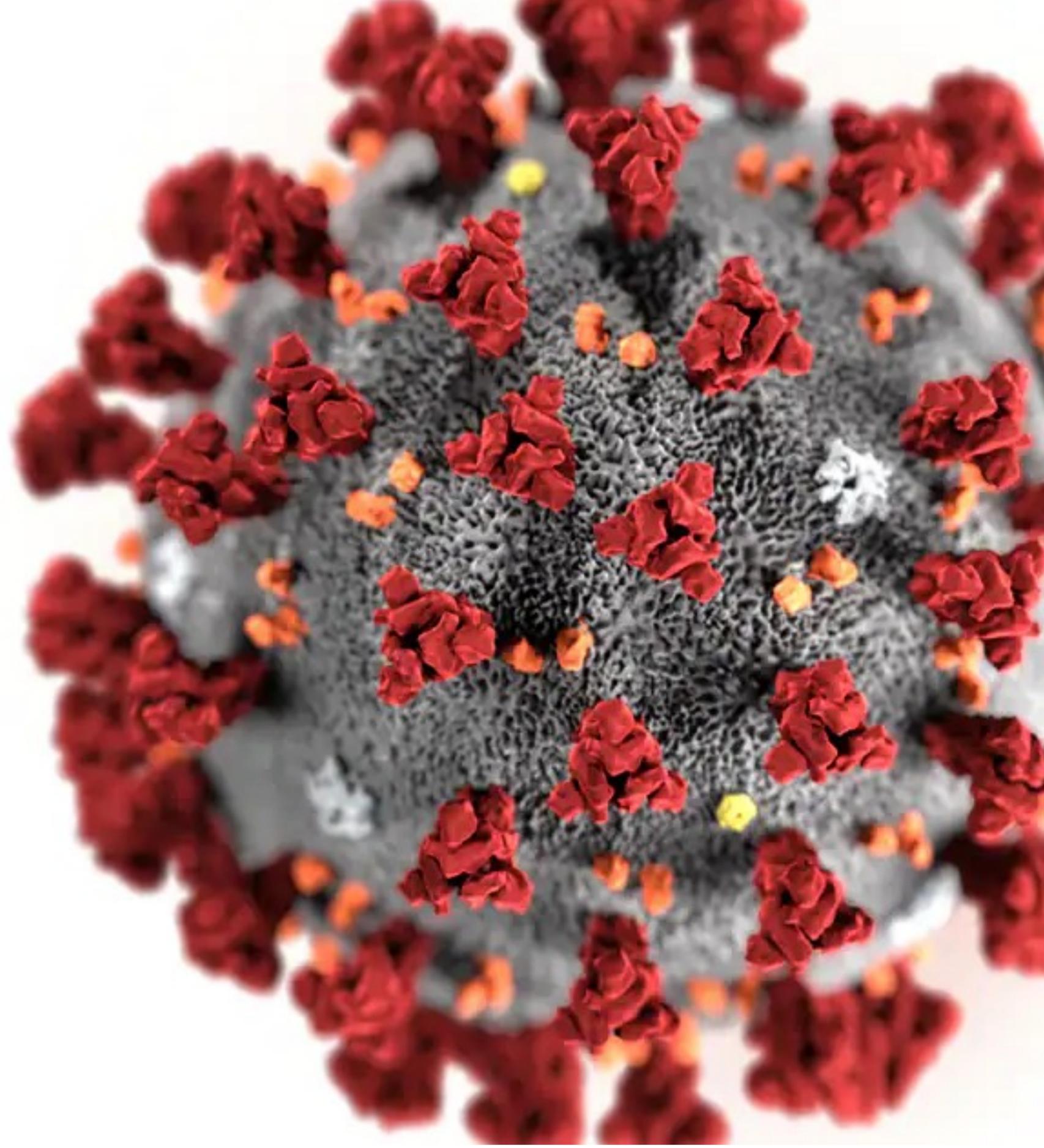


Coevolução

BIO 0119

Ana Paula Aprígio Assis

paulaassis@ib.usp.br





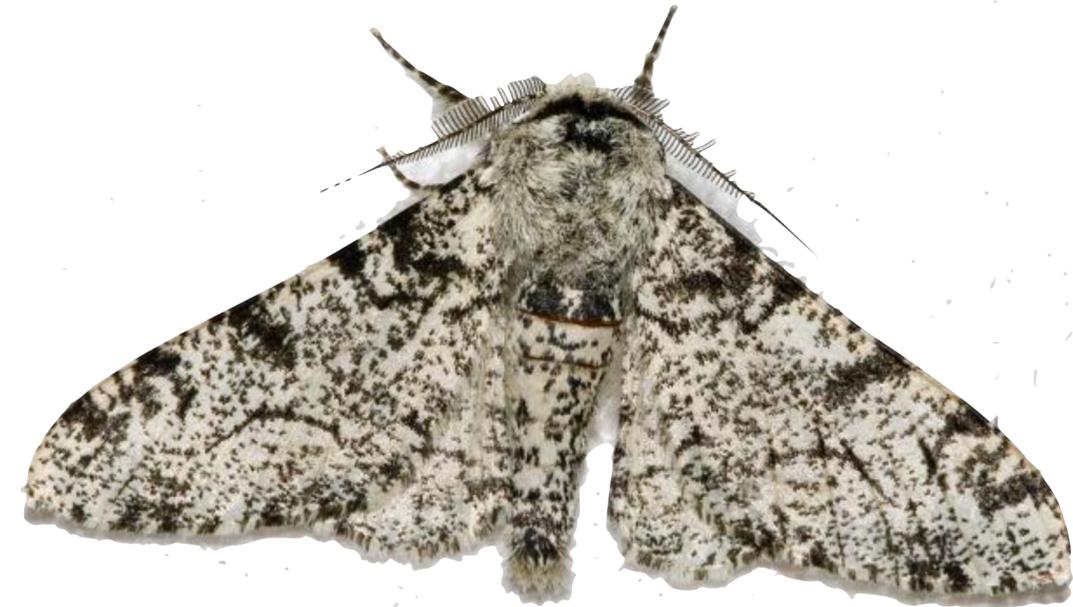
“Todas as manhãs a gazela acorda sabendo que tem que correr mais veloz que o leão ou será morta. Todas as manhãs o leão acorda sabendo que deve correr mais rápido que a gazela ou morrerá de fome. Não importa se és um leão ou uma gazela: quando o sol desponta o melhor é começares a correr.”

Mia Couto

Seleção natural

Seleção natural

1.) Existe variação

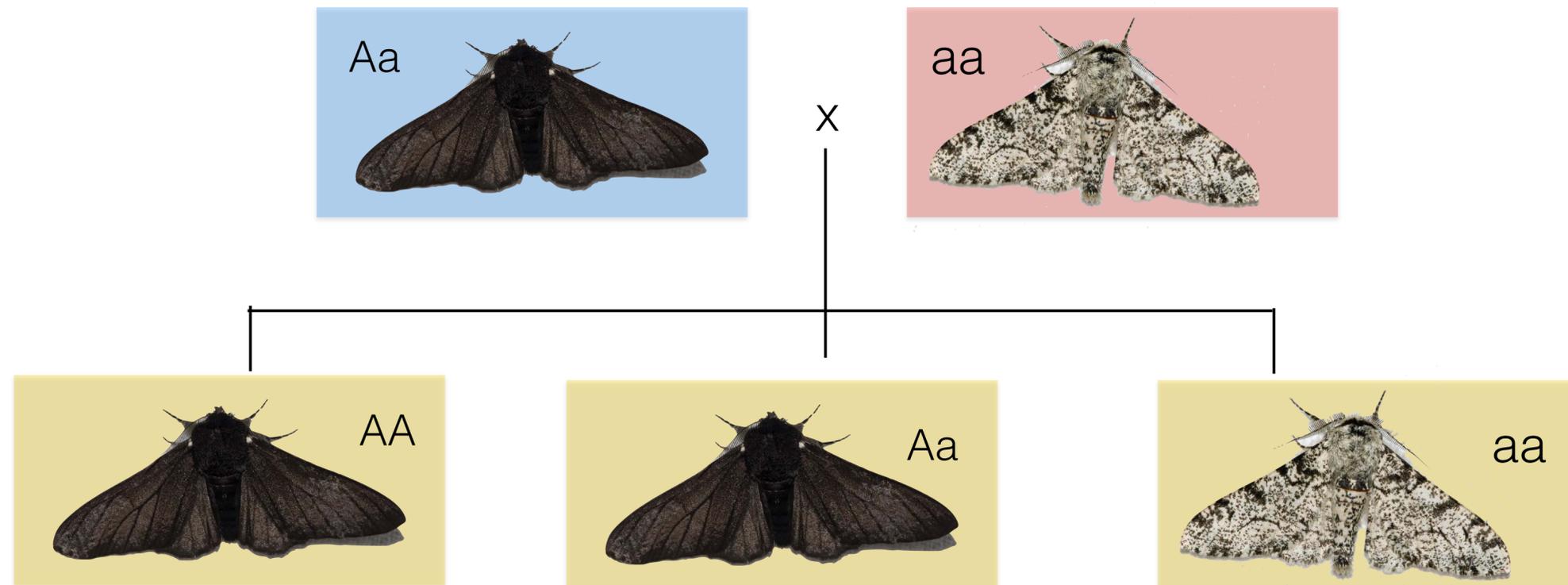


Biston betularia

Seleção natural

2.) Variação é herdável

Herança autossômica dominante

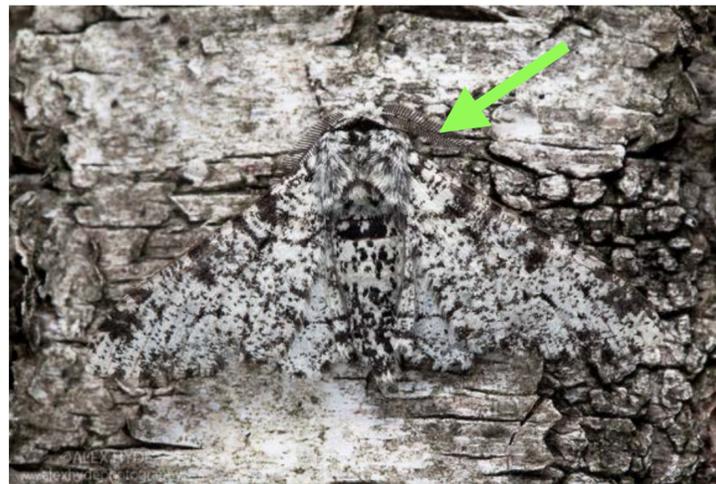


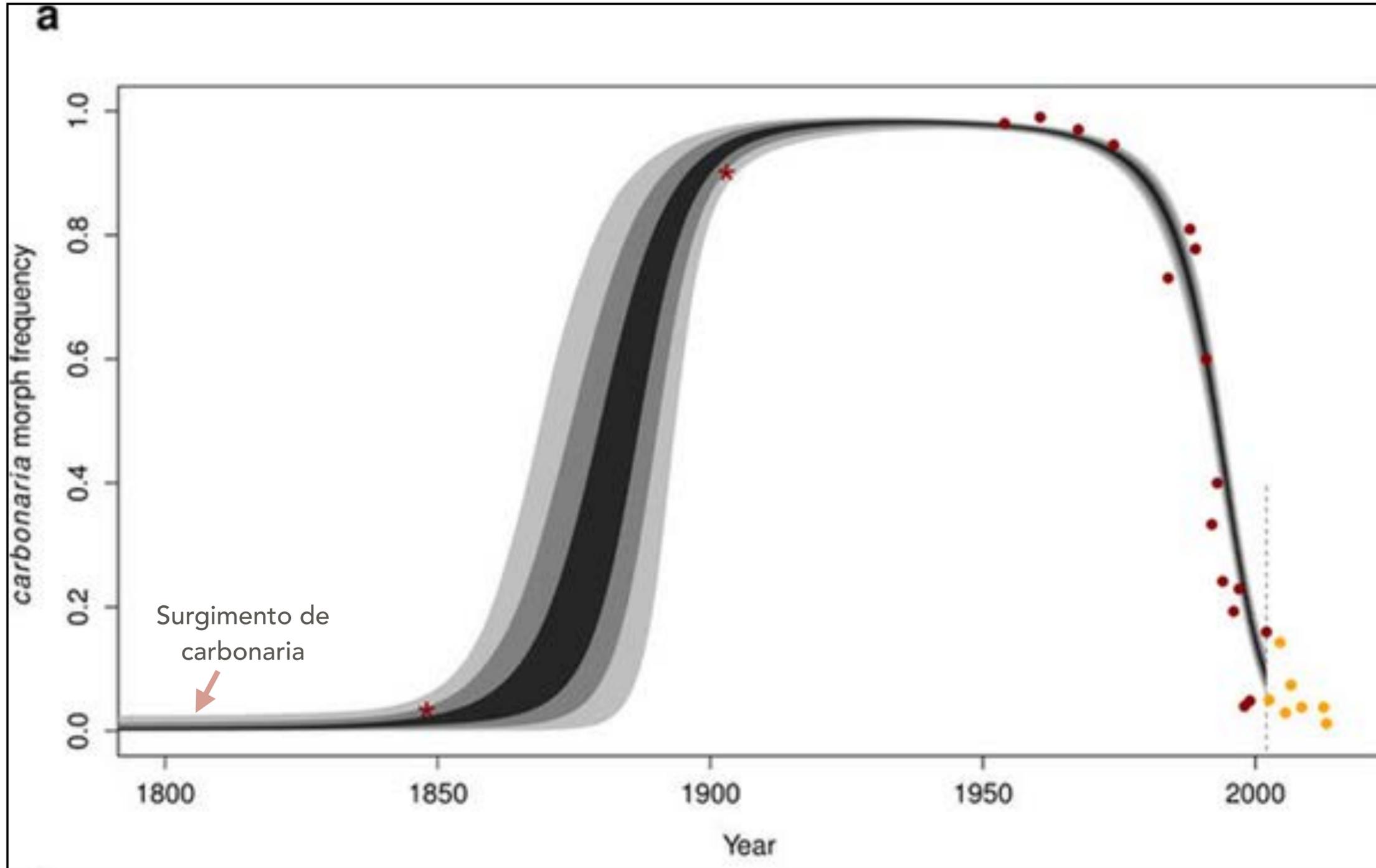
3 : 1

Seleção natural

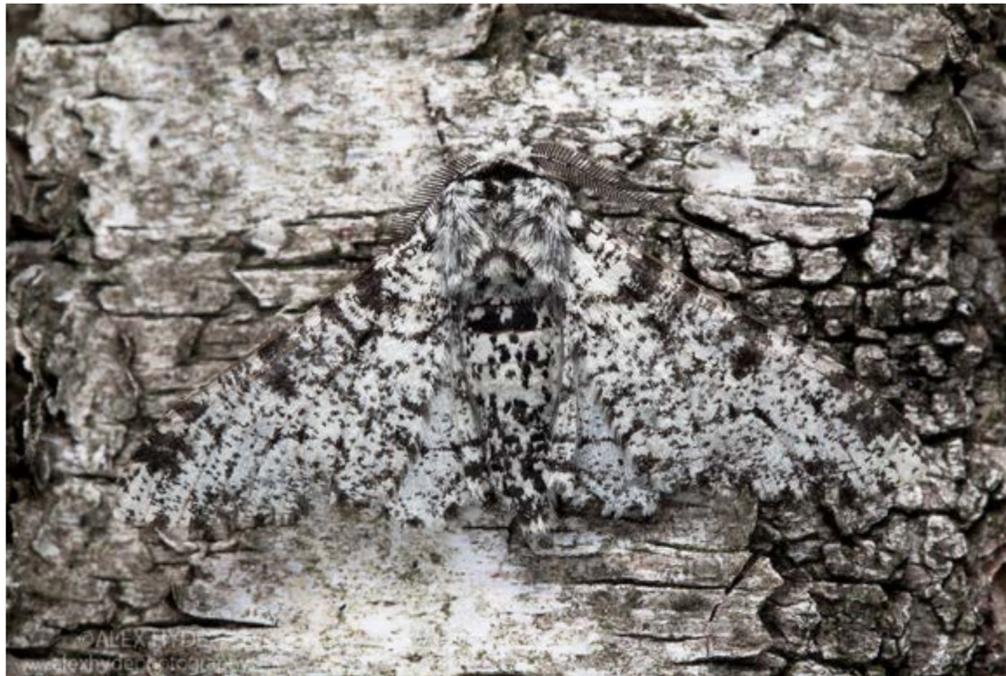
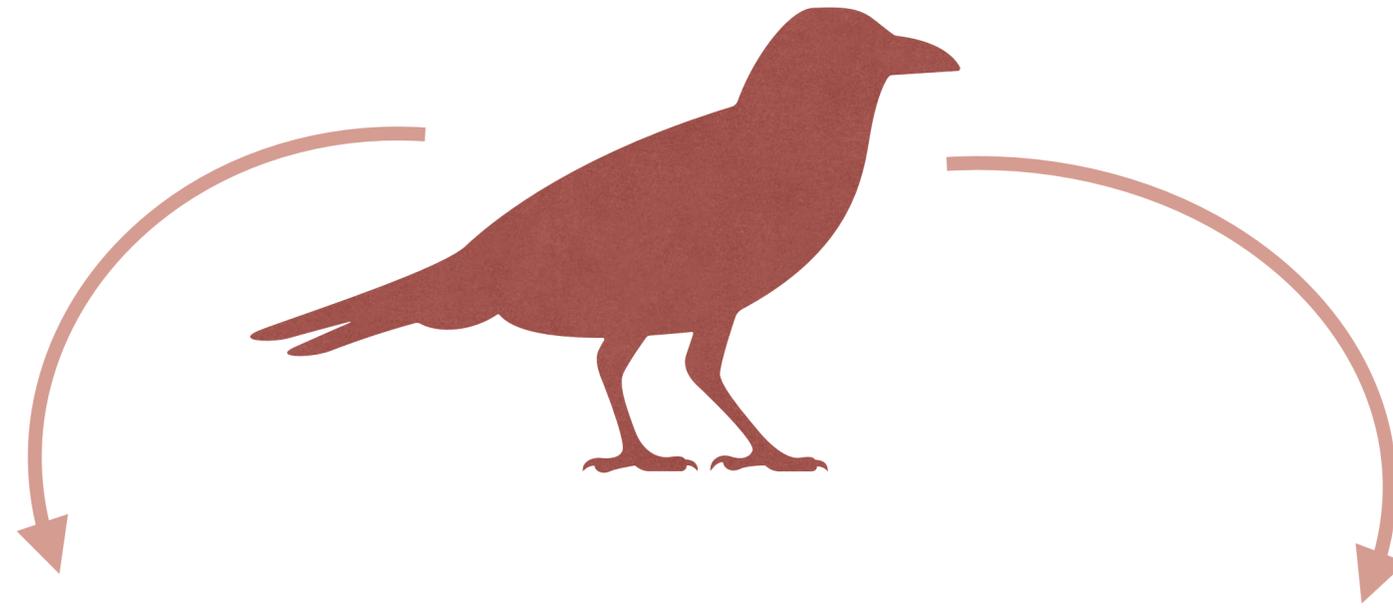
3.) Reprodução/Sobrevivência diferencial

Revolução industrial

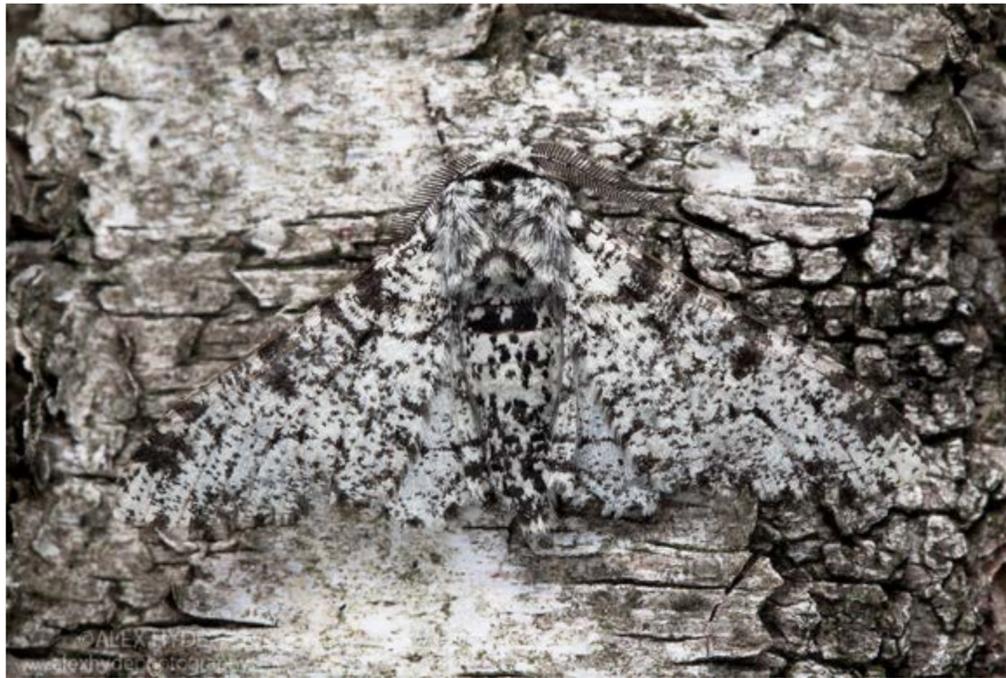
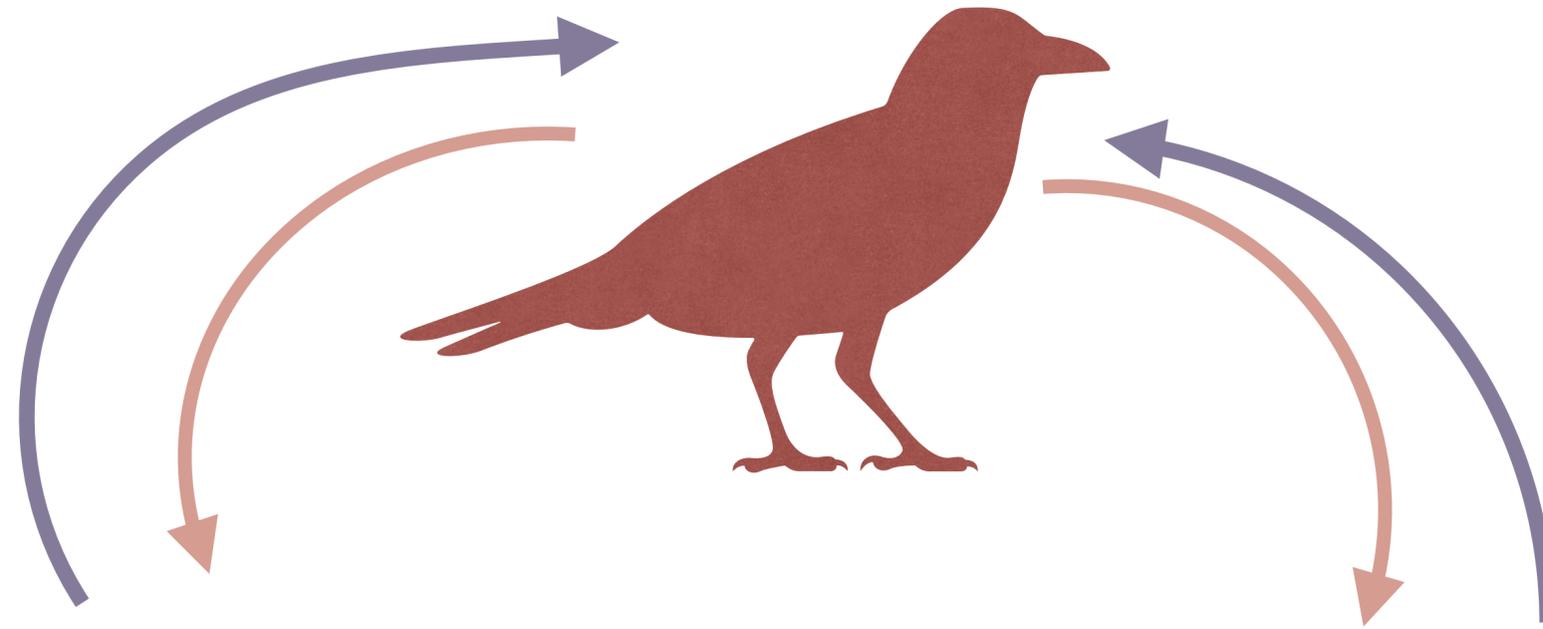




Mas qual o agente seletivo de carbonaria?



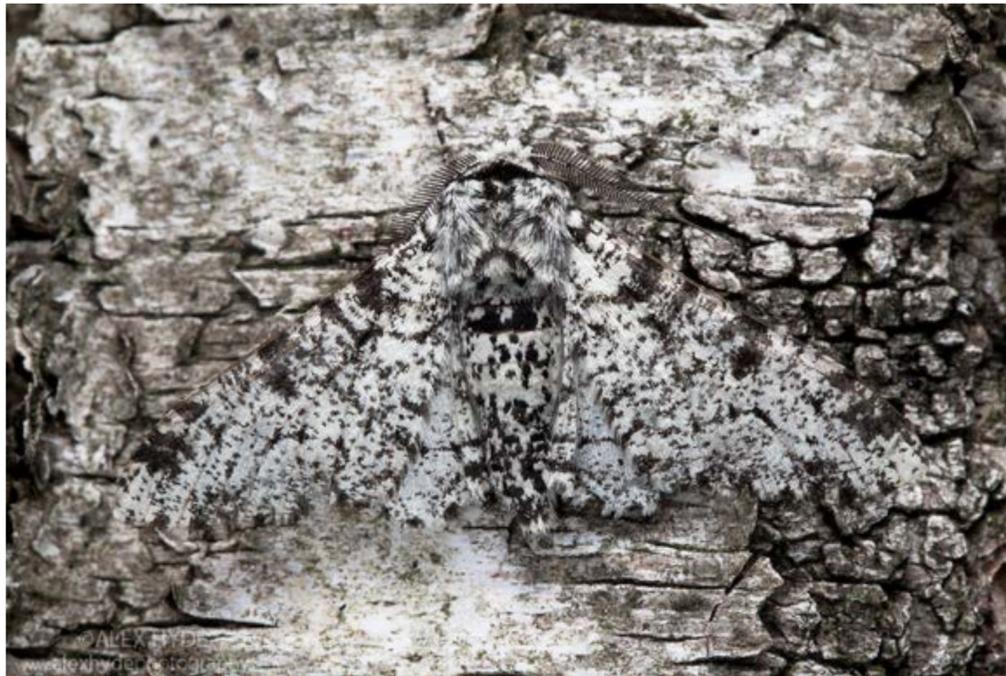
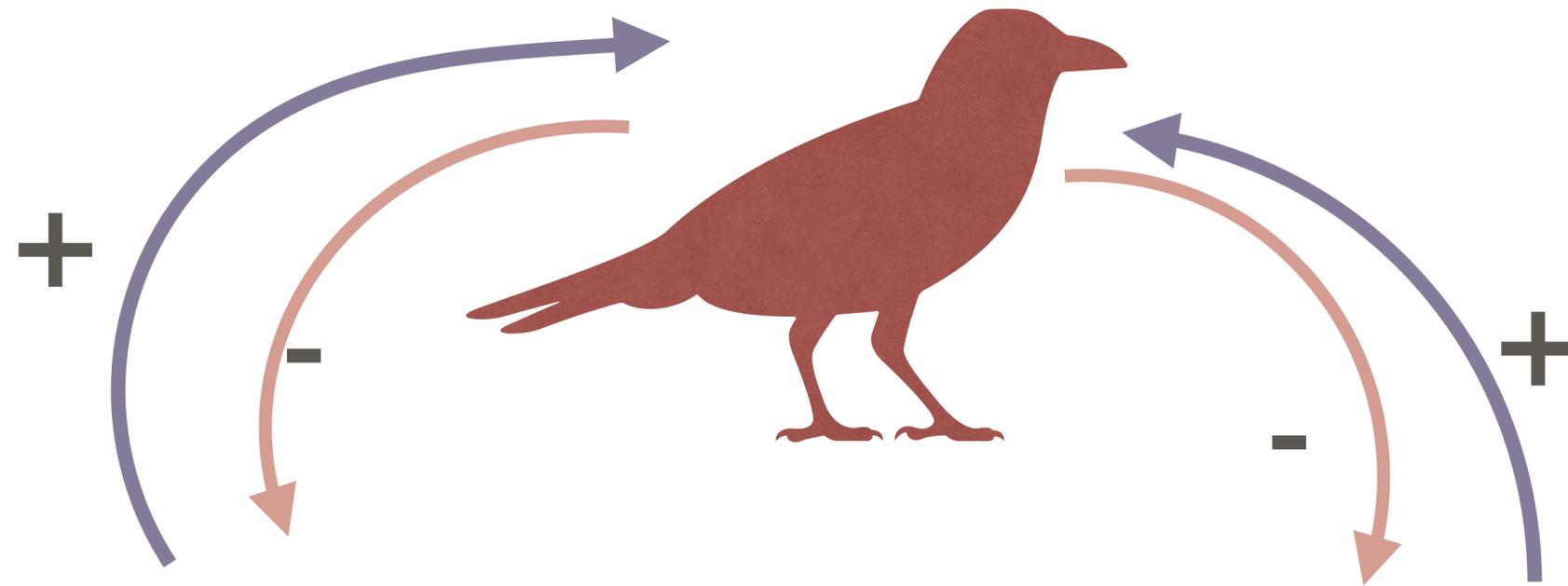
Mas qual o agente seletivo de carbonaria?



