AG OFFICE HOURS OUTDOORS THIS FRIDAY—COME TO HARVARD YARD IF YOU CAN (ZOOM TOO)

ALSO, OUR LAST TWO CLASSES WILL LIKELY OFFER AN IN-PERSON OPTION IN HARVARD HALL 202

Prediction: Week 7

quick review of outdoor **Navigation Exercise**

1 year ago

Coming up: Linz (3/23); Radcliffe AI/Health (4/1); your final projects…

"Prediction vs. Prophecy"

John Snow & Cholera (edX highlights & more)

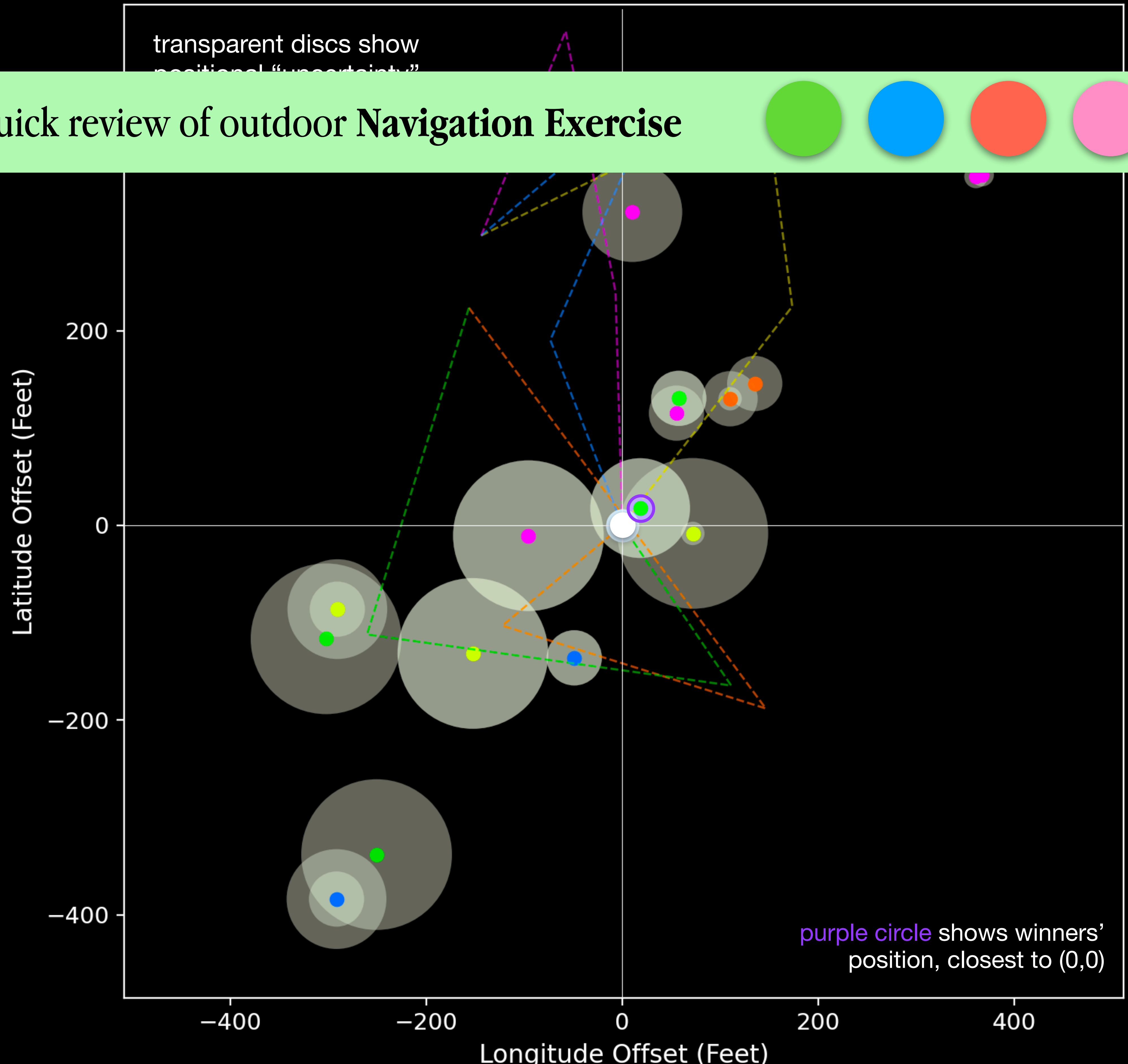
Modeling *the spread of epidemics, and* ***uncertainty***

Bookkeeping **SIR Models** **SEIR Models** **Agent-based models** **Data-driven models**

Prediction and decision in the face of **uncertainty**: COVID-19 and Harvard (discussions)

Thursday & in section: COVID-19 student readings discussion (see Canvas Tuesday eve)

Special Guest for Thursday's discussions: geneticist/epidemiologist **Dr. Immaculata DeVivo,** Professor at Harvard' T.H. Chan School of Public Health and at Harvard Medical School quick review of outdoor **Navigation Exercise**



The Coronavirus Outbreak | Latest Updates | Maps | How to Prepare | Market Updates | Newsletter

LIVE UPDATES Updated 11 minutes ago

Coronavirus Live Updates: W.H.O. Declares Pandemic as Number of

1 year ago

Chancellor Angela Merkel foresees two-thirds of Germans being infected. The U.S., with more than 1,000 cases and business disruptions, weighs possible responses.

RIGHT NOW "All countries can still change the course of this pandemic," said the W.H.O.'s leader, Dr. Tedros Adhanom Ghebreyesus, adding, "We need each other."

新冠病毒疫情最新消息

Here's what you need to know:

- This is a global pandemic, the W.H.O. says.
- "It is going to get worse," a leading American scientist says.
- Governments step up fiscal interventions as the virus threatens economies.
- Germany warns that the worst is yet to come.
- Stocks drop again, as investors wait for Trump to act.
- As virus races across Europe, nations step up restrictions.
- Delays in testing set back the U.S. coronavirus response.

Coronavirus "Pandemic"

NYT web clipping as of March 11, 2020 12:42 PM

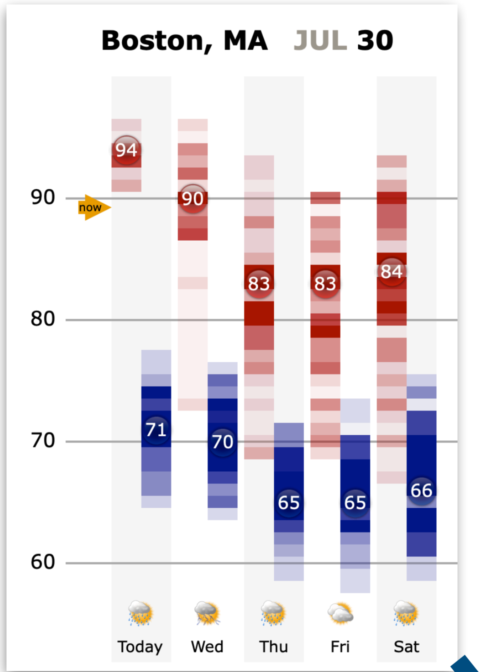
www.nytimes.com/2020/03/11/world/coronavirus-news.html#link-1452bb3f

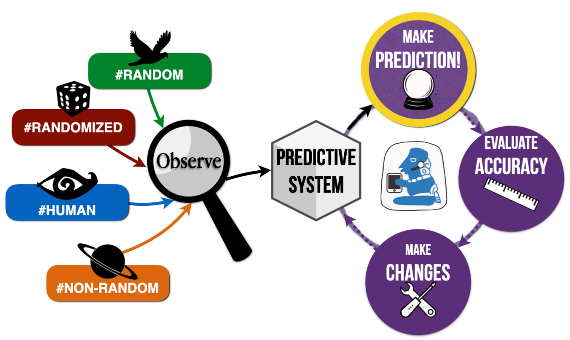
“Prediction vs. Prophecy”

"When Knowledge Conquered Fear"

"When Knowledge Conquered Fear" is the third episode of the American documentary television series Cosmos: A Spacetime Odyssey. It premiered on March 23, 2014 on Fox, and premiered on March 24, 2014 on National Geographic Channel. [Wikipedia]. IMDB link

