Review of COVID-19 Models

NEWS IN BRIEF

CDC Unveils List Of Twitter Accounts You Can Follow To Piece Together Vaccine Information

1/05/21 2:10PM

ATLANTA—In an effort to keep the public abreast of the latest developments in the Covid-19 pandemic, CDC director Robert R. Redfield unveiled a list of Twitter accounts Tuesday that Americans could follow to piece together vaccine

MORE FROM G/O MEDIA

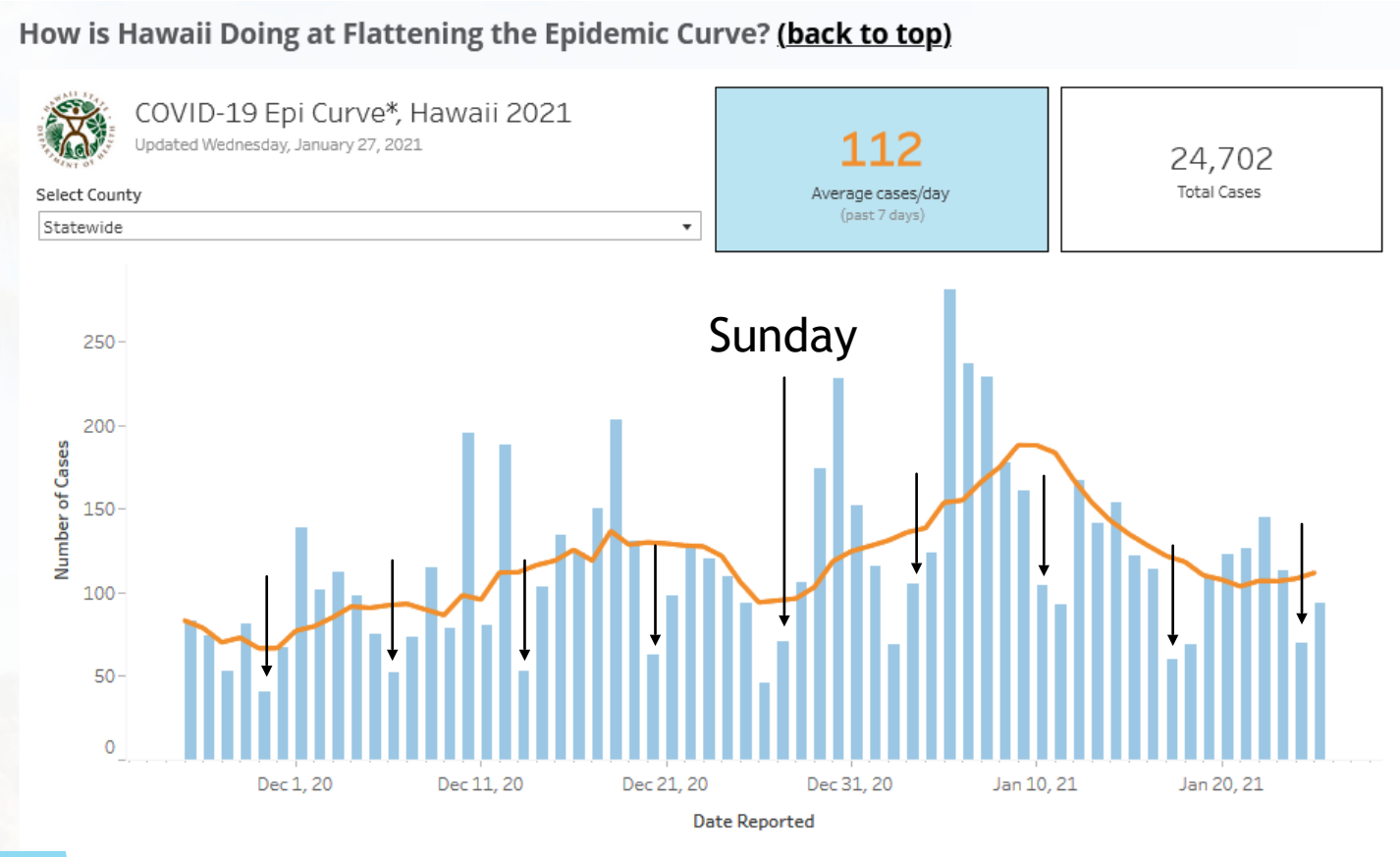
READ ON the ONION
Tearful Justin Trudeau Chains Self To Keystone Pipeline To Stop Biden Administration From Destroying Oil Industry Heritage Site

READ ON the ONION
Fun Toy Banned Because Of Three Stupid Dead Kids

READ ON the ONION
Merck Halts Development Of Coronavirus Vaccines

READ ON the ONION
National Guard Returns To Endless Sleep Under Mount Rushmore Until Nation Calls Upon Them Again

COVID-19 data is messy



Star Advertiser
Thursday, January 28, 2021 | Today's Paper | 77°

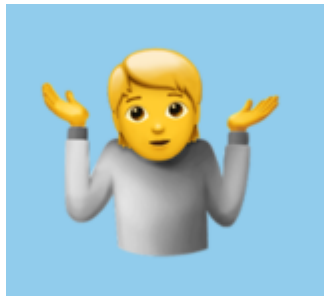
TOP NEWS

Records review adds 60 COVID-19-related deaths to Hawaii tally; state records 123 new infections

https://www.staradvertiser.com/2021/01/25/breaking-news/hawaii-records-123-new-coronavirus-infections-bringing-statewide-total-to-25275/

"Our close inspection of death certificates not only revealed 60 previously unreported deaths. It also uncovered flaws that led to delays in the current reporting system," Char said in a statement.

What is a model?



- A physical, mathematical, or otherwise logical representation of a system, entity, phenomenon, or process

DoD. 1998. "'DoD modeling and simulation (M&S) glossary," in *DoD Manual 5000.59-M*. Arlington, VA, USA: US Department of Defense. January. P2.13.22. Available at http://www.dtic.mil/whs/directives/corres/pdf/500059m.pdf

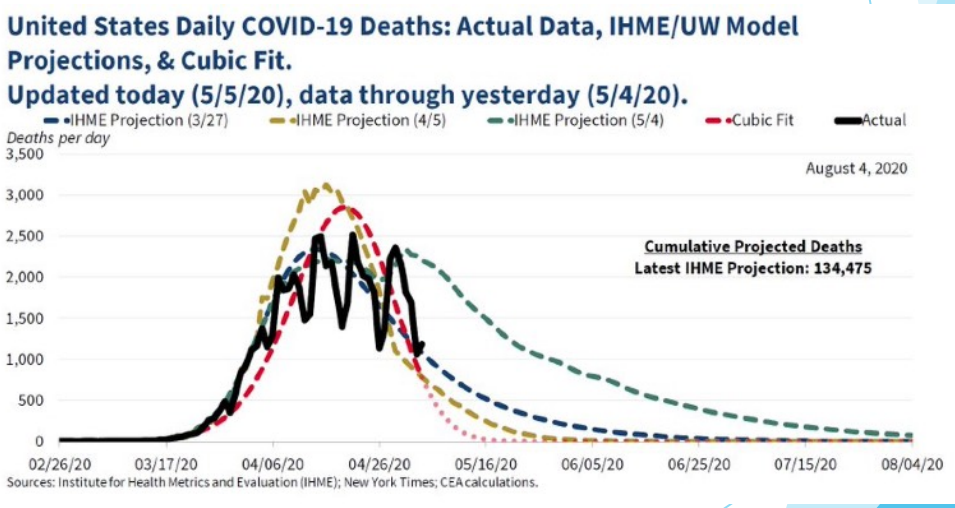
Why use COVID-19 models?

