COVID Model Projections

June 16, 2021

BC COVID-19 Modelling Group

About BC COVID-19 Modelling Group

The BC COVID-19 Modelling Group works on rapid response modelling of the COVID-19 pandemic, with a special focus on British Columbia and Canada.

The interdisciplinary Group was convened by Caroline Colijn (SFU) and Dan Coombs (UBC) with support from the Pacific Institute for the Mathematical Sciences.

https://bccovid-19group.ca
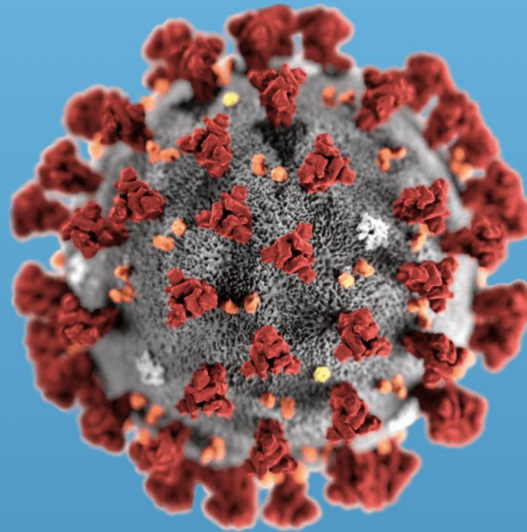
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Independent and freely offered advice, using a diversity of modelling approaches.

# BC: Facing old and new variants of concern

Key messages

- The Step 1 reopening on May 25 did not cause a major change in the rate of decline in daily case numbers.
- Delta (B.1.617.2) cases remain roughly constant, but recent changes in how VOC are identified and lack of access to the underlying data has led to challenges interpreting trends and modelling the VOC.
- In other locations, Delta shows a consistent growth advantage over Alpha (B.1.1.7).
- The number of Delta cases is likely to grow over the next few weeks but this growth will be moderated by the high levels of vaccination in BC (and potentially contained if enough people get vaccinated).
- Although first dose vaccinations have slowed (particularly among 40-59 year olds), there has been a remarkable uptake in vaccinations among 18-29 year olds, with about one-quarter of this age group receiving vaccinations in the latest two weeks of data.

Plus a mini-tutorial on "vaccine efficacy" and what it means.

State of the COVID-19 Pandemic in BC

Covid-19 daily new cases in British Columbia (up to Sun Jun 13)

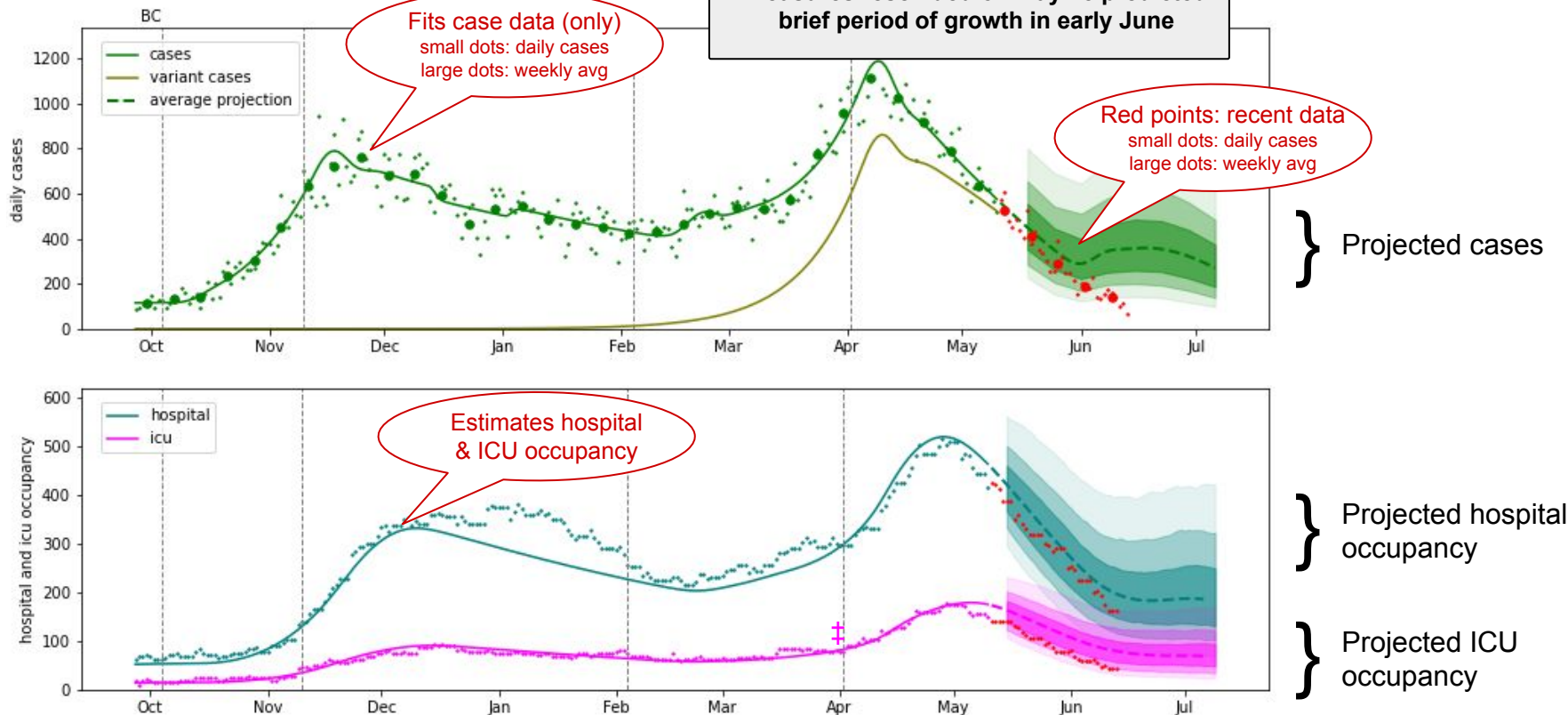Timeline of **closure** and **reopening** events
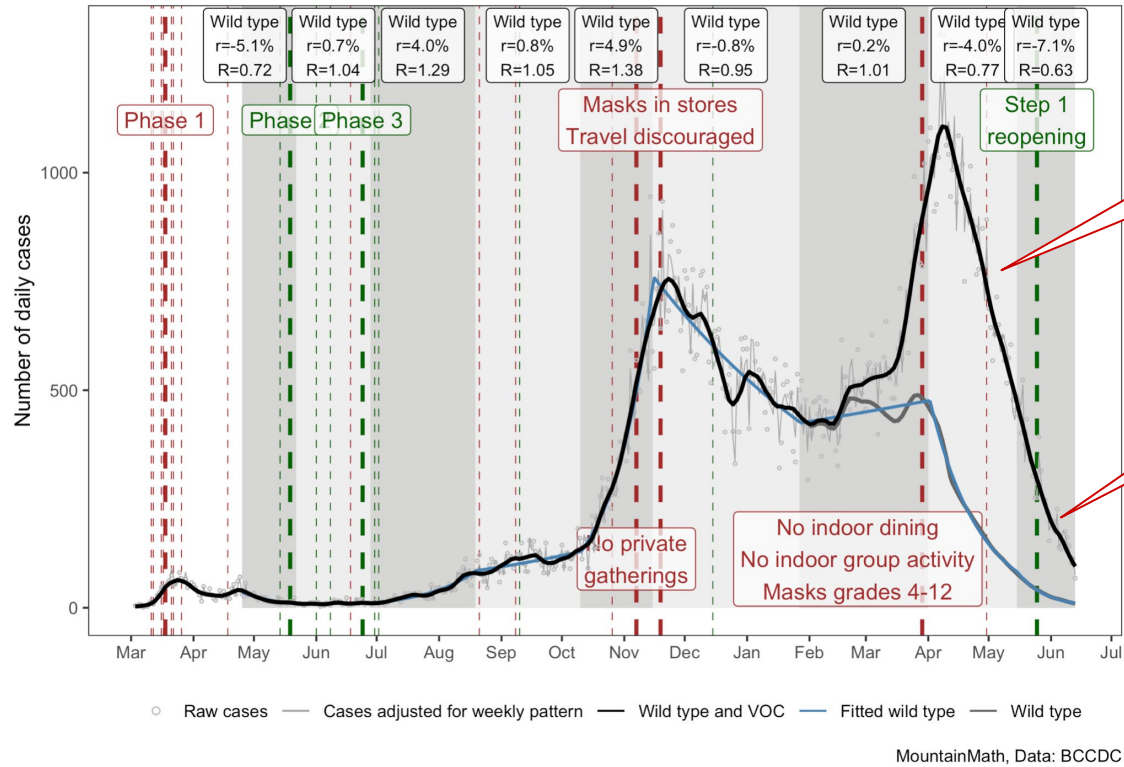
MountainMath, Data: BCCDC

