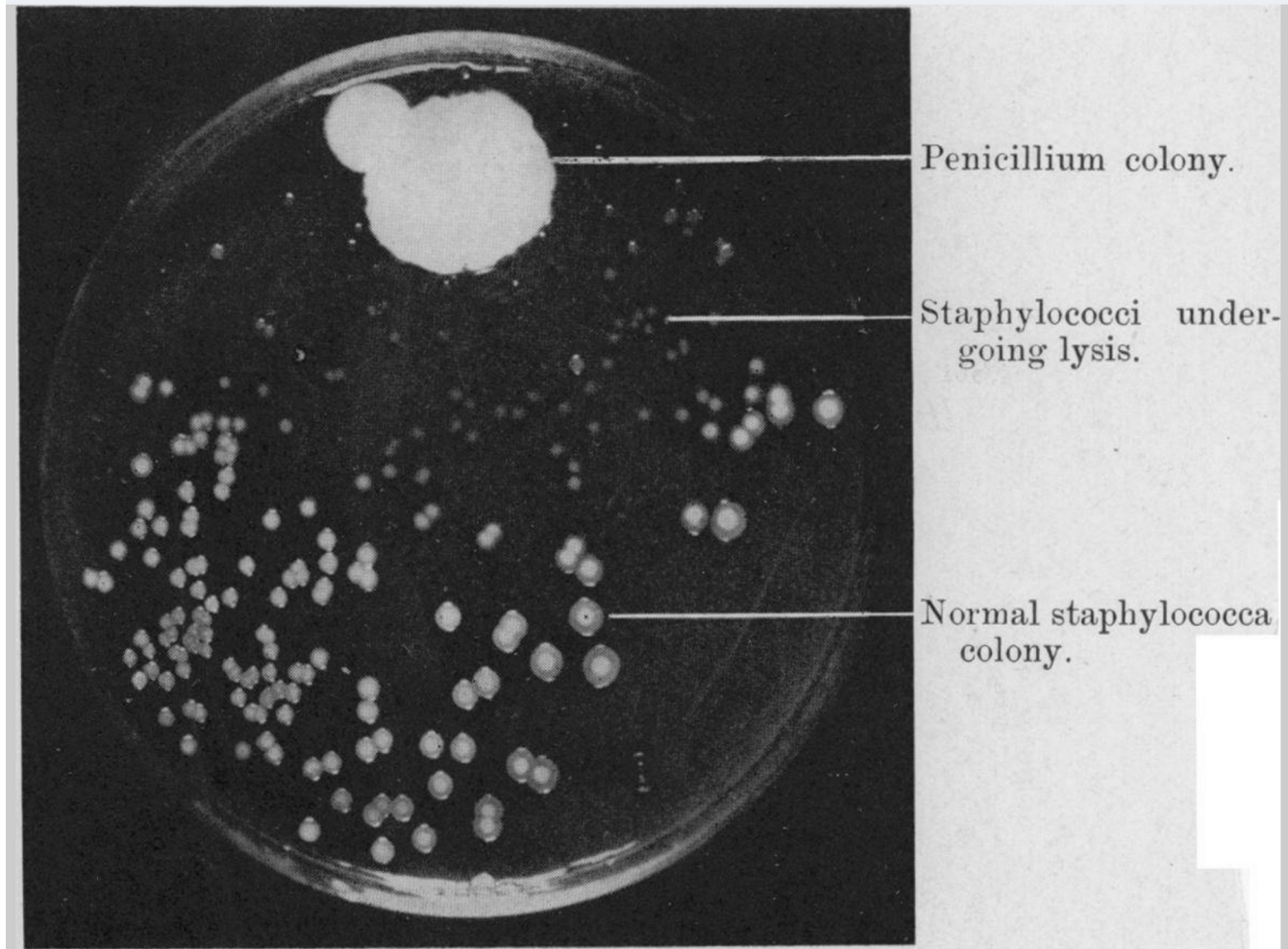
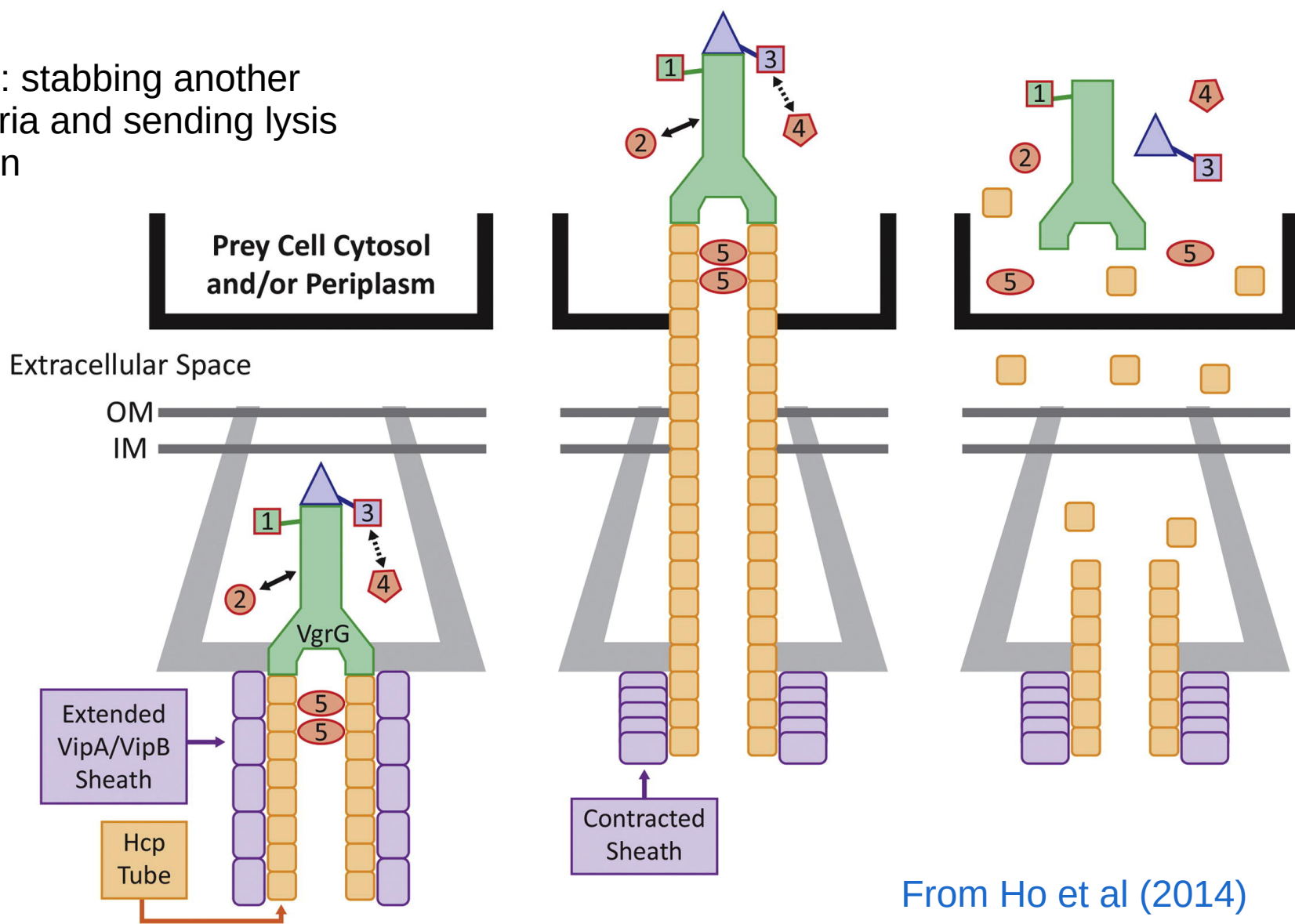