- Forecast number of cases, hospitalizations, ICU beds, fatalities, etc.
- Determine whether our healthcare systems will be overwhelmed (and if so when)
- See impacts of interventions and policy measures

Mechanistic vs Statistical models

Mechanistic model - makes assumptions about how a system or process works

Statistical model - fits curves using existing data



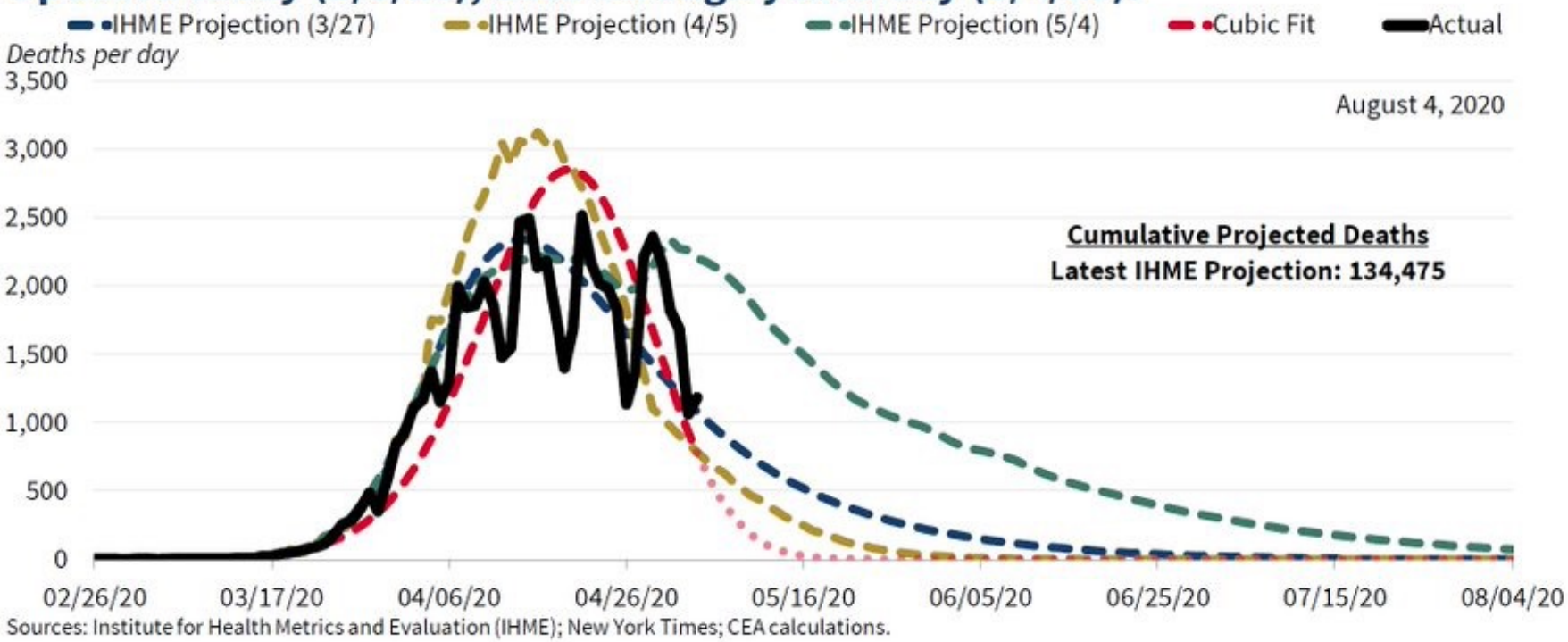
Statistical Models

“fit curves using existing data”

White House Council of Economic Advisers

CEA @WhiteHouseCEA · May 5

To better visualize observed data, we also continually update a curve-fitting exercise to summarize COVID-19's observed trajectory. Particularly with irregular data, curve fitting can improve data visualization. As shown, IHME's mortality curves have matched the data fairly well.



https://twitter.com/WhiteHouseCEA/status/1257680258364555264

White Hous

Jason Furman @jasonfurman · May 6

This might be the lowest point in the 74 year history of the Council of Economic Advisers. The stakes on the epidemiological questions are so high that this utterly superficial and misleading "modeling" has no place whatsoever in any discussion of the government's response.

CEA @WhiteHouseCEA · May 5

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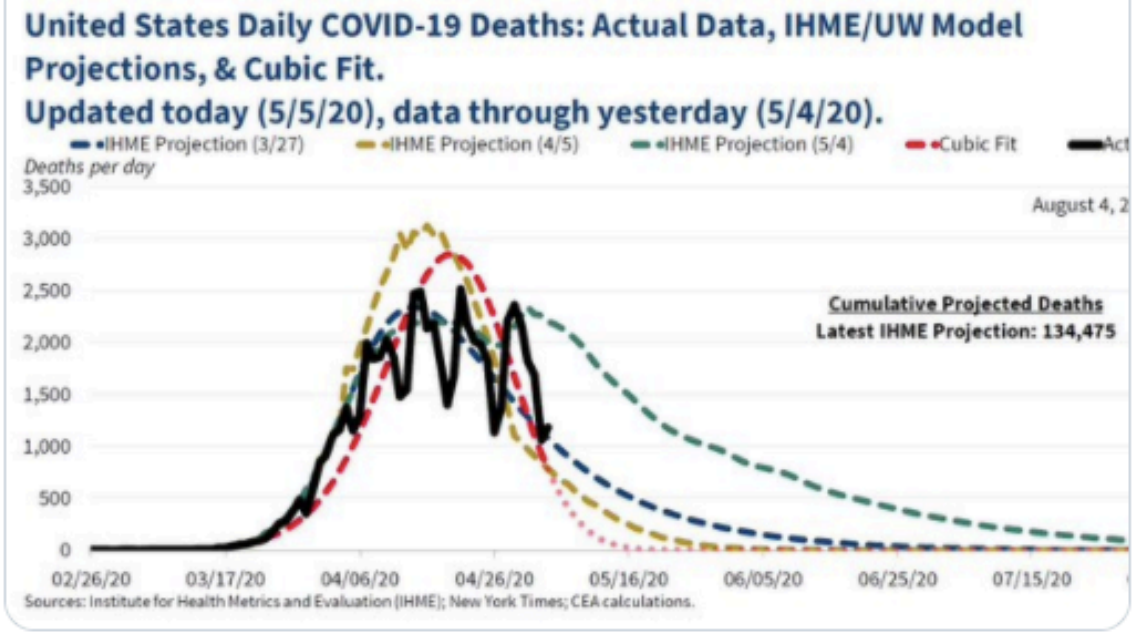
Show this thread

