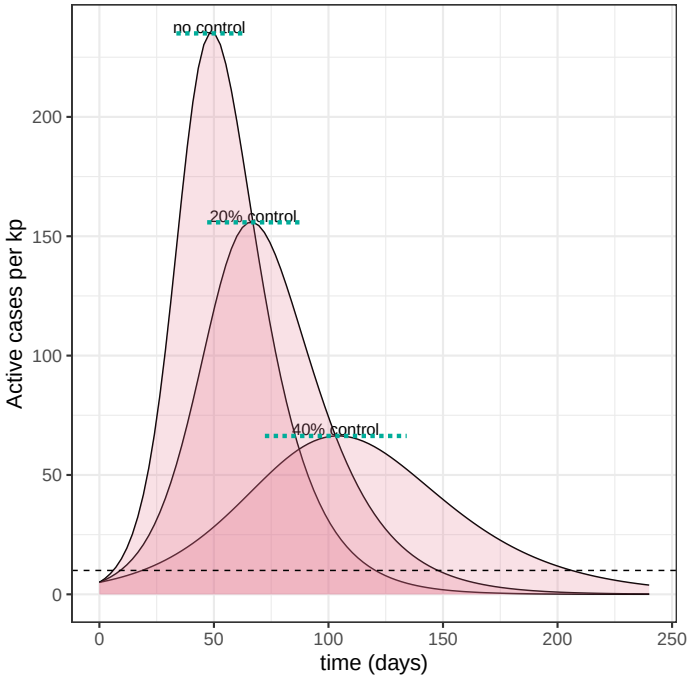
UNIT 8B: Coronavirus

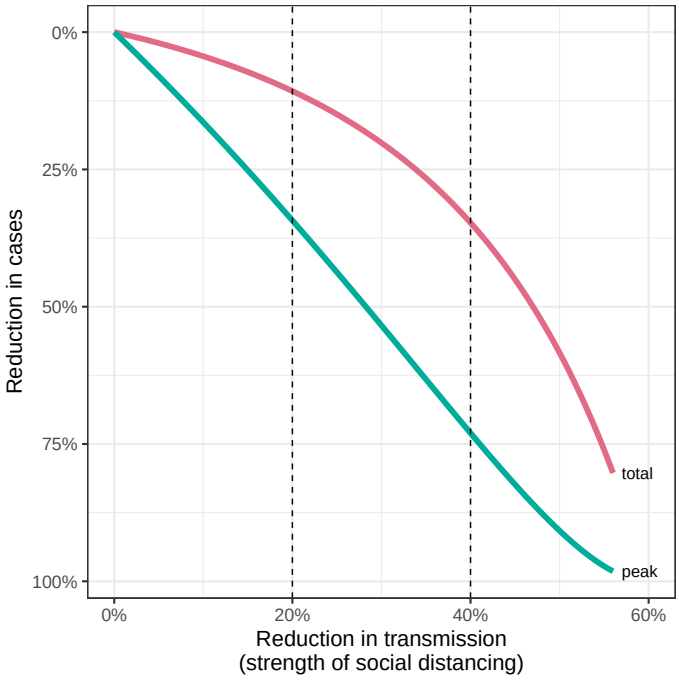
1 Initial projections

What happens when we flatten?

- Poll: Which scenario has the lowest total number of cases shown (area under the curve)?

Flattening the curve





Flattening the curve

- More flattening than reduction in total
  - **Answer:** As long as $\mathcal{R}_0$ is medium-to-large we expect almost everyone to get infected in a simple model
  - **Answer:** Changes in $\mathcal{R}_0$ don't affect area under the curve
  - **Answer:** But they can have big effects on the peak
- What are some benefits of just flattening?
  - **Answer:** Less peak demand
  - **Answer:** More time to find solutions:
    - **Answer:** Better treatments
    - **Answer:** Vaccines

Behaviour and policy change

- Why were our early models so wrong?
  - **Answer:** People and governments changed behaviour much more than we expected
    - **Answer:** Fear of overflowing hospitals and chaos in general
  - **Answer:** Population heterogeneity
    - **Answer:** Not everyone mixes the same, or at the same time
    - **Answer:** A less important effect so far

