The History and Future of the COVID-19 Pandemic in North Carolina

Justin Lessler
Department of Epidemiology, UNC Gillings School of Public Health

Testimony to the Joint Legislative Commission on Governmental Operations Subcommittee on the Use and Distribution on Federal COVID Funding, November 3, 2021

Brief Disclaimer

- The following presentation represents my own personal scientific views and does not represent those of any other individual or institution.

- It is based on the information currently available to me and my current understanding of the scientific evidence.

- I have no direct conflicts of interest, but have served as an expert witness on cases where issues of the length of the pandemic are at issue.

The what and why of epidemiology?

- Epidemiologists study the distribution and causes of diseases in populations.

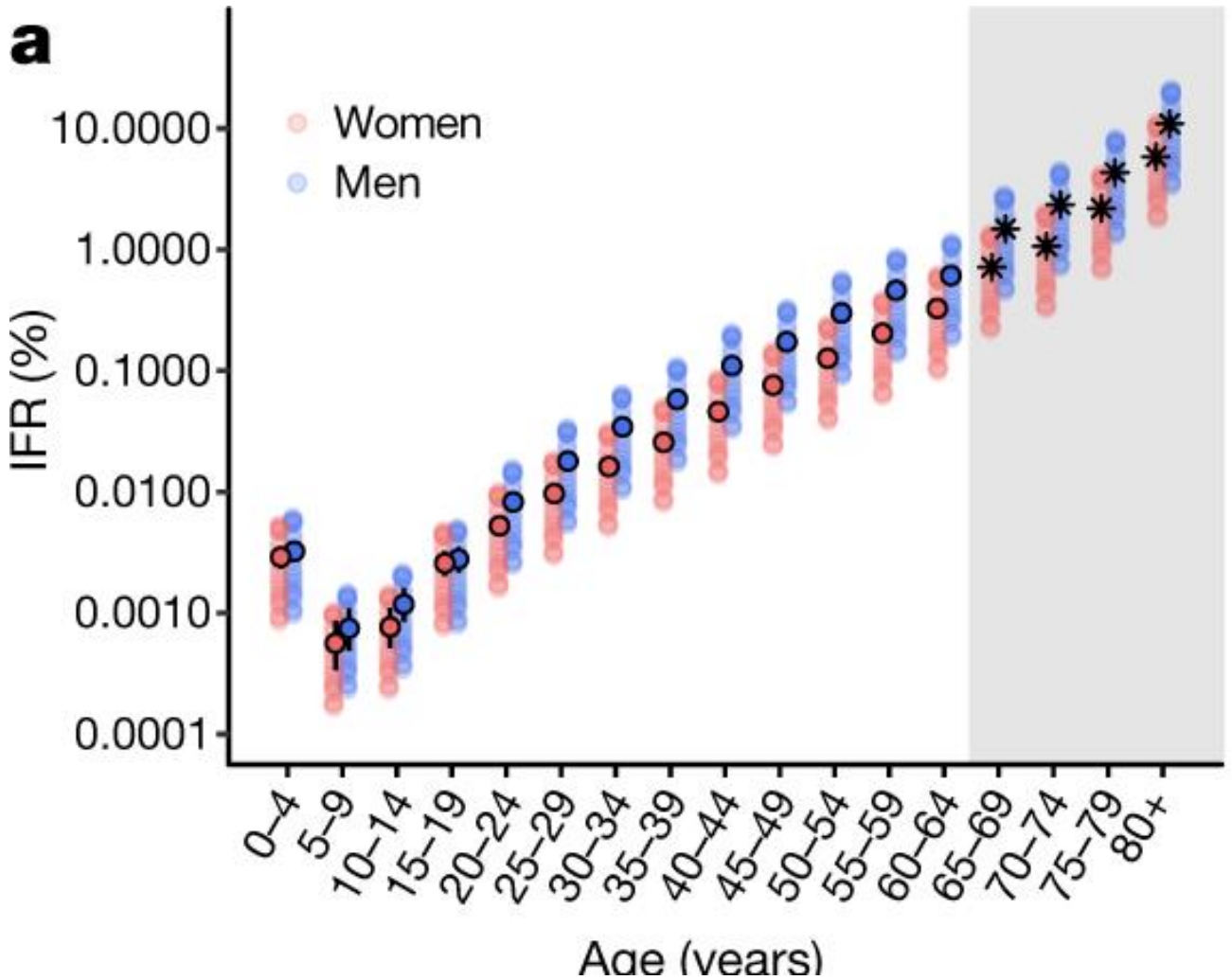
- I study *infectious disease dynamics*, or specifically how epidemics of infectious diseases evolve and change over time.

- **Clinical researchers** try to understand what factors make one patient recover why another dies, or what treatments work best to cure disease. **Epidemiologists** try to understand what makes epidemics worse in some places than others, and how to best control spread.

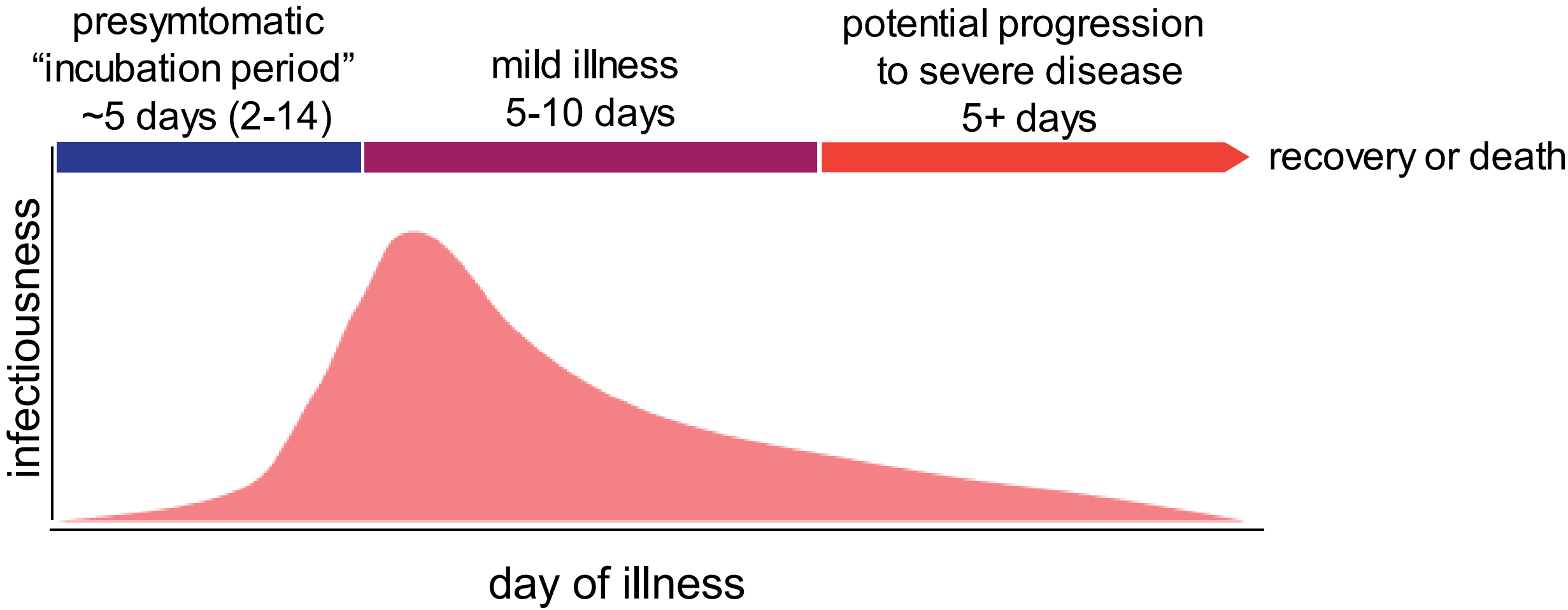
A Quick Primer on COVID-19 Epidemiology and Control

How deadly is COVID-19?

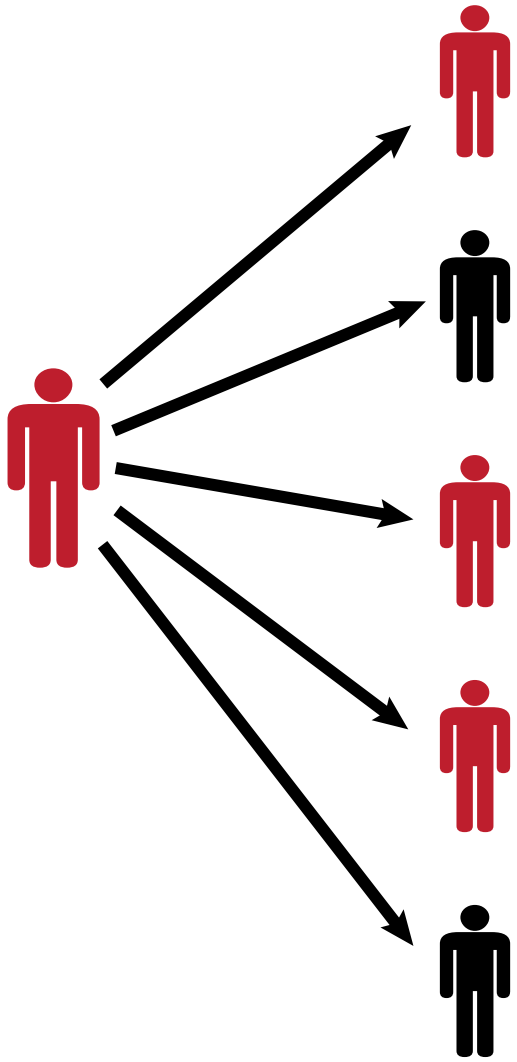
- In the US COVID-19 kills about 1 in every 200 people **unvaccinated** people who are **infected**.
  - some evidence this may be higher for Delta
- The probability of death is highly age dependent, doubling with about every 10 years of age.



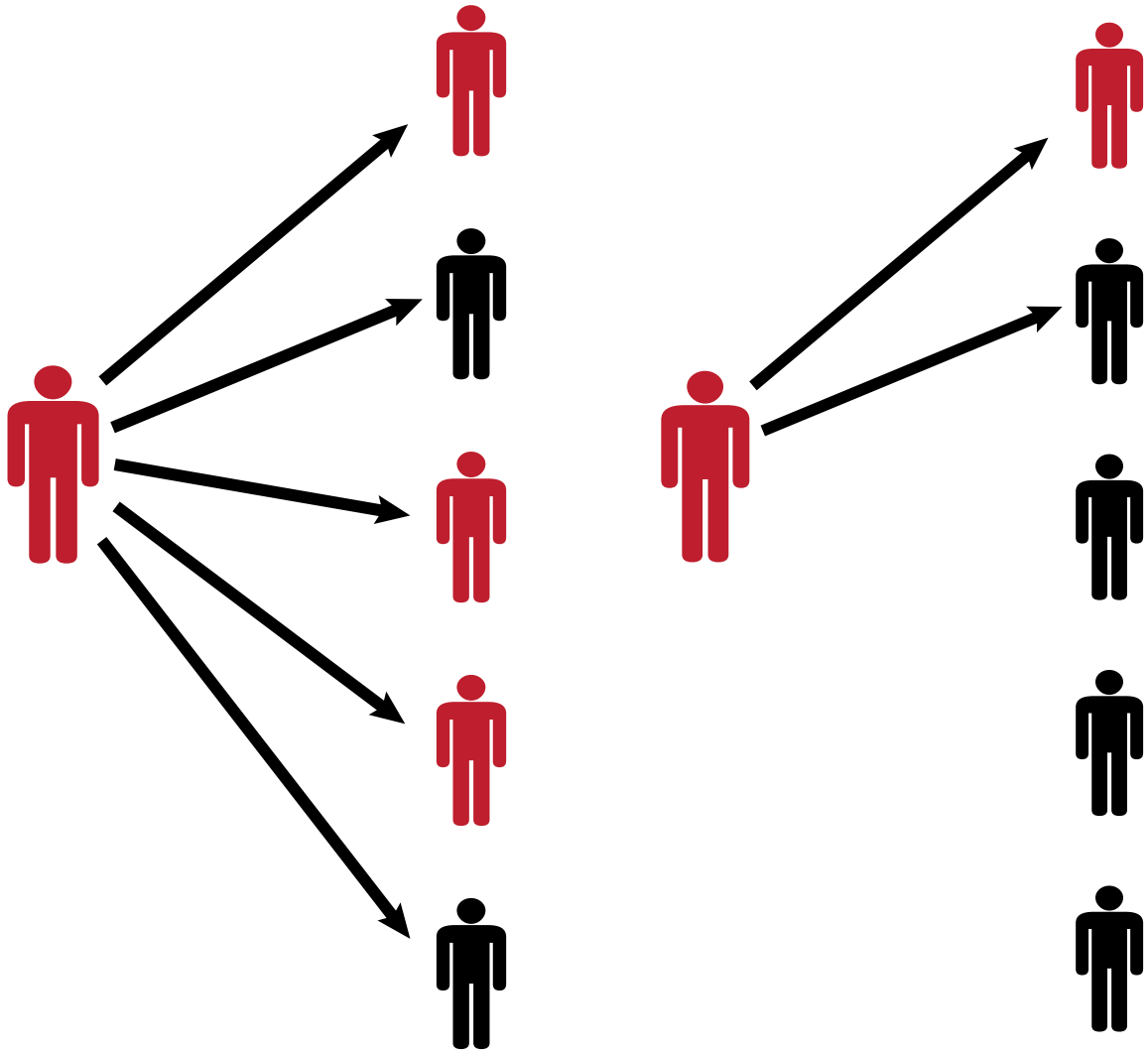
The course of COVID-19 infection



The three modes of control

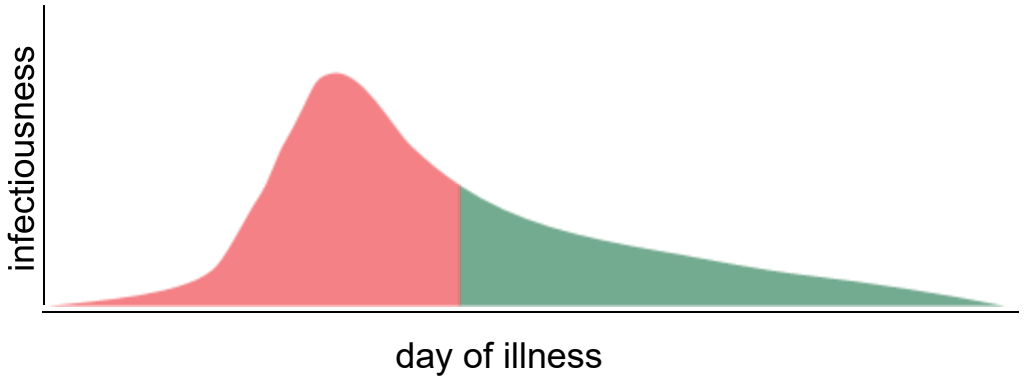


The three modes of control

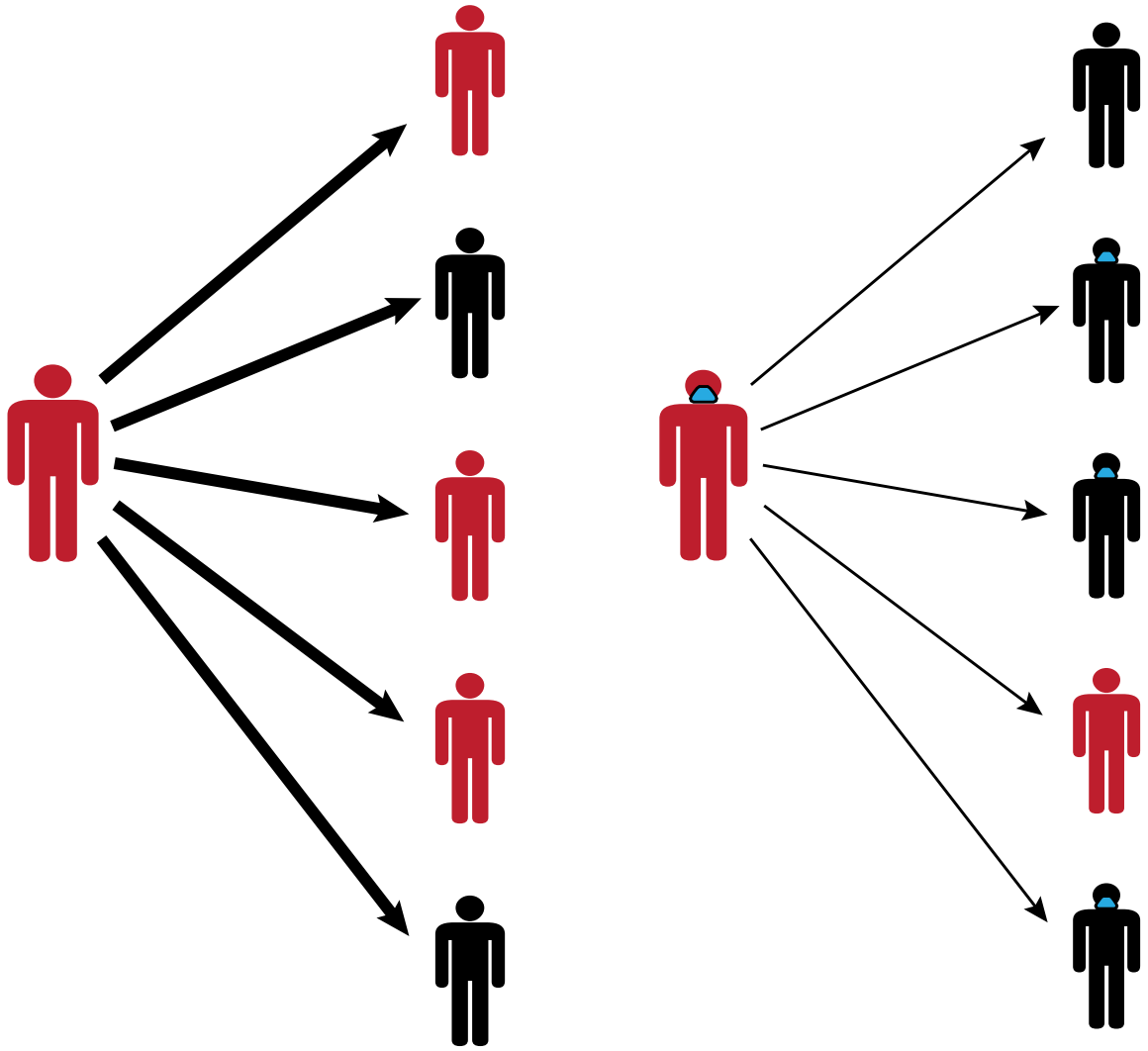


Reducing contacts

- mandated social distancing
- voluntary behavior change
- symptom screening
- test-trace-isolate programs
- regular prophylactic testing



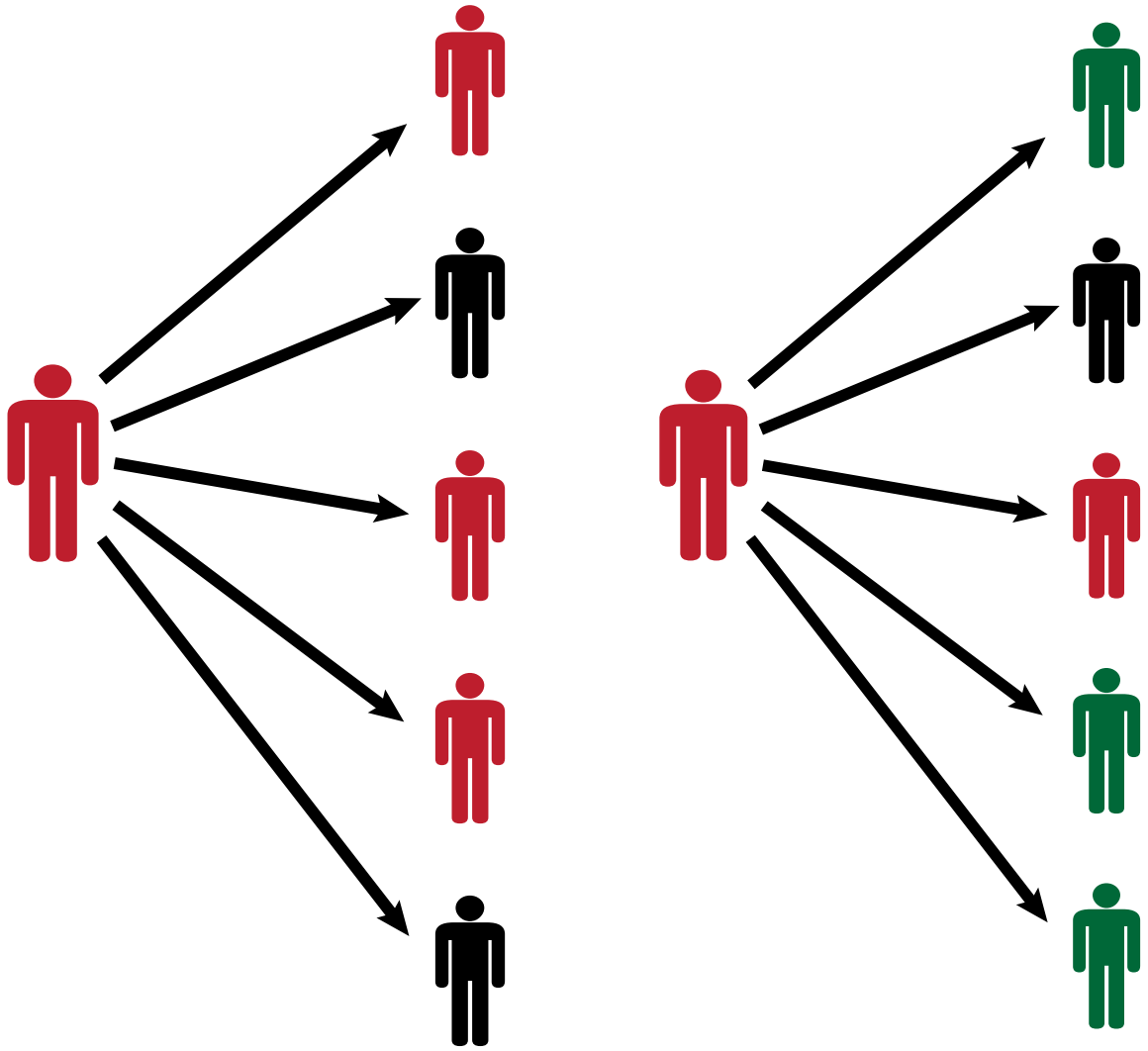
The three modes of control



Reducing per contact risk

- masks
- moving interactions outside
- ventilation
- hand washing

The three modes of control



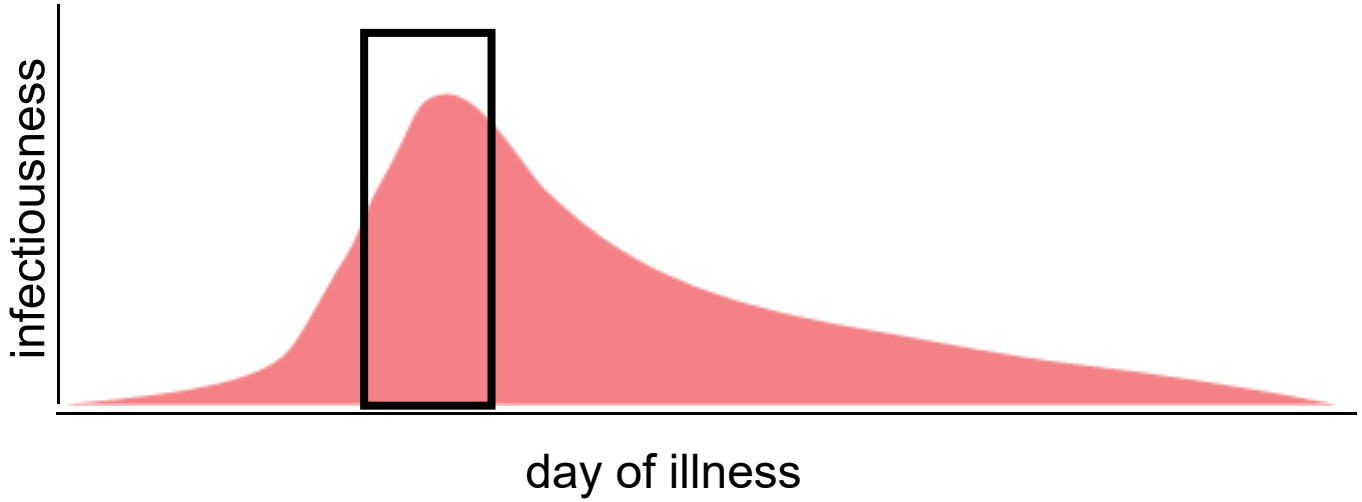
Reducing susceptibility

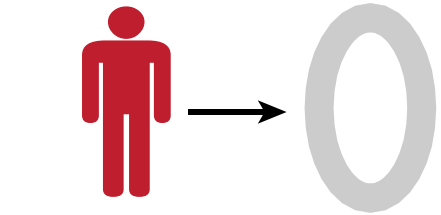
- vaccination
- prophylactic treatment
- natural infection*

* - to be avoided

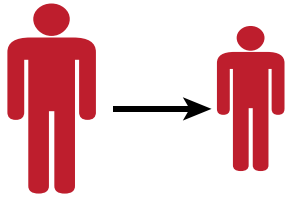
Why are 8% of people responsible for 80% of transmission?

How did you spend your most infectious day?