Current data on Delta in BC is uncertain, making it challenging to interpret recent trends

Source (J. von Bergmann) Case data from BC COVID-19 Database (http://www.bccdc.ca/health-info/diseases-conditions/covid-19/data). Vertical lines give dates of public health measures (major as thick lines, minor as thin lines). Grey dots are raw case counts, grey lines is cases abused for weekly pattern, black STL trend line and blue fitted periods of constant exponential growth.

May 14 projection

Projection for scenario with circuit breaker measures rescinded on May 25 predicted brief period of growth in early June

Fits case data (only)
small dots: daily cases
large dots: weekly avg

Red points: recent data
small dots: daily cases
large dots: weekly avg

Projected cases

Estimates hospital & ICU occupancy

Projected hospital occupancy

Projected ICU occupancy

Source (D. Karlen). See www.pypm.ca. Homogeneous mixing (no age structure). Vaccination rate assumptions: 45,000/day up until 75% vs 65% vaccinated, with 90% asymptotic effectiveness of first dose (see Appendix of May 14 report for comparison to real-world effectiveness). Projection is for a scenario rescinding the March 30 measures (the "circuit breaker") on May 25, returning BC to activity levels in early 2021. ‡To match ICU data, the fraction of cases leading to ICU admission is increased by 60% ± 20% in early April. Bands show approximate 50%, 80%, and 95% intervals.

Updated model fit to case data by Health Authority
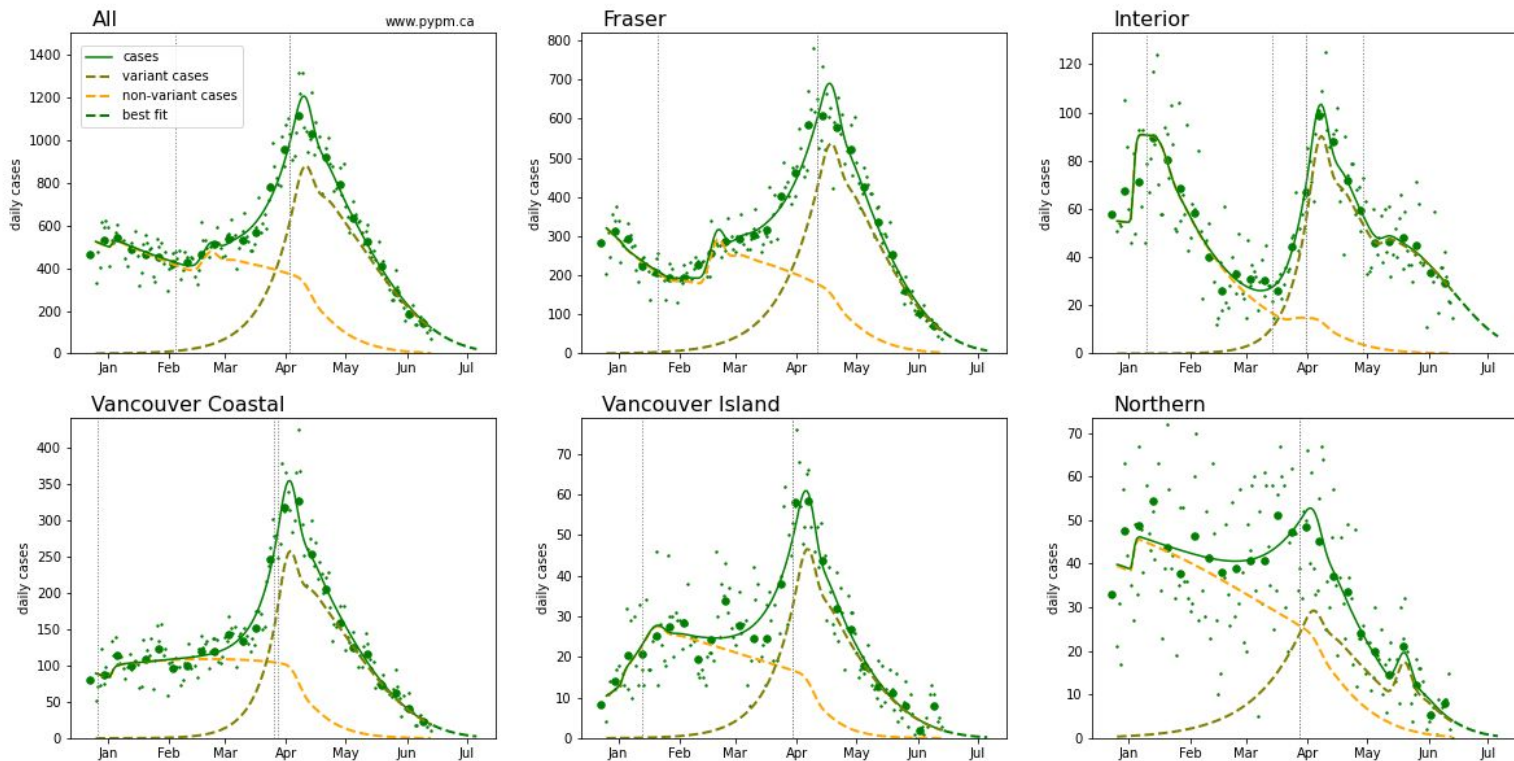
Continued decline in all HA except:

