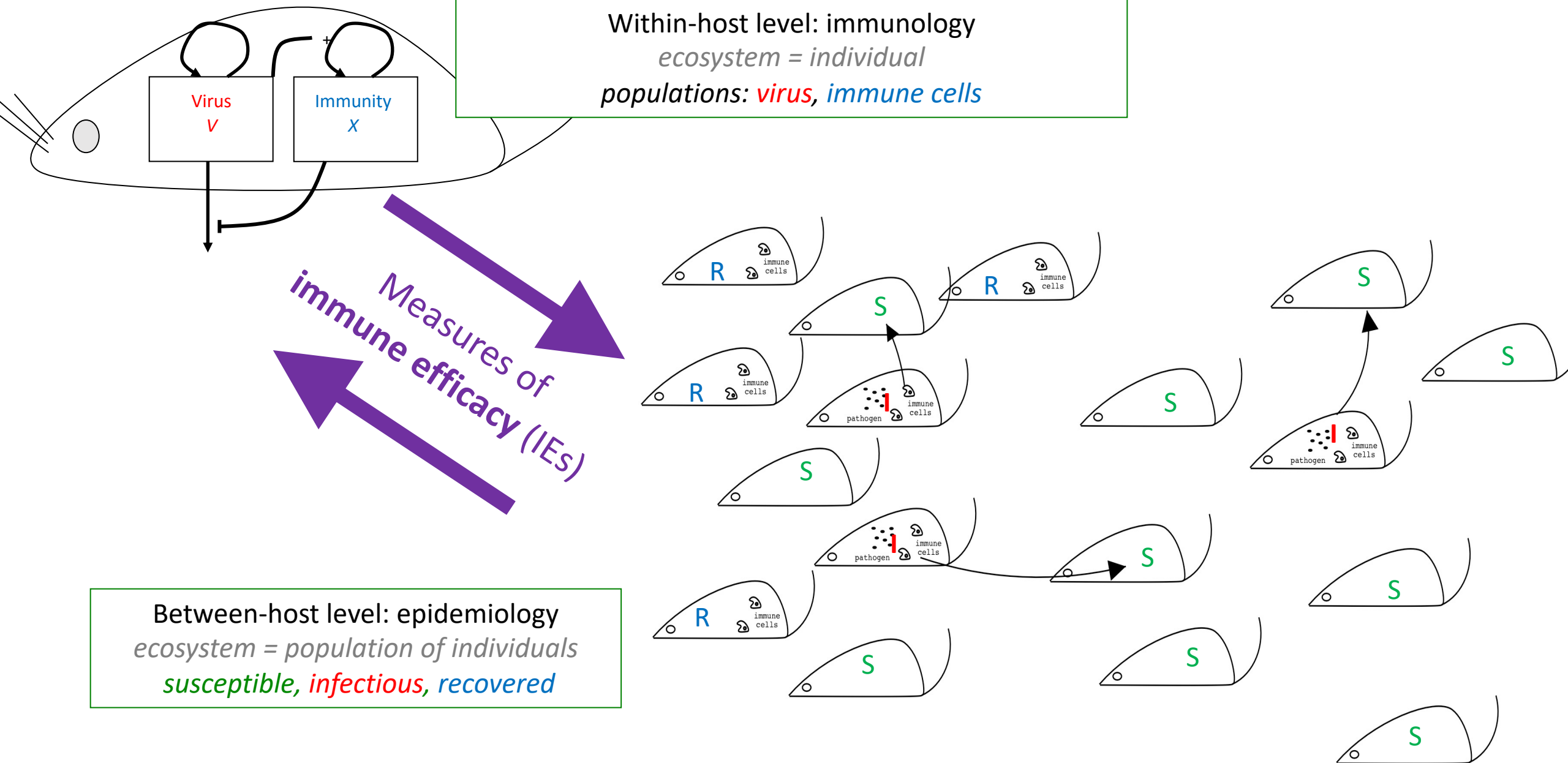


Immuno-epidemiology and herd immunity to COVID-19

An ecological view of infectious disease



Measures of Immune Efficacy

Immunity can protect in 3 ways:

1. Reduce ***susceptibility*** to infection: IE_s
(reduces the probability of getting infected)

If an immune host becomes infected, immunity may:

2. Reduce ***pathology***: IE_p
(and the probability of death)
3. Reduce ***infectivity***: IE_i
(virus transmission from the infected individual).

Measles – the classic model

Immunity provides
lifelong protection
from subsequent
infection

$$IE_S = 1$$

Immune individuals reduce the
spread of infections in the
population

long-term herd immunity

disease eradication possible

Panum (1847) Faroe islands

Iceland

Norway

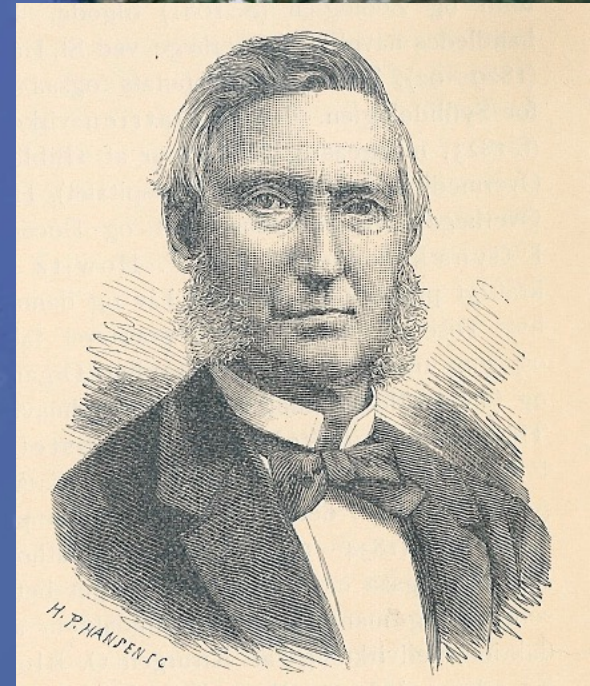
Faroe
Islands

Scotland

Measles epidemics in 1781 and 1846.