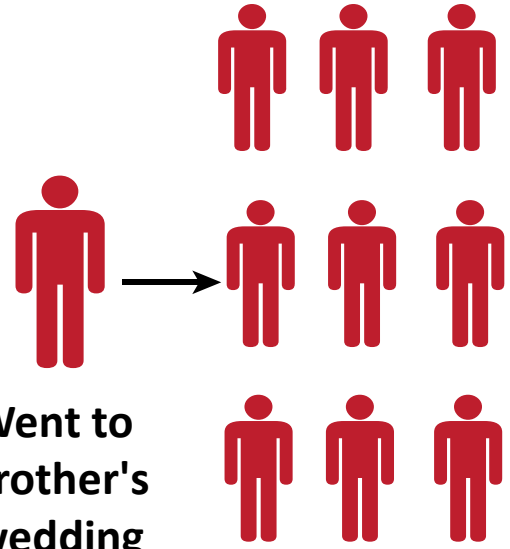




Watched TV

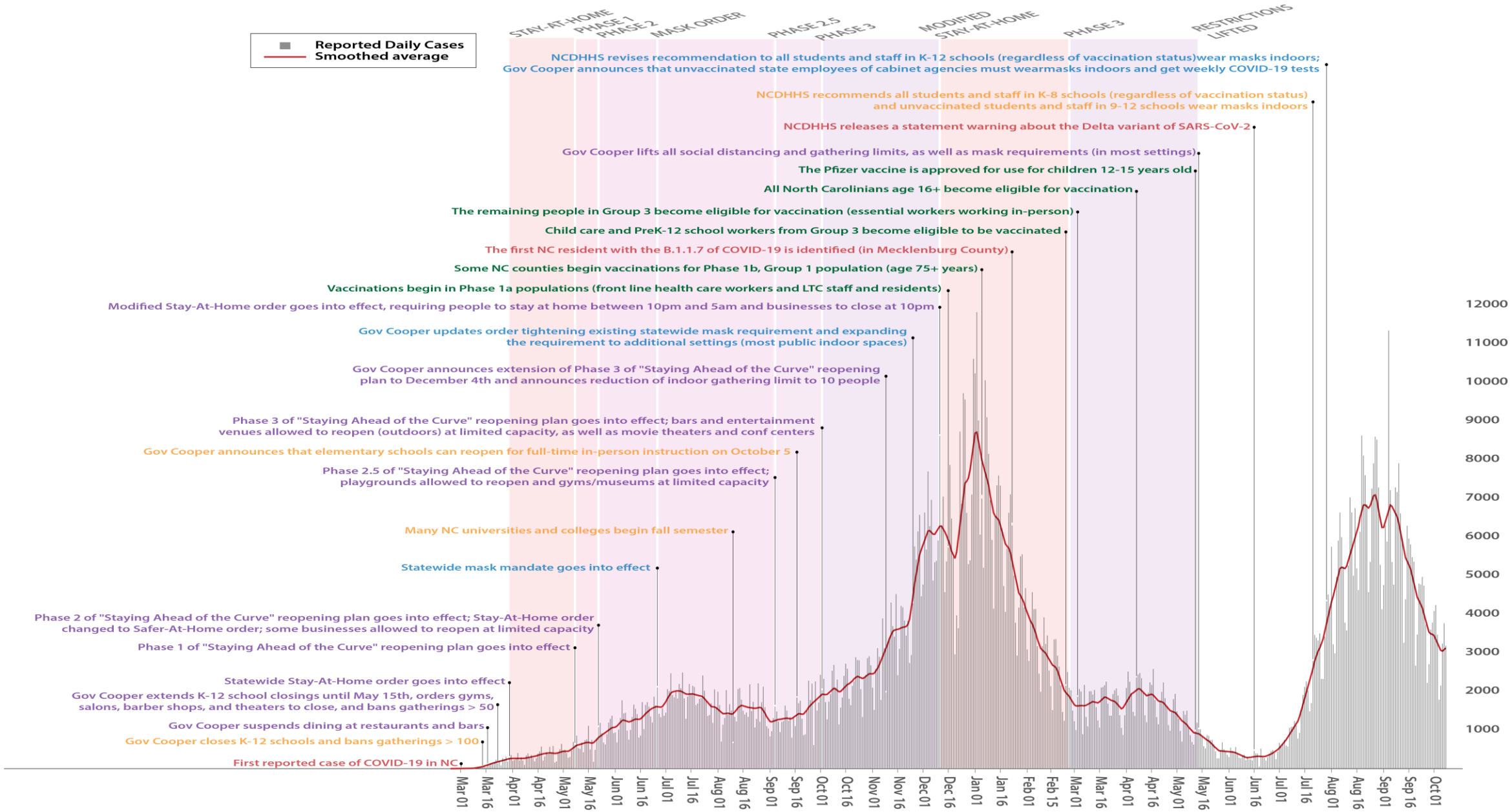


Went to work



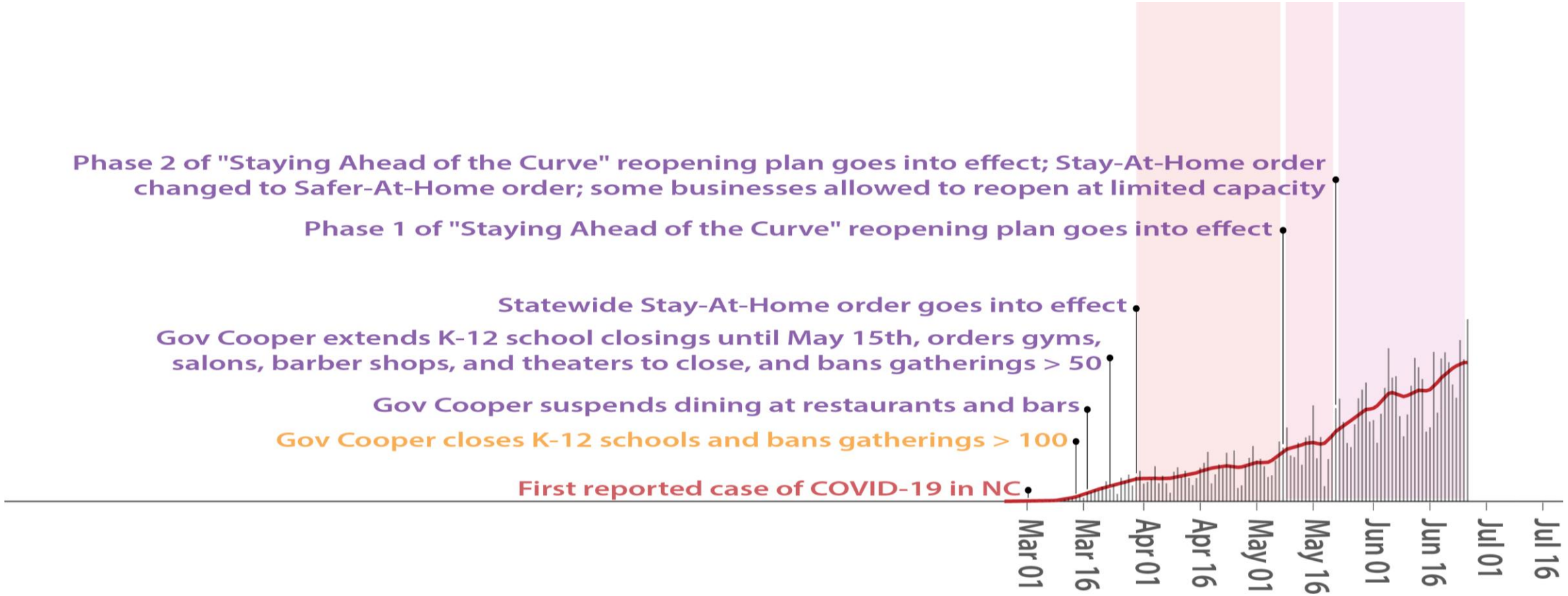
Went to brother's wedding

An annotated review of the COVID-19 pandemic in North Carolina



adapted from nc-covid.org with thanks to Paul Delamater

Spring 2020: Uncertainty and Lockdowns



Uncertainty in early 2020

- Infection fatality rate:
  - 1 in 1,000 to 1 in 60

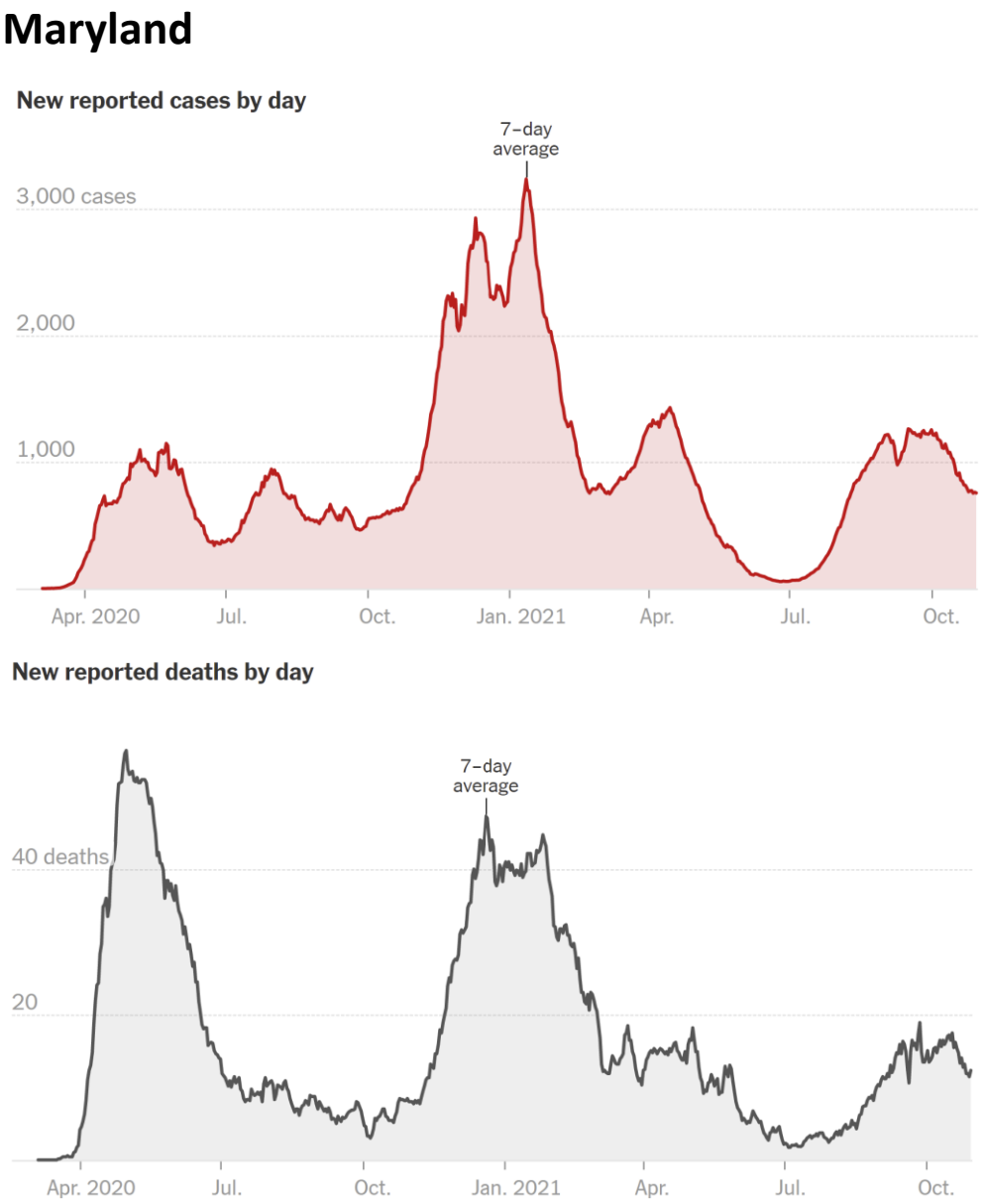
- Transmission efficiency
  - R_0 in range 2-4
  - relative roles of different modes of transmission

- Relative susceptibility of children

- When would we have a vaccine and how good would it be?

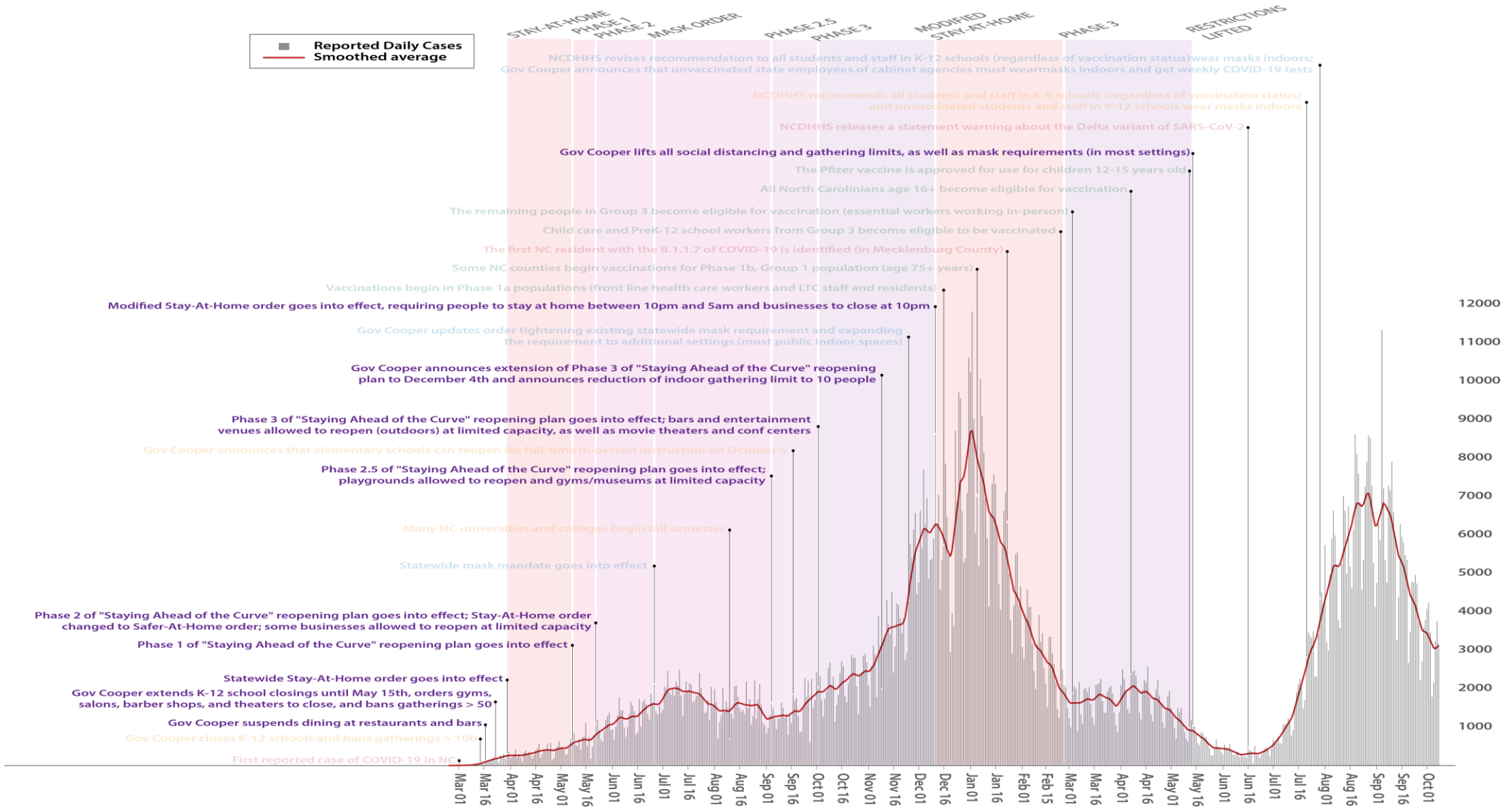
The Silent Epidemic

- Most cases have mild symptoms.
- Deaths and hospitalizations are delayed weeks or longer after infection.
- Testing in the United States was severely limited in the early stages of the pandemic.
- Hence early spread went largely undetected, and many states likely had large spring epidemics not reflected in their case numbers.



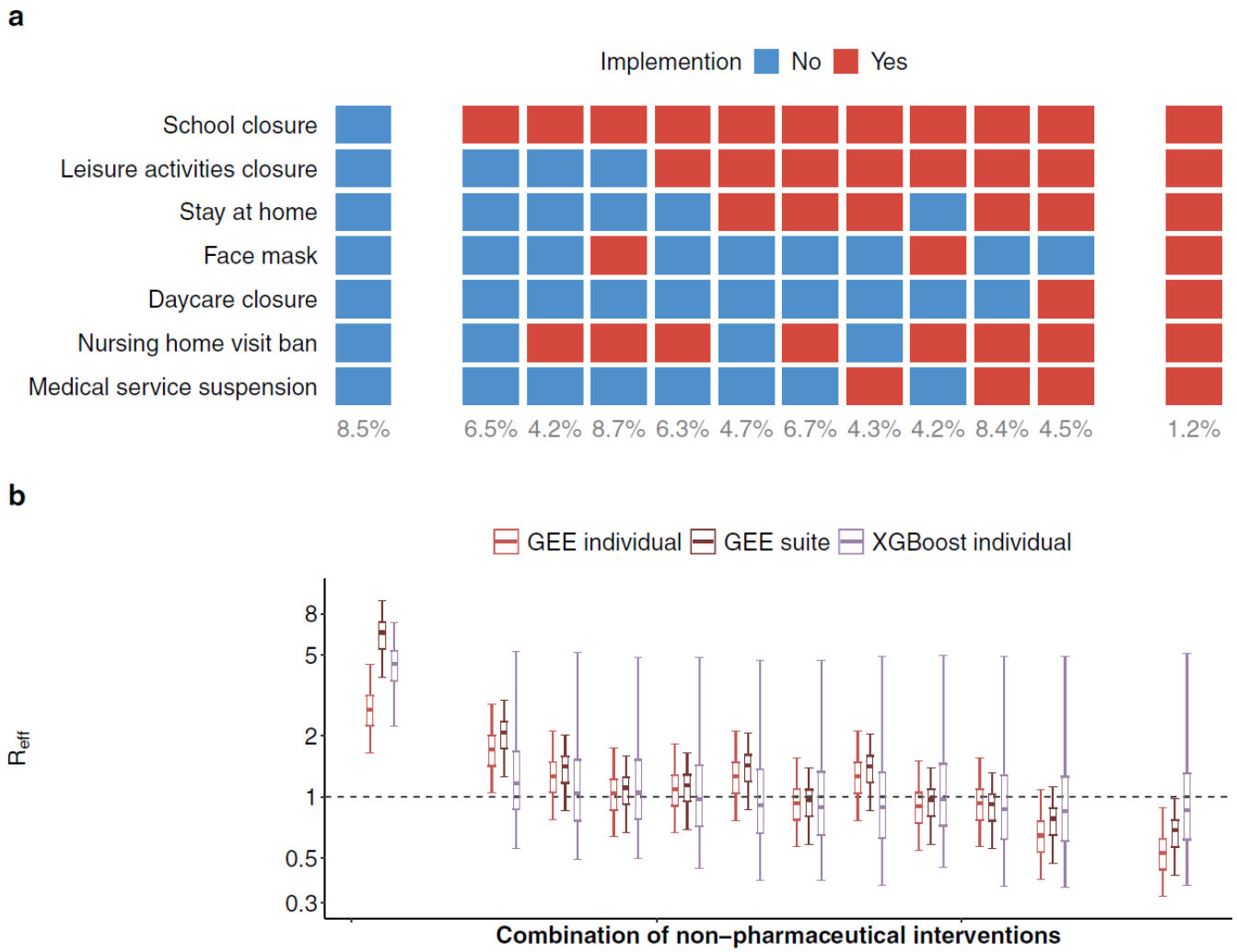
https://www.nytimes.com/interactive/2021/us/maryland-covid-cases.html

The impact of lockdowns and social distancing



How well do “lockdowns” work?

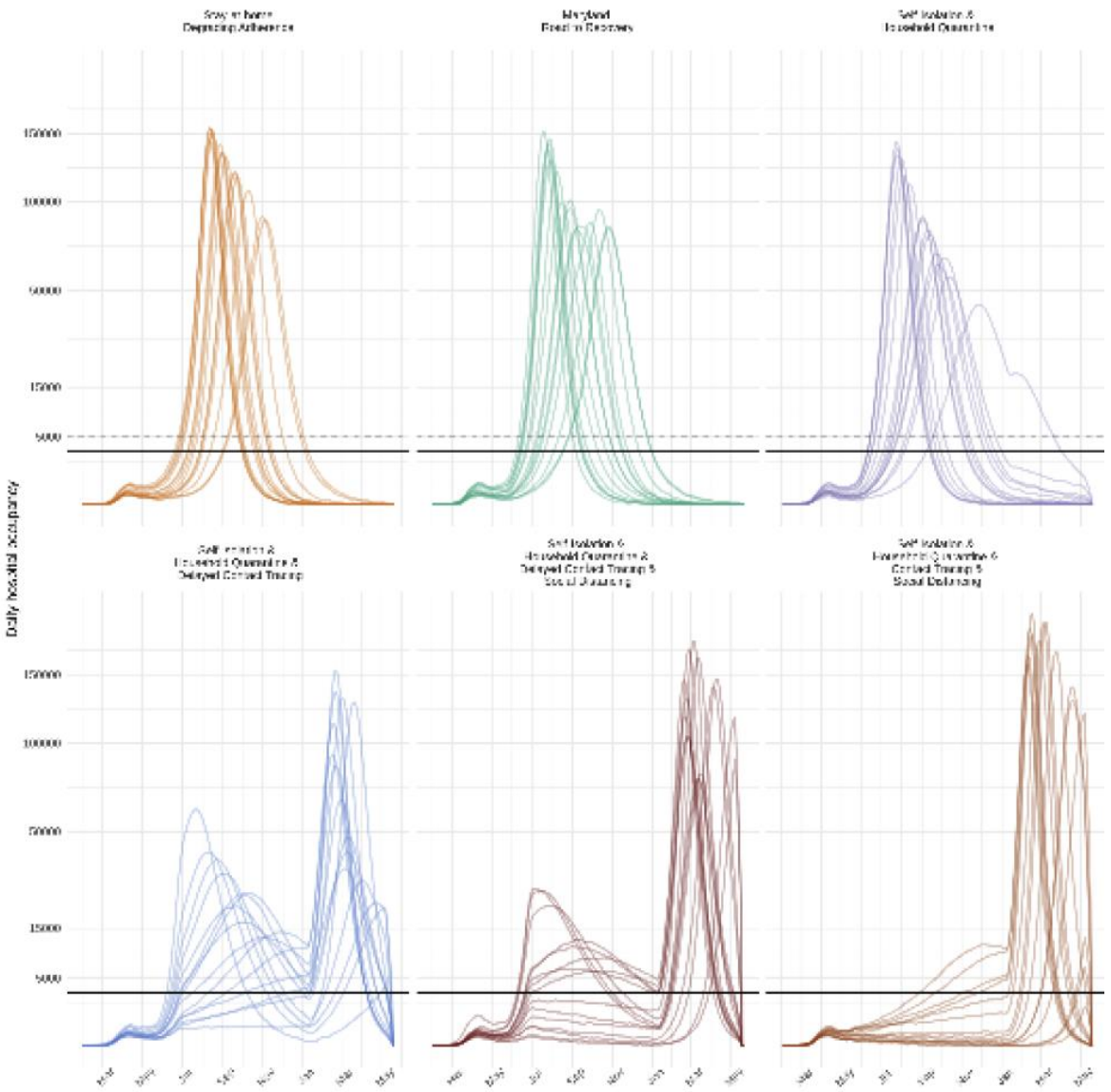
- The vast majority of studies show that layered social distancing measures such as business closures, limits on gatherings and stay at home orders, reduce COVID-19 spread.
- Multiple measures are needed to contain COVID-19 spread.
- Impacts are delayed.
- Globally, sustained lockdowns have universally resulted in “turning the curve” of the local epidemic.



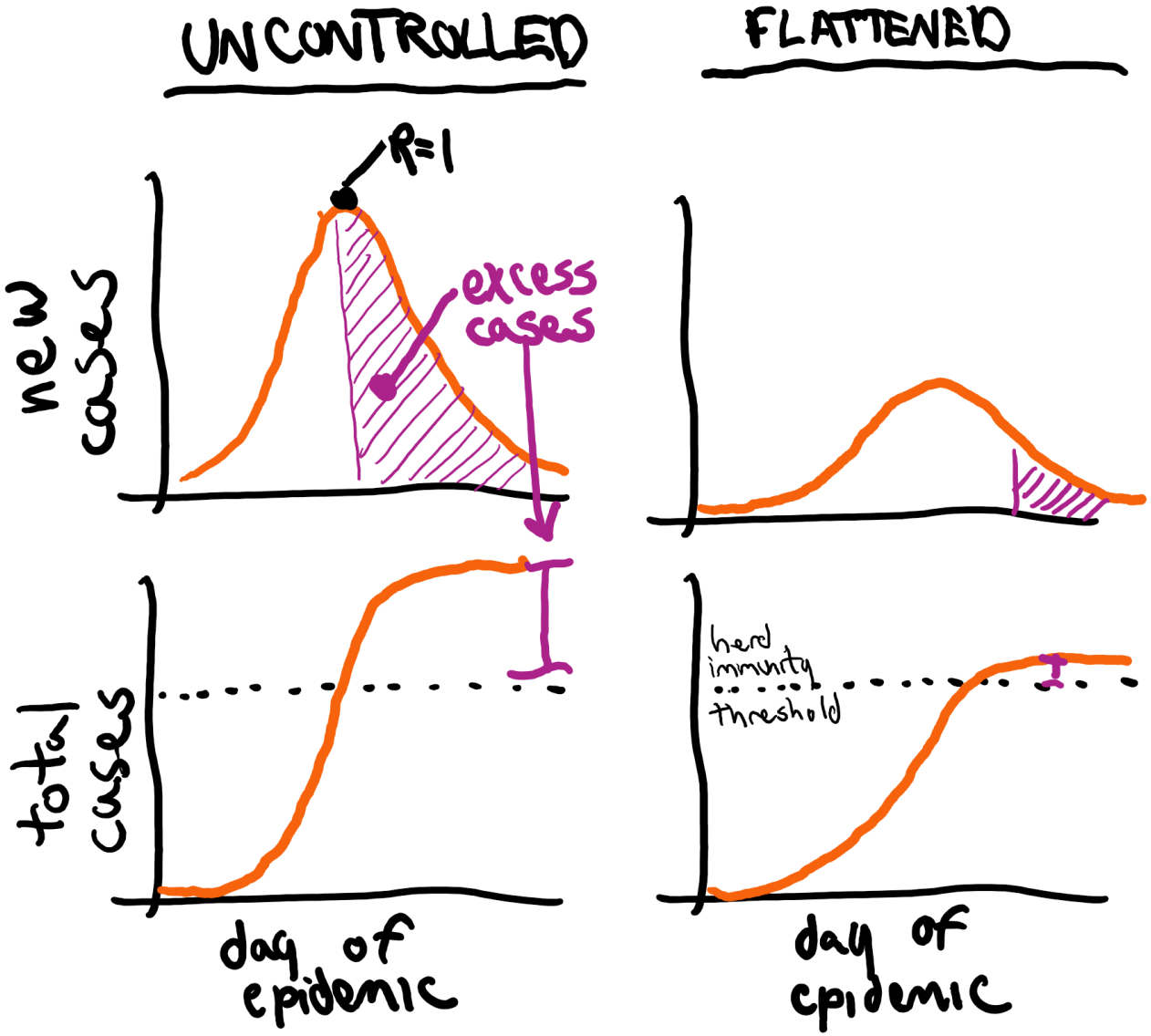
Yang et al. Nature Communications 2021

Kicking the can down the road?

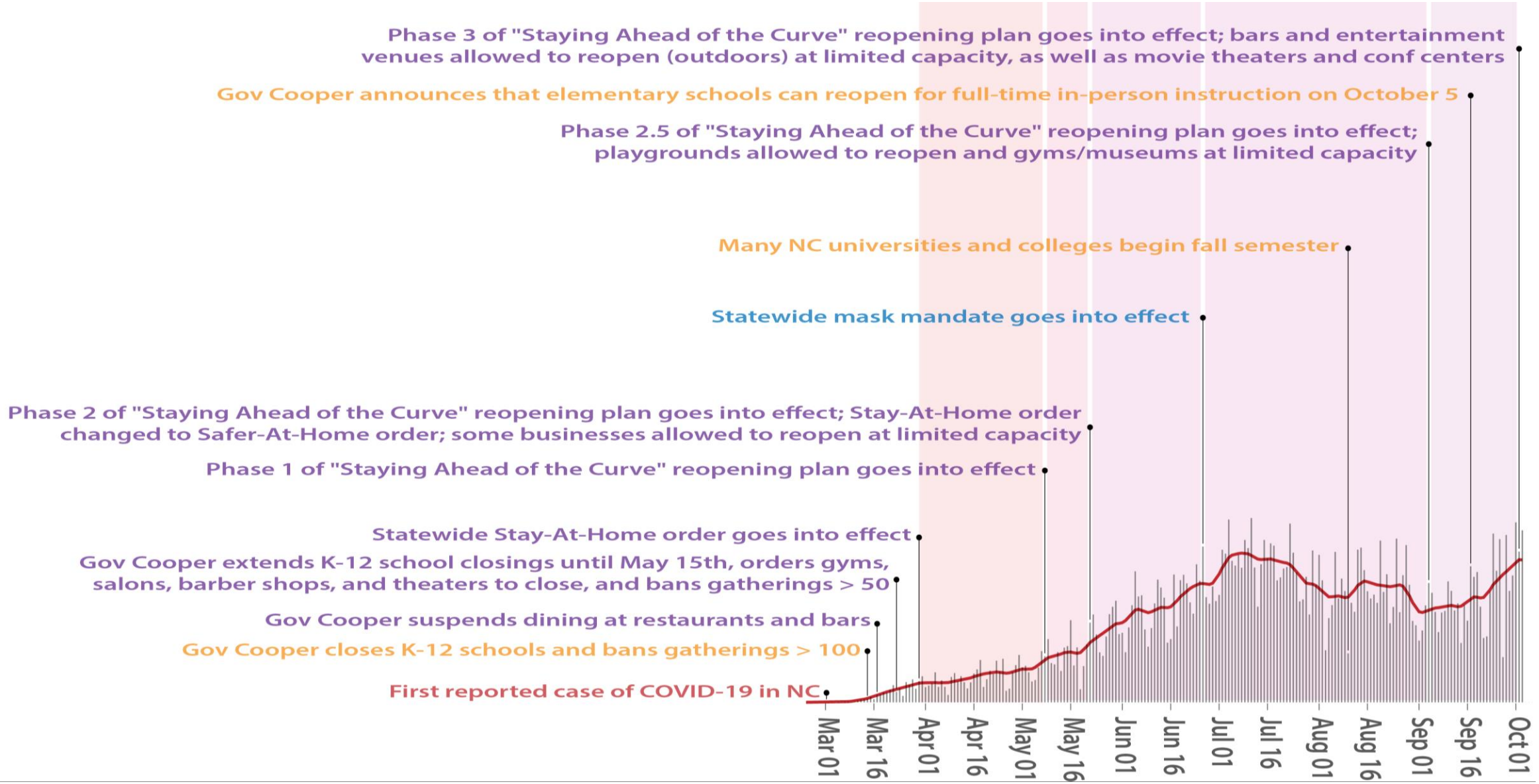
- Highly effective control measures stop the accumulation of immunity in the population.
- Hence they the population remains susceptible to outbreaks once they are lifted.
- They buy critical time for building hospital capacity, improving treatment, and development of a vaccine.