- Interior – Transmission rate increased (late April)
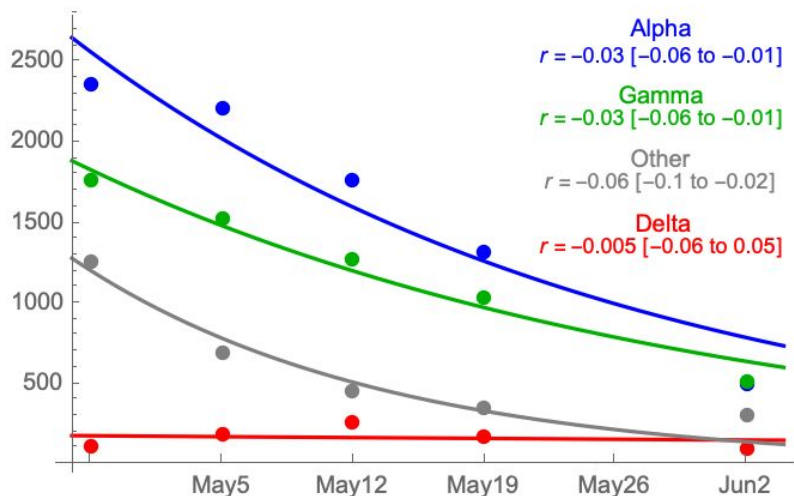
- Northern – Burst of infections in May (outbreak?)

Source (D. Karlen). See www.pypm.ca. These models have no age structure. Assumes future vaccination rate of 1st doses of 45,000/day (given to all ages and in proportion to HA populations until 75% of the population is vaccinated), ultimate 1st dose effectiveness is 90%. Vaccination model benchmarked with data from Israel: see link. Assumes current public health measures remain in place in June.
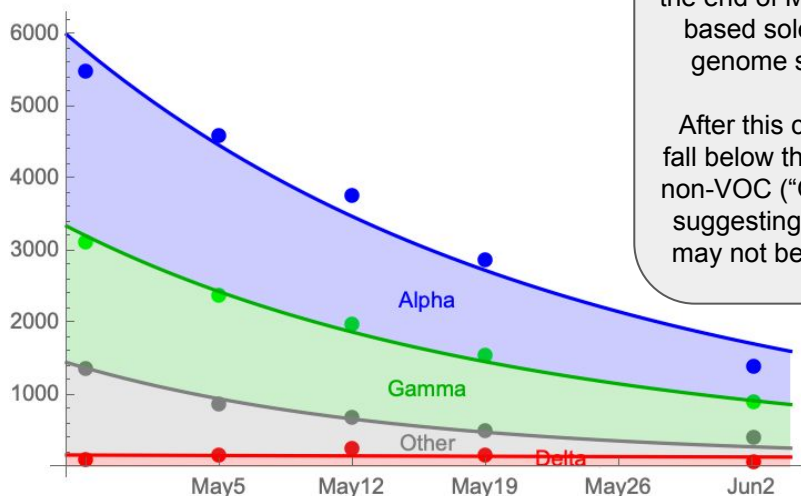
Spread of Delta in BC

Typing of cases reported by the BCCDC from April 25 to June 5 indicates that all variants are declining, except Delta, which remains roughly steady.

Number of variant cases

Alpha
$r = -0.03$ [-0.06 to -0.01]

Gamma
$r = -0.03$ [-0.06 to -0.01]

Other
$r = -0.06$ [-0.1 to -0.02]

Delta
$r = -0.005$ [-0.06 to 0.05]

Total cases

Alpha

Gamma

Other

Delta

Typing of VOC changed at the end of May and is now based solely on whole genome sequencing.

After this change, VOC fall below their trends and non-VOC ("Other") above, suggesting that the data may not be comparable.

Source (S. Otto). Fit to weekly Variant report from BCCDC (subtypes of B.1.617 not distinguished until last epiweek, which reports B.1.617.2). Uses weekly cumulative case numbers for each epiweek (mid-date of epiweek shown on the x axis) and multiplies by the "Sample prevalence VOCs" to estimate the number of each variant in each week. Exponential model fit is used to estimate daily growth rate, r. Note that r estimates are highly uncertain with so few data points [95% CI in square brackets], as well as changes in data structure.

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Spread of Delta in Alberta

- In Alberta, VOC data are more complete and provided daily, allowing us to estimate a selection coefficient for Delta (B.1.617.2) over Alpha (B.1.1.7):
    - s = 0.10 +/- 0.004 per day (68% CL)

- Currently, Delta accounts for ~20% of the variants circulating in Alberta.

- Delta is estimated to be growing in number:
    - r = 0.026 per day [95% CI: 0.01, 0.043]
 which corresponds to a 26 day doubling time (95% CI: 16-70 days), even before the recent reopening.

CAVEATS: Analysis does not account for future vaccinations. Labs in Alberta have recently gone back through and typed past samples for Delta. Critically, *this analysis assumes that the back-typing is nearly complete for Delta.*
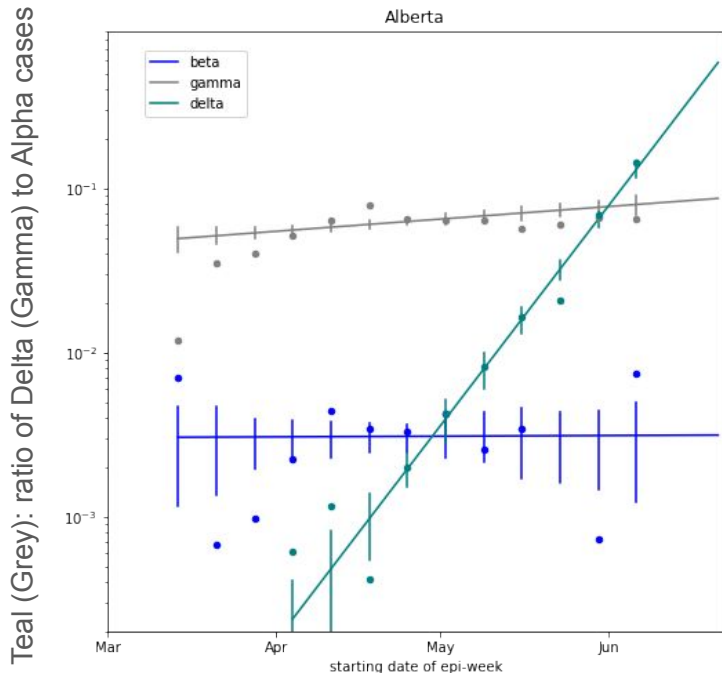

Source (S. Otto and Dean Karlen). Data from source file https://www.alberta.ca/stats/covid-19-alberta-statistics.htm#variants-of-concern (accessed June 14, using data through June 7). The estimate of the growth rate (*r*) depends on an inference of sampling fraction in May, which was based on a fit of the total proportion of all VOC from April 10 to June 7, 2021.

