], Dena Goffman[5*], Yaakov Beilin[8,9*], Ruth Landau[6], Cynthia Gyamfi-Bannerman[5], Brian T. Bateman[7], Daniel Katz[8,9], Jonathan Gal[8], Angela Bianco[9], Joanne Stone[9], Daniel Larremore[3], Caroline O. Buckee[2], Yonatan H. Grad[1]

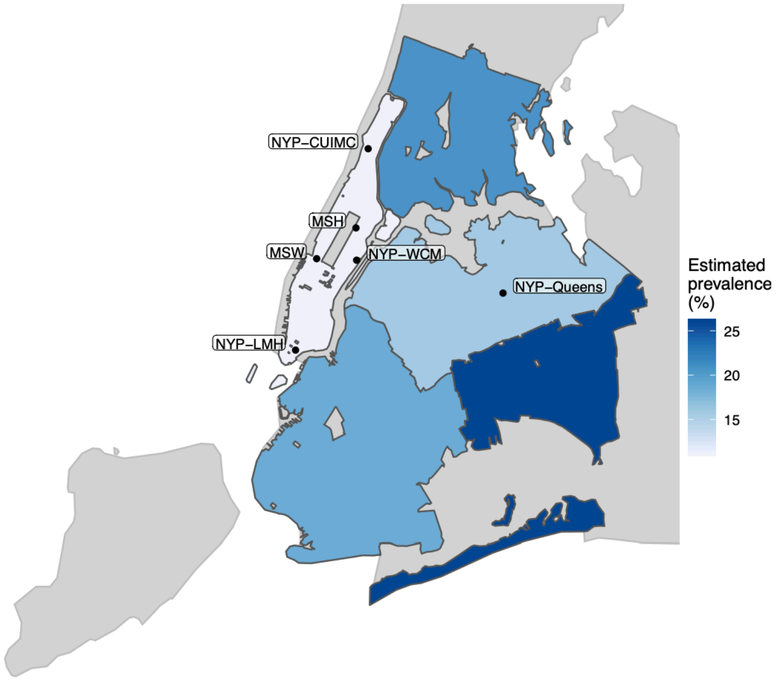
- Estimate SARS-CoV-2 prevalence in pregnant women in NYC and extrapolate to the whole population
- Compare with mobility data from Facebook's "Data For Good" initiative