Coevolução

- Mudança recíproca por seleção natural entre espécies que interagem

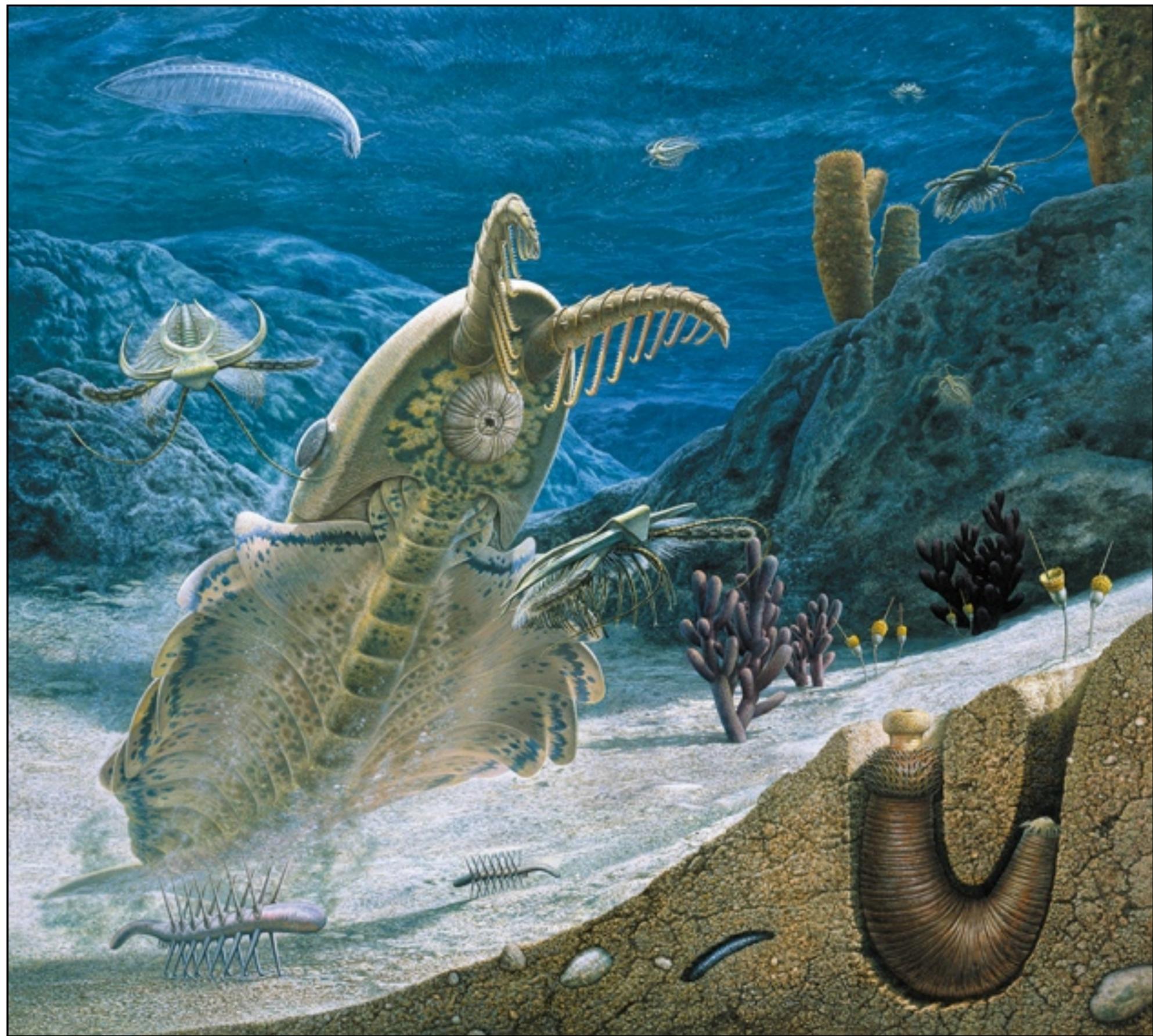
Coevolução



Antagonismo

- Interação entre indivíduos de espécies diferentes que causa **redução de aptidão** de um dos indivíduos e **aumento na aptidão** do outro indivíduo

Quão importante são interações antagonistas para evolução??

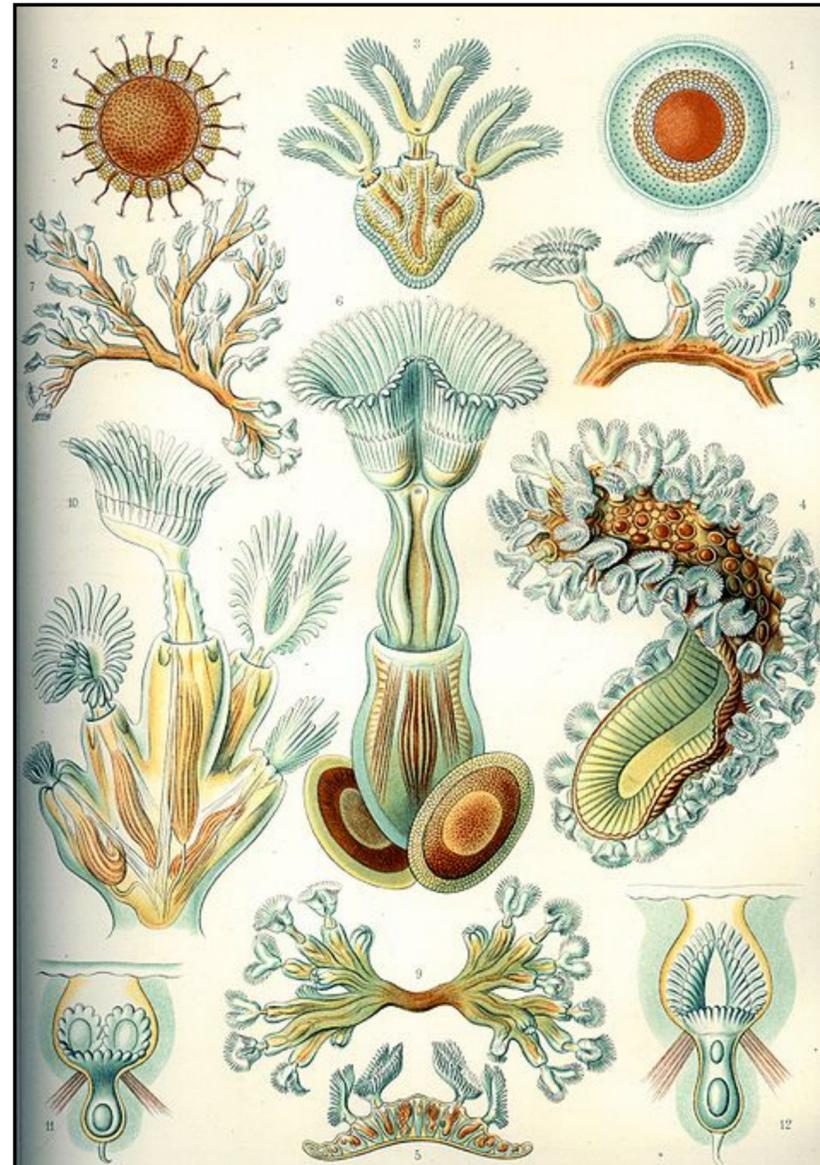


Explosão Cambriana

~500 milhões de anos atrás

Em um curto período de 15-30 milhões de anos **todos os atuais filos de animais** (com exceção de um) surgiram no registro fóssil

Explosão cambriana





**DEFESAS CONTRA INIMIGOS
NATURAIS**



Como escapar de um predador

Camuflagem



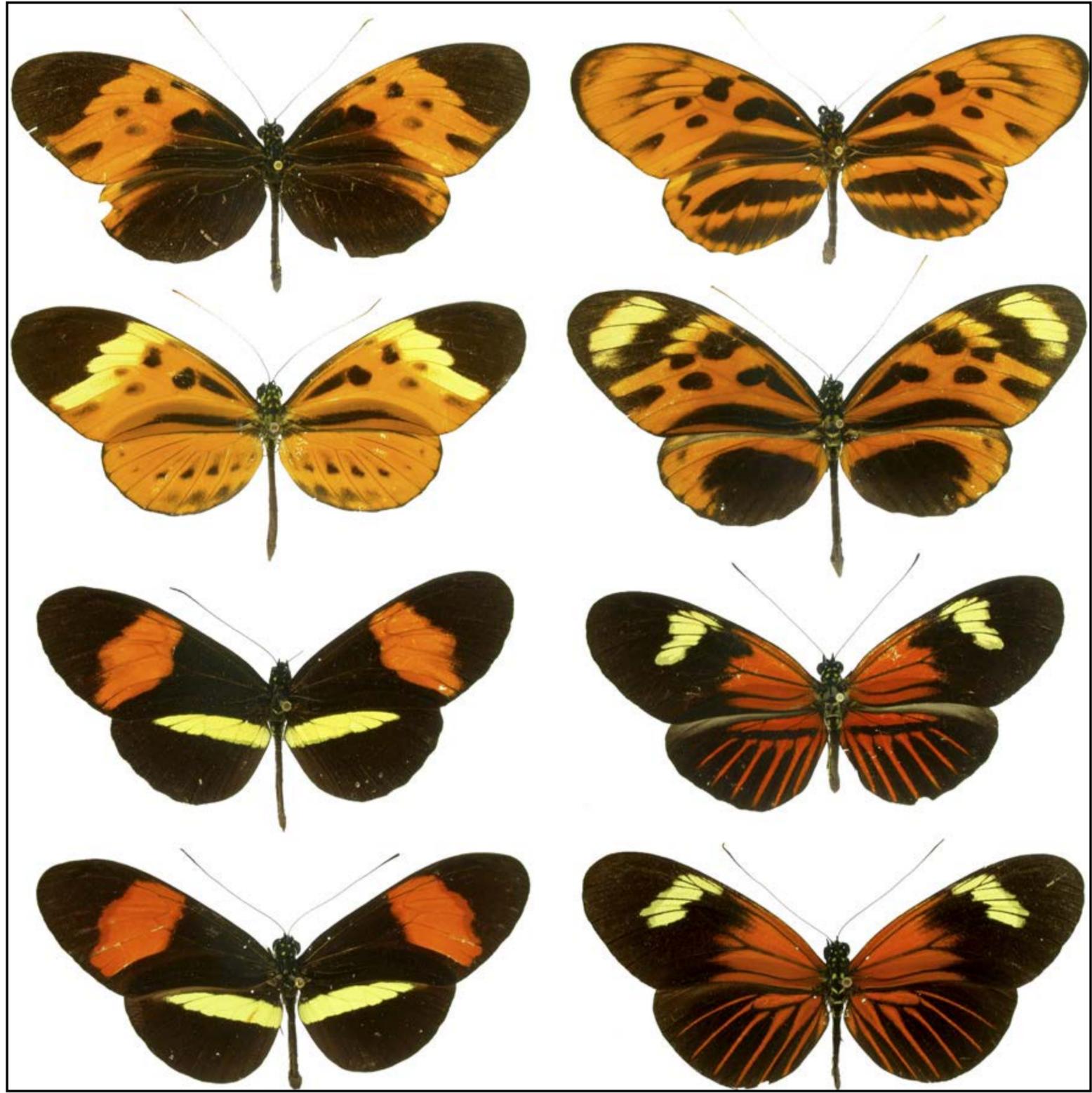
Copyright Brian Freiermuth, insituexsitu.com



Como escapar de um predador

Aposematismo





Como escapar de um predador

Mimetismo



Mimetismo

```
graph TD; A[Mimetismo] --> B[Batesiano]; A --> C[Mulleriano];
```

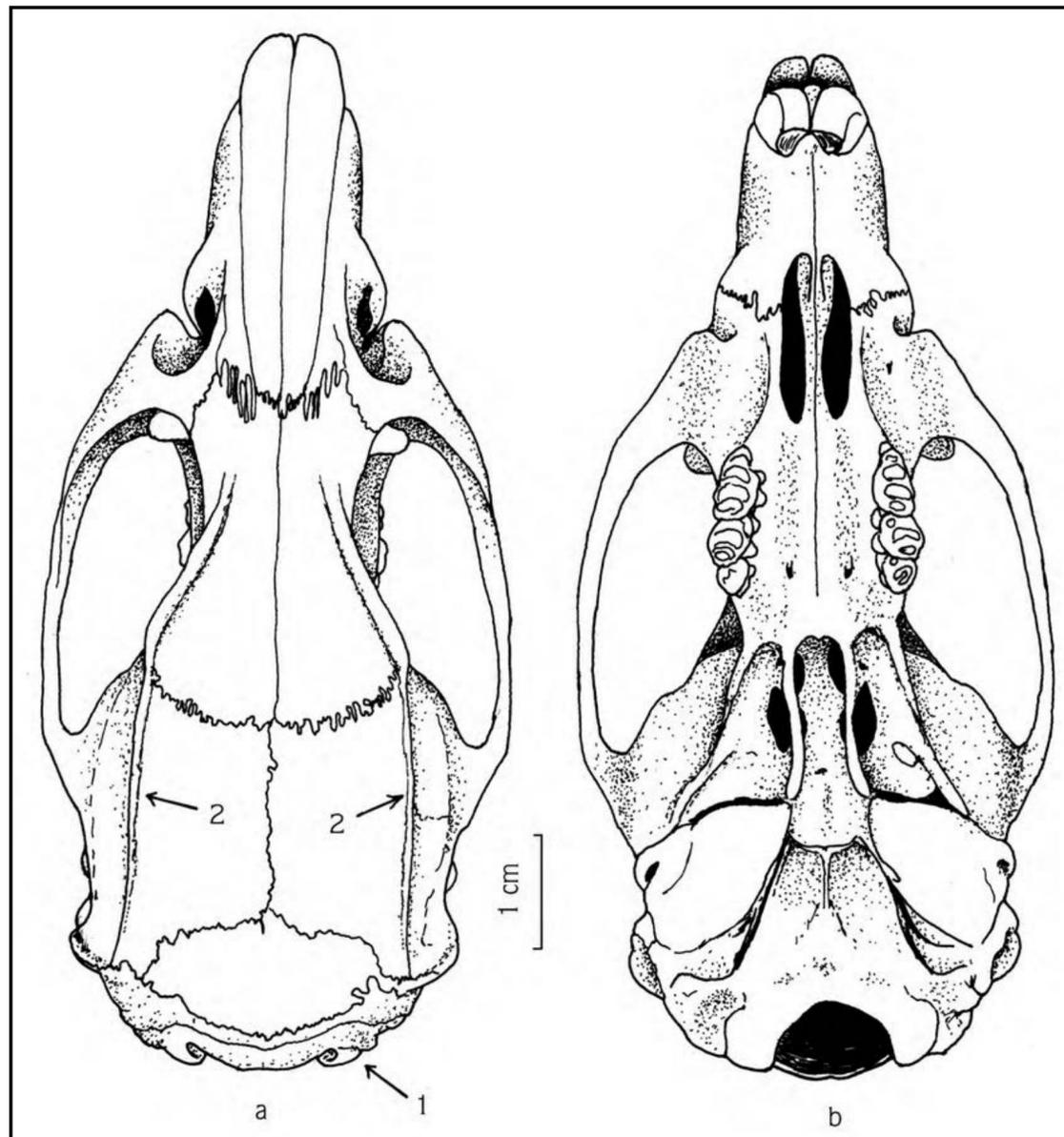
The diagram illustrates the classification of mimicry. At the top, the word 'Mimetismo' is written in white on a black rectangular background. Two red arrows originate from the bottom center of this box and point downwards and outwards to two separate boxes below. The left box is olive green and contains the word 'Batesiano' in black. The right box is light blue and contains the word 'Mulleriano' in black.

Batesiano

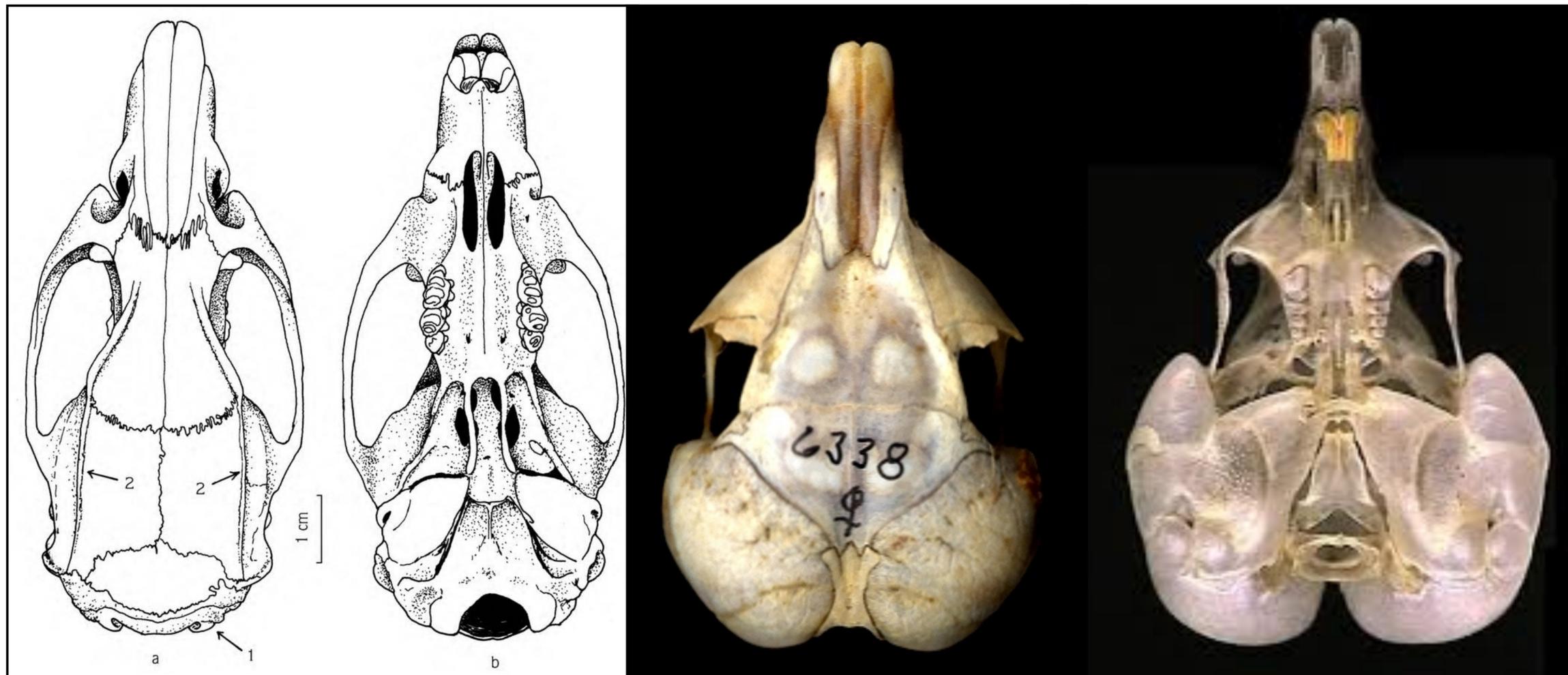
Mulleriano

Como escapar de um predador

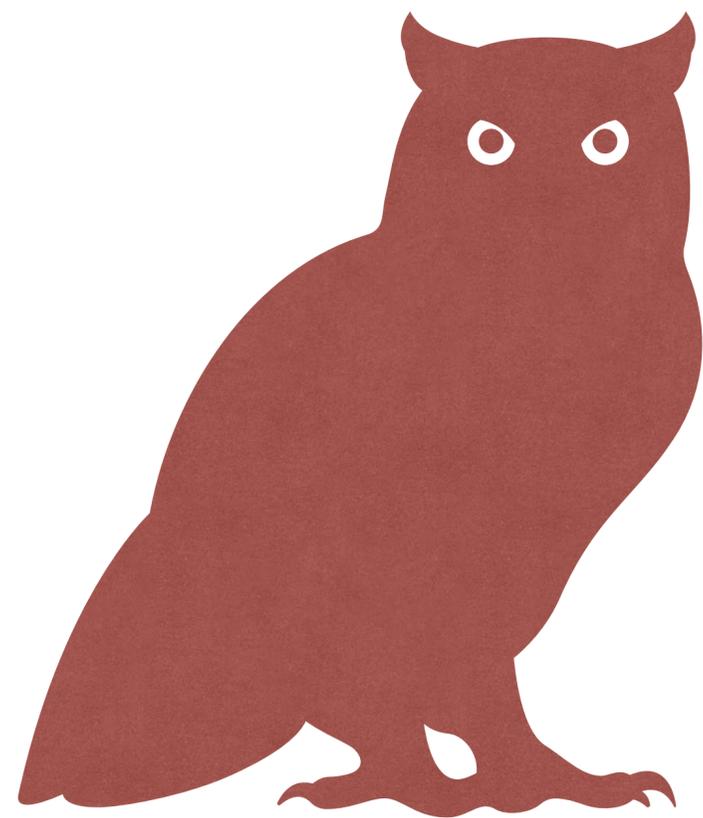
Como escapar de um predador



Como escapar de um predador



Como escapar de um predador

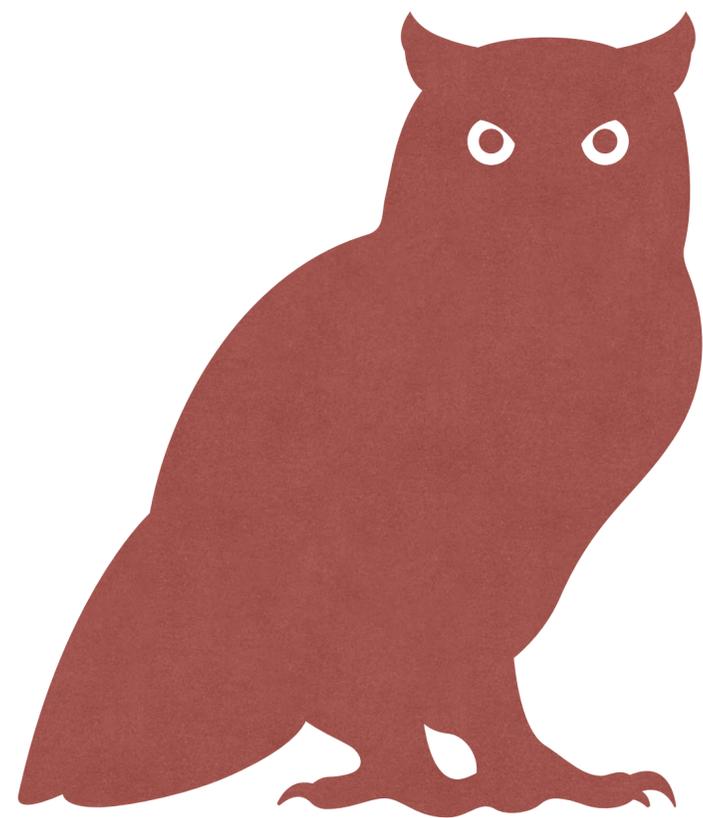


Maior acuidade auditiva!



Webster, 1962

Como escapar de um predador



Maior acuidade auditiva!



Webster, 1962

Como escapar de um predador



Hlgham et al., 2017



Endless forms most beautiful....



Interações antagonistas

Interações antagonistas

Quem são?
Onde vivem?
O que comem?