Take-a-Sweater

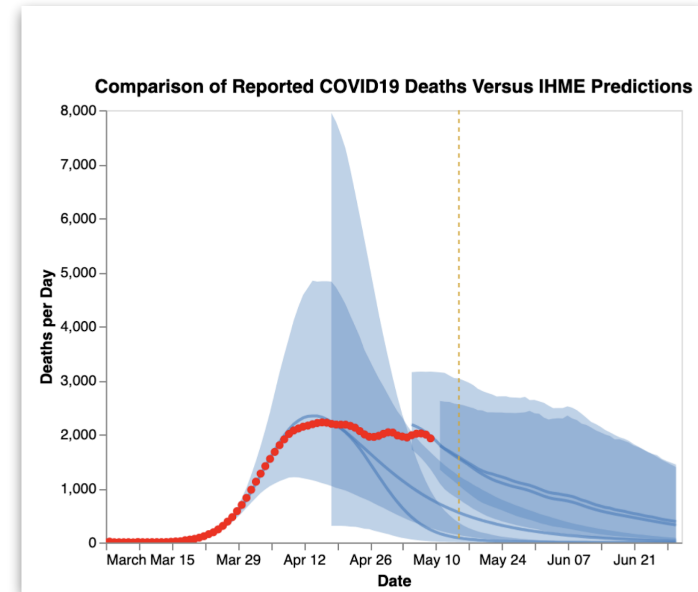




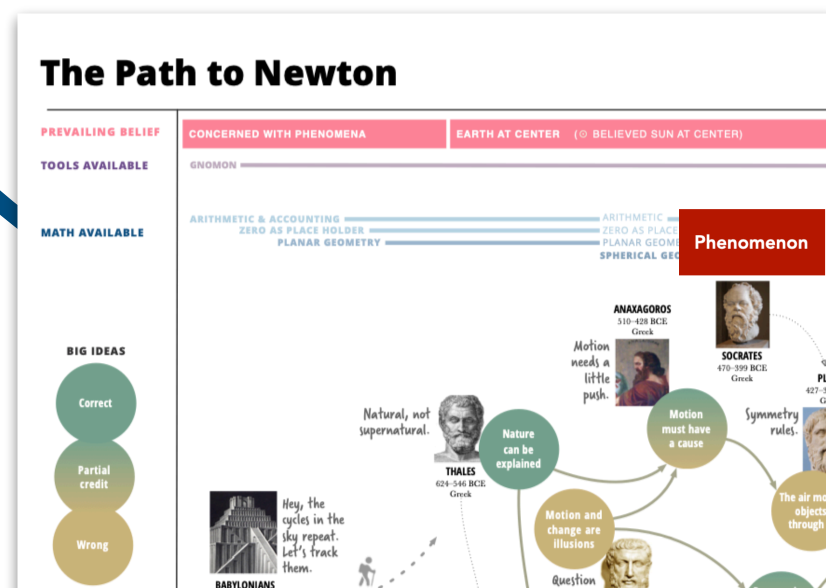
PredictionX

predictionx.org

IHME COVID-19



The Path to Newton

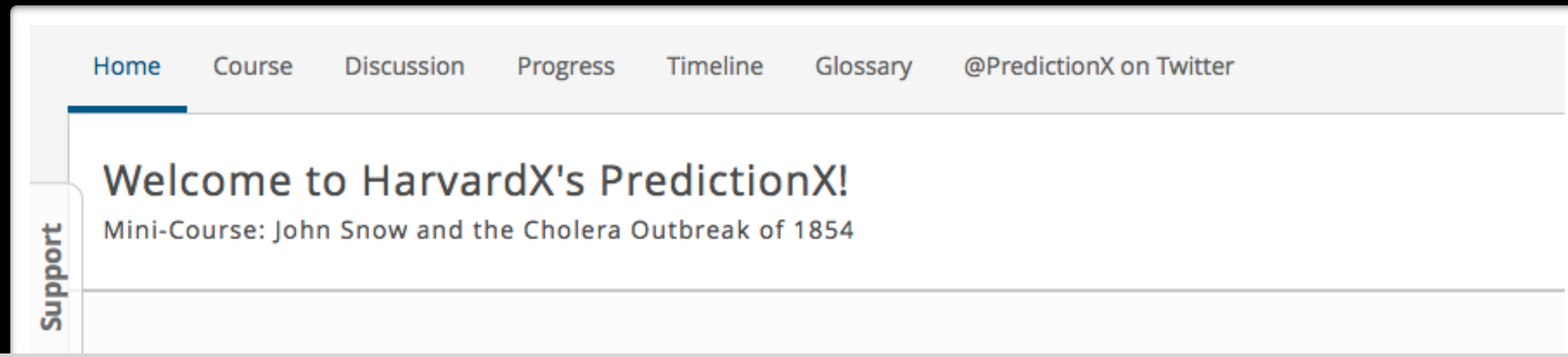


Phenomenon	Observation*	Data	Rule	Theory	Explanation	Prediction

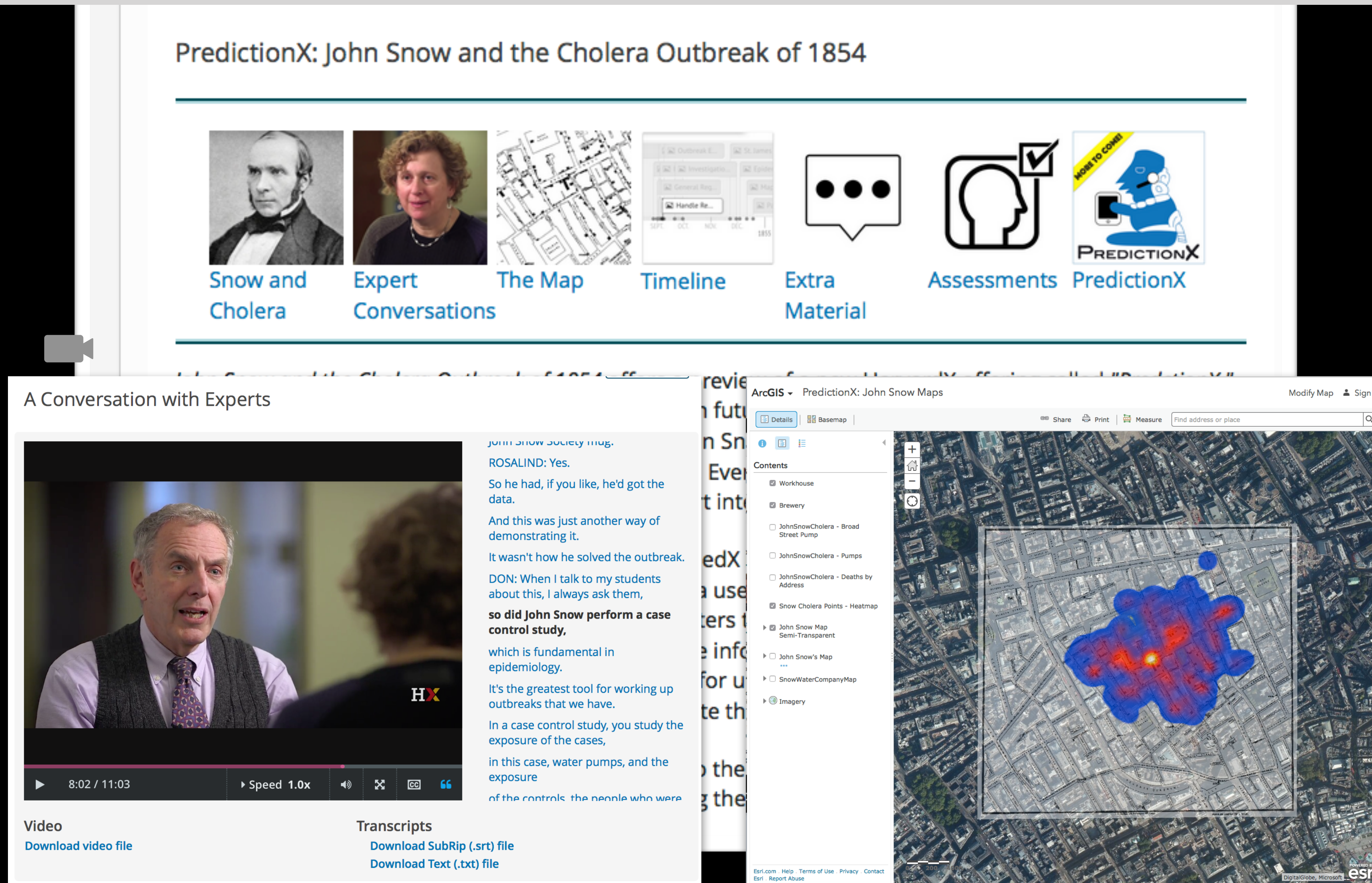
takeasweater.com

path-to.org

gluesolutions.io/social-impact



John Snow & Cholera (edX highlights & more)



featuring Don Goldmann, AG & Rosalind Stanwell-Smith

John Snow & Cholera (edX highlights & more)

Key facts to remember

1. Water-borne nature of cholera was a new idea in 1854 (and earlier)
2. Miasma (bad air) was prevailing theory
3. Very hard, for John Snow, to convince people of his water-borne theory
4. Germ theory of disease not fully accepted until c. 1880s
5. Crowding in London made for the dangerous sanitary conditions that fostered spread
6. Not clear how much of an effect the “drastic” act of removal of the pump handle had
7. Exceptions to the pattern proved key (brewery, workhouse, Ely family in Hampstead)
8. Drastic change (to sanitary systems, and treatment of cholera) followed, eventually
9. “Epidemiology” as a discipline, was essentially born from Snow’s work
10. Snow’s was not a “case-controlled study.”

Study Design

DATA COLLECTION

Before, **During** or **After**
before (e.g. measure planet positions to predict orbits), *during* (measure shaking in an earthquake), *after* (interview lung cancer victims)

Active vs. Passive
active (e.g. by survey), or *passive* (e.g. by GPS sensor)

Study vs. Ad-Hoc
pre-designed study (e.g. Framingham Nurses' Study) vs. *ad-hoc* (e.g. mining patient medical records)

Before | *During* | *After* | *Active* | *Passive* | *Study* | *Ad-hoc*

Comparative | *Time-track* | *Hypothesis* | *Empirical* | *Description* | *Prediction: Probabilistic* | *Prediction: Deterministic*

STUDY DESIGN

Comparative
Case-control, drug treatment vs. non-drug; Ptolemy vs. Copernicus(?)

Time-tracking
Cohort study, Halley's Comet

Hypothesis vs. Empirical
e.g. cholera is in water vs. what could be making people sick with cholera?

GOAL

Description
Reduce complexity of data collected (e.g. represent data with a fitted function)

Prediction: Probabilistic
Inherently random (e.g. sports outcomes) or with randomness caused by reducible uncertainty (e..g climate change)

Prediction: Deterministic Theory
using a tested, predictive, theory that agrees with observation to within measurement error (e.g. gravity)

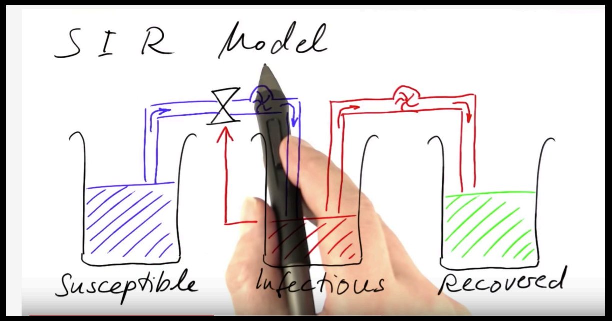
John Snow & Cholera (maps)

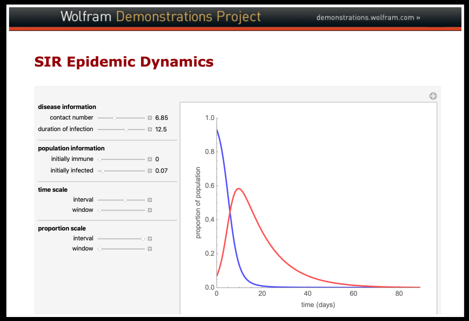
*Modeling the spread of epidemics, and **uncertainty***

Bookkeeping **SIR Models** **SEIR Models** **Agent-based models** **Data-driven models**

Bookkeeping — **e.g. (#infected) x (%fatal (age group, region))=probability of death**

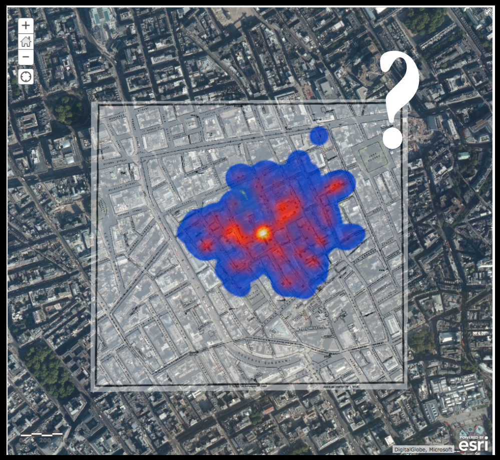
SIR Models (Susceptible-Infected-Removed)





SEIR Models — **like SIR, but allowing for "Exposed" uninfected group**

Agent-based models — **account for spatial & behavioral factors…**



Data-driven models — **e.g. Blue Dot prediction**

Info from these links: "Modern Predictive Systems", OneNote collection (available via Canvas)

Bookkeeping for COVID-19: consider a x b x d

a:Probability of exposure = high
b: Probability of any symptoms = medium
c: also consider probability of diagnosis at all = medium/high
d: Probability of "death," see below

a: 0.7 (70%)
b: 0.2 (20%)
c: 0.7 (70%)
d: 0.002 (0.2%)
a x b x d =0.03%

from March 11, 2020

Age of Coronavirus Deaths

COVID-19 Fatality Rate by AGE:

***Death Rat**e = (number of deaths / number of cases) = **probability of dying if infected by the virus** (%). This probability differs depending on the age group. The percentages shown below **do not have to add up to 100%**, as they **do NOT represent share of deaths by age** group. Rather, it represents, for a person in a given age group, the **risk of dying** if infected with COVID-19.

AGE	DEATH RATE confirmed cases	DEATH RATE all cases
80+ years old	**21.9%**	**14.8%**
70-79 years old		**8.0%**
60-69 years old		**3.6%**
50-59 years old		**1.3%**
40-49 years old		**0.4%**
30-39 years old		**0.2%**
20-29 years old		**0.2%**
10-19 years old		**0.2%**
0-9 years old		**no fatalities**

Pre-existing medical conditions (comorbidities)

Patients who reported no pre-existing ("comorbid") medical conditions had a case fatality rate of 0.9%. Pre-existing illnesses that put patients at higher risk of dying from a COVID-19 infection are:

COVID-19 Fatality Rate by COMORBIDITY:

***Death Rat**e = (number of deaths / number of cases) = **probability of dying if infected by the virus** (%). This probability differs depending on pre-existing condition. The percentage shown below does **NOT represent in any way the share of deaths by pre-existing condition**. Rather, it represents, for a patient with a given pre-existing condition, the **risk of dying** if infected by COVID-19.

PRE-EXISTING CONDITION	DEATH RATE confirmed cases	DEATH RATE all cases
Cardiovascular disease	**13.2%**	**10.5%**
Diabetes	**9.2%**	**7.3%**
Chronic respiratory disease	**8.0%**	**6.3%**
Hypertension	**8.4%**	**6.0%**
Cancer	**7.6%**	**5.6%**
no pre-existing conditions		**0.9%**

***Death Rate** = (number of deaths / number of cases) = **probability of dying if infected by the virus** (%). The percentages **do not have to add up to 100%**, as they **do NOT represent share of deaths by condition.**

https://www.worldometers.info/coronavirus/coronavirus-age-sex-demographics/

Modeling the spread of epidemics, and UNCERTAINTY

Notes On $\mathcal{R}_0$

James Holland Jones *
Department of Anthropological Sciences
Stanford University

May 1, 2007

1 The Basic Reproduction Number in a Nutshell

The basic reproduction number, $\mathcal{R}_0$, is defined as the expected number of secondary cases produced by a single (typical) infection in a completely susceptible population. It is important to note that $\mathcal{R}_0$ is a dimensionless number and not a rate, which would have units of time^{-1}. Some authors incorrectly call $\mathcal{R}_0$ the "basic reproductive rate."