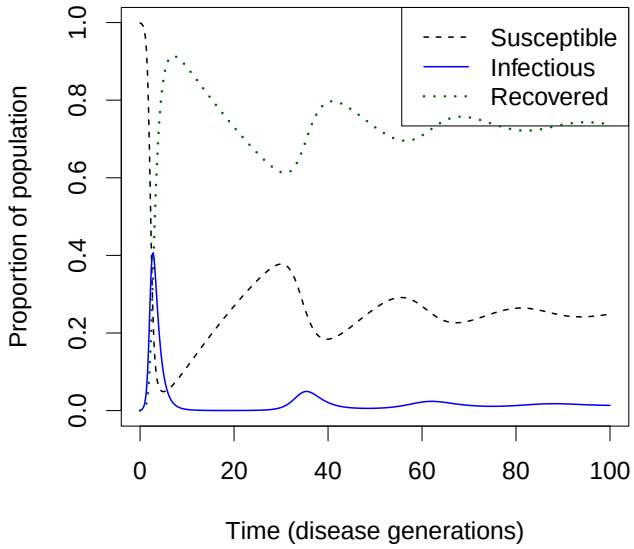
2 Endemic coronavirus

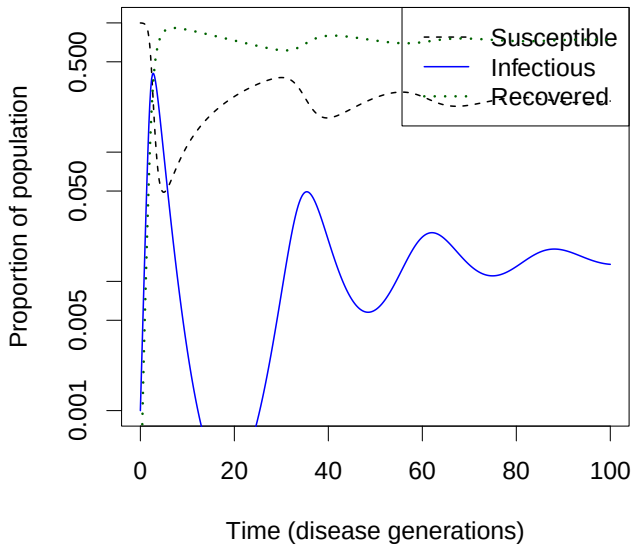
- Poll: What does it mean for SARS-CoV-2 to become "endemic"
  - **Answer:** Not going extinct
  - **Answer:** Not *too* much variation in annual incidence
- What it doesn't mean:
  - **Answer:** Not fluctuating
  - **Answer:** Not dangerous
- *Comment:* A lot of double negatives, make sure you're clear!

Disease burnout

- A disease that has a big epidemic and leaves very few susceptibles behind can go locally or globally extinct – we call this burnout
- Lots of evidence for influenza or measles burning out in isolated areas during less global times

Disease burnout





Adaptive responses

- How do people respond to fear of COVID-19?
  - **Answer:** Masking, distancing, booster shots
  - **Answer:** Mandates, lockdowns
- What effects do we expect if people's worry levels about SARS-CoV-2 fluctuate with virus levels?
  - **Answer:** Will increase spread when levels are high (or growing)
  - **Answer:** Tendency to stabilize the dynamics
    - **Answer:** Smaller outbreaks, less chance of random extinction

Burnout and SARS-CoV-2

- Burnout seems very rare in the global era
- Adaptive responses work against burnout
  - When things are bad, people are more careful: less overshoot
  - When things are good, people are less careful: less chance to keep the virus down

3 Pathogen aggressiveness

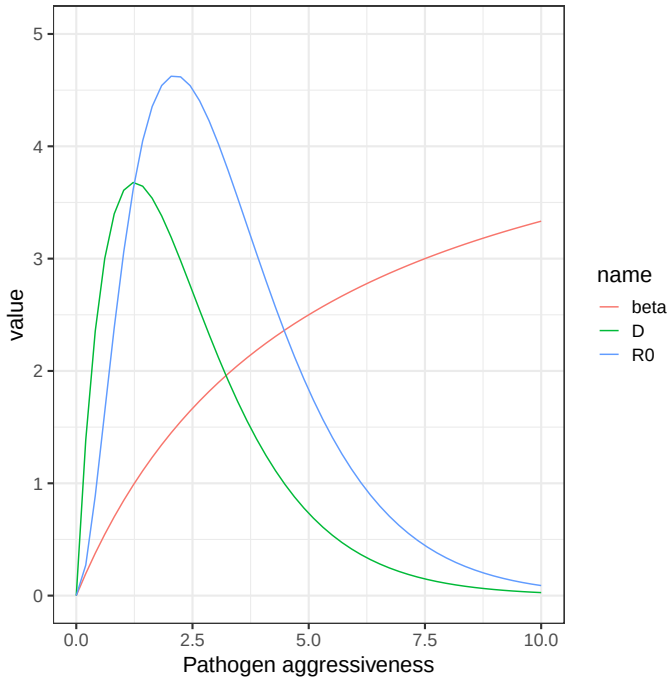
- Poll: Should viruses evolve to become more or less dangerous?

- **Answer:** It depends
- **Answer:** The virus evolves in the way that's best for the virus
- **Answer:** Host death and host recovery are equally bad!

Which strain will win?

- If the competing strains produce similar immune responses, this is exactly like equal competition: infections are competing for a single resource:
  - **Answer:** Susceptible humans
- The winner will be the strain that has the highest "carrying capacity":
  - **Answer:** Removes the largest number from susceptible pool
  - **Answer:** Highest $\mathcal{R}_0$
  - **Answer:** This could be more or less deadly
  - **Answer:** Removal by killing and removal by recovery have similar effects on the virus

Pathogen aggressiveness



- Pathogen will evolve to maximize $\mathcal{R}_0$.
- Is not affected by whether duration D is ended by host death, or by immune system clearing the pathogen

Human evolution

- We have evolved very good immune systems, but we can't always stay ahead of the viruses
- Should people evolve to favor the spread of more or less dangerous viruses?
  - **Answer:** Less dangerous!
  - **Answer:** Viruses that do well in the upper respiratory tract may spread better
  - **Answer:** Viruses that do well in the lower respiratory tract are more dangerous
  - **Answer:** Have we evolved to make this a tradeoff for viruses?

Omicron example

- Omicron spreads *much* better than earlier SARS-CoV-2 viruses
- It does less well in the lungs and better in the upper airways
- SARS-CoV-2 *may* be evolving in a less dangerous direction
  - There is no guarantee
  - Delta spread better and was *more* dangerous than previous

4 The future of SARS-CoV-2

What is different about SARS-CoV-2?

- What is the main difference between SARS-CoV-2 and other colds and flus?
  - **Answer:** There was almost no immunity before 2020
  - **Answer:** It is still adapting to humans

Human immunity

- The immune system is very complicated and very effective
  - T cells and B cells recognize different parts of the **pathogen**
  - Even partial recognition often protects people against severe outcomes
- Vaccines
  - Also likely to protect against severe outcomes

Immunity and the virus

- Our immune systems may see different variants of the virus differently:
  - Cross-immunity to a different strain might be less effective than direct immunity to the strain I was infected with
- How will this change our picture of competition?
  - **Answer:** It makes it easier for different strains to co-exist
  - **Answer:** We don't know yet how much easier. Some viruses (HPV) have dozens of co-existing strains. Others (influenza A) have limited cross-immunity, but strong population-level competition

Herd immunity

- Poll: What is meant by herd immunity?
  - **Answer:** A level of immunity in the population that interferes with *the spread of the pathogen*
    - **Answer:** In particular, the phenomenon of immune people protecting others by reducing population-level spread
  - **Answer:** May or may not mean that the pathogen cannot survive
- How much herd immunity do we need?
  - **Answer:** About $1 - 1/\mathcal{R}_0$ for $\mathcal{R}_{\text{eff}} \approx 1$
  - **Answer:** In the long run, we expect to see about the right number of susceptibles to keep the infectious individuals in balance
  - **Answer:** If we can get above this level through vaccination, there is a chance to drive the pathogen extinct, in theory

Can herd immunity drive SARS-CoV-2 extinct?

- What extinct viruses do we know about? How did they get there?
  - **Answer:** Smallpox and rinderpest
  - **Answer:** Vaccination!
    - **Answer:** Herd immunity by vaccination is the only realistic hope for driving SARS-CoV-2 extinct
    - **Answer:** Burnout did not work!
  - **Answer:** What about our luck with measles, mumps, polio, influenza, etc?
    - **Answer:** SARS-CoV-2 is mutating more effectively than most of these!

Levels of disease

- In the long run, how long we go between COVID-19 infections will likely depend mostly on how long our immunity lasts, or else on
  - **Answer:** how often we get vaccine boosters

Just another seasonal coronavirus (JASC)

- This is a *theory* that lack of population immunity is the *only* difference between SARS-CoV-2 and other viruses that cause common colds
  - Some versions of the theory account for SARS-CoV-2 continuing to evolve in that direction
- Poll: What do you think of this theory?
  - **Answer:** We all had versions of the common cold viruses as young children
  - **Answer:** The common cold viruses face a high level of population immunity and can't have big outbreaks the way SARS-CoV-2 does.
    - **Answer:** Smaller doses may be correlated with less-severe cases
  - **Answer:** It's good to hope, but we shouldn't count on it
  - **Answer:** We don't know how SARS-CoV-2 is going to evolve

Moving forward

- We need to pay attention and figure out how strongly to prioritize SARS-CoV-2 control
- We also need to be thinking about detecting and responding to the next pandemic!
  - **Answer:** Better surveillance
  - **Answer:** Routine monitoring of viruses from patient samples