The three Ts of virulence evolution during zoonotic emergence

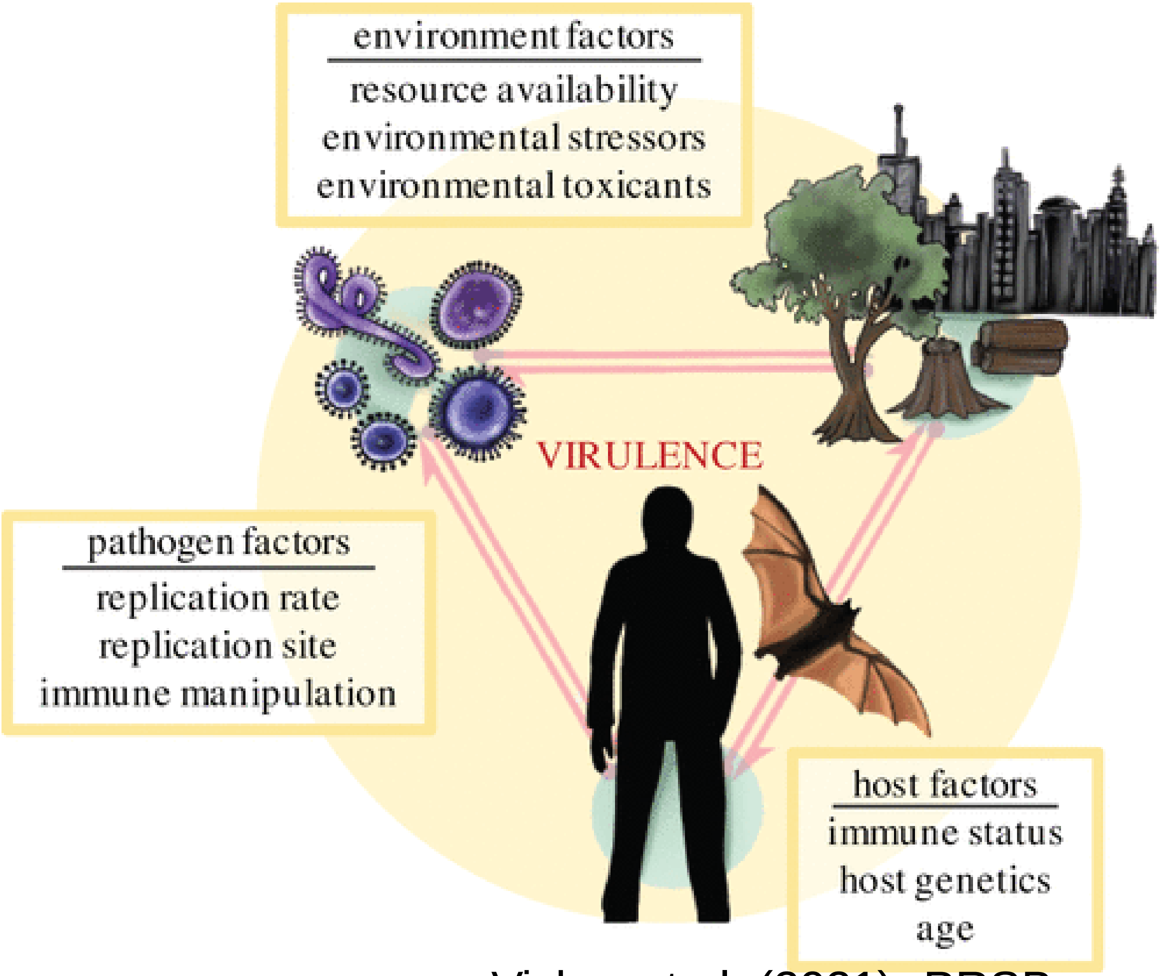
Elisa Visher

March 15, 2022

What do we mean by virulence?

In disease ecology, virulence is defined as the additional mortality rate due to infection in mathematical models.

For virulence evolution, we are primarily interested in the pathogen factors controlling disease severity, though host and environmental factors will also affect infection outcomes.



Visher et al. (2021). PRSB.

Can we even predict pathogen evolution?

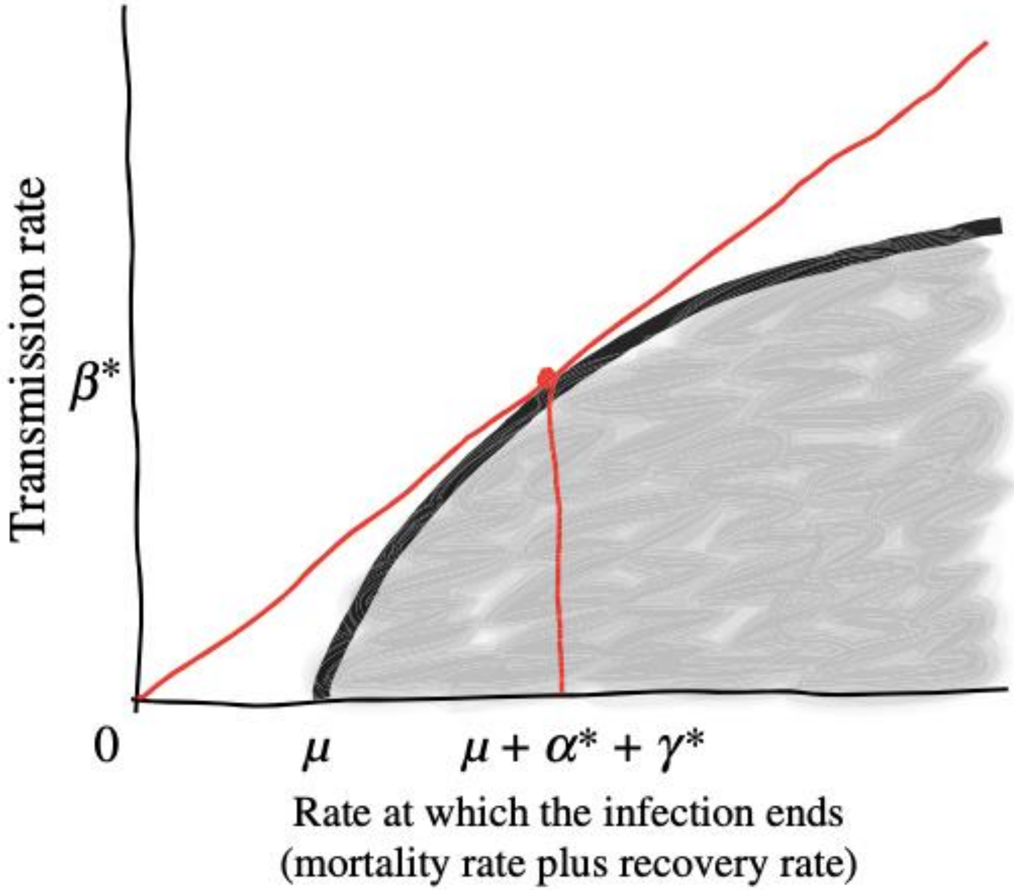
Virulence can adaptively evolve

Myxoma virus
in rabbits

WikiCommons

The Virulence – Transmission Trade-off

Modern theory generally predicts that pathogens “should” evolve **intermediate** levels of virulence because the costs of virulence trade-off with the benefits of higher transmission rates.

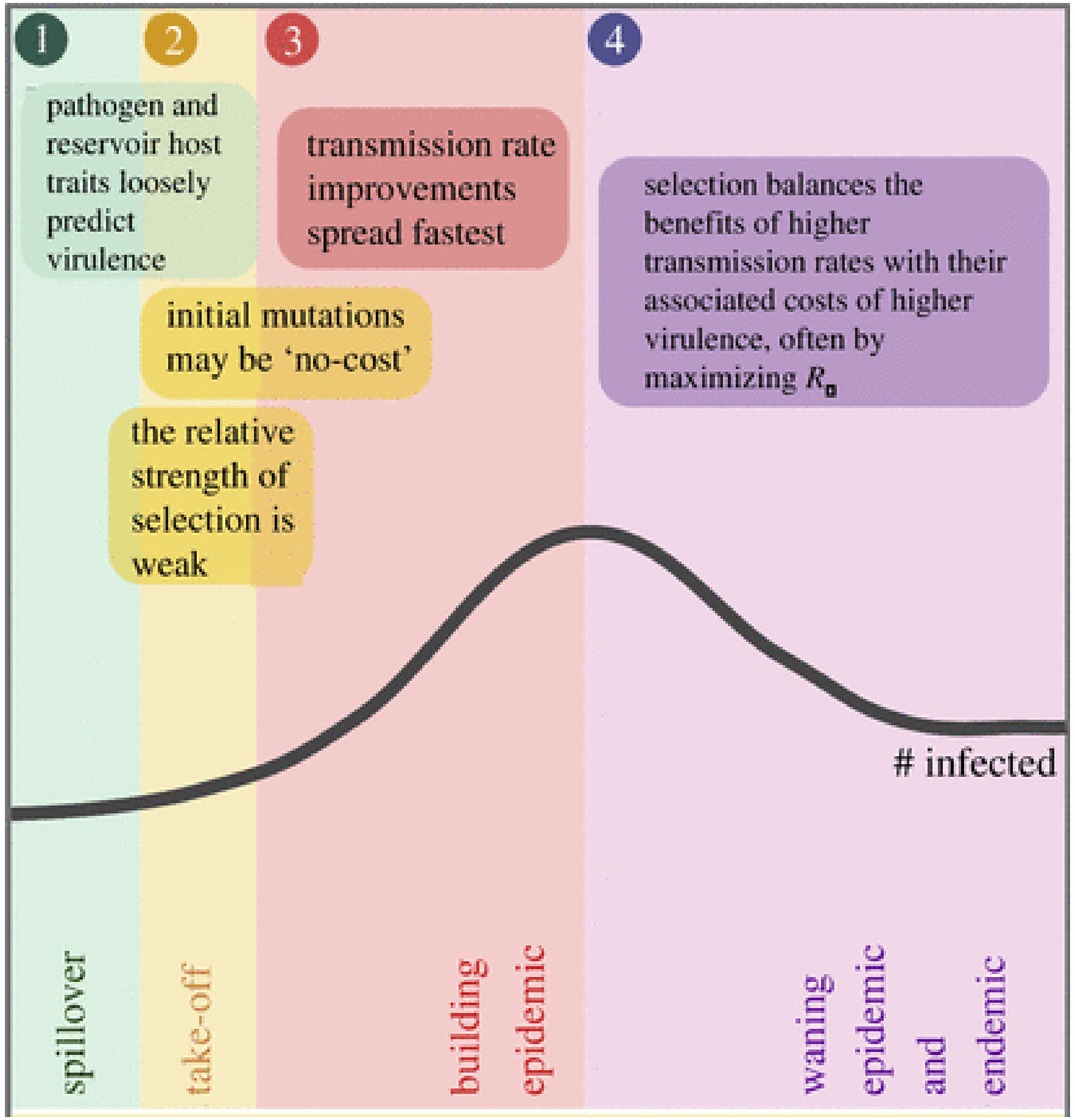


Alizon et al. (2009). J. Evol. Biol.

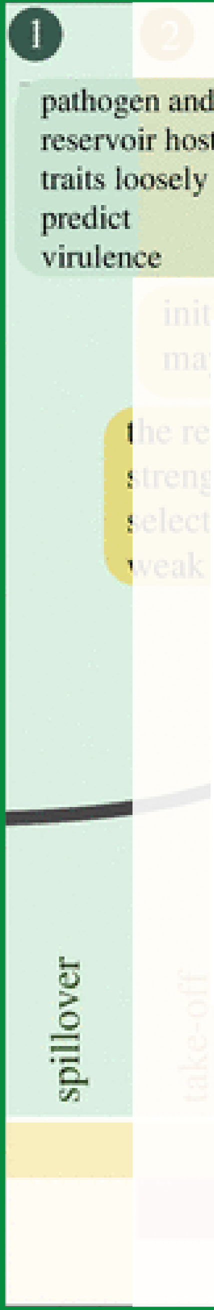
How does this change in newly emerged zoonotic diseases?

The three Ts:

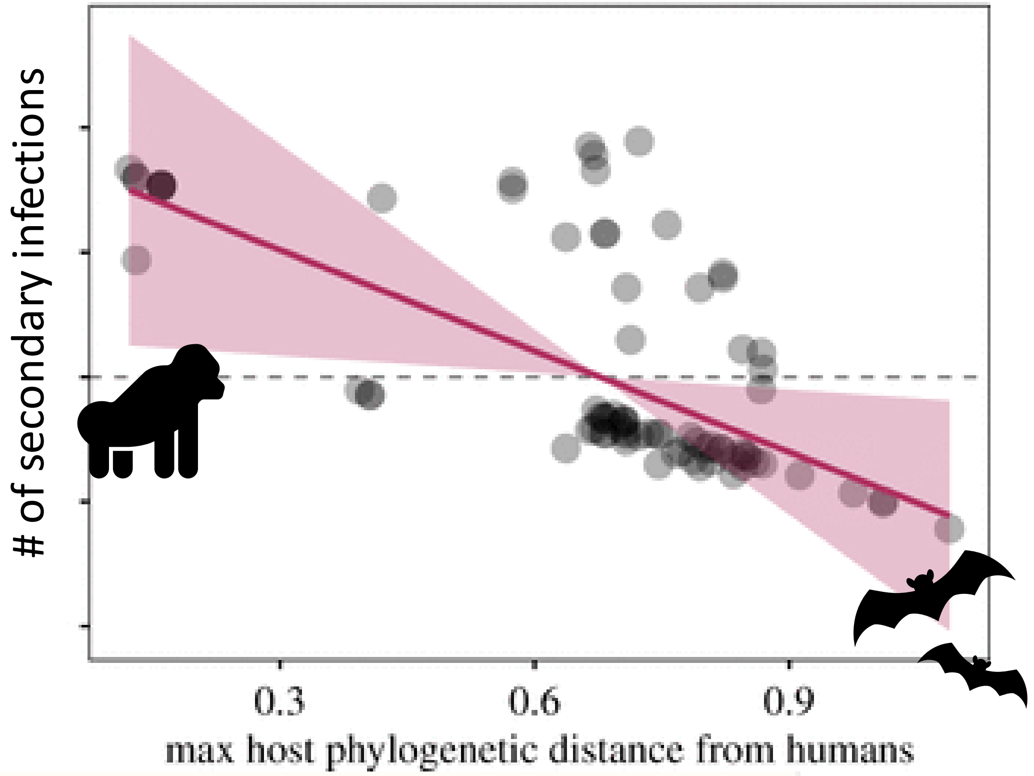
1. Trade-Offs
2. Transmission
3. Time Scales

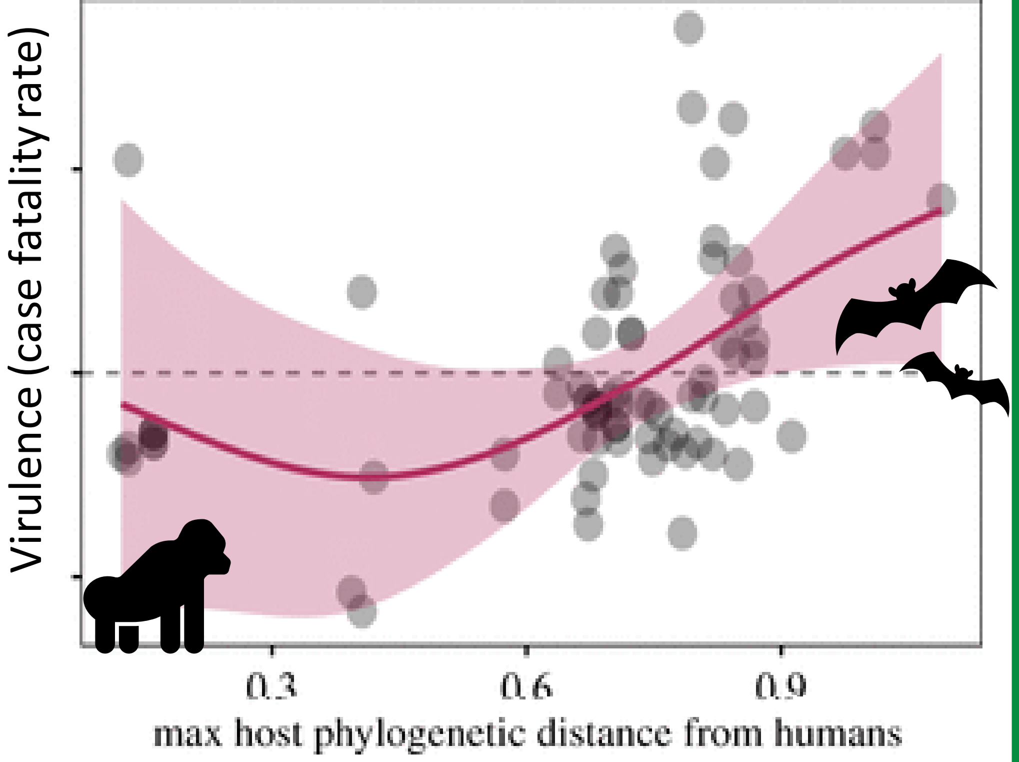


Visher et al. (2021). PRSB.



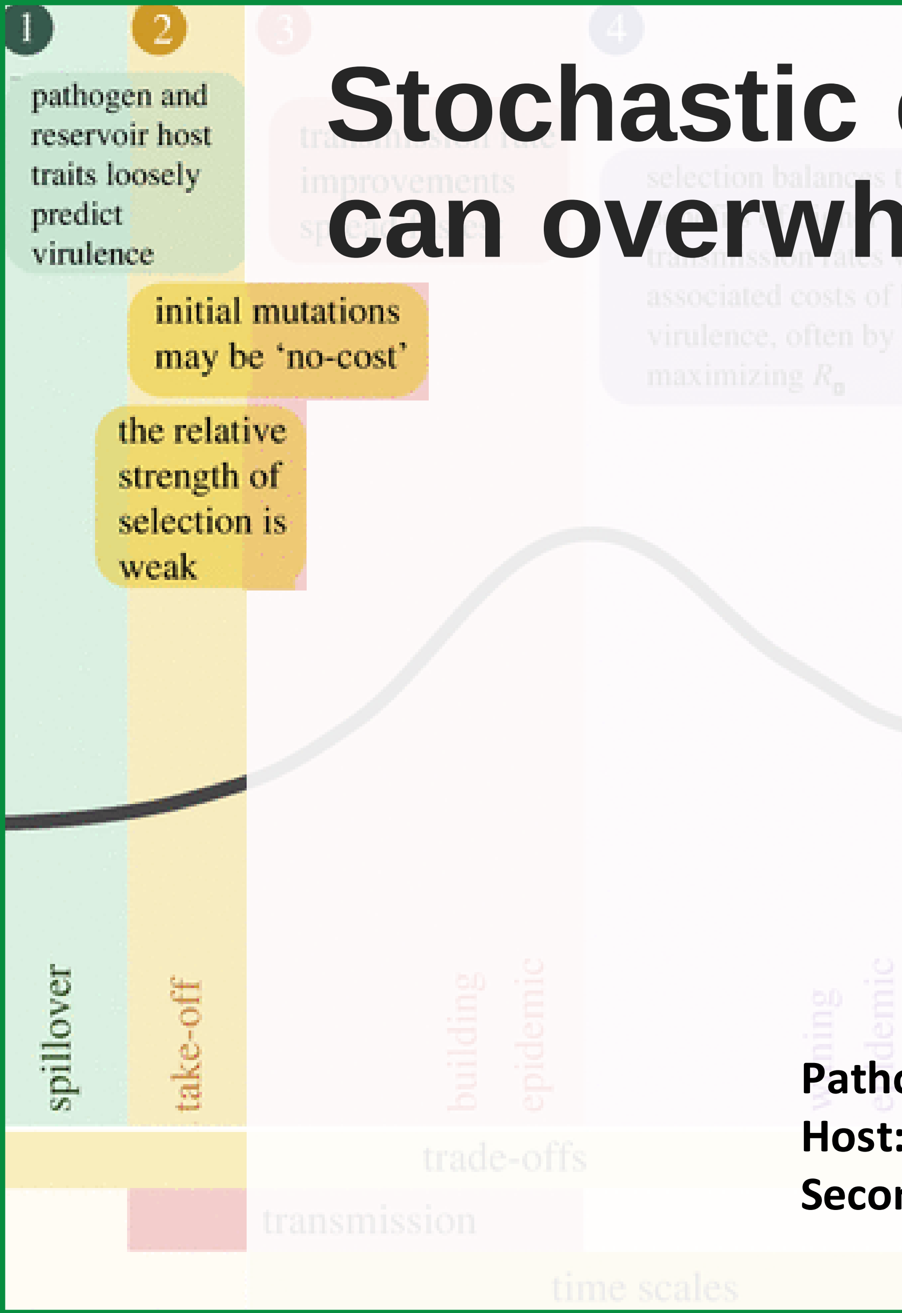
Pathogen and reservoir host traits loosely predict R0 and virulence

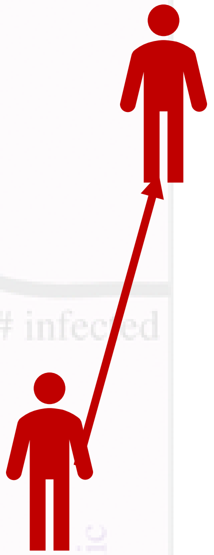




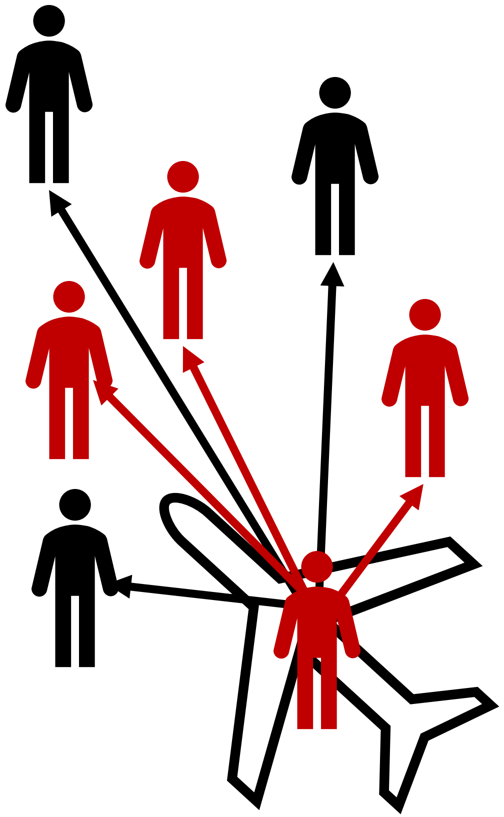
Guth et al. (2019). Phil. Trans.

Stochastic effects in small populations can overwhelm selection



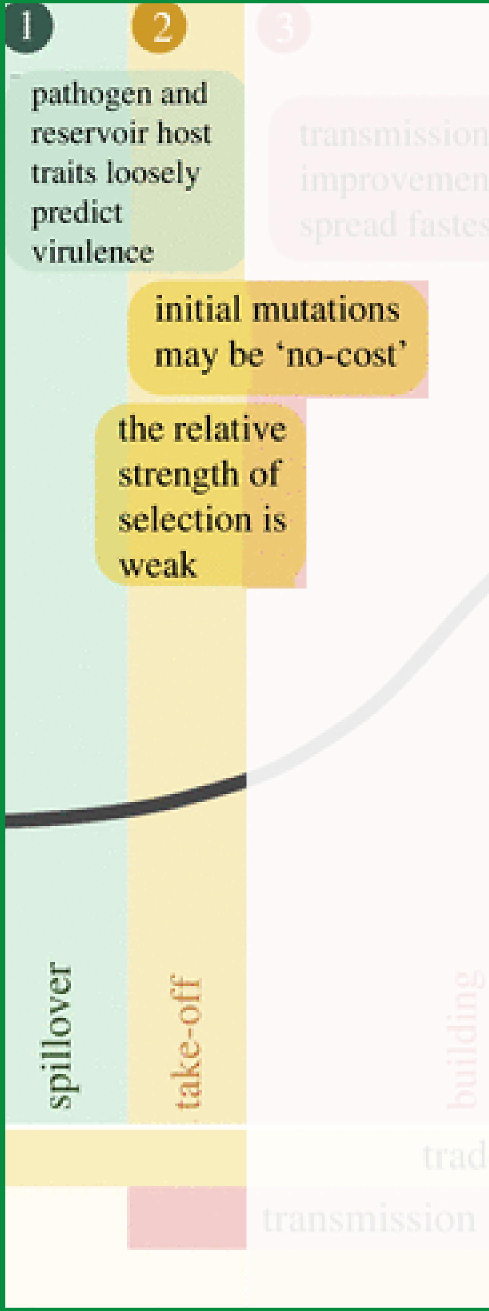


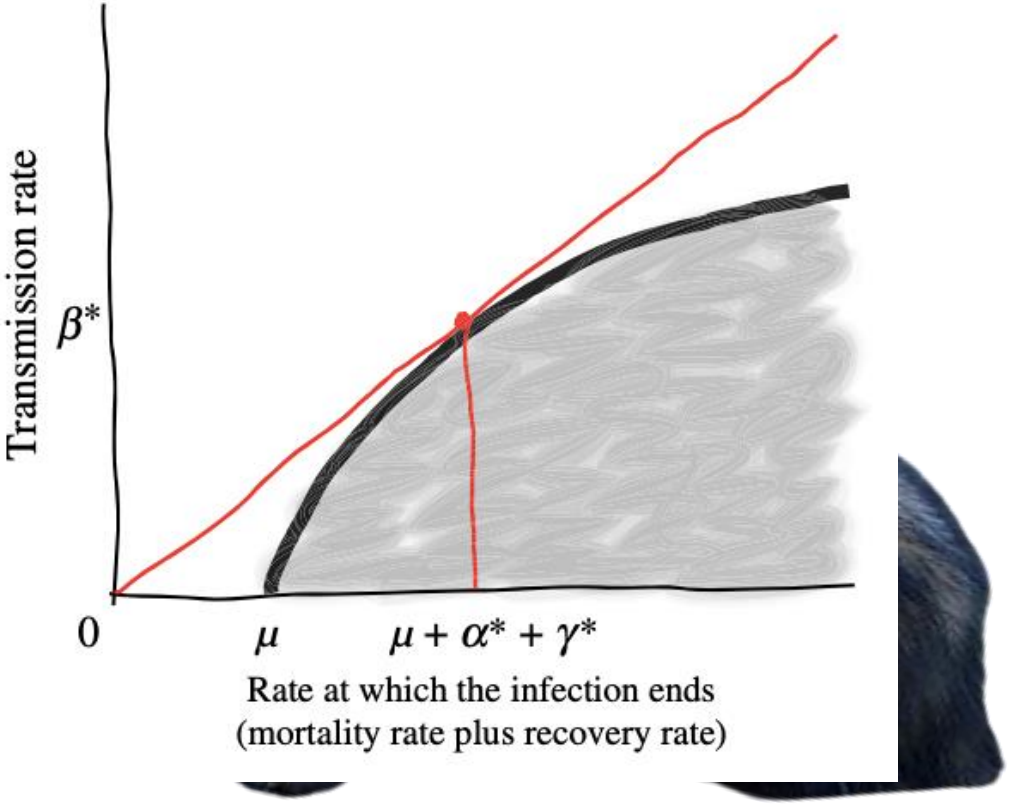
Pathogen: 90% infection rate
Host: Contacts 1 Susceptible
Secondary Cases = 1



Pathogen: 50% infection rate
Host: Contacts 6 Susceptibles
Secondary Cases = 3

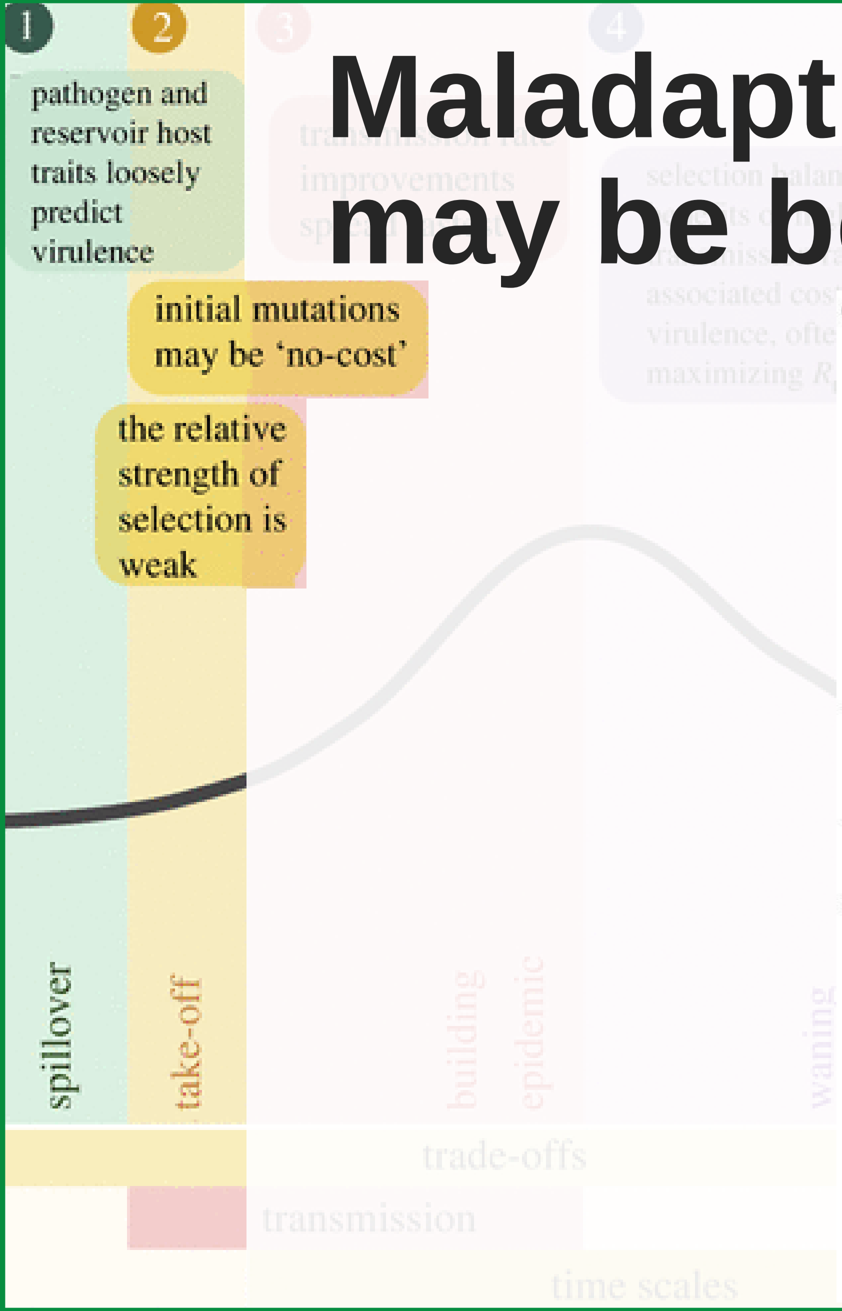
Why is it difficult to predict how a novel zoonotic pathogen will evolve when it spills over into humans?

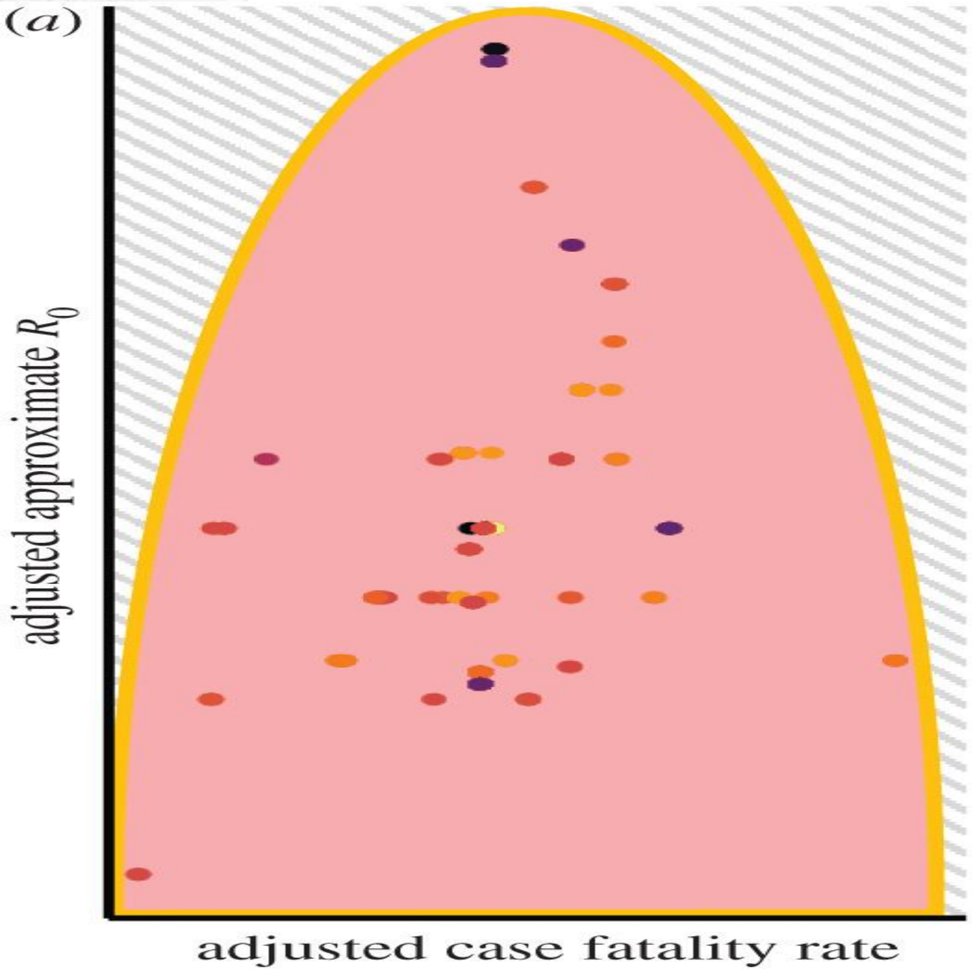




Herfst et al (2012), Imai et al. (2012), Wikicommons

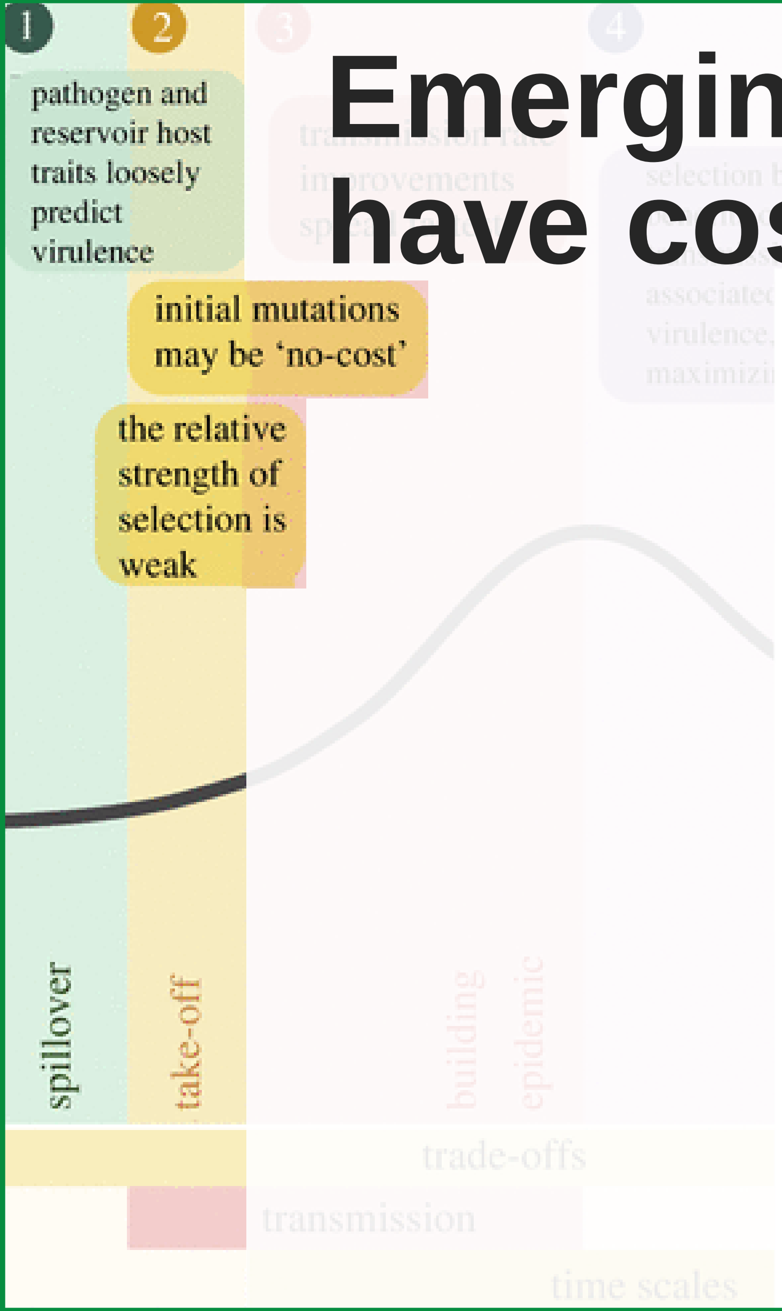
Maladapted zoonotic pathogens may be below the Pareto front

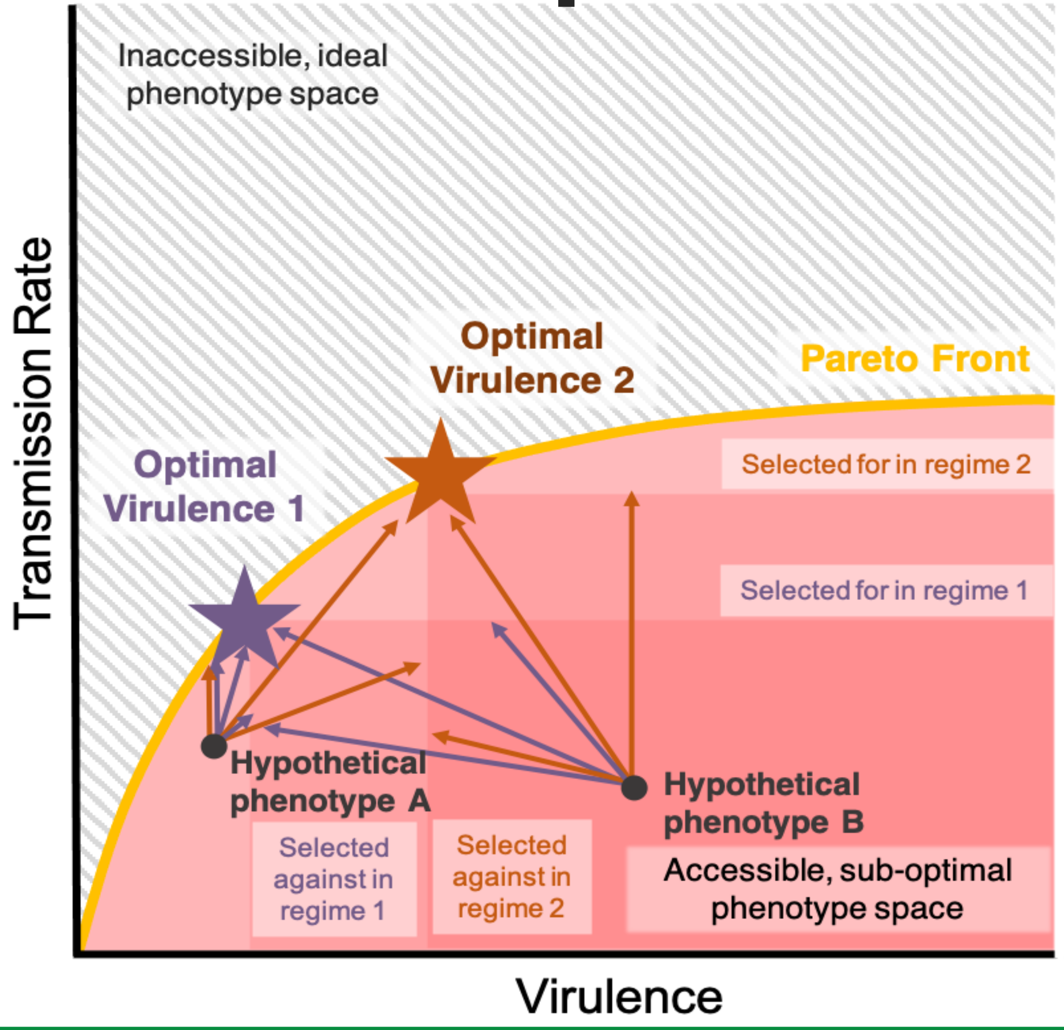




Visher et al. (2021). PRSB.

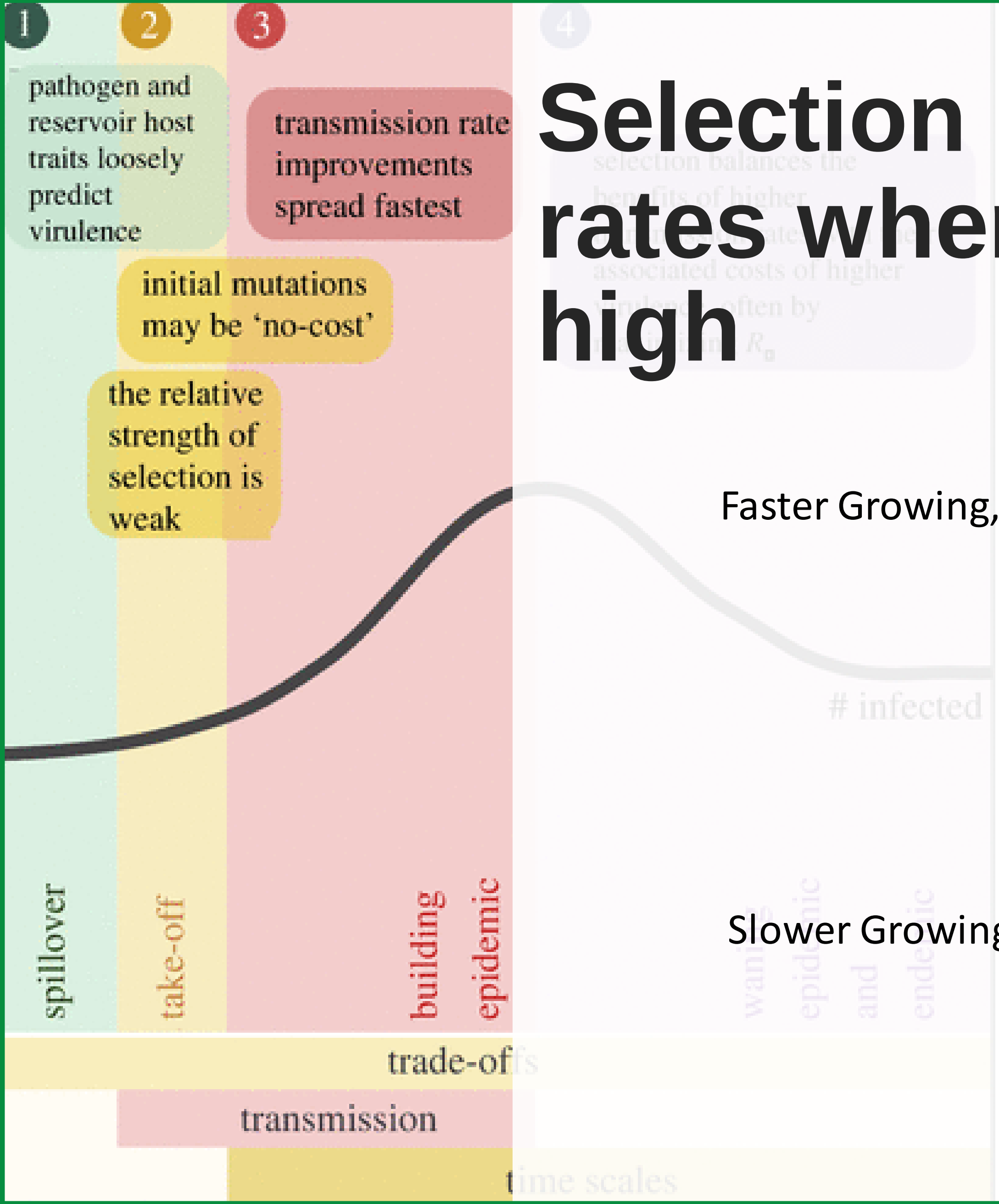
Emerging zoonotic pathogens may have costless adaptive mutations

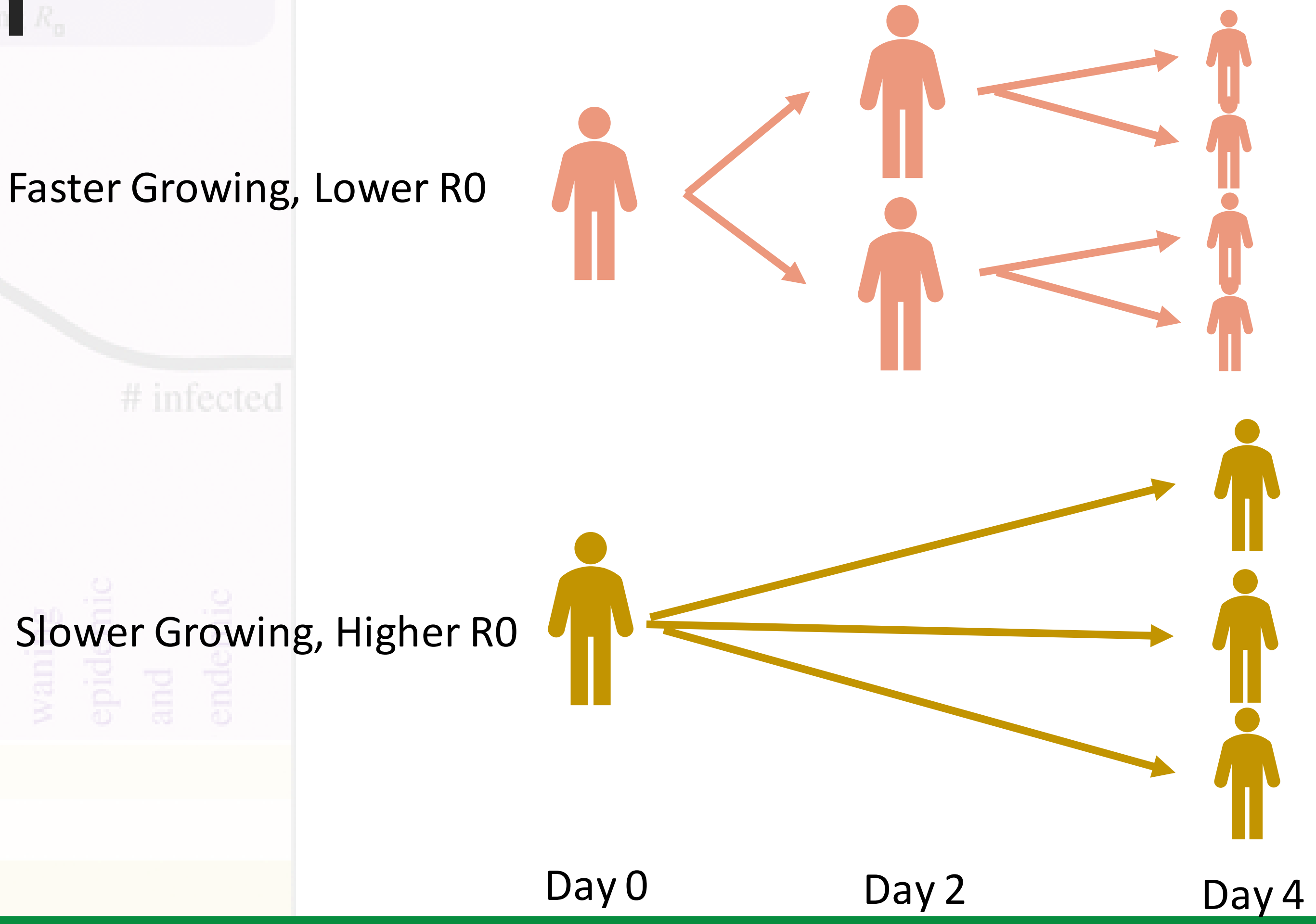


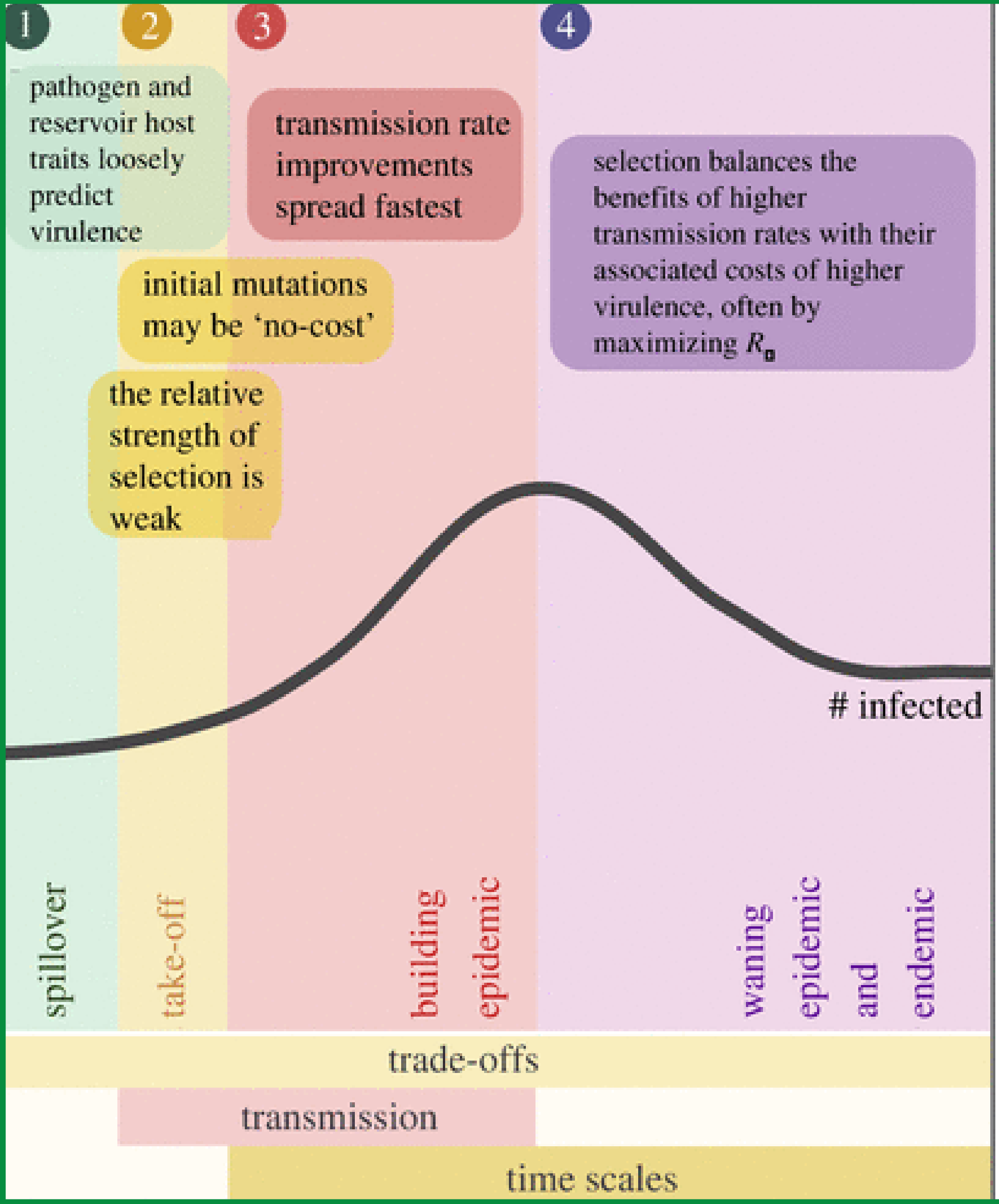


Visher et al. (2021). PRSB.

Selection favors high transmission rates when susceptible density is high

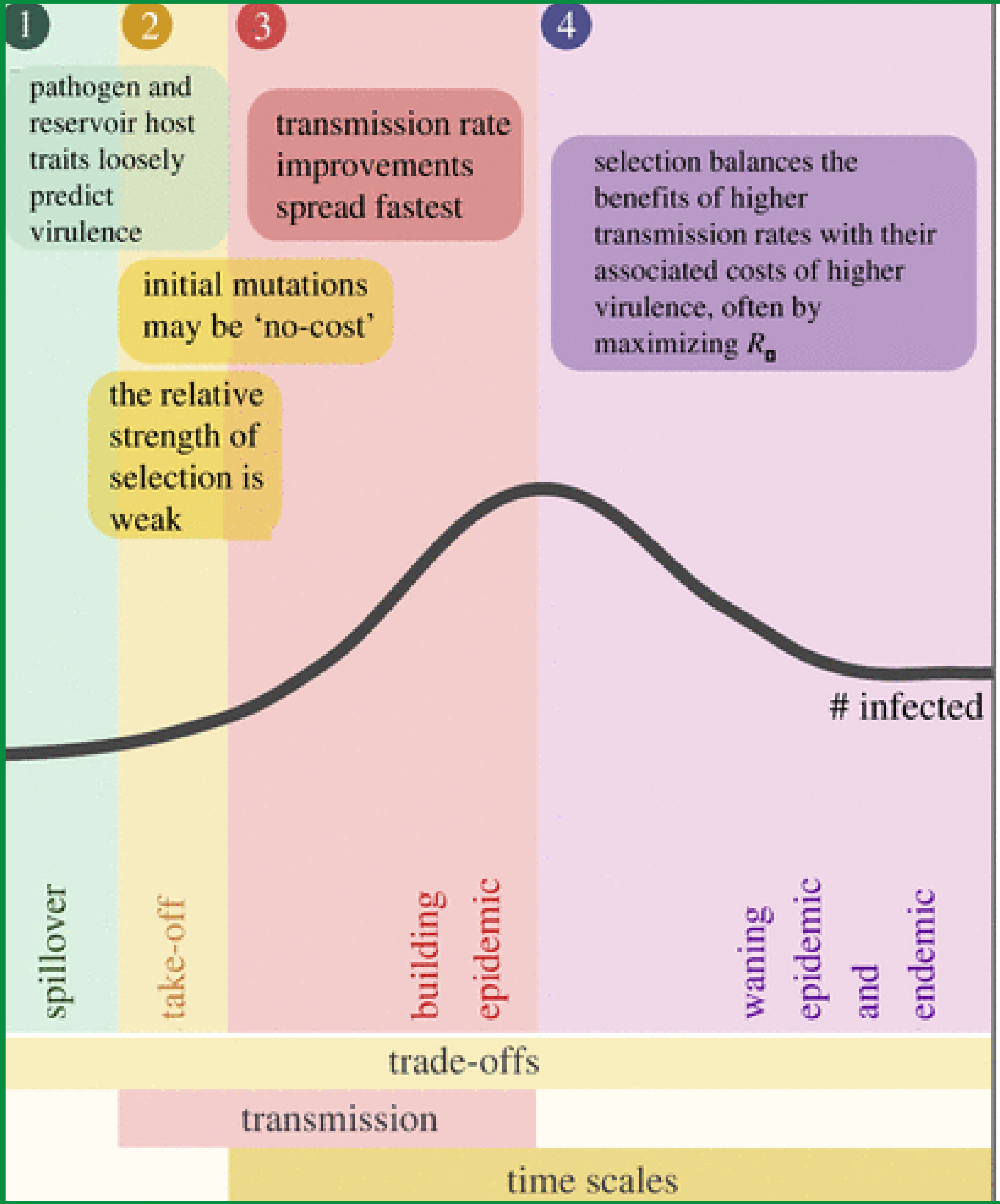






Selection favors high R_0 (the total number of secondary infections in a susceptible population) **at equilibrium**

Visher et al. (2021). PRSB.



Conclusions…

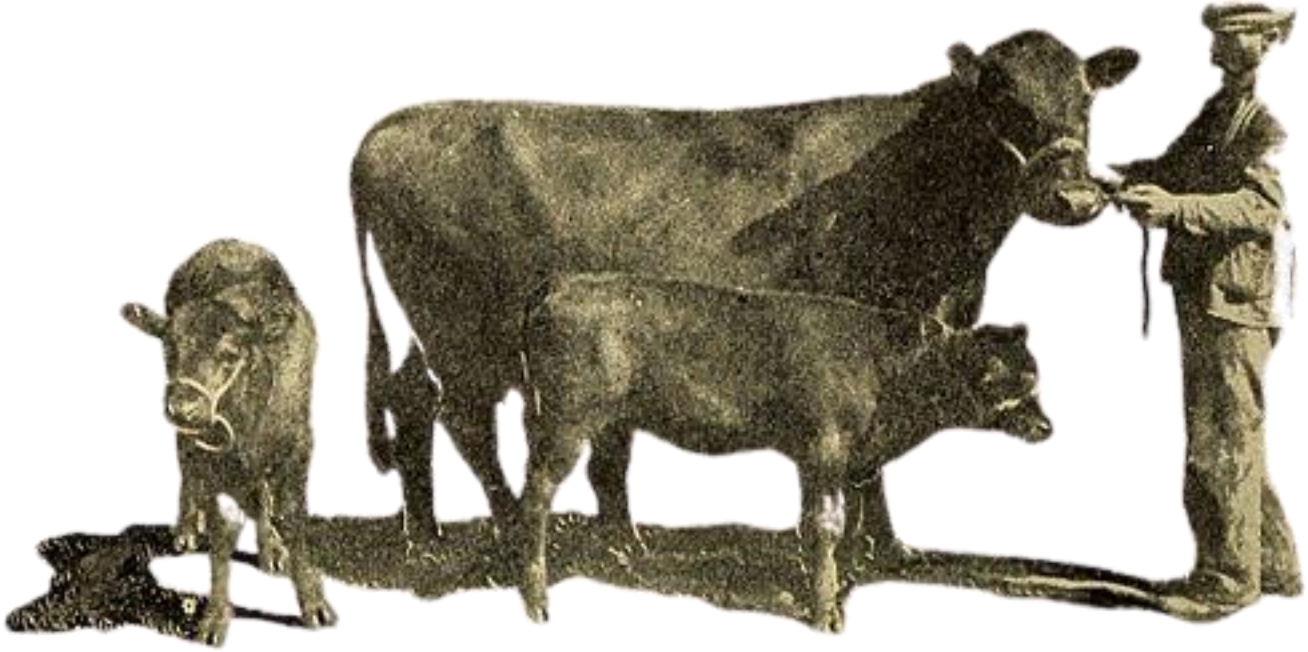
Virulence and transmission rate may trade-off

Selection may increase transmission rate

Evolutionary dynamics may change with time

Visher et al. (2021). PRSB.

Can we evolutionarily manage virulence?



WikiCommons

PROCEEDINGS B

royalsocietypublishing.org/journal/rspb

The three Ts of virulence evolution during zoonotic emergence

https://doi.org/10.1098/rspb.2021.0900

Thanks to my collaborators!

Claire Evensen
Sarah Guth
Edith Lai
Marina Norfolk
Carly Rozins
Nina A. Sokolov
Melissa Sui
Michael Boots

Twitter: @evisher
Email: elisa_visher@berkeley.edu
Website: elisavisher.weebly.com