We can use the fact that $\mathcal{R}_0$ is a dimensionless number to help us in calculating it.

$$\mathcal{R}_0 \propto \left(\frac{\text{infection}}{\text{contact}}\right) \cdot \left(\frac{\text{contact}}{\text{time}}\right) \cdot \left(\frac{\text{time}}{\text{infection}}\right)$$

More specifically:

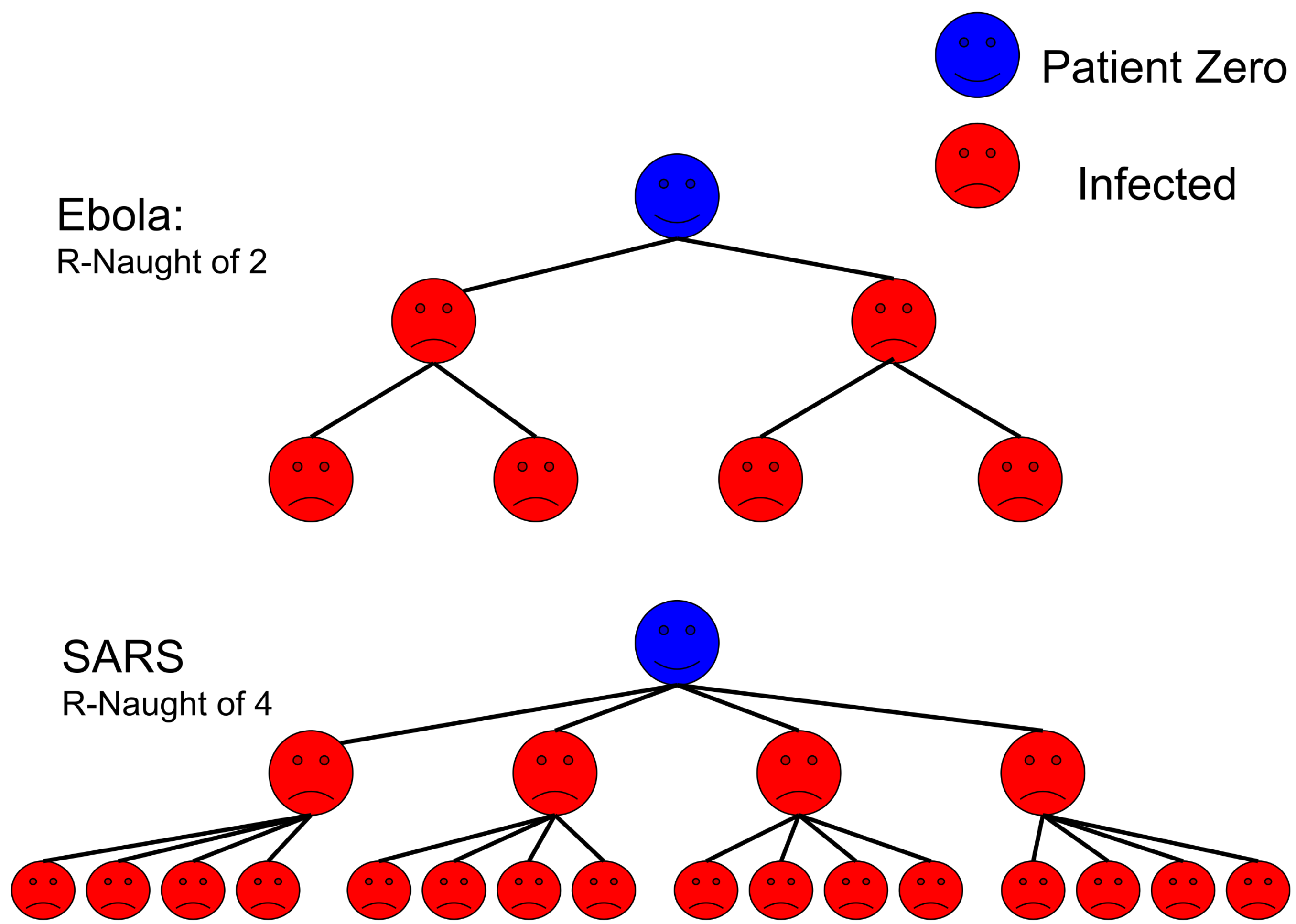
$$\mathcal{R}_0 = \tau \cdot \bar{c} \cdot d \tag{1}$$

where τ is the transmissibility (i.e., probability of infection given contact between a susceptible and infected individual), $\bar{c}$ is the average rate of contact between susceptible and infected individuals, and d is the duration of infectiousness.

Notes on R_0 (OneNote) Notes on R_0 (Original source)

The meaning of R_0

"expected number of cases directly generated by one case in a population where all individuals are susceptible to infection"



Values of R_0 of well-known infectious diseases[1]

Disease	Transmission	R_0
Measles	Airborne	12–18
Diphtheria	Saliva	6–7
Smallpox	Airborne droplet	5–7
Polio	Fecal–oral route	5–7
Rubella	Airborne droplet	5–7
Mumps	Airborne droplet	4–7
Pertussis	Airborne droplet	5.5[2]
HIV/AIDS	Sexual contact	2–5
SARS	Airborne droplet	2–5[3]
COVID-19	Airborne droplet	1.4-3.9[4][5][6][7]
Influenza (1918 pandemic strain)	Airborne droplet	2–3[8]
Ebola (2014 Ebola outbreak)	Body fluids	1.5–2.5[9]
MERS	Airborne droplet	0.3-0.8[10]

https://en.wikipedia.org/wiki/Basic_reproduction_number

What is for R_0 COVID-19: It's *still* uncertain

The NEW ENGLAND JOURNAL of MEDICINE

SUBSCRIBE OR RENEW

EDITORIAL
Triumph and Tragedy of 21st Century Tuberculosis Drug Development

Notable Articles of 2019
1 exclusive collection

ORIGINAL ARTICLE
First Case of 2019 Novel Coronavirus in the United States

ORIGINAL ARTICLE

Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus–Infected Pneumonia

Qun Li, M.Med., Xuhua Guan, Ph.D., Peng Wu, Ph.D., Xiaoye Wang, M.P.H., Lei Zhou, M.Med., Yeqing Tong, Ph.D., Ruiqi Ren, M.Med., Kathy S.M. Leung, Ph.D., Eric H.Y. Lau, Ph.D., Jessica Y. Wong, Ph.D., Xuesen Xing, Ph.D., Nijuan Xiang, M.Med., et al.

January 29, 2020
DOI: 10.1056/NEJMoa2001316
Chinese Translation 中文翻译

Article Figures/Media

Metrics

https://www.nejm.org/doi/10.1056/NEJMoa2001316

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update—this simple estimate from 3/11/20 gave ~100K deaths for US, which ~was the actual value for 5/26/20

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SIR Epidemic Dynamics

TERMINOLOGY

"contact number" (ɣ)

= [infection rate, α] / [recovery rate, β]

(for an SIR model $\alpha/\beta=R_0$)

CRITICAL ASSUMPTION

no spatial variations, correlations

disease information

contact number 6.85

duration of infection 12.5

population information

initially immune 0

initially infected 0.07

time scale

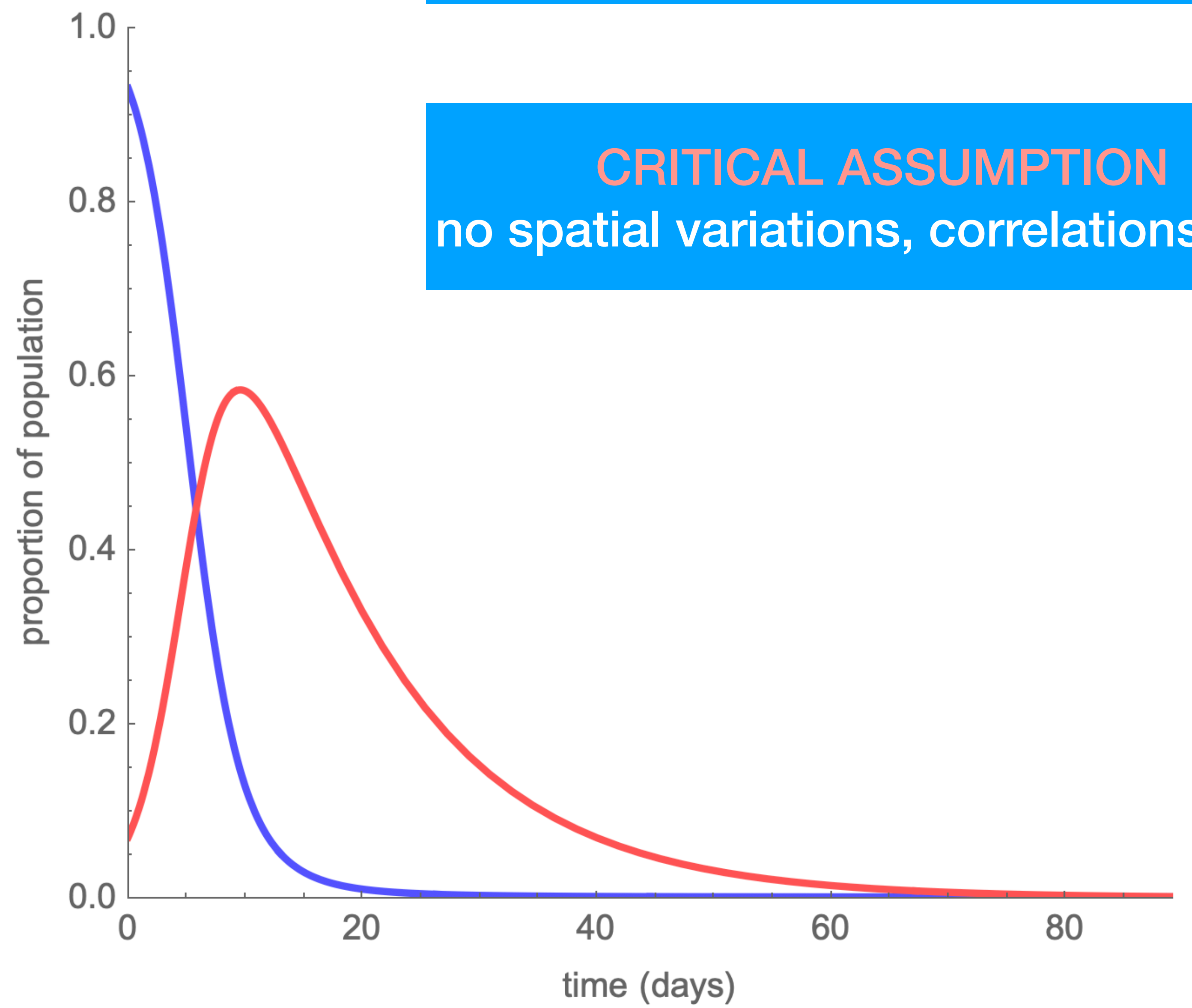
interval

window

proportion scale

interval

window



Source: https://demonstrations.wolfram.com/SIREpidemicDynamics/

Opinion

No One Knows What's Going to Happen

Stop asking pundits to predict the future after the coronavirus. It doesn't exist.

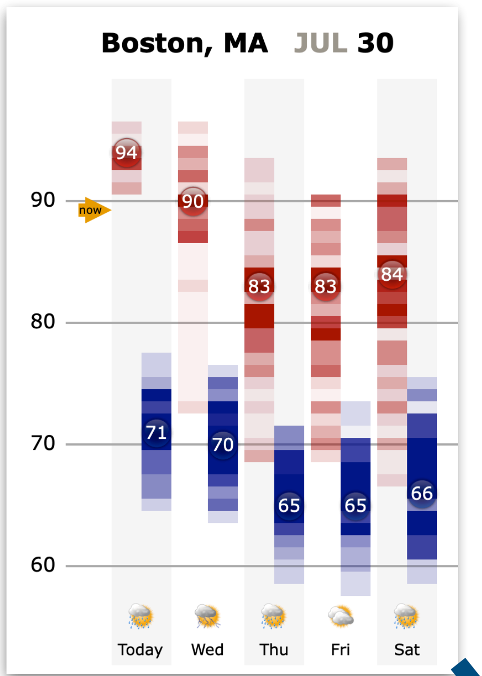
By Mark Lilla
Dr. Lilla is a professor of humanities at Columbia.

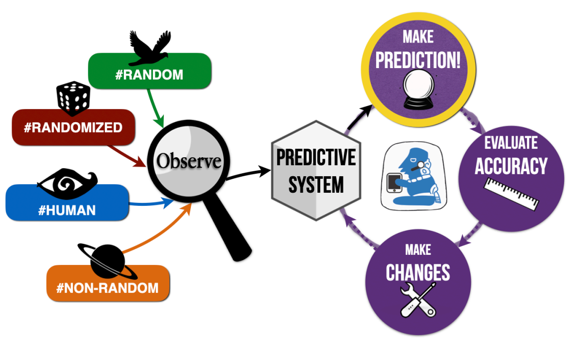
May 22, 2020

The best prophet, Thomas Hobbes once wrote, is the best guesser. That would seem to be the last word on our capacity to predict the future: We can't.