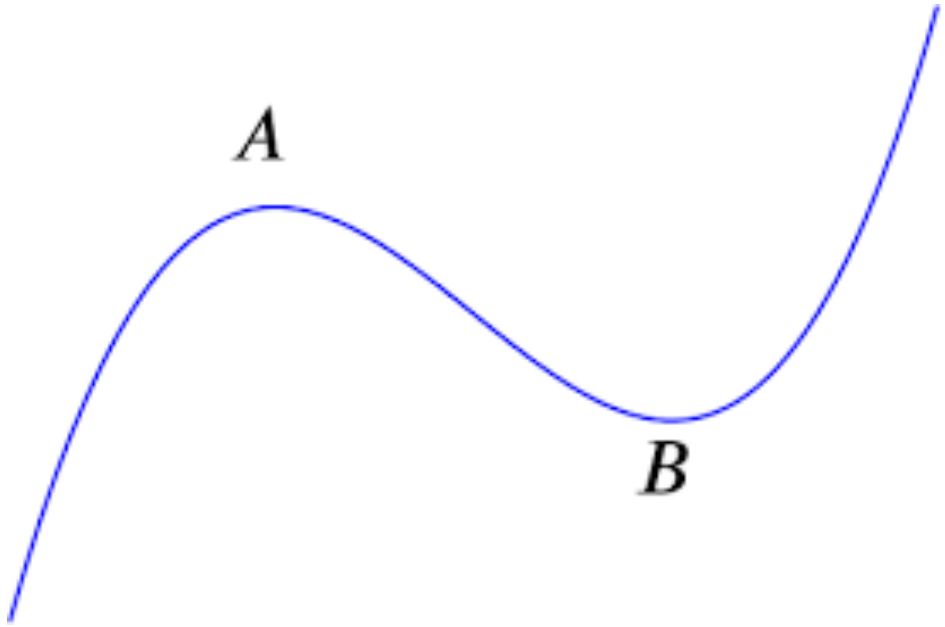


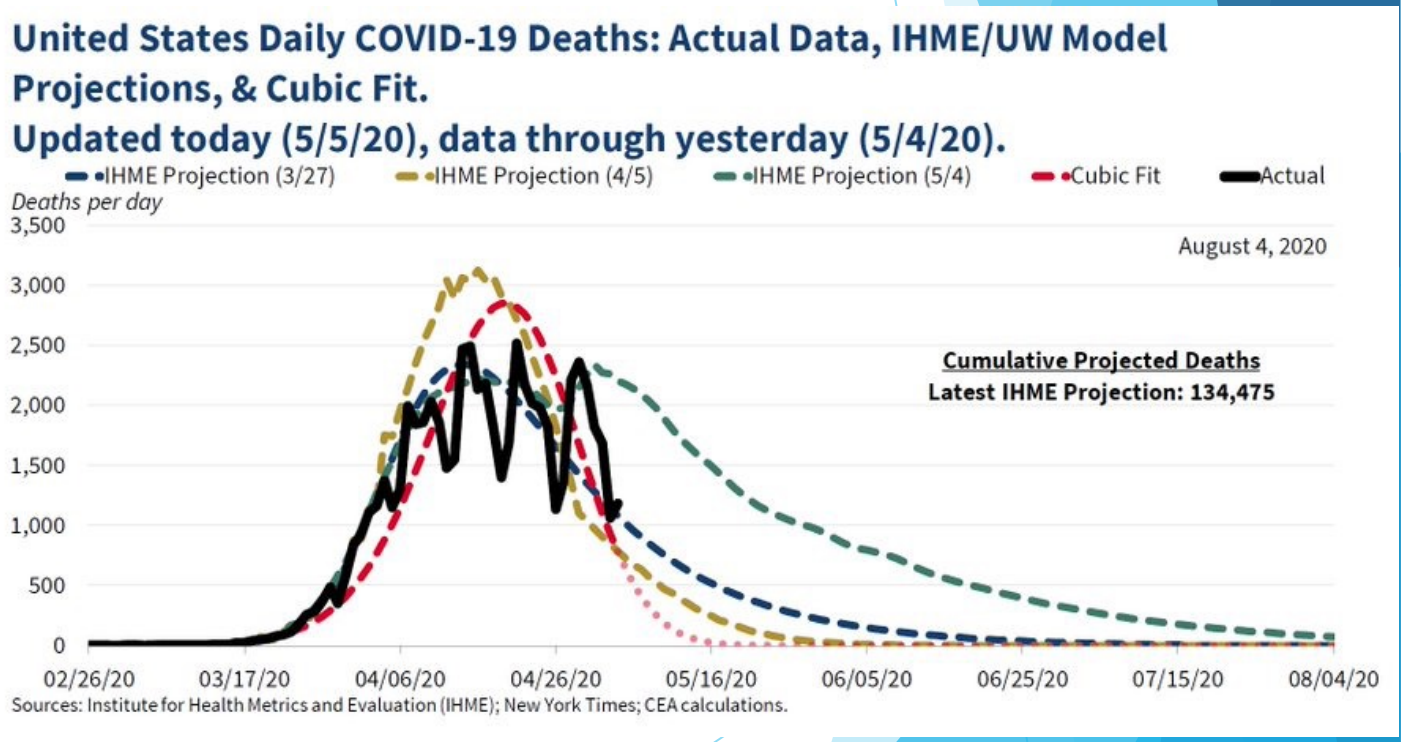
116 1.4K 4K

https://twitter.com/jasonfurman/status/1257707830787915777?lang=en

White House Council of Economic Advisers

- "Cubic fit"
  $y=ax^3+bx^2+cx+d$





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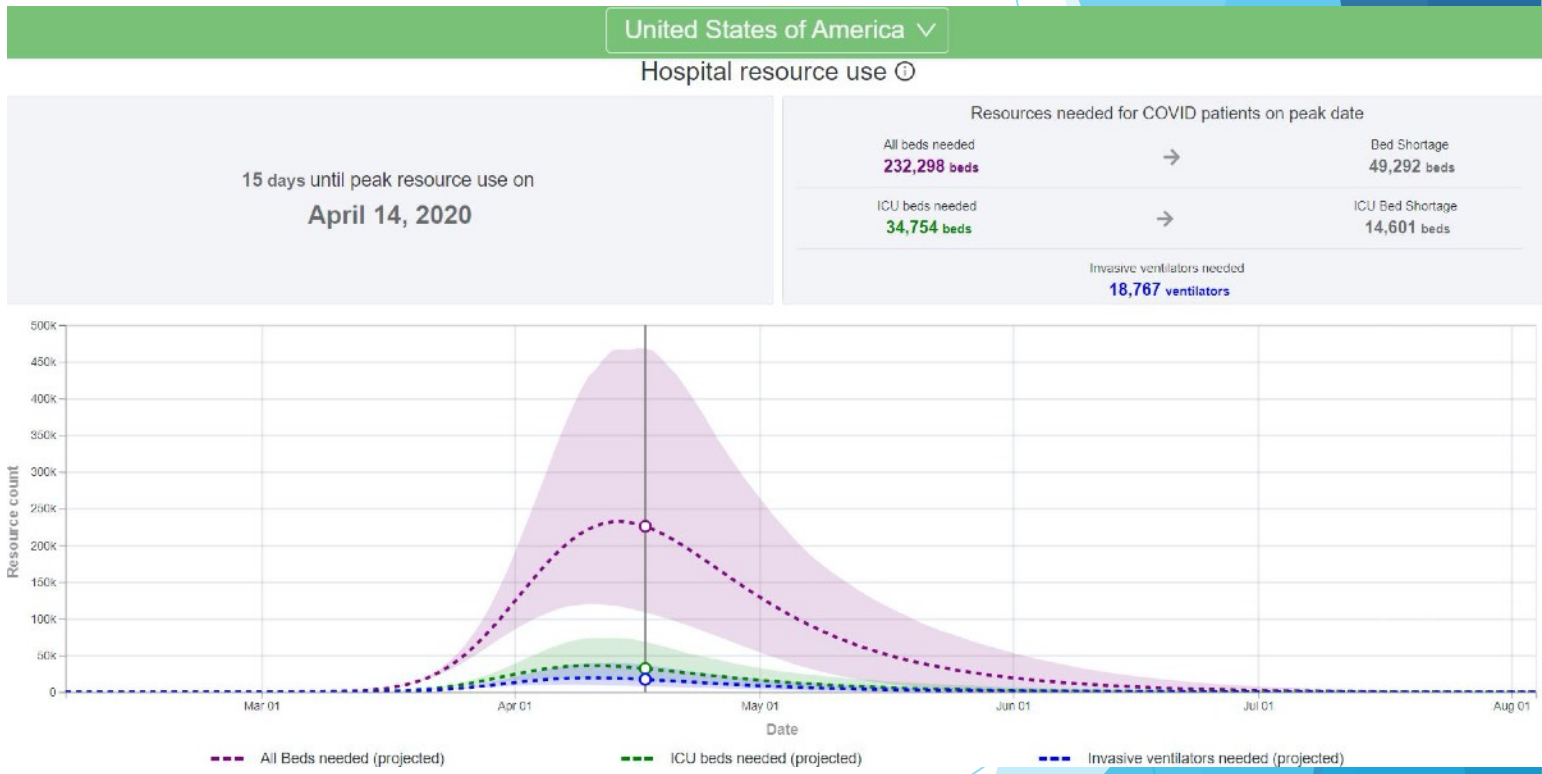
The IHME Model