During the 1846 epidemic

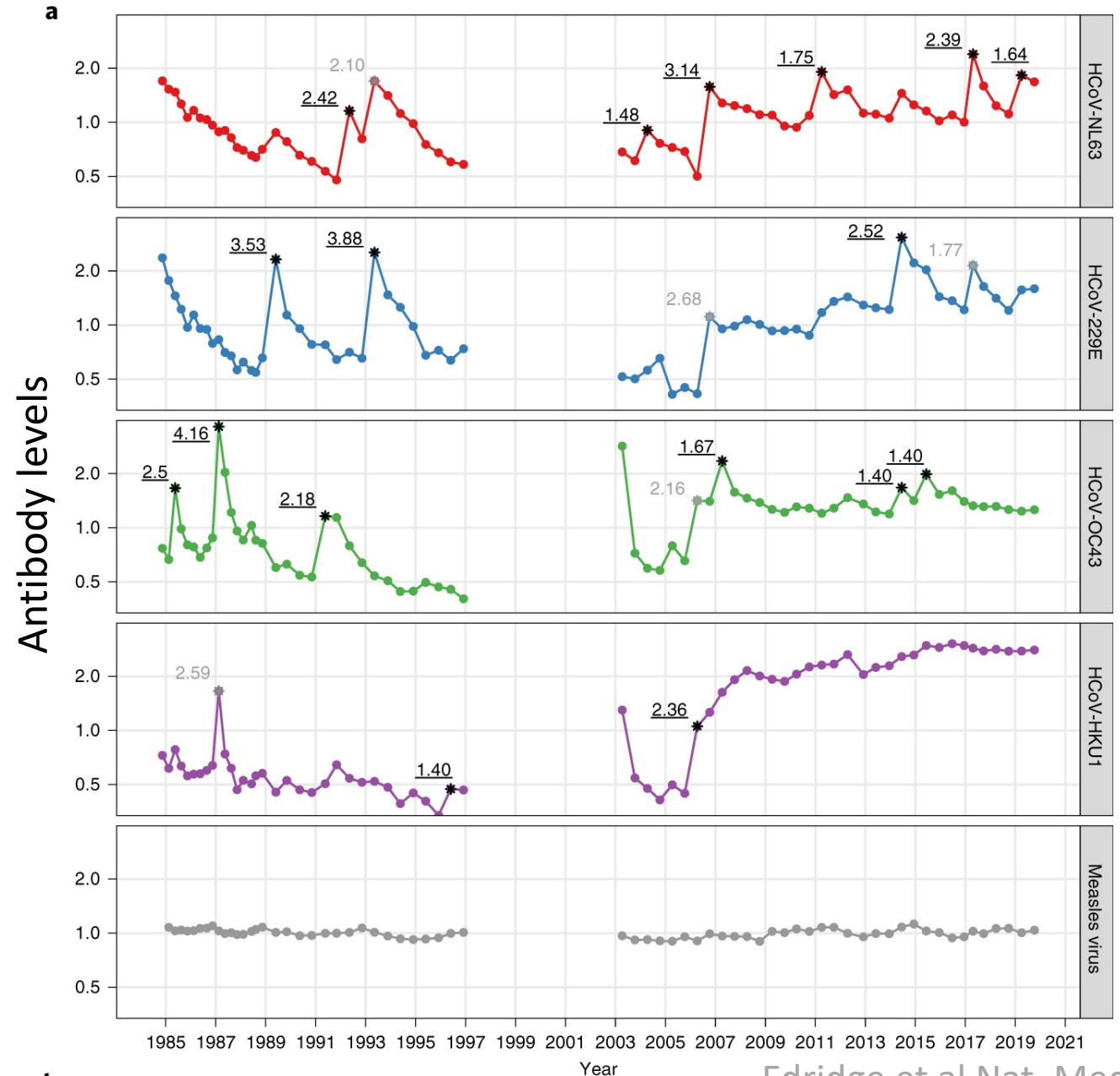
- 99.5% of susceptible individuals infected
- 0/98 survivors of 1781 epidemic infected



Endemic Human Coronaviruses

Evidence of re-infection

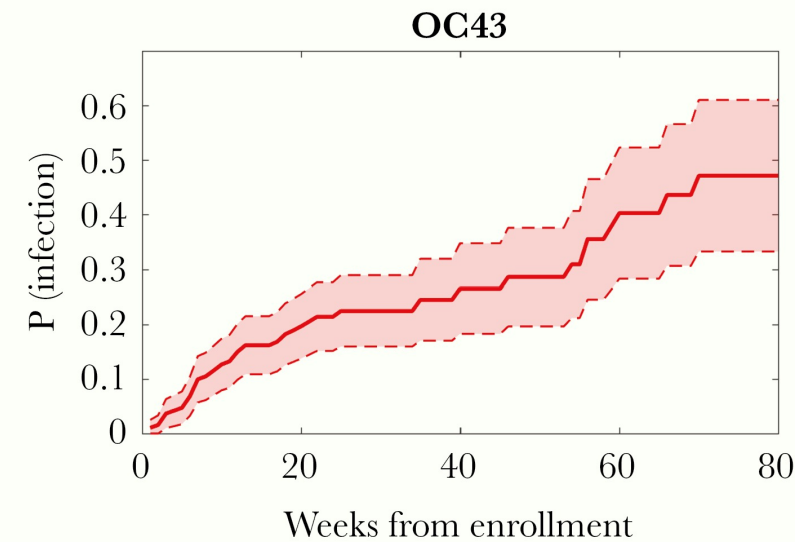
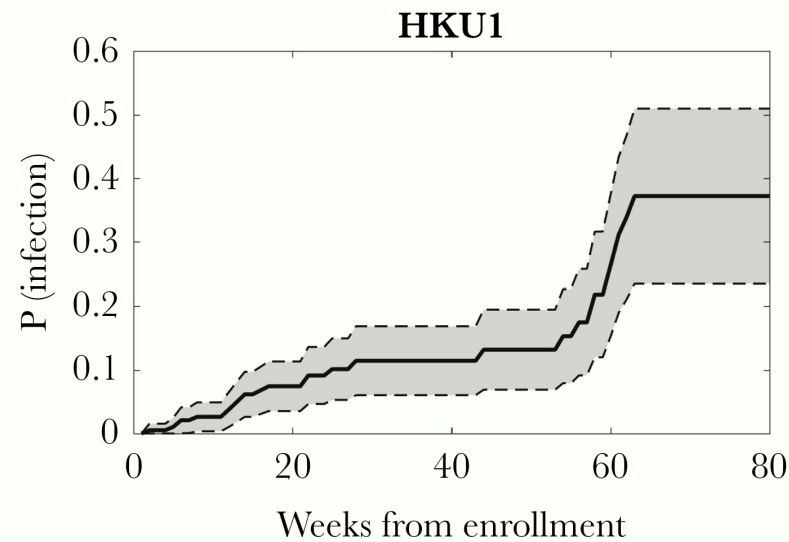
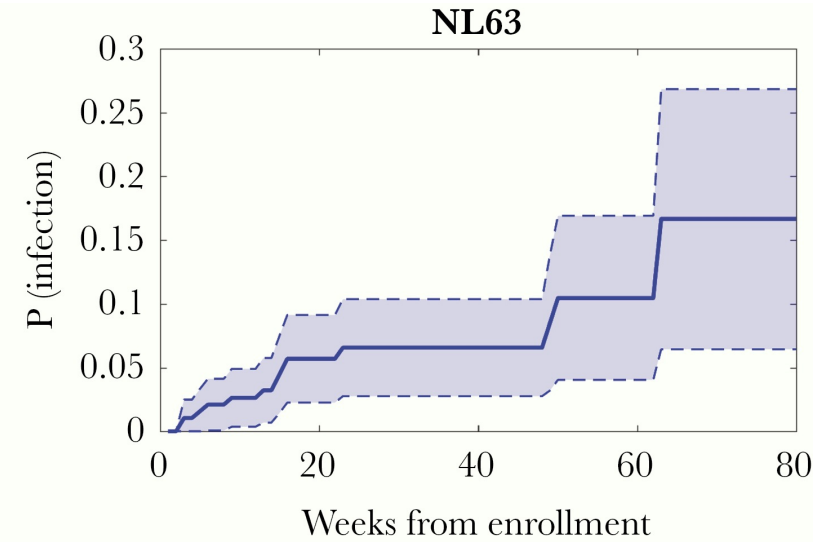
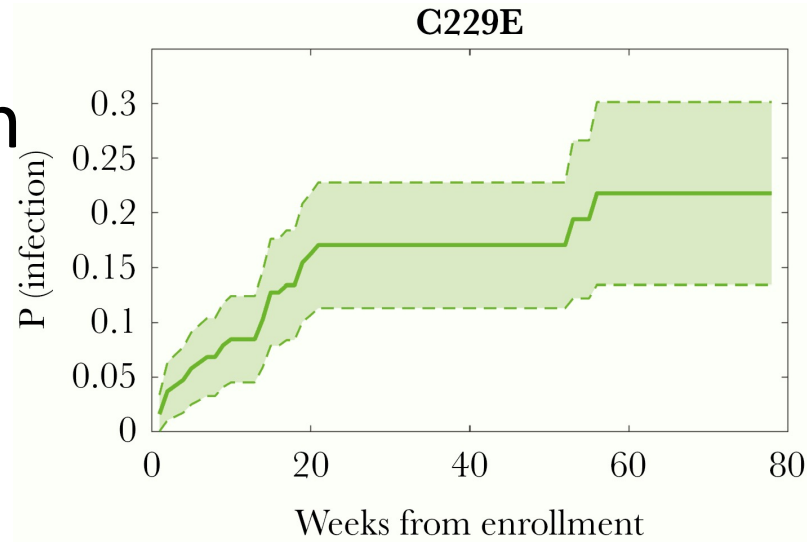
- Antibody levels get boosted every few years ($IE_S < 1$).
- Cross-immunity within alpha and beta strains.



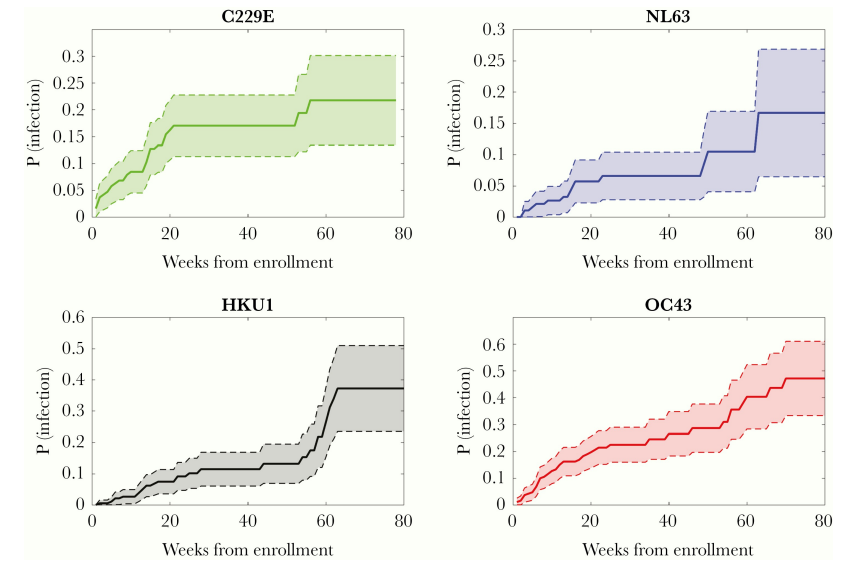
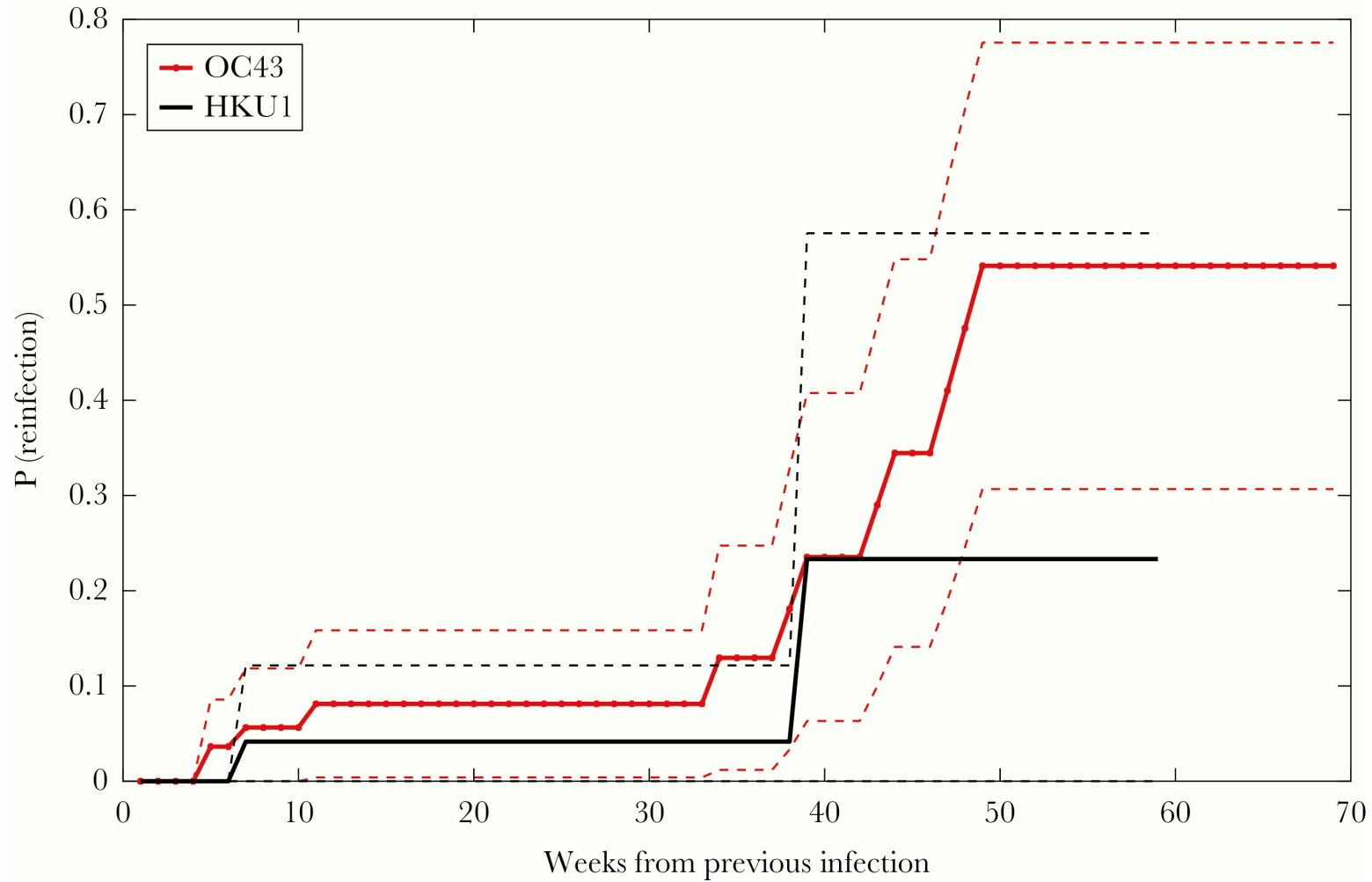
Endemic Human Coronaviruses

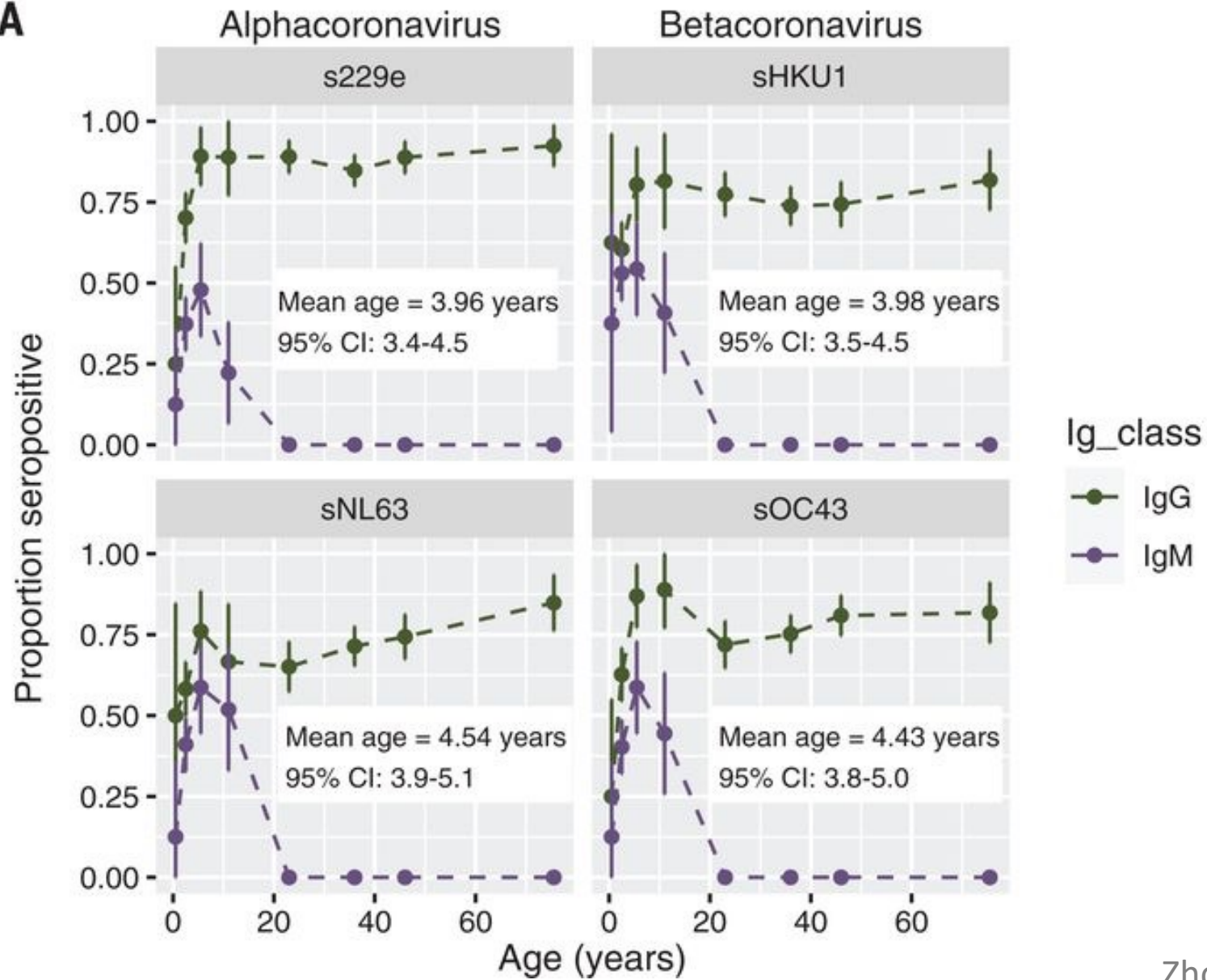
Evidence of re-infection

- Virus measurement shows periodic boosting



Endemic Human Coronaviruses – reinfection studies



A

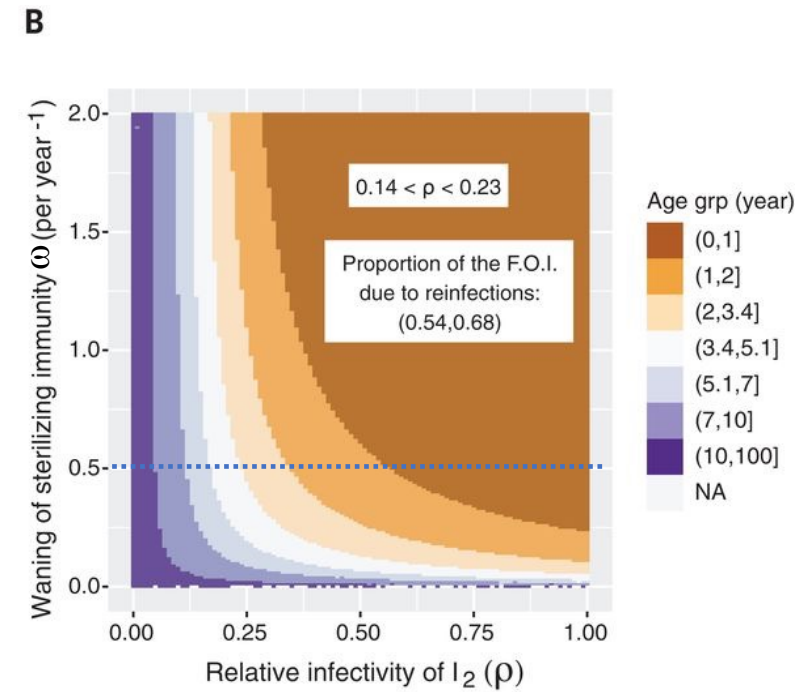
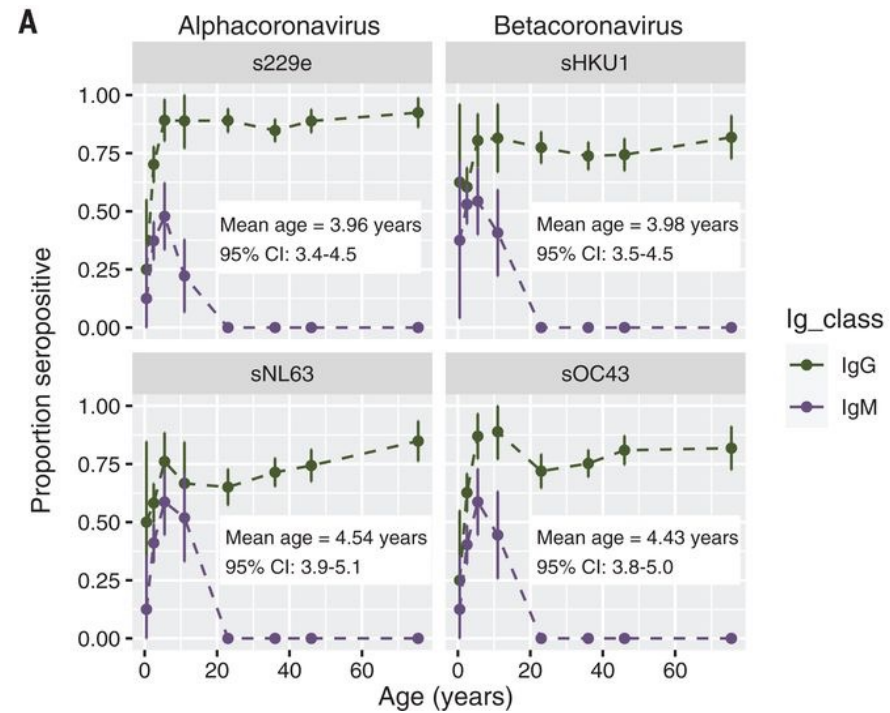
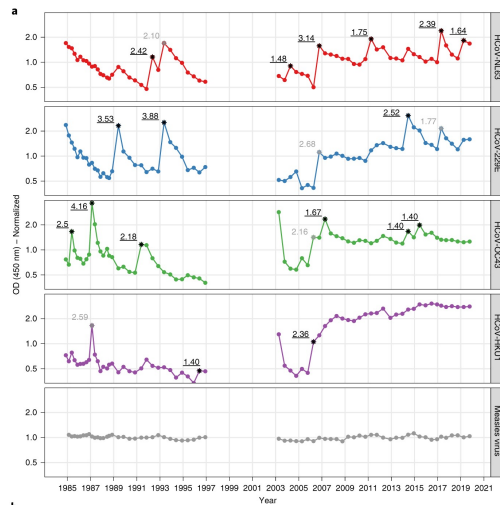
Endemic Human Coronaviruses

Immunity wanes:

1. individuals get re-infected ($IE_S < 1$)

2. Virtually no severe disease ($IE_p \sim 1$)

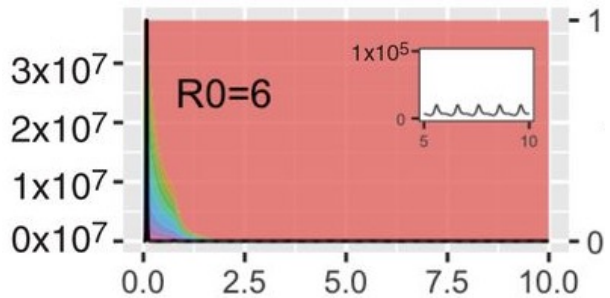
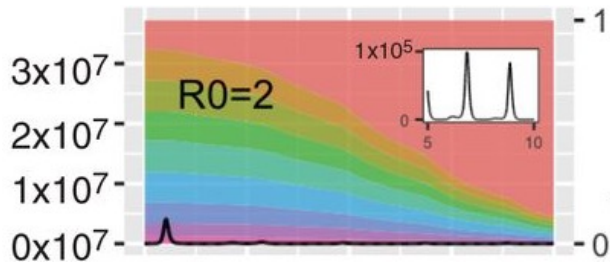
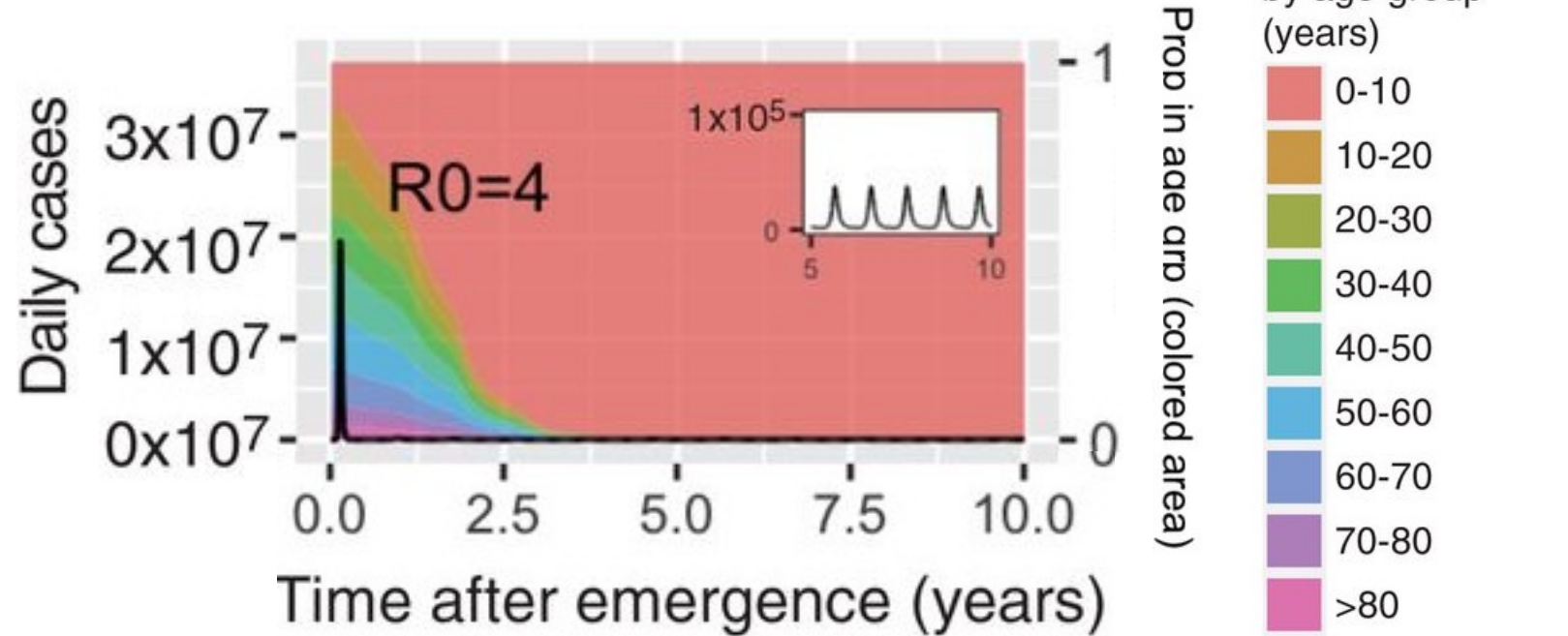
3. Transmission from secondary infections ($IE_1 < 1$)



Novel CoV - transition to endemicity

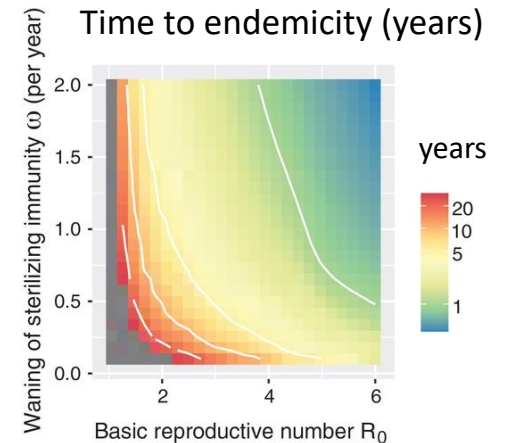
At $t=0$,
primary infections in all age groups.

Over time, primary infections are
restricted to the youngest age
group.



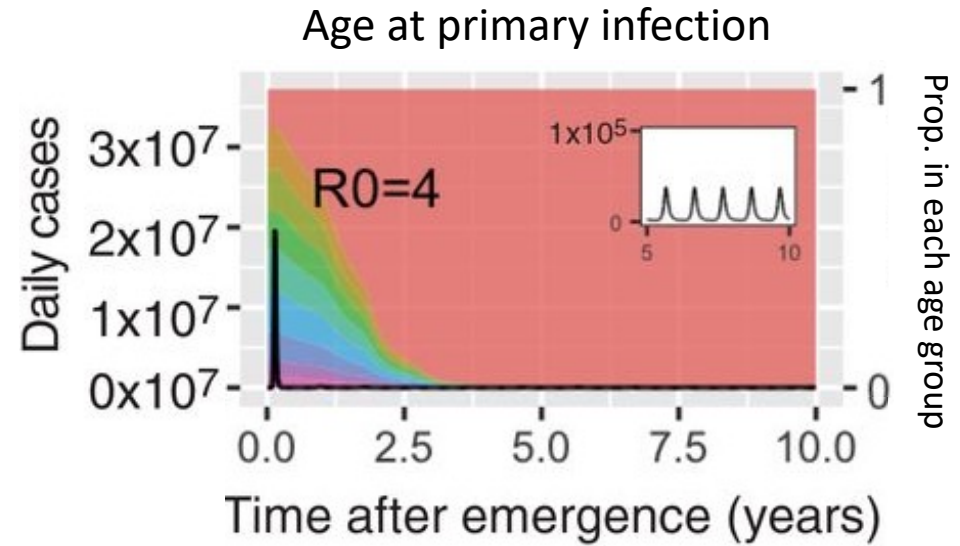
Time to endemicity depends on:

- R_0
- waning of immunity

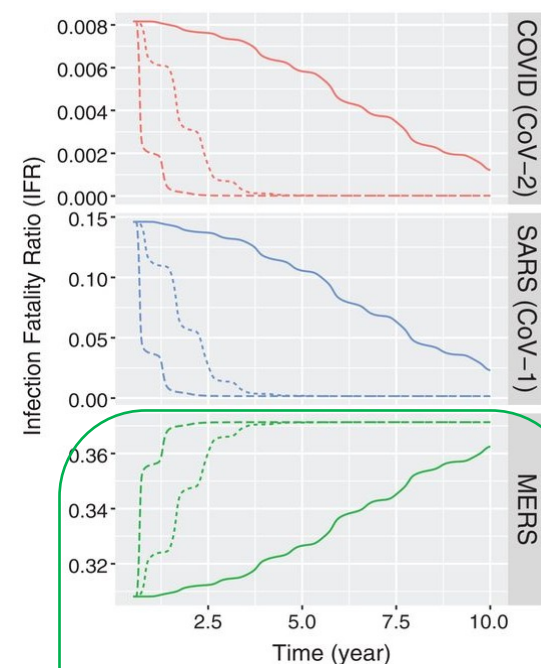
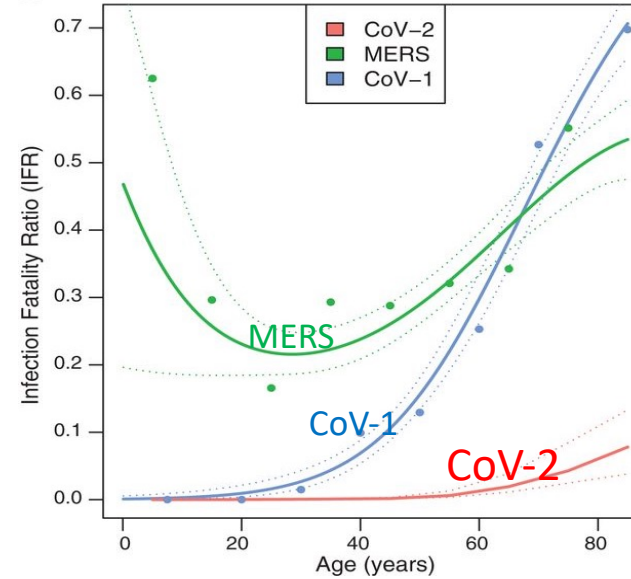


Disease Severity During the Transition to Endemicity

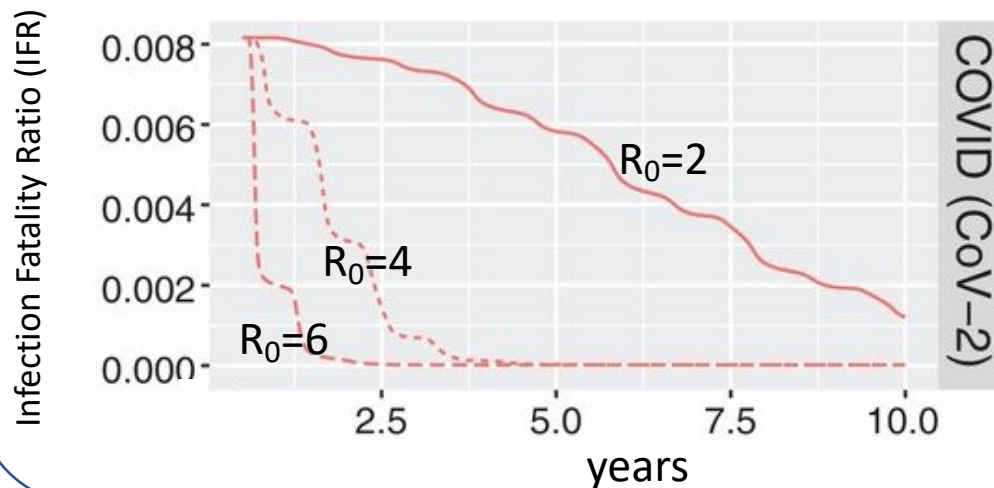
1. At $t=0$, primary infections in all age groups
Over years, primary infections restricted to the youngest age group



2. Primary infection with CoV-2: severe only in the old

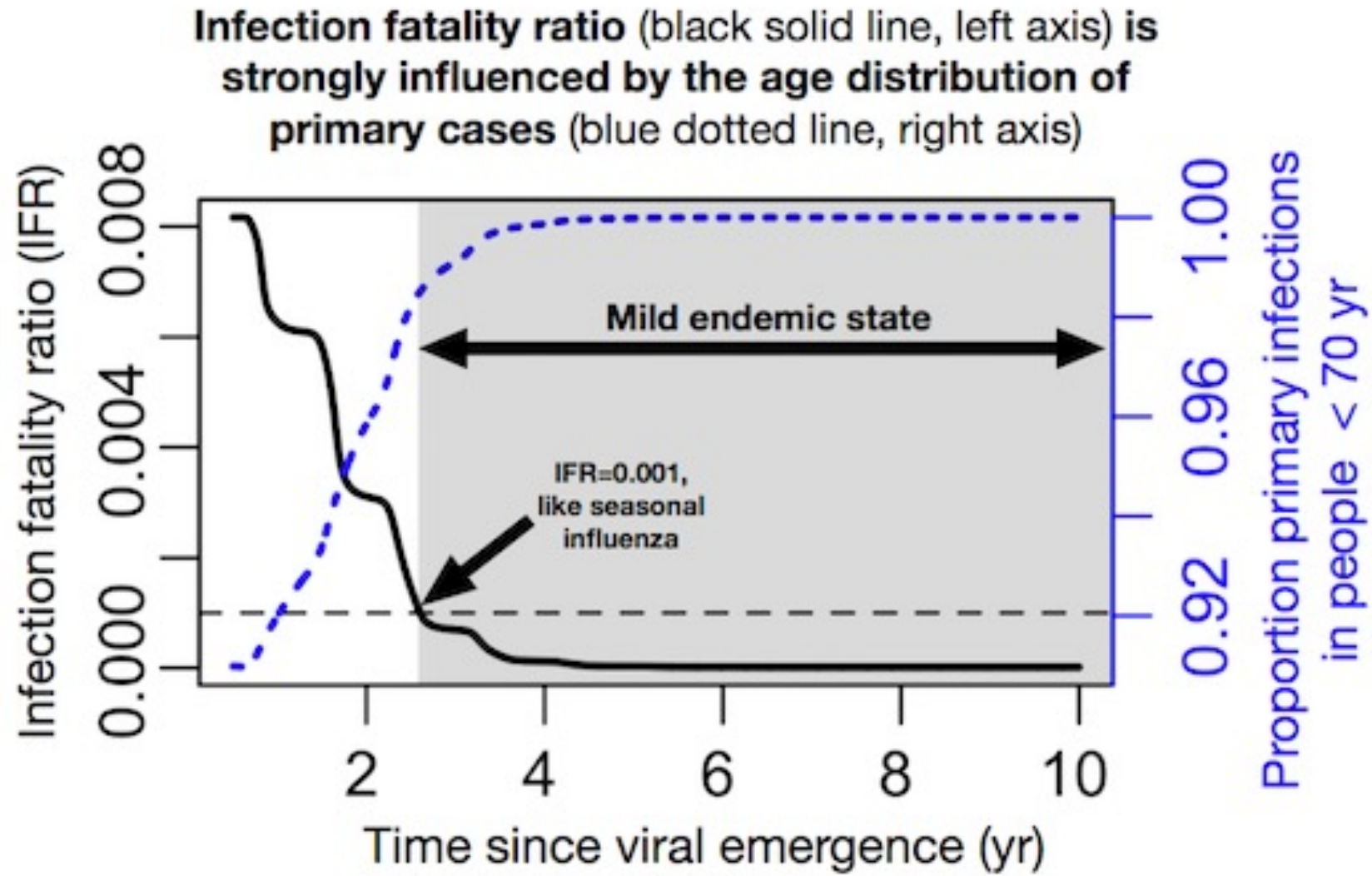


3. THEREFORE # severe cases will decline
(since secondary cases are mild)



this would be different for MERS, which is more severe in the young

In conclusion ...



What do we need to measure?

to validate or disprove our model for the transition to benign endemicity

Does prior infection or vaccination provide long-lasting protection from pathology (high IE_p)? Does it hold for:

1. CoV-2
2. Is one infection/vaccination sufficient to generate protective immunity?
(does it depend on the age of the individual)
3. What is the effect of virus variants?
(Is there a change in age-dependence of disease severity?)
4. What is the effect of waning of the different components of immunity.

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