But it is a truth humans have never been able to accept. People facing immediate danger want to hear an authoritative voice they can draw assurance from; they want to be told what will occur, how they should prepare, and that all will be well. We are not well designed, it seems, to live in uncertainty. Rousseau exaggerated only slightly when he said that when things are truly important, we prefer to be wrong than to believe nothing at all.

Take-a-Sweater

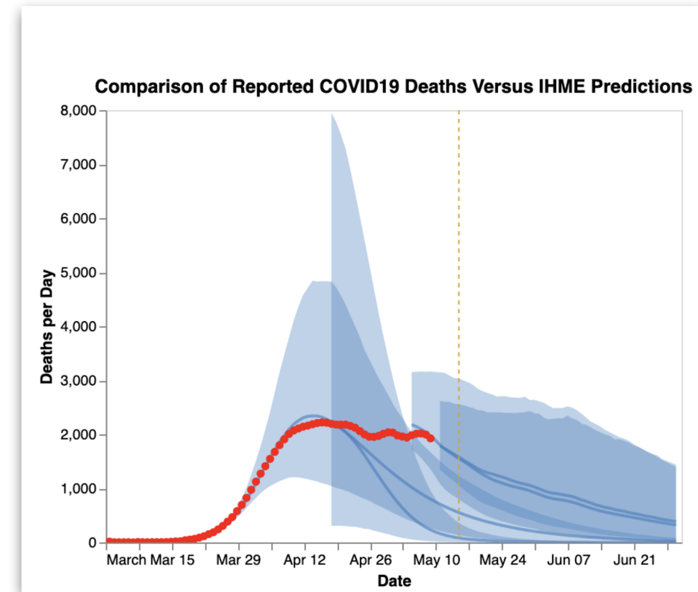




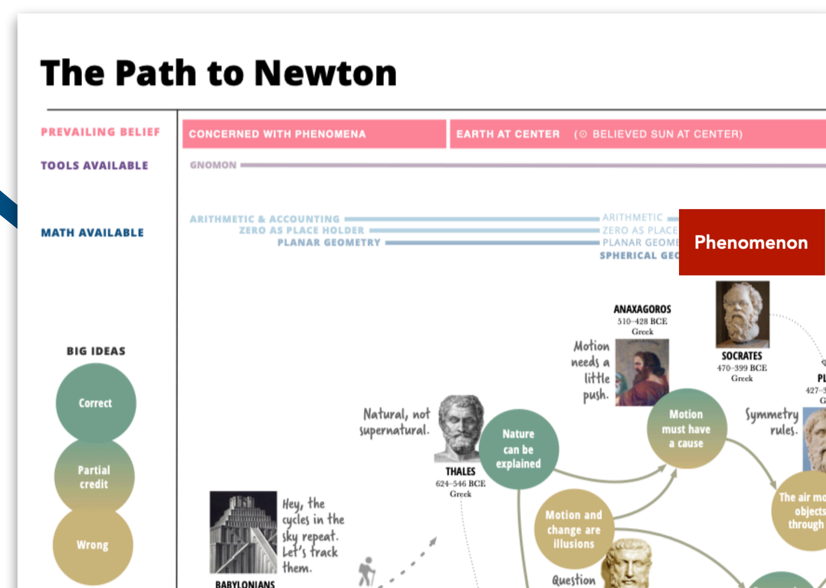
PredictionX

predictionx.org

IHME COVID-19



The Path to Newton



Phenomenon	Observation*	Data	Rule	Theory	Explanation	Prediction

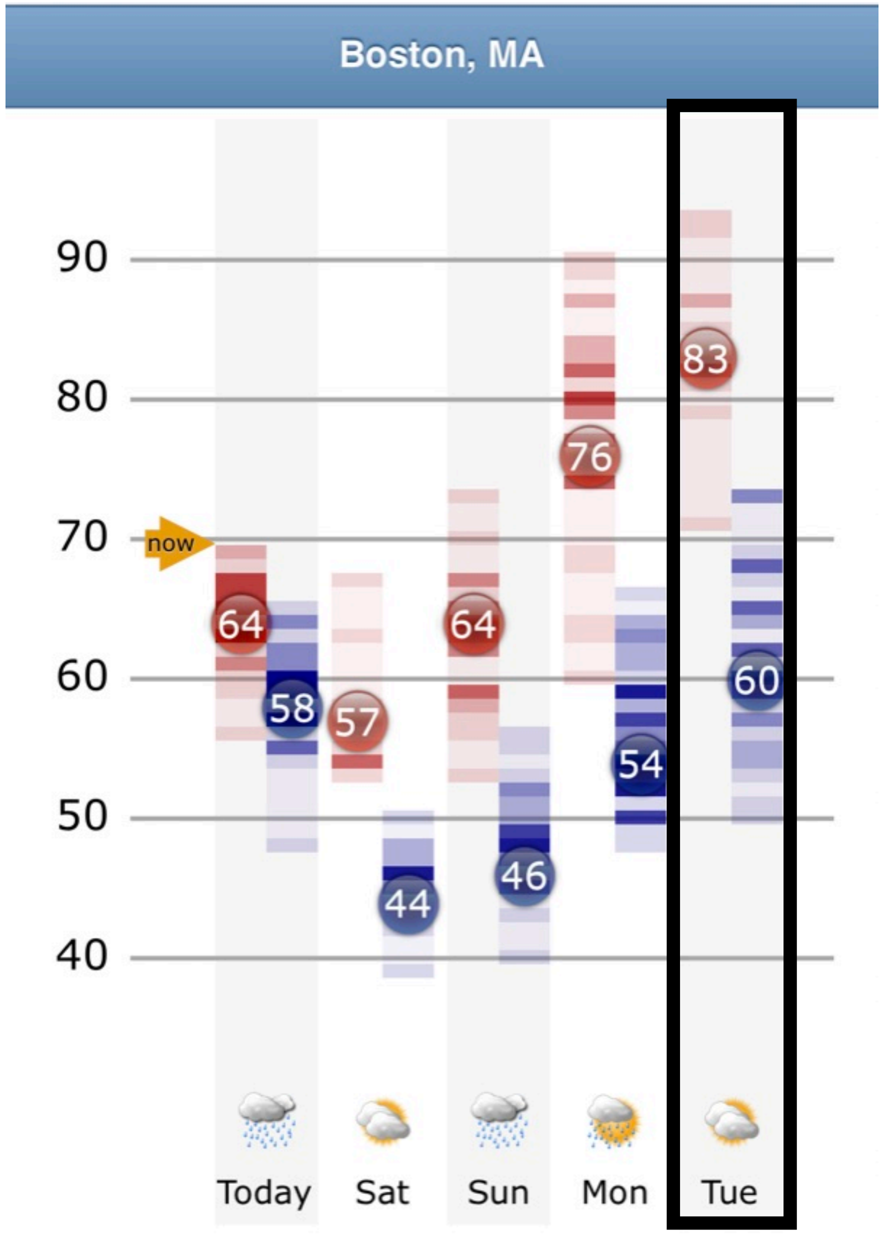
takeasweater.com

path-to.org

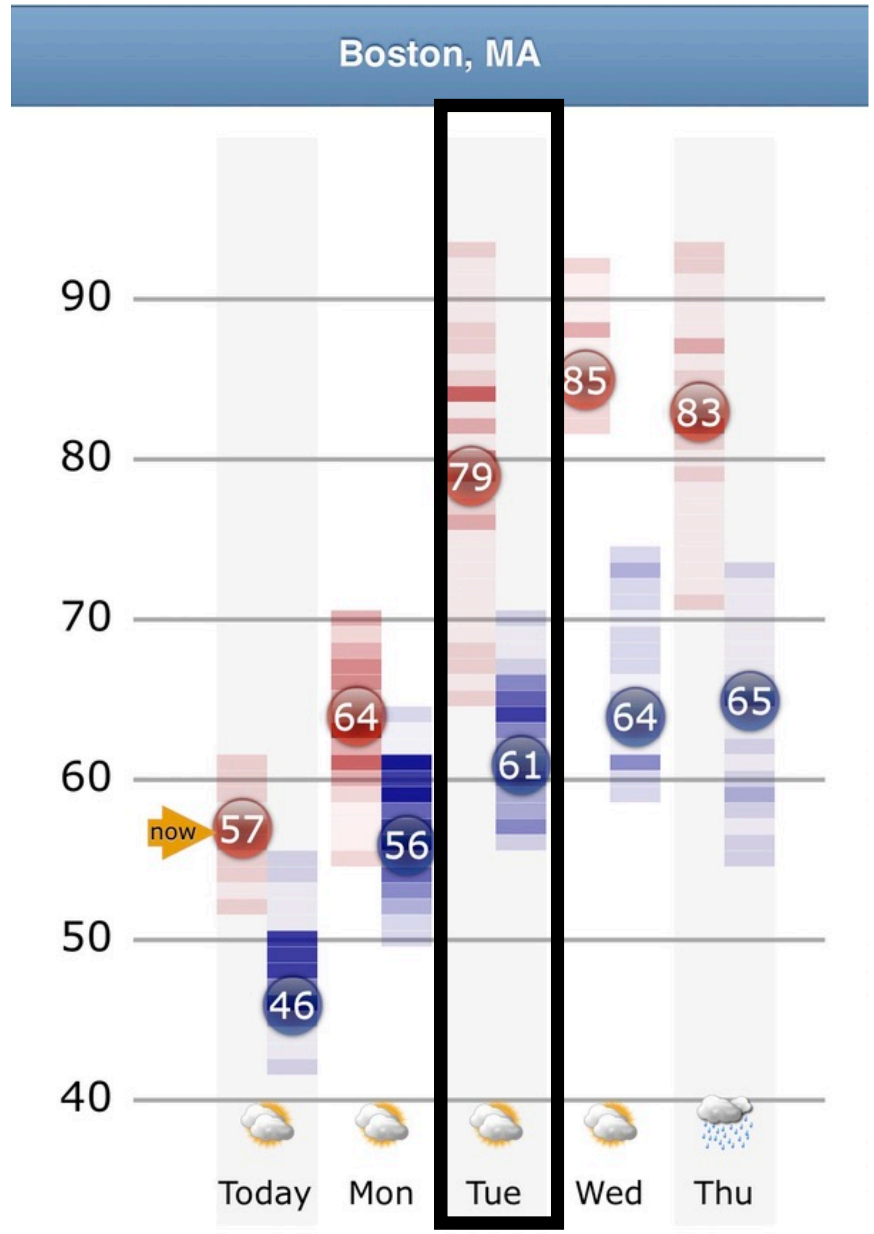
gluesolutions.io/social-impact

May 26, 2020 weather for Boston, predicted in the past…

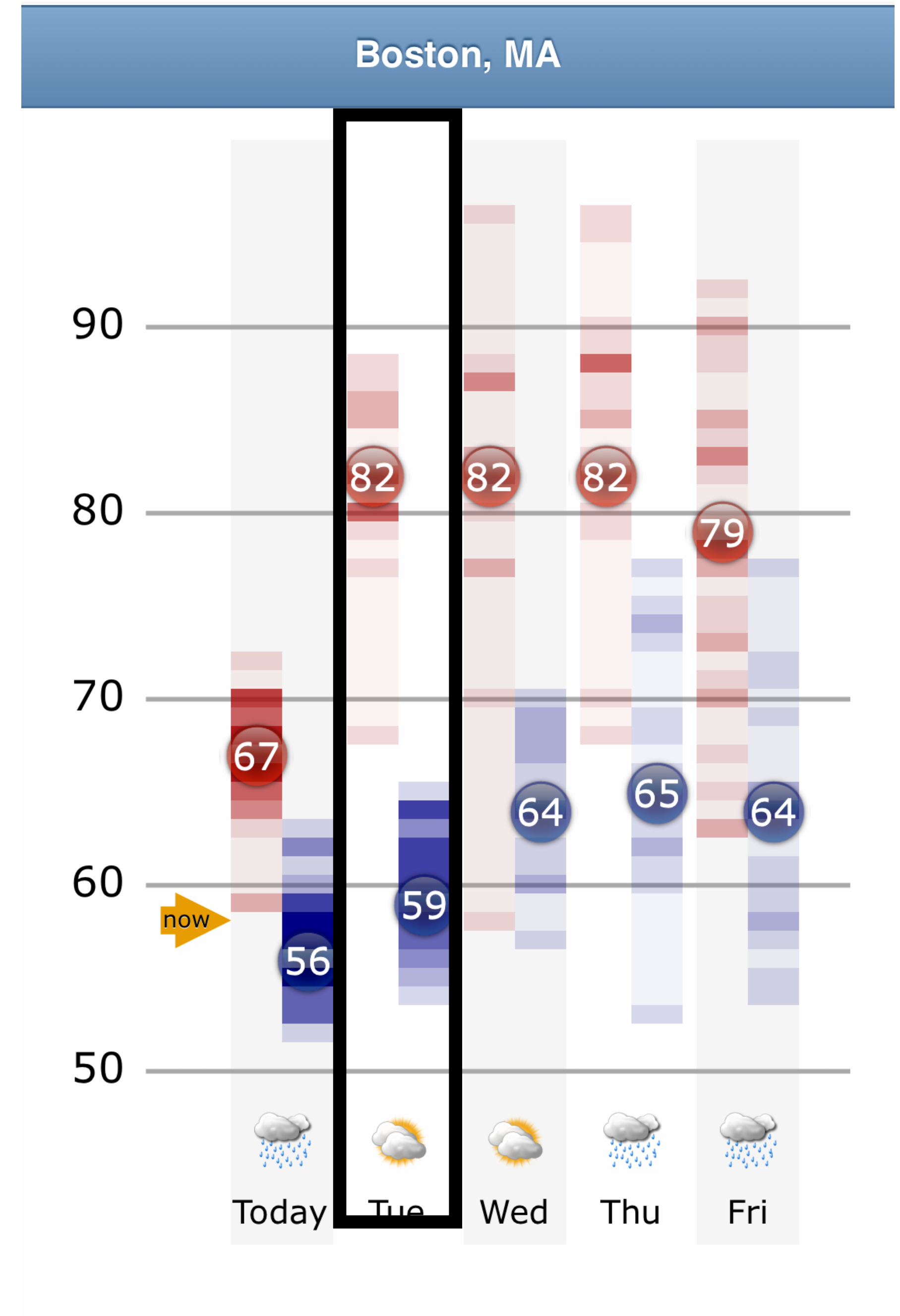
Friday, May 22, 2020



Sunday, May 24, 2020



Monday, May 25, 2020



from takeasweater.com

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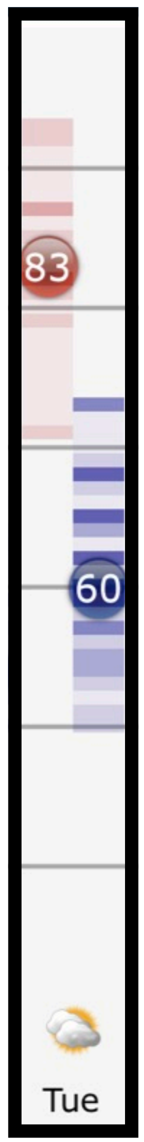

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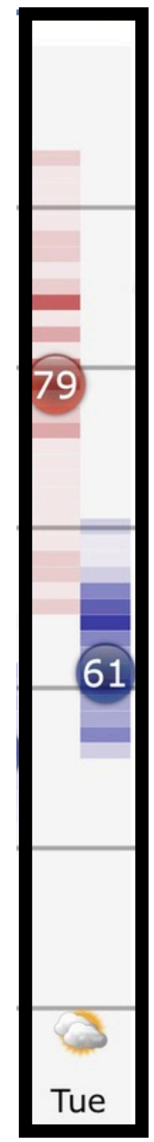

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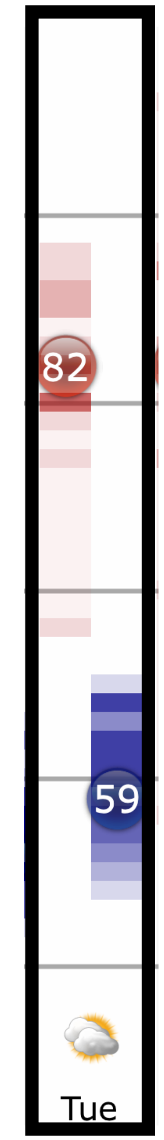

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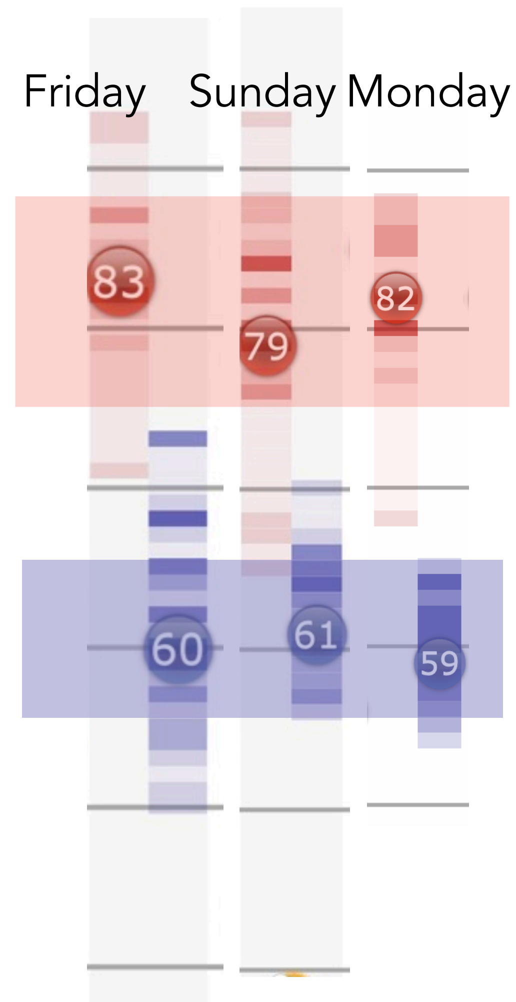


Predictions ~fall within "expected" uncertainty ranges.