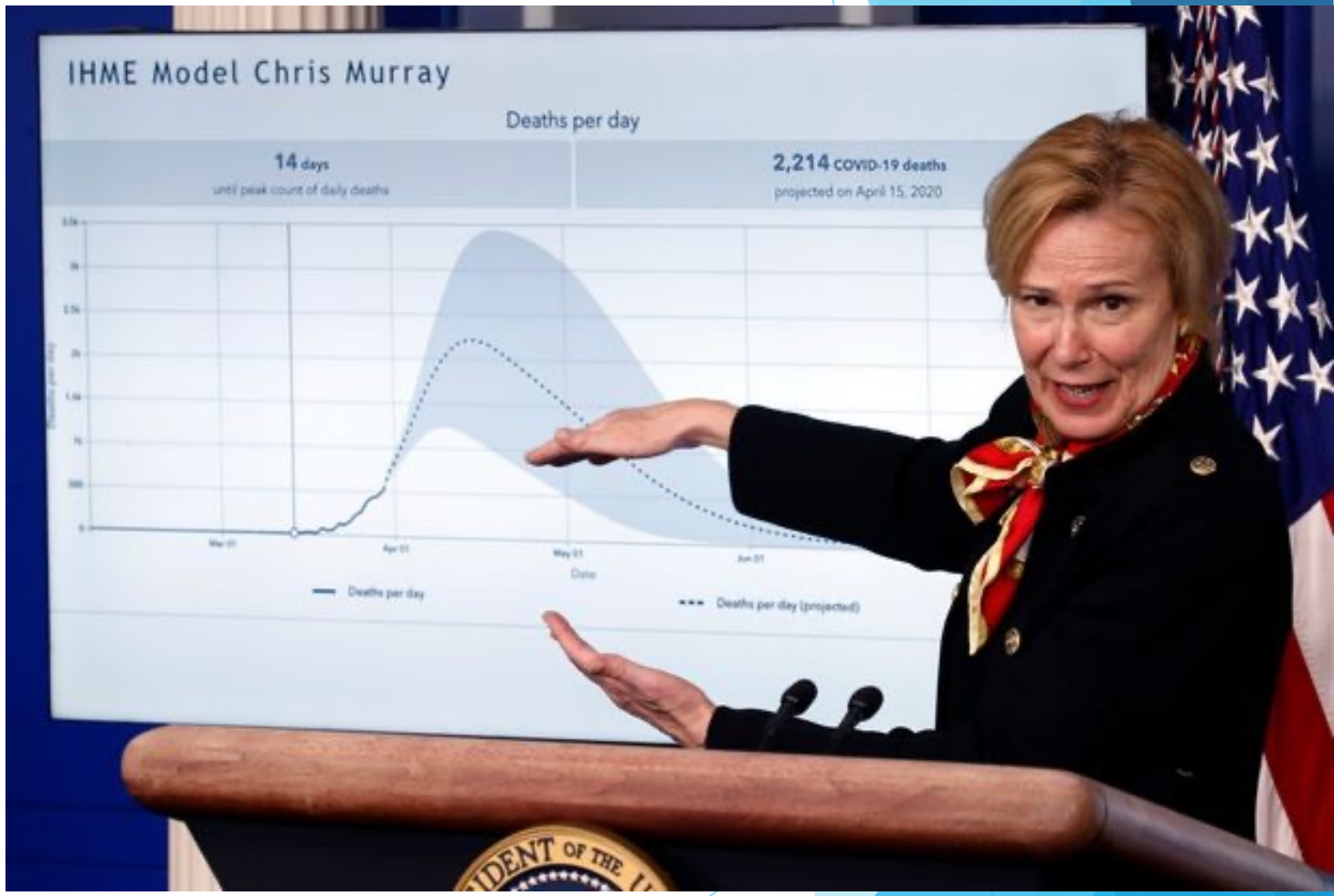
- The Institute for Health Metrics (IHME) is an independent global health research center at the University of Washington
- The IHME model was the main model used in early days of COVID-19
- Has projections by state and country for hospitalizations, ICU bed usage, and fatalities



https://covid19.healthdata.org/

The IHME Model

- Statistical model - early on used the existing death data from China and Italy to predict what would happen in the United States and elsewhere.
- Criticisms about the IHME model
  - Was overly optimistic
  - Continually updated with significant changes to numbers
  - The true number of next day deaths were outside of the 95% prediction intervals 70 percent of the time[1]



1.

[1] https://arxiv.org/abs/2004.04734

Mechanistic Models

"make assumptions about how a system or process works"

https://www.engadget.com/2017/01/01-korea-mech-robot-first-steps.html

What are SIR models?

S
Susceptible

I
Infectious

R
Removed

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

$$\frac{dI}{dt} = \frac{\beta IS}{N} - \frac{I}{T_{inf}}$$

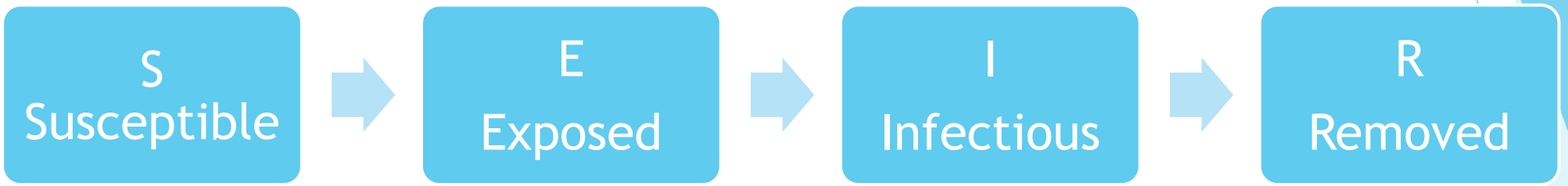
$$\frac{dR}{dt} = \frac{I}{T_{inf}}$$

R_0 (basic reproduction number) - the number of new infections caused by one infected individual in a population where everyone is susceptible

T_{inf} - duration of infectiousness

β (beta) - the rate of infection (number of infections caused over time)

What are SEIR models?



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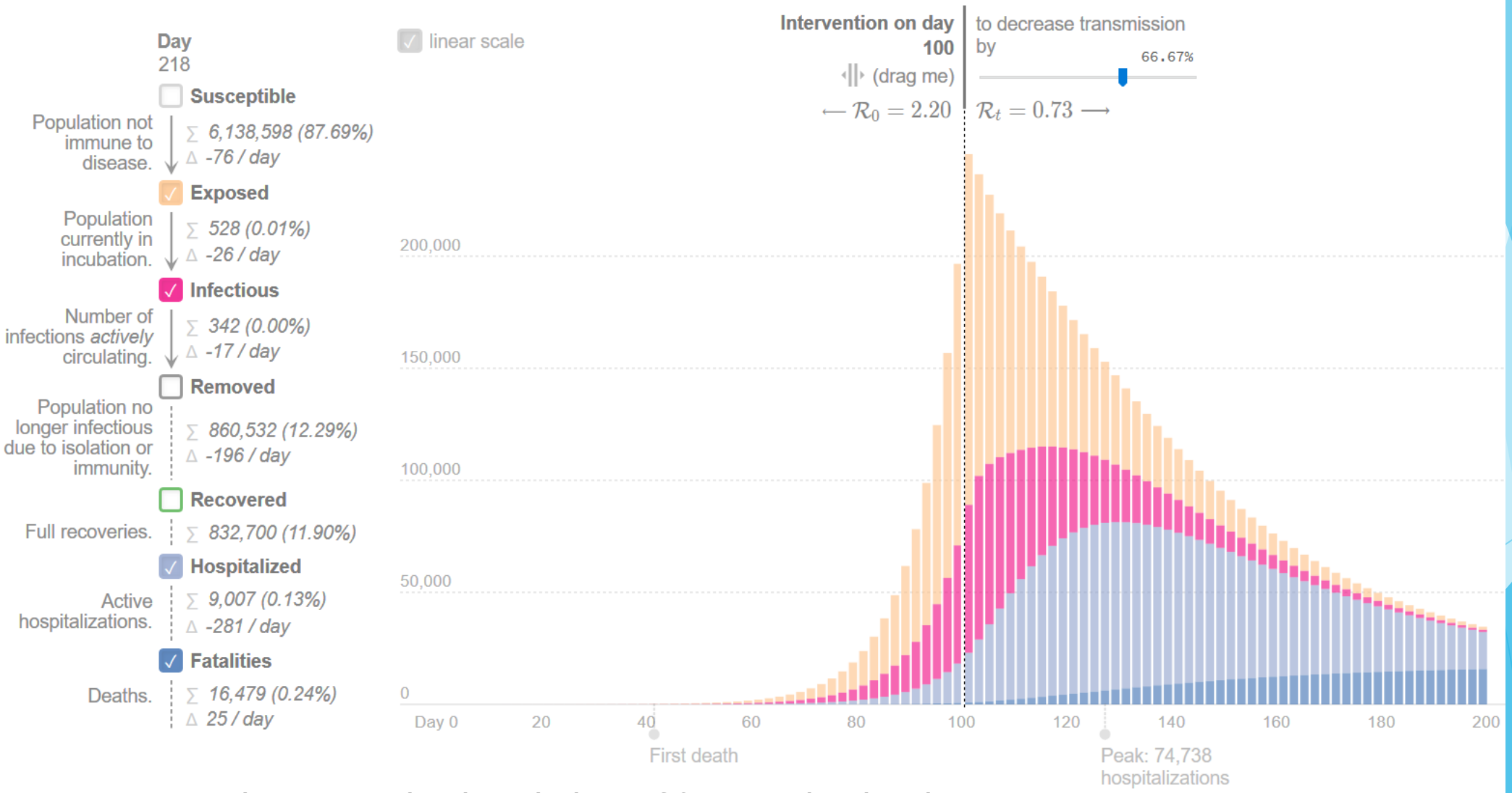
Epidemic Calculator



https://gabgoh.github.io/COVID/index.html

Epidemic Calculator

Transmission Dynamics

Population Inputs

Size of population.

7,000,000

Number of initial infections.

1

Basic Reproduction Number $\mathcal{R}_0$

Measure of contagiousness: the number of secondary infections each infected individual produces.

2.2

Transmission Times

Length of incubation period, T_{inc}.

5.20 days

Duration patient is infectious, T_{inf}.

2.9 Days

Clinical Dynamics

Mortality Statistics

Case fatality rate.

2.00 %

Time from end of incubation to death.

32 Days

Recovery Times

Length of hospital stay

28.6 Days

Recovery time for mild cases

11.1 Days

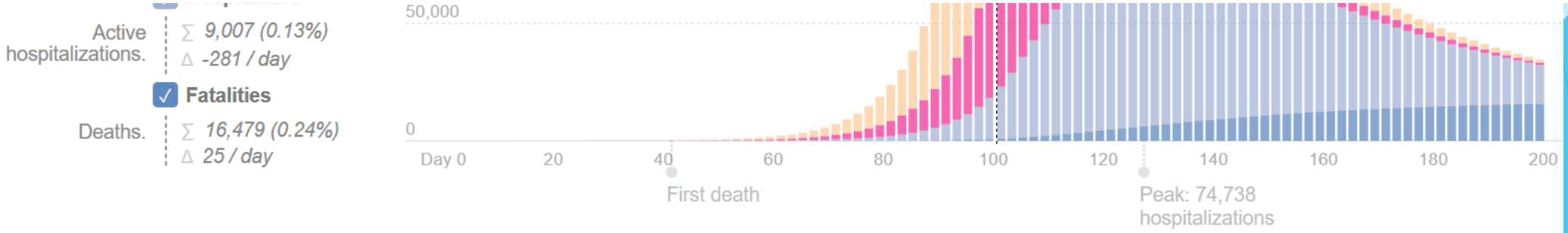
Care statistics

Hospitalization rate.

20.00 %

Time to hospitalization.

5 Days



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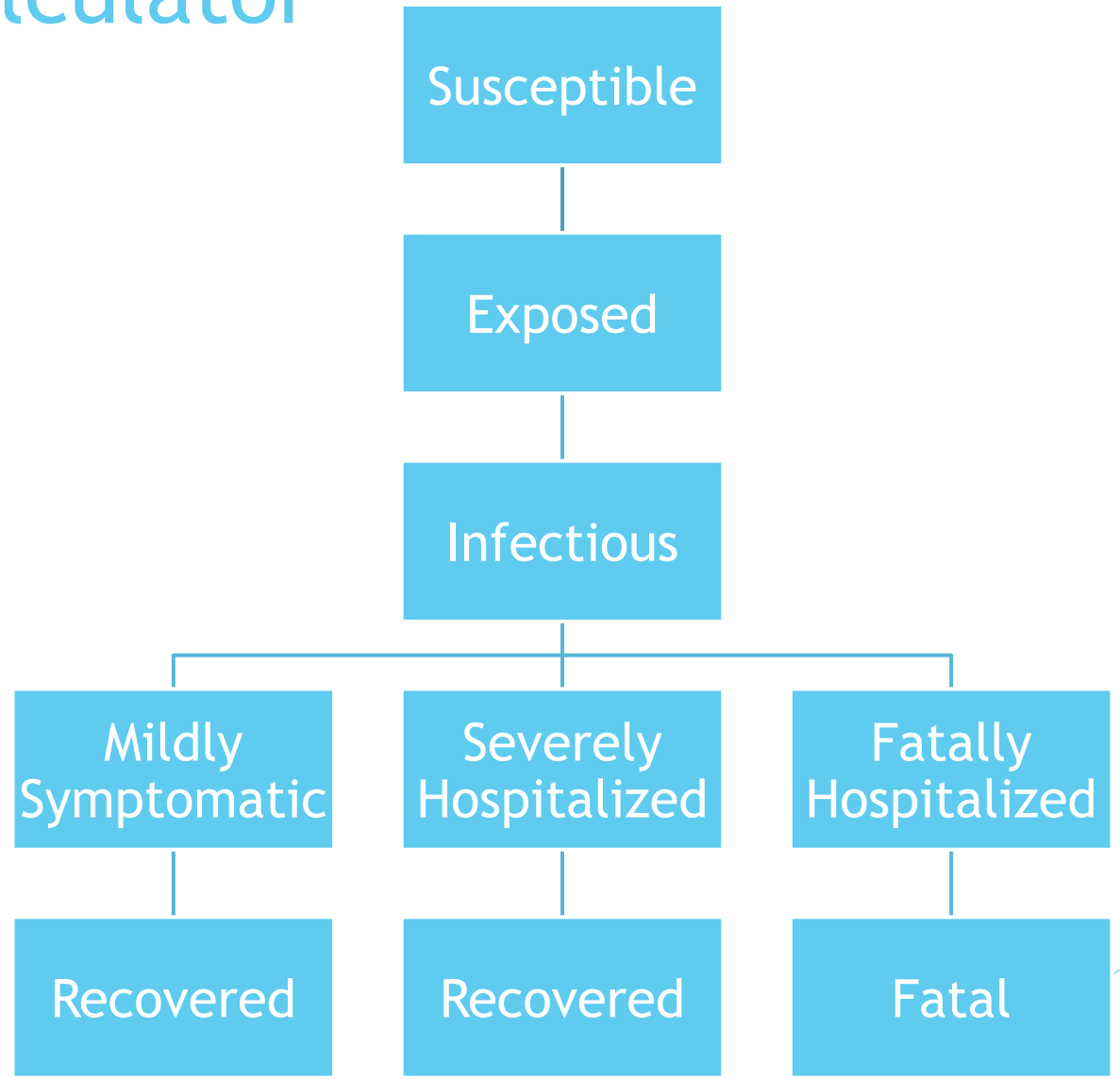

Epidemic Calculator

```
116     var a     = 1/D_incbation
117     var gamma = 1/D_infectious
118
119     var S        = x[0] // Susectable
120     var E        = x[1] // Exposed
121     var I        = x[2] // Infectious
122     var Mild     = x[3] // Recovering (Mild)
123     var Severe   = x[4] // Recovering (Severe at home)
124     var Severe_H = x[5] // Recovering (Severe in hospital)
125     var Fatal    = x[6] // Recovering (Fatal)
126     var R_Mild   = x[7] // Recovered
127     var R_Severe = x[8] // Recovered
128     var R_Fatal  = x[9] // Dead
129
130     var p_severe = P_SEVERE
131     var p_fatal  = CFR
132     var p_mild   = 1 - P_SEVERE - CFR
133
134     var dS        = -beta*I*S
135     var dE        =  beta*I*S - a*E
136     var dI        =  a*E - gamma*I
137     var dMild     =  p_mild*gamma*I   - (1/D_recovery_mild)*Mild
138     var dSevere   =  p_severe*gamma*I - (1/D_hospital_lag)*Severe
139     var dSevere_H =  (1/D_hospital_lag)*Severe - (1/D_recovery_severe)*Severe_H
140     var dFatal    =  p_fatal*gamma*I  - (1/D_death)*Fatal
141     var dR_Mild   =  (1/D_recovery_mild)*Mild
142     var dR_Severe =  (1/D_recovery_severe)*Severe_H
143     var dR_Fatal  =  (1/D_death)*Fatal
144
```

https://github.com/gabgoh/epcalc/blob/master/src/App.svelte

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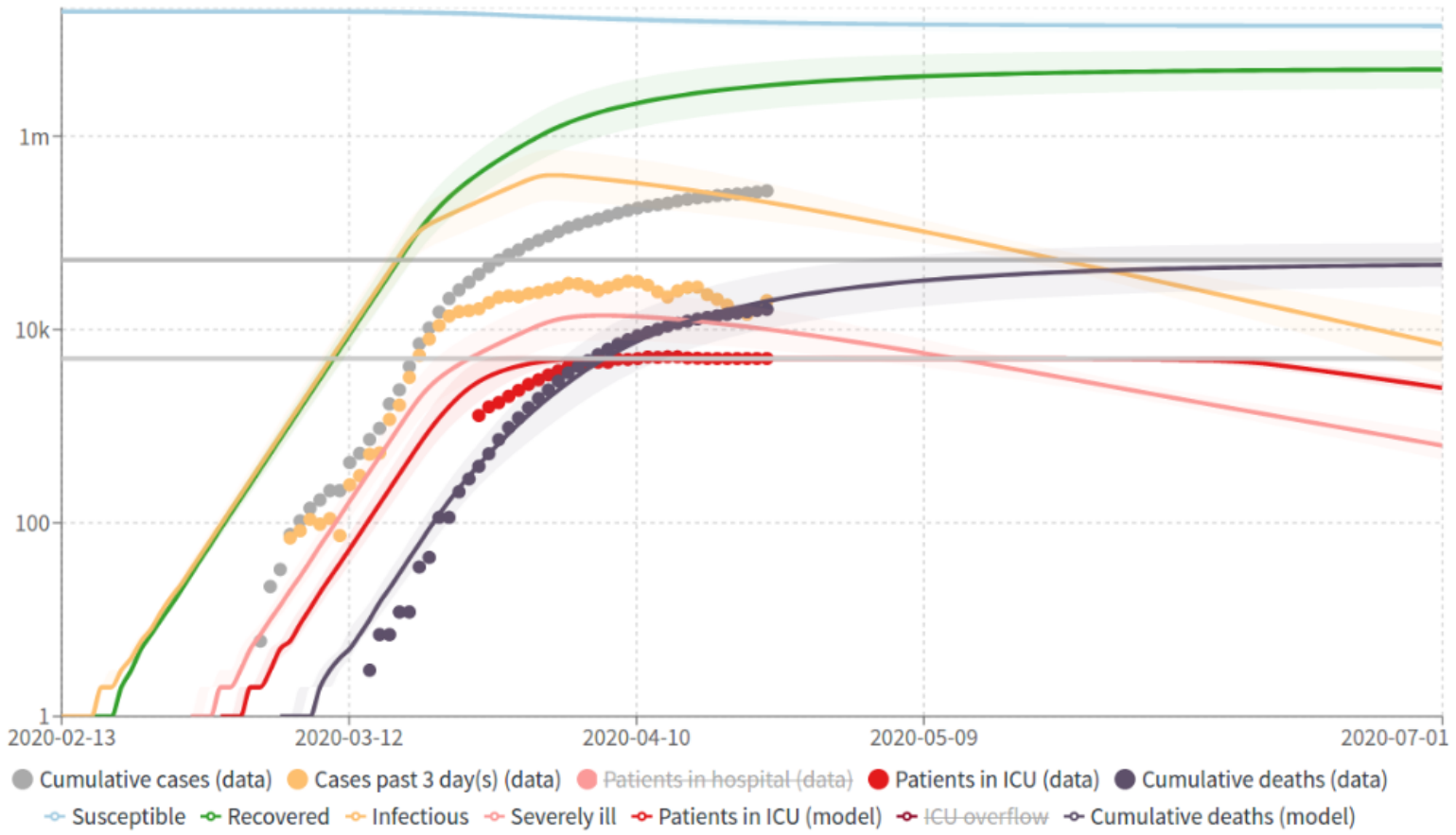
COVID-19 Scenarios Model (University of Basel)



https://covid19-scenarios.org/

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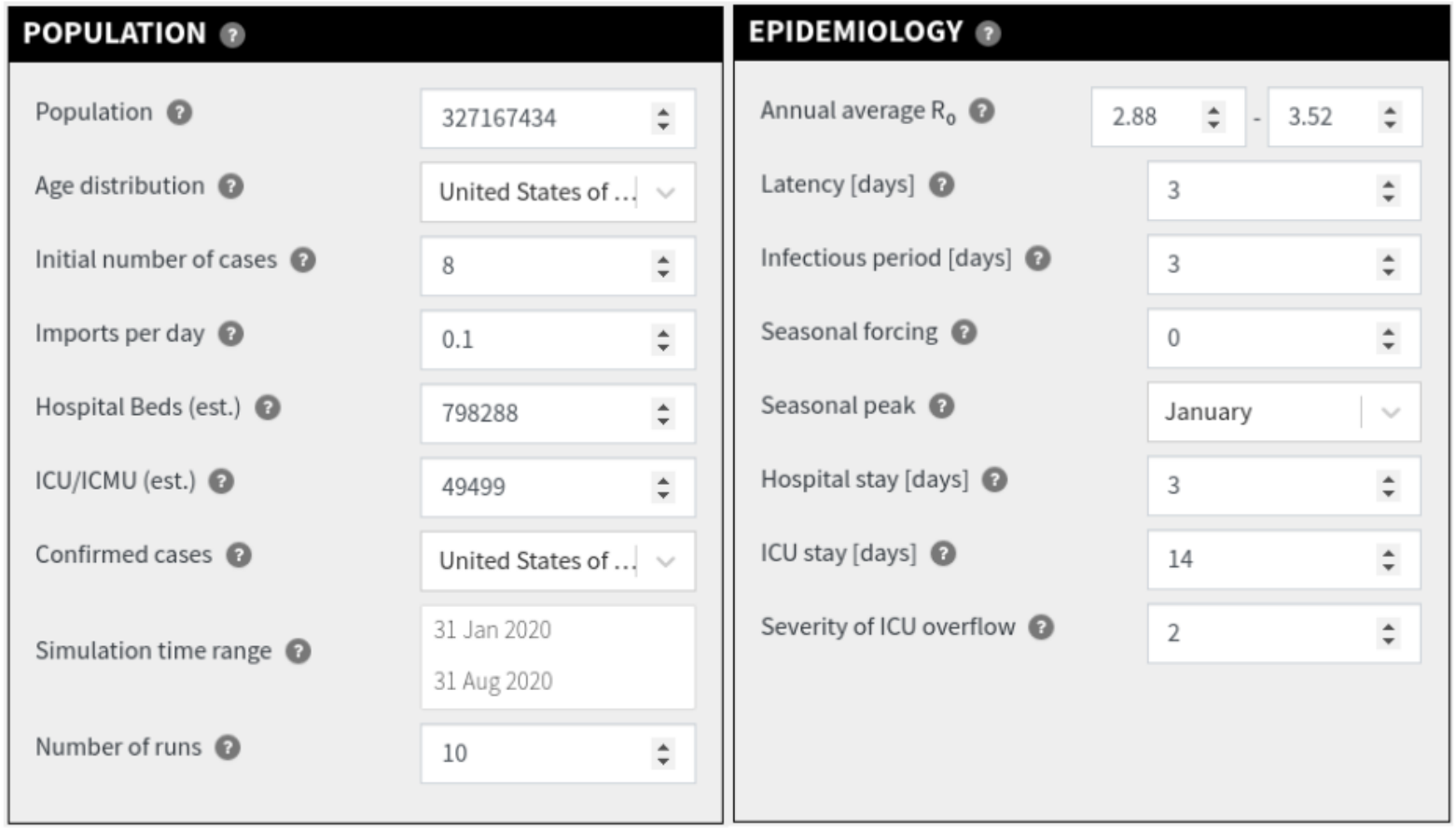

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COVID-19 Scenarios Model (University of Basel)

Age group	Age distribution	Confirmed % total	Severe % of confirmed	Critical % of severe	Fatal % of critical	Fatal % of all infections	Isolated % total
0-9	884945	5	1	5	30	0.00075	0
10-19	834866	5	3	10	30	0.0045	0
20-29	1039727	10	3	10	30	0.009	0
30-39	1219227	15	3	15	30	0.02	0
40-49	1166590	20	6	20	30	0.072	0
50-59	1320623	25	10	25	40	0.25	0
60-69	977436	30	25	35	40	1.1	0
70-79	751994	40	35	45	50	3.1	0
80+	459214	50	50	55	50	6.9	0

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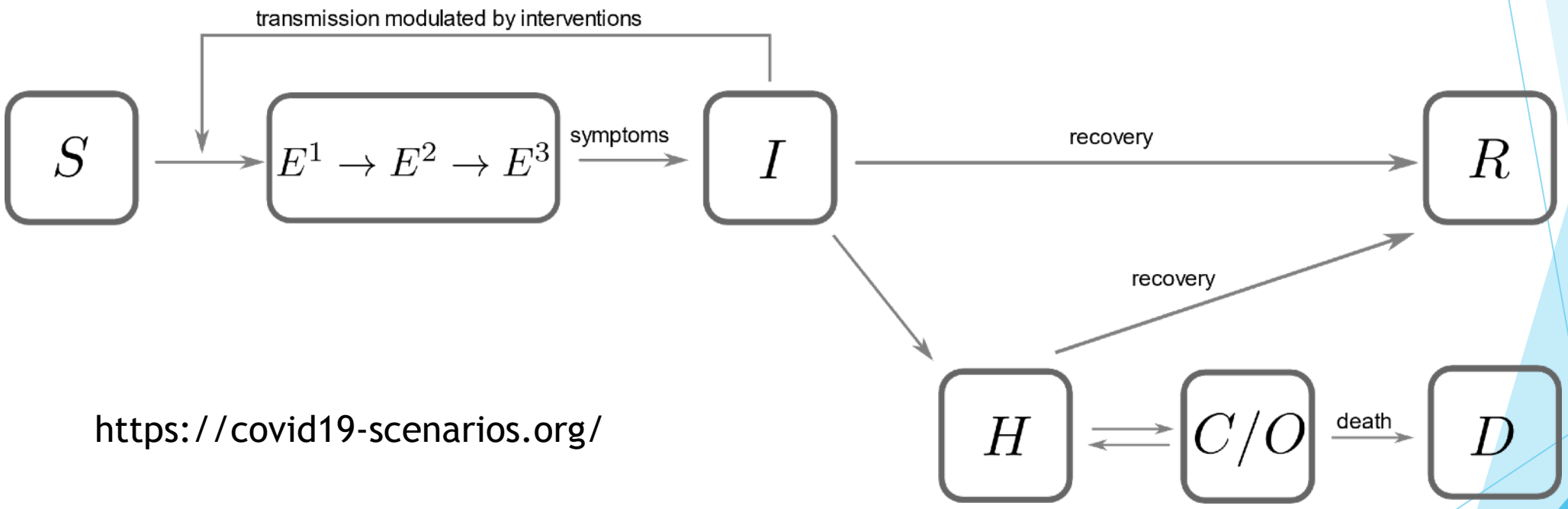

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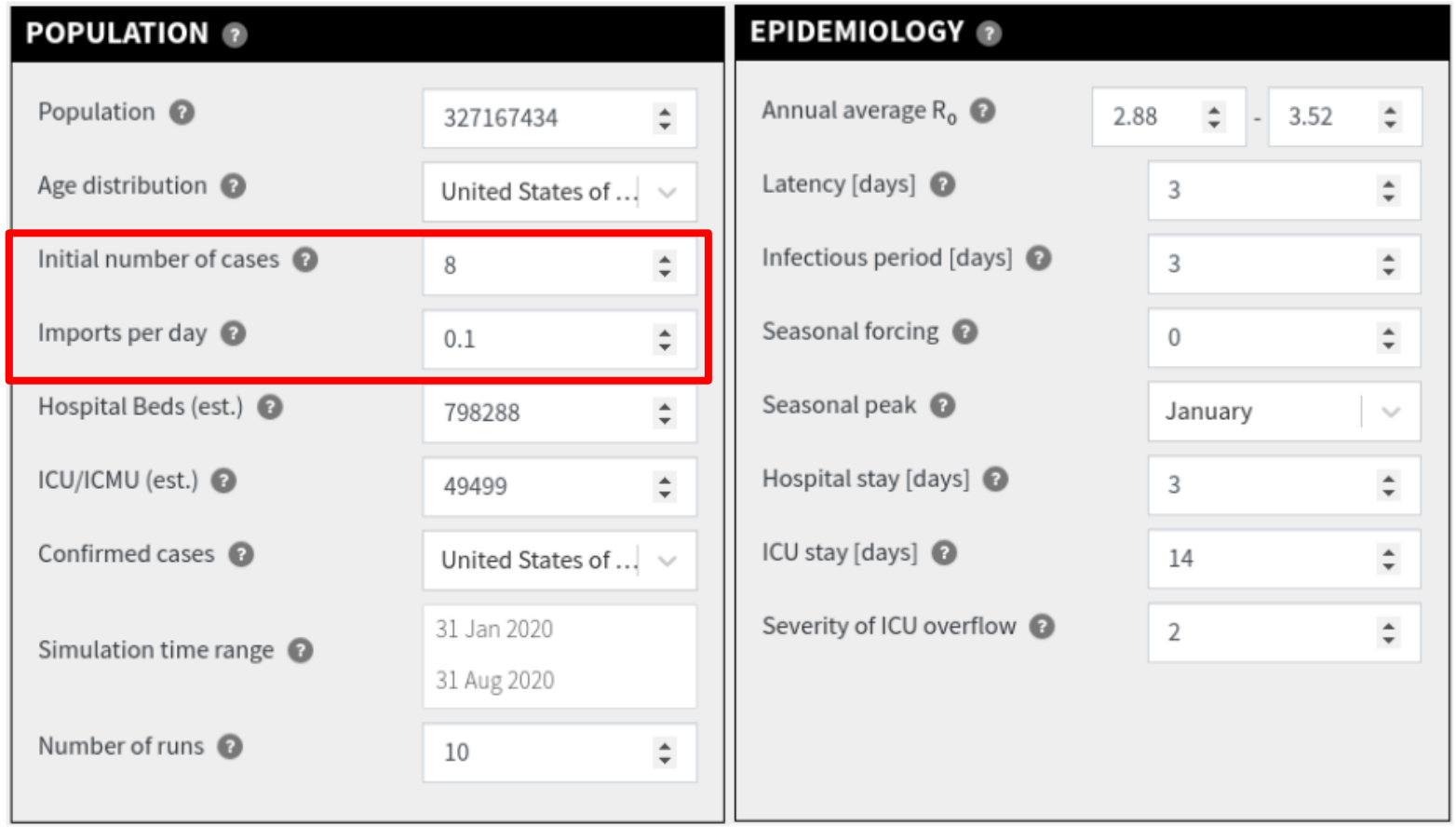

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COVID-19 Scenarios Model (University of Basel)

- How does the model implement initial number of cases?
- Looking at the source code ->

```
// specification of the initial condition: there are numCases at tMin
// of those, 0.3 are infectious, the remainder is exposed and will turn
// infectious as they propagate through the exposed categories.
const initialInfectiousFraction = 0.3

ageDistribution.forEach(({ population }, i) => {
  const n = Math.round((population / Z) * N)
  pop.current.susceptible[i] = n
  pop.current.exposed[i] = [0, 0, 0]
  pop.current.infectious[i] = 0
  pop.current.severe[i] = 0
  pop.current.critical[i] = 0
  pop.current.overflow[i] = 0
  pop.cumulative.hospitalized[i] = 0
  pop.cumulative.recovered[i] = 0
  pop.cumulative.critical[i] = 0
  pop.cumulative.fatality[i] = 0

  if (i === Math.round(ageDistribution.length / 2)) {
    pop.current.susceptible[i] -= numCases
    pop.current.infectious[i] = initialInfectiousFraction * numCases
    const e = ((1 - initialInfectiousFraction) * numCases) / pop.current.exposed[i].length
    pop.current.exposed[i] = pop.current.exposed[i].map((_) => e)
  }
})
```

https://github.com/neherlab/covid19_scenarios/blob/master/src/algorithms/initialize.ts

COVID-19 Scenarios Model (University of Basel)

- How does the model implement imported cases per day?
- Looking at the source code ->

```
// Compute all fluxes (apart from overflow states) barring no hospital bed constraints
const fracInfected = sum(pop.current.infectious) / P.populationServed

for (let age = 0; age < pop.current.infectious.length; age++) {
  // Initialize all multi-faceted states with internal arrays
  flux.exposed[age] = Array(pop.current.exposed[age].length)

  // Susceptible -> Exposed
  flux.susceptible[age] =
    P.importsPerDay[age] +
    (1 - P.frac.isolated[age]) * P.rate.infection(time) * pop.current.susceptible[age] * fracInfected

  // Exposed -> Internal -> Infectious
  pop.current.exposed[age].forEach((exposed, i, exposedArray) => {
    flux.exposed[age][i] = P.rate.latency * exposed * exposedArray.length
  })

  // Infectious -> Recovered/Critical
  flux.infectious.recovered[age] = pop.current.infectious[age] * P.rate.recovery[age]
  flux.infectious.severe[age] = pop.current.infectious[age] * P.rate.severe[age]
```

https://github.com/neherlab/covid19_scenarios/blob/master/src/algorithms/model.ts

Thank you! Any questions?