# “Active” competition

- From [Fleming, 1929](#): (some) Antibiotics are weapons produced by microbes to kill other microbes
- Bacteria also secrete toxins to kill competitors
- T6SS
- CRISPRs!!

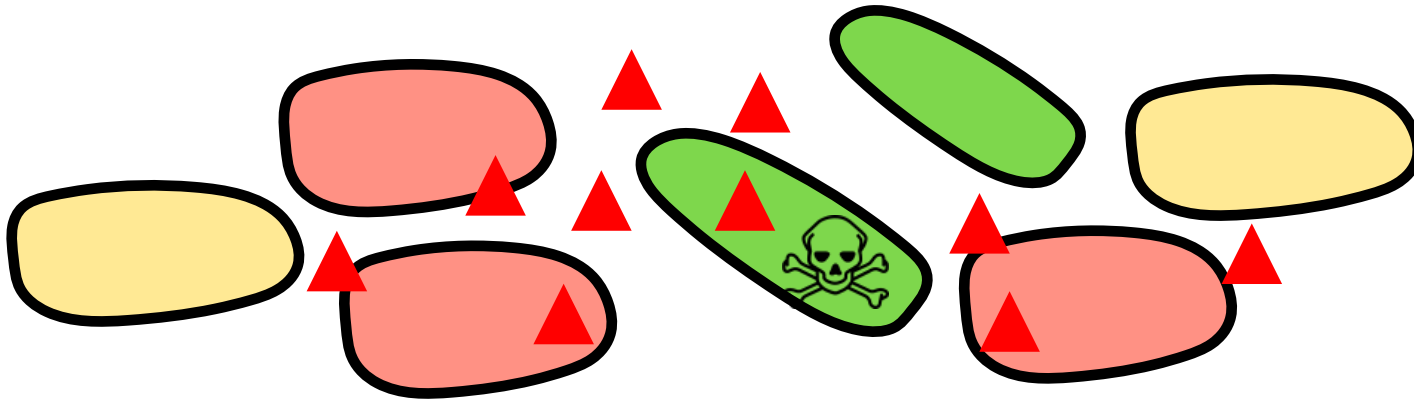









T6SS: stabbing another bacteria and sending lysis protein



From Ho et al (2014)

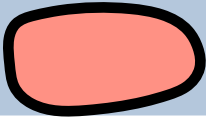
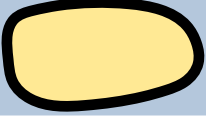
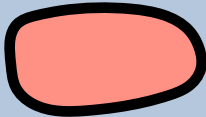