You'll read all of these short essays (and 1 more article, each) for Thursday.

The Prediction Project

The Past and Present of the Future

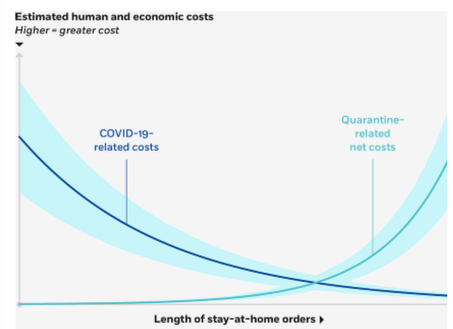
HOME ABOUT MATERIALS COURSES TALKS WRITINGS PRESS FORUM

Writings

This section highlights writings by Professor Goodman on contemporary topics related to uncertainty and prediction. While these pieces are not official Prediction Project material, they contain major conceptual ideas from the Prediction Project's courses applied to major real life questions. These articles reflect Professor Goodman's personal views, not official Harvard policy.

Data Driven Dilemmas Posed by COVID-19

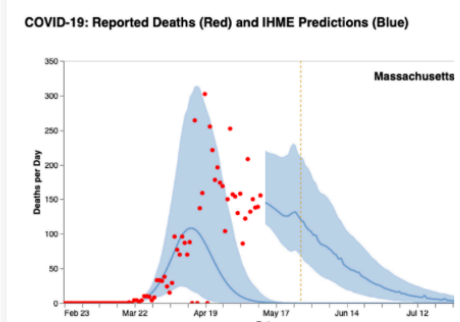
In this essay, Alyssa discusses the **complex tradeoffs** involved with decision making in an age of pandemic. Scientists face ethical dilemmas when choosing to view this crisis in a rational or emotional way.



Read More

Uncertainty about Uncertainty

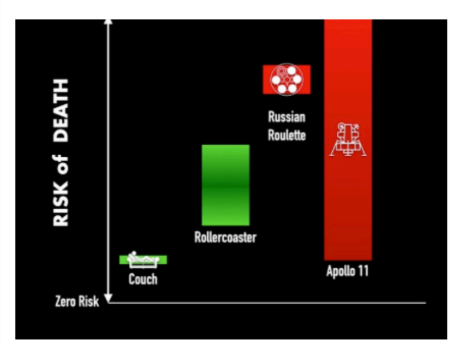
This commentary piece examines predictions of uncertainty in IHME COVID-19 models. She sheds light on the tendency of these important models to **underestimate** uncertainty in deaths per day estimates.



Read More

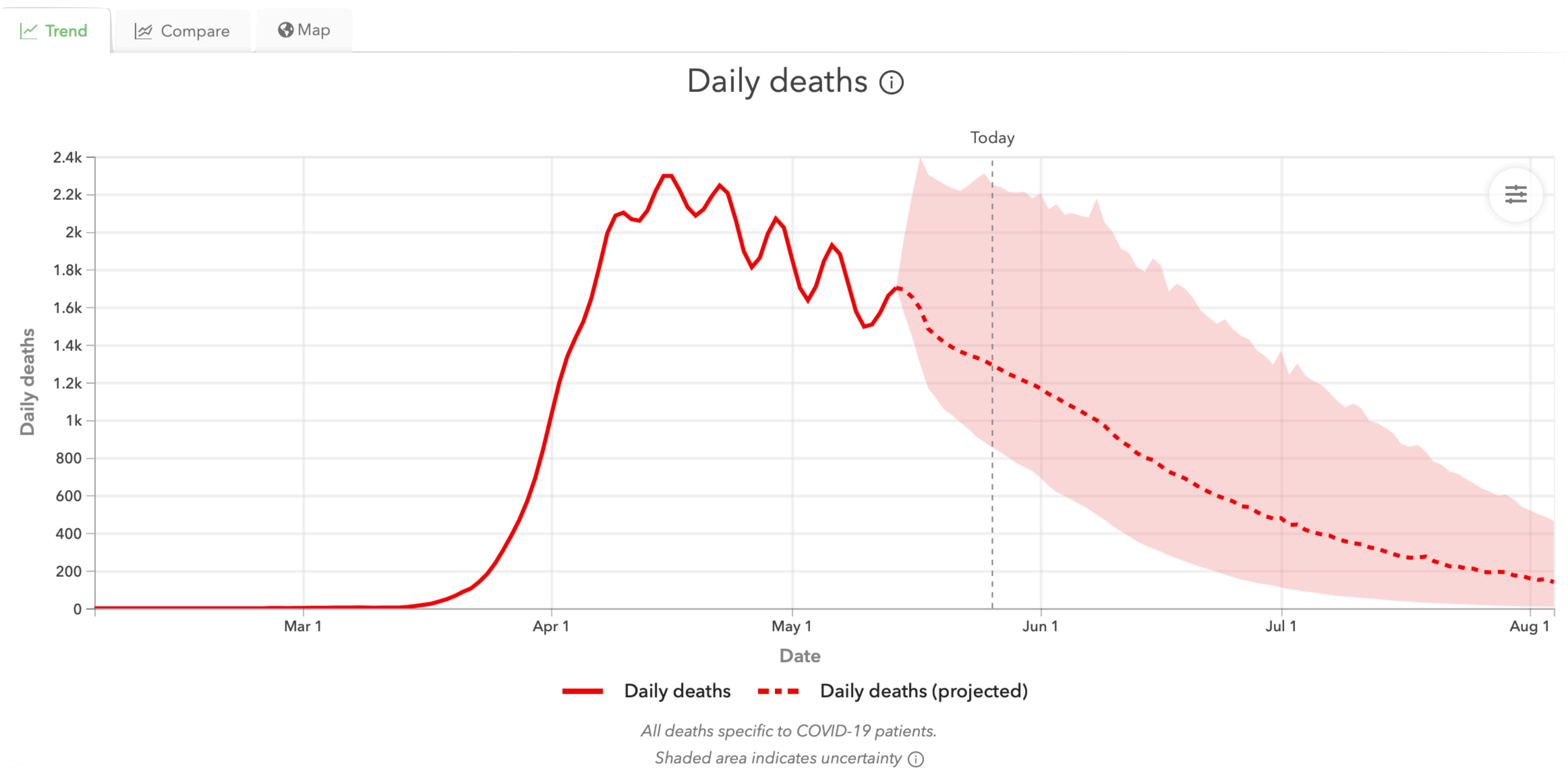
Uncertain Risks

We know how to express **risk** and **uncertainty** with numbers, but people don't always take practical actions based on those numbers. **The COVID crisis brings this contrast into sharp focus.**