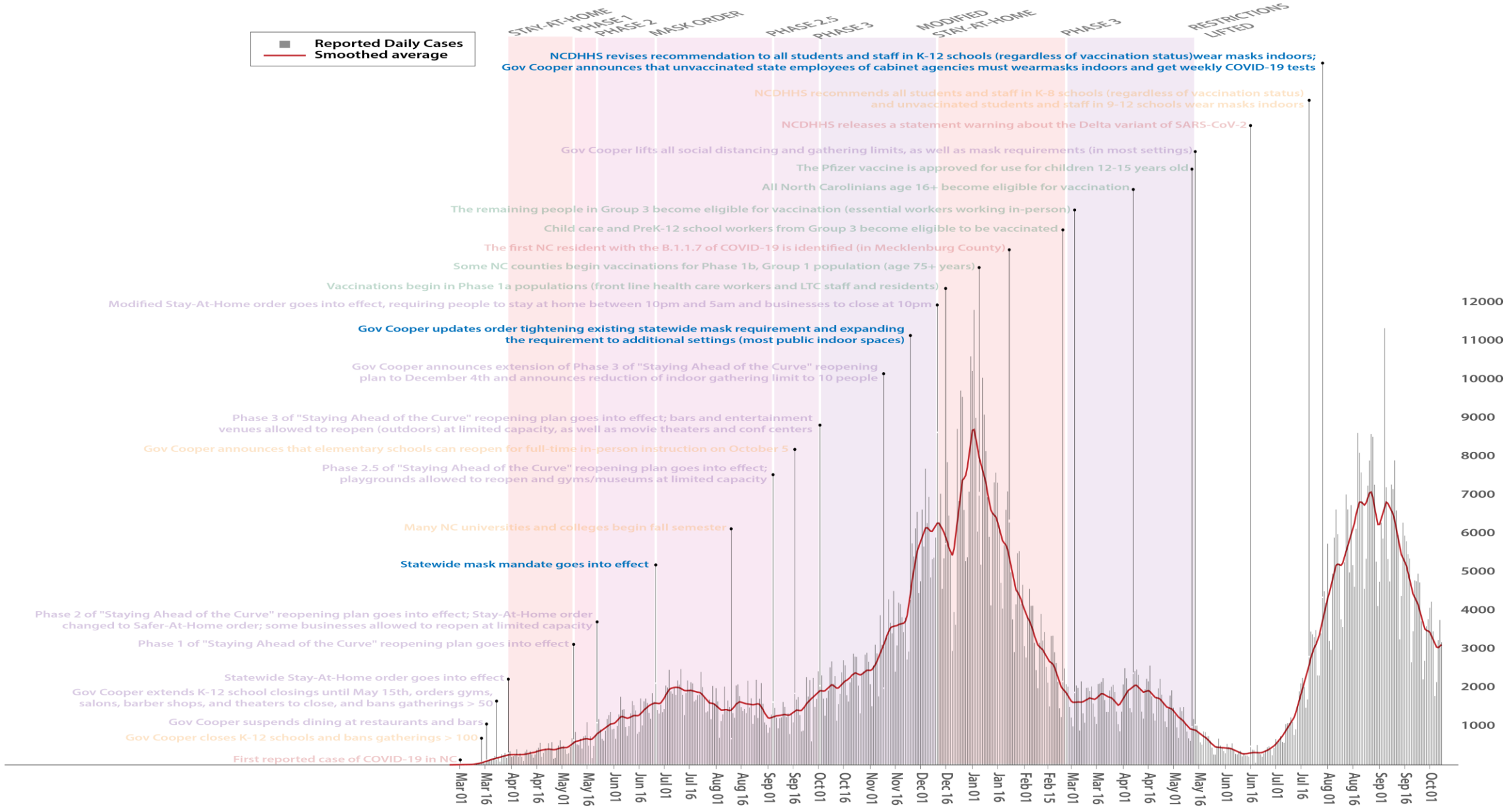
Herd immunity and flattening the curve.



Summer 2020: A brief respite



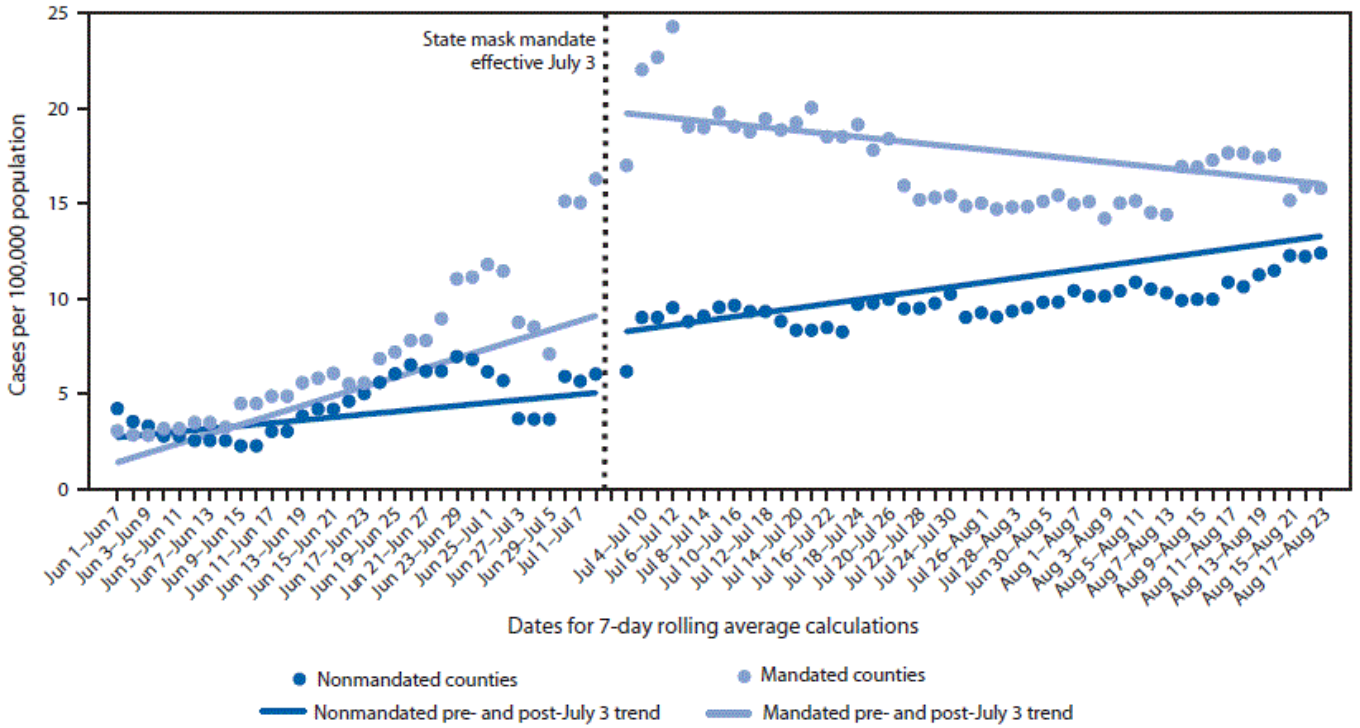
The impact of masking?

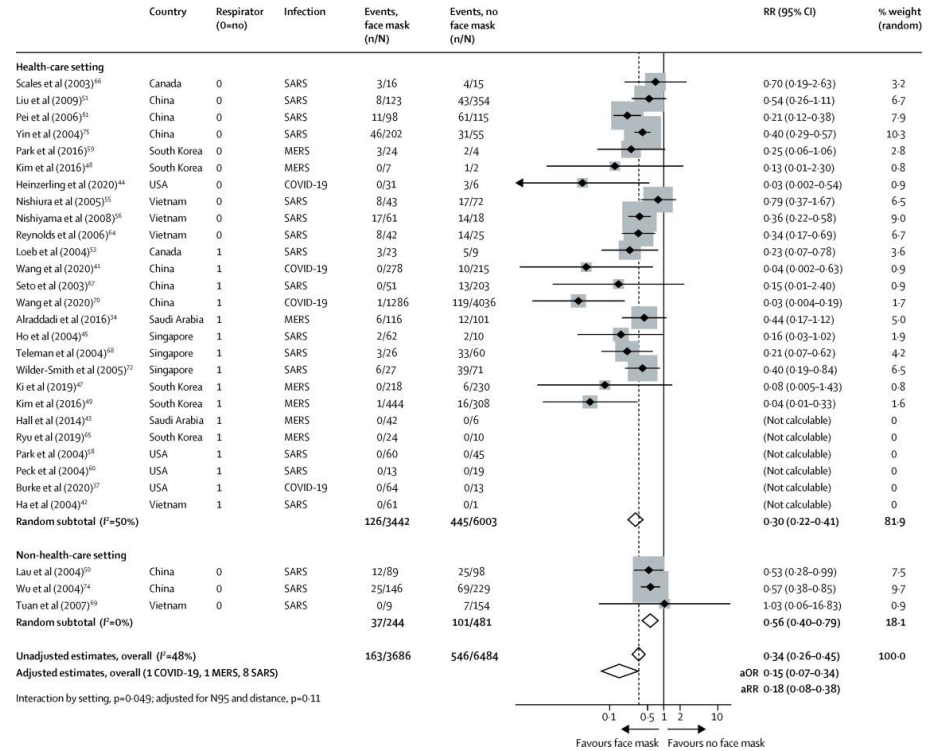


The impact of masks

- Masks decrease an individuals chance of being infected by 60-70% with strong adherence.

- Masking mandates decrease the efficiency of community COVID-19 transmission by 10-20% (US Spring/Summer 2020 data)

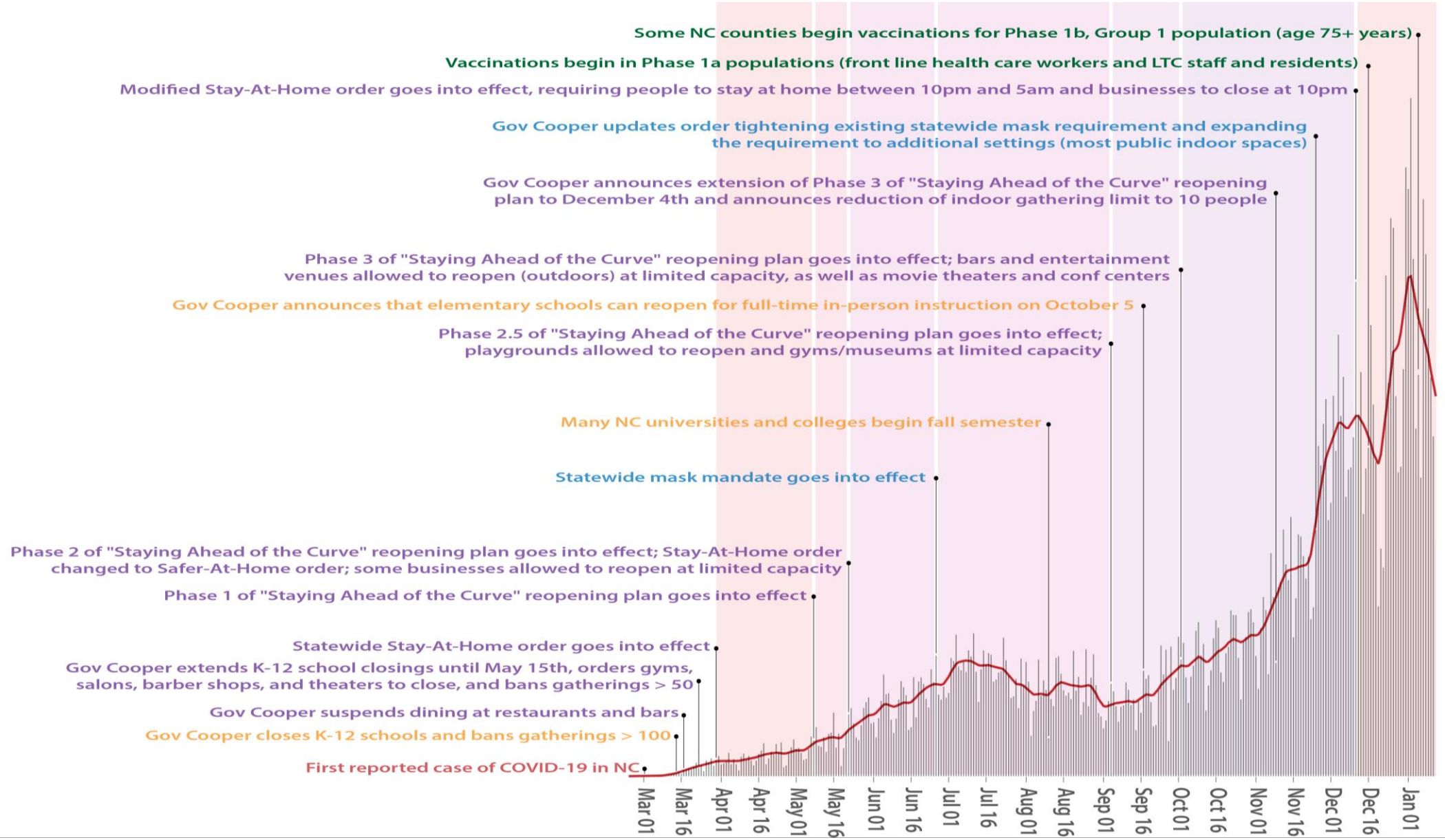




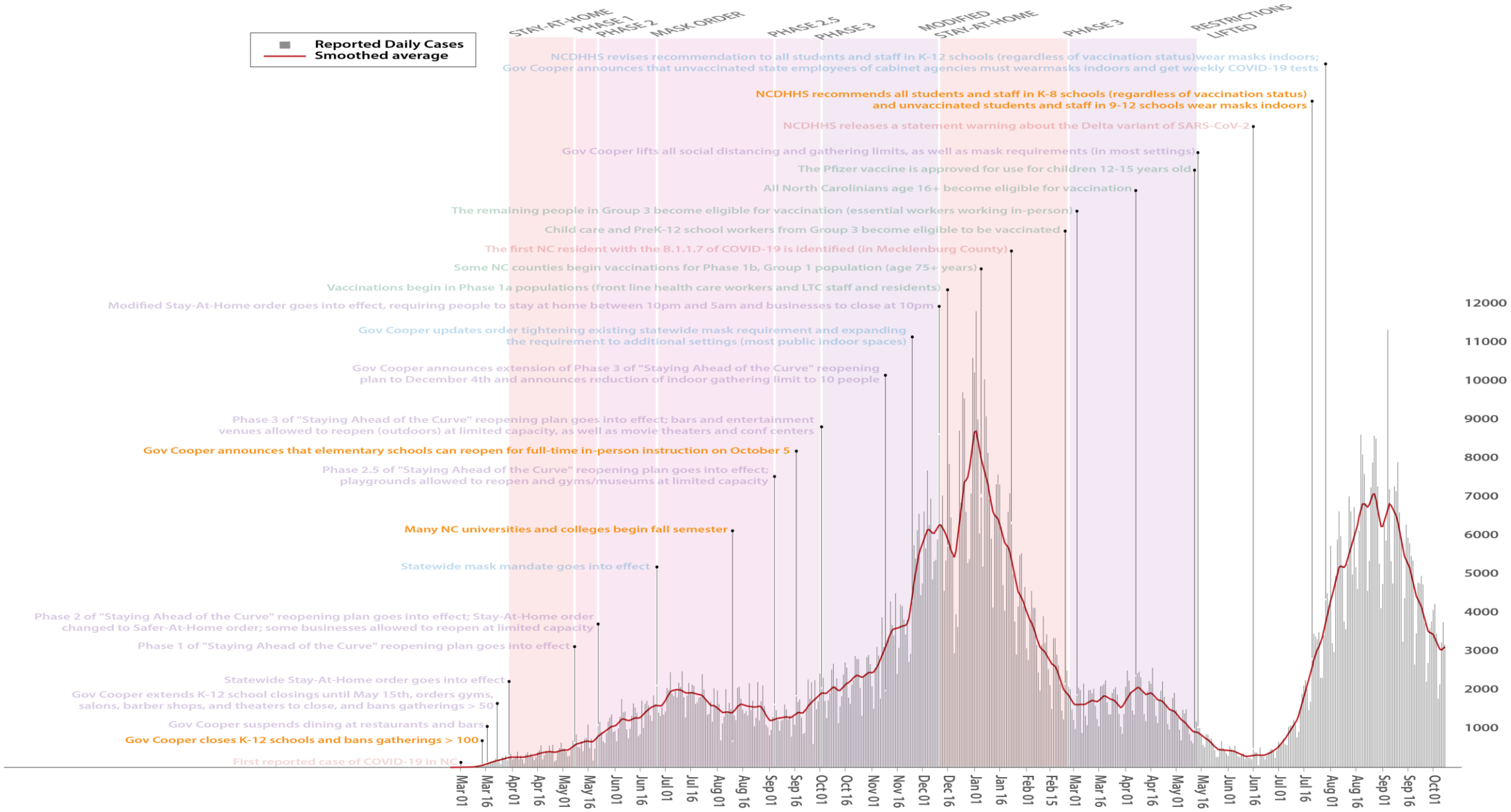
	Country	Respirator (0=no)	Infection	Events, face mask (n/N)	Events, no face mask (n/N)	RR (95% CI)	% weight (random)
Health-care setting							
Scales et al (2003)[66]	Canada	0	SARS	3/16	4/15	0·70 (0·19–2·63)	3·2
Liu et al (2009)[51]	China	0	SARS	8/123	43/354	0·54 (0·26–1·11)	6·7
Pei et al (2006)[41]	China	0	SARS	11/98	61/115	0·21 (0·12–0·38)	7·9
Yin et al (2004)[75]	China	0	SARS	46/202	31/55	0·40 (0·29–0·57)	10·3
Park et al (2016)[59]	South Korea	0	MERS	3/24	2/4	0·25 (0·06–1·06)	2·8
Kim et al (2016)[48]	South Korea	0	MERS	0/7	1/2	0·13 (0·01–2·30)	0·8
Heinzerling et al (2020)[44]	USA	0	COVID-19	0/31	3/6	0·03 (0·002–0·54)	0·9
Nishiura et al (2005)[55]	Vietnam	0	SARS	8/43	17/72	0·79 (0·37–1·67)	6·5
Nishiyama et al (2008)[56]	Vietnam	0	SARS	17/61	14/18	0·36 (0·22–0·58)	9·0
Reynolds et al (2006)[64]	Vietnam	0	SARS	8/42	14/25	0·34 (0·17–0·69)	6·7
Loeb et al (2004)[53]	Canada	1	SARS	3/23	5/9	0·23 (0·07–0·78)	3·6
Wang et al (2020)[43]	China	1	COVID-19	0/278	10/215	0·04 (0·002–0·63)	0·9
Seto et al (2003)[67]	China	1	SARS	0/51	13/203	0·15 (0·01–2·40)	0·9
Wang et al (2020)[70]	China	1	COVID-19	1/1286	119/4036	0·03 (0·004–0·19)	1·7
Alraddadi et al (2016)[74]	Saudi Arabia	1	MERS	6/116	12/101	0·44 (0·17–1·12)	5·0
Ho et al (2004)[45]	Singapore	1	SARS	2/62	2/10	0·16 (0·03–1·02)	1·9
Teleman et al (2004)[68]	Singapore	1	SARS	3/26	33/60	0·21 (0·07–0·62)	4·2
Wilder-Smith et al (2005)[72]	Singapore	1	SARS	6/27	39/71	0·40 (0·19–0·84)	6·5
Ki et al (2019)[47]	South Korea	1	MERS	0/218	6/230	0·08 (0·005–1·43)	0·8
Kim et al (2016)[49]	South Korea	1	MERS	1/444	16/308	0·04 (0·01–0·33)	1·6
Hall et al (2014)[43]	Saudi Arabia	1	MERS	0/42	0/6	(Not calculable)	0
Ryu et al (2019)[65]	South Korea	1	MERS	0/24	0/10	(Not calculable)	0
Park et al (2004)[58]	USA	1	SARS	0/60	0/45	(Not calculable)	0
Peck et al (2004)[60]	USA	1	SARS	0/13	0/19	(Not calculable)	0
Burke et al (2020)[37]	USA	1	COVID-19	0/64	0/13	(Not calculable)	0
Ha et al (2004)[42]	Vietnam	1	SARS	0/61	0/1	(Not calculable)	0
Random subtotal (I^2=50%)				**126/3442**	**445/6003**	**0·30 (0·22–0·41)**	**81·9**
Non-health-care setting							
Lau et al (2004)[50]	China	0	SARS	12/89	25/98	0·53 (0·28–0·99)	7·5
Wu et al (2004)[74]	China	0	SARS	25/146	69/229	0·57 (0·38–0·85)	9·7
Tuan et al (2007)[69]	Vietnam	0	SARS	0/9	7/154	1·03 (0·06–16·83)	0·9
Random subtotal (I^2=0%)				**37/244**	**101/481**	**0·56 (0·40–0·79)**	**18·1**
Unadjusted estimates, overall (I^2=48%)				**163/3686**	**546/6484**	**0·34 (0·26–0·45)**	**100·0**
Adjusted estimates, overall (1 COVID-19, 1 MERS, 8 SARS)						**aOR 0·15 (0·07–0·34)**	
						aRR 0·18 (0·08–0·38)	

Interaction by setting, p=0·049; adjusted for N95 and distance, p=0·11

Fall 2020 to Winter 2021: The winter surge

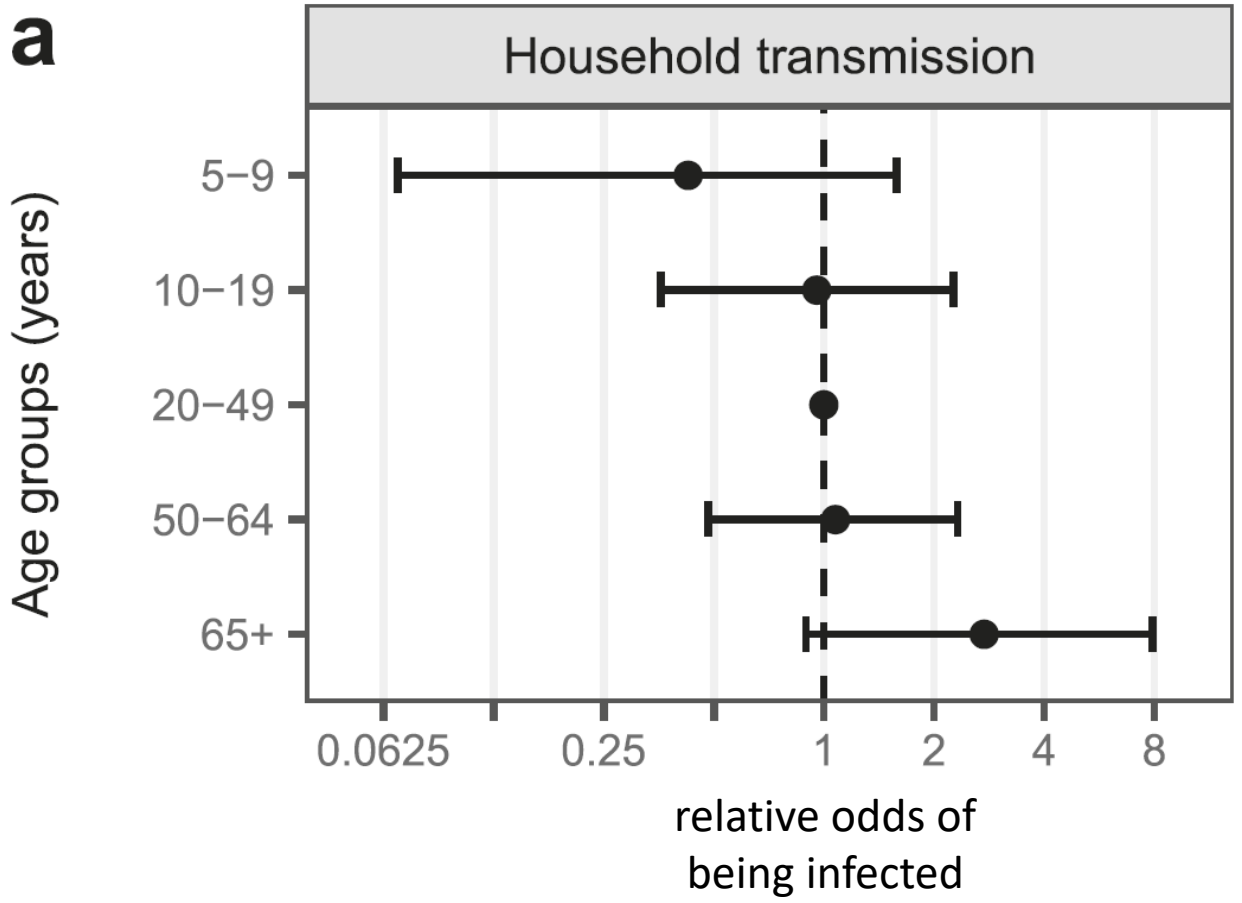


Schools and COVID-19 Transmission



Schools and COVID-19 Transmission

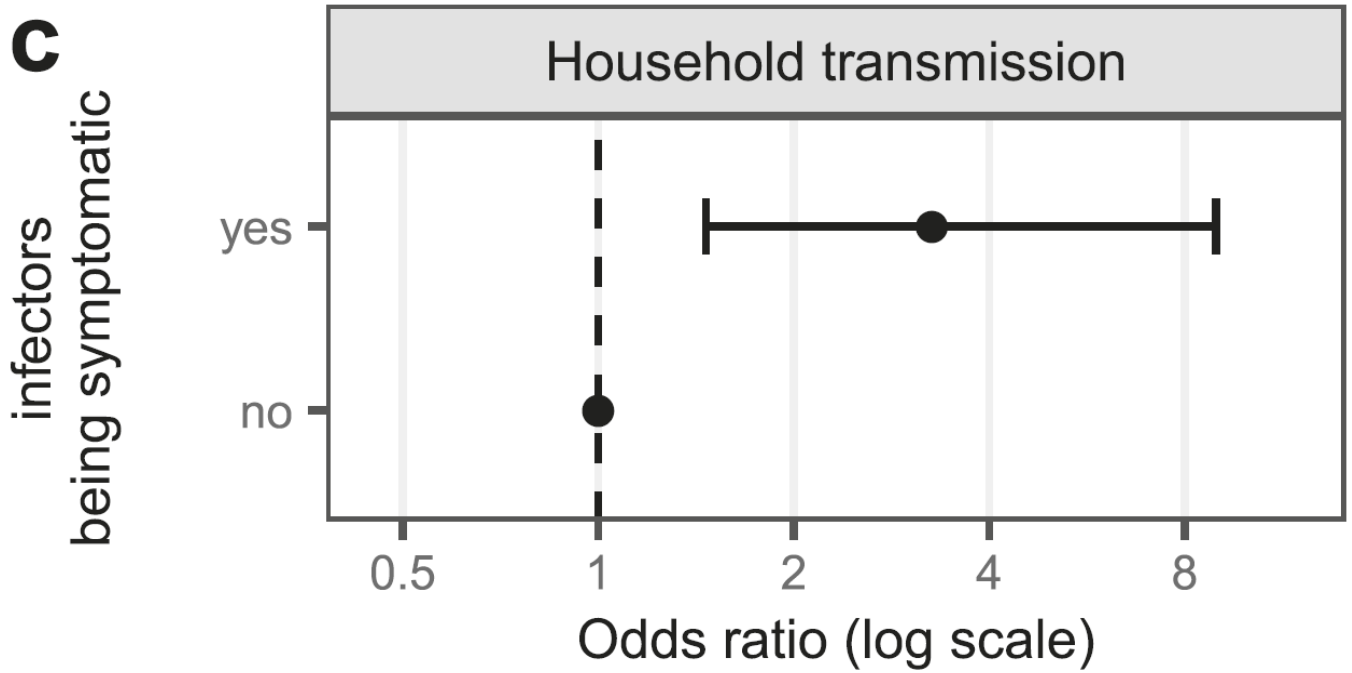
- For the original strain children are half as likely to get infected if exposed than adults.
- Children are less likely get sick if infected.
- Unclear if children are less likely to transmit if symptomatic.
- Unclear if this has changed with Alpha and Delta variants.



Bi et al., Nature Communications 2021

Schools and COVID-19 Transmission

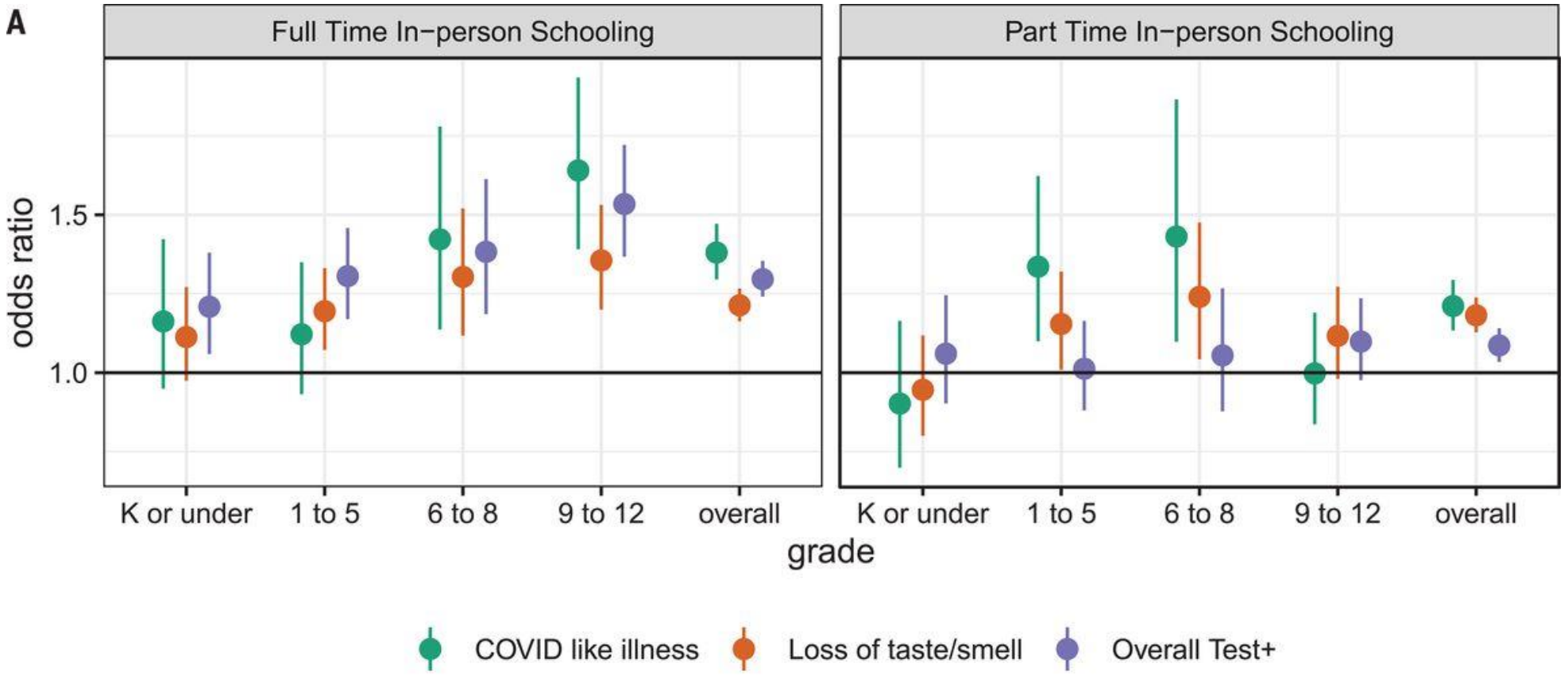
- For the original strain children are half as likely to get infected if exposed than adults.
- Children are less likely get sick if infected.
- Unclear if children are less likely to transmit if symptomatic.
- Unclear if this has changed with Alpha and Delta variants.



Bi et al., Nature Communications 2021

Schools and COVID-19 Transmission

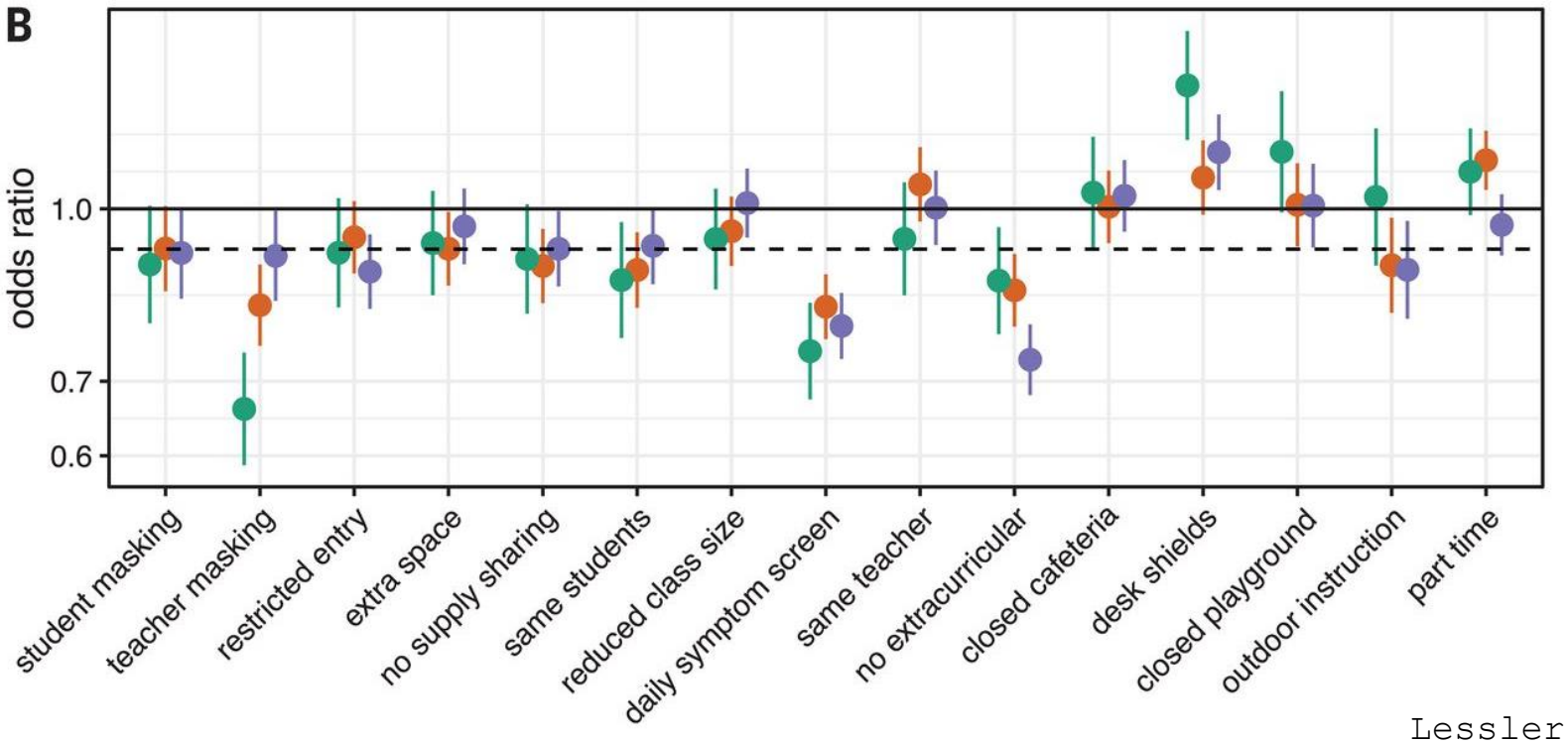
- **People living with a child in in-person** school are around 30% more likely to report COVID-19 related outcomes than those living with a child not in in-person school.



Lessler et al., Science 2021

Schools and COVID-19 Transmission

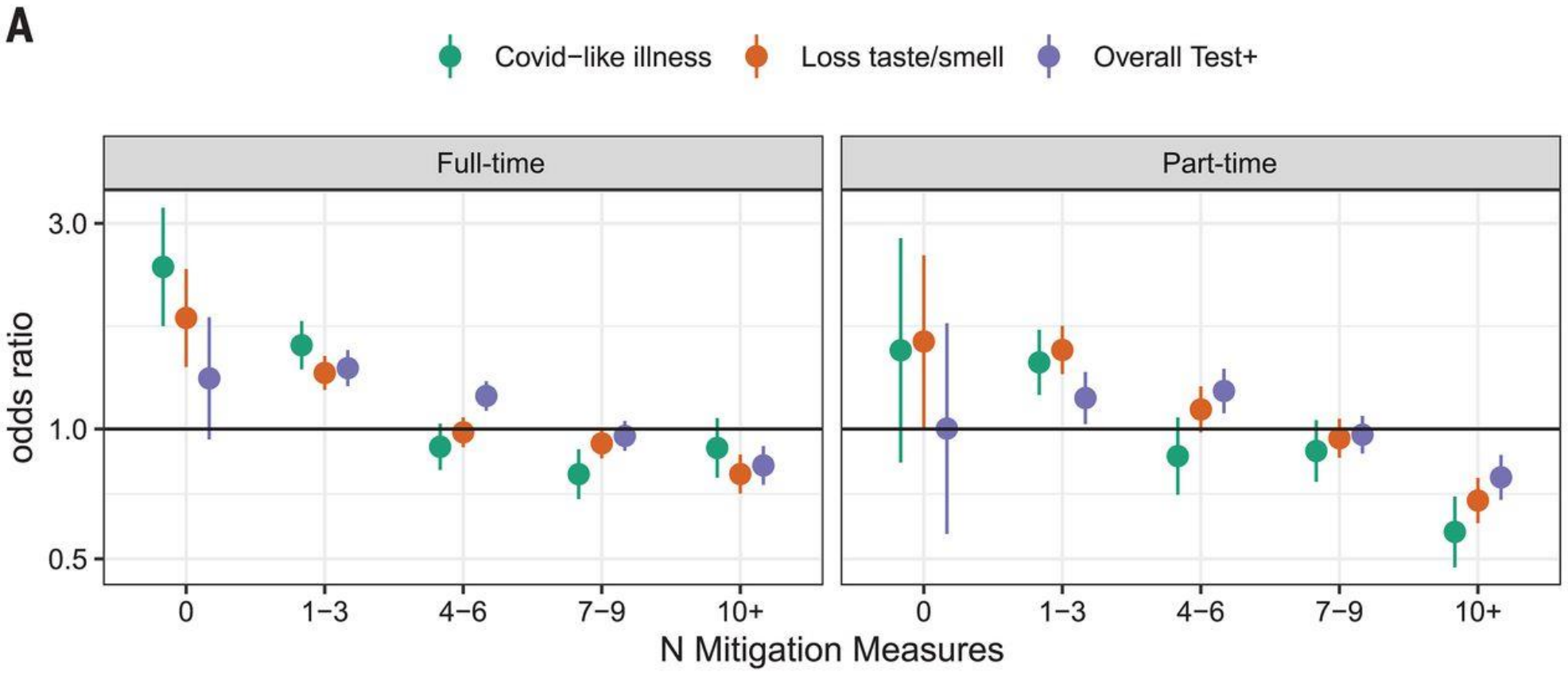
- Each additional mitigation measure put in place leads to about an 8% reduction in the chances of a household member reporting a COVID-19 related outcome.
- Teacher masking, daily symptom screens and cancelling extracurricular activities stand out as effective



Lessler et al., Science 2021

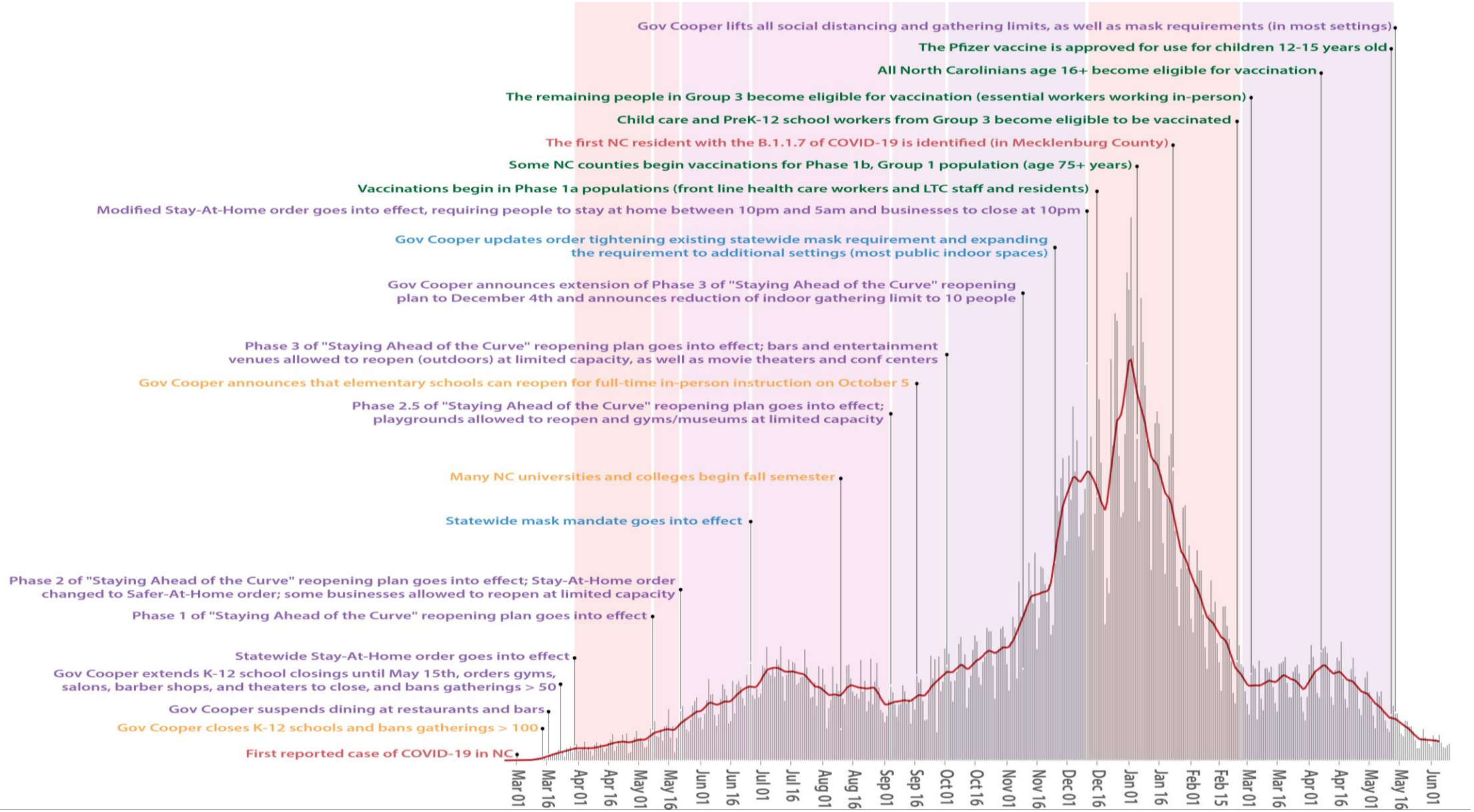
Schools and COVID-19 Transmission

- Once 7+ mitigation measures are in place there is no excess risk of reporting COVID-19 related outcomes among household members of kids attending in-person school.

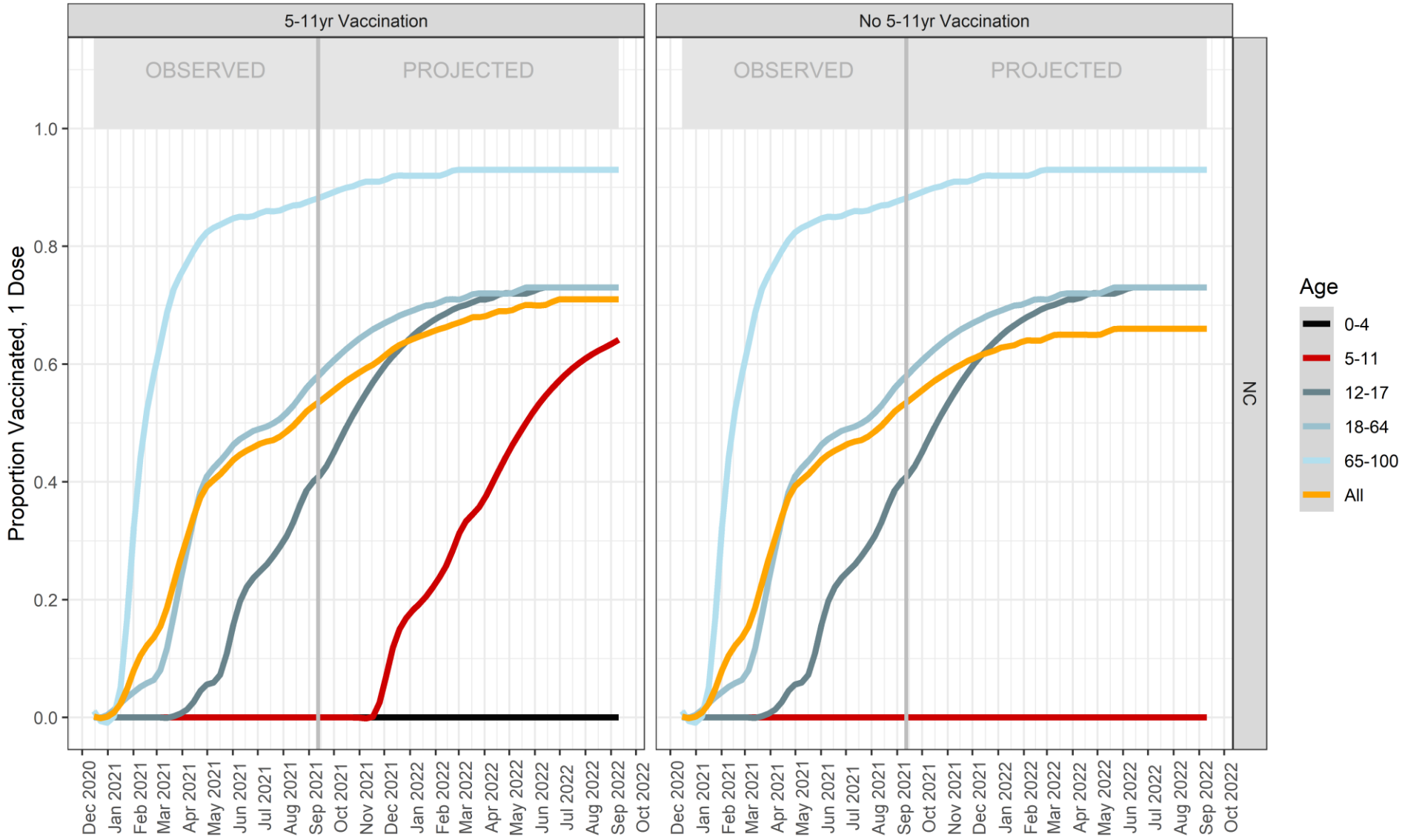


Lessler et al., Science 2021

Spring to Summer 2021: Vaccination and Decline



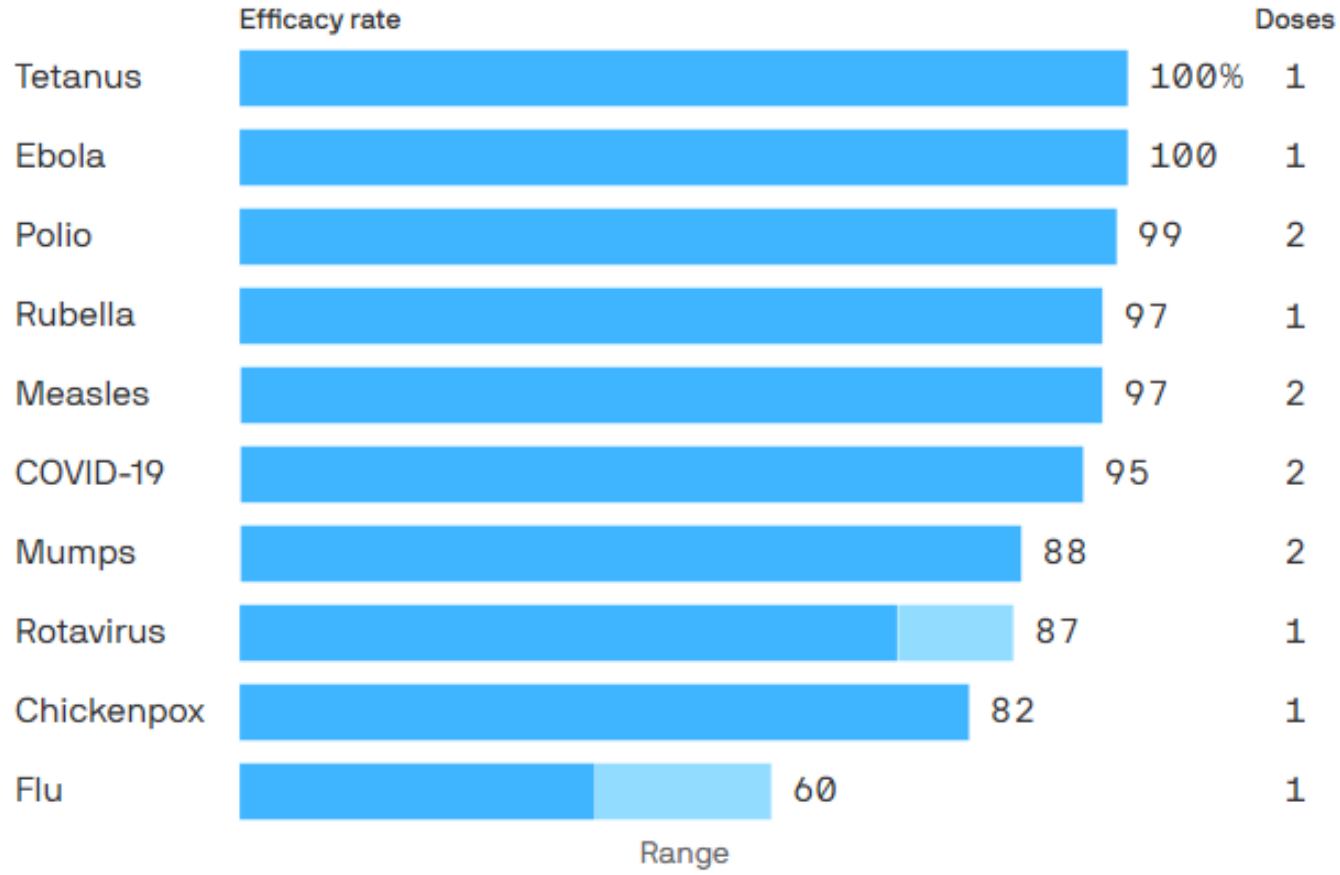
Past and projected vaccination rates in NC



How well does the vaccine work?

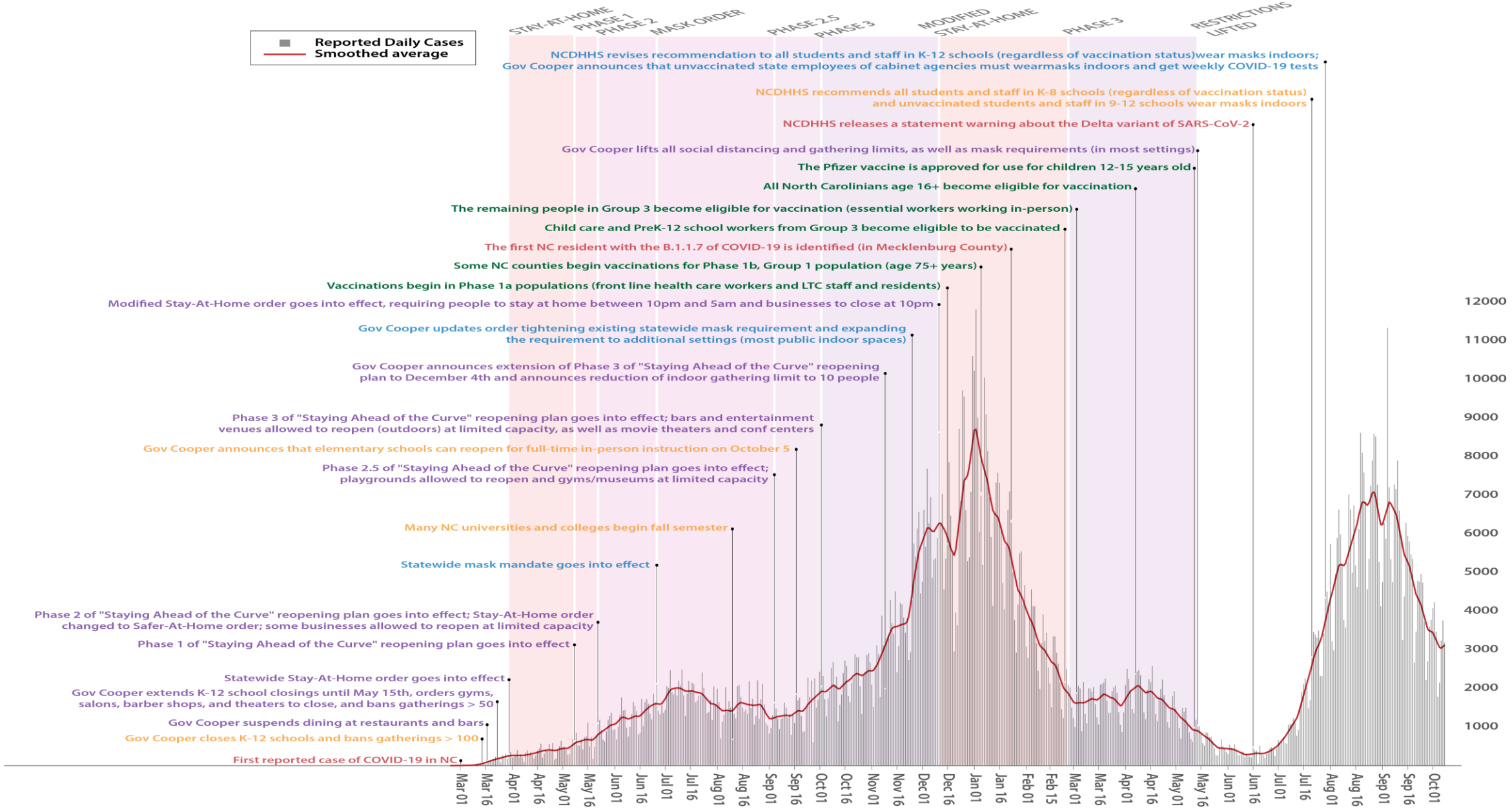
mRNA vaccines are:

- > 90% effective against hospitalization and death
- >70% effective against infection
- Declines as we get further out from vaccination
- Slightly less effective in those 65 or older.



Data: CDC, Moderna and Pfizer; Note: Flu vaccine based on yearly average from 2009-2019. Moderna and Pfizer coronavirus vaccine efficacy based on early clinical trial data. Chart: Sara Wise/Axios

Summer to Fall 2021: The Delta Wave

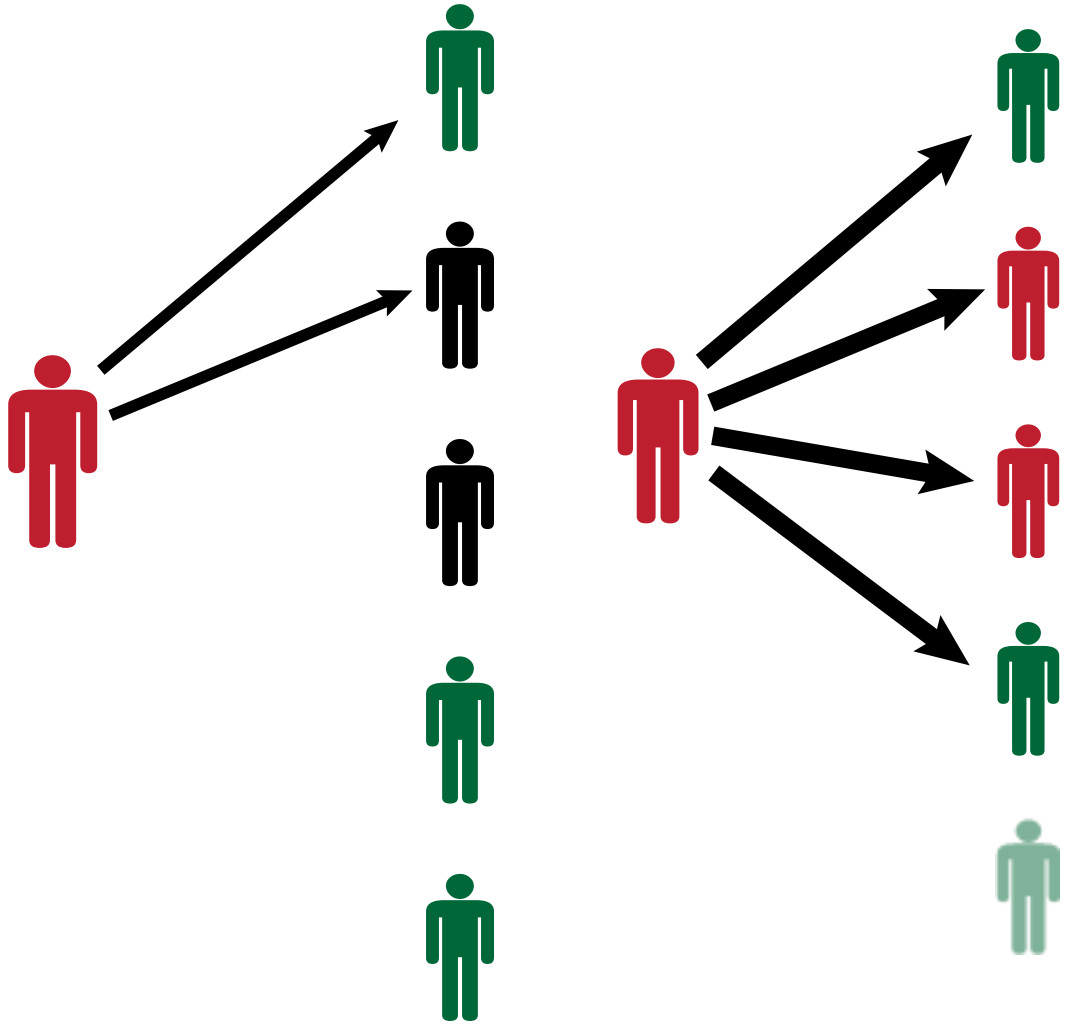


Why has Delta been so bad?

- Delta is about 1.5 times as transmissible as Alpha and over twice as transmissible as the original strain.

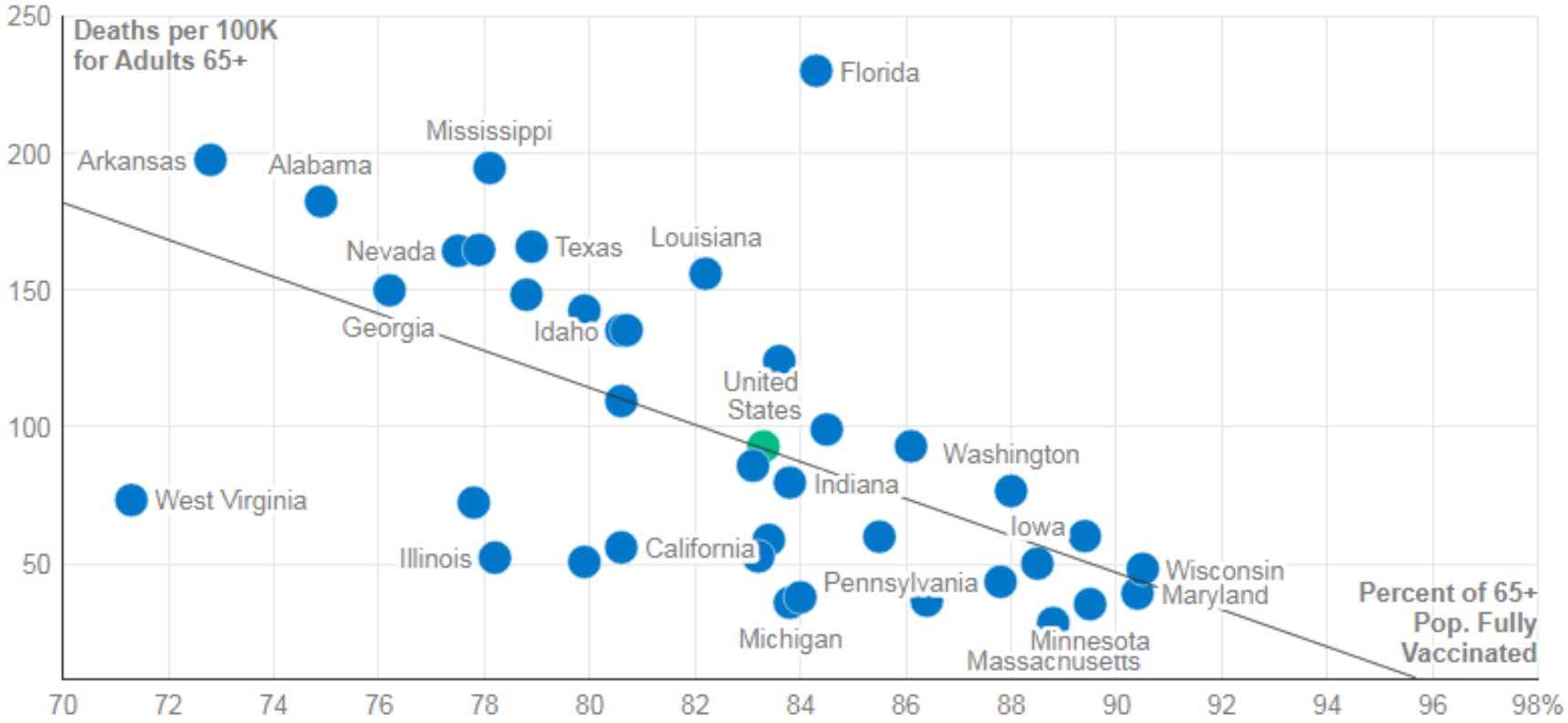
- Delta's emergence coincided with reductions in mandated control measures and voluntary changes in behavior.

- Some reductions in vaccine efficacy associated with the risk of Delta.



Vaccines blunt the impact of Delta

COVID-19 deaths for adults 65 and older per 100,000 between July 1, 2021 and September 25, 2021, among the 65 and older population of each state



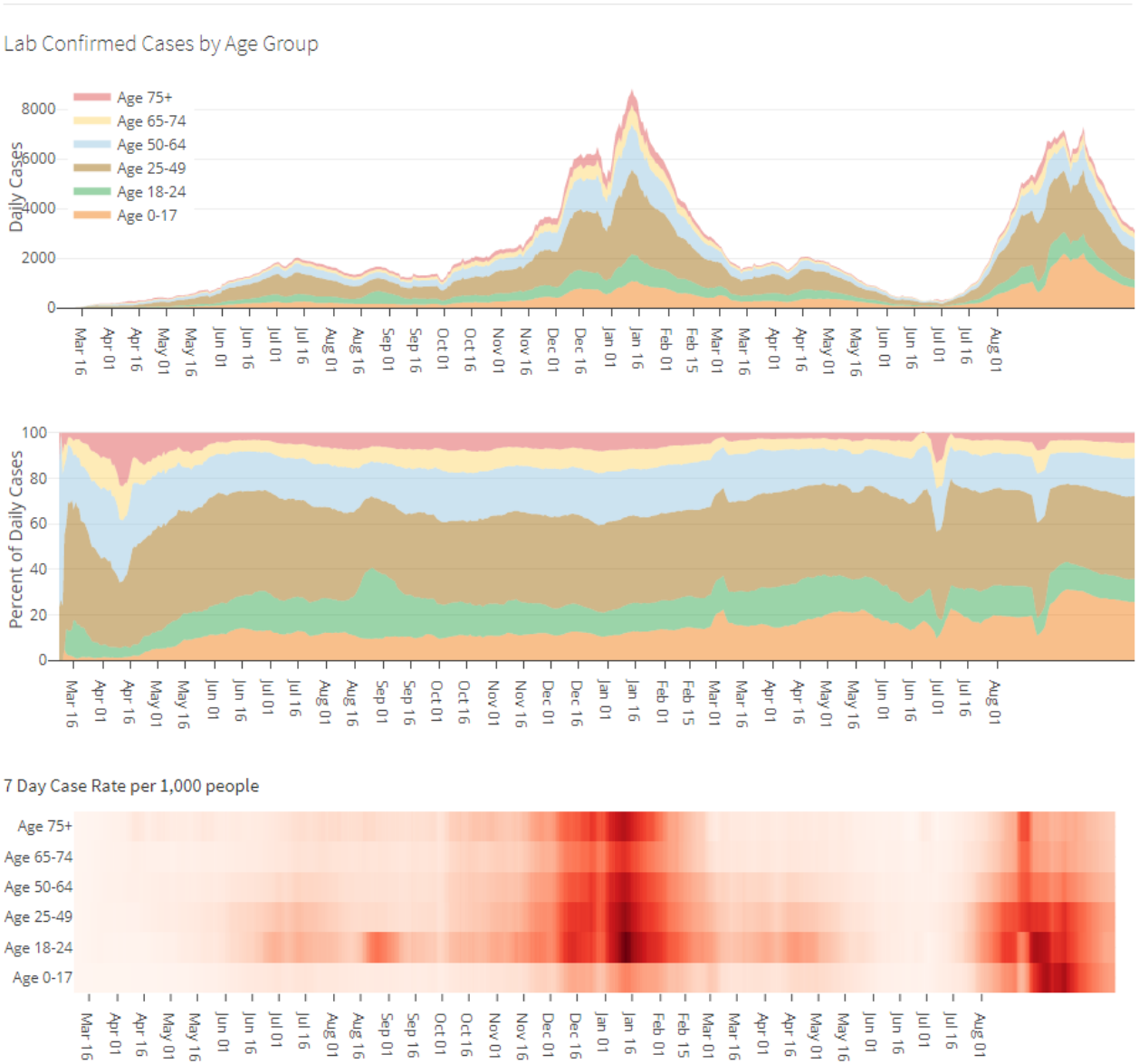
NOTE: States were excluded from this analysis where there was a discrepancy of more than 10% between the total number of COVID-19 deaths by age group and the total number of deaths overall within the state. We calculated the Pearson correlation coefficient, which indicated there was a significant negative correlation between vaccination rates and death rates among older adults: r= –.59, p-value <.001. See methods for additional information.

SOURCE: KFF analysis of the CDC Provisional COVID-19 Death Counts by Sex, Age, and State data July 1 - September 25, 2021. Population estimates of adults 65 and older from each state are from the 2019 US Census Bureau. • PNG

KFF

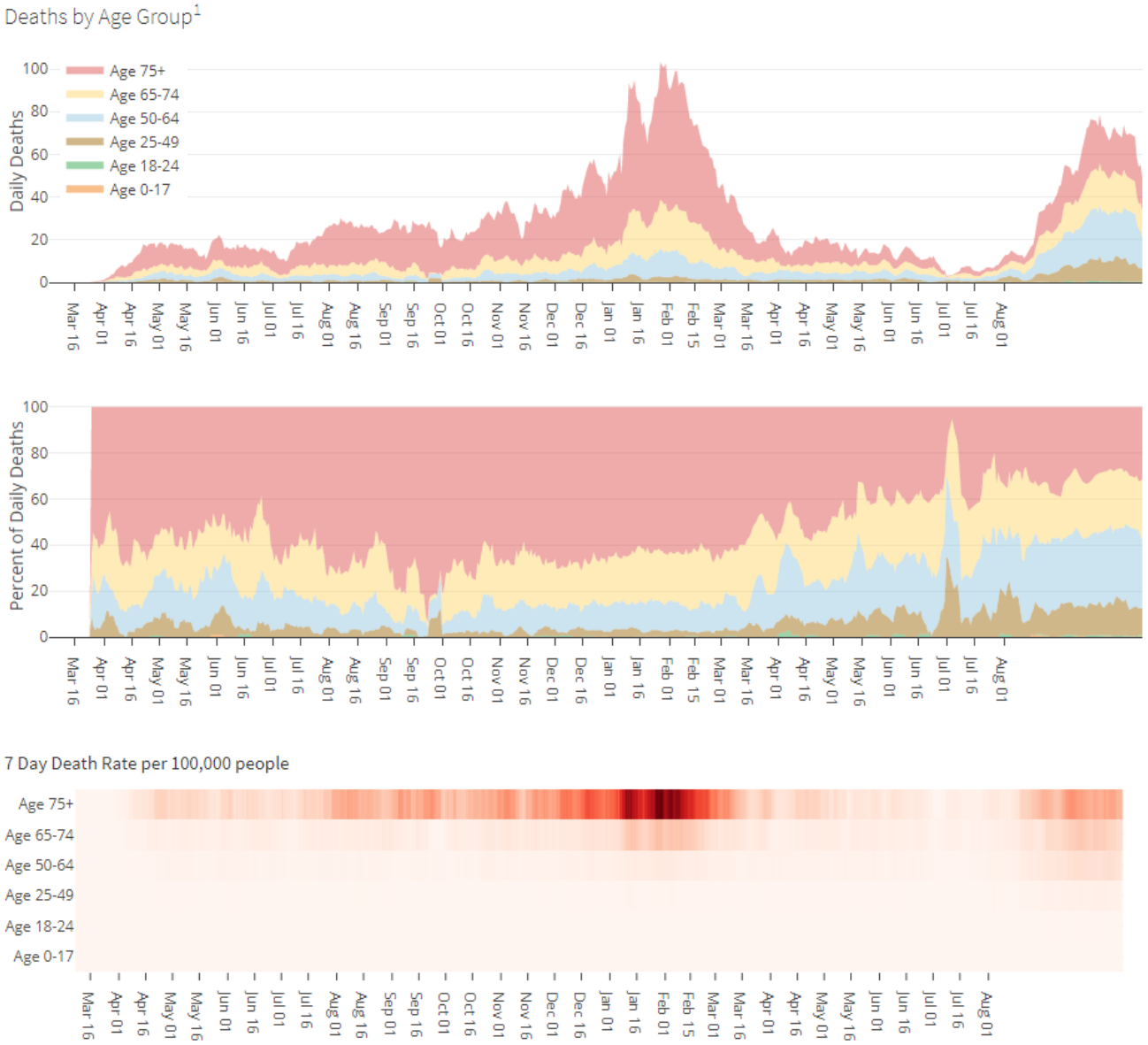
Delta and the changing epidemiology of the pandemic.

- Cases have been younger in the Delta wave than in previous waves.
- This likely reflects the impact of a more infectious virus differential vaccination/immunity by age.
- This effect is even more stark for deaths.



Delta and the changing epidemiology of the pandemic.

- Cases have been younger in the Delta wave than in previous waves.
- This likely reflects the impact of a more infectious virus differential vaccination/immunity by age.
- This effect is even more stark for deaths.



The Impact of the Pandemic in North Carolina

The pandemic that was…

The pandemic in North Carolina so far:*

- **3.9 million infected (over 1 in every 3 North Carolinians)**
- 1.4 million cases (about 1 in every 7)
- 550,000-820,000 hospitalized (about 1 in every 20 to 1 in every 12)
- 18,000 deaths (over 1 in every 600)
- About 5.6 million fully vaccinated (over 1 in every 2)

numbers from nc-covid.org and NYT covid tracker on October 31,2021

The pandemic that was…

The pandemic in North Carolina so far:*

- 3.9 million infected
  (over 1 in every 3 North Carolinians)
- **1.4 million cases**
  (about 1 in every 7)
- 550,000-820,000 hospitalized
  (about 1 in every 20 to 1 in every 12)
- 18,000 deaths
  (over 1 in every 600)
- About 5.6 million fully vaccinated
  (over 1 in every 2)

numbers from nc-covid.org and NYT covid tracker on October 31,2021

The pandemic that was…

The pandemic in North Carolina so far:*

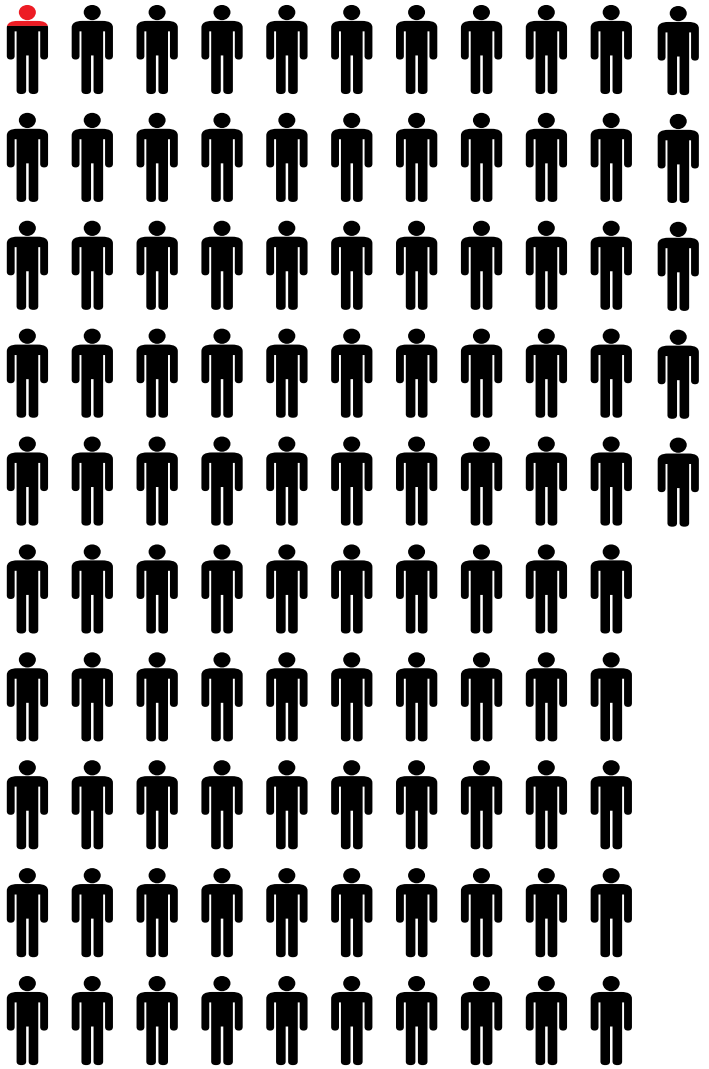
- 3.9 million infected
  (over 1 in every 3 North Carolinians)
- 1.4 million cases
  (about 1 in every 7)
- **550,000-820,000 hospitalized**
  (about 1 in every 20 to 1 in every 12)
- 18,000 deaths
  (over 1 in every 600)
- About 5.6 million fully vaccinated
  (over 1 in every 2)

numbers from nc-covid.org and NYT covid tracker on October 31,2021

The pandemic that was…

The pandemic in North Carolina so far:*

- 3.9 million infected
  (over 1 in every 3 North Carolinians)
- 1.4 million cases
  (about 1 in every 7)
- 550,000-820,000 hospitalized
  (about 1 in every 20 to 1 in every 12)
- **18,000 deaths**
  (over 1 in every 600)
- About 5.6 million fully vaccinated
  (over 1 in every 2)



numbers from nc-covid.org and NYT covid tracker on October 31,2021

…and the pandemic that wasn't.

An uncontrolled pandemic:

- *Original strain:*
  7.8 million infections and
  47,000 deaths

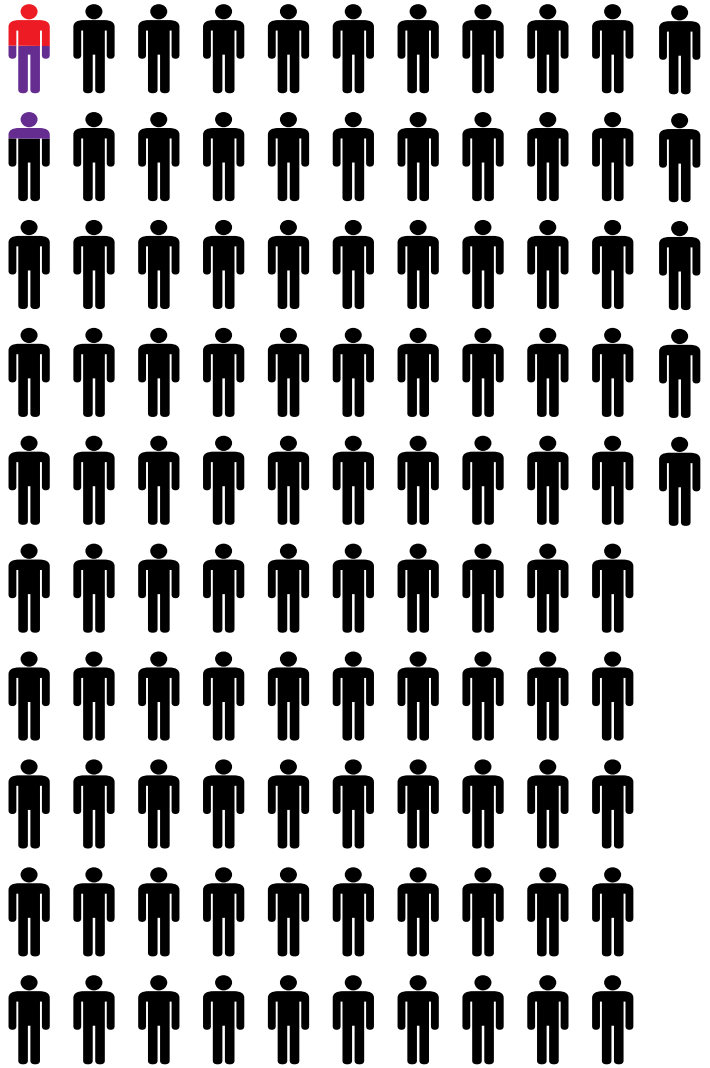
- *Delta like:*
  10.2 million infections and
  up to 134,000 deaths

…and the pandemic that wasn't.

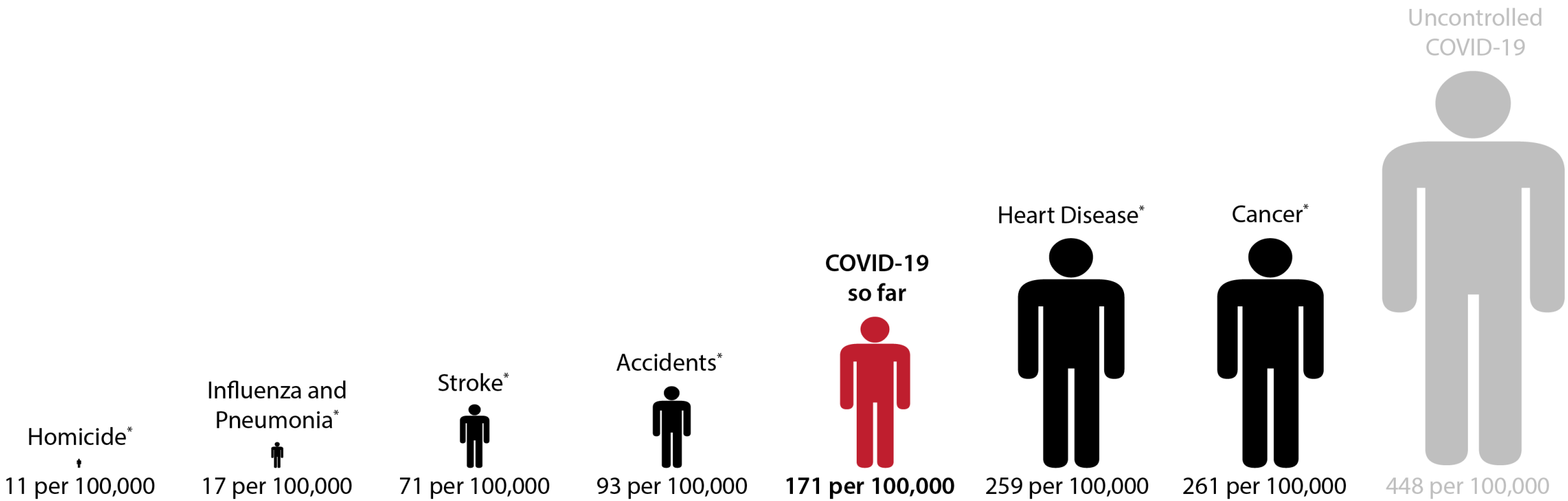
An uncontrolled pandemic:

- *Original strain:*
  7.8 million infections and
  47,000 deaths

- *Delta like:*
  10.2 million infections and
  up to 134,000 deaths

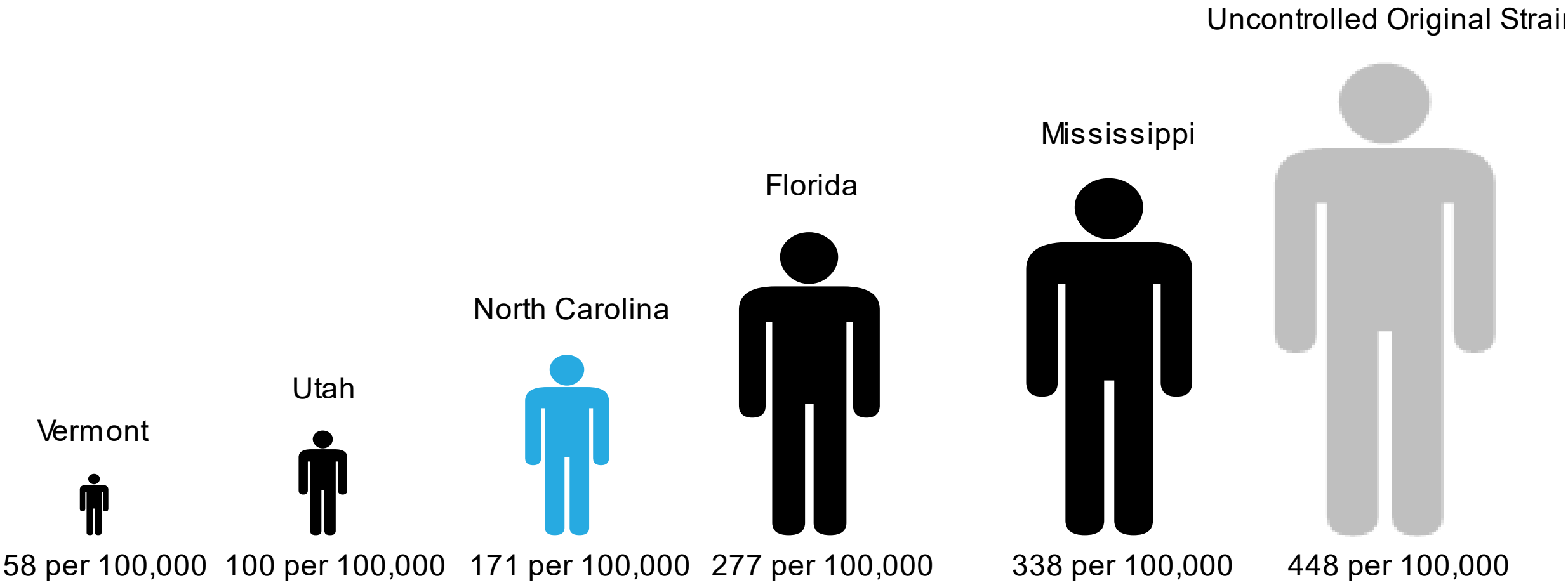


North Carolina COVID-19 deaths in context



* - projected deaths March 1, 2020 – October 31, 2021 based on 2017 rate.

North Carolina COVID-19 deaths in context



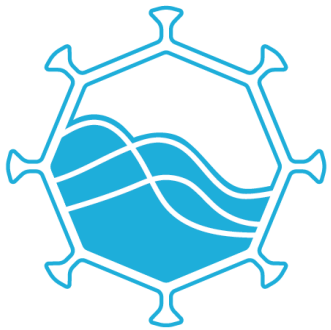
The pandemic that was...

The pandemic in North Carolina so far:*

- 3.9 million infected
  (over 1 in every 3 North Carolinians)
- 1.4 million cases
  (about 1 in every 7)
- 550,000-820,000 hospitalized
  (about 1 in every 20 to 1 in every 12)
- 18,000 deaths
  (over 1 in every 600)
- **About 5.6 million fully vaccinated**
  (over 1 in every 2)

numbers from nc-covid.org and NYT covid tracker on October 31,2021

The Future



COVID-19 ScenarioModelingHub

PennState Huck Institutes of the Life Sciences

Infectious Disease DYNAMICS — Johns Hopkins Bloomberg School of Public Health

University of Massachusetts Amherst

NIH Fogarty

INTERNATIONAL VACCINE ACCESS CENTER

MIDAS

University of Pittsburgh

APL Johns Hopkins Applied Physics Laboratory

University of Virginia — Biocomplexity Institute

USC University of Southern California

MOBS LAB

Northeastern University

University of Notre Dame

Columbia University

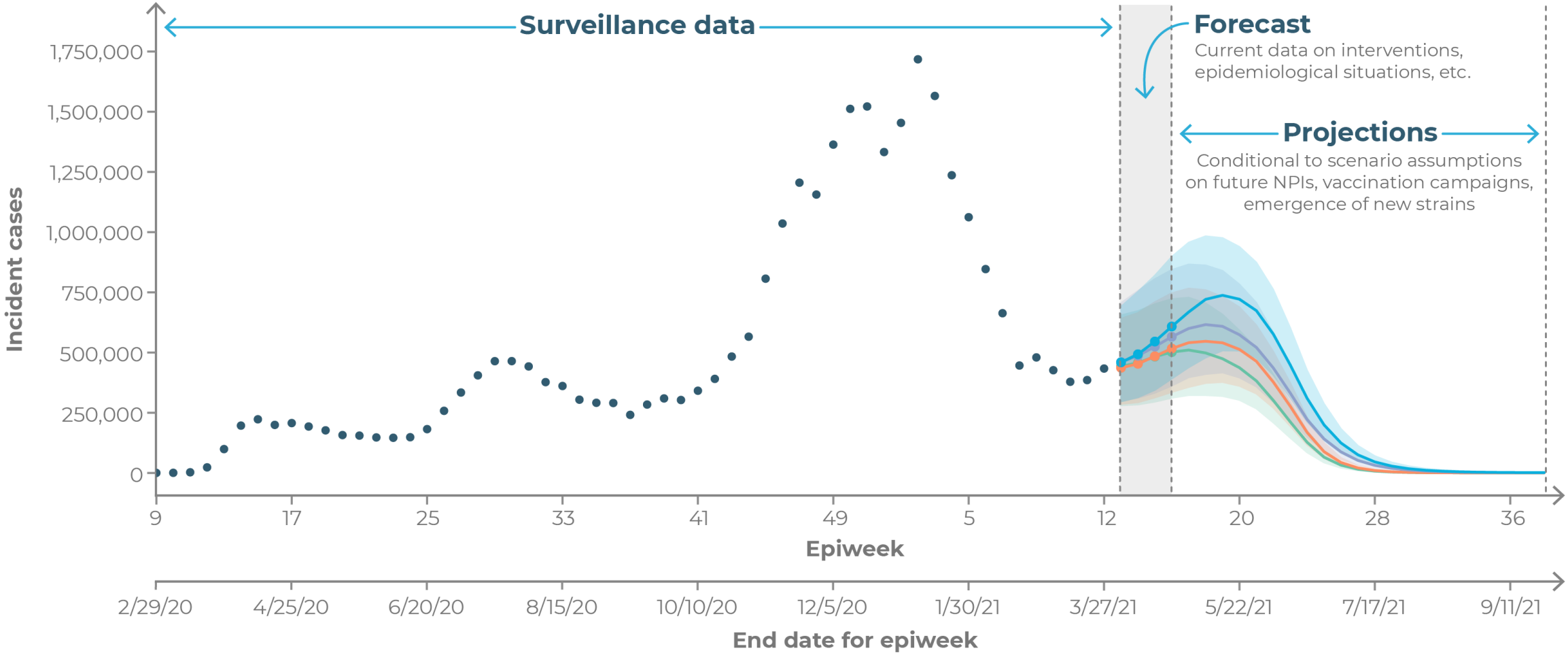
University of North Carolina Charlotte

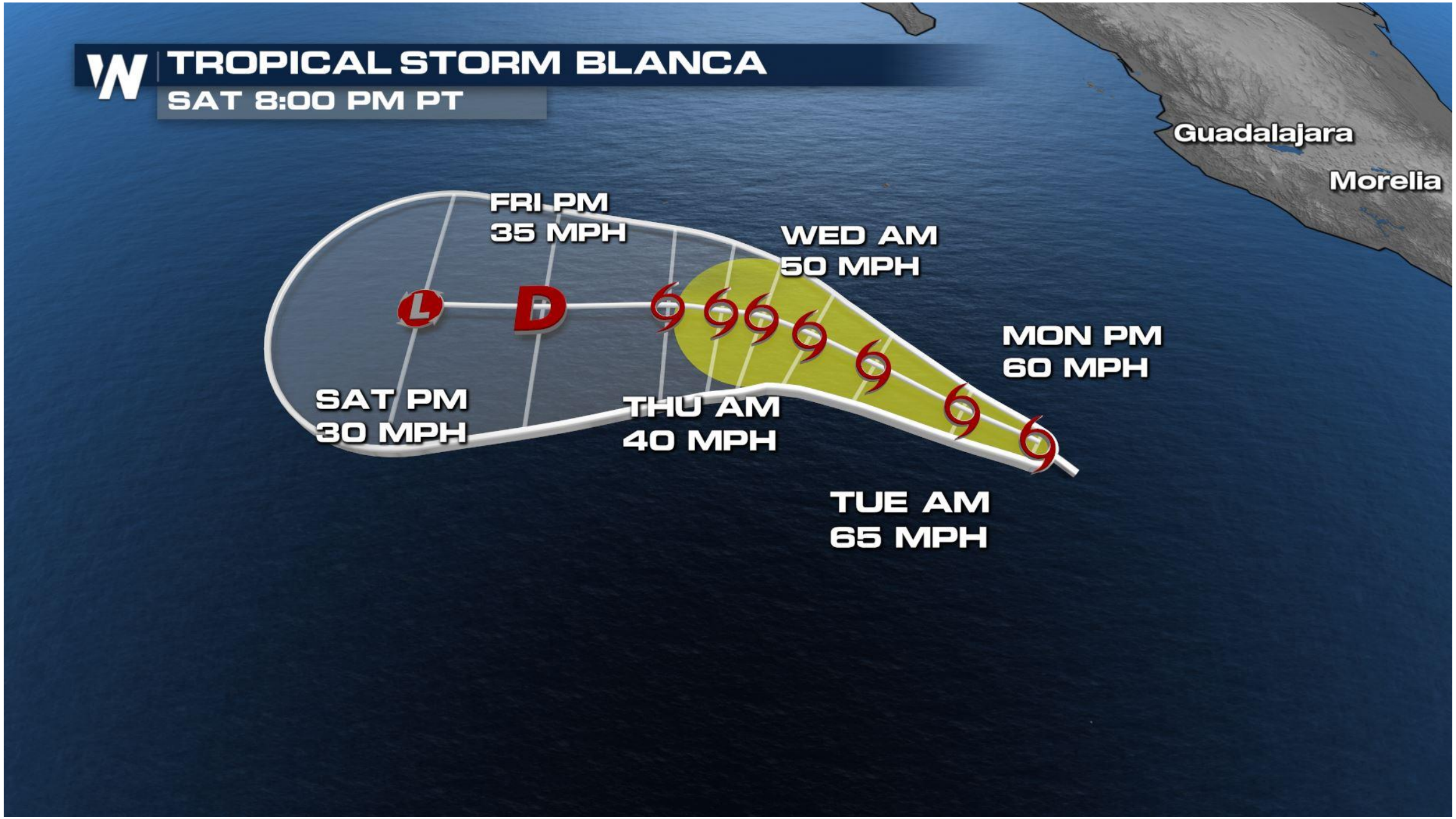
COVID-19 ScenarioModelingHub

COVID-19 ForecastHub

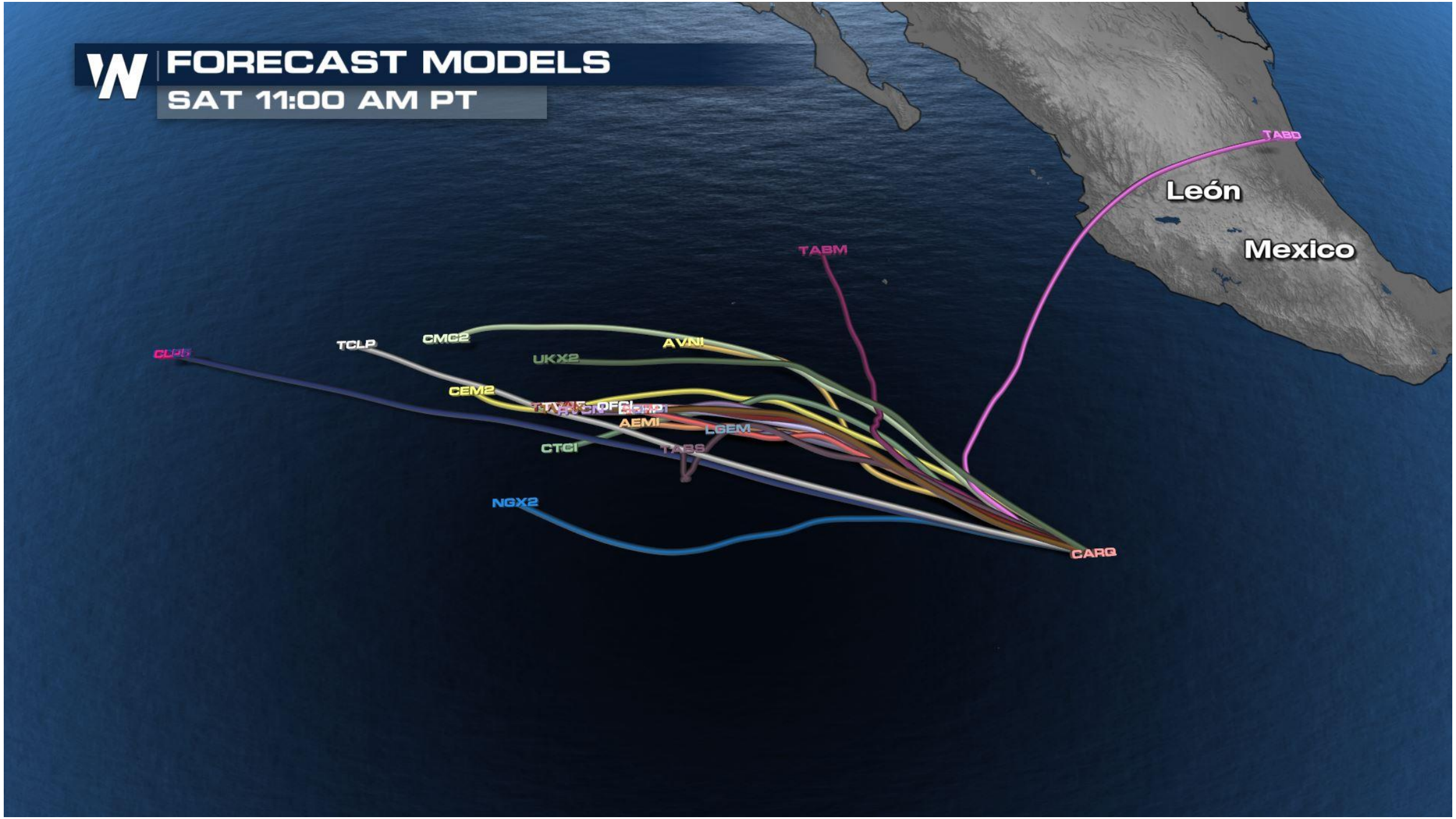
The University of North Carolina at Chapel Hill

Planning scenarios, not forecasts!





From [Tropical Storm Blanca Strengthens in the Eastern Pacific - WeatherNation (weathernationtv.com)]



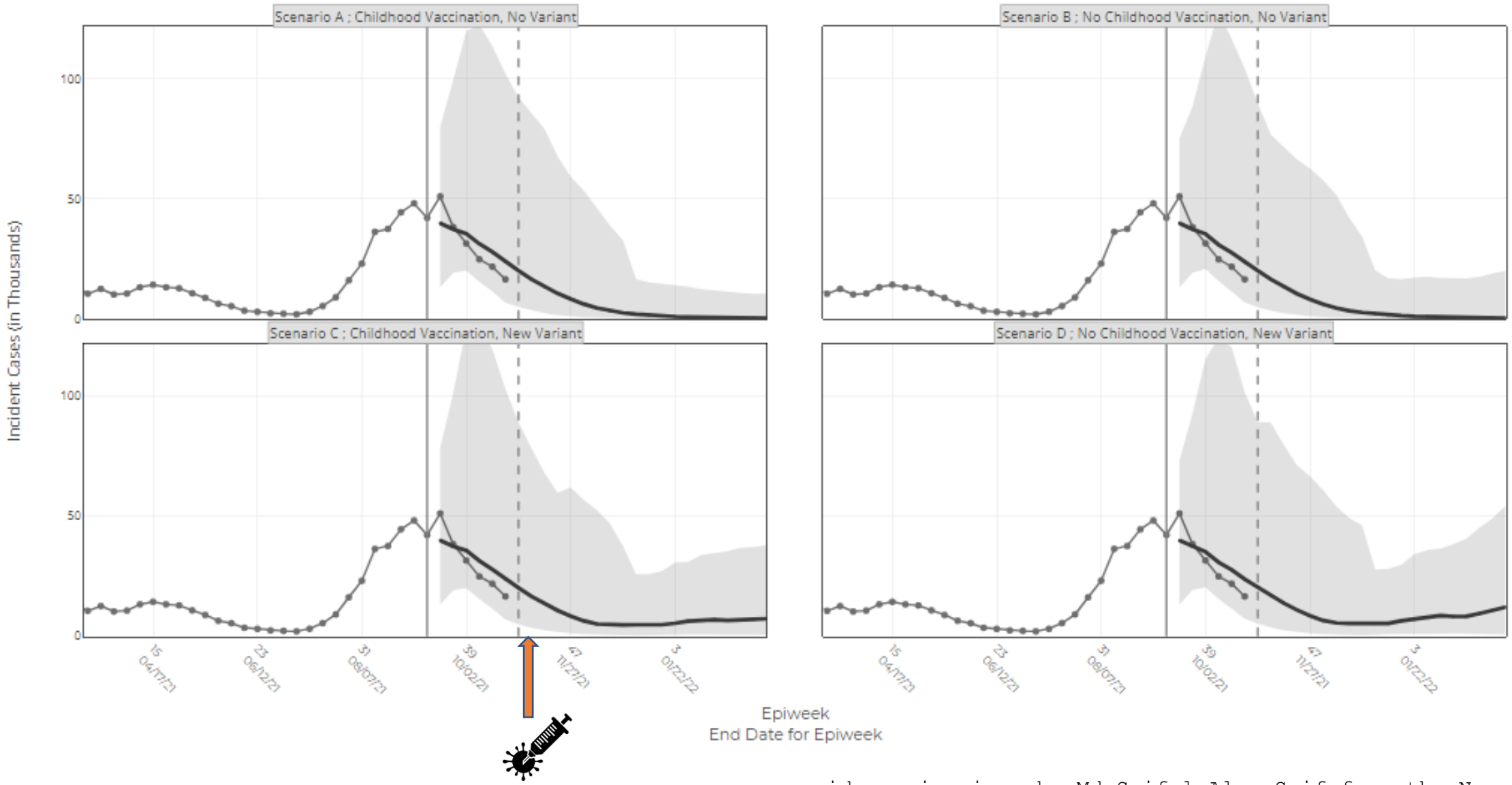
From [Tropical Storm Blanca Strengthens in the Eastern Pacific - WeatherNation (weathernationtv.com)] / cyclocane.com

Round 9 Scenario Definitions

Immunization 5-11 yrs	Variant emergence: The same mix of variants circulate throughout the projection period. No change in virus transmissibility.	Variant emergence: A more transmissible variant emerges, comprising 1% of circulating viruses on **Nov 15**. The new variant is **1.5X** as transmissible as viruses circulating at the beginning of the projection period.
Vaccination among 5-11yrs is approved and immunization begins on Nov 1. Each state's uptake rate reflects the percent coverage increases observed for 12-17-year-olds since distribution began on May 13.	A	C
No vaccination for children under 12	B	D

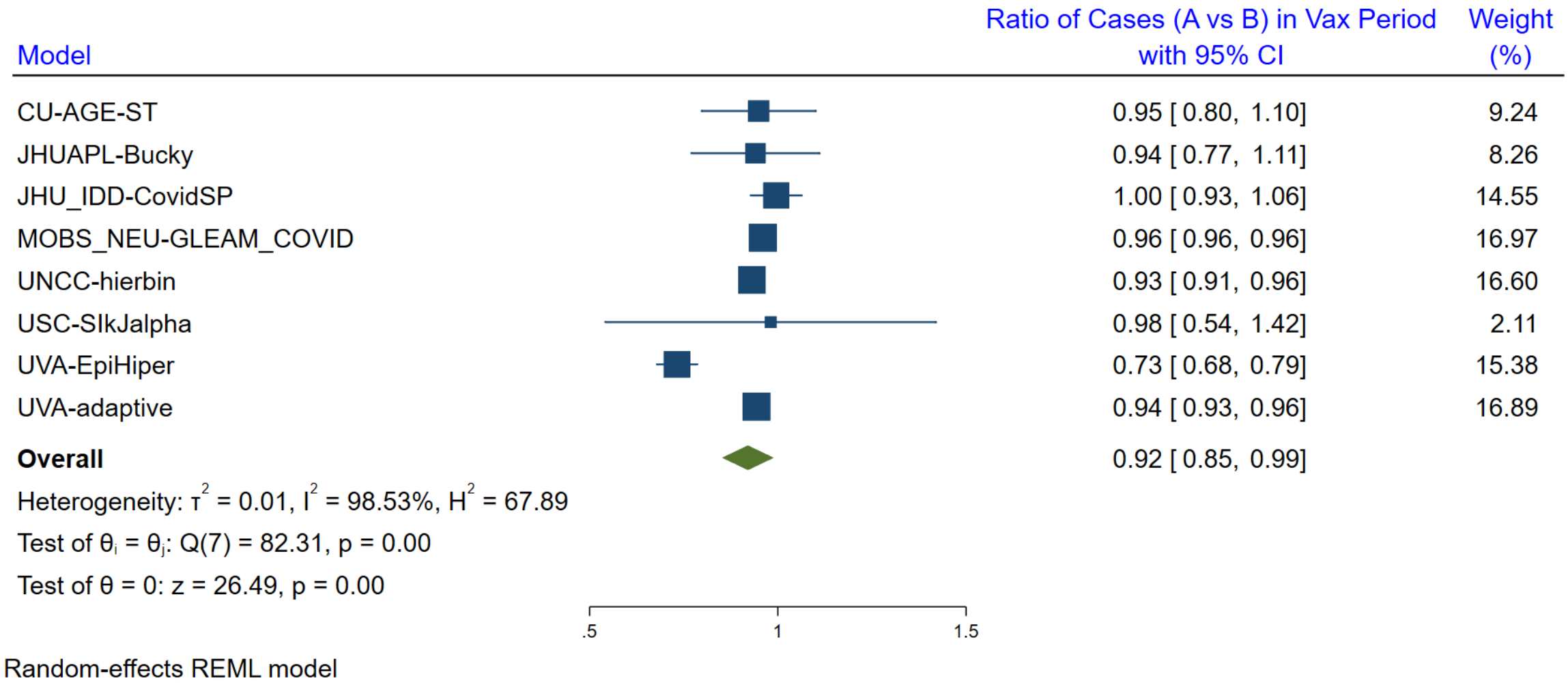
- Under 12 yrs immunization starts Nov 1
- Vaccine parameters at teams' discretion
- Report age-specific projections

Results, General Projections

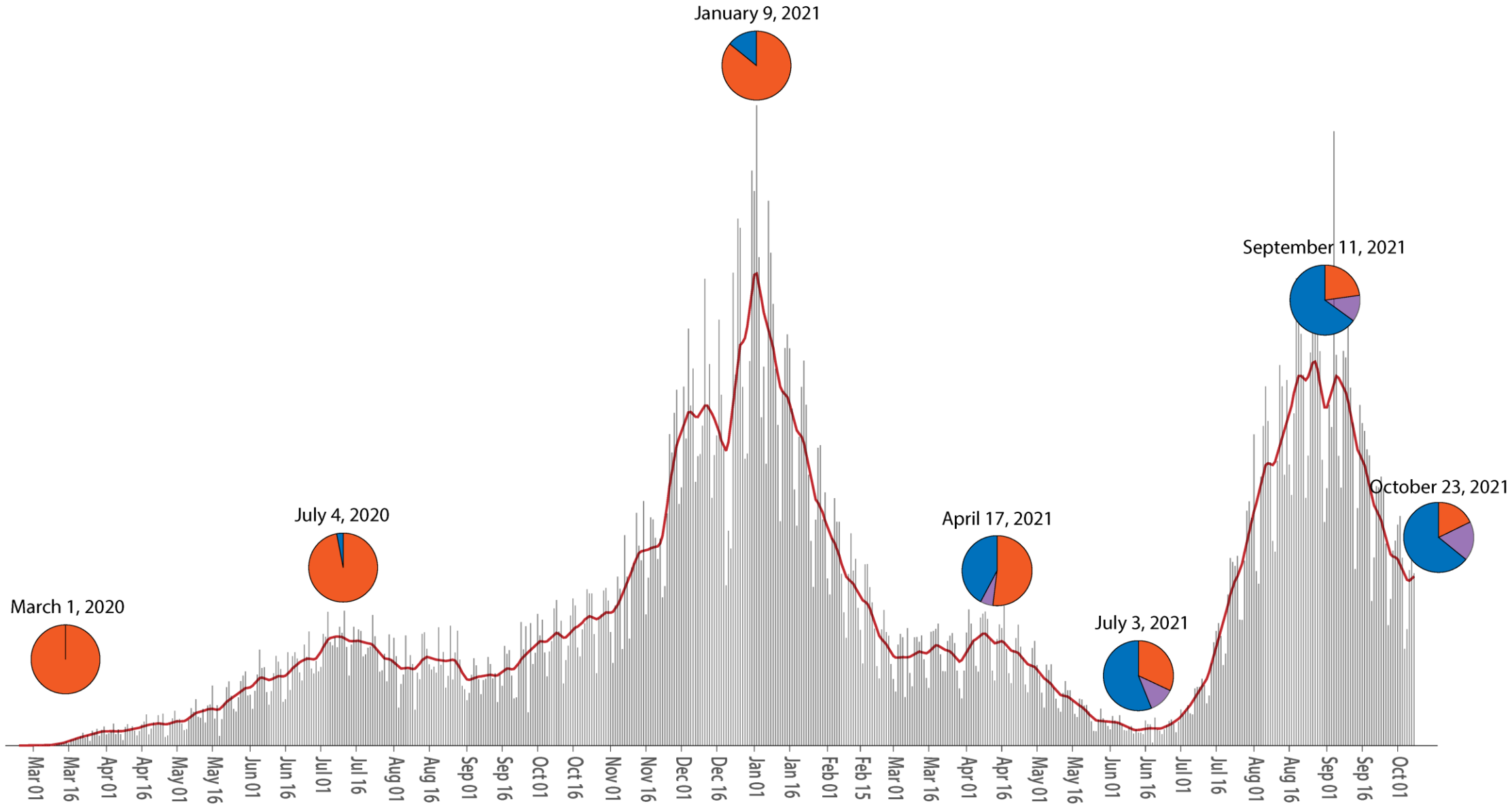


covid vaccine icon by Md Saiful Alam Saif from the Noun Project

Results: The impact of vaccinating 5-11 year olds



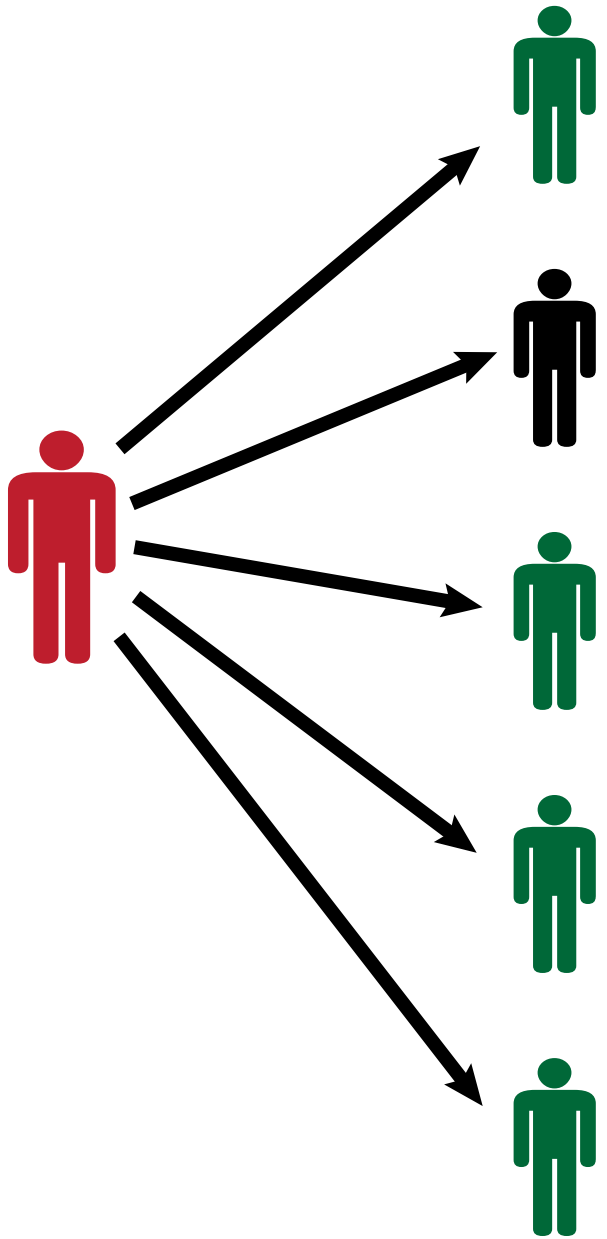
The accumulation of immunity in North Carolina



How could this all be wrong?

Future threats

- Immune escape
- Stronger than expected behavioral or seasonal impacts
- Higher than expected COVID-19 detection/death rates.
- Something else?



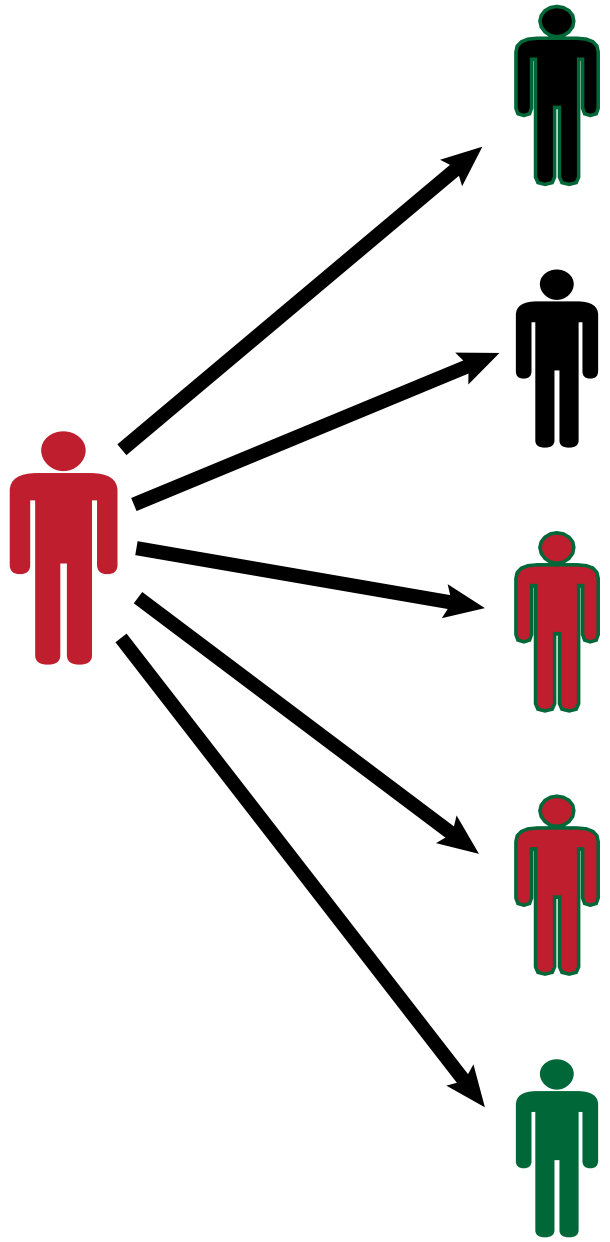
Future threats

- **Immune escape**

- Stronger than expected behavioral or seasonal impacts

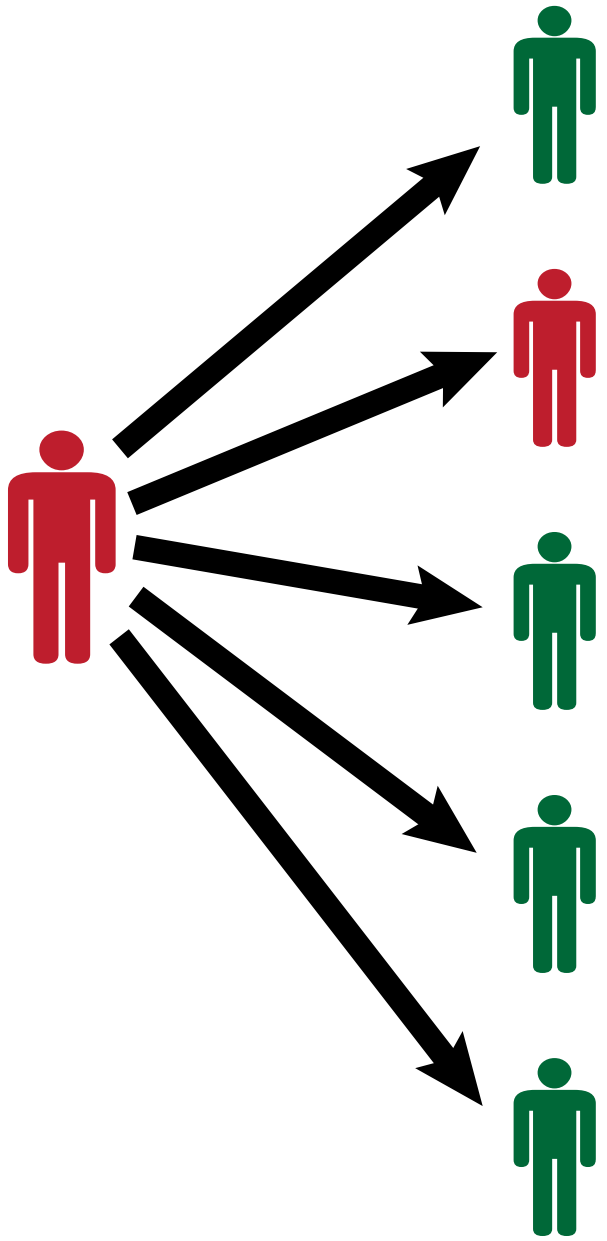
- Higher than expected COVID-19 detection/death rates.

- Something else?



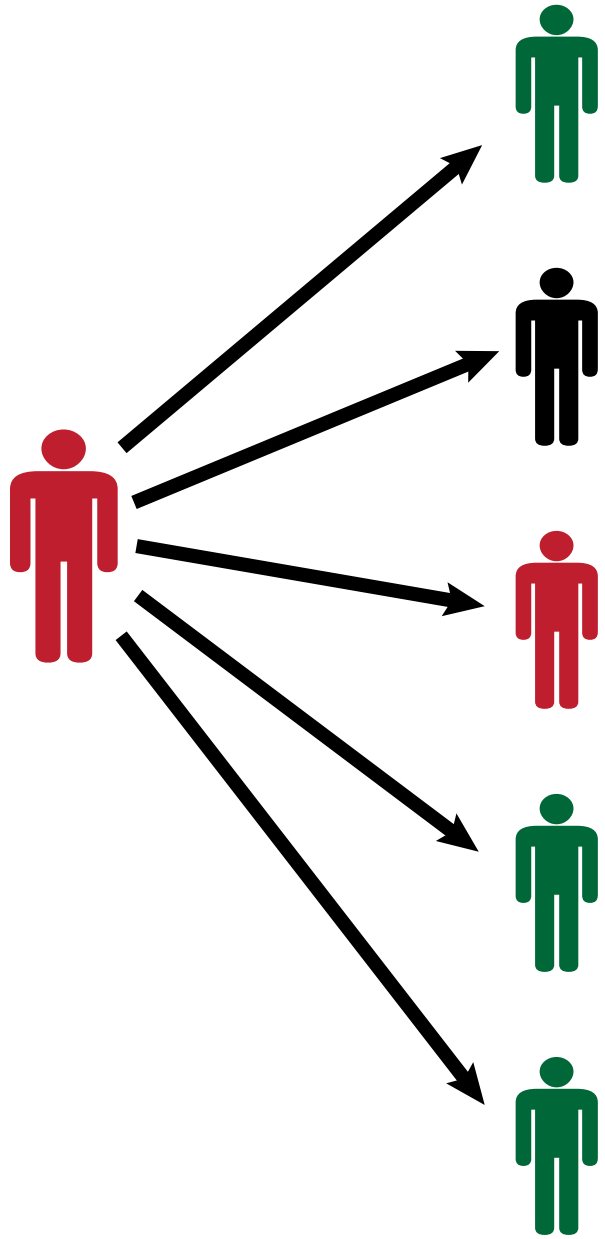
Future threats

- Immune escape
- **Stronger than expected behavioral or seasonal impacts**
- Higher than expected COVID-19 detection/death rates.
- Something else?



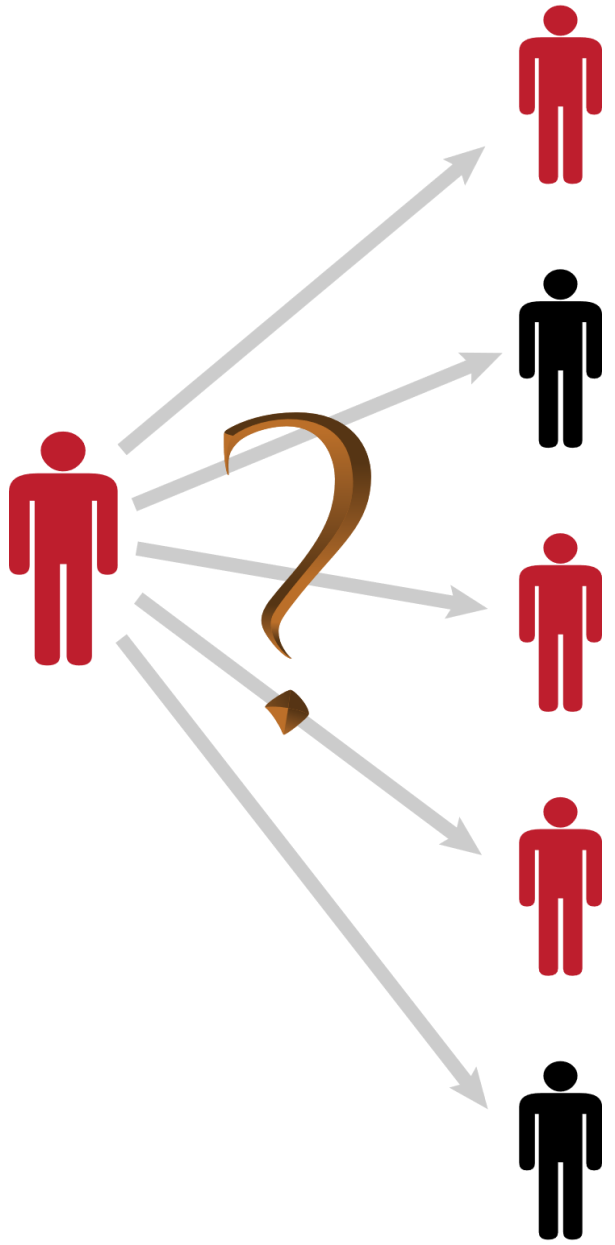
Future threats

- Immune escape
- Stronger than expected behavioral or seasonal impacts
- **Higher than expected COVID-19 detection/death rates.**
- Something else?



Future threats

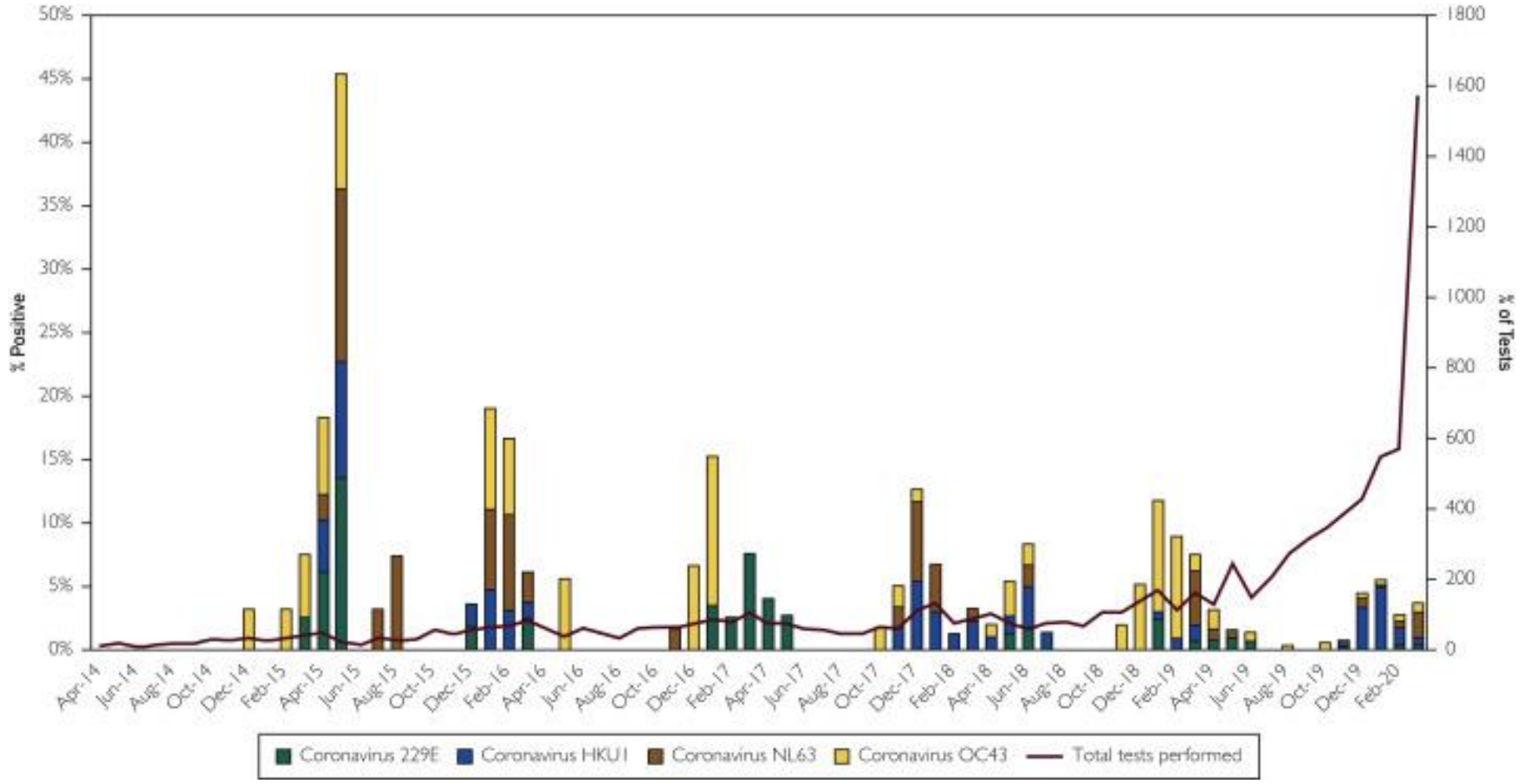
- Immune escape
- Stronger than expected behavioral or seasonal impacts
- Higher than expected COVID-19 detection/death rates.
- **Something else?**



What does COVID-19 look like in 10 years?

A seasonal coronavirus?

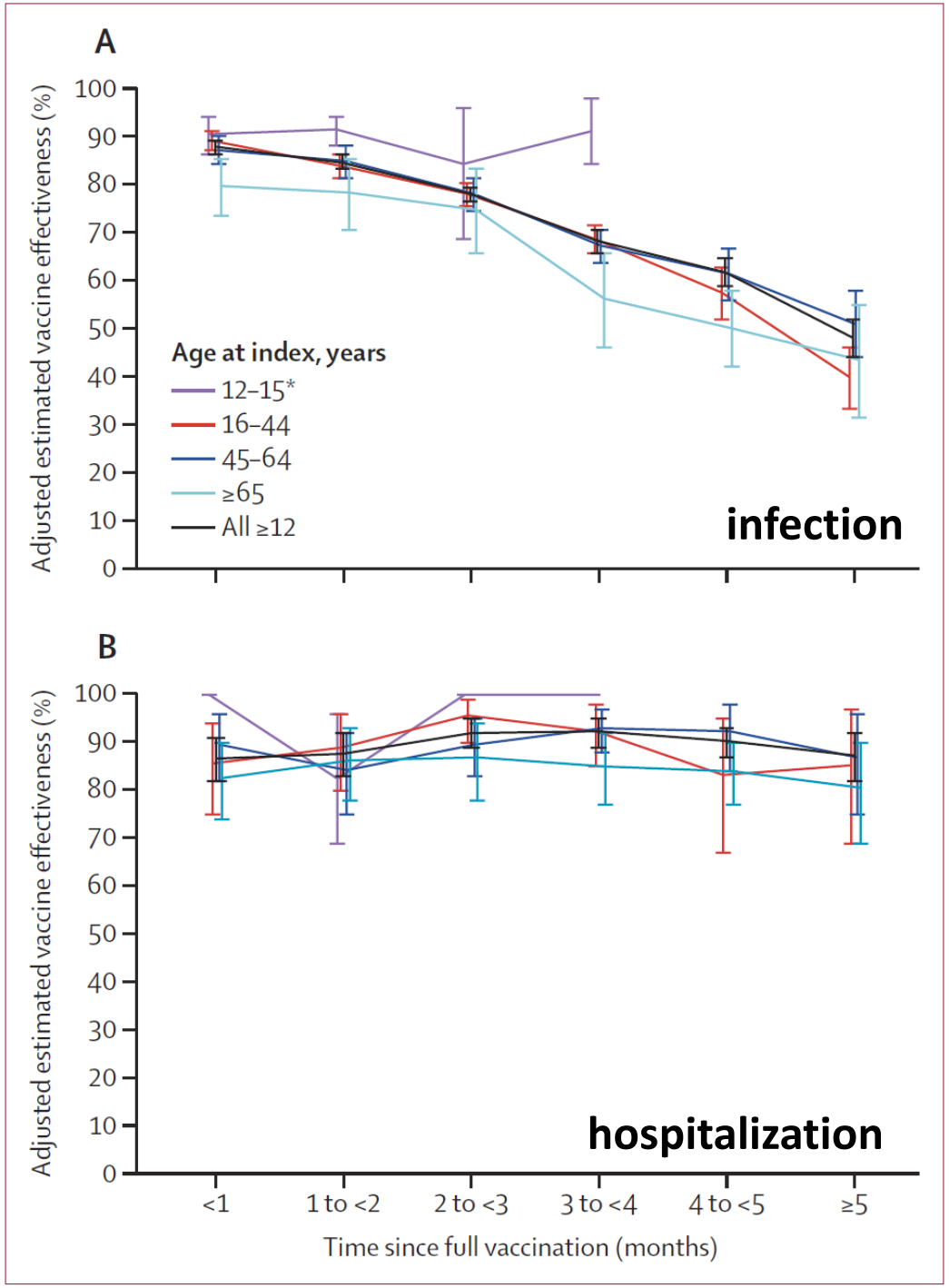
- Most coronaviruses and other respiratory pathogens settle down to cause seasonal epidemics, it is likely COVID-19 will do the same…



Rucinski et al., Mayo Clinic Proceedings 2020

A mild childhood infection?

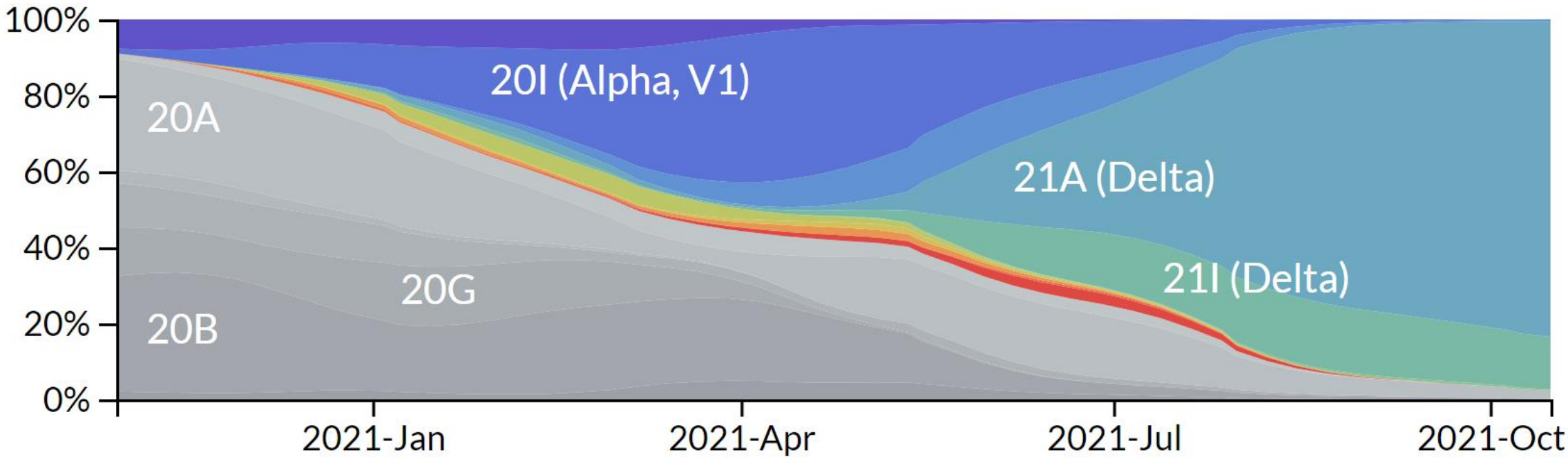
- Decades in the future only very young children will be seeing COVID-19 for the first time.
- Currently, young children appear to be **very** unlikely to have severe disease, so most of these first infections will be mild.
- Older individuals will have pre-existing immunity from vaccine or previous infection, hence will have more mild symptoms if they are infected at all.



Tartof et al., The Lancet 2021

Annual vaccination?

- The variants prove that there is every possibility that SARS-CoV-2 continues to evolve away from human immunity (like influenza), and repeated vaccination will be needed.



Summing Up

- The impact of COVID-19 in North Carolina has been middling compared to all US states.

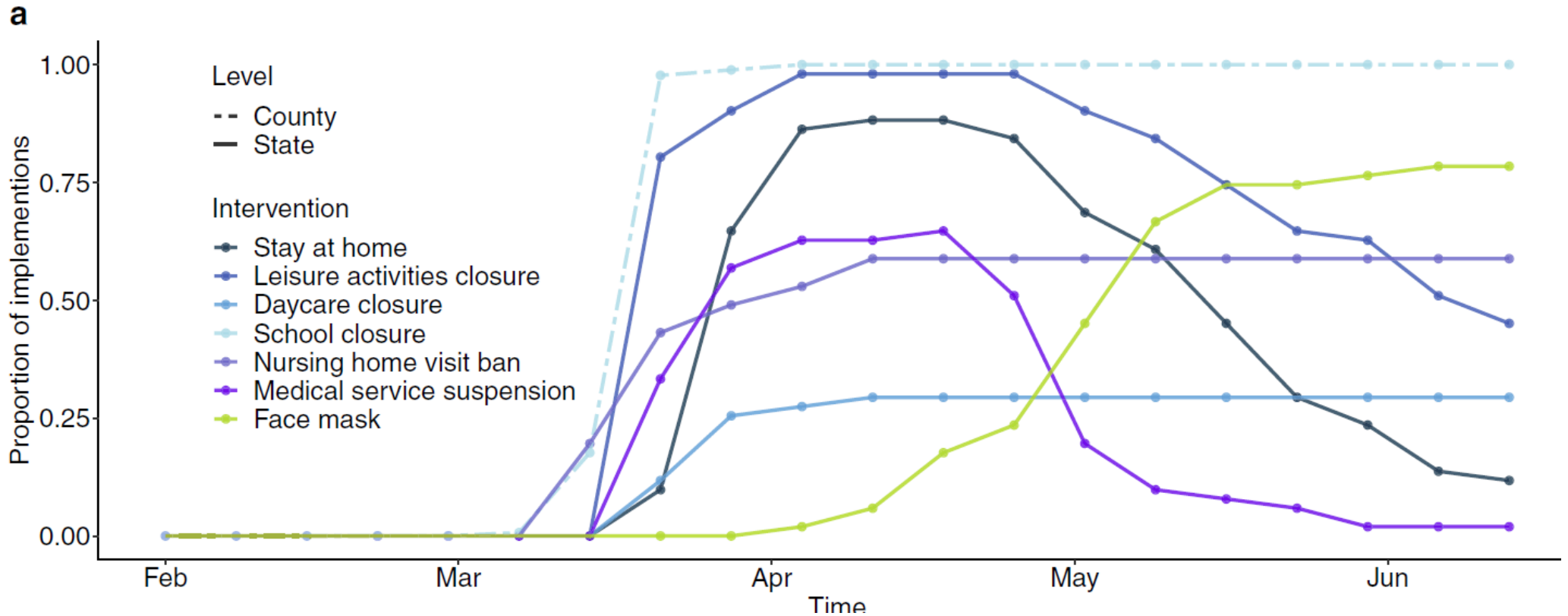
- Control measures from masks, to lockdowns, to vaccination have been effective in controlling COVID-19, but will not eradicate the disease.

- We are likely entering a new phase of the pandemic with things looking good over the short term and a long term outlook where COVID-19 remains a threat, but not a big one.

- The virus has surprised us before, and very well could again, so caution and humility are needed as we look to the future.

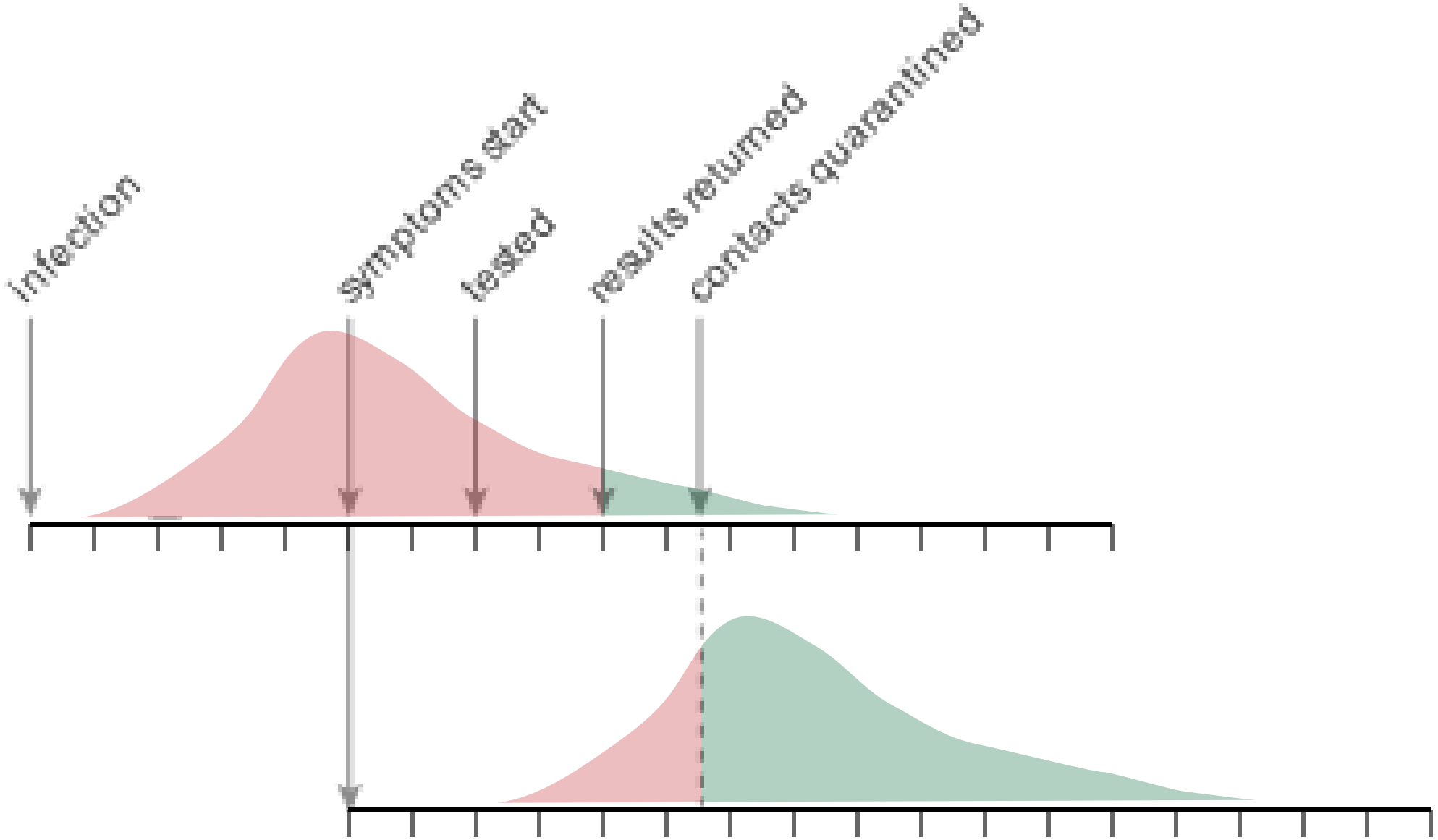
Backup

How well do “lockdowns” work?

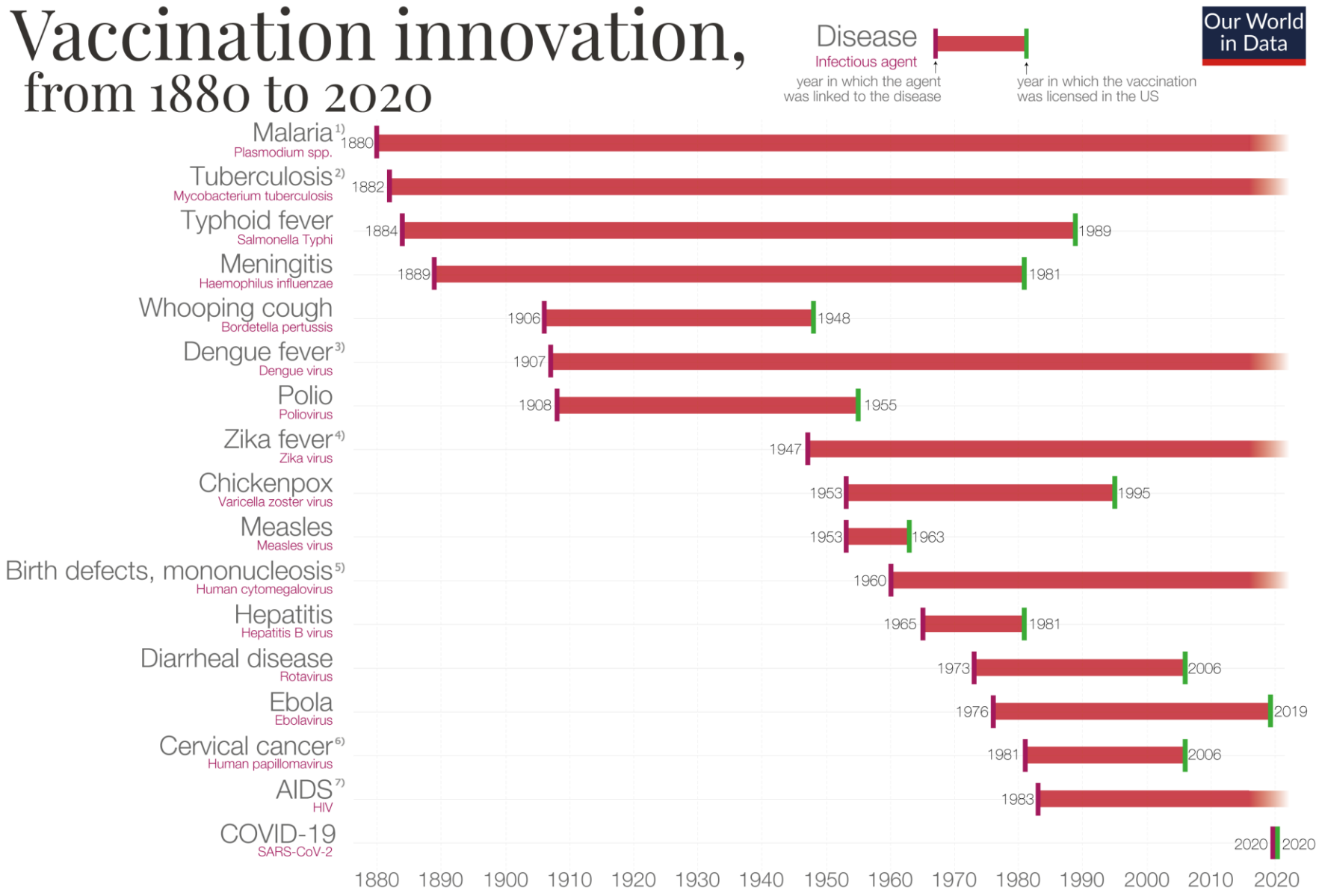


Yang et al. Nature Communications 2021

Why should we quarantine?



Vaccination innovation, from 1880 to 2020



1) – 2016 vaccine RTS,S undergoing pilot trials in select countries after being approved by European regulators in 2015.
2) – The only approved vaccine is bacilli Calmette-Guérin (BCG), developed in 1921 but its efficacy in adults is variable. Other tuberculosis vaccines are currently in development.
3) – 2016 partially effective vaccine CYD-TDV, sold under the brand name Dengvaxia.
4) – Successful first human clinical trials of a vaccine against the virus in 2016. Only in 2016 did the WHO issue statements of concern about the zika virus' links to Guillain-Barré Syndrome (GBS) and microcephaly.
5) – A number of vaccine candidates are under investigation.
6) – Not all cervical cancers are caused by the HPV virus and the HPV vaccine can protecet against other cancers caused by the HPV virus.
7) – 2009 efficacy findings for vaccine candidate RV 144 has shown some promise. In stage III human trials.

Vaccine-preventable diseases in the US

Shown is the reduction of cases and deaths after the introduction of the vaccine

Our World in Data

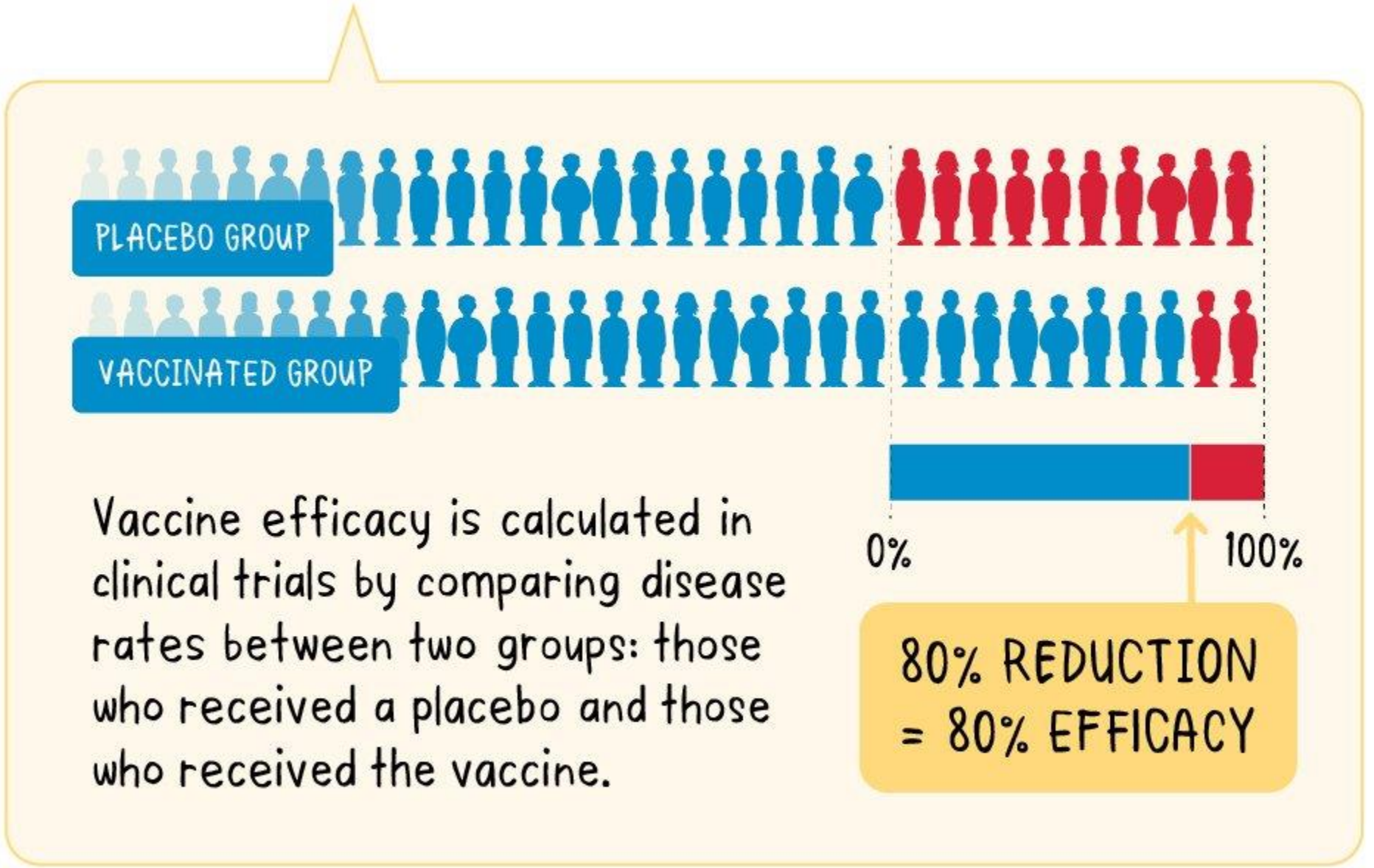
	Cases			Deaths		
	Pre-vaccine: 158 cases per million per year (1936-45)	100% Reduction	Post-vaccine: 0 cases per million per year	Pre-vaccine: 13.7 deaths per million per year (1936-45)	100% Reduction	Post-vaccine: 0 deaths per million per year
Diphtheria						
	Pre-vaccine: 3044 cases per million per year (1953-62)	99.99% Reduction	Post-vaccine: 0.2 cases per million per year	Pre-vaccine: 2.5 deaths per million per year (1953-62)	100% Reduction	Post-vaccine: 0 deaths per million per year
Measles						
	Pre-vaccine: 830 cases per million per year (1963-68)	97.4% Reduction	Post-vaccine: 22 cases per million per year	Pre-vaccine: 0.2 deaths per million per year (1963-68)	100% Reduction	Post-vaccine: 0 deaths per million per year
Mumps						
	Pre-vaccine: 1534 cases per million per year (1934-43)	96.6% Reduction	Post-vaccine: 52 cases per million per year	Pre-vaccine: 30.8 deaths per million per year (1934-43)	99.7% Reduction	Post-vaccine: 0.09 deaths per million per year
Pertussis						
	Pre-vaccine: 141 cases per million per year (1941-50)	100% Reduction	Post-vaccine: 0 cases per million per year	Pre-vaccine: 10 deaths per million per year (1941-50)	100% Reduction	Post-vaccine: 0 deaths per million per year
Acute Poliomyeltis						
	Pre-vaccine: 103 cases per million per year (1951-54)	100% Reduction	Post-vaccine: 0 cases per million per year	Pre-vaccine: 11.8 deaths per million per year (1951-54)	100% Reduction	Post-vaccine: 0 deaths per million per year
Paralytic Poliomyeltis						
	Pre-vaccine: 242 cases per million per year (1966-68)	99.98% Reduction	Post-vaccine: 0.04 cases per million per year	Pre-vaccine: 0.09 deaths per million per year (1966-68)	100% Reduction	Post-vaccine: 0 deaths per million per year
Rubella						
	Pre-vaccine: 0.76 cases per million per year (1966-69)	99.6% Reduction	Post-vaccine: 0.003 cases per million per year	Pre-vaccine: no data (1966-69)	no data	Post-vaccine: 0 deaths per million per year
Congenital Rubella Syndrome						
	Pre-vaccine: 250 cases per million per year (1900-49)	100% Reduction	Post-vaccine: 0 cases per million per year	Pre-vaccine: 2.9 deaths per million per year (1900-49)	100% Reduction	Post-vaccine: 0 deaths per million per year
Smallpox						
	Pre-vaccine: 4 cases per million per year (1947-49)	96.6% Reduction	Post-vaccine: 0.14 cases per million per year	Pre-vaccine: 3.2 deaths per million per year (1947-49)	99.6% Reduction	Post-vaccine: 0.01 deaths per million per year
Tetanus						
	Pre-vaccine: 465 cases per million per year (1986-95)	89% Reduction	Post-vaccine: 51 cases per million per year	Pre-vaccine: 0.5 deaths per million per year (1986-95)	88.7% Reduction	Post-vaccine: 0.06 deaths per million per year
Hepatitis A						
	Pre-vaccine: 273 cases per million per year (1982-91)	83.9% Reduction	Post-vaccine: 44 cases per million per year	Pre-vaccine: 1 death per million per year (1982-91)	83.6% Reduction	Post-vaccine: 0.16 deaths per million per year
Acute Hepatitis B						
	Pre-vaccine: 84 cases per million per year (1980s)	99.8% Reduction	Post-vaccine: 0.17 cases per million per year	Pre-vaccine: no data (1980s)	no data	Post-vaccine: 0.02 deaths per million per year
Haemophilus Influenza type b						
	Pre-vaccine: 233 cases per million per year (1997-99)	40.5% Reduction	Post-vaccine: 139 cases per million per year	Pre-vaccine: 24 deaths per million per year (1997-99)	31.3% Reduction	Post-vaccine: 16.5 deaths per million per year
Pneumococca Disease						
	Pre-vaccine: 16018 cases per million per year (1990-94)	87.2% Reduction	Post-vaccine: 2046 cases per million per year	Pre-vaccine: 0.41 deaths per million per year (1990-94)	84.3% Reduction	Post-vaccine: 0.06 deaths per million per year
Varicella						