Growth advantage of Delta (B.1.617.2)
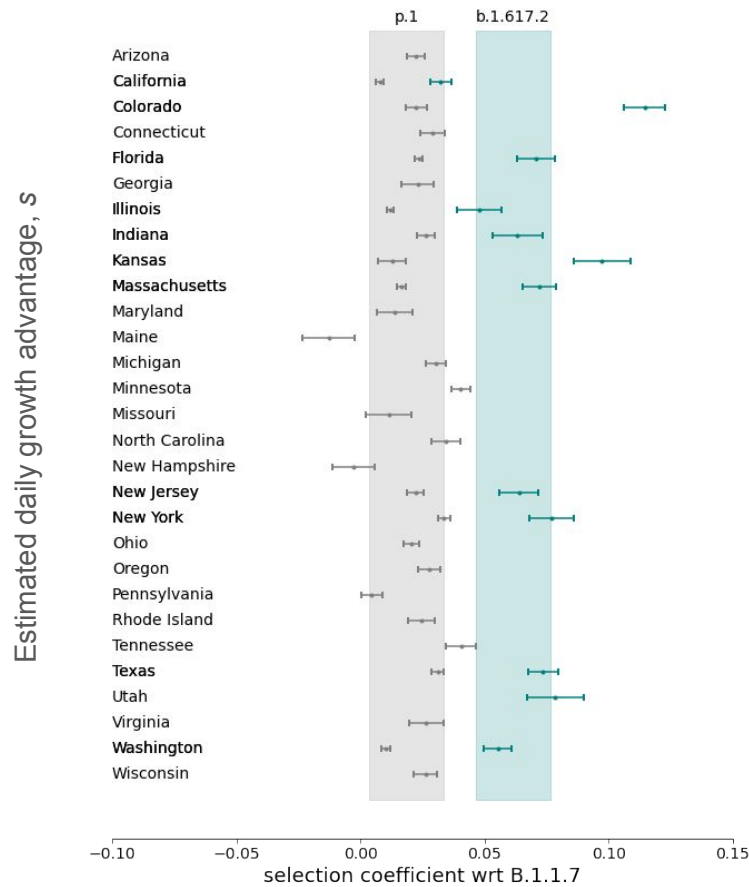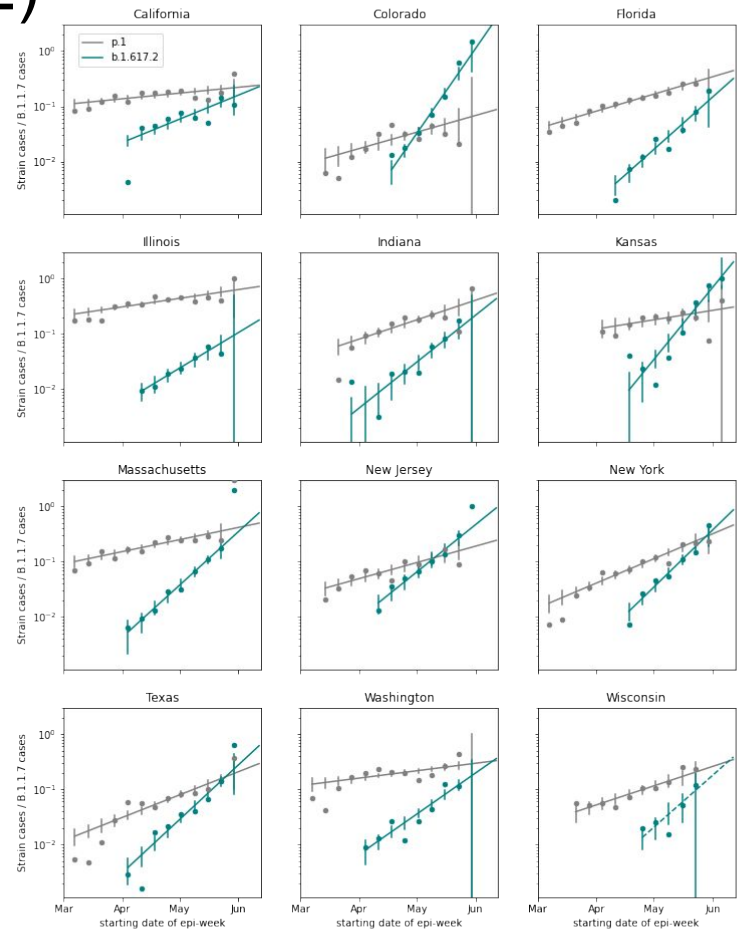
Source (D. Karlen). Fit to GISAID data as compiled by outbreak.info for USA. Growth advantage ("selection coefficient", *s*) measures the daily rise in the frequency of a variant, either Delta(B.1.617.2) or Gamma (P.1), relative to the frequency of Alpha (B.1.1.7).