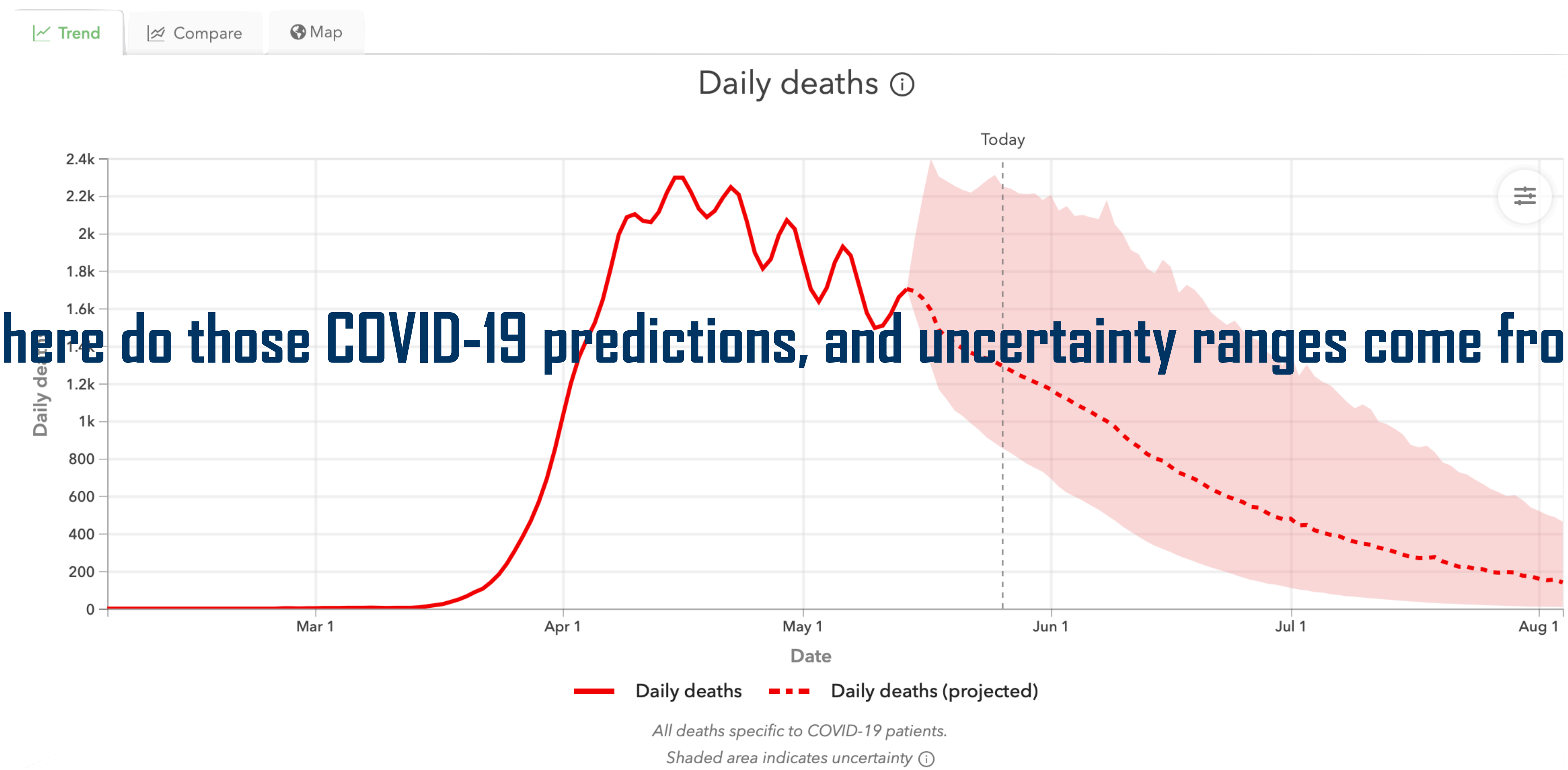
Read More

May 26, 2020 IHME forecast for US COVID-19 Daily Deaths, with Uncertainty

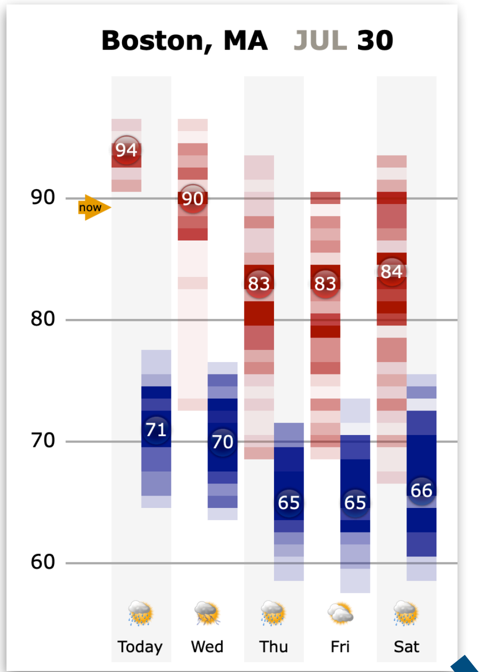


Predictions are shown with "expected" uncertainty ranges.

Where do those COVID-19 predictions, and uncertainty ranges come from?



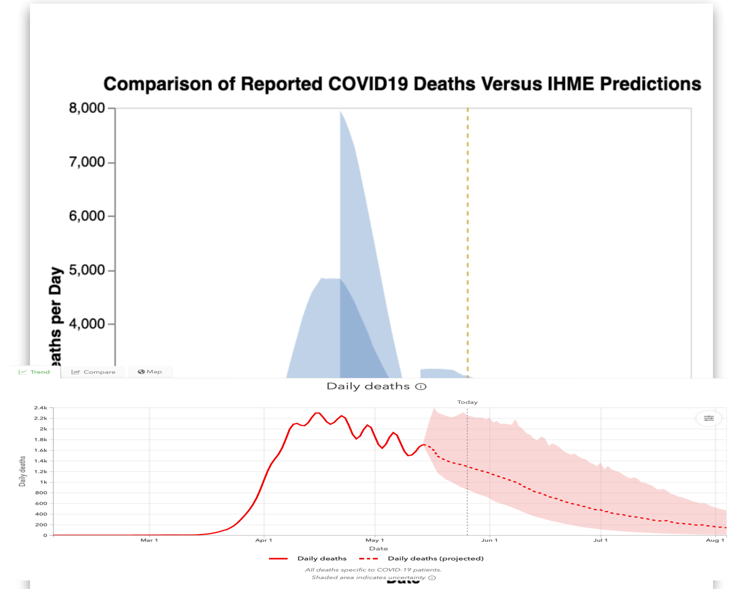
Take-a-Sweater



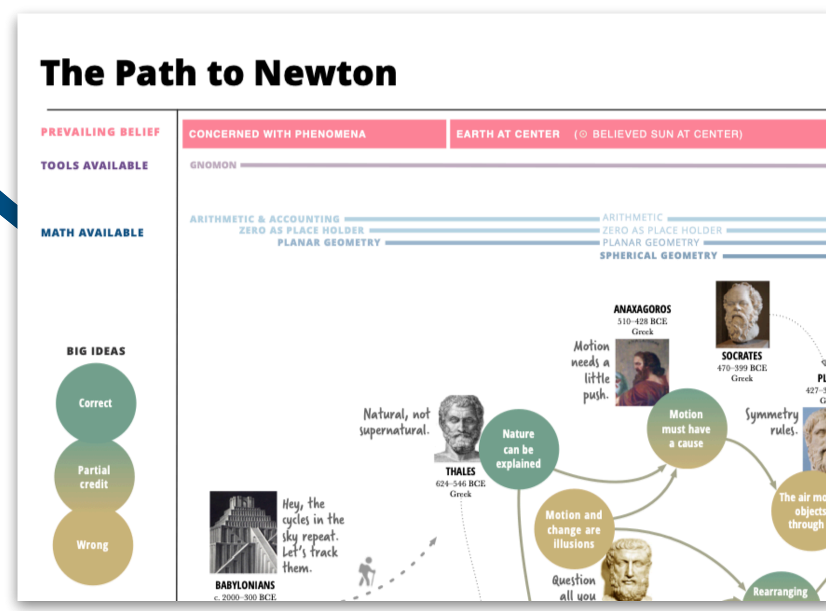
PredictionX

predictionx.org

IHME COVID-19



The Path to Newton

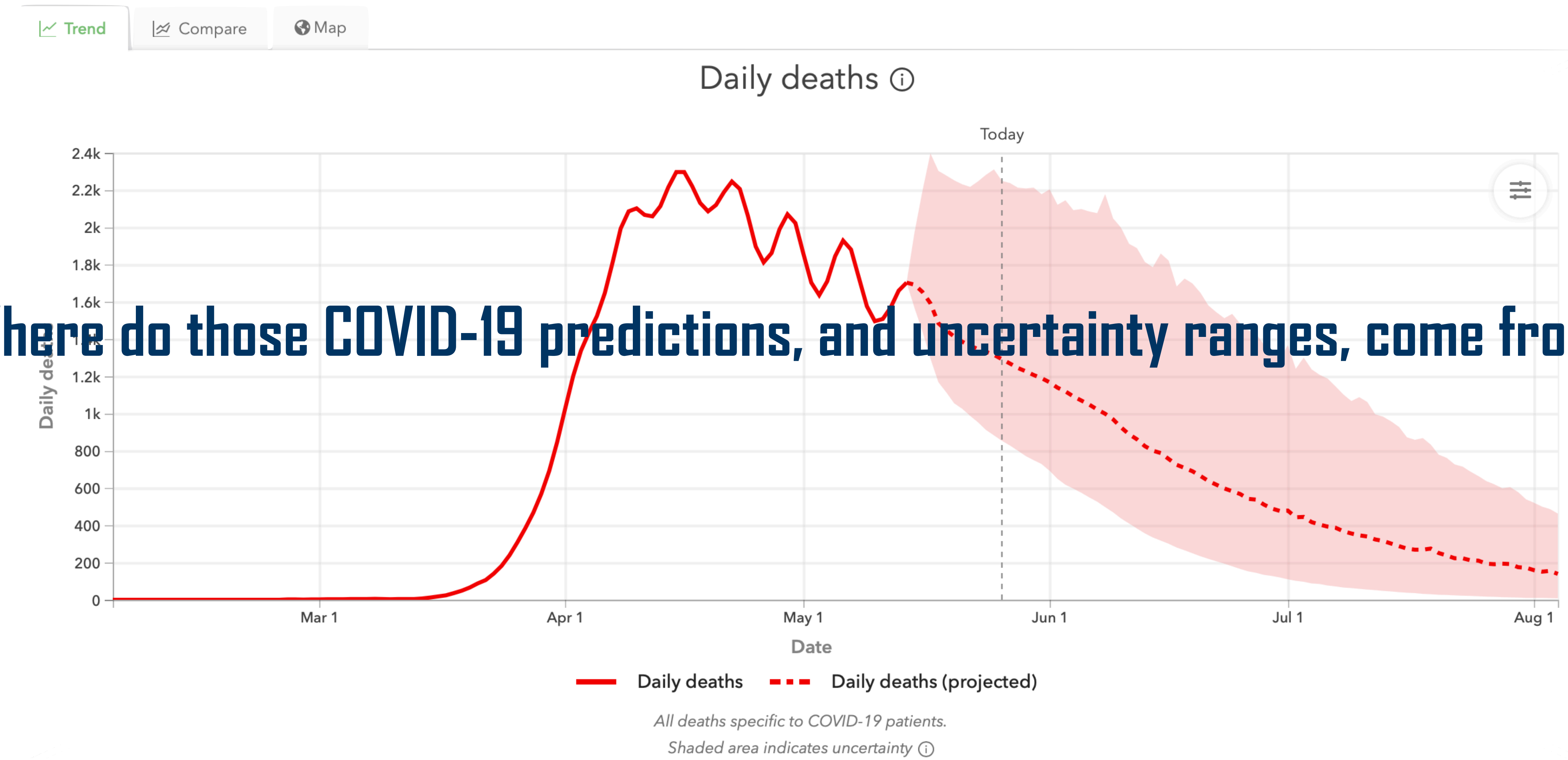


takeasweater.com

path-to.org

gluesolutions.io/social-impact

Where do those COVID-19 predictions, and uncertainty ranges, come from?