Predação



Parasitismo



Parasitismo

Photograph by Darlyne A. Murawski



Herbivoria



Parasitoidismo

Interações antagonistas



Interações antagonistas



Resultado

intimidade

Interações antagonistas

Resultado



intimidade

Interações antagonistas

Morte



Dano



intimidade

Interações antagonistas

Morte

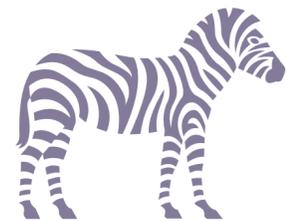
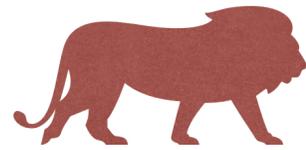


Dano



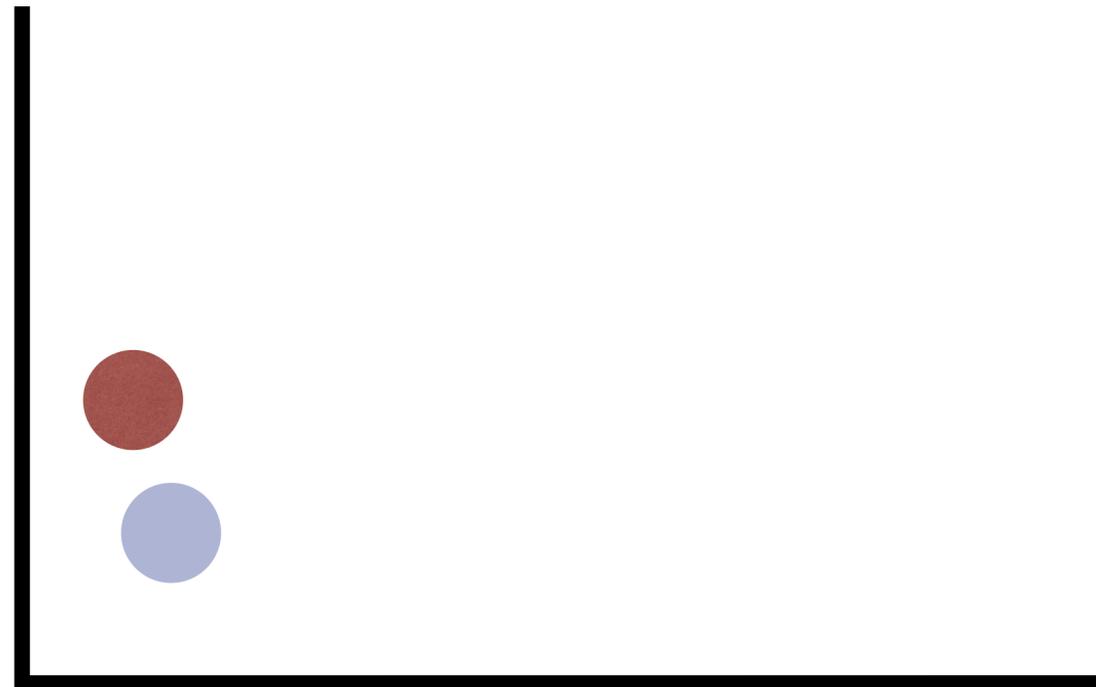
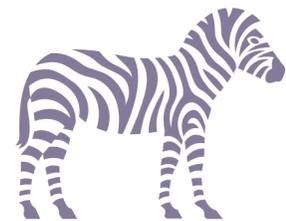
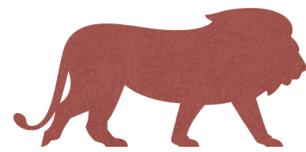
intimidade

Escalonamento



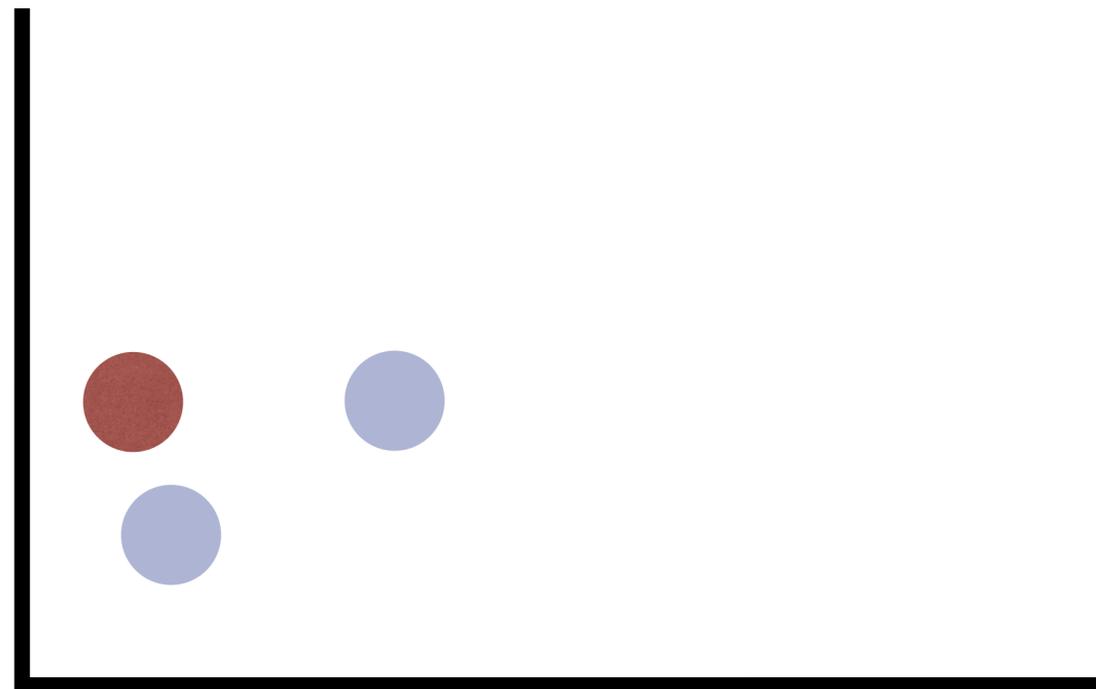
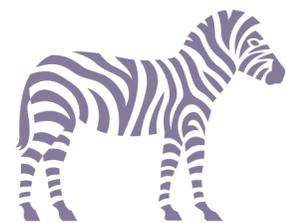
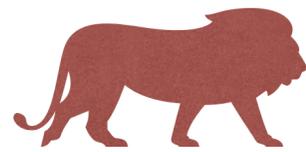
tempo

Escalonamento



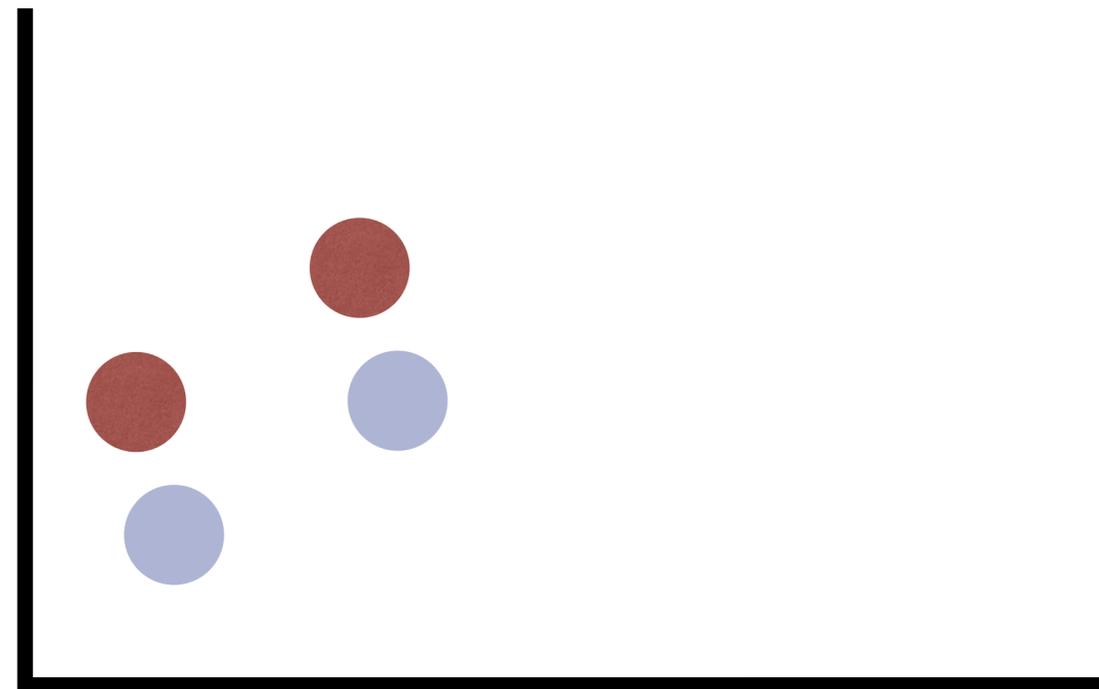
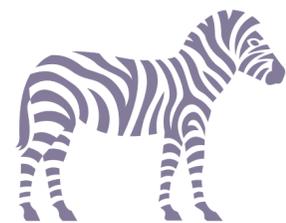
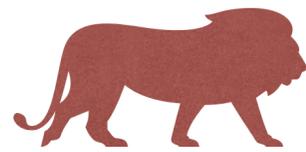
tempo

Escalonamento



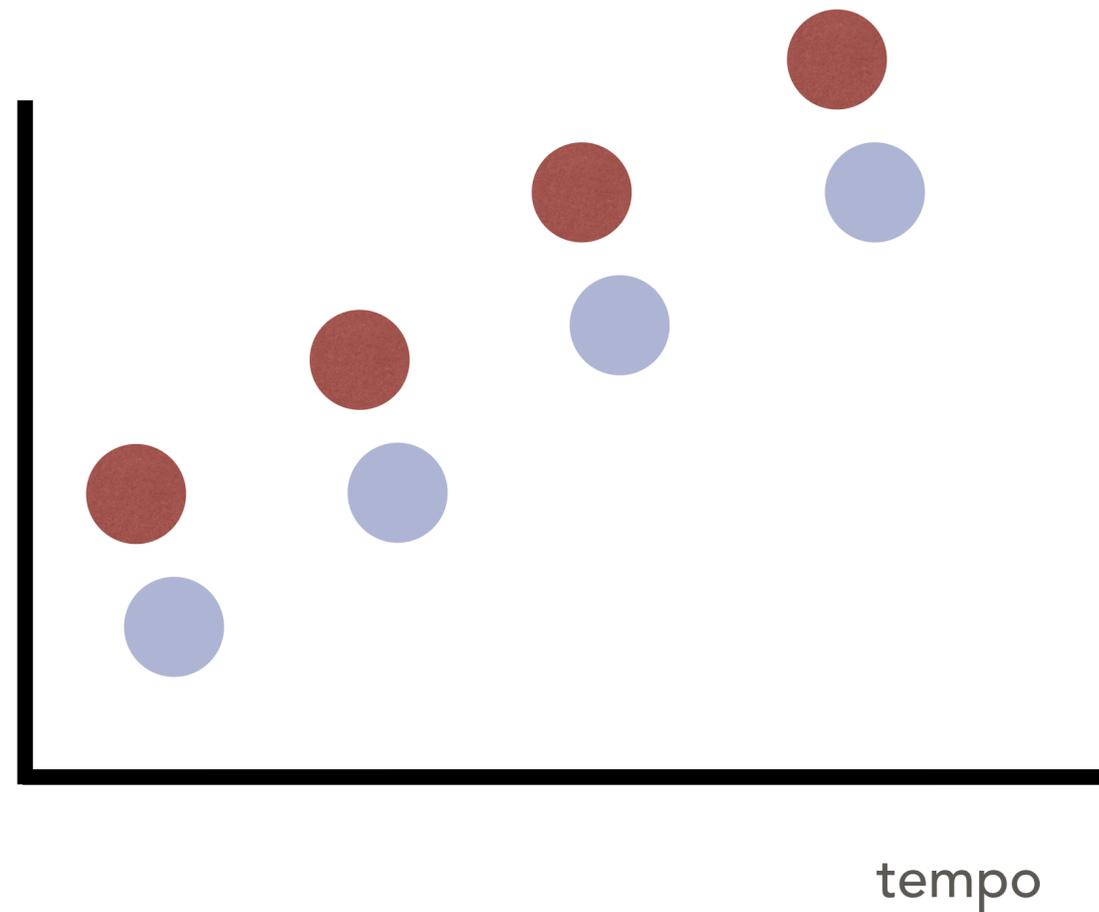
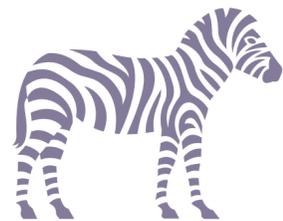
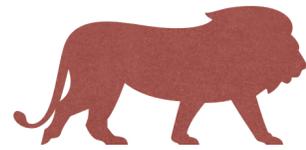
tempo

Escalonamento



tempo

Escalonamento

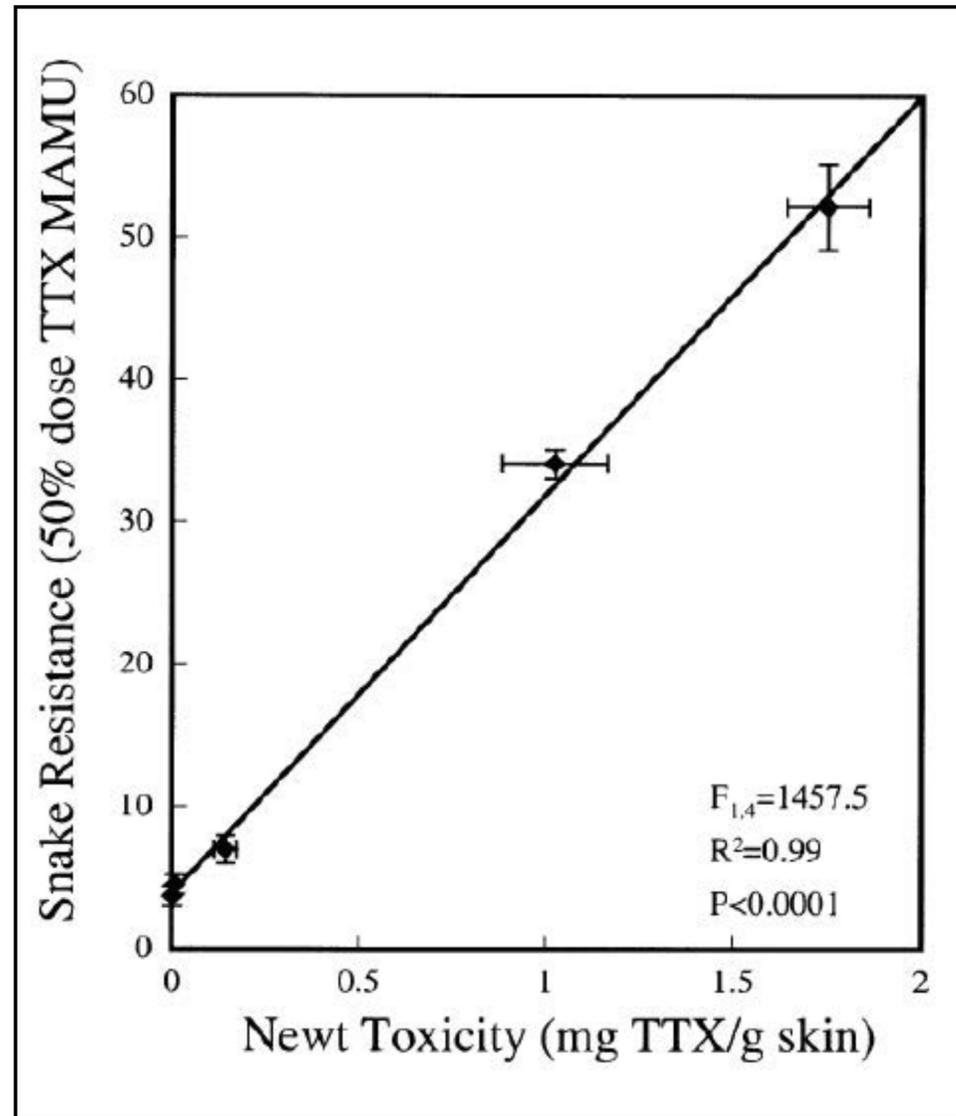


**Corrida
armamentista**

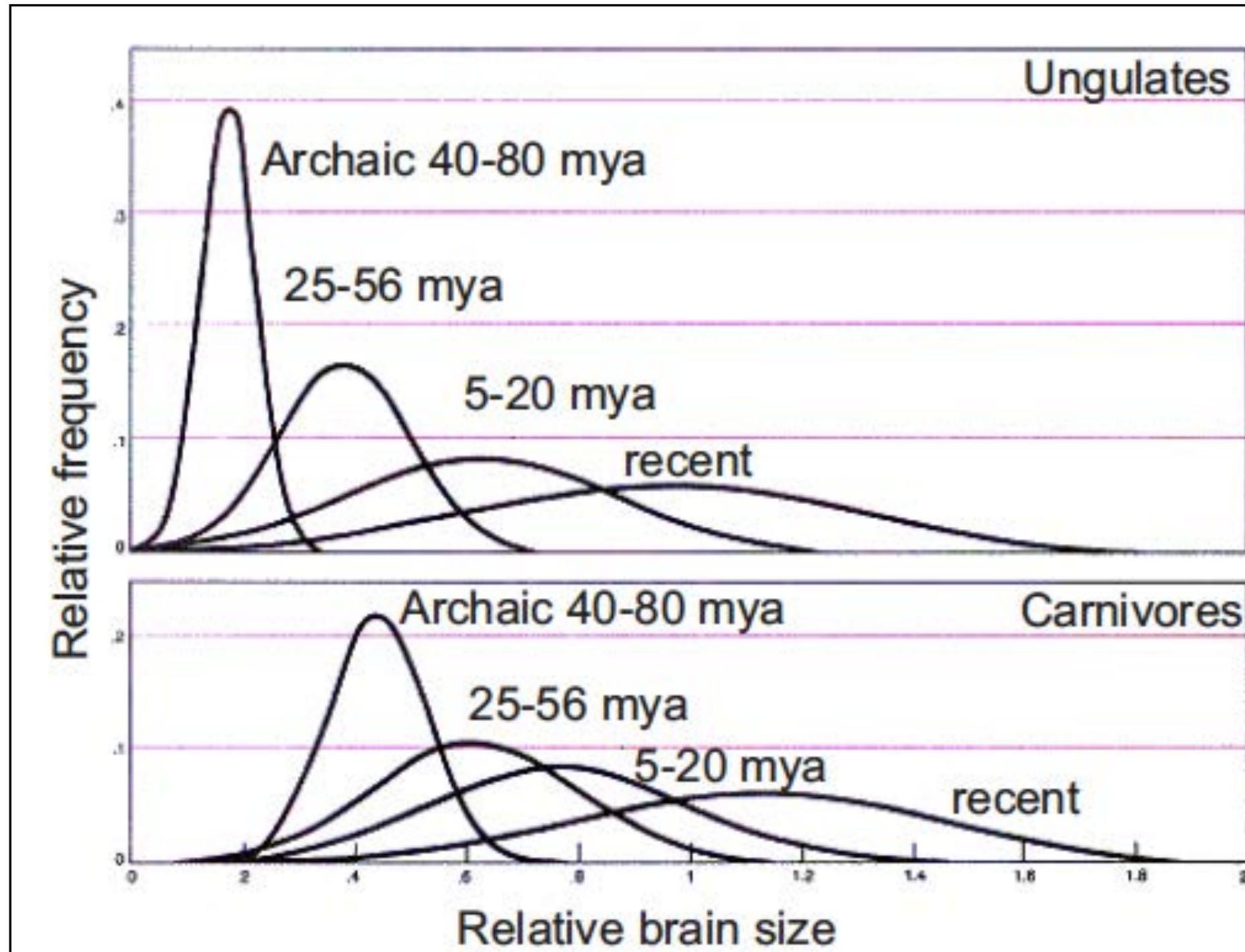




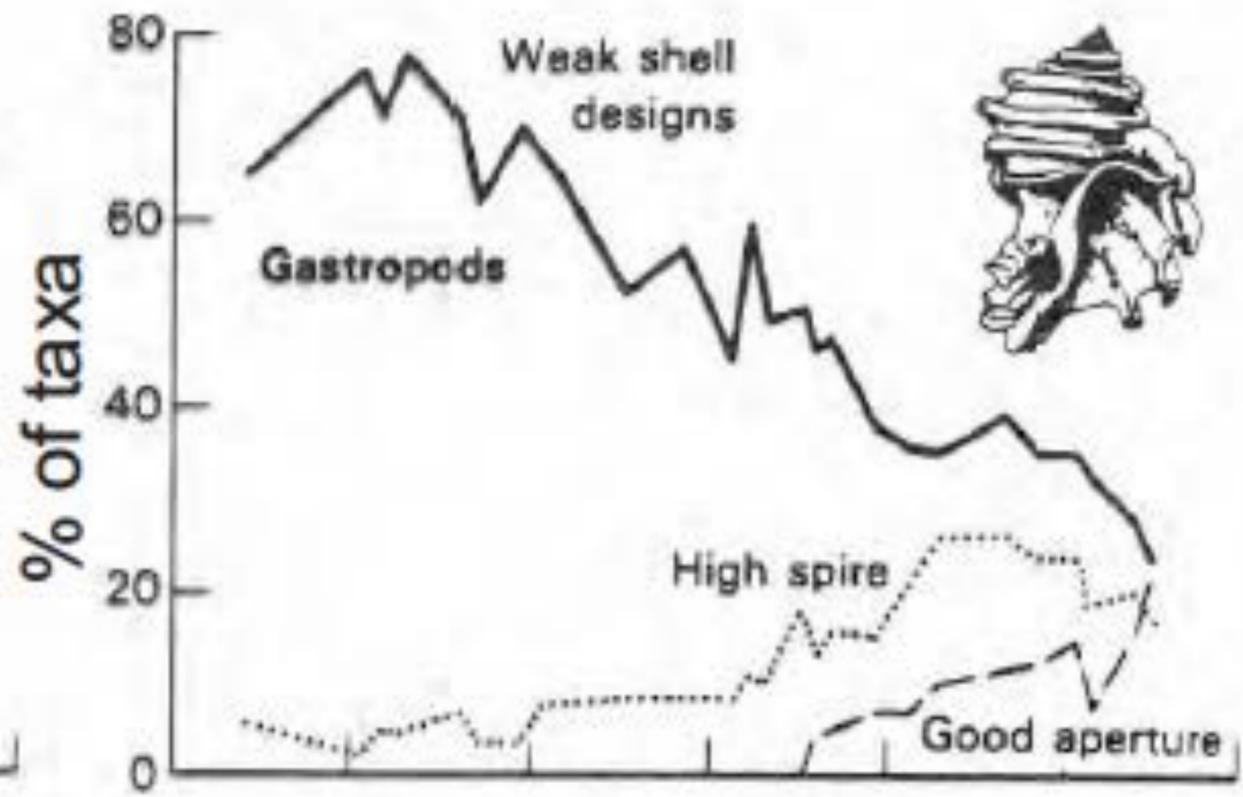
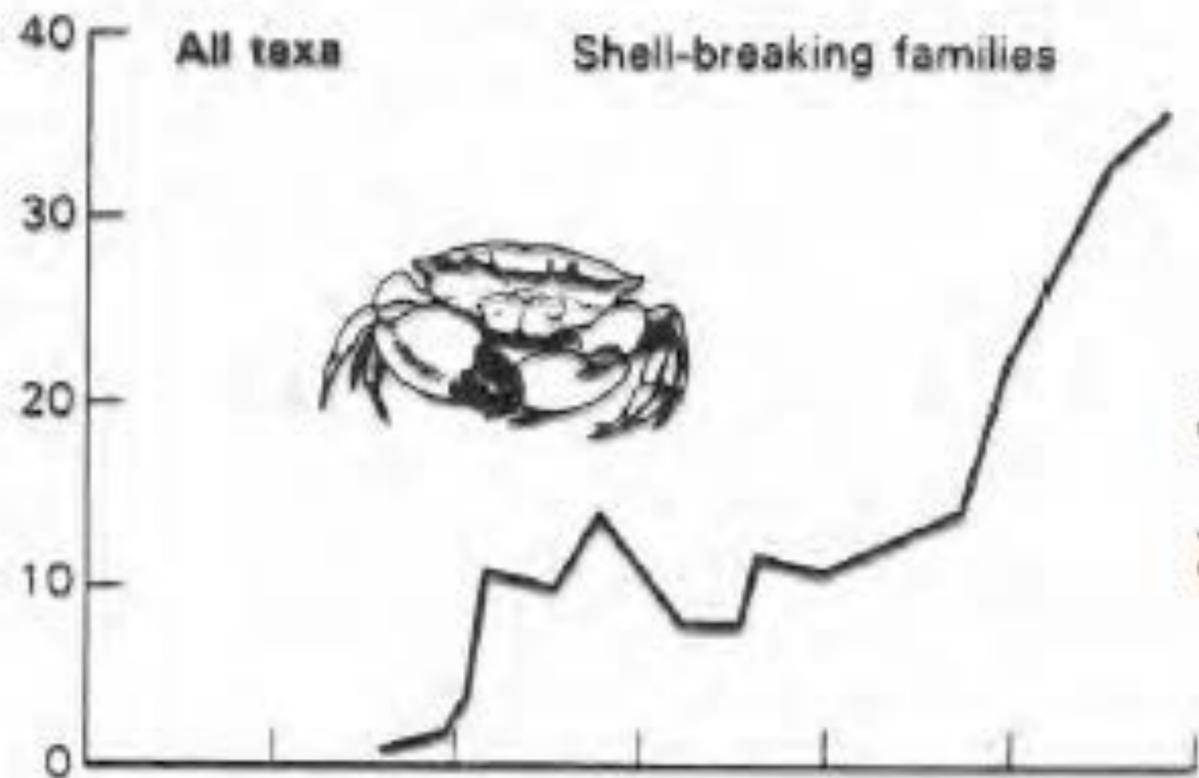
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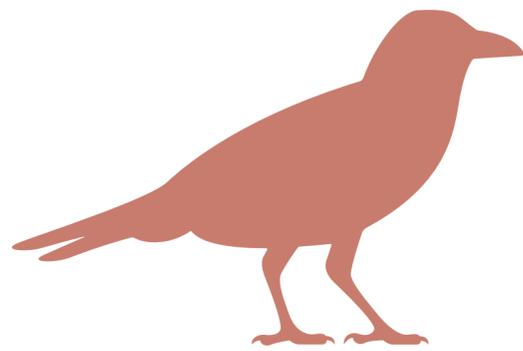




Number of shell-breaking families



Flutuações

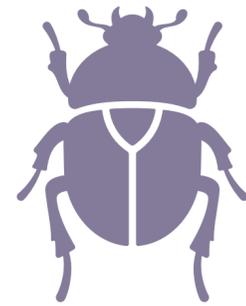
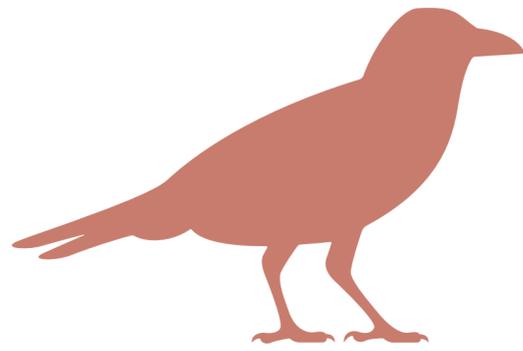


Fitness

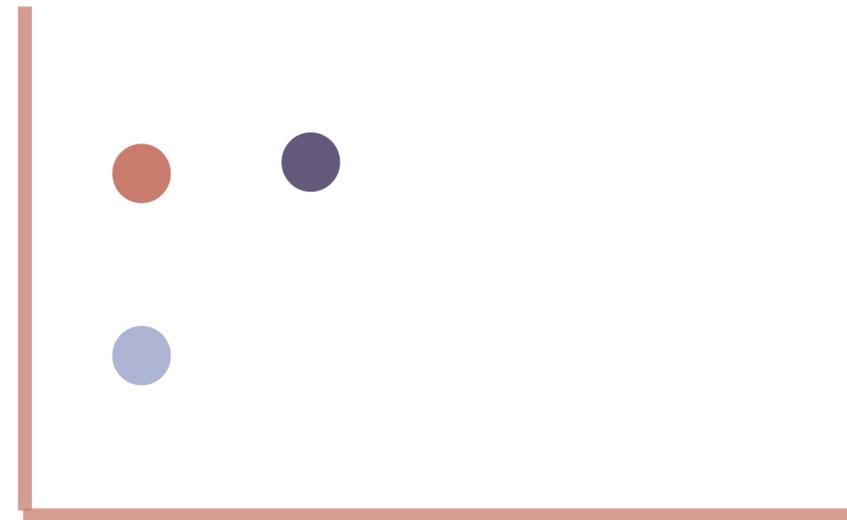


Tempo

Flutuações

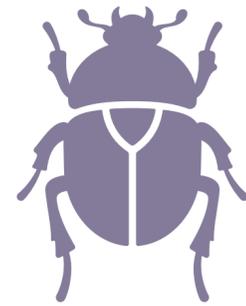
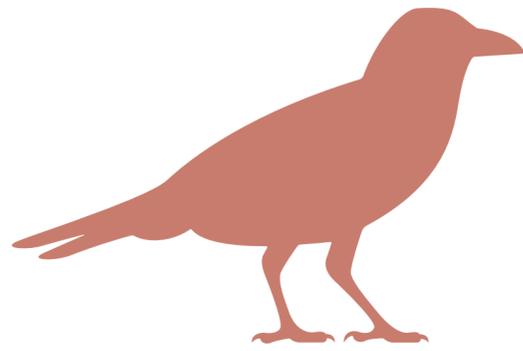