# Competition is (sometimes) cooperation



Individuals of type  secrete a toxin  that kills individuals of type   
Benefit for:  eating the food released / not eaten by   
 is immune against his own toxin 

Mutant  does **not** secrete  but is still immune against it  
→ compared to wild-type , the mutant  does not pay the cost of producing   
But still benefits from production by 

# Competition is (sometimes) cooperation

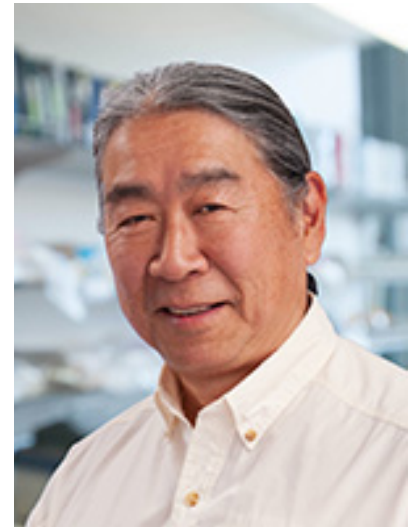
		
	$1 - c + b$	$1 - c + b/2$
	$1 + b/2$	1

Prisoner's dilemma  
when  $b > c > b/2$

(Because then  $T > R > P > S$   
and  $R > (T+S)/2$ )

➔ Costly traits that harm others (often distant species)  
are often cooperative (towards close relative)

See eg  
Chao and Levin (1981)



# Cooperation, competition and the evolution of virulence

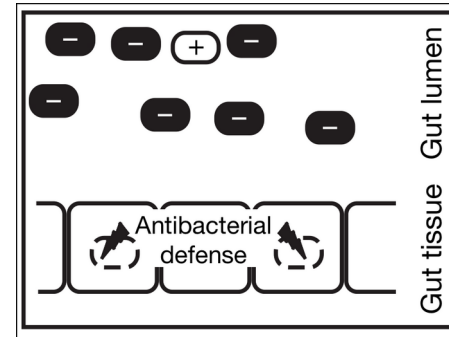
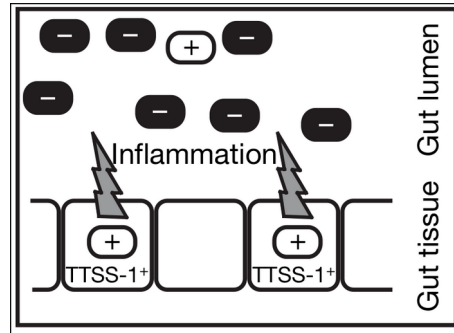
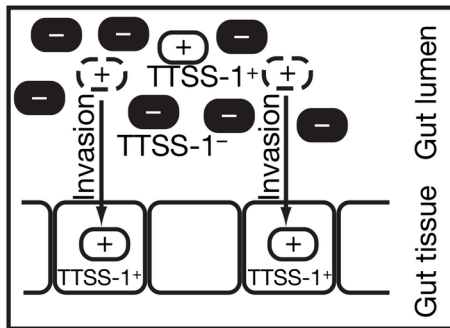
Why does evolution of pathogens lead to virulence (damage to the host) ?

Hypothesis: to the host are side effect of **within-host competition** between several pathogens (see eg Brown et al 2009 and Frank 1992)

→ The cost of virulence (host weakened or dead) is shared between all pathogens within the same host, while the benefits go the virulent ones



Steve Frank



Virulence sometimes as well relies on cooperation, see eg [Ackermann et al \(2008\)](#)

# Modeling and simulating evolution with interactions

- No space? Possible but rarely interesting  
→ Classical game theory  
**Replicator equation** is the standard approach

	A	B
A	a	b
B	c	d

$x$  is the frequency of A

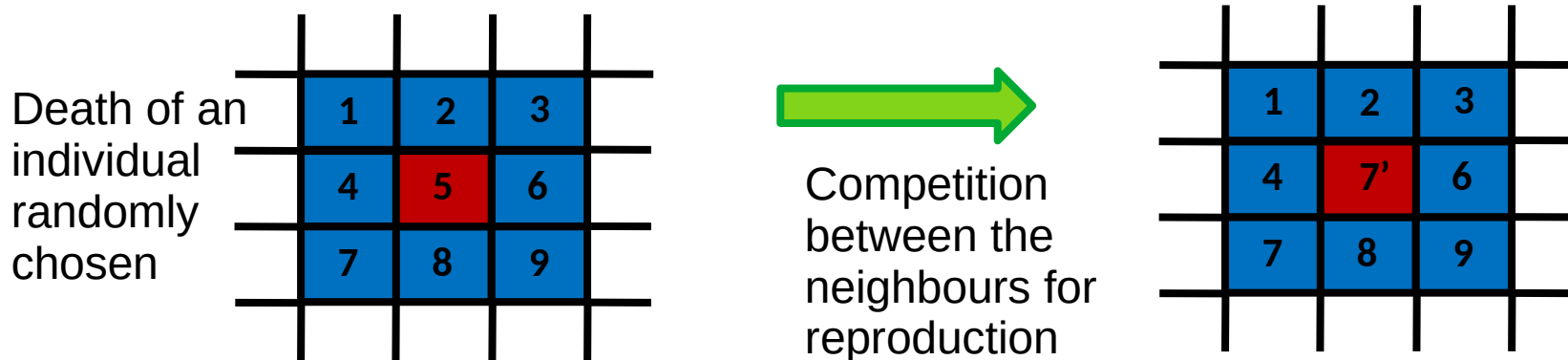
$f_B = cx + d(1 - x)$  is the payoff of B