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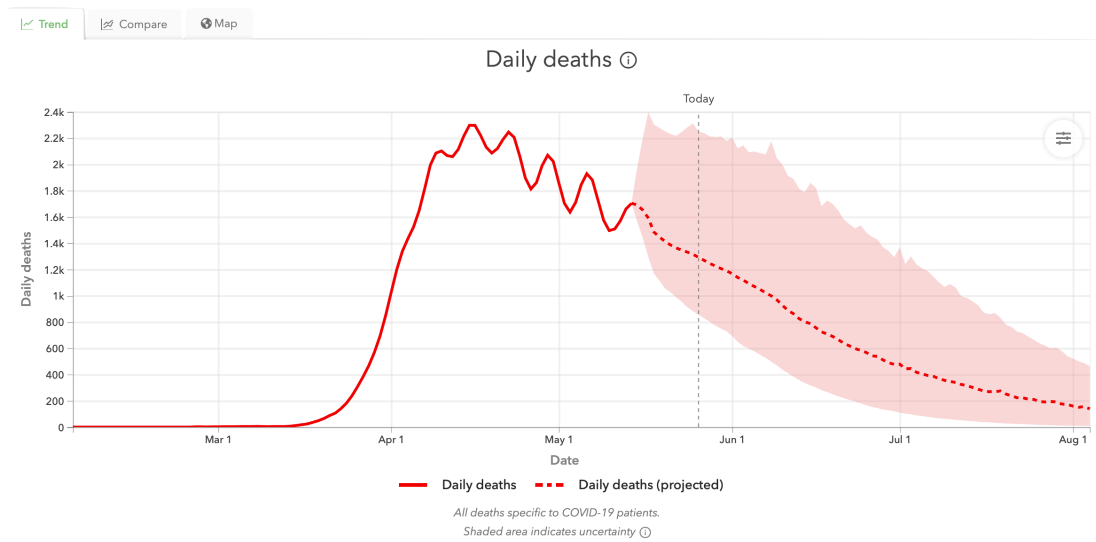
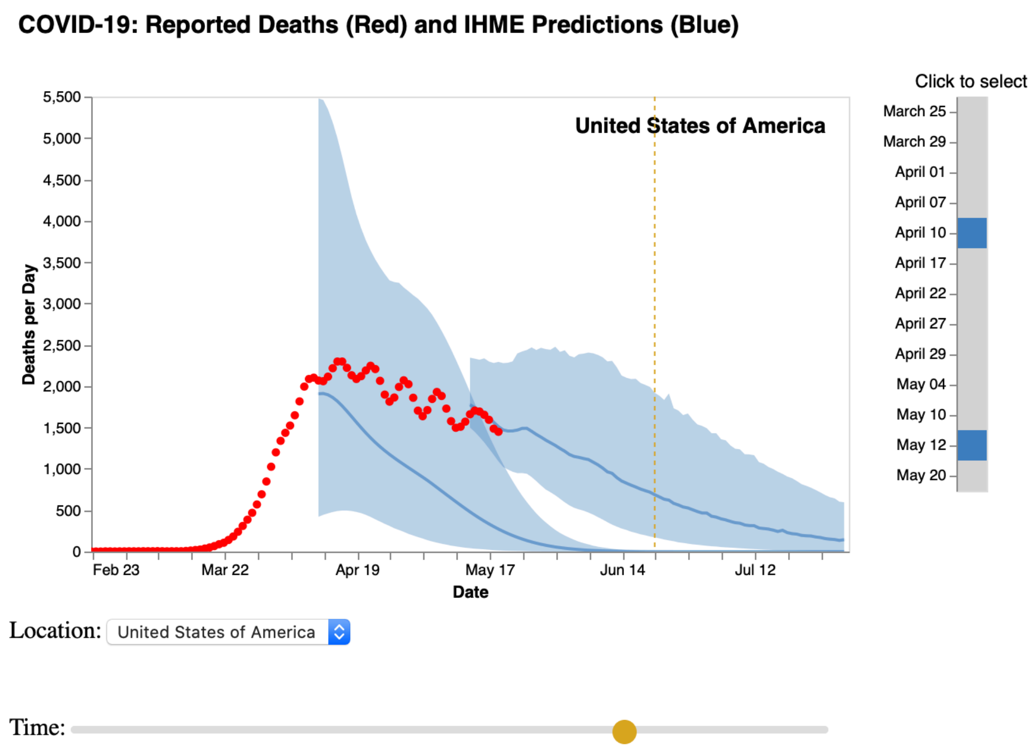


covid19.healthdata.org/
united-states-of-america

And how uncertain are the uncertainties?



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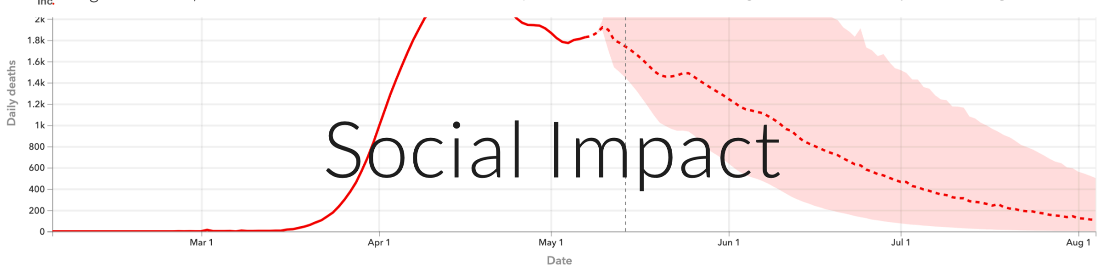
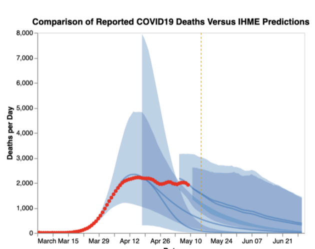
Where do those COVID-19 predictions, and uncertainty ranges, come from?

glue solutions inc. gluesolutions, inc. Home Gallery Our Team The Software glue-con Social Impact Working with Us





IHME Models over time, for the United States, for 4 representative dates, made with the interactive tools offered below.

IHME Model Uncertainty, Visualized over Time

The Institute for Health Metrics and Evaluation (IHME) creates, maintains, updates, and publishes an open-source statistical model of the impact of the COVID-19 pandemic, based on open-data resources. As a public service, glue solutions, inc. here offers an online tool for visualizing the evolution of the IHME models over time.

The general public has seen many versions of the IHME "Daily Deaths" plots, including in several White House briefings. Our goal here is to offer a look at **how the models change**—appropriately, in response to new data and information—over time, and how that affects model updates. In a companion essay online at the Prediction Project site, we offer more context on why this evolution is so interesting.

(Banner above shows sample IHME "Daily Deaths" graphic, from 14 May 2020.)

What's this tool for? Using the interactive graphics below, you can re-create the display of deaths/day akin to what would have been visible at IHME's (site on a range of modeling dates, for any region you select. In addition, you can show more than one model (date) at a time, to make comparisons.

How should I interpret what I see? In each of the panels below: **red** dots show reported *actual* deaths per day; solid **blue** lines show forecasts, and light regions show uncertainty bands. Those **uncertainty bands** indicate ranges of possible outcomes, as forecast on the date when the model was made. Th should account for 95% of possible outcomes. As one can see by moving the time slider below each graph, the model and its associated uncertainty bar time. As more and more models are added, regions where shading appears darkest are regions where models have been most consistent.

There are **four versions** of the IHME evolution visualization offered below. They are as follows (with source links in [brackets]):

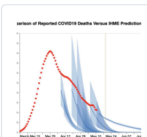
1. For the United States, showing only 4 representative model dates. [source, GitHub] [mobile site]
2. For the United States, offering a wide range of model dates [source, GitHub]
3. For the World, showing only 4 representative model dates [source, GitHub] [mobile site]
4. For the World, offering a wide range of model dates [source, GitHub]

This content is **licensed** as CC BY, with attribution "glue solutions, inc." Static graphics can be extracted using the three dots at the upper right of each

How can I share interesting graphs I create? Join the discussion at the 10QViz.org IHME COVID-19 Model Uncertainty Visualization page to upload your graphic and tell the world what it shows you. (You can download your graphic using the three dots at the top right of each panel below.)

At present, this site's visualization interactions work best on larger screens. We provide links to standalone views of the visualization showing 4 representative model dates that may work better on many mobile devices.

Tweet Analytics



Alyssa A. Goodman @AlyssaAGoodman
We think everyone needs to SEE how the **@IHME_UW #Covid_19** models have changed, so we made a tool https://www.gluesolutions.io/social-impact to visualize the forecasts over TIME, and explained it here https://predictionx.org/uncertainty-covid19 .... This is a preview. More to come... pic.twitter.com/41tQlk1qFa

Impressions times people saw this Tweet on Twitter	58,682
Total engagements times people interacted with this Tweet	9,097

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The Prediction Project

Thoughts, Resources, Course, Seminar and Someday a Book

WELCOME CONTENT▾ COURSES▾ TALKS+▾ COMMENTARY▾ CREDITS

Essays

UNCERTAINTY ABOUT UNCERTAINTY

Data-Driven Dilemmas posed by COVID-19

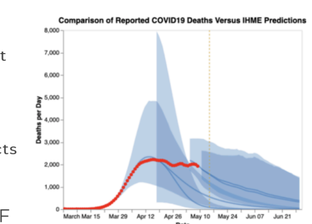
HOME / COMMENTARY /

Uncertainty about Uncertainty

by Alyssa A. Goodman, May 18, 2020

This essay accompanies the release of an online tool for visualization of IHME COVID-19 forecasts' evolution over time and a community discussion of visualizations created with the tool.

Uncertainty about the future has motivated predictions for millennia. Sometimes, we're just curious—but other times, we really *need* to know. As the present pandemic evolves, our urgent societal need to plan has motivated many scientists to predict the spread and effects of the novel coronavirus.



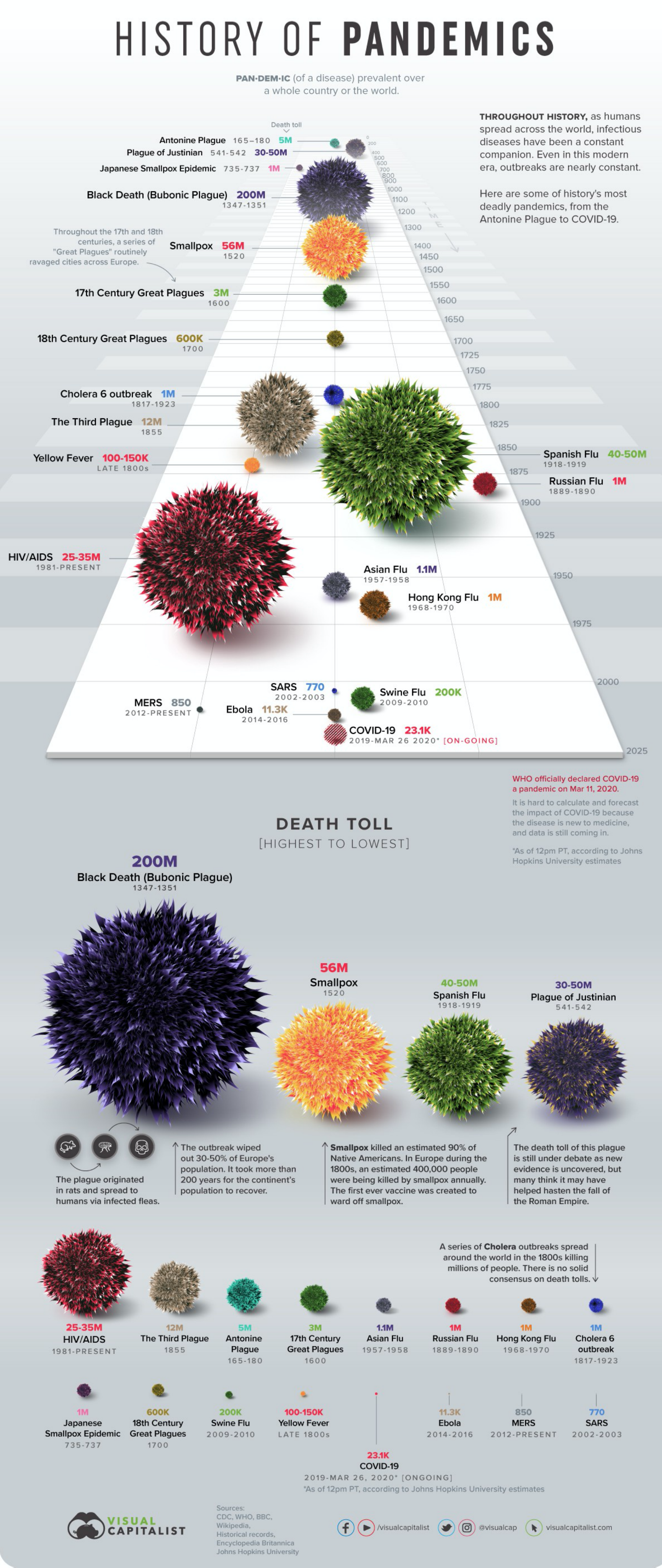
Click here open the interactive site and explore the visualizations on your own.

BACKGROUND: TWO BROAD CLASSES OF MODELS

Amongst the many predictions being used by governments to guide policy are two broad classes: infectious disease models based on an understanding of how contagion spreads; and more mechanism-agnostic statistical models informed primarily by data about prior outcomes. To the uninitiated, these approaches, both of which rely on statistical modeling, may sound the same—but they are not.