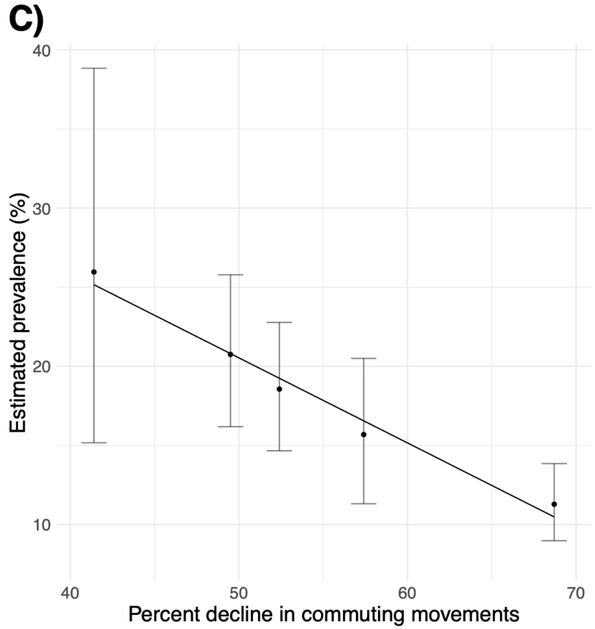


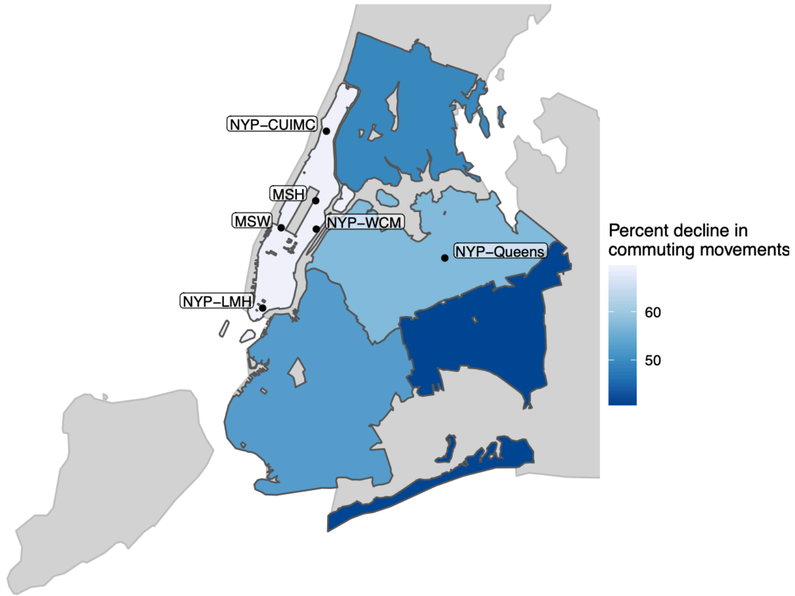
COVID-19 Testing Group

https://larremorelab.github.io/covid-calculator2

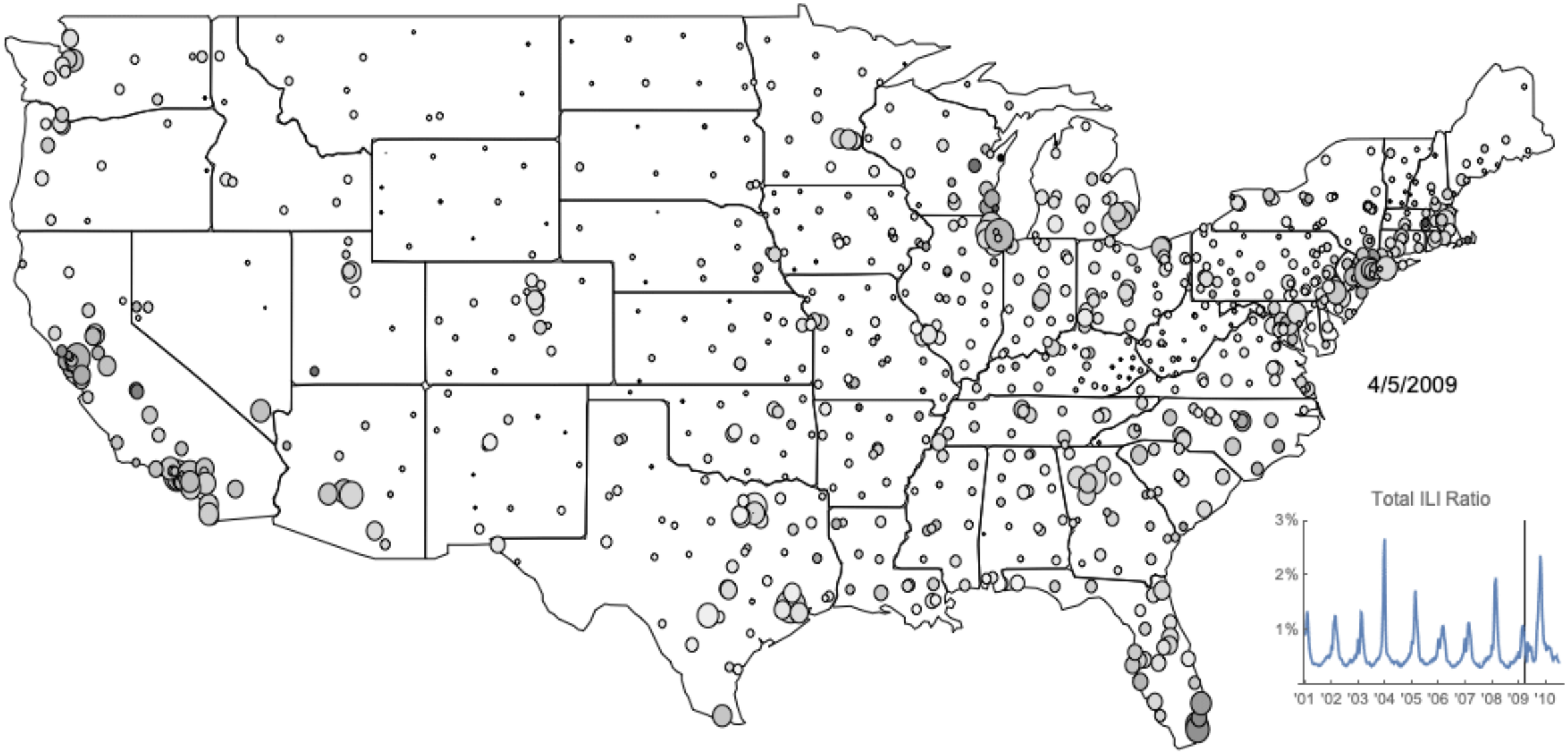








Part III: where are we now?