Past and future growth
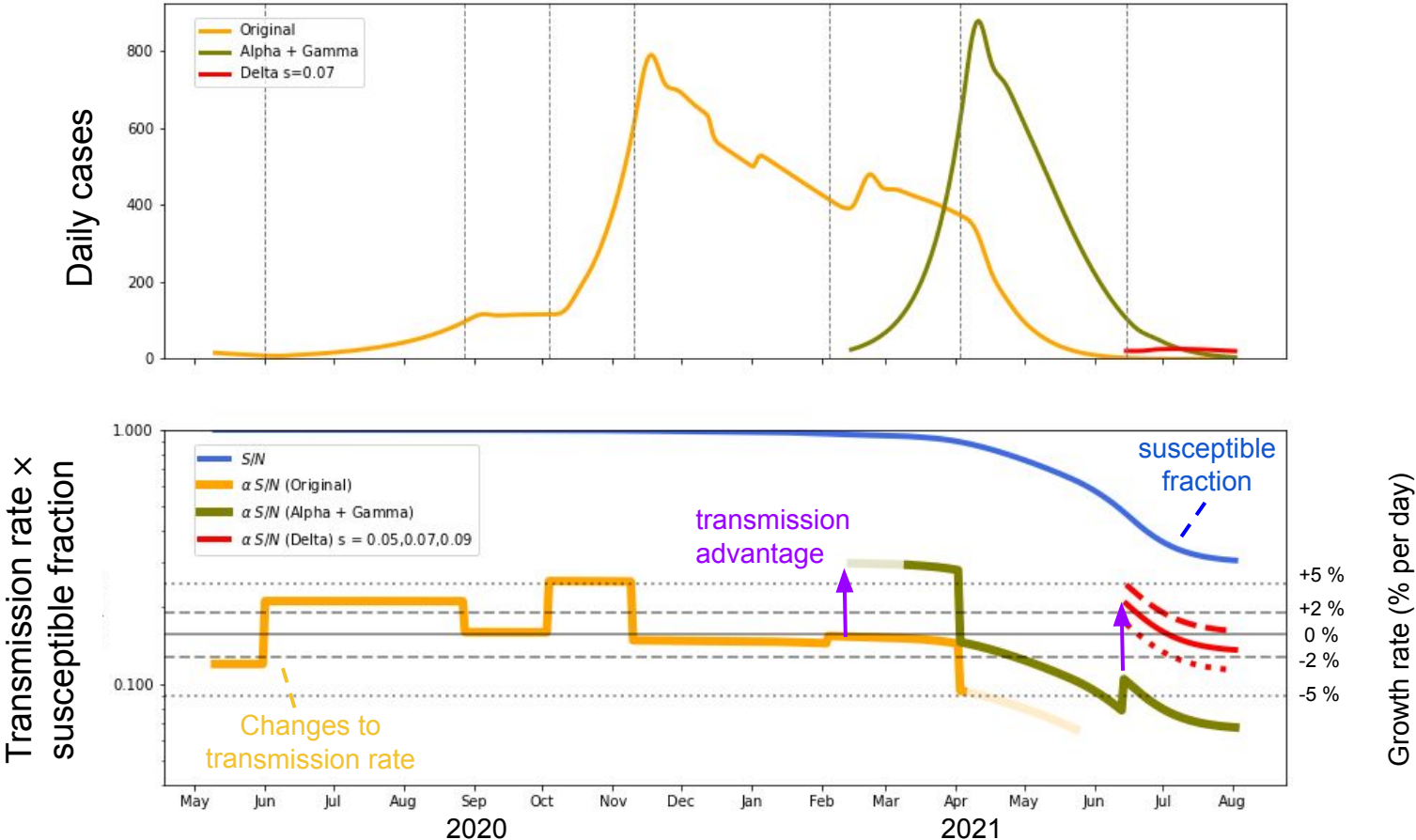
BC incidence projections: contact and reopening

Incidence continues to decline, with vaccinations[§] contributing to that decline.

This decline is robust to some increase in contact rates* among those distancing (+30% in yellow, +15% in green).

Step 1 of BC's reopening plan has not led to an increase in cases.

This does not take potential reduced efficacy to VOC (e.g. delta variant) into account.

BC

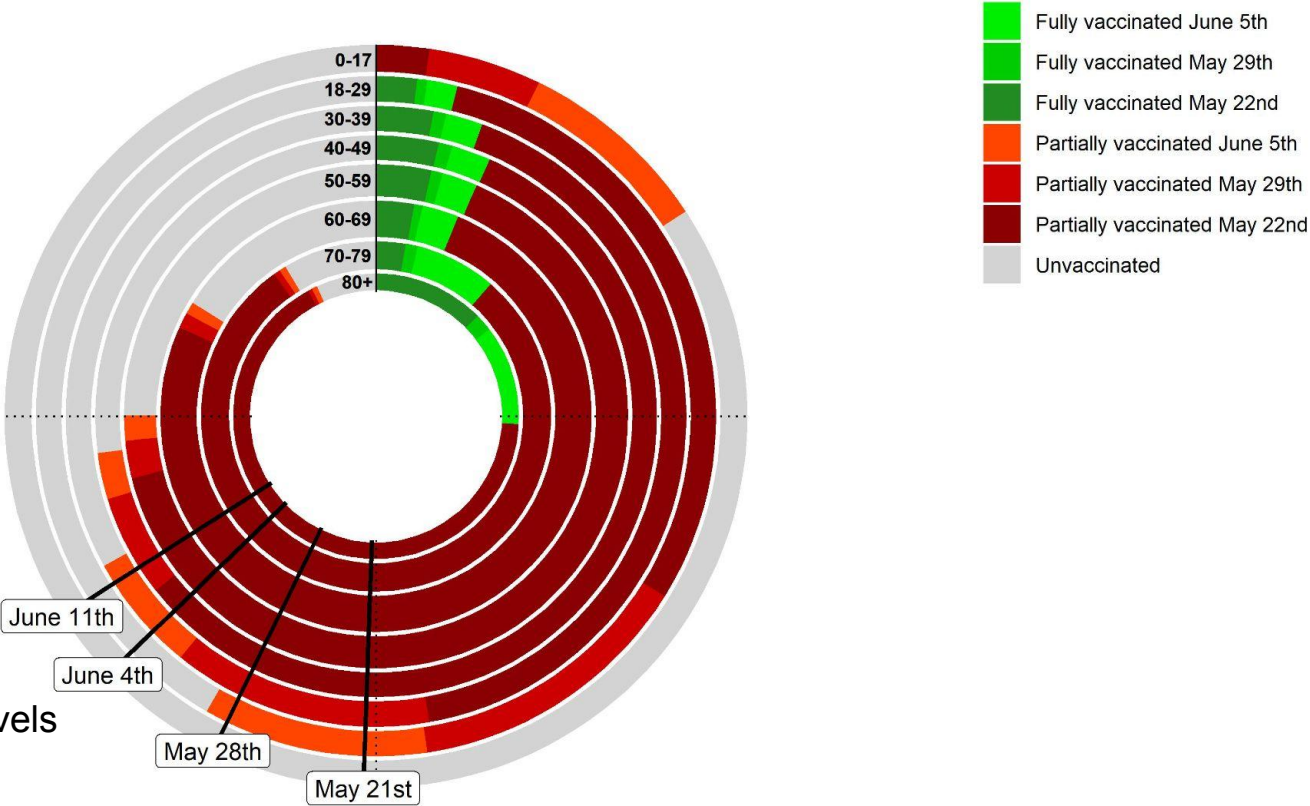Yellow: 30% increase in contact*. Green: as now. Purple: 30% decrease in contact.
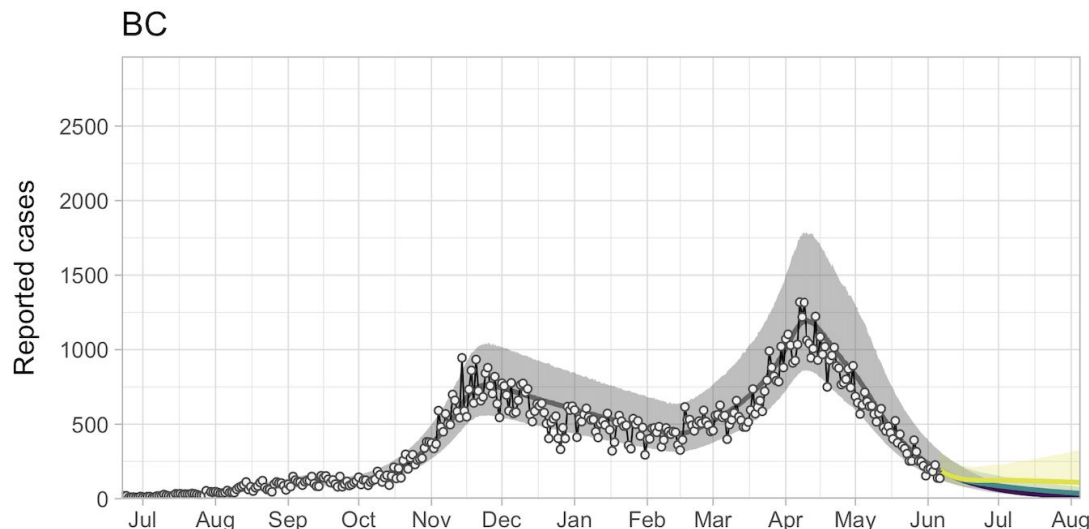
Source (E. Are, C. Colijn). Daily case numbers projected forward, accounting for B.1.1.7 and P.1 data from BCCDC variant reports. These data provide % of cases that were VOC by week (see appendix slide 23). These data were fit by a logistic function to estimate percent VOC by day (see Appendix of April 14 report). Assuming a 40% increase in transmissibility (consistent with the estimated selection *s* in the Appendix of April 14 report), the percent VOC is used to create an overall reproduction number *R* for the virus population. *R* changes in time as the VOC rises in frequency. The social distancing parameter (among others) is estimated to fit the data using the 'covidseir' R package (M. Irvine, S. Anderson). §Vaccination is incorporated by removing susceptibles at a rate accounting for contact by age, vaccination by age and susceptibility of contacts. * Measured as *f*, the relative contact rate among those willing and able to distance.

Closing the circle: Vaccination status by age

June 12th update includes data through June 4th, 2021

Legend:
- Fully vaccinated June 5th
- Fully vaccinated May 29th
- Fully vaccinated May 22nd
- Partially vaccinated June 5th
- Partially vaccinated May 29th
- Partially vaccinated May 22nd
- Unvaccinated

Age groups: 0-17, 18-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80+

June 11th
June 4th
May 28th
May 21st

Making progress:
Average vaccination levels
by date in BC

Closing the circle: Vaccination status by age

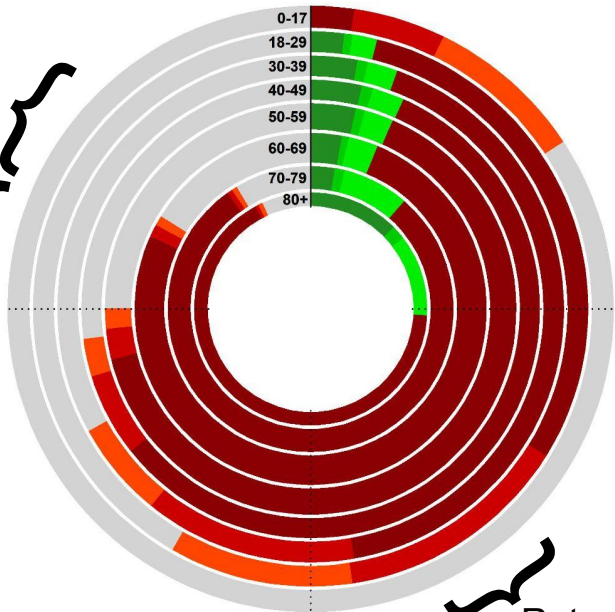June 12th update includes data through June 4th, 2021

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If vaccines were 100% effective:

Herd immunity if $R_0 \sim 5\text{-}6$

Herd immunity if $R_0 \sim 4\text{-}5$

R_0 for B.1.617.2 unknown but may be ~4 to 7 given an R_0 for B.1.1.7 of ~2.8 to 5.4* without control measures

Age groups (rings): 0-17, 18-29, 30-39, 40-49, 50-59, 60-69, 70-79, 80+

Herd immunity: the level of immunity in a population at which a disease starts to decline*

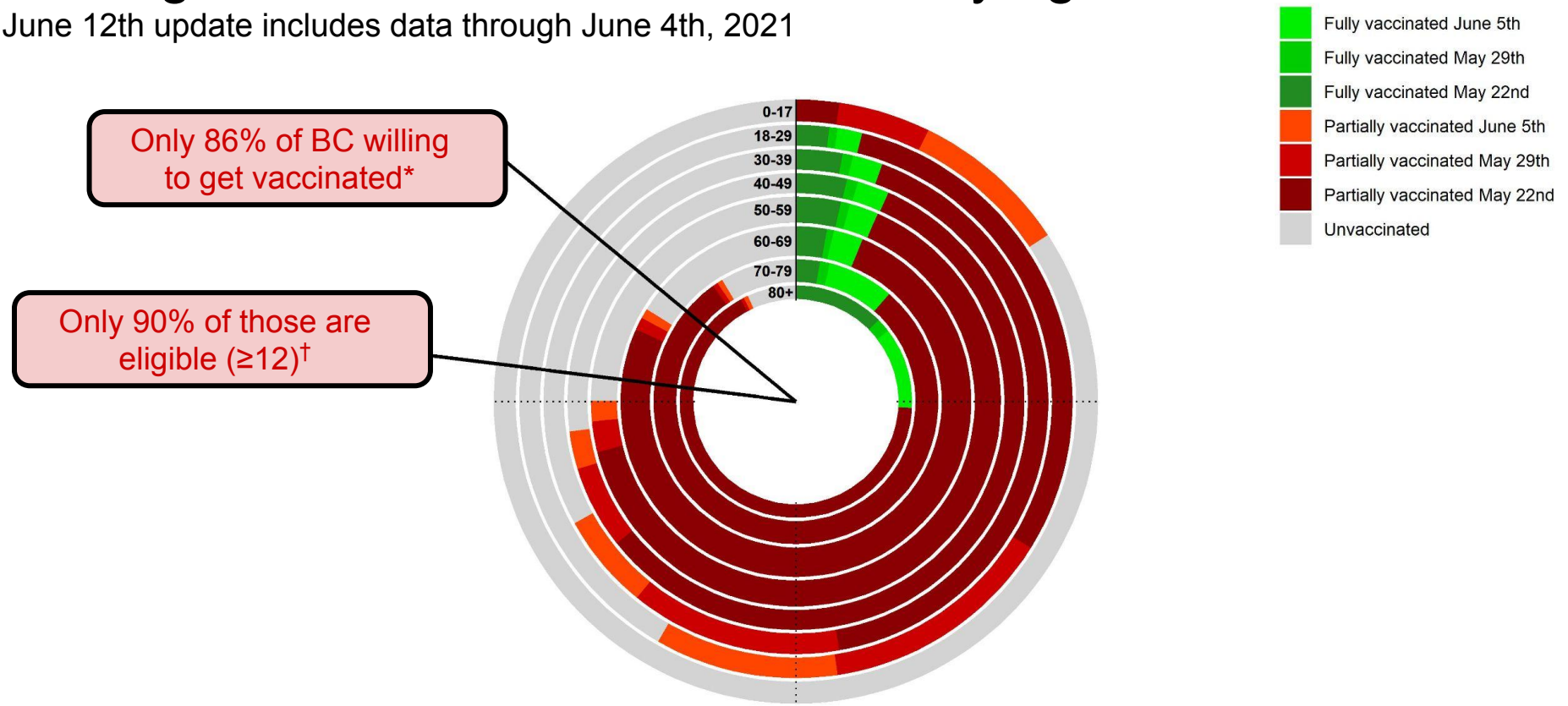$\rightarrow (1\text{-}f)\, R < 1$ where f is level of immunity