Models of infectious disease take into account, with varying levels of complexity: how many, and importantly *why*, people are susceptible, infected, immune, or have succumbed to a virus at any given point in time and space. The mathematics of these models moves people between groups called "Susceptible," "Exposed," "Infected," and "Removed," and so are often called "SEIR" models. At the philosophical other end of the modeling spectrum, what we call "**mechanism-agnostic**" approaches use information about cases, testing, hospital admissions, and deaths, to create algorithms that forecast what will happen under various combinations of conditions, given what's happened under similar conditions in the past. Purely mechanism-agnostic approaches do not factor in medically-informed information about how an infectious disease spreads.

gluesolutions.io/social-impact


HISTORY OF PANDEMICS
PAN·DEM·IC (of a disease) prevalent over a whole country or the world.
THROUGHOUT HISTORY, as humans spread across the world, infectious diseases have been a constant companion. Even in this modern era, outbreaks are nearly constant.
Here are some of history's most deadly pandemics, from the Antonine Plague to COVID-19.
Death toll
Antonine Plague 165–180 5M
Plague of Justinian 541-542 30-50M
Japanese Smallpox Epidemic 735-737 1M
Black Death (Bubonic Plague) 200M 1347-1351
Throughout the 17th and 18th centuries, a series of "Great Plagues" routinely ravaged cities across Europe.
Smallpox 56M 1520
17th Century Great Plagues 3M 1600
18th Century Great Plagues 600K 1700
Cholera 6 outbreak 1M 1817-1923
The Third Plague 12M 1855
Yellow Fever 100-150K LATE 1800s
Spanish Flu 40-50M 1918-1919
Russian Flu 1M 1889-1890
HIV/AIDS 25-35M 1981-PRESENT
Asian Flu 1.1M 1957-1958
Hong Kong Flu 1M 1968-1970
MERS 850 2012-PRESENT
SARS 770 2002-2003
Swine Flu 200K 2009-2010
Ebola 11.3K 2014-2016
COVID-19 23.1K 2019-MAR 26 2020* [ON-GOING]
WHO officially declared COVID-19 a pandemic on Mar 11, 2020.
It is hard to calculate and forecast the impact of COVID-19 because the disease is new to medicine, and data is still coming in.
*As of 12pm PT, according to Johns Hopkins University estimates
DEATH TOLL
[HIGHEST TO LOWEST]
200M Black Death (Bubonic Plague) 1347-1351
56M Smallpox 1520
40-50M Spanish Flu 1918-1919
30-50M Plague of Justinian 541-542
The plague originated in rats and spread to humans via infected fleas.
The outbreak wiped out 30-50% of Europe's population. It took more than 200 years for the continent's population to recover.
Smallpox killed an estimated 90% of Native Americans. In Europe during the 1800s, an estimated 400,000 people were being killed by smallpox annually. The first ever vaccine was created to ward off smallpox.
The death toll of this plague is still under debate as new evidence is uncovered, but many think it may have helped hasten the fall of the Roman Empire.
A series of Cholera outbreaks spread around the world in the 1800s killing millions of people. There is no solid consensus on death tolls.
25-35M HIV/AIDS 1981-PRESENT
12M The Third Plague 1855
5M Antonine Plague 165-180
3M 17th Century Great Plagues 1600
1.1M Asian Flu 1957-1958
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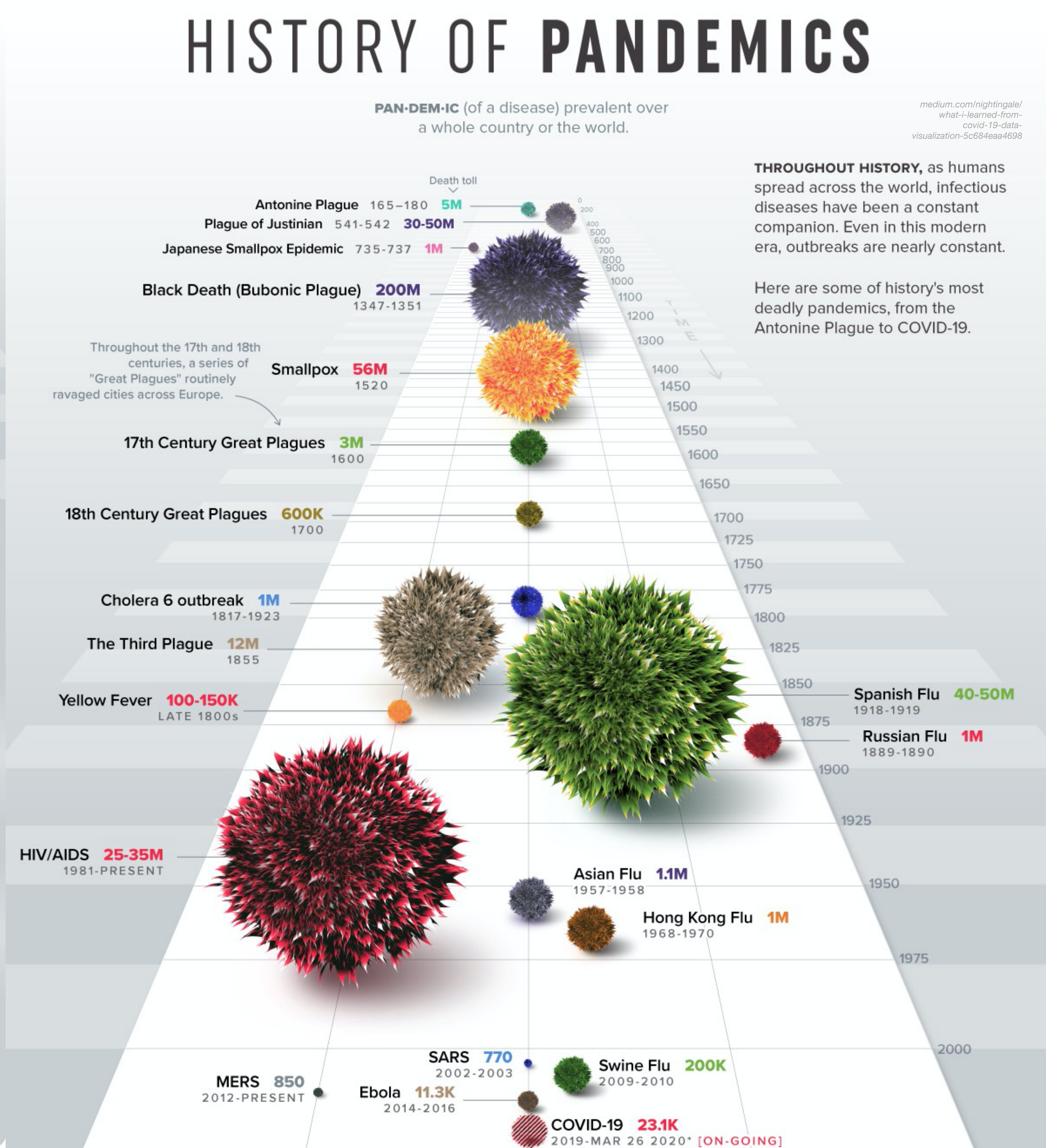
770 SARS 2002-2003
VISUAL CAPITALIST
Sources: CDC, WHO, BBC, Wikipedia, Historical records, Encyclopedia Britannica Johns Hopkins University
/visualcapitalist
@visualcap
visualcapitalist.com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medium.com/nightingale/what-i-learned-from-covid-19-data-visualization-5c684eaa4698
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TIME
0
200
400
500
600
700
800
900
1000
1100
1200
1300
1400
1450
1500
1550
1600
1650
1700
1725
1750
1775
1800
1825
1850
1875
1900
1925
1950
1975
2000

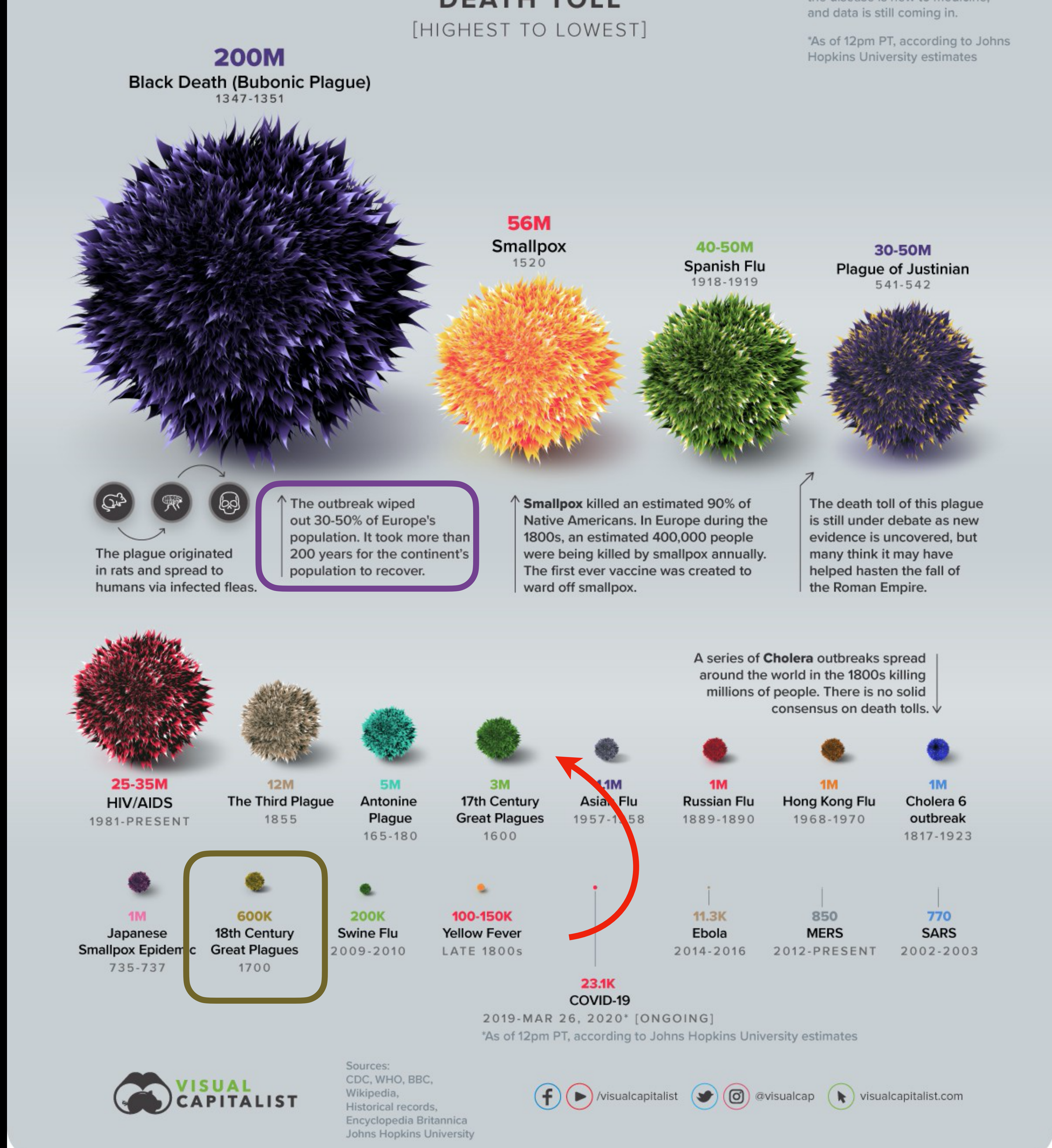
BUT…let's do the RISK calculation properly

18th Century Great Plagues
600K in 1750
800 million/600K=
1 person in 1,300 dead

COVID-19
2.6 M (so far)
8 billion/2.6 million=
1 person in 3000 dead

So, *per capita*, the risk of dying from the 18th Century Great Plague was 3000 /1,300 = **2x worse** than COVID-19 (so far).

And that was for a relatively "mild" plague.



https://tinyurl.com/covid-gened-questions

Prediction: Week 7

quick review of outdoor **Navigation Exercise**

1 year ago

Coming up: Linz (3/23); Radcliffe AI/Health (4/1); your final projects…

"Prediction vs. Prophecy"

John Snow & Cholera (edX highlights & more)

Modeling *the spread of epidemics, and* ***uncertainty***

Bookkeeping **SIR Models** **SEIR Models** **Agent-based models** **AI models**

Prediction and decision in the face of **uncertainty**: COVID-19 and Harvard (discussions)

Thursday & in section: COVID-19 student readings discussion (see Canvas Tuesday eve)

Special Guest for Thursday's discussions: geneticist/epidemiologist **Dr. Immaculata DeVivo,** Professor at Harvard' T.H. Chan School of Public Health and at Harvard Medical School