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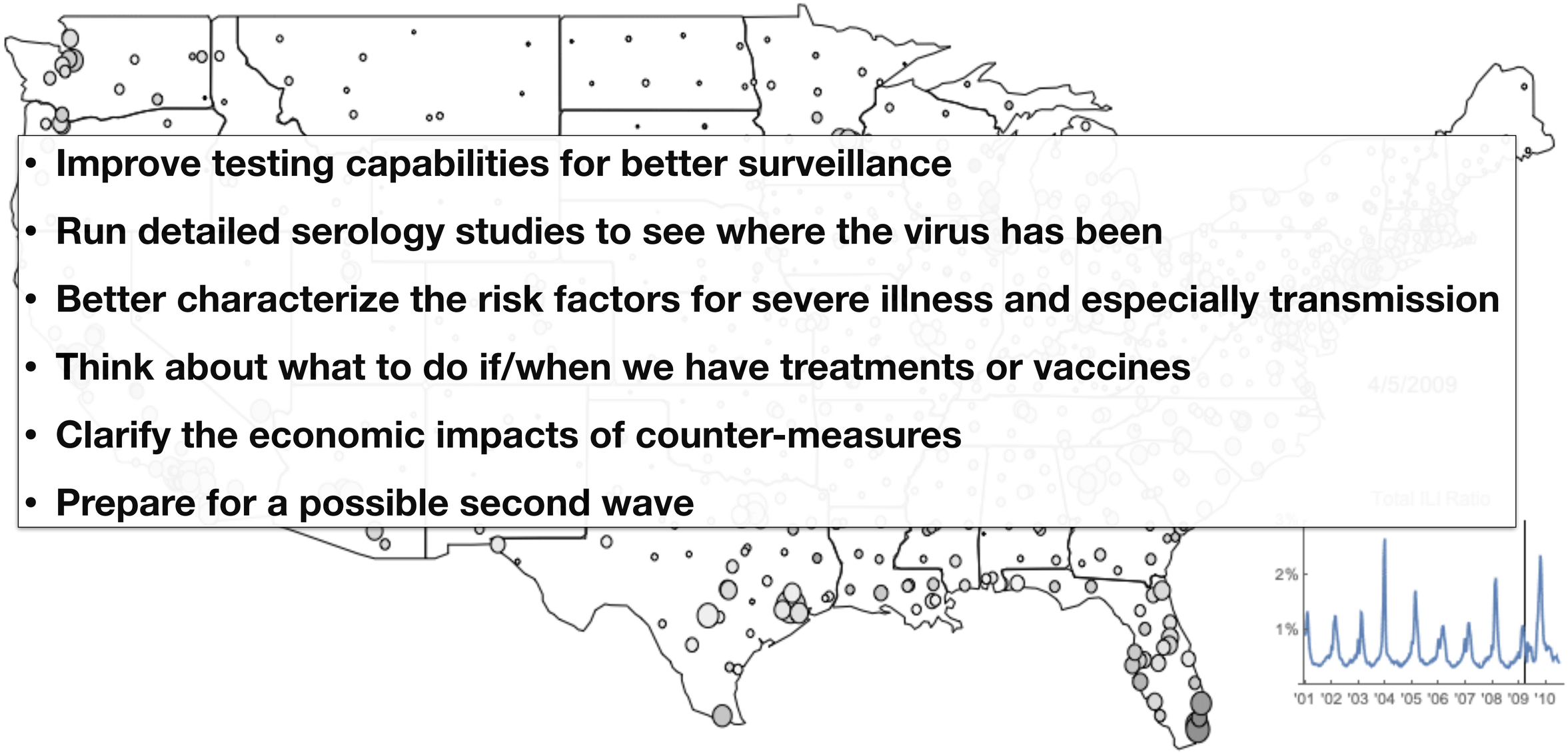

- Improve testing capabilities for better surveillance
- Run detailed serology studies to see where the virus has been
- Better characterize the risk factors for severe illness and especially transmission
- Think about what to do if/when we have treatments or vaccines
- Clarify the economic impacts of counter-measures
- Prepare for a possible second wave

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Projecting the transmission of SARS-CoV-2 through the postpandemic period

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Caroline Buckee

Yonatan Grad

+ many others in CCDD, Grad Lab, and hospitals across New York City