Fitness

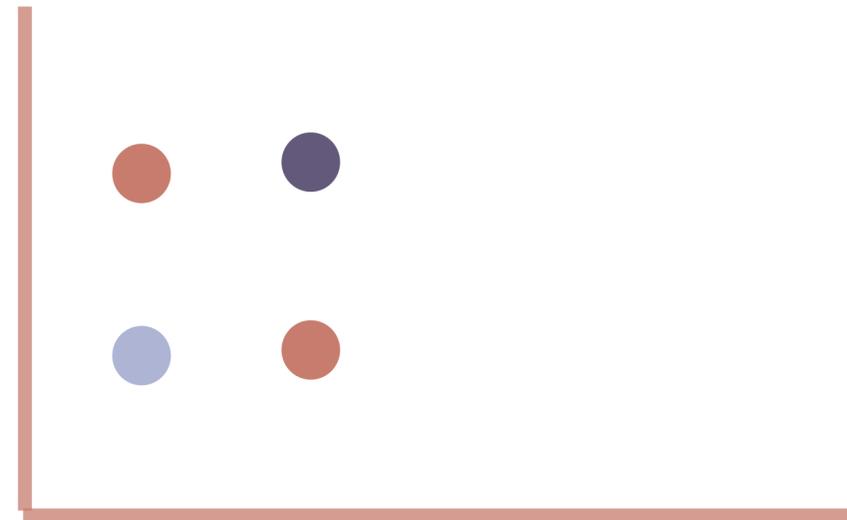


Tempo

Flutuações

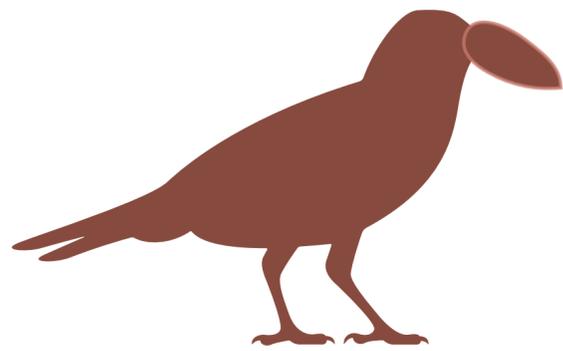


Fitness

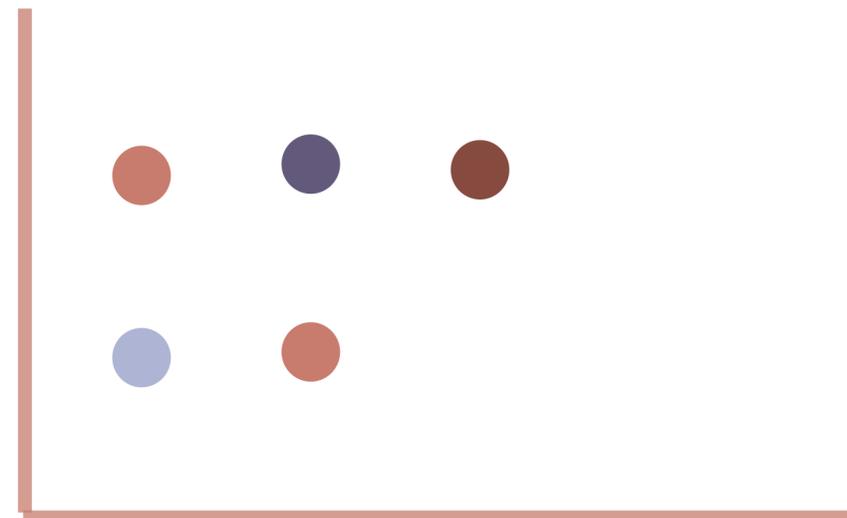


Tempo

Flutuações

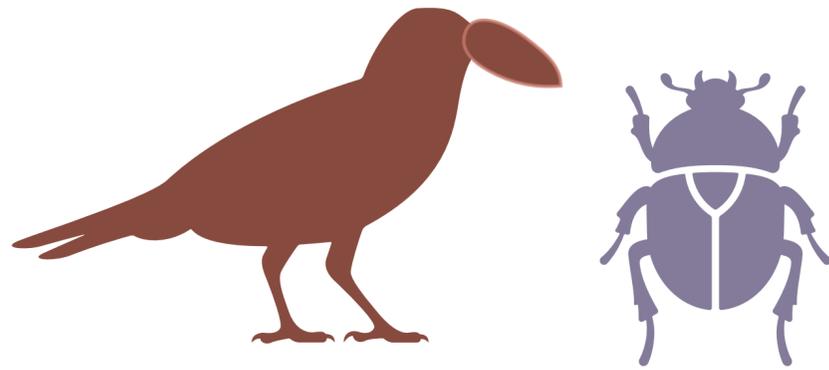


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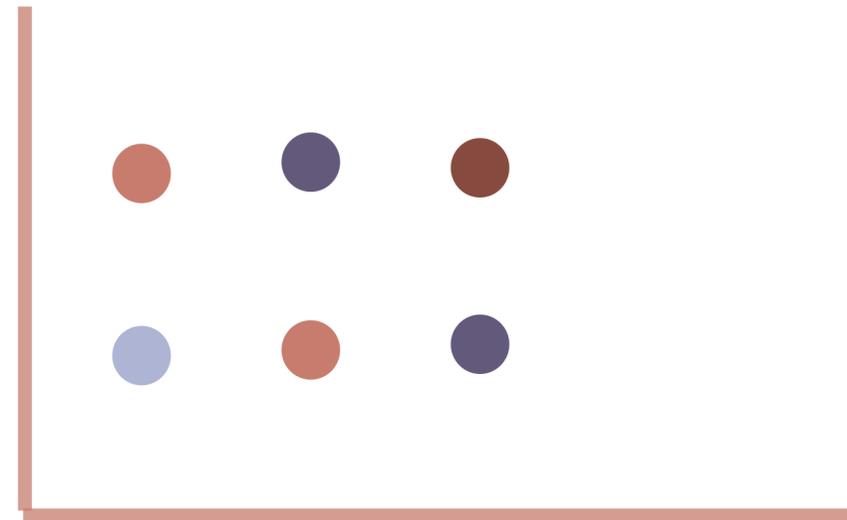


Tempo

Flutuações

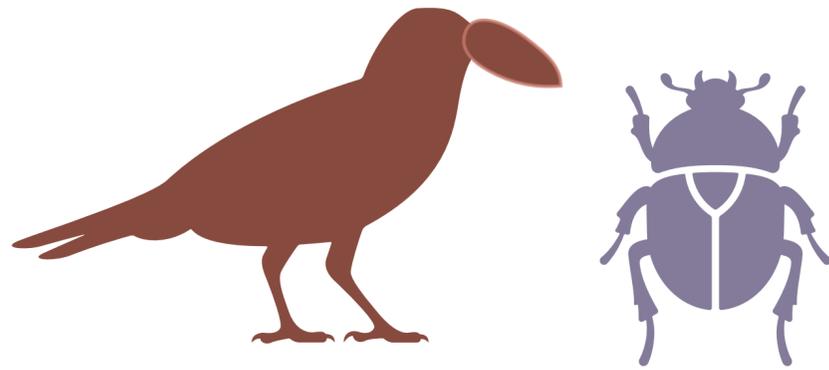


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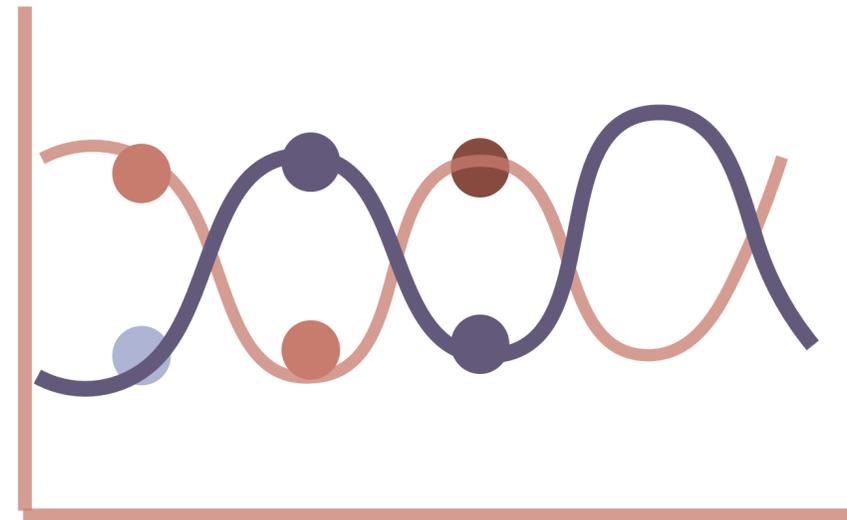


Tempo

Flutuações

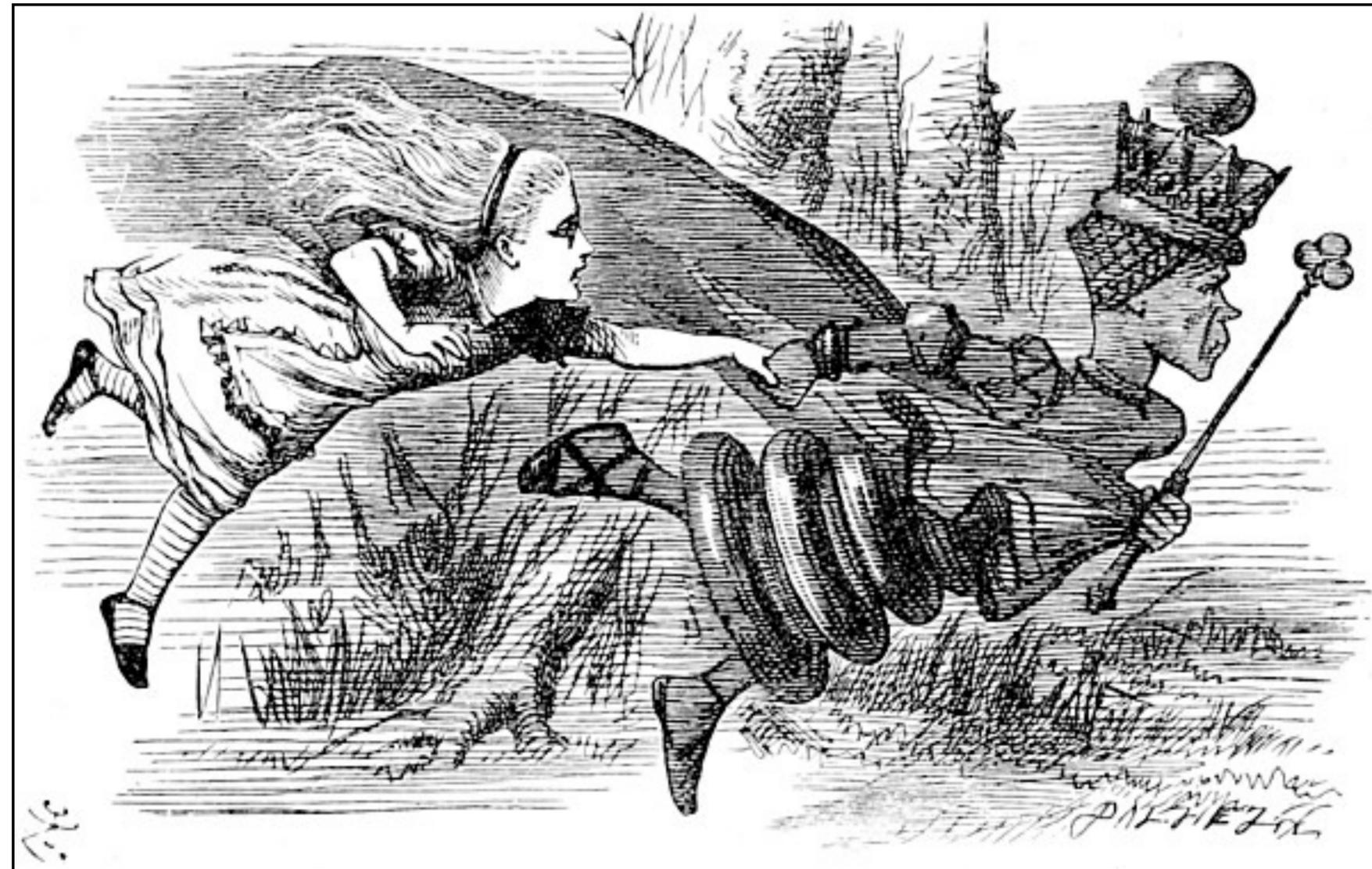


Fitness



Tempo

“Well, in our country,” said Alice, still panting a little, “you'd generally get to somewhere else- if you run very fast for a long time, as we've been doing.”
“A slow sort of county!” said the Queen. “Now, here, you see, it takes all the running you can do, to keep in the same place.”

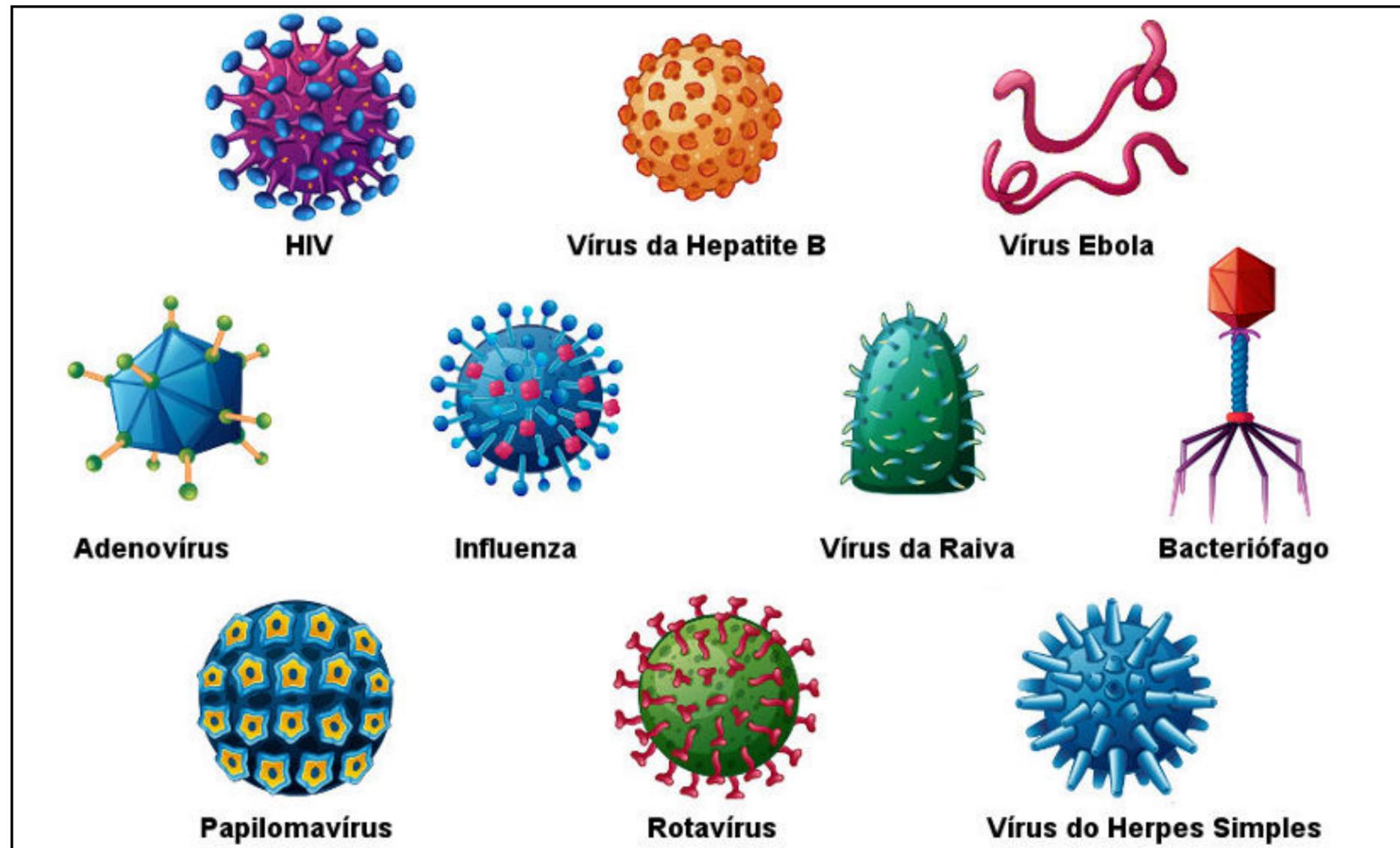


A hipótese da Rainha Vermelha

Red Queen hypothesis, named in honor of the colorful character in Lewis Carroll's *Through the Looking-Glass* who must run constantly to stay in the same place. According to this hypothesis, all species are in an evolutionary arms race with other species, such as pathogens that are evolving rapidly to defeat their host's defensive systems. This creates a shifting adaptive landscape for the host.



Interações parasita - hospedeiro



Interações antagonistas

Morte



Dano

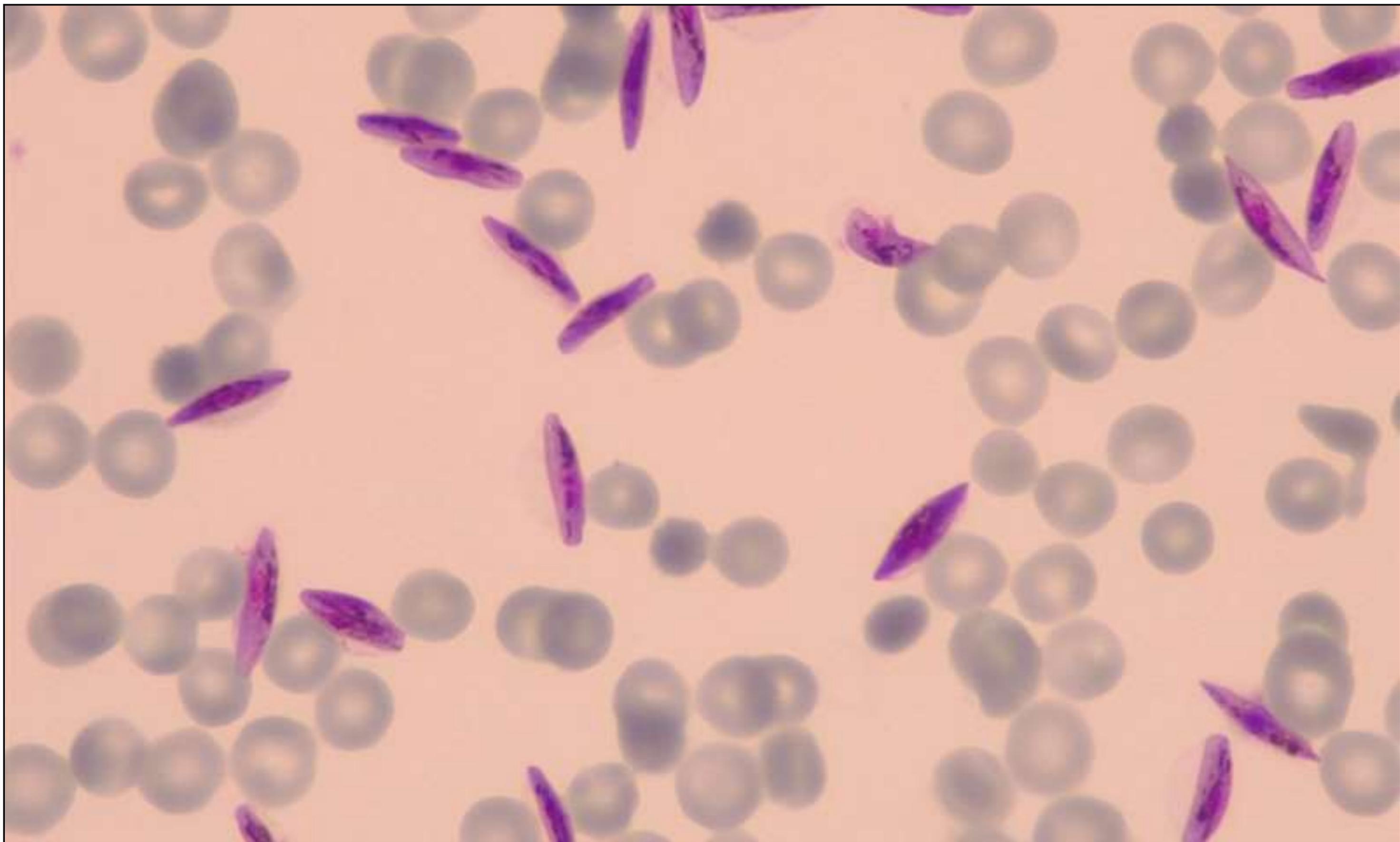


intimidade

Interações parasita - hospedeiro

Parasitas são predadores que comem suas vítimas em unidades de menos de um.

E.O. Wilson









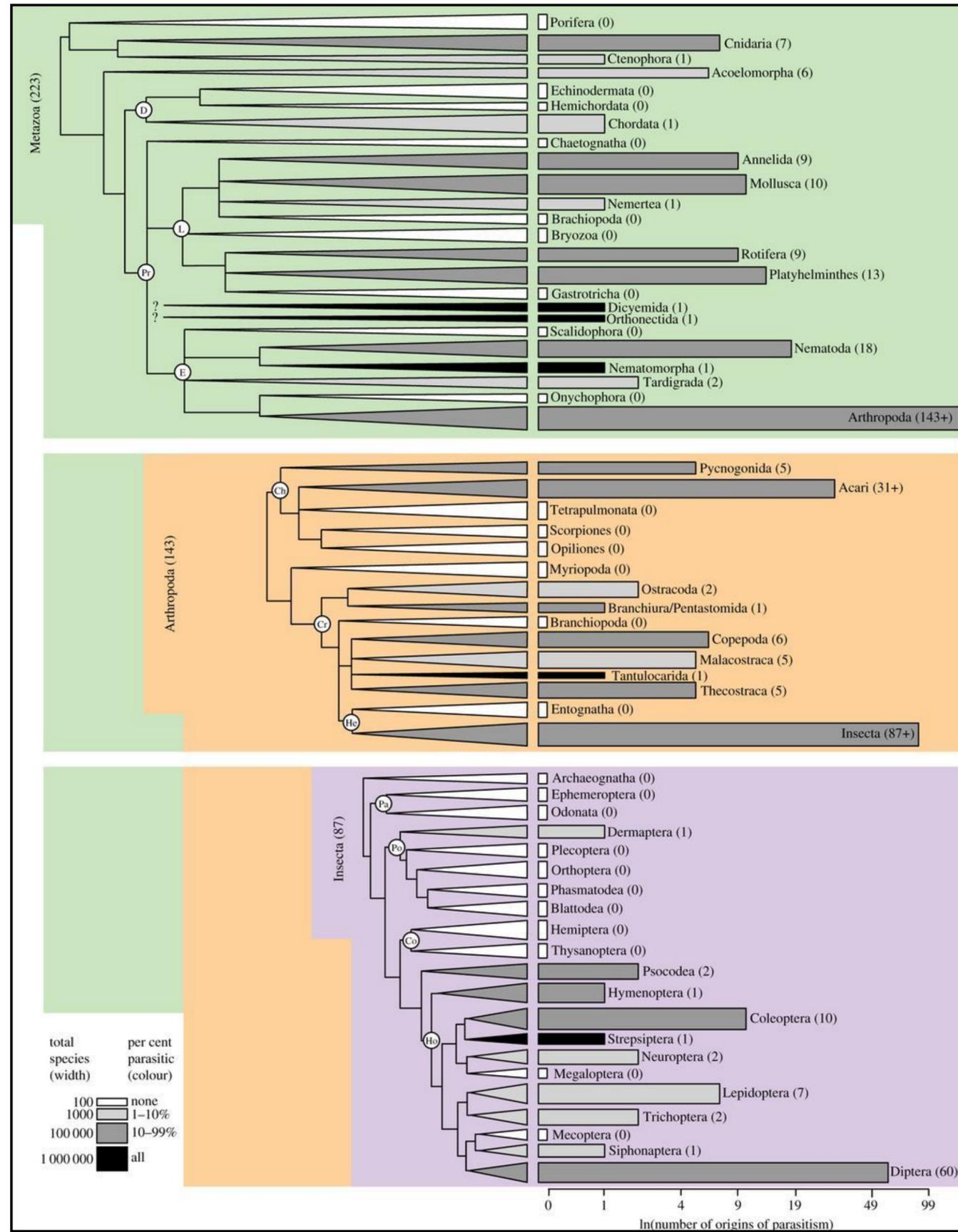


Interações parasita - hospedeiro

Cerca de ***METADE*** dos animais
tem modo de vida parasita!!!

Interações parasita - hospedeiro

Surgiu pelo menos **223** vezes na história dos animais!



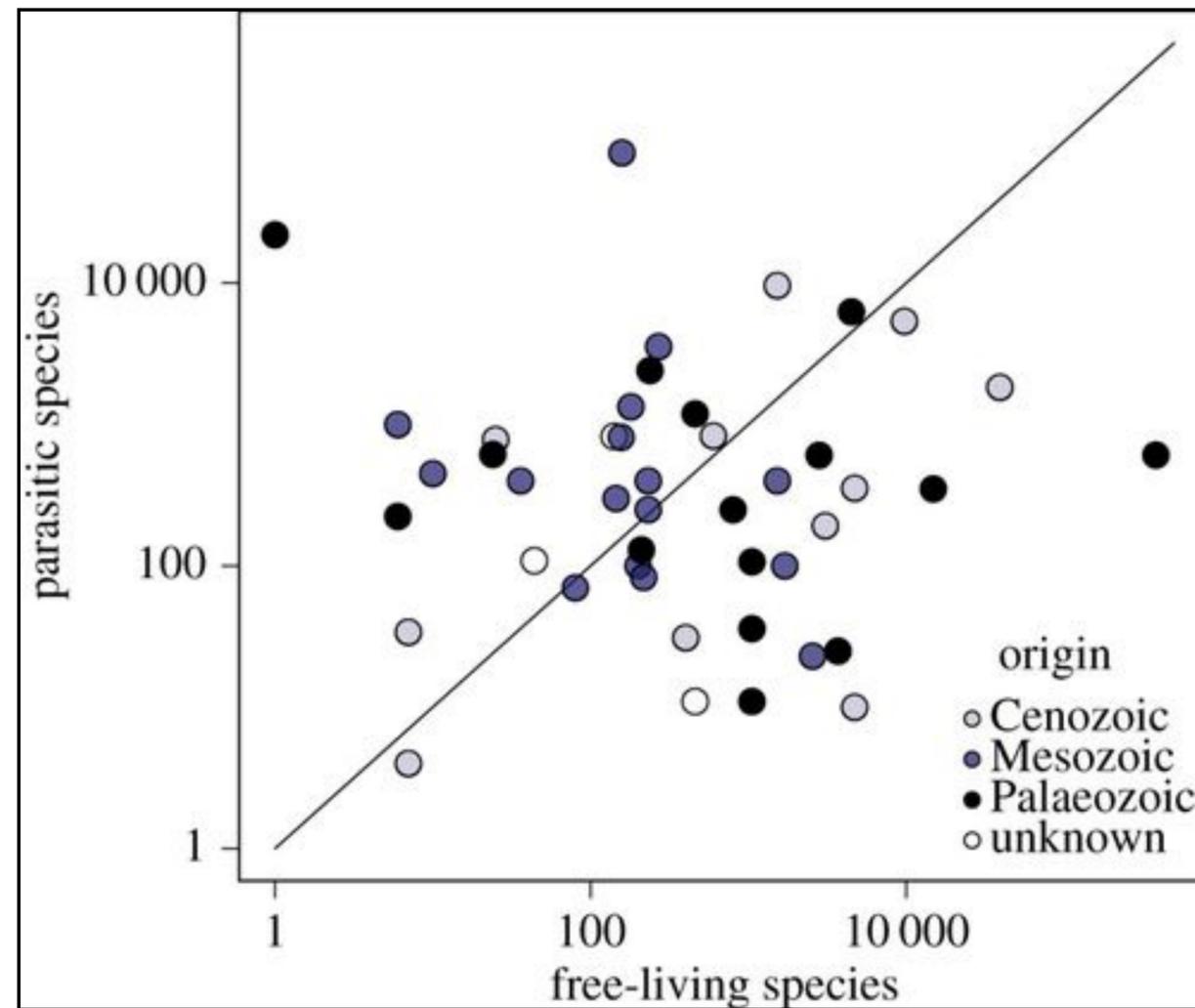
Interações parasita - hospedeiro

Once you go **parasite** you never
go back!

Interações parasita - hospedeiro

Or **Beco evolutivo?** ever
go back.