$f_A = ax + b(1 - x)$  is the payoff of A

$$\frac{dx}{dt} = x(1 - x)(f_A - f_B) = x(f_A - \bar{f})$$

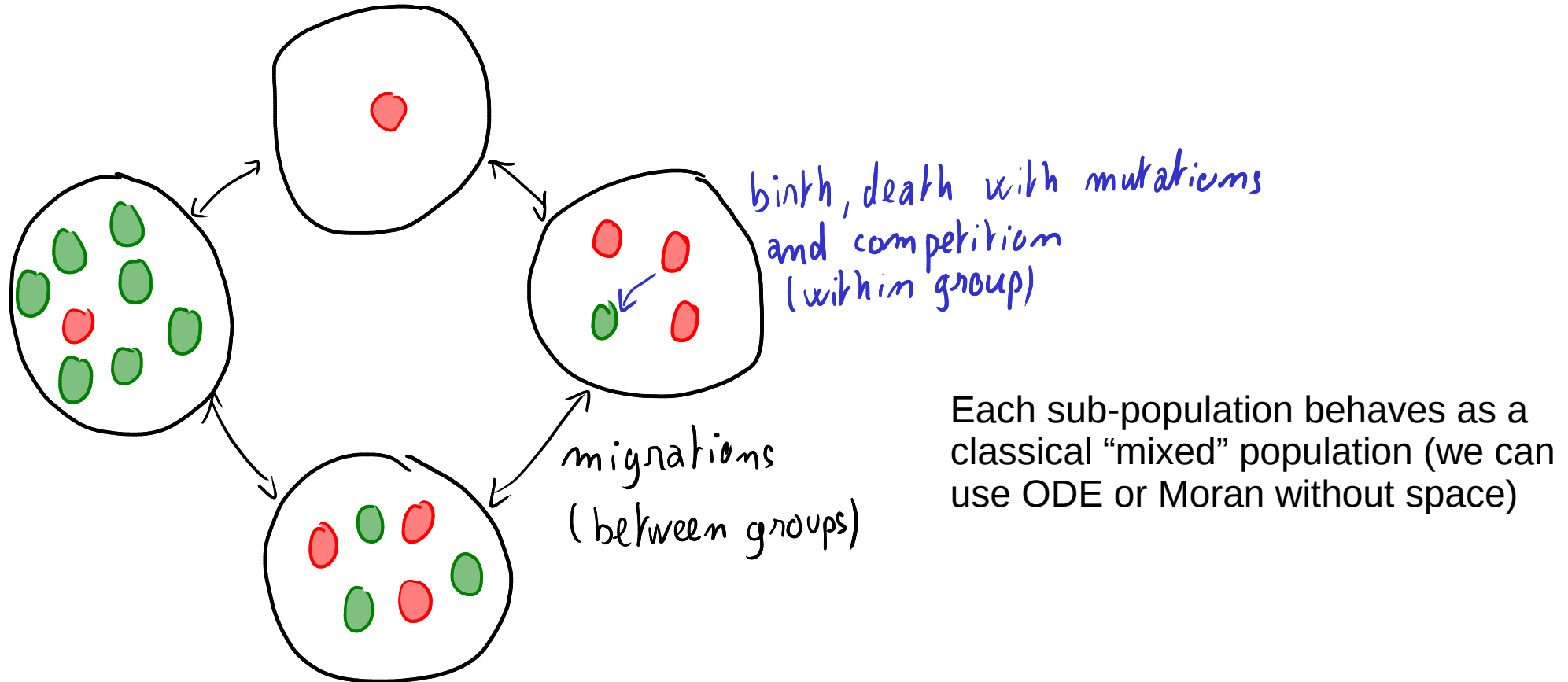
# Modeling and simulating evolution with interactions

- In space: rare to have analytical expressions (but see [vanBaalen 2000](#)) → usually simulations. First option: 2D lattice
  - Individual-based
  - Asynchronous (Moran) or synchronous (Wright-Fisher)
  - Probability of reproduction determined by *local* competition
  - Fitness of an individual also depends on its neighbours



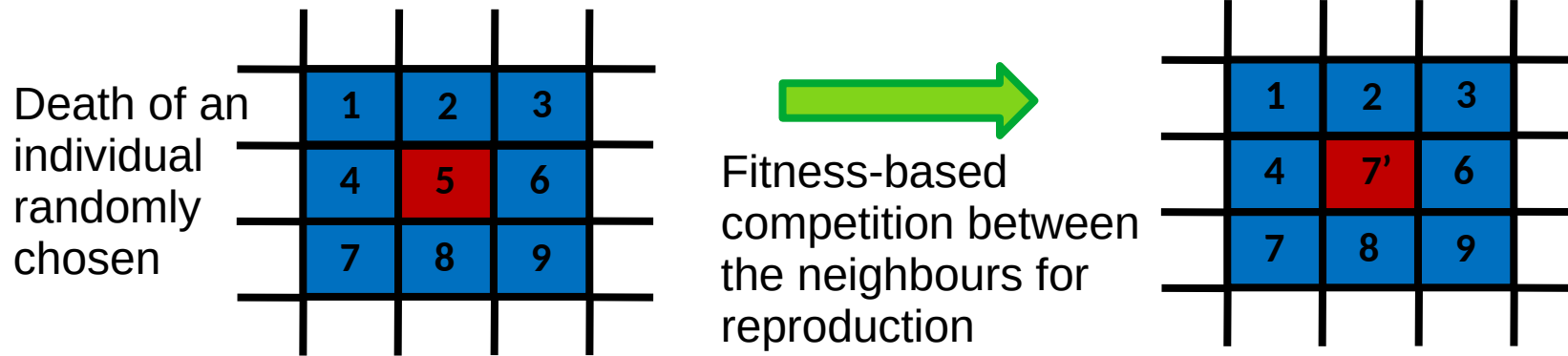
# Modeling and simulating evolution with interactions

- In space, second option: meta-populations / island model / ...





# Implementation



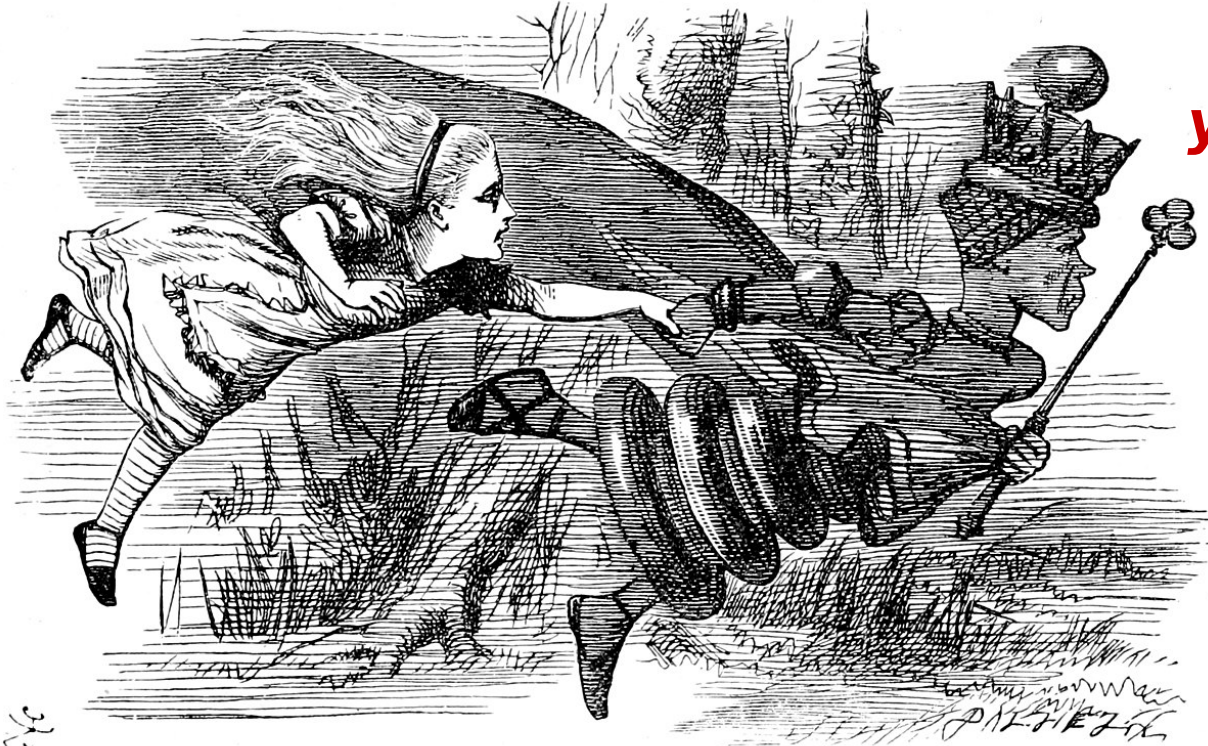
**Exercise:** Implement a Moran process on a lattice / torus with fitness depending on a cooperative dilemma

- payoff of an individual  $i$  is  $1 + b \times N_i - c \times C_i$ , where  $N_i$  is the number of individuals of type C in the neighbourhood of  $i$ , and  $C_i$  is 1 if  $i$  is of type C and 0 otherwise.

- probability of picking individual  $i$  for reproduction is  $\frac{f_i^m}{\sum_{k \in neighbours(i)} f_k^m}$

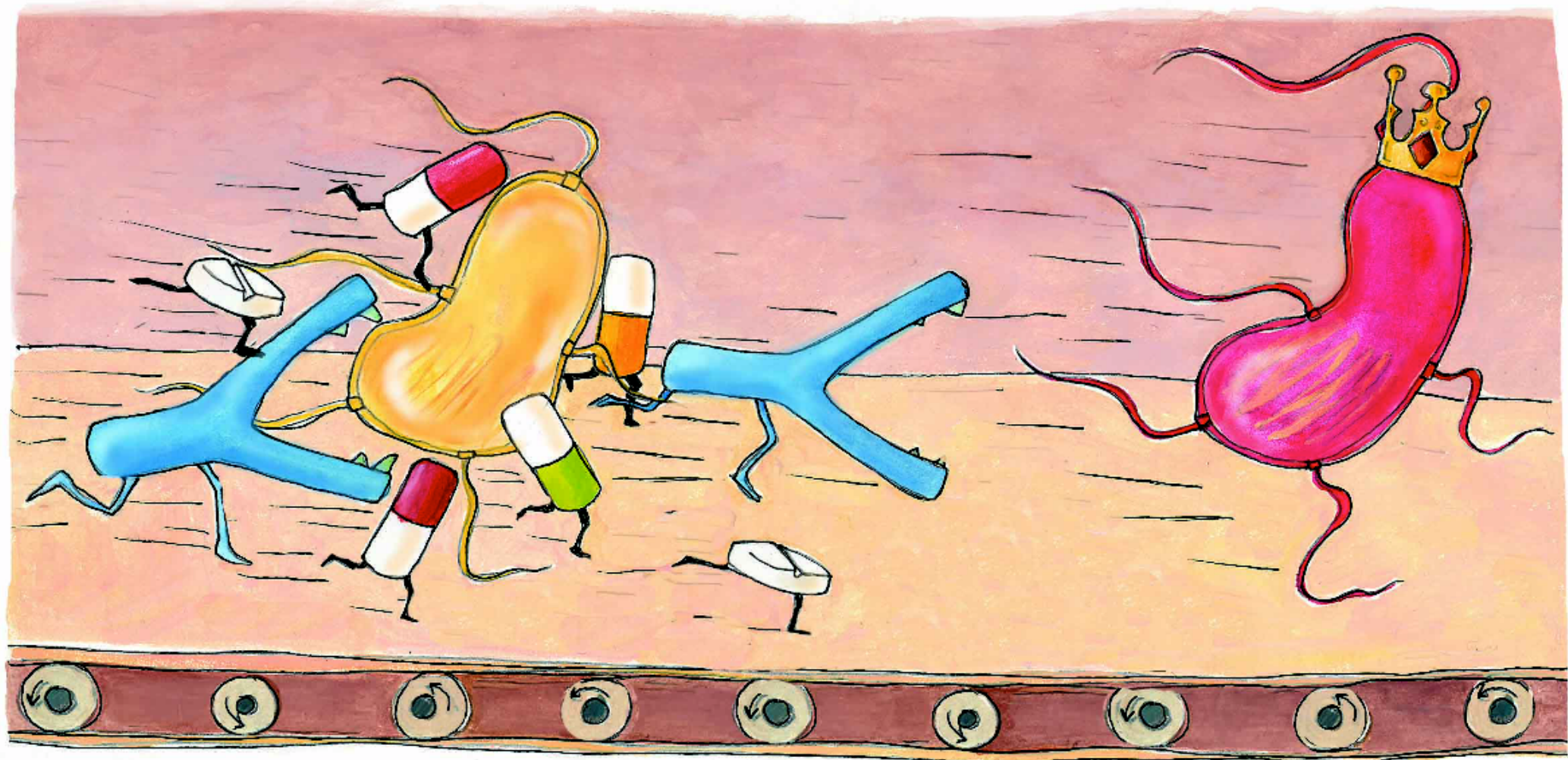
# Cooperation and competition are key to understand microbial evolution

Evolution is not about being good (adapted to a fixed abiotic environment), but about being better than others → **Red queen dynamics**



***“It takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that.”***

***Lewis Carroll***



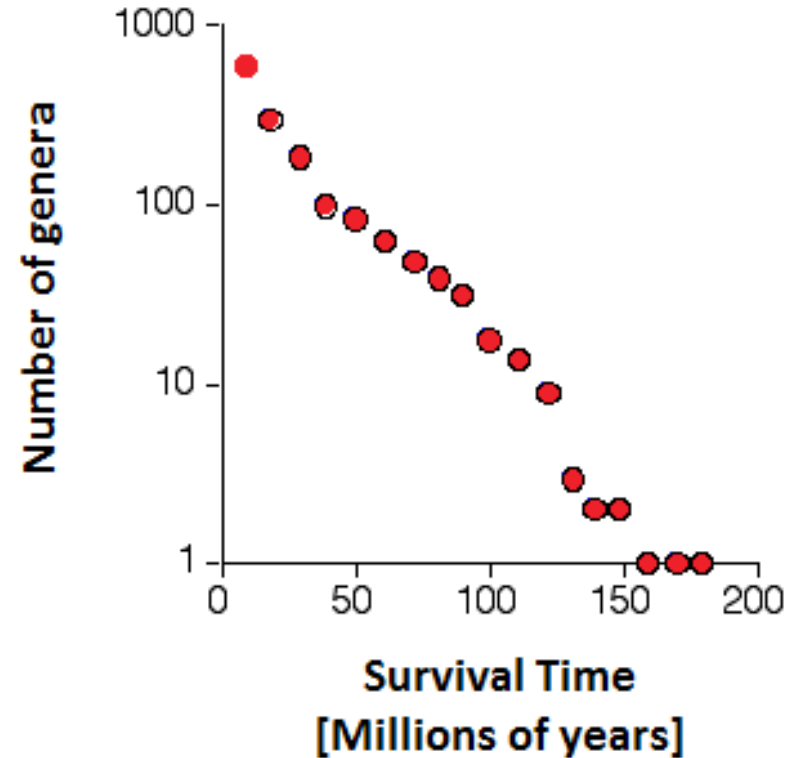
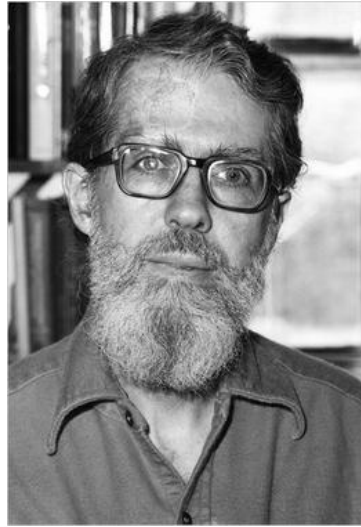
The bacterial Red Queen (unknown original author – somewhere in “La Recherche” 199X – communicated by F. Taddei )

# The Red Queen hypothesis in details

Leigh Van Valen, 1973: survival times of the genera are exponentially distributed

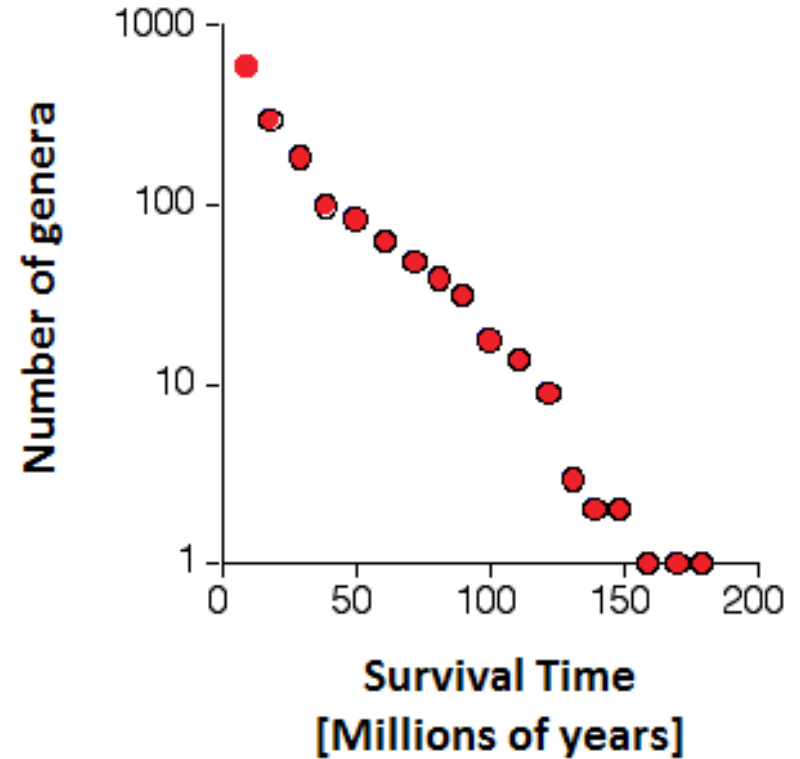
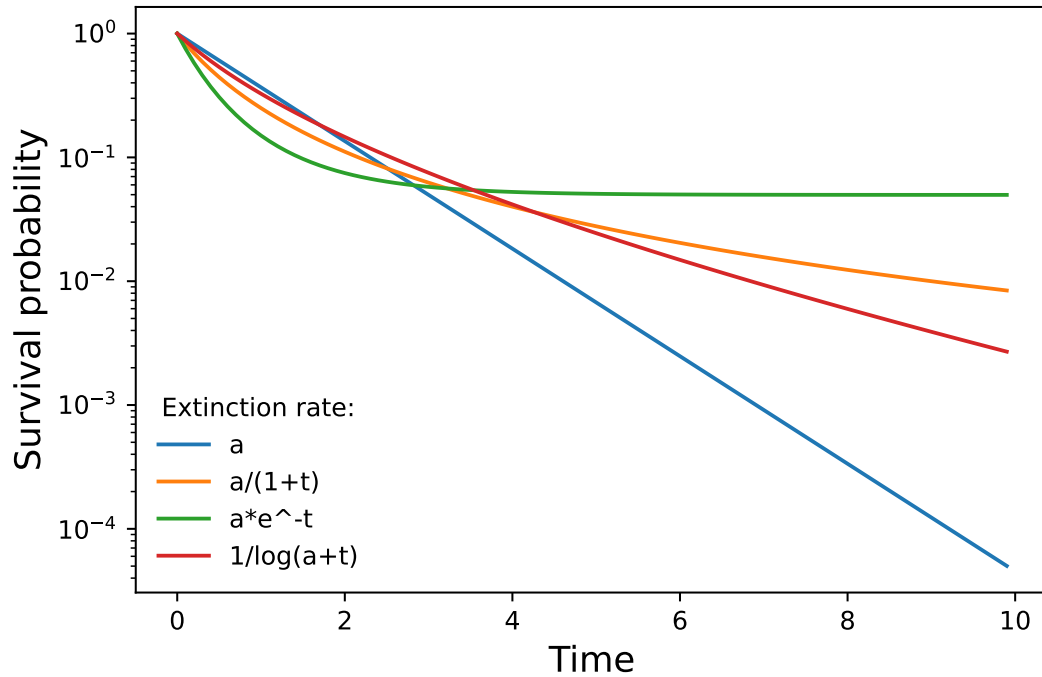
→ constant probability of extinction of a genus per unit of time

Unexpected, because if evolution gradually makes the genus *better*, then extinction probability should decrease over time



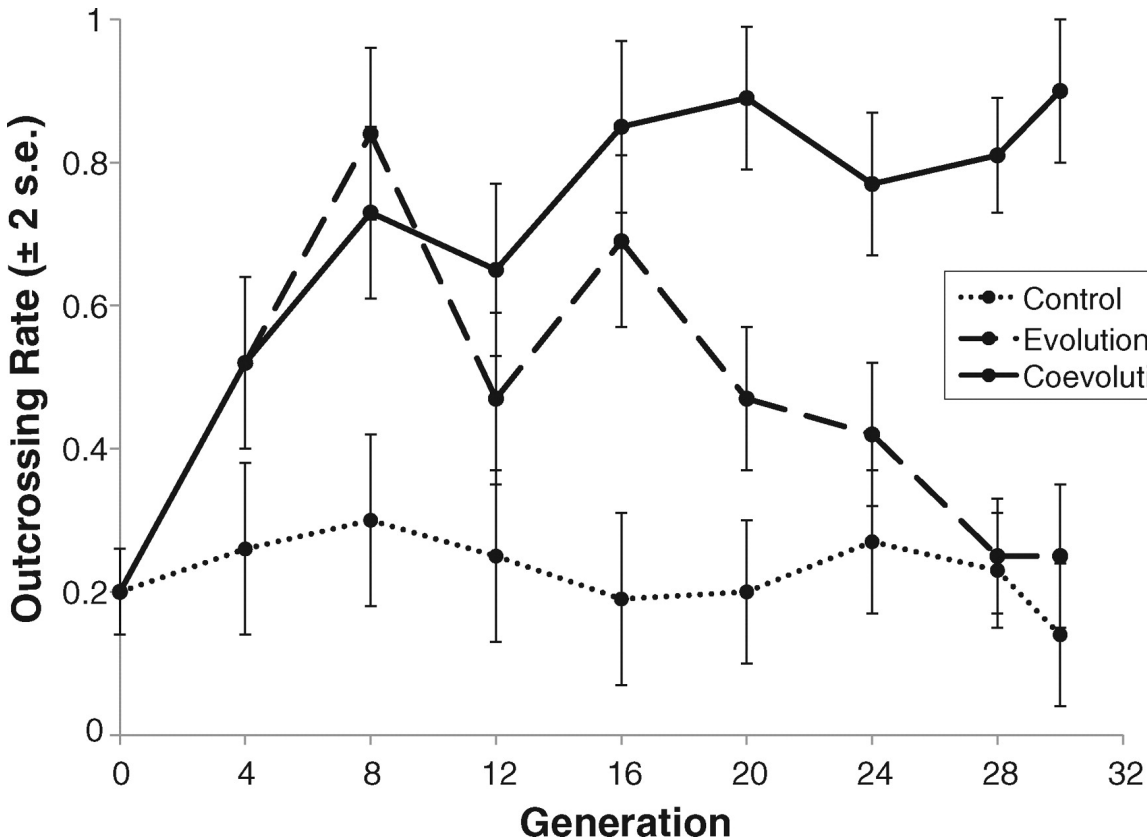
→ Hypothesis: **evolution is a zero-sum game**, absolute fitness of a genus does not increase over time because other genera in competition with the focal genus also adapt

# The Red Queen hypothesis in details



Not sure about the mathematical arguments? See example computations in the notebook  
The left panel shows that only a constant extinction rate reproduces the observed curves

# The Red Queen hypothesis in the context of evolution of sex in “higher” organisms



“Arm race” competition with other species could select for mechanisms increasing generation of diversity, such as sexual reproduction

Picture from [Morran et al \(2011\)](#)

Here, *C. elegans* evolving alone; with a non-evolving parasite; or with a co-evolving parasite  
*C. elegans* has two modes of reproduction: clonal and sexual

# The Red Queen hypothesis in the context of evolution of sex in “higher” organisms



Michael Eisen #912238   
@mbeisen

*C. elegans*. They wiggle forward. They wiggle backwards. And occasionally they fuck themselves. That's it.



Just the Zoo of Us  @JusttheZooofUs · Jul 18, 2020

What is the most overhyped animal? 🐼🐼

[Show this thread](#)

“Arm race” competition with other species could select for mechanisms increasing generation of diversity, such as sexual reproduction

→ The selection of traits which control generation of genetic diversity (previously discussed) should be thought in the context of competition