All post-vaccine cases refer to 2006

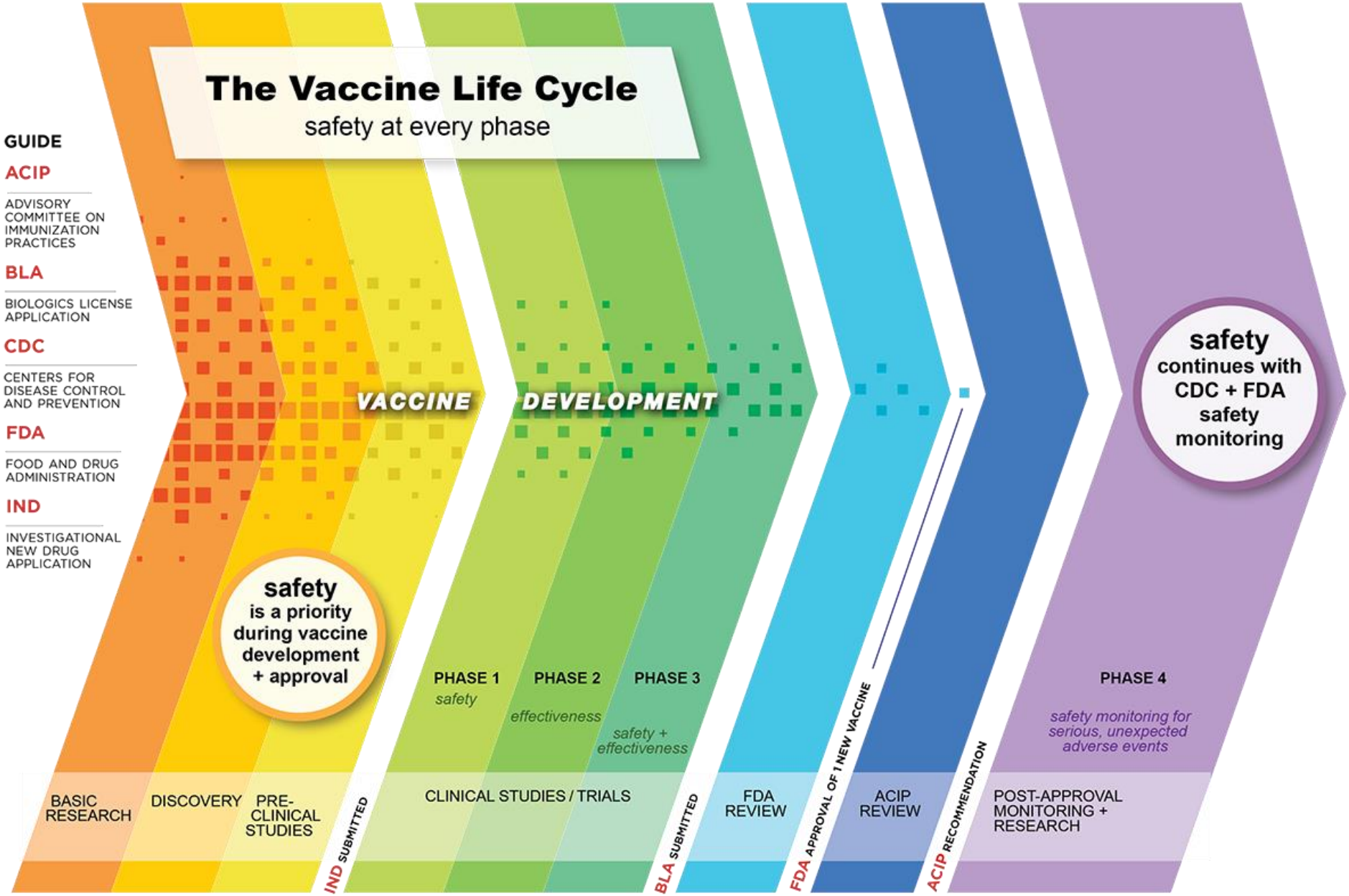
All post-vaccine deaths refer to 2004

Data source: Roush and Murphy (2007) - Historical comparisons of morbidity and mortality for vaccine-preventable diseases in the United States. In The Journal of the American Medical Association, 298, 18, 2155--2163.

How well does the vaccine work?

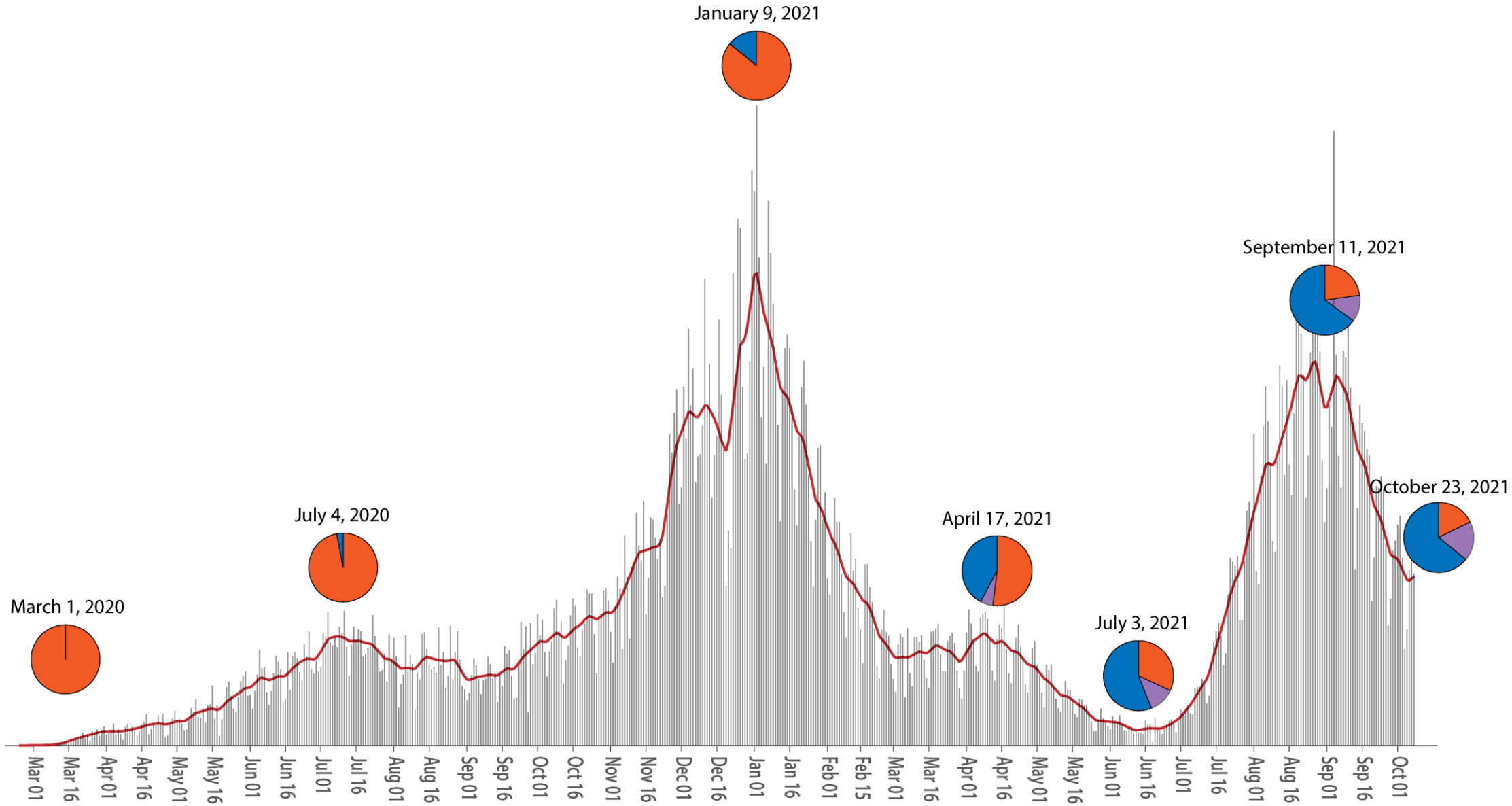


An amazing accomplishment



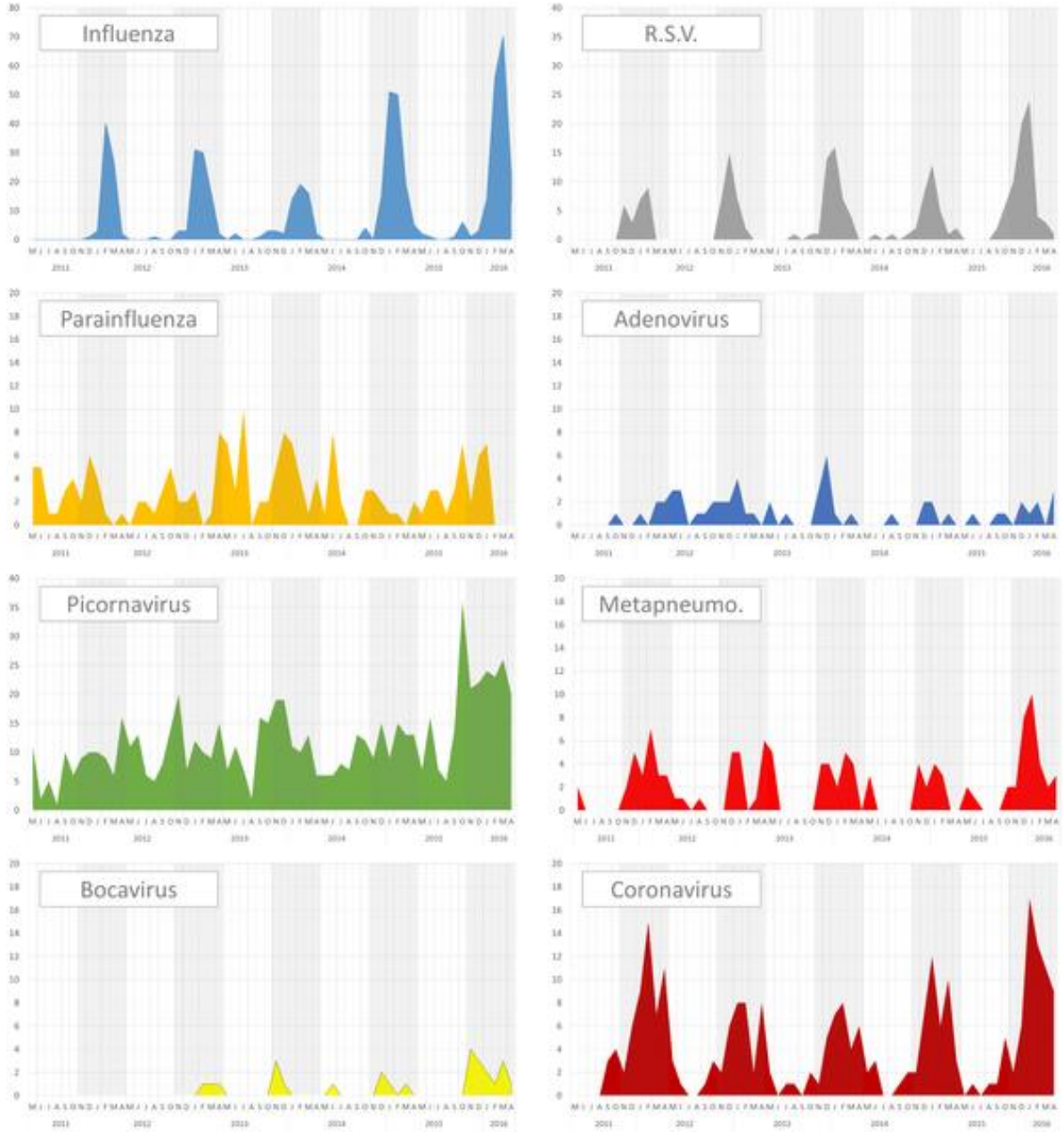
CDC.gov

The accumulation of immunity in North Carolina



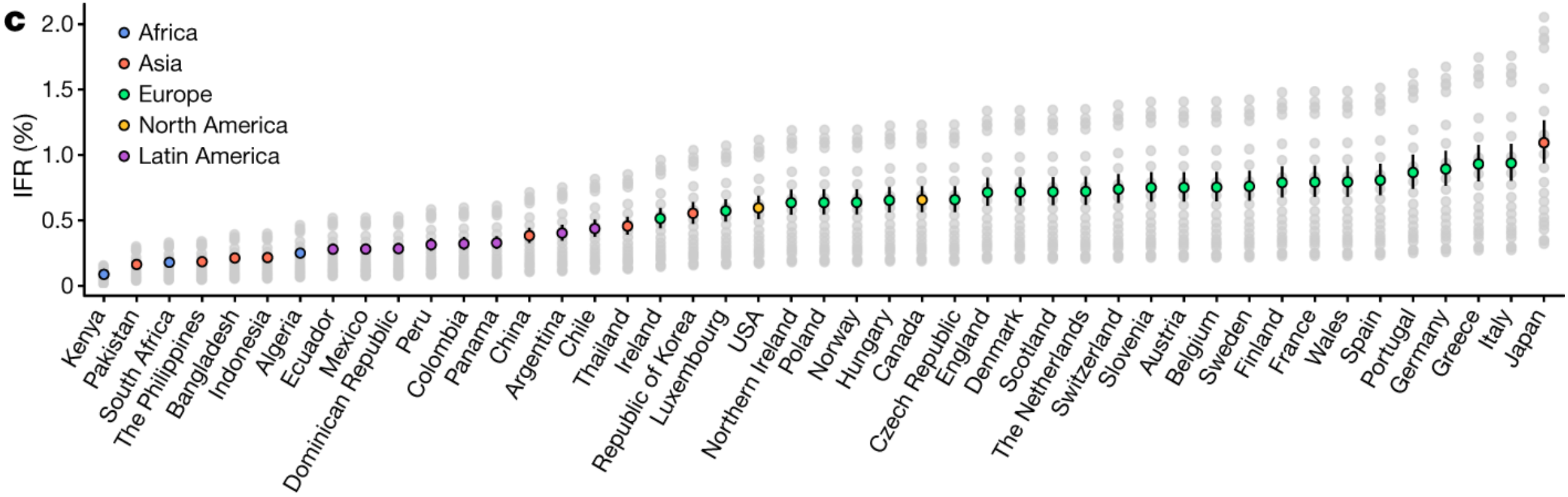
A seasonal coronavirus?

- Most coronaviruses and other respiratory pathogens settle down to cause seasonal epidemics, it is likely COVID-19 will do the same.

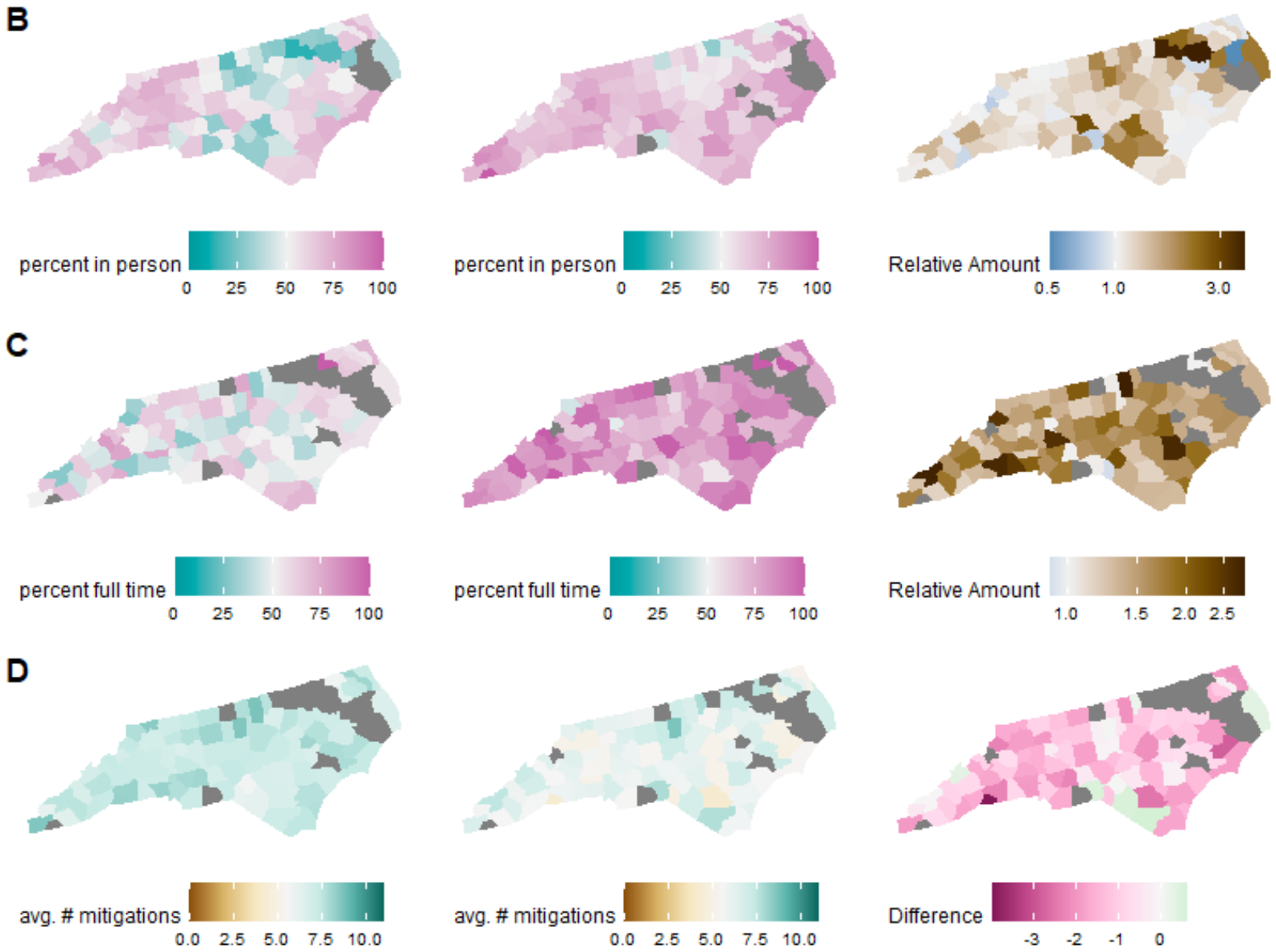


Visseaux et al., PLoS ONE 2017

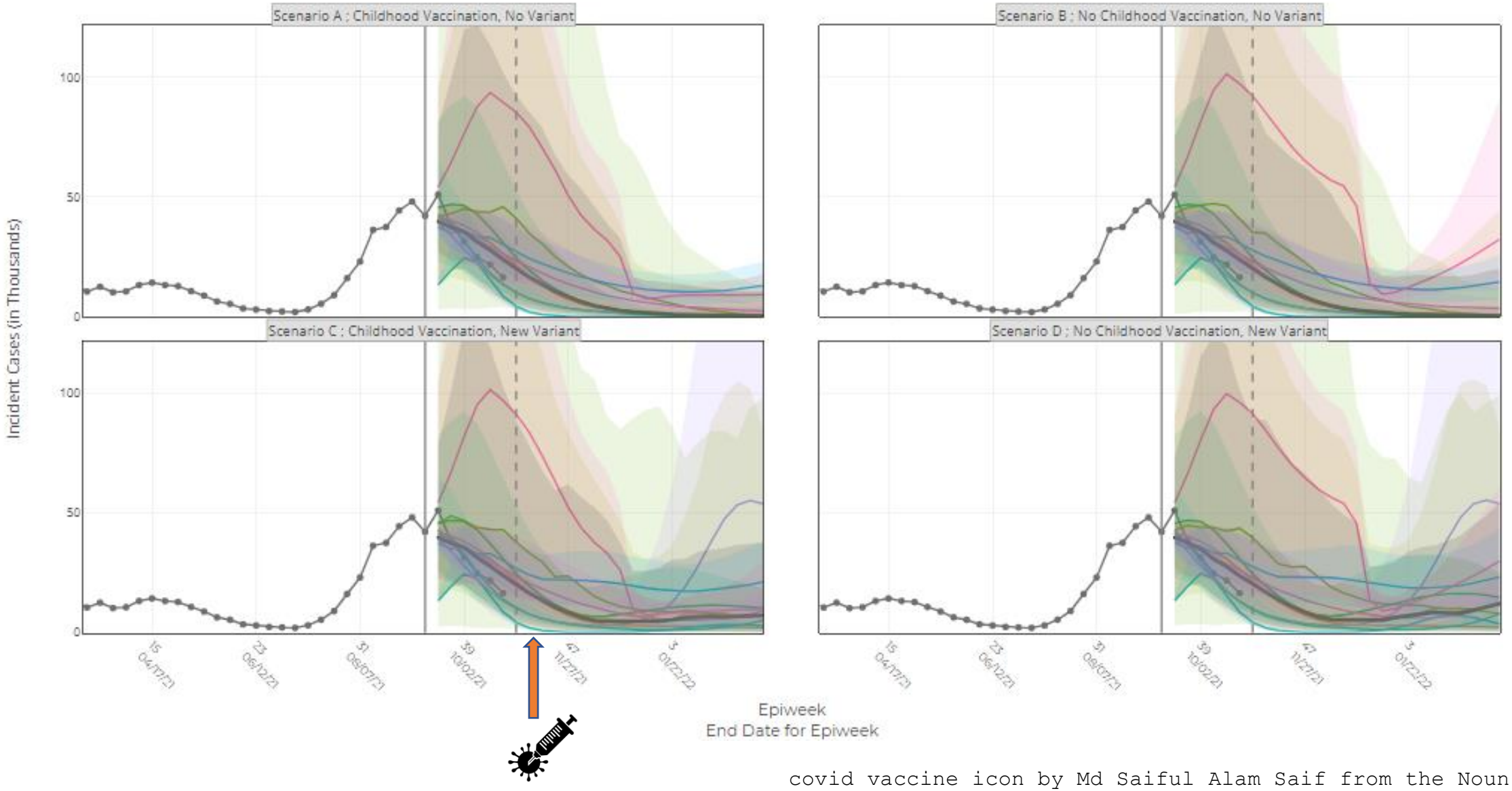
Older populations have higher death rates.



Schools and COVID-19 Transmission

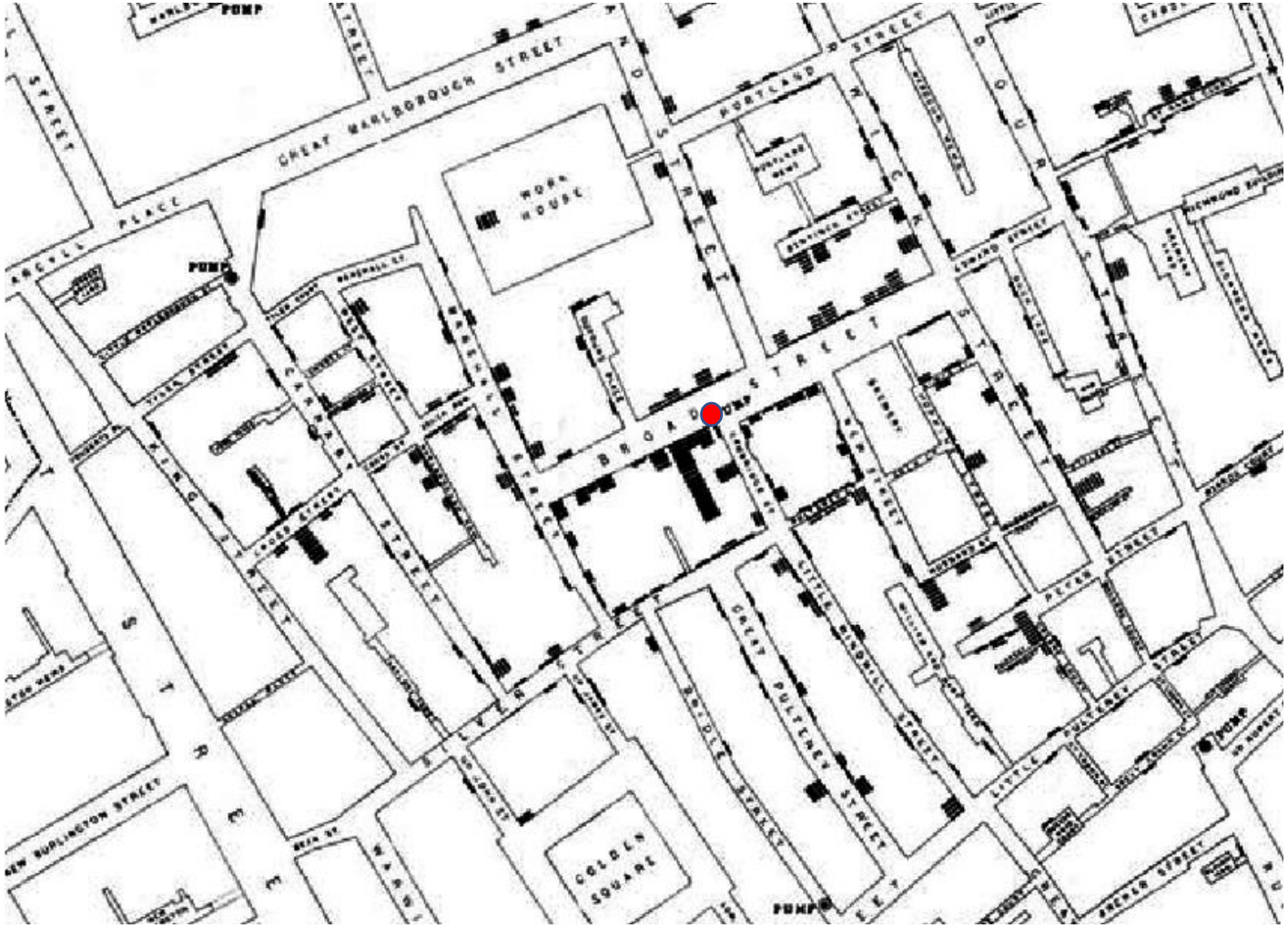


Results, General Projections



covid vaccine icon by Md Saiful Alam Saif from the Noun Project

John Snow and the Broad Street Pump



An amazing accomplishment