Reproductive number (R): number of new cases per case, called R_0 in the absence of any control measures.

Return to Feb/March 2021 activities when $R \sim 1.7$ for B.1.1.7 & P.1 in BC[†]

Source (B. Wiley). Design by Blake Shaffer (https://blakeshaffer.shinyapps.io/app_vaccines/) [†]https://bccovid-19group.ca/post/april-2021-report/
*Public Health Ontario: https://www.publichealthontario.ca/-/media/documents/ncov/covid-wwksf/2021/02/wwksf-herd-immunity.pdf, assuming B.1.617.2 has a selective advantage of s=0.05 and using a 6.5 day generation time to translate to reproductive numbers (as in Volz et al.). *Typically assumes no or minimal control measures.

Closing the circle: Vaccination status by age

June 12th update includes data through June 4th, 2021

Only 86% of BC willing to get vaccinated*

Only 90% of those are eligible (≥12)†

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- Fully vaccinated June 5th
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Closing the circle: Vaccination status by age

June 12th update includes data through June 4th, 2021

Fully vaccinated June 5th
Fully vaccinated May 29th
Fully vaccinated May 22nd
Partially vaccinated June 5th
Partially vaccinated May 29th
Partially vaccinated May 22nd
Unvaccinated

Only 86% of BC willing to get vaccinated*

Only 90% of those are eligible (≥12)†

&

First dose only partially effective against symptomatic infection‡

0-17
18-29
30-39
40-49
50-59
60-69
70-79
80+

Pfizer
Moderna
AstraZeneca

Herd immunity with no control measures will not be achieved until more of BC is fully vaccinated.

http://www.getvaccinated.gov.bc.ca

Vaccination status by age group

Last age-based BC data update June 05
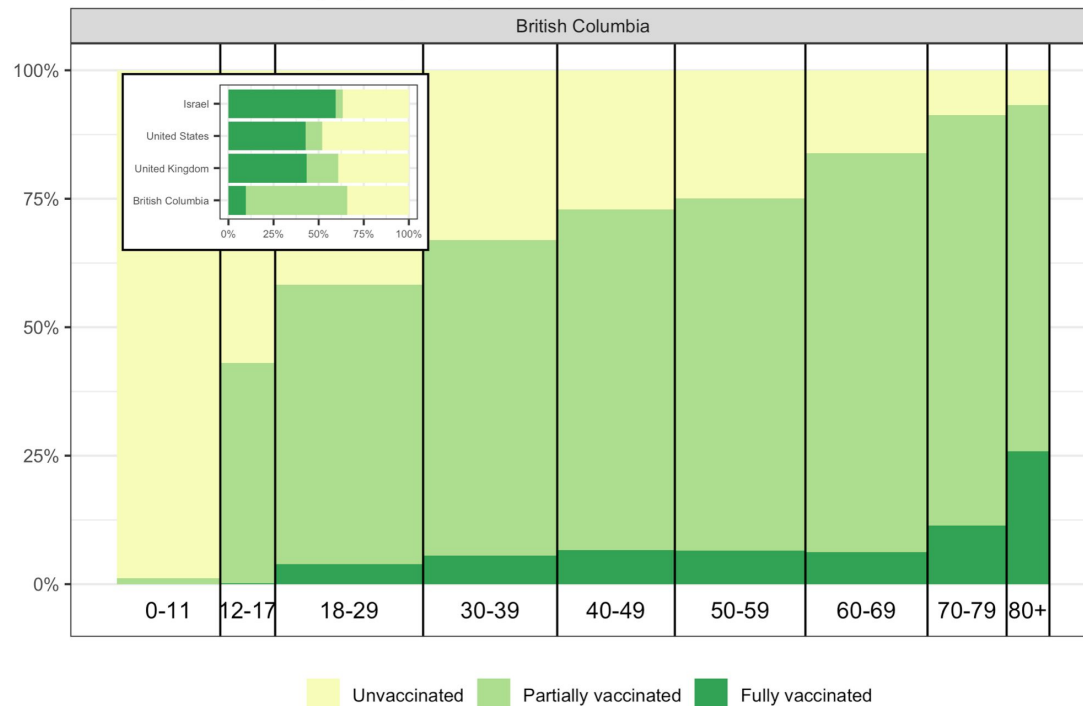
Data: PHAC, StatCan Table 17-10-0005, Our World in Data

Israel: 63.3% vaccinated (at least one dose, 59.4% fully vaccinated). Uses a traffic light model that opens up regionally depending on local infection levels.

UK: 60.1% vaccinated (at least one dose, 43.4% fully vaccinated). Schools fully open with optional rapid testing available and masks for secondary students; indoor dining open with safety protocols; outdoor socializing up to 30, indoor up to 6 people. Step 4 reopening has been postponed because of Delta.

Countries with high vaccination levels are reopening slowly

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Interpreting "vaccine efficacy"

What does 80% effective mean?

- You and your friend do everything together.
- Only you are fully vaccinated.
- Your friend is 5x more likely to get COVID19 than you

How to understand 80%

See appendix to look under the hood at the math behind "vaccine efficacy"

- 80% describes your RELATIVE risk.
- This is what clinical trials are designed to measure.
- In the real world, given that you have been vaccinated,
  you are 1/5 as likely to get COVID19 as if you had been unvaccinated.

It's like having an umbrella that opens up and works, but only 80% of the time.
You are going hiking. Do you get wet? Well, *if it rains,* you get wet with probability 20%.

Interpreting "vaccine efficacy"

Common interpretations of "80% effective" that are WRONG

❌ 1 - You are 80% protected.
❌ 2 - You have a 20% chance of getting COVID19.
❌ 3 - Each time you get exposed to someone with COVID19, you have a 1/5 chance of getting infected.
❌ 4 - Out of 100 vaccinated people like you, 20% will get COVID19.
❌ 5 - If you get COVID, your symptoms will be only 20% as severe.
❌ 6 - 80% of the time I encounter someone with COVID, I'm protected. I'm at risk 20% of the time.
~ 7 - I got vaccinated, so I can safely behave as normal with little risk of infection

Points 1-6 are wrong.
Point 3 is close: "you have 1/5 the chance of being infected as if you were unvaccinated" is correct
Point 7 is reasonably accurate, with the caveat that risk depends on behavioral, personal and environmental factors. Your personal risk of infection depends on you behave after vaccination.

People want to say "if I go to a bar my chance of getting COVID19 is z%". Unfortunately, this probability depends on unique circumstances, and cannot be accurately estimated. What we CAN say is that "if I go to a bar, my risk is only 1/5 as much as it would be if I weren't vaccinated."

Late Breaking

Major increase in genome sharing by BC

GISAID

Since our last report, BC has uploaded over 9,000 full genomes to the global database, GISAID.

These sequences allow scientists to better:
- Identify new variants
- Estimate rates of spread
- Detect importations

Thank you to all the people that make this data happen!!

Fraction of SARS-CoV-2 genomes in GISAID from samples collected in 2021
(Light bars indicate newly added 2021 sequences since May 31, with the number of added genomes indicated at top.)
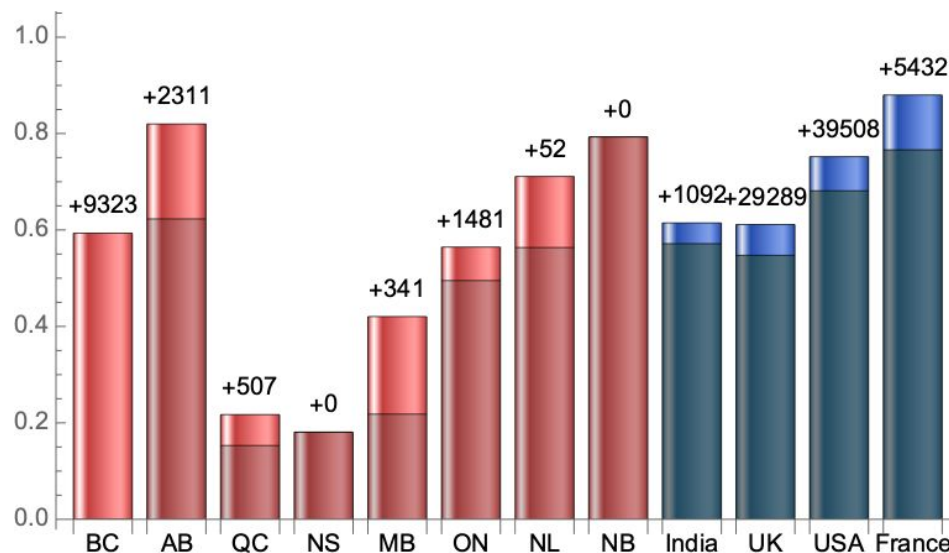
	BC	AB	QC	NS	MB	ON	NL	NB	India	UK	USA	France
2021 samples:	9334	9639	1724	242	710	12 086	251	303	15 763	281 211	421 748	42 017
All samples:	15 727	11 761	7947	1340	1690	21 408	353	382	25 650	460 019	560 894	47 740

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Final messages

Slow changes in transmission following the Step 1 reopening on May 25 have avoided a rise in cases.
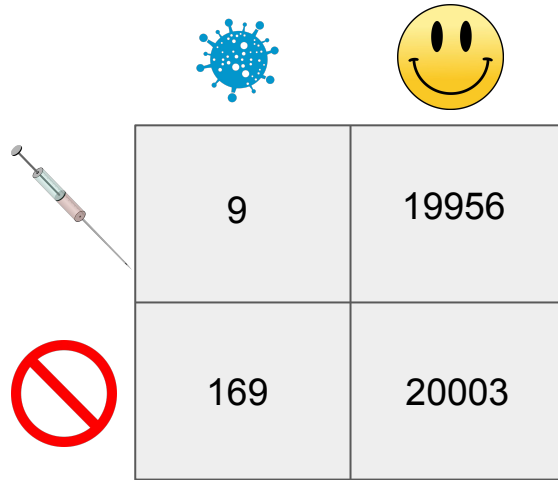
We should aim for more than 70% vaccination of 18+ (~60% of all ages) in order to allow more reopening safely, especially in light of newly emerging VOC, like Delta (B.1.617.2).

Spread of Delta (B.1.617.2) is consistent with it growing 5-10% faster *per day* relative to Alpha (B.1.1.7) in many jurisdictions.

Data from BC on the VOC is currently hard to interpret due to changes in accounting.

Since our last report, BC has ramped up submissions of COVID-19 genomes, with nearly 10,000 recent uploads to GISAID.

*Including restaurant reopenings, small indoor gatherings, allowance for low impact gym activities.

Appendix: The math behind vaccine efficacy

	🦠	🙂
💉	9	19956
🚫	169	20003

$$\text{Estimated effectiveness rate} = 1 - \frac{\widehat{P}(\text{COVID} \mid \text{Vaccinated, } B)}{\widehat{P}(\text{COVID} \mid \text{Unvaccinated, } B)}$$

$$= 1 - \frac{9/19965}{169/20172}$$

$$\approx 95\%$$

Example calculation of "vaccine efficacy" (VE). Important caveats:
- The rate is estimated based on data in the table. Another trial would lead to slightly different estimates
- "Real world" efficacy for "vaccines" is closer to 80%, which is still extremely good.
- The event B means "enrolled in the clinical trial"
- B is important. It incorporates many features of interest that occurred during the trial. Among these are:
  - Prevailing infectiousness (variants, number of surrounding infectious,...)
  - Behavior (lockdowns, how much individuals interact)
  - Environmental factors (weather)
  - Duration of the study (longer time means more exposure)
  - All of these are "as they occurred during the trial"
- Randomization means that B is the same in both arms. It can be cancelled from the numerator and denominator, allowing the estimate to be extrapolated to others scenarios, independent of B.
- This is the magic of randomization and well constructed clinical trials. They allow for extrapolation outside of the trial setting.
- The same data can be used to estimate $\widehat{P}(\text{COVID} \mid \text{Vaccinated, } B) \approx 0.045\%$
- But the dependence on B can no longer be removed
- Understanding "your susceptibility in your current environment" requires knowing how your current environment relates to that during the trial
- So this estimate is not useful for your decision making. We don't know your probability of infection if you go out to eat on a specific day. We only know that it is lower (80% lower) if you're vaccinated.

Source (D. McDonald). Data in the above table comes from the second row of Table 2 in the article Safety and Efficacy of the BNT162b2 mRNA Covid-19 Vaccine. These are the reported positives and negatives 7 days after the second dose in Phase 2 / 3 trials of the Pfizer/BioNtech vaccine.