Interações parasita - hospedeiro

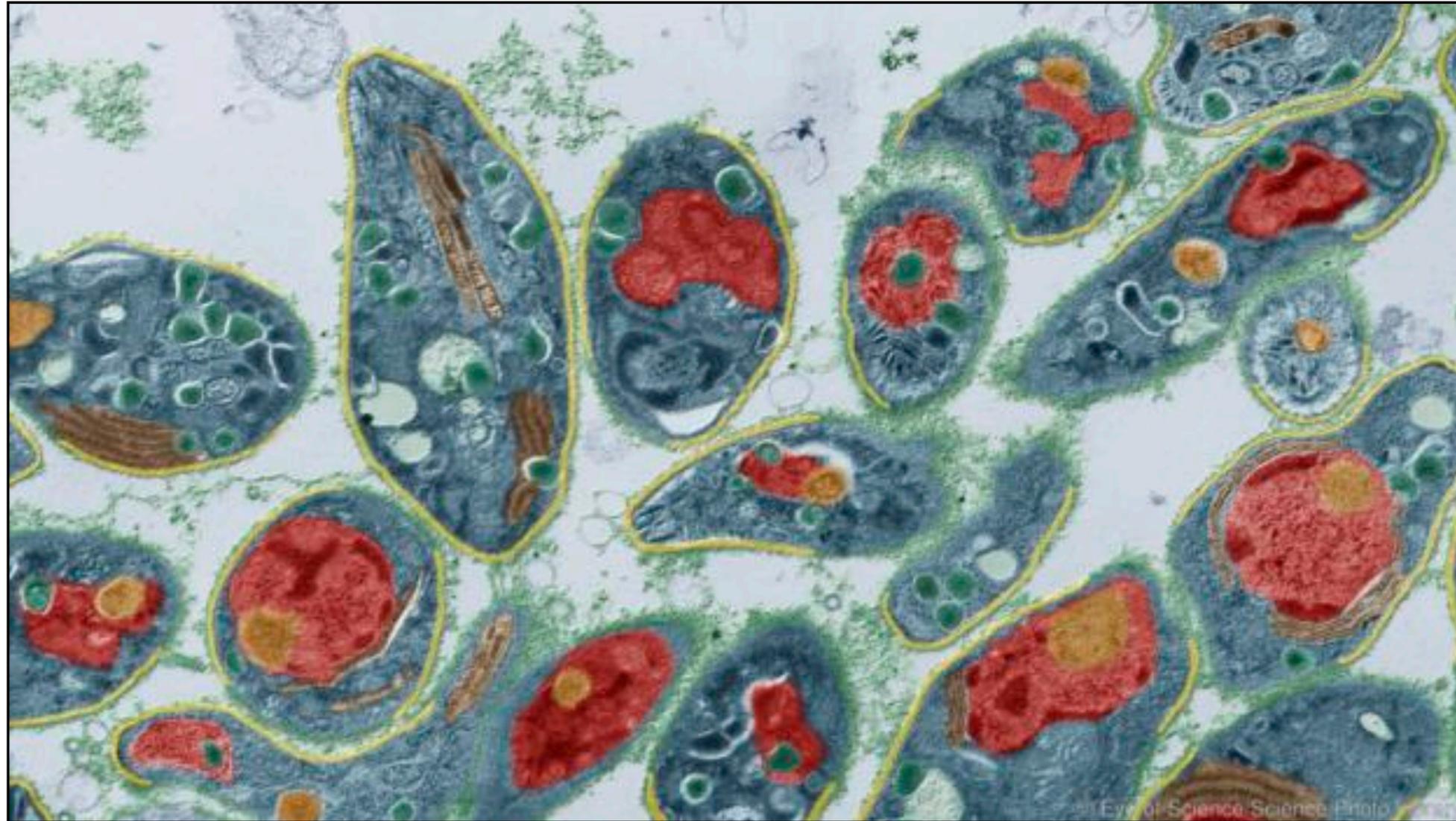


Interações parasita - hospedeiro

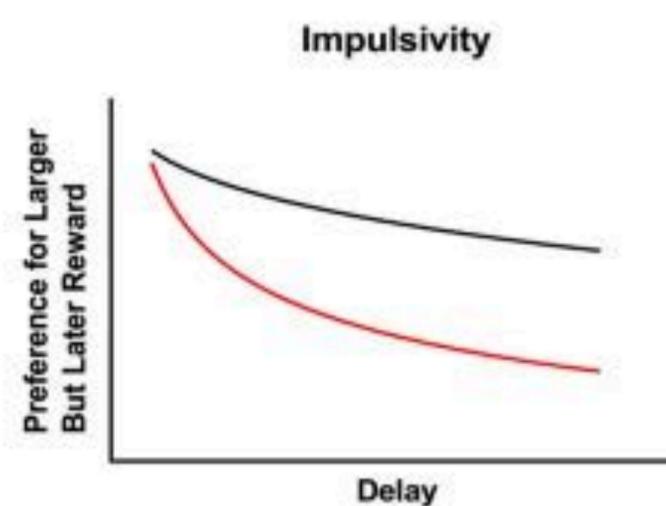
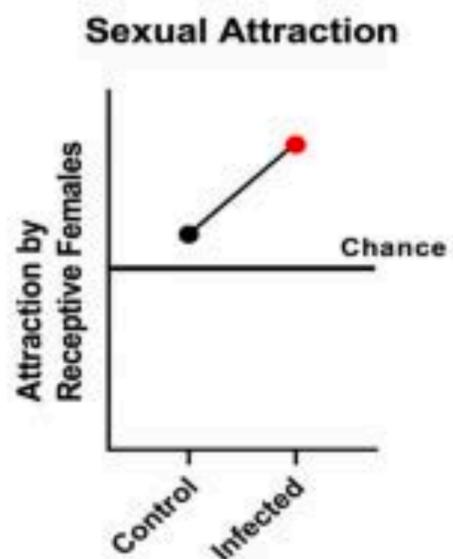
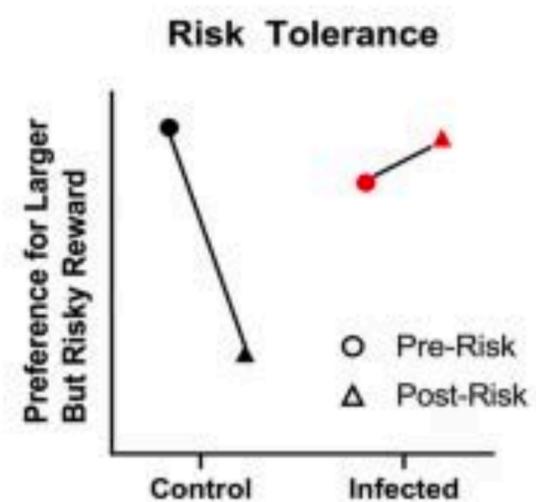
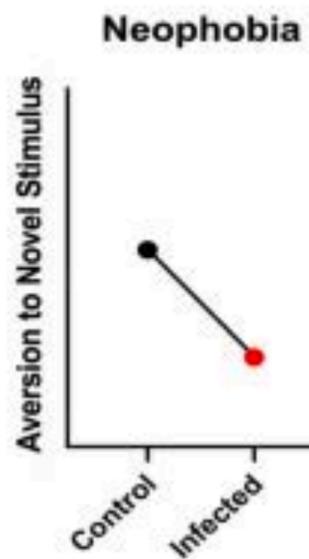
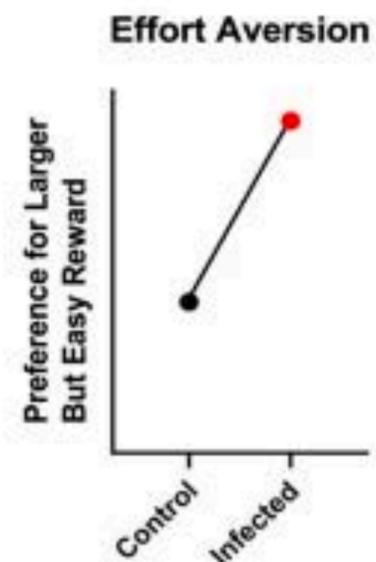
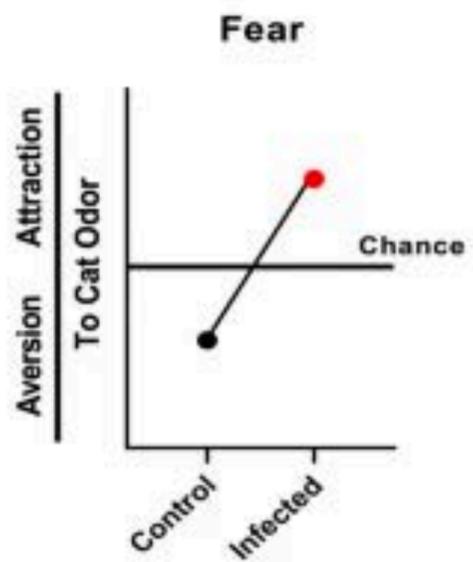
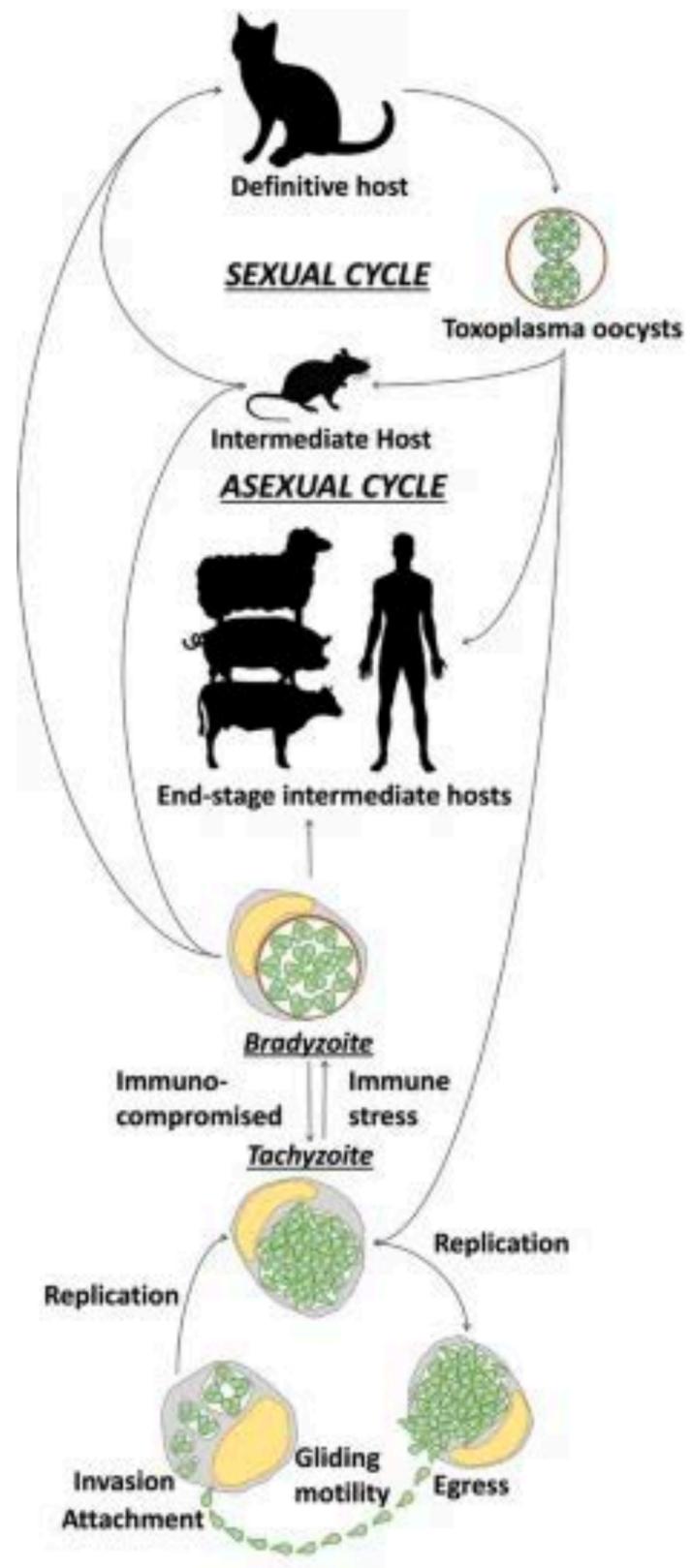


Paragordius tricuspidatus

Interações parasita - hospedeiro



Toxoplasma gondii



communications biology

ARTICLE

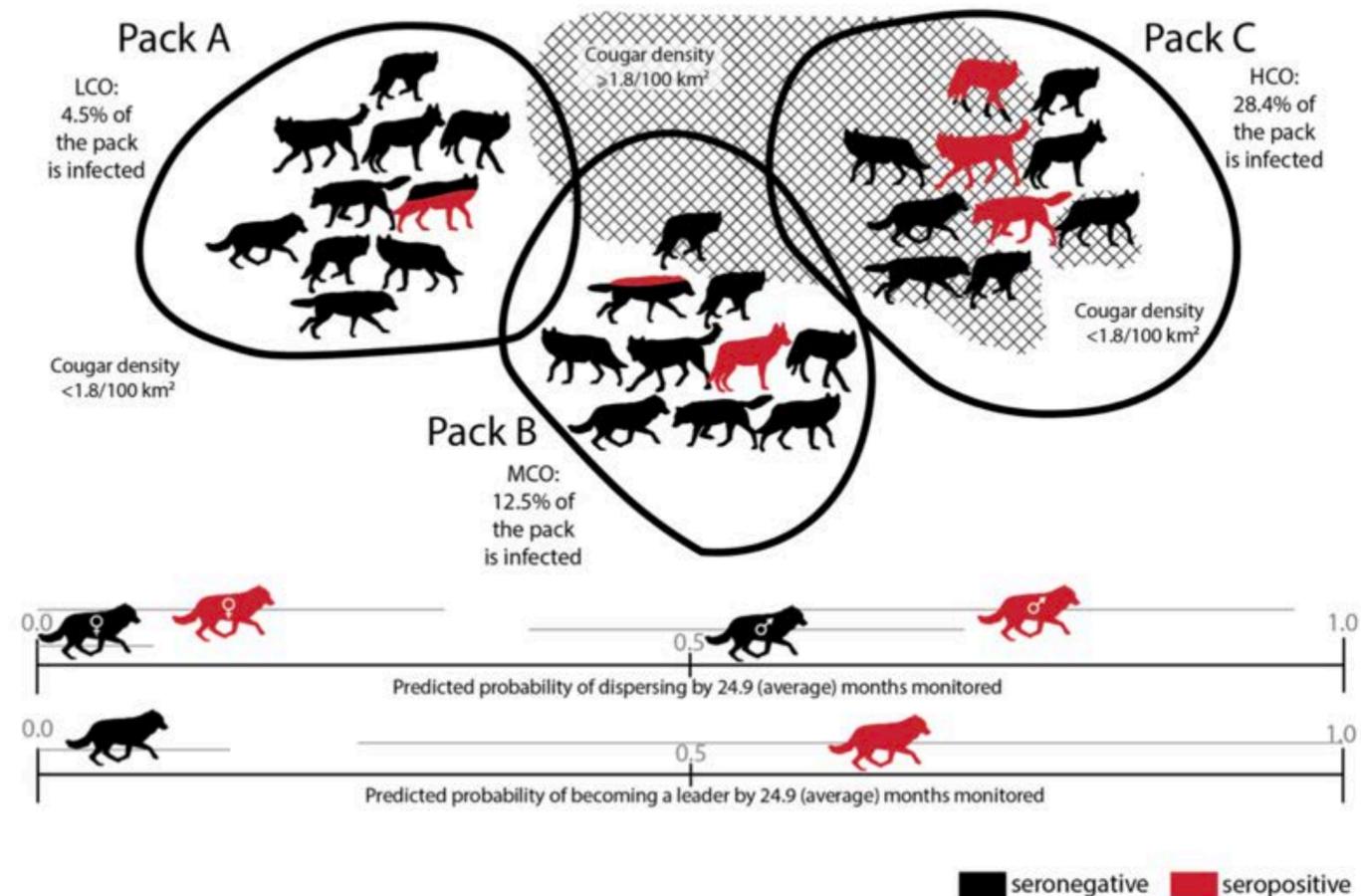
<https://doi.org/10.1038/s42003-022-04122-0>

OPEN

 Check for updates

Parasitic infection increases risk-taking in a social, intermediate host carnivore

Connor J. Meyer ^{1,2,3}✉, Kira A. Cassidy^{1,3}, Erin E. Stahler ¹, Ellen E. Brandell¹, Colby B. Anton¹, Daniel R. Stahler¹ & Douglas W. Smith¹



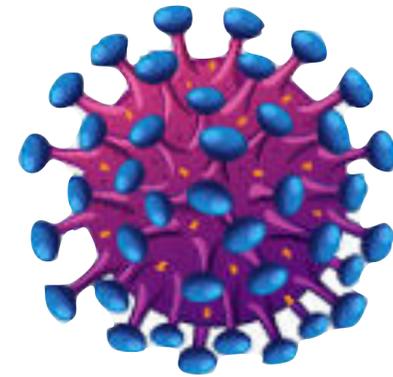
Interações parasita - hospedeiro

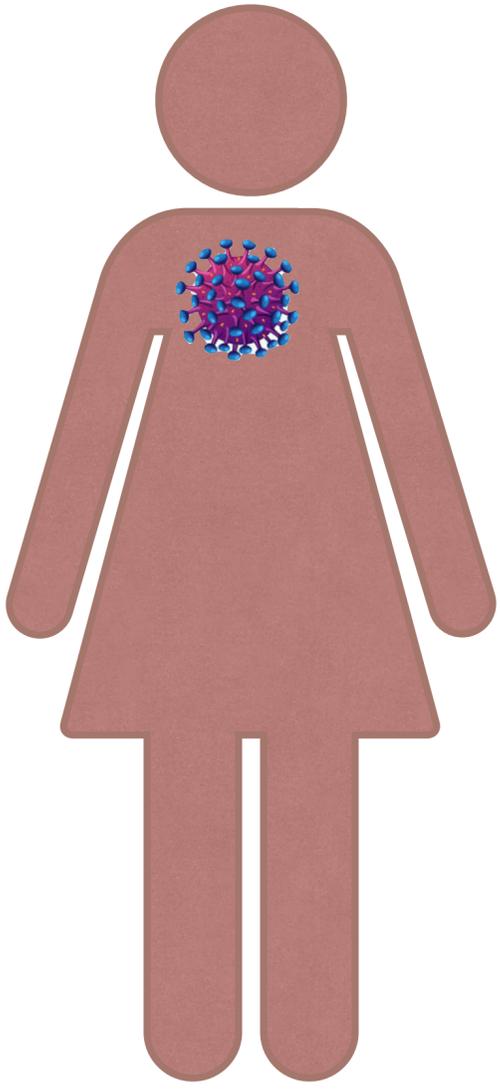


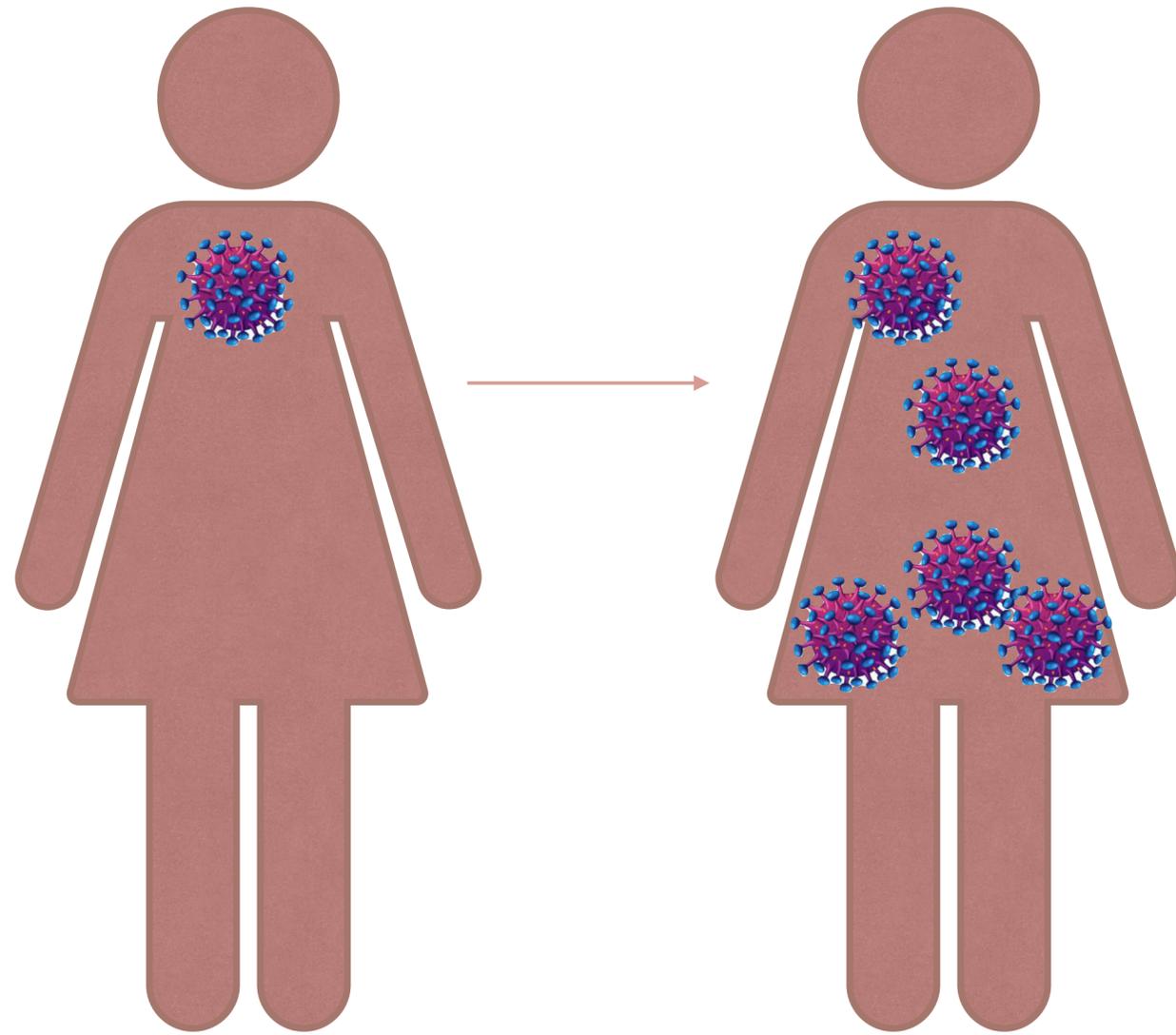
Hyposoter ebeninus

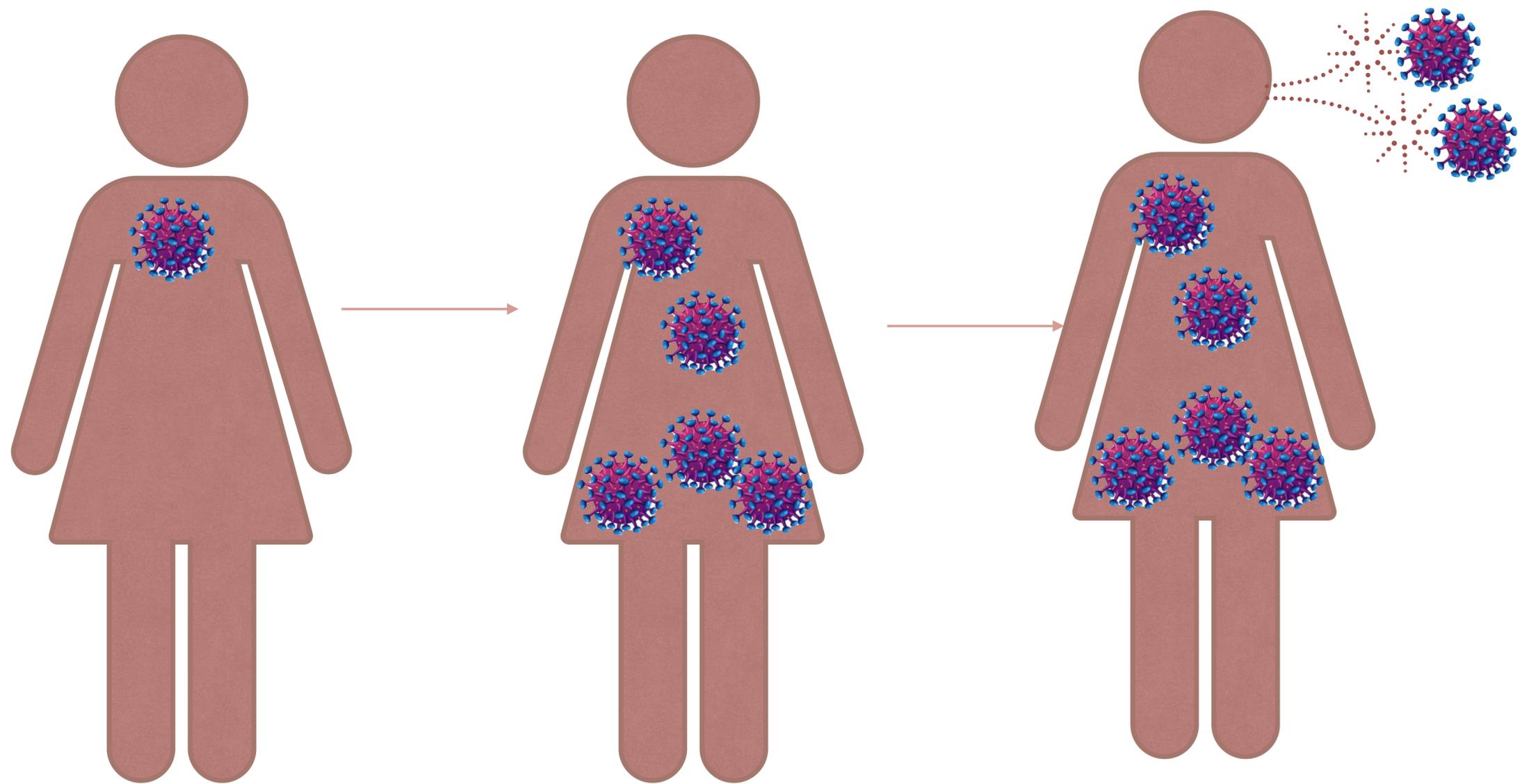
Evolução da virulência

Virulência



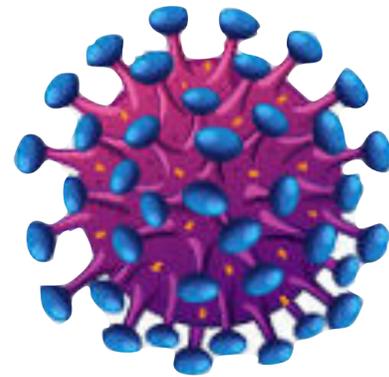






Evolução da virulência

Virulência



Diminuição do fitness do hospedeiro causado por uma infecção

Evolução da virulência

**Por que alguns parasitas prejudicam
seus hospedeiros????**

Evolução da virulência

**Por que alguns parasitas prejudicam
seus hospedeiros????**

**O que pode acabar prejudicando o
próprio parasita**

Evolução da virulência

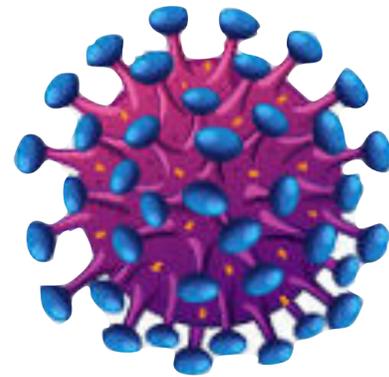
Virulência



Tempo

Evolução da virulência

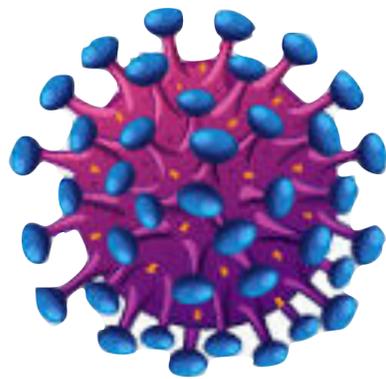
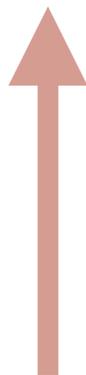
Virulência



Diminuição do fitness do
hospedeiro causado por uma
infecção

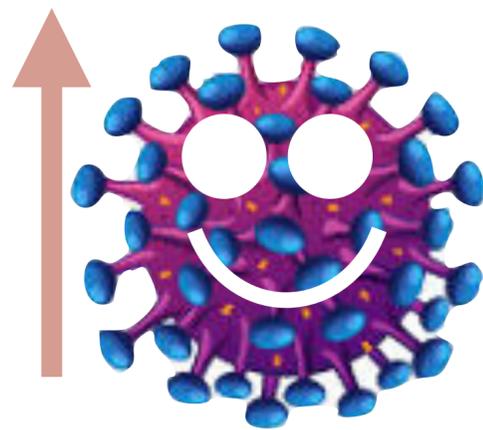
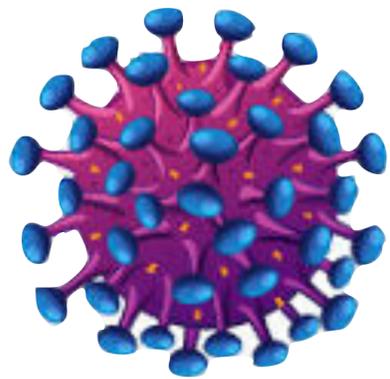
Evolução da virulência

Virulência



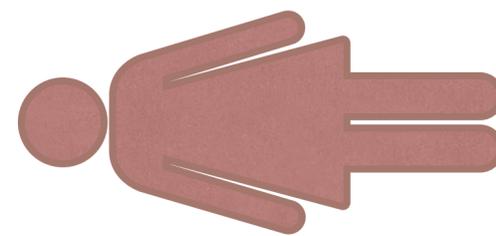
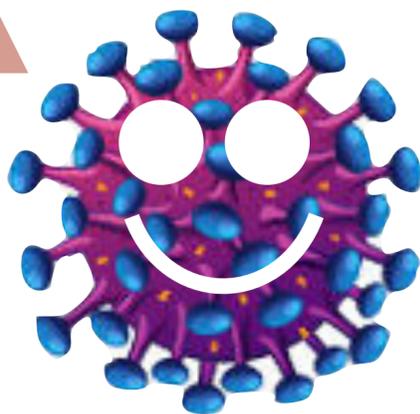
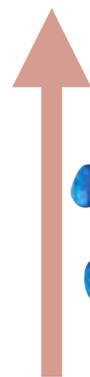
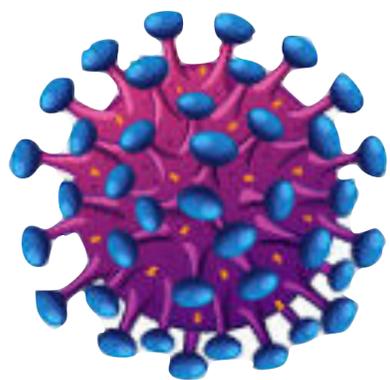
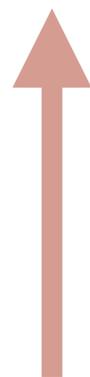
Evolução da virulência

Virulência



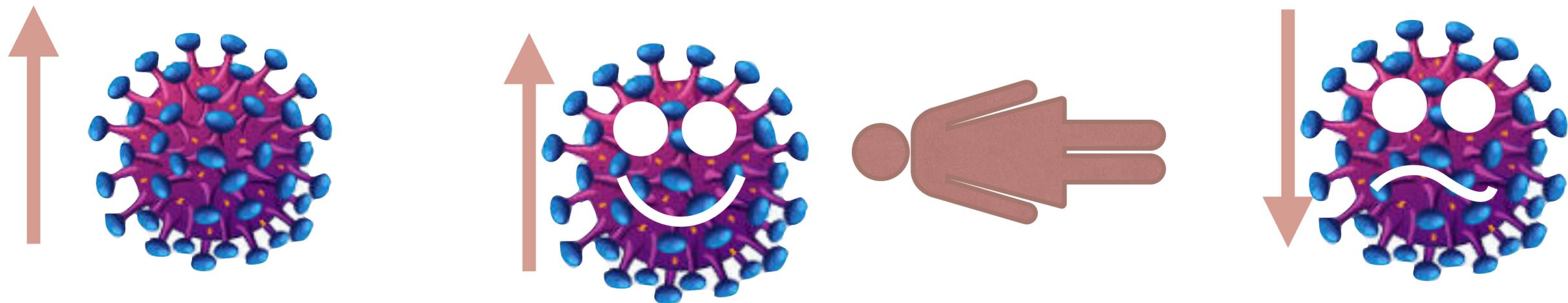
Evolução da virulência

Virulência



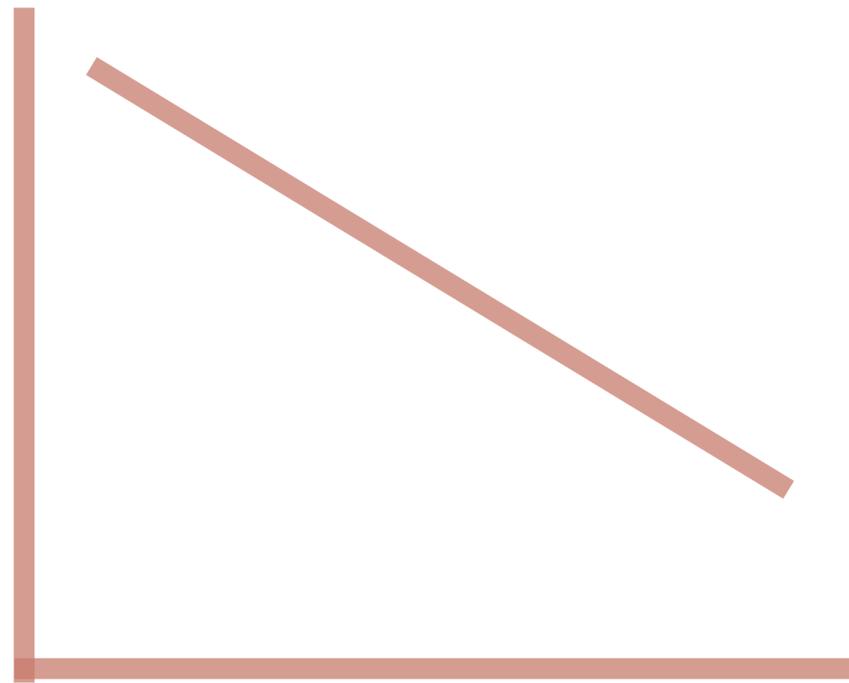
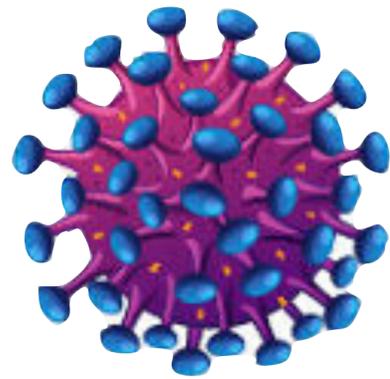
Evolução da virulência

Virulência



Evolução da virulência

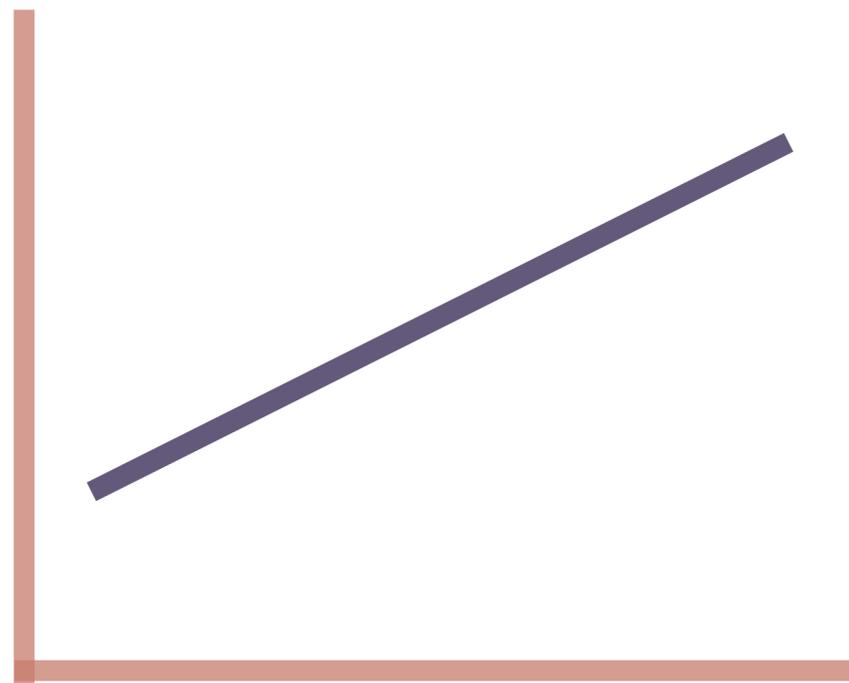
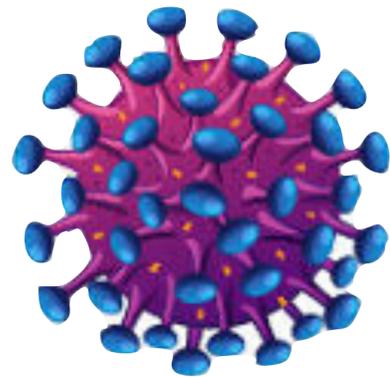
Virulência



Sobrevivência do
hospedeiro

Evolução da virulência

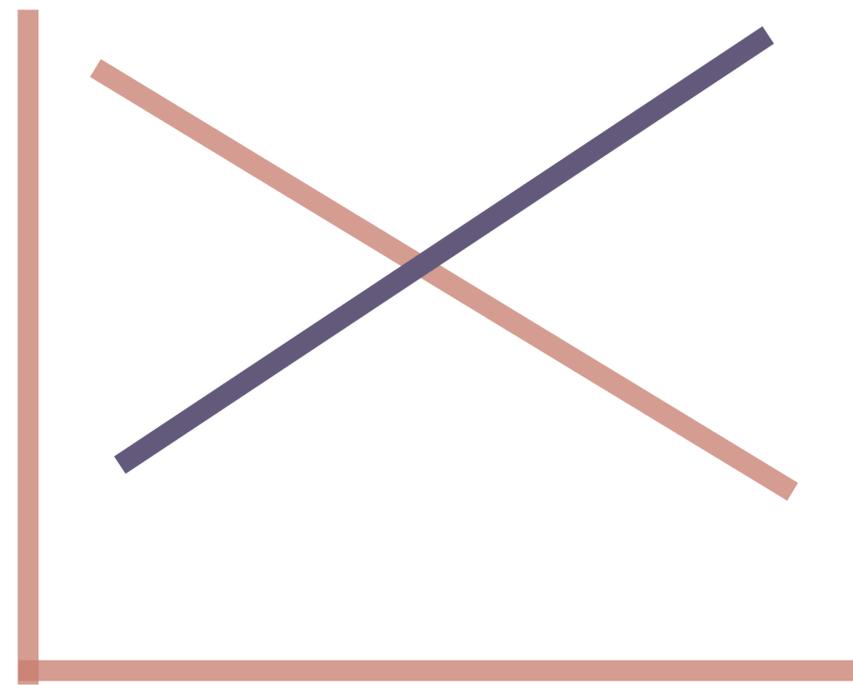
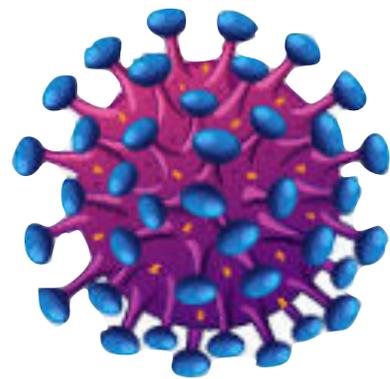
Transmissão



Sobrevivência do
hospedeiro

Evolução da virulência

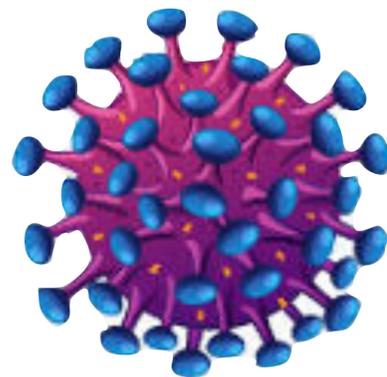
Virulência
Transmissão



**Sobrevivência do
hospedeiro**

Evolução da virulência

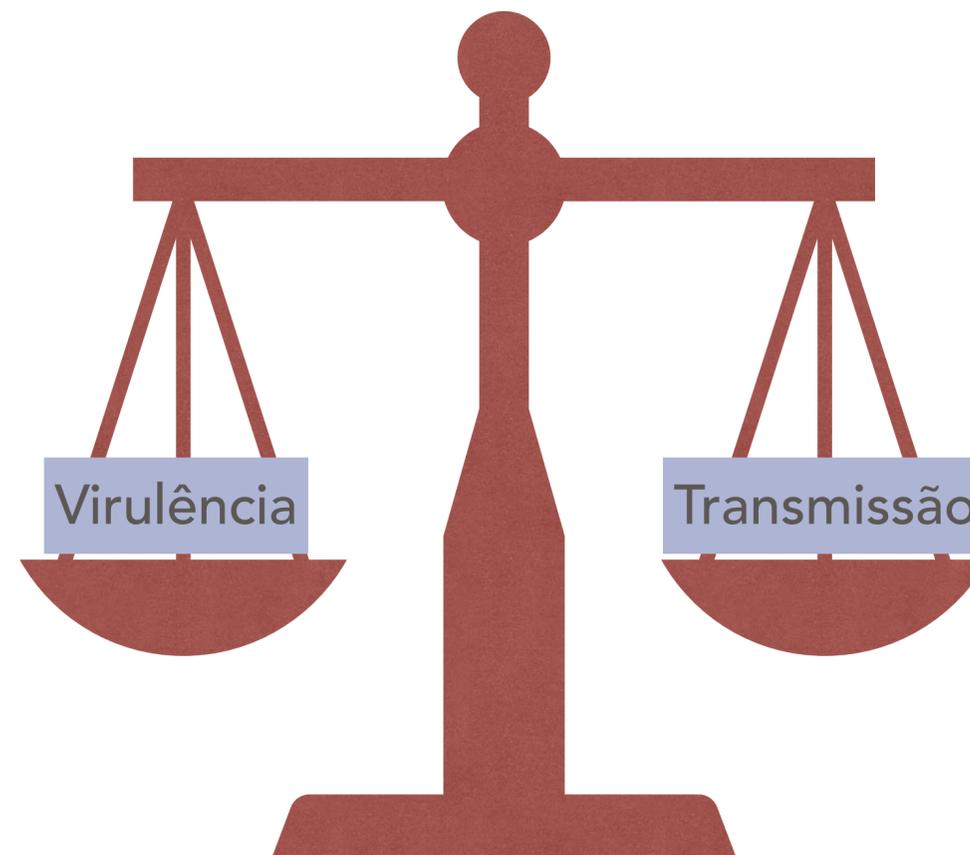
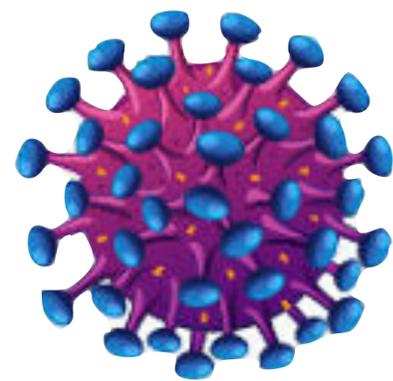
Virulência
Transmissão

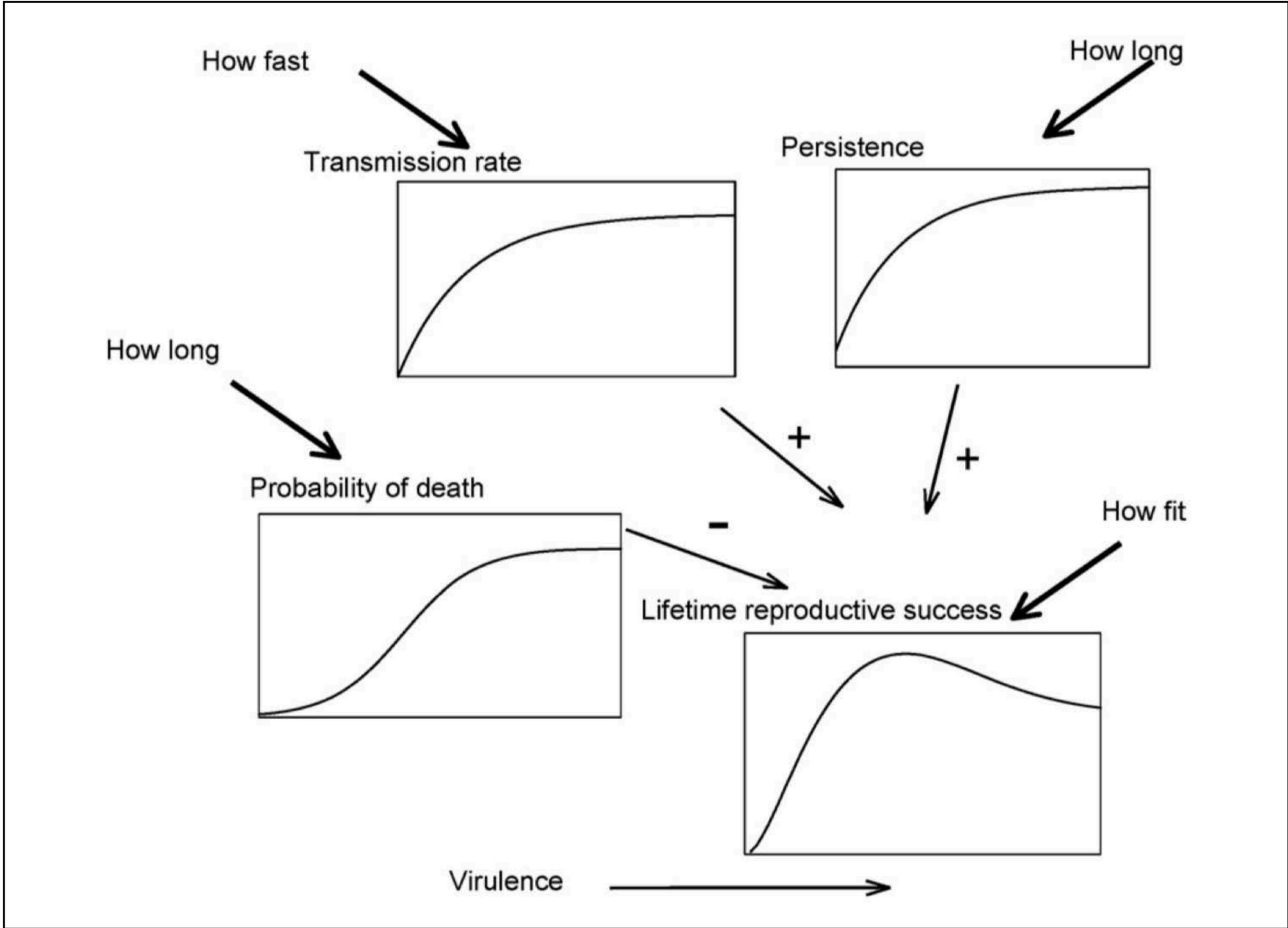


Trade-Off : Uma situação na qual a mudança em um traço causa aumento do fitness, porém leva a mudança em outro traço que reduz o fitness

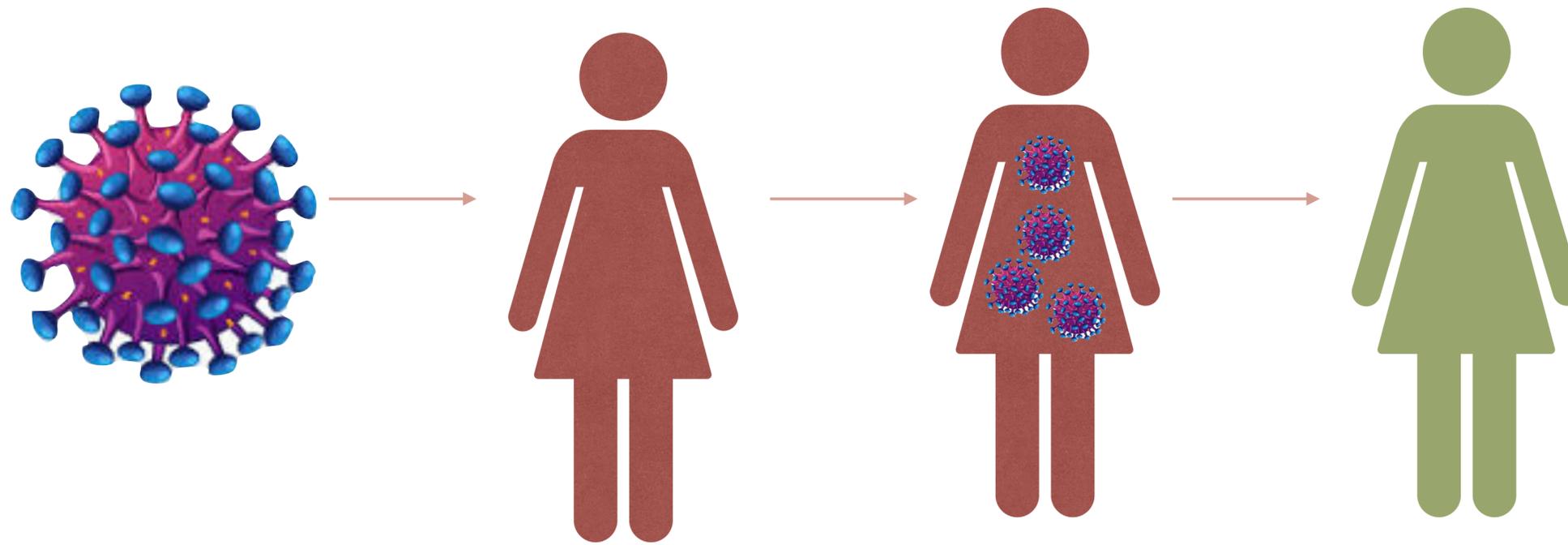
**Sobrevivência do
hospedeiro**

Evolução da virulência



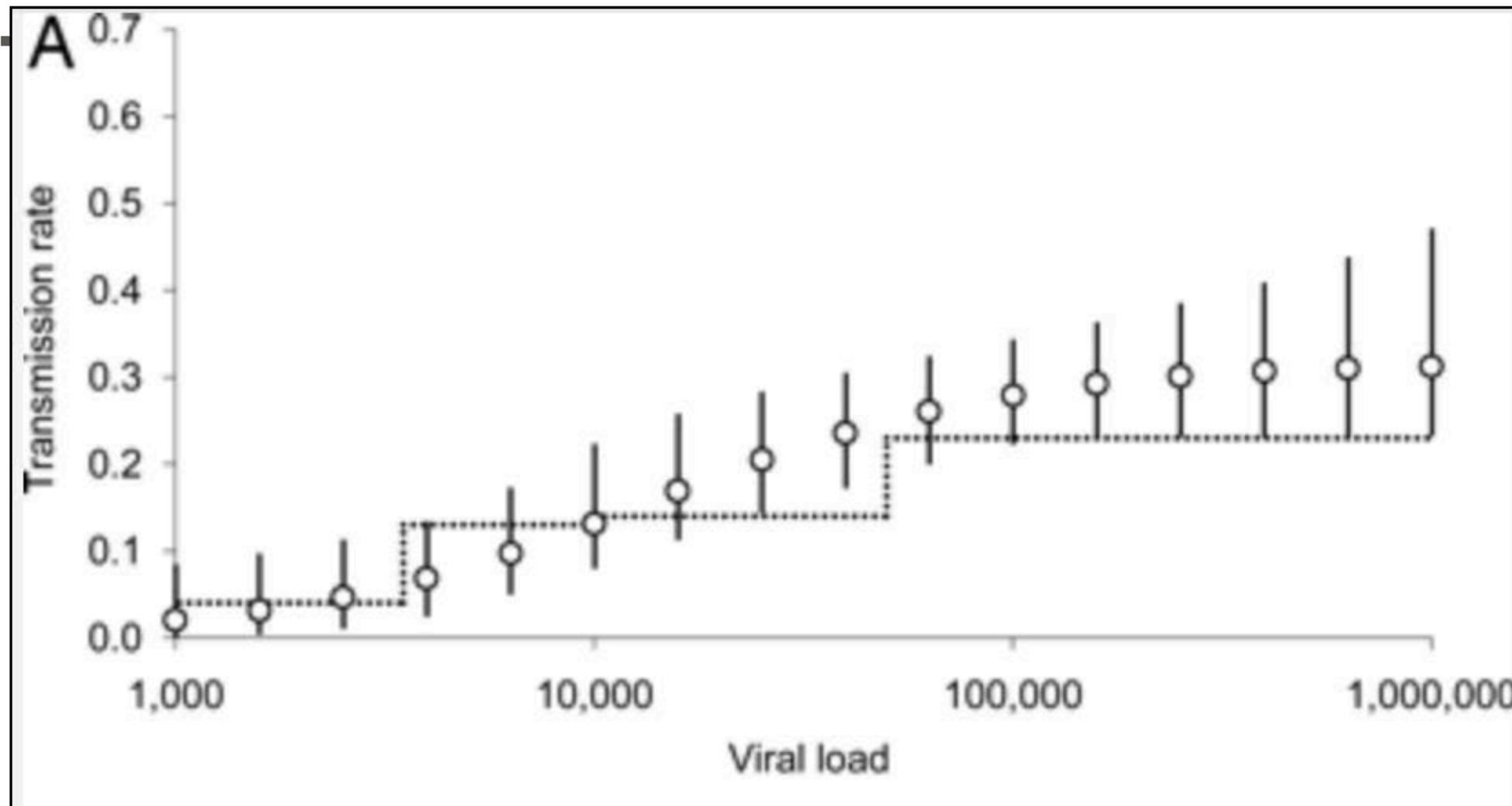


HIV

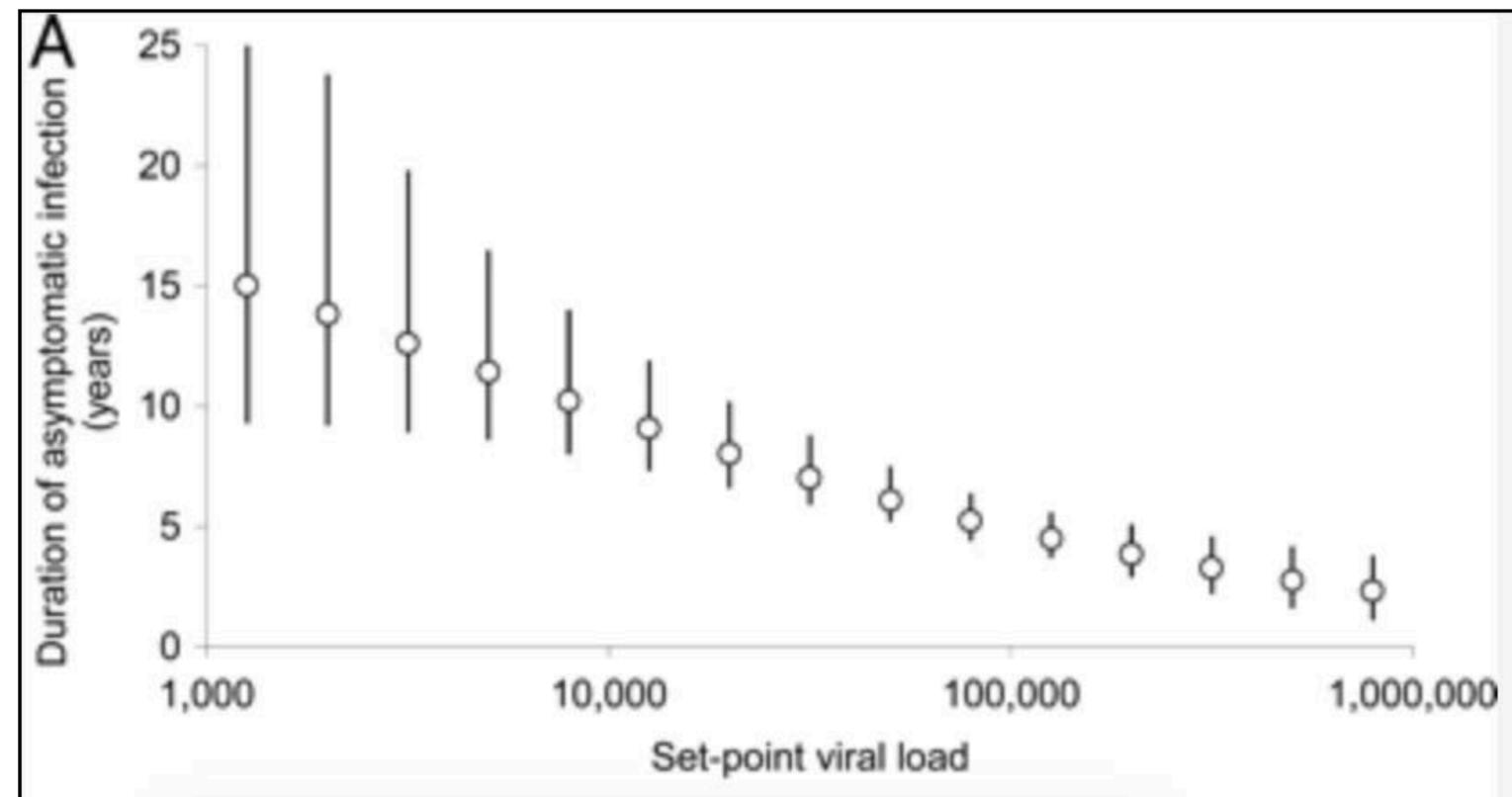
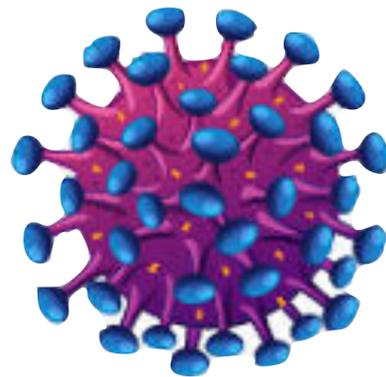


assintomático

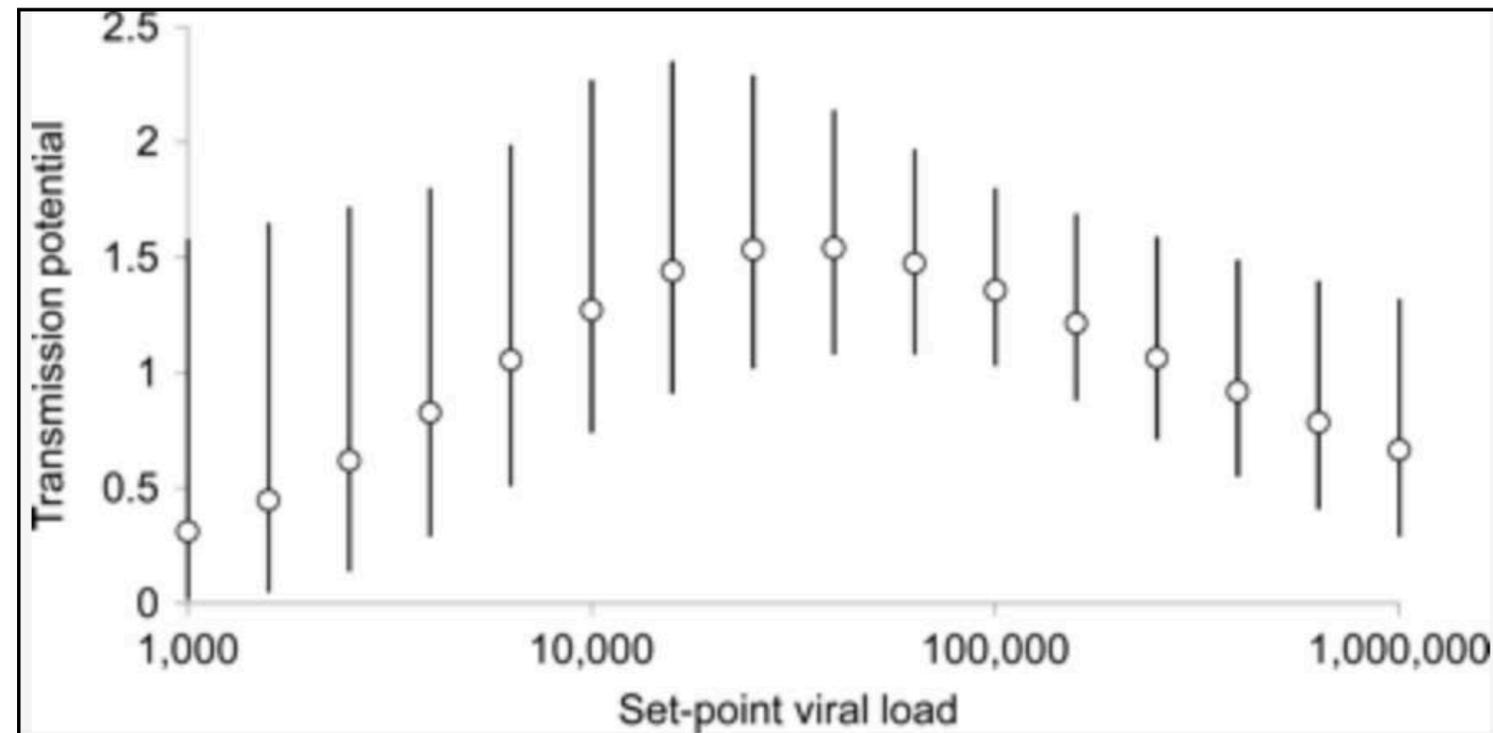
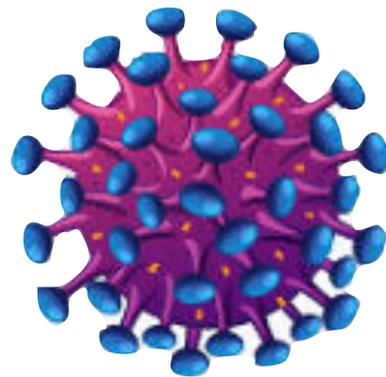
HIV



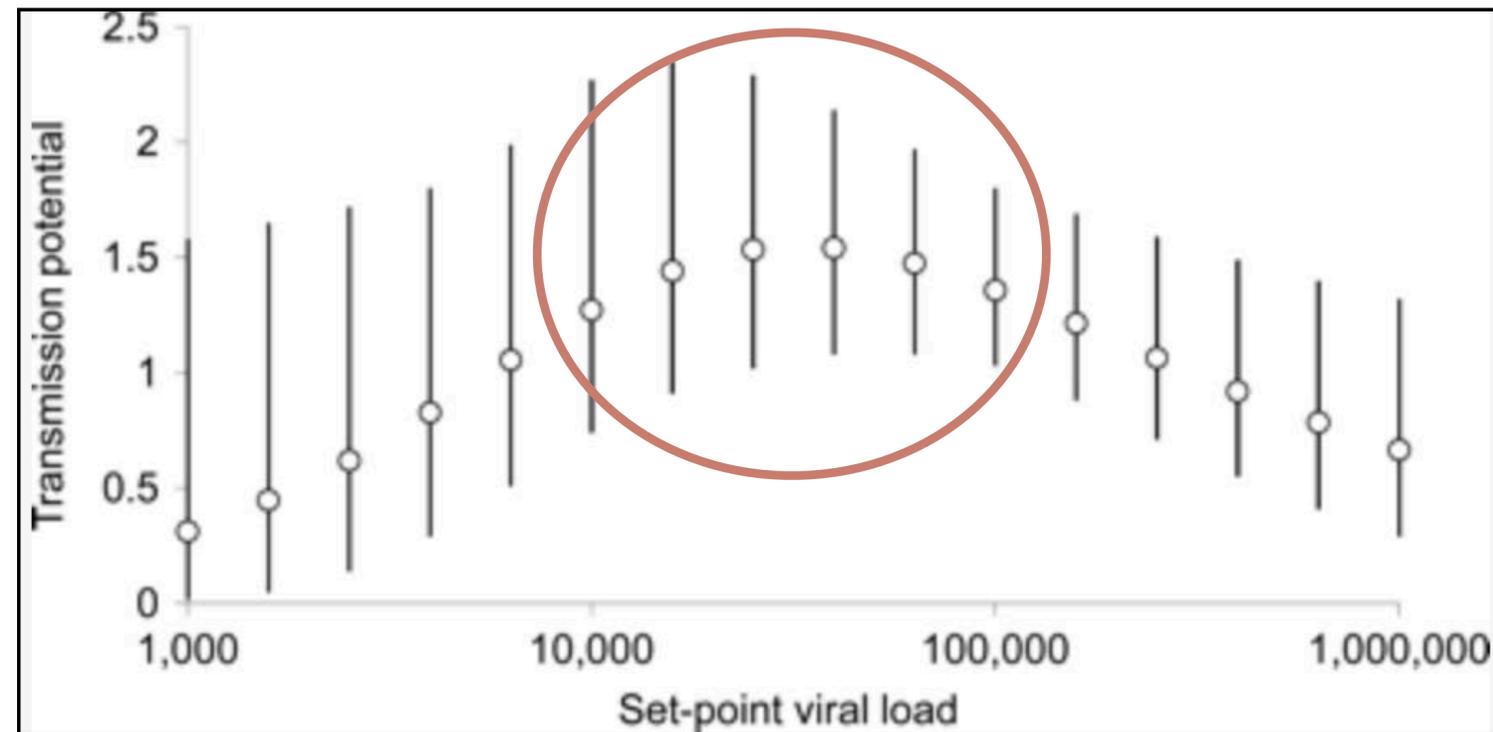
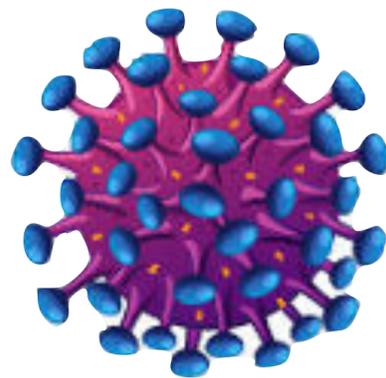
HIV



HIV



HIV



Evolução da virulência

Trade-off ente
virulência e
transmissão



Virulência em
níveis
intermediários

Evolução da virulência

Trade-off ente
virulência e
transmissão



Virulência em
níveis
intermediários

Parasitas de
transmissão direta

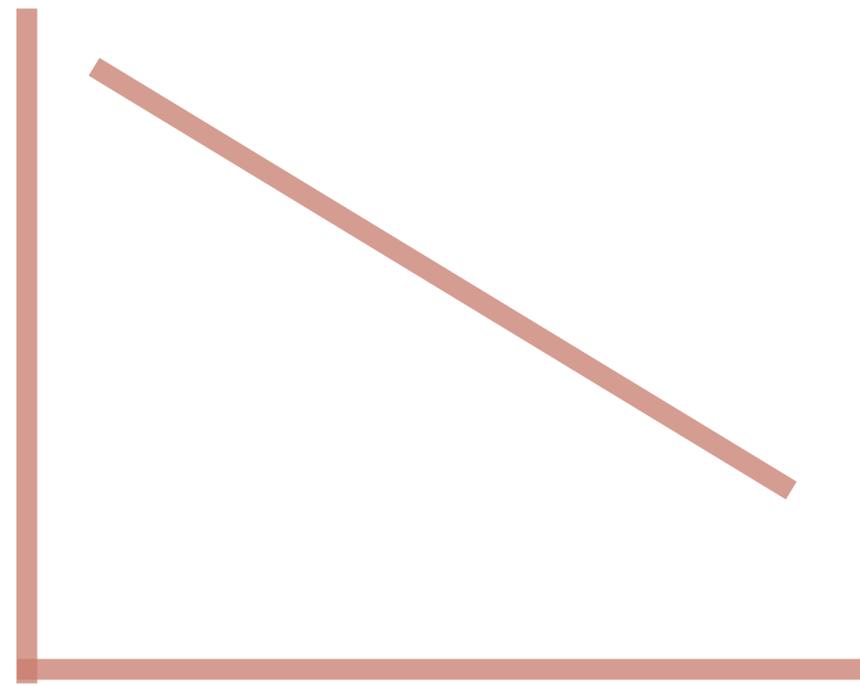
Evolução da virulência

Parasitas de
transmissão
indireta??

A maldição do faraó

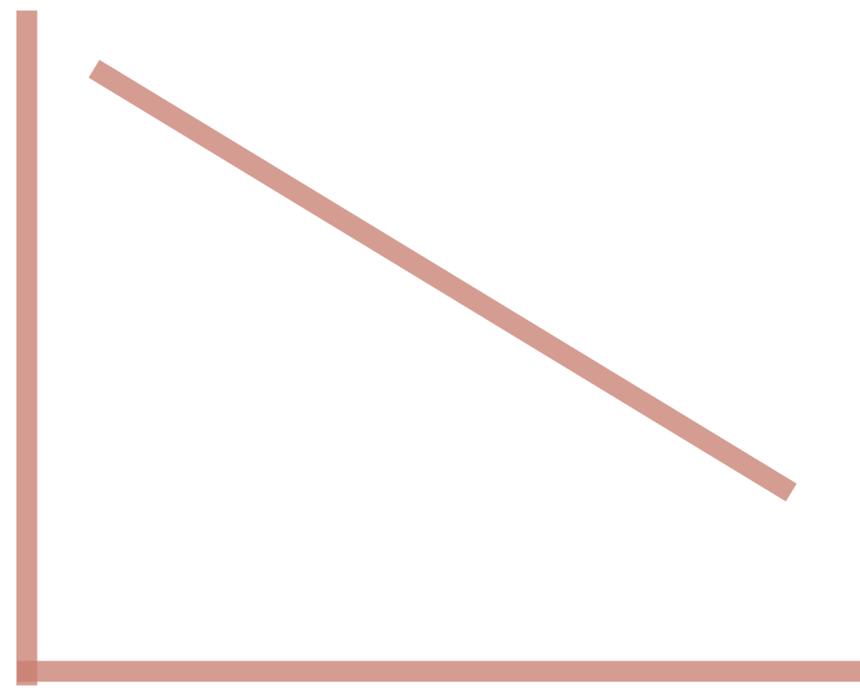


Virulência

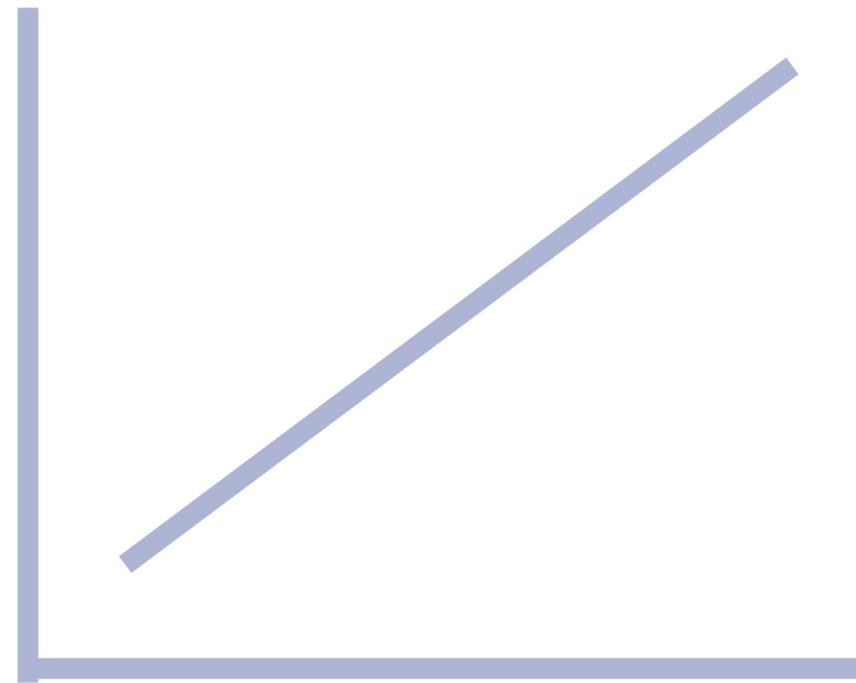


Sobrevivência do
hospedeiro

Virulência

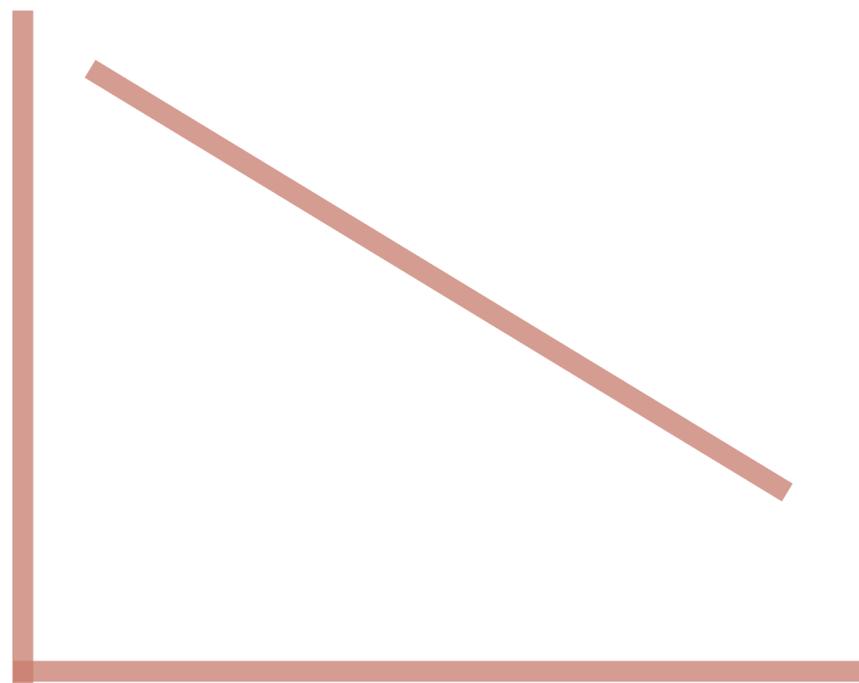


Sobrevivência do
hospedeiro

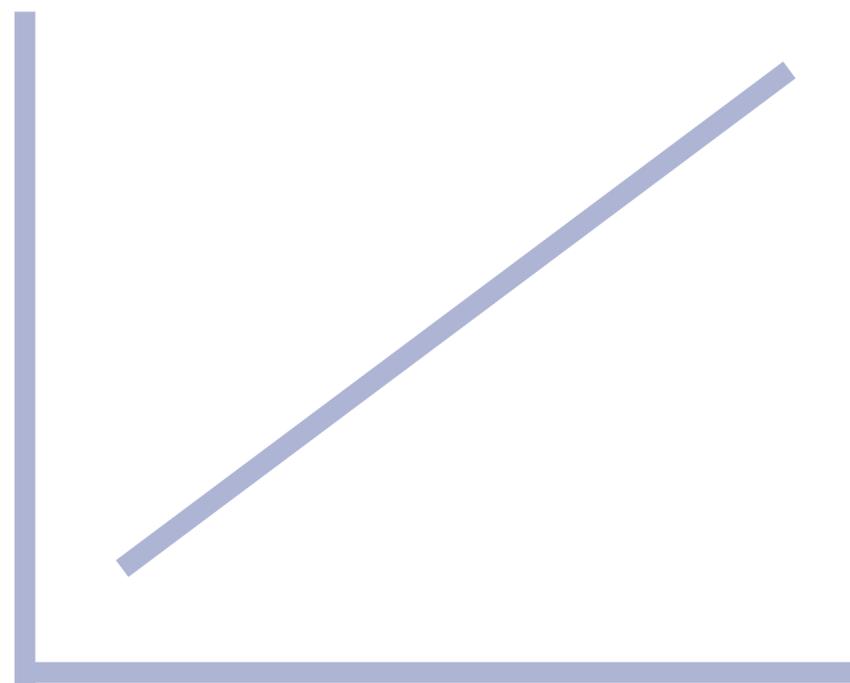


Transmissão

Virulência

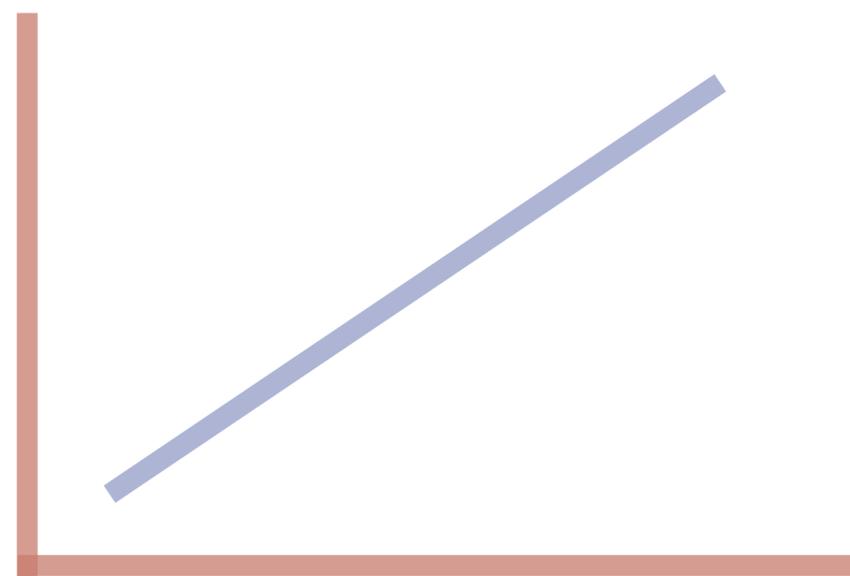


Sobrevivência do
hospedeiro



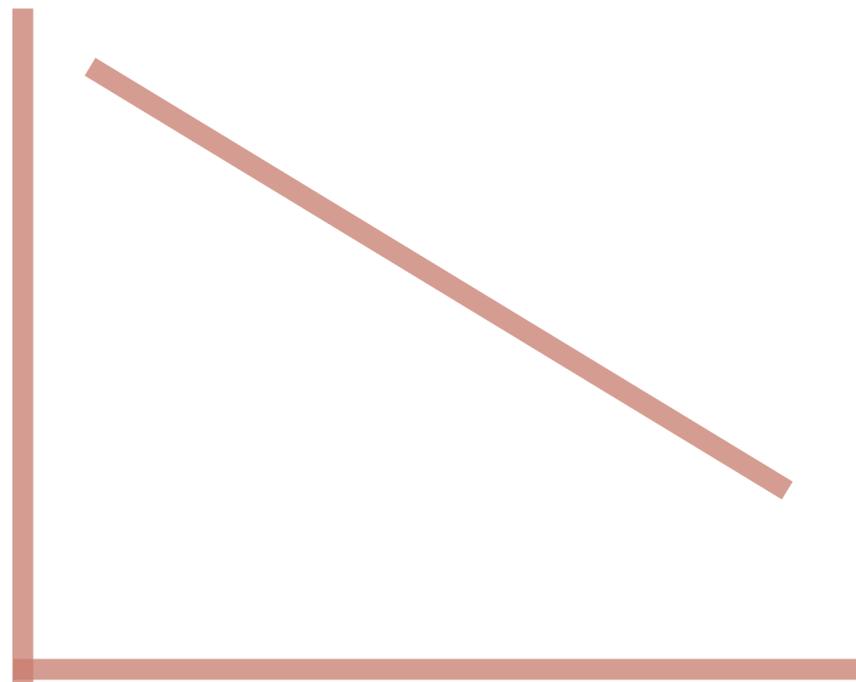
Transmissão

Transmissão

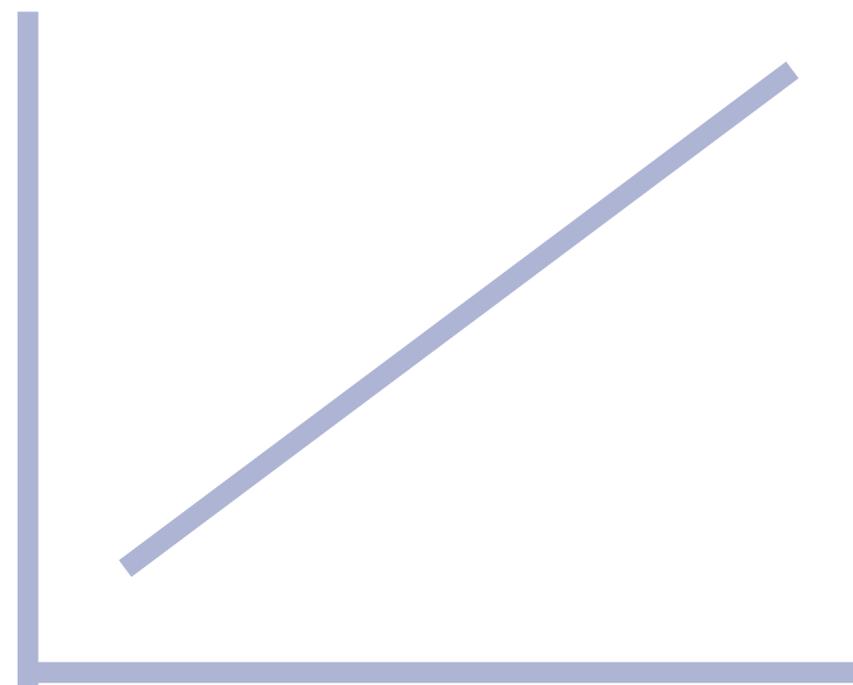


Sobrevivência do
hospedeiro

Virulência

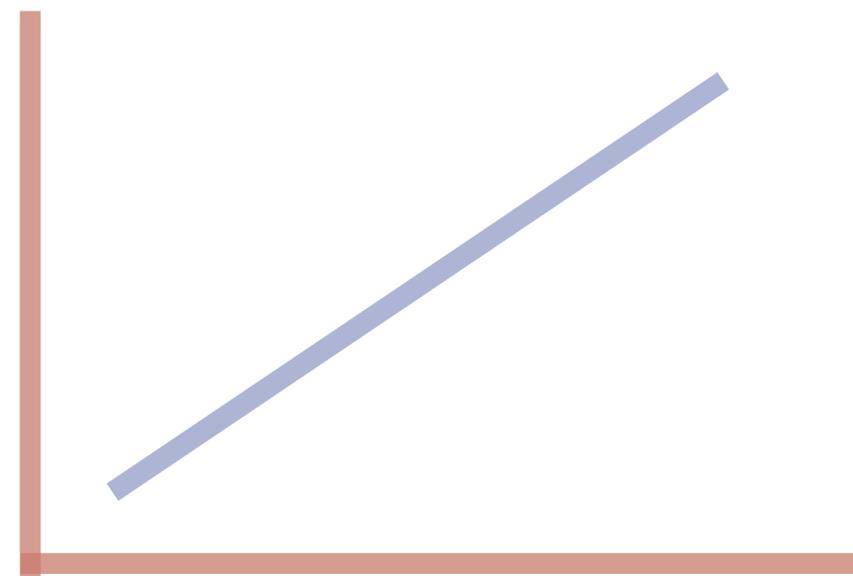


Sobrevivência do
hospedeiro



Transmissão

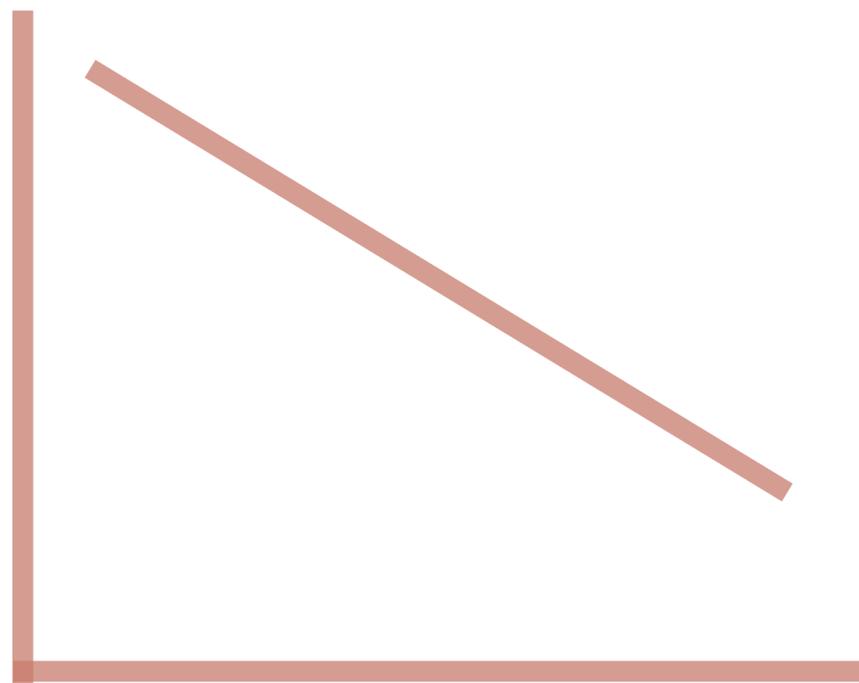
Transmissão



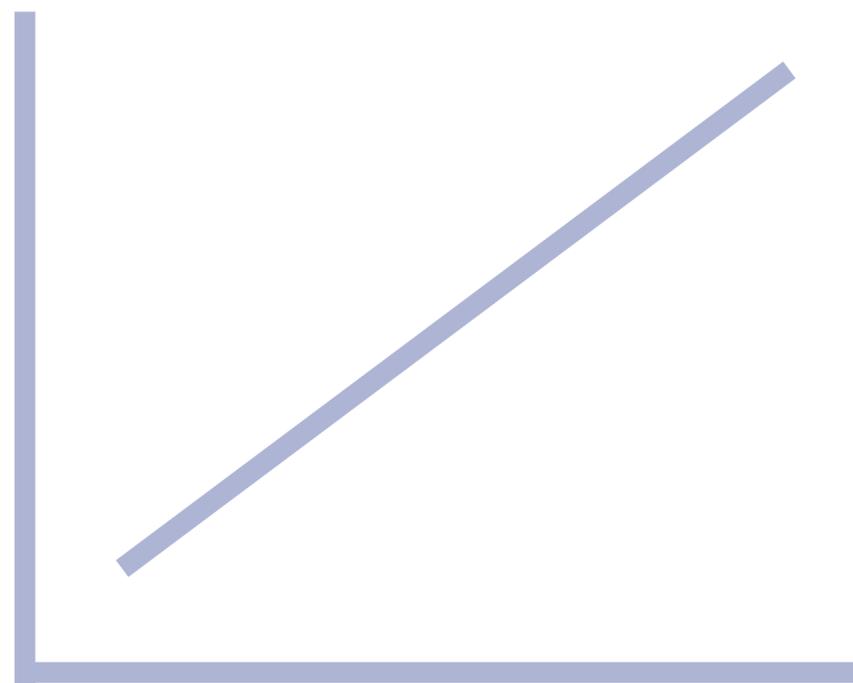
Sobrevivência do
hospedeiro

Parasitas de
transmissão direta

Virulência

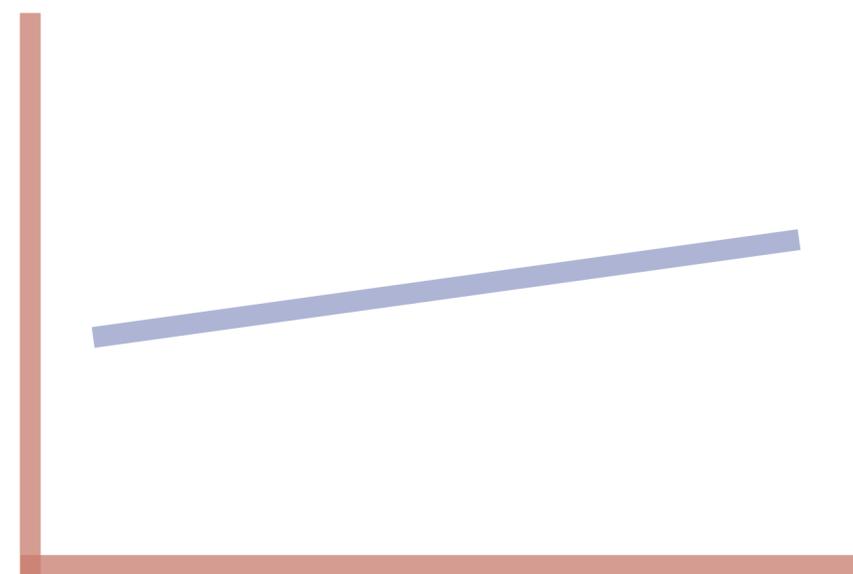


Sobrevivência do
hospedeiro



Transmissão

Transmissão



Sobrevivência do
hospedeiro

Parasitas de
transmissão
indireta

A maldição do faraó



Dependência do
hospedeiro para
transmissão

Virulência

A maldição do faraó

Table 14. *Ranking of mortality and tendencies for waterborne transmission across species*

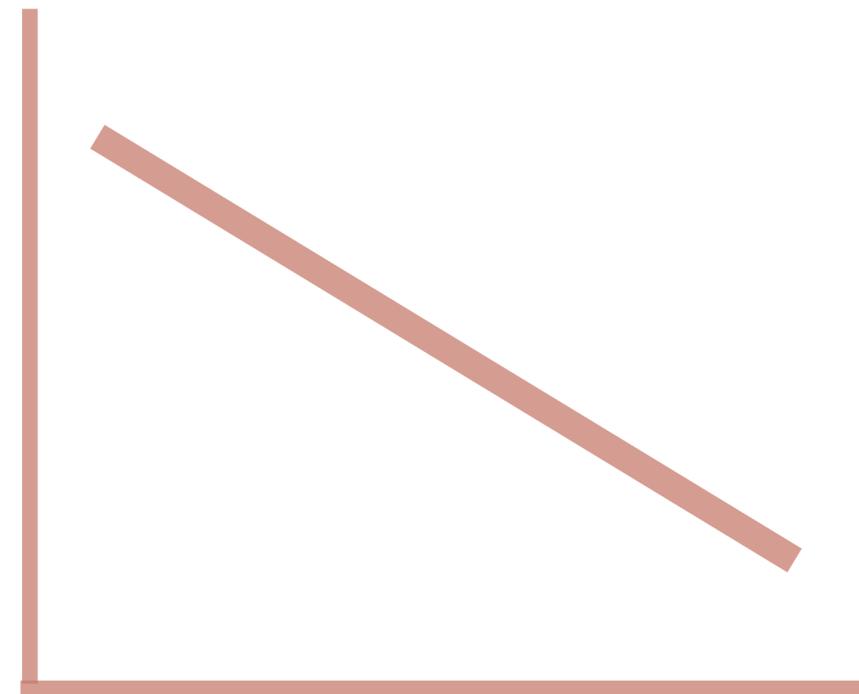
Pathogen	Mortality		Waterborne outbreaks	
	%	rank	%	rank
<i>V. cholerae</i> , classical biotype	15.7	1	83.3	1
<i>Shigella dysenteriae</i> type 1	7.5	2	80.0	2
<i>Salmonella typhi</i>	5.8	3	74.0	3
<i>V. cholerae</i> , el tor biotype	1.44	4	50.0	4
<i>Shigella flexneri</i>	1.32	5	48.3	5
<i>Shigella sonnei</i>	0.65	6	27.8	6
Enterotoxigenic <i>E. coli</i>	< 0.1	8*	20.0	7
<i>Campylobacter jejuni</i>	< 0.1	8*	10.7	8
Non-typhoid salmonella	< 0.1	8*	1.56	9

* See text for discussion of ranking.

Vibrio cholerae

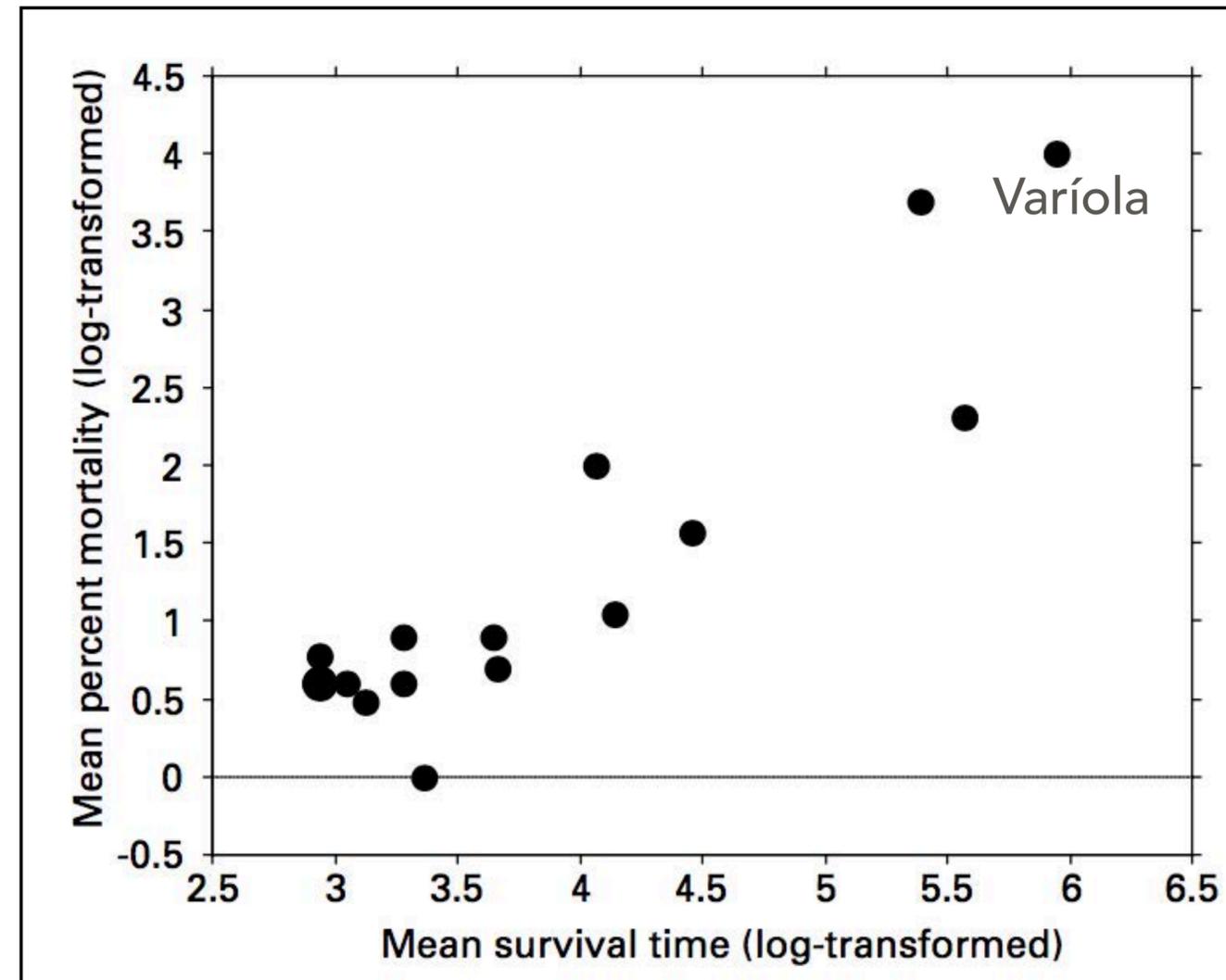


Virulência



Condições sanitárias

Doenças respiratórias humanas



Transmissão por vetor- expectativa teórica

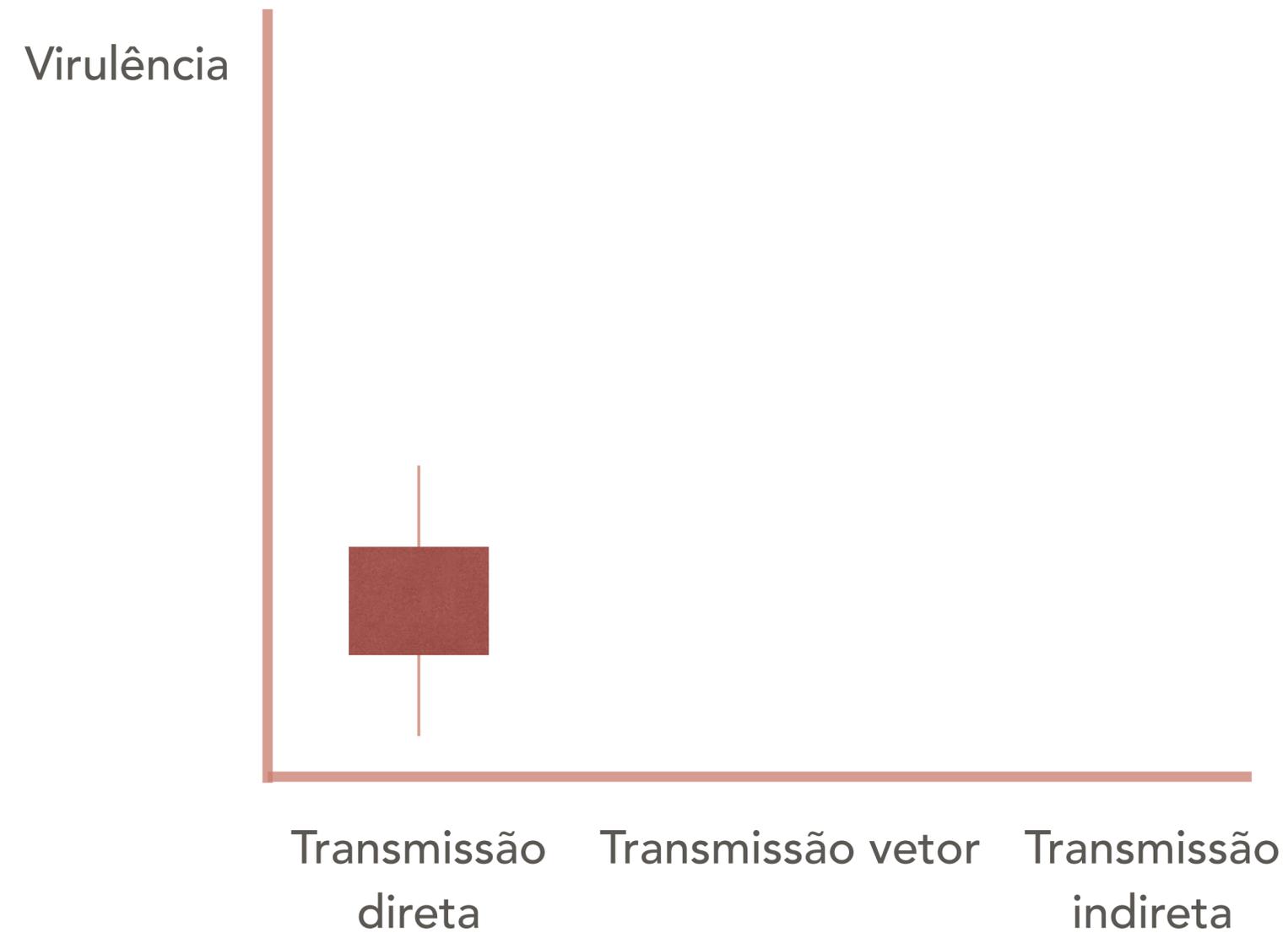
Virulência

Transmissão
direta

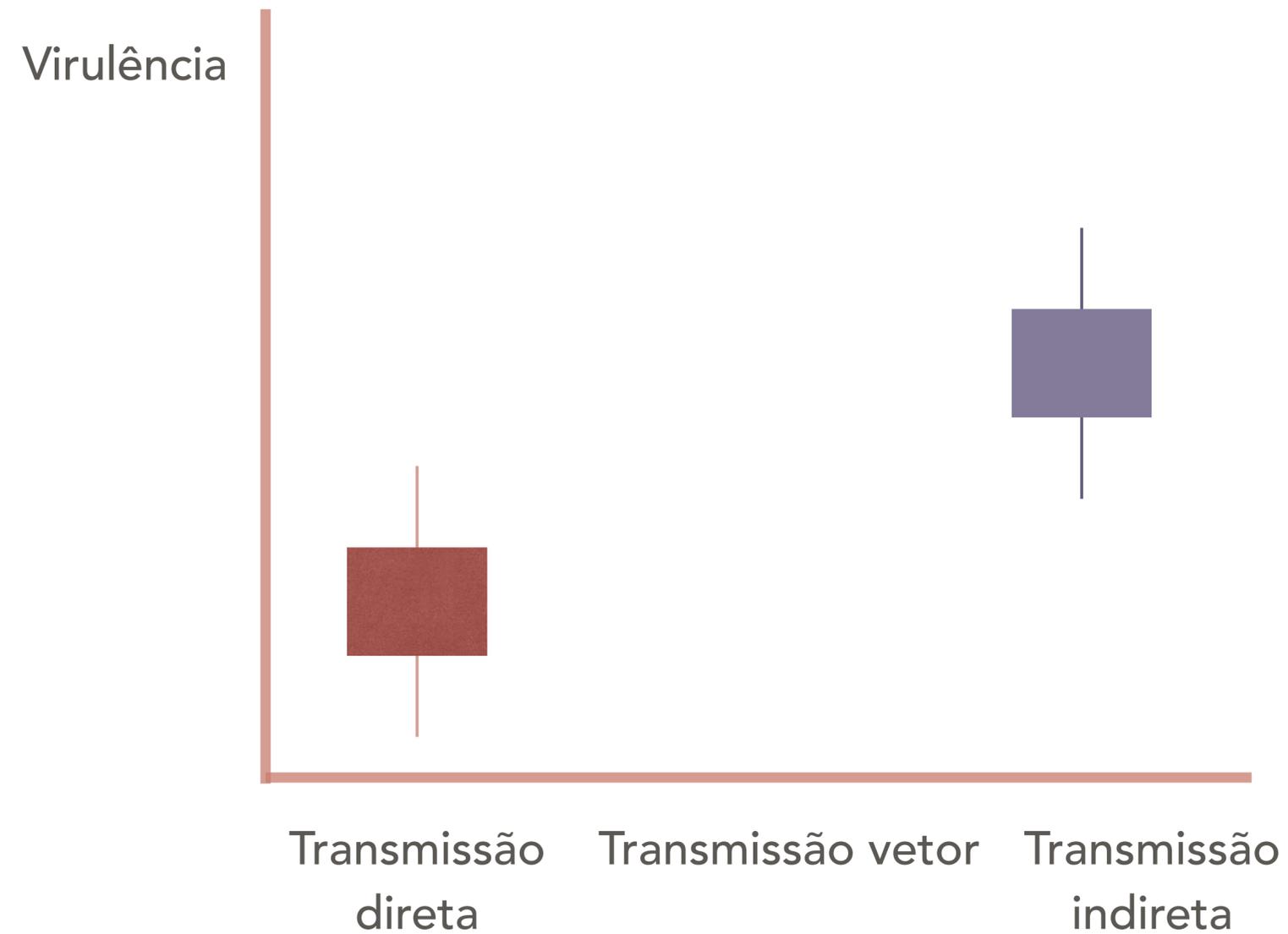
Transmissão vetor

Transmissão
indireta

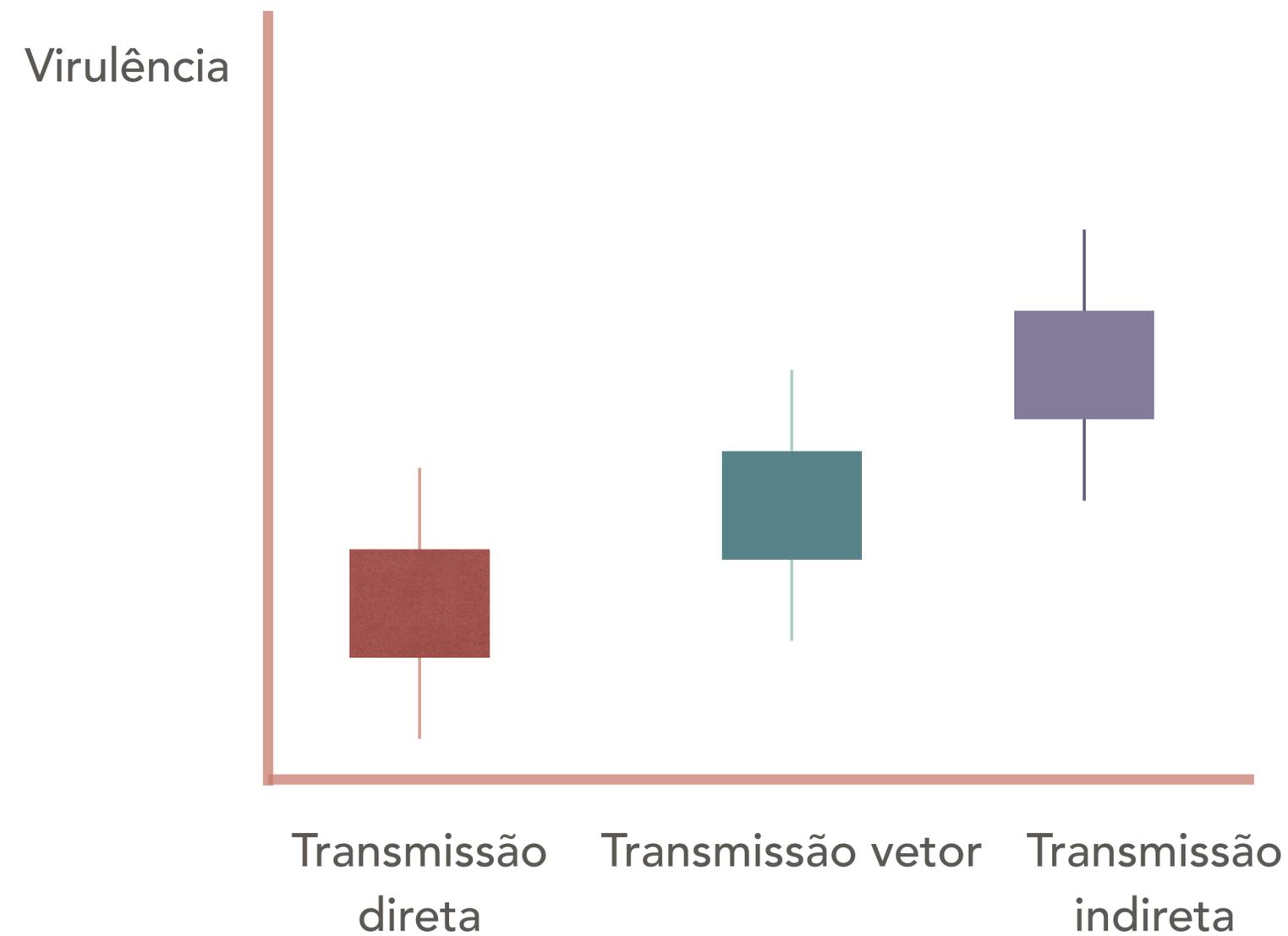
Transmissão por vetor- expectativa teórica



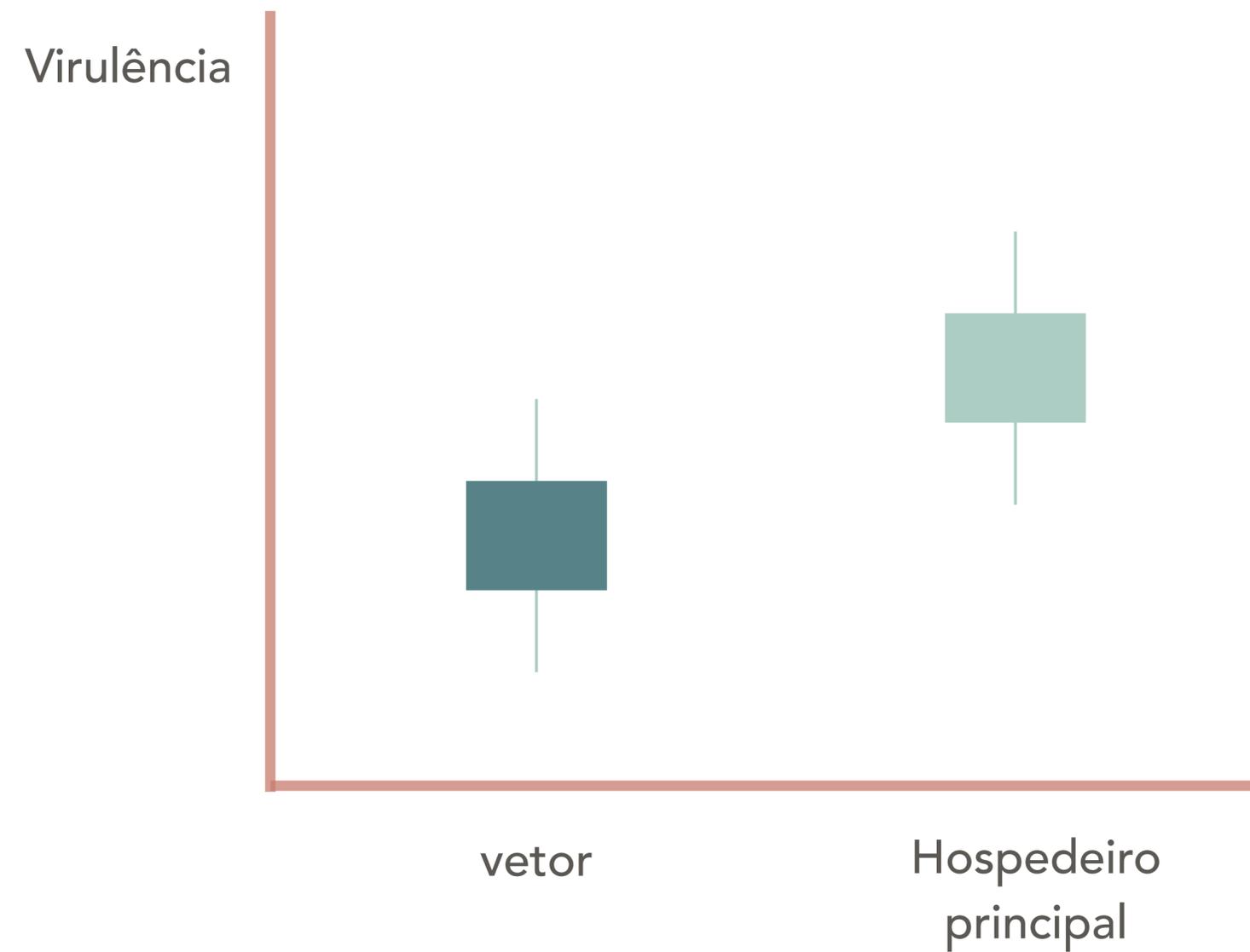
Transmissão por vetor- expectativa teórica



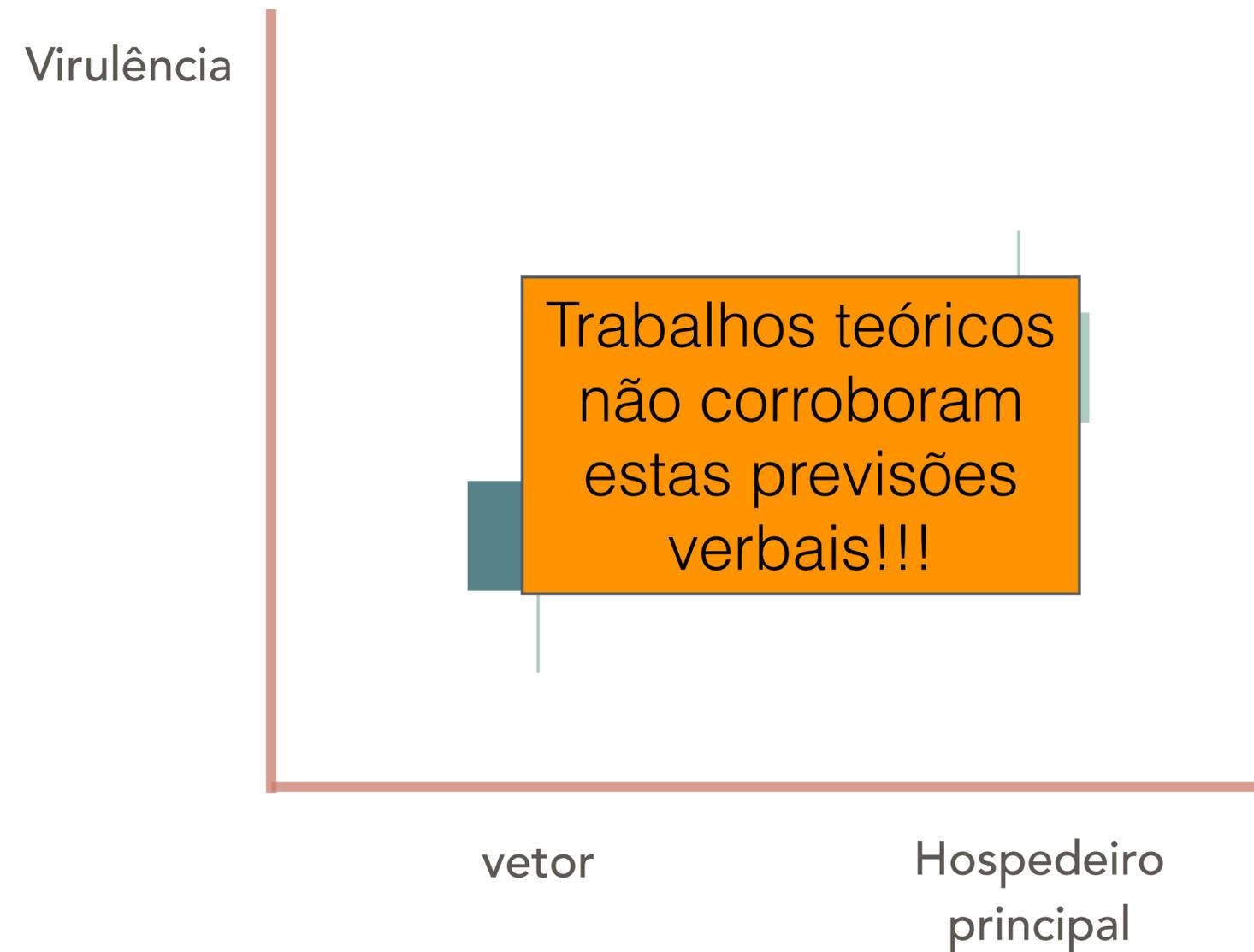
Transmissão por vetor- expