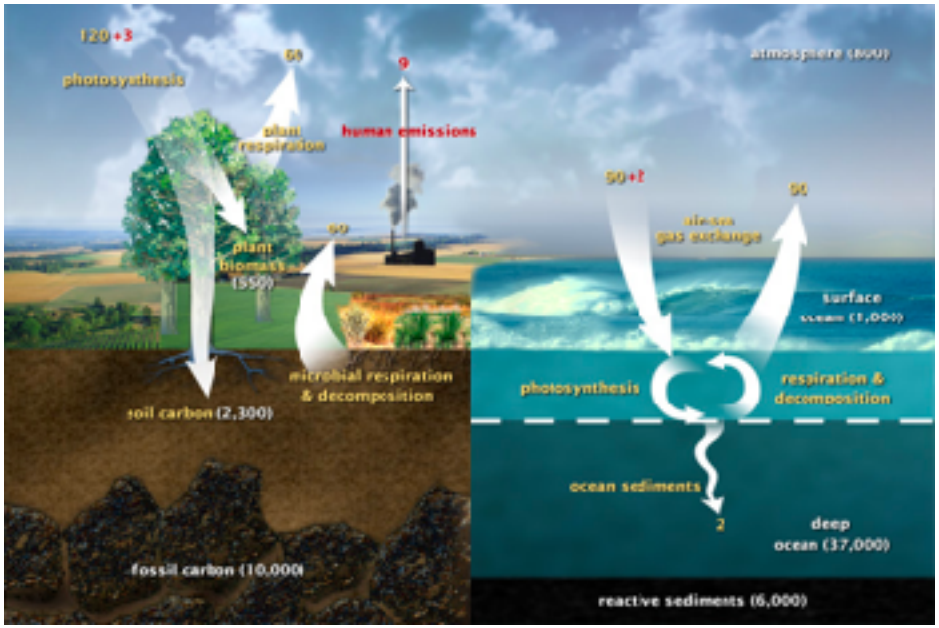
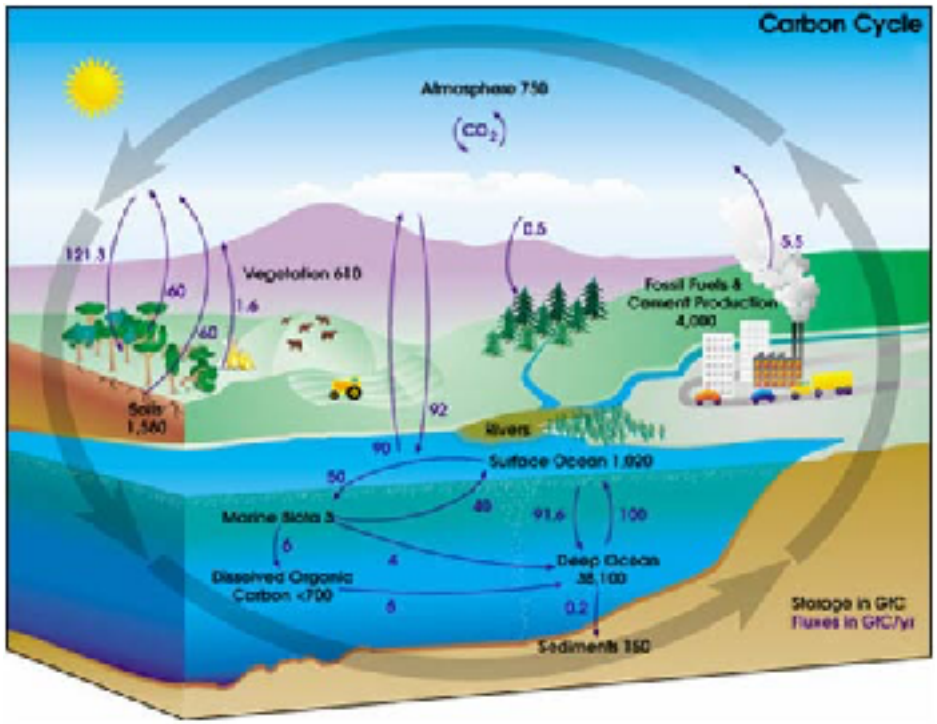
The Carbon cycle



earthobservatory.nasa.gov/features/CarbonCycle



skepticalscience.com/co2-residence-time.htm

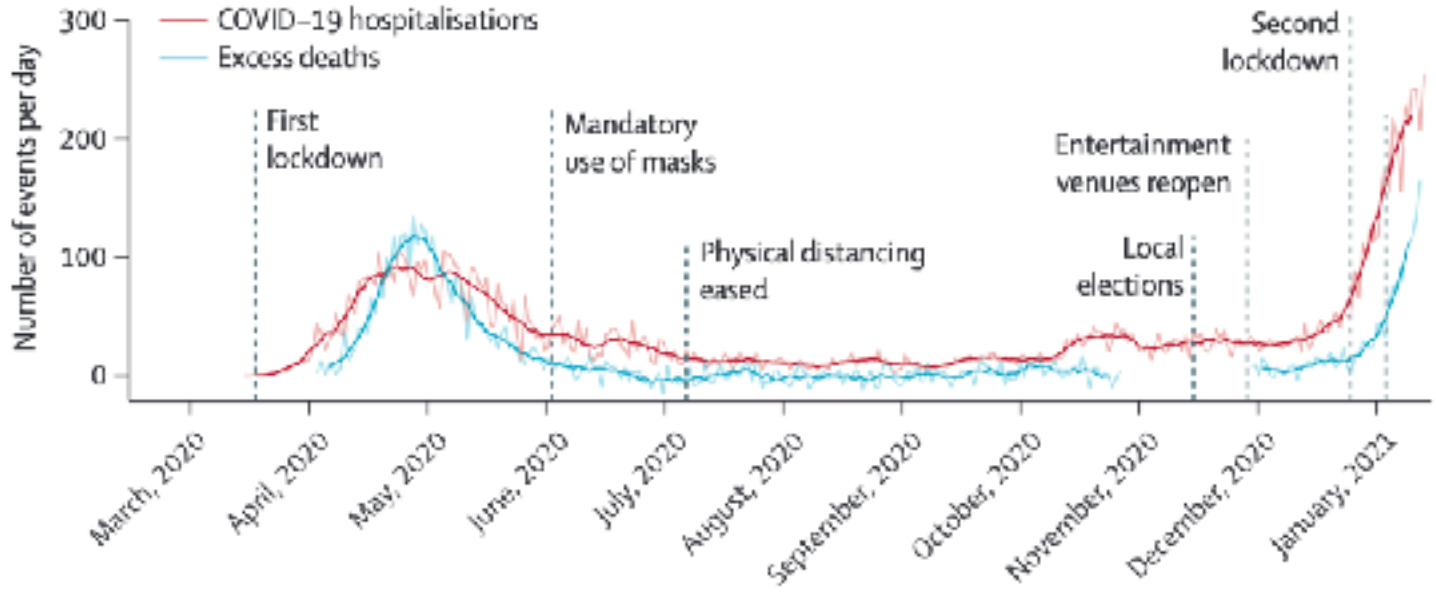
The human CO2 production (9 giga ton/y) is small compared to the natural emissions (60+60+90), and the natural buffers. Why then do we observe such a large increase in atmospheric CO2 levels?

$$\frac{dA}{dt} = f_{OA}O - f_{AO}A + f_{VA}V - f_{AV}A + h$$

Resurgence of COVID-19 in Manaus, Brazil, despite high seroprevalence

www.thelancet.com Vol 397 February 6, 2021

*Ester C Sabino, Lewis F Buss, Maria P S Carvalho, Carlos A Prete Jr, Myuki A E Crispim, Nelson A Fraiji, Rafael H M Pereira, Kris V Parag, Pedro da Silva Peixoto, Moritz U G Kraemer, Marcia K Oikawa, Tassila Salomon, Zulma M Cucunuba, Márcia C Castro, Andreza Aruska de Souza Santos, Vitor H Nascimento, Henrique S Pereira, Neil M Ferguson, Oliver G Pybus, Adam Kucharski, Michael P Busch, Christopher Dye, Nuno R Faria



$$\frac{\mathrm{d}S}{\mathrm{d}t} = wR - \beta S\frac{I}{N}\,, \quad \frac{\mathrm{d}I}{\mathrm{d}t} = \beta S\frac{I}{N} - (d+r)I \quad \text{and} \quad \frac{\mathrm{d}R}{\mathrm{d}t} = rI - wR\,,$$

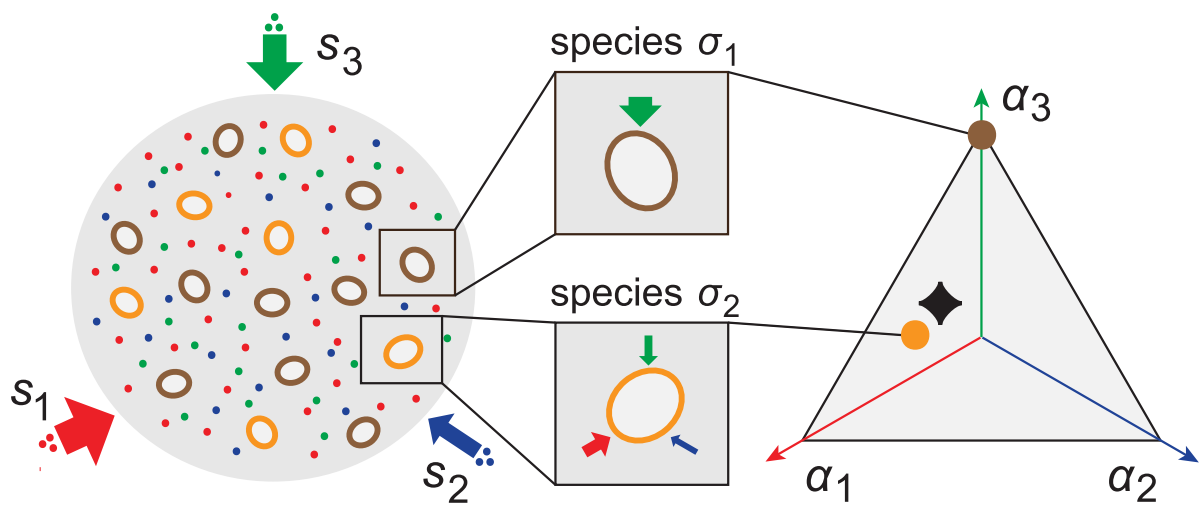
All data publicly available and it now extends way beyond second wave.
Fit SIR models to the data with and without waining of immunity
Is the second peak due to a second variant of SARS-CoV-2?

Co-existence by trade-offs? Q9.8

PRL **118,** 028103 (2017) PHYSICAL REVIEW LETTERS week ending 13 JANUARY 2017

Metabolic Trade-Offs Promote Diversity in a Model Ecosystem

Anna Posfai,[1] Thibaud Taillefumier,[2] and Ned S. Wingreen[1,3]



Motivated by recent studies of phytoplankton, we introduce trade-offs into a resource-competition model and find that an unlimited number of species can coexist. Our model spontaneously reproduces several notable features of natural ecosystems, including keystone species and population dynamics and abundances characteristic of neutral theory, despite an underlying non-neutral competition for resources.

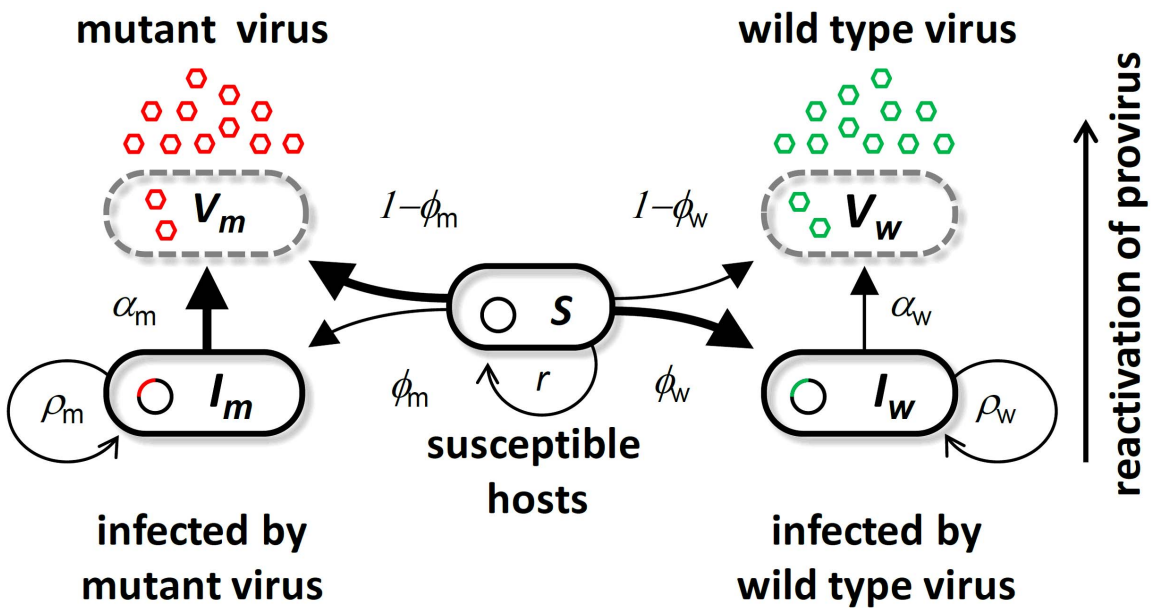
Temperate phages

OPEN ACCESS Freely available online

PLOS | PATHOGENS

Evolution of Virulence in Emerging Epidemics

Thomas W. Berngruber[1]*, Rémy Froissart[2,3], Marc Choisy[3,4], Sylvain Gandon[1]



$$\dot{S} = rS(1-(S+I)/K) - abSV - mS$$

$$\dot{I} = \rho I(1-(S+I)/K) + ab\varphi_{\bullet}VS - (\alpha_{\circ}+m)I$$

$$\dot{V} = ab(1-\varphi_{\bullet})VSB + \alpha_{\circ}BI - mV - a(S+I)V$$

Why are some pathogens more virulent than others? Theory predicts that pathogens that 'keep their host alive' can sometimes outcompete virulent pathogens in times when transmission to new susceptible hosts is unlikely. Yet, this prospect of finding a new susceptible host changes itself throughout an epidemic. In the early stage of an epidemic susceptible hosts are abundant and virulent pathogens that invest more into horizontal transmission should win the competition. Later on, the spread of the infection reduces the pool of susceptible hosts and may reverse the selection on virulence. This may favor benign pathogens after the acute phase of the epidemic. To put these predictions to the test we monitor the competition of the temperate bacterial virus λ and its virulent mutant λcI857 in experimental epidemics. Our experimental results agree remarkably well with all our theoretical predictions.

Competitive exclusion and parasitism (Q10.2)

We studied the effect of a pathogen on winning species:

$$\frac{\mathrm{d}S_j}{\mathrm{d}t} = bN_j(1 - \sum N_i/k) - d_jS_j - \beta_jS_jI_j \quad \text{and} \quad \frac{\mathrm{d}I_j}{\mathrm{d}t} = \beta_jS_jI_j - (d_j + \delta_j)I_j \ ,$$

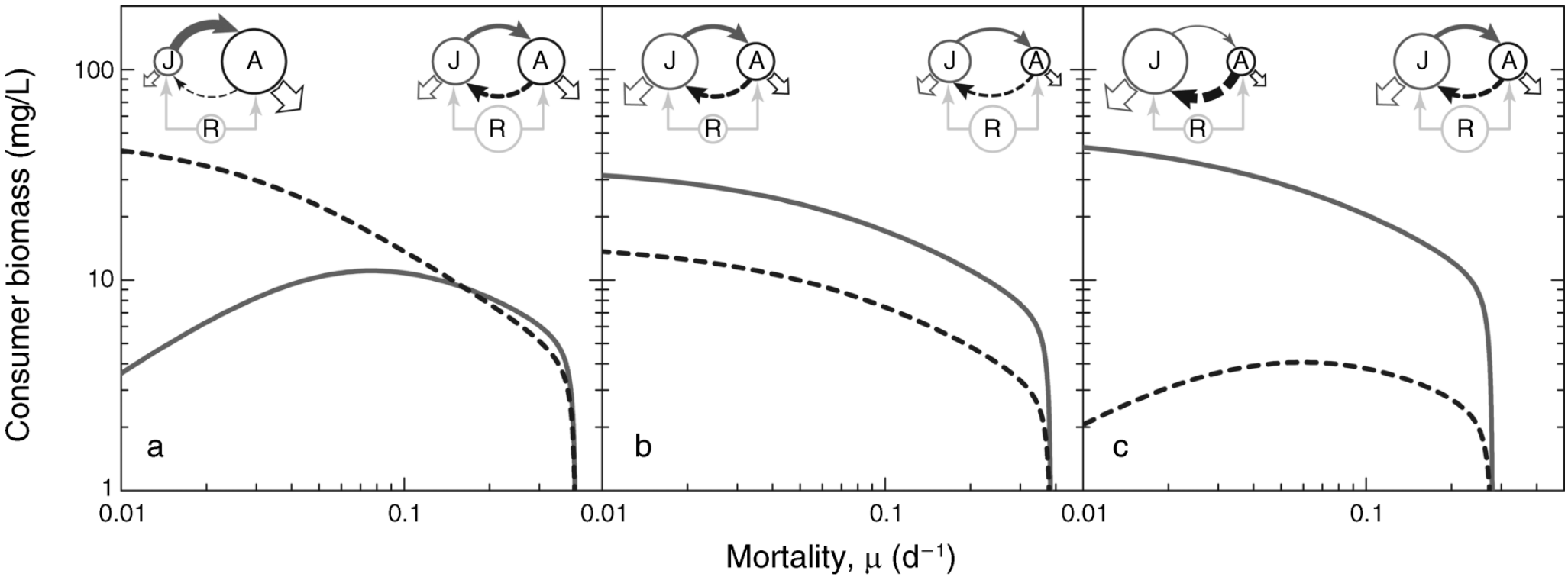
$$N_j = S_j + I_j$$

What is the effect of pathogens on co-existence?

How does this depend on their virulence?

Janzen-Connell hypothesis: parasites evolve towards most dominant species (negative density dependence)
[Bagchi *et al.*, Nature, 2014]

Symmetry breaking in ecological systems through different energy efficiencies of juveniles and adults

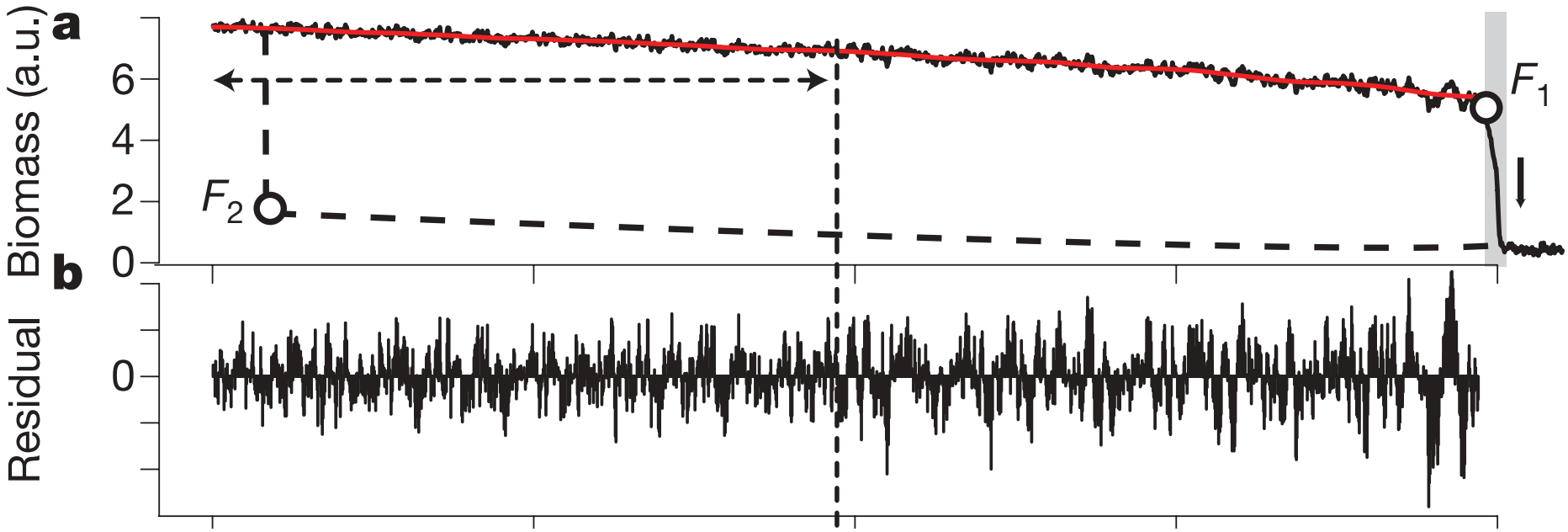


Persson & De Roos Ecology 2013; De Roos & Persson, Princeton UP, 2013

Ontogenetic development for dummies, try to repeat these results with:

$$R = K - c_1 J - c_2 A \;, \quad \frac{\mathrm{d}J}{\mathrm{d}t} = \frac{eAR}{h_2 + R} - \frac{mJR}{h_1 + R} - \mu d_1 J \quad \text{and} \quad \frac{\mathrm{d}A}{\mathrm{d}t} = \frac{mJR}{h_1 + R} - \mu d_2 A$$

Early-warning signals for critical transitions (Q11.2)



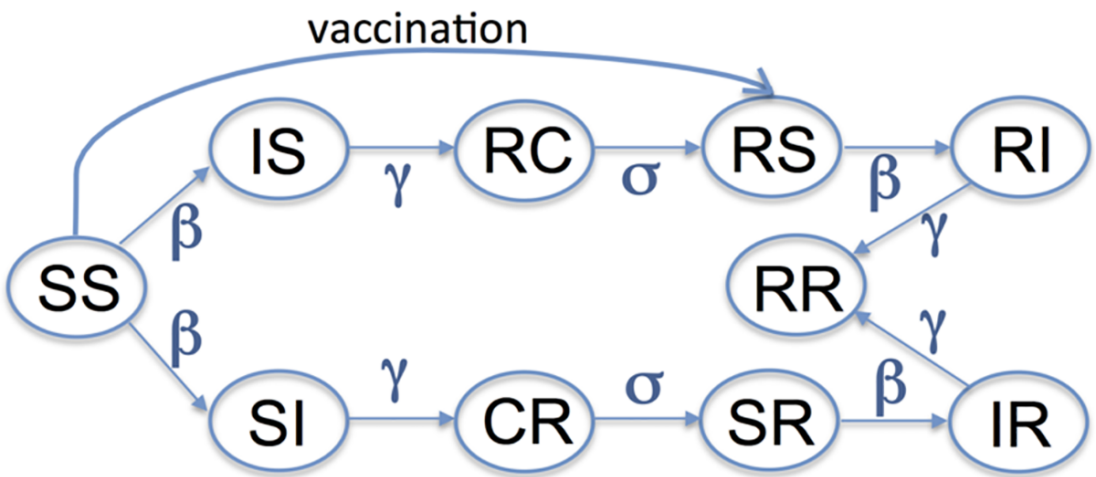
Increasing the harvest rate over time

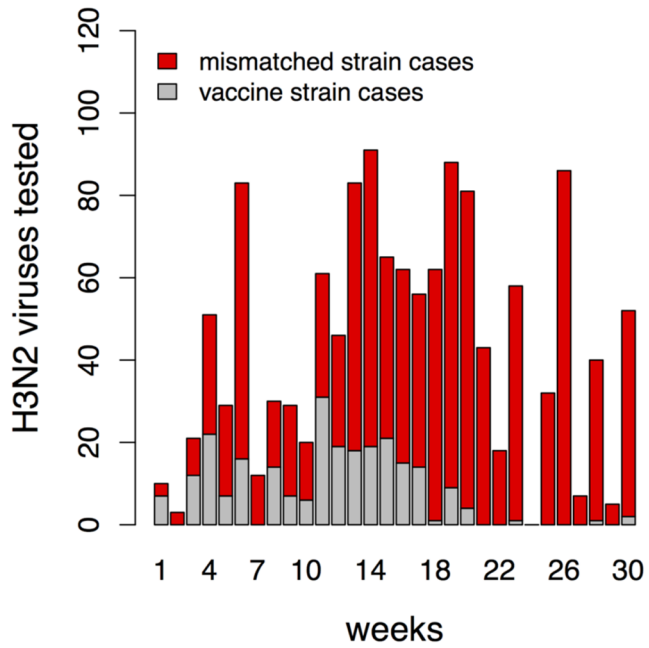
Test whether or not this works in "real-world" example of models for grazing in Sahel zone.

Influenza strain replacement

Intermediate levels of vaccination coverage may minimize seasonal influenza outbreaks

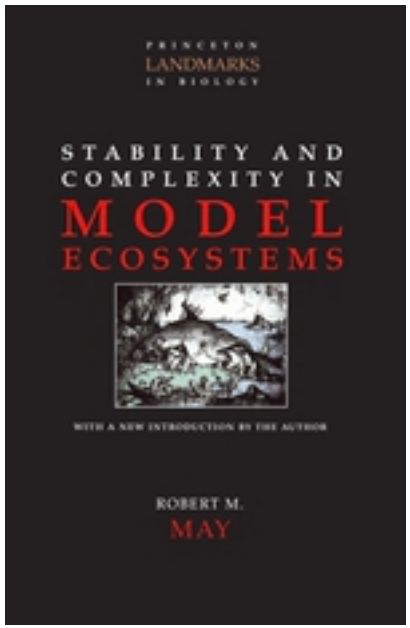
Veronika I. Zarnitsyna[1]*, Irina Bulusheva[2], Andreas Handel[3], Ira M. Longini[4], M. Elizabeth Halloran[5,6], Rustom Antia[7]*





Our models predict that the total number of seasonal influenza infections is minimized at an intermediate (rather than maximal) level of vaccination, and, somewhat counter-intuitively, further increasing the level of the vaccination coverage may lead to higher number of influenza infections and be detrimental to the public interest.

How can large systems be stable?



This book is a classic studying the relationship between the complexity of a system (number of species and their number of interactions), and the likelihood that the system would be stable.

In chapter 10 we provide several exercises, each with R-scripts, to repeat and extend this classic work. A central question is the "scaling" by setting all diagonal elements to A_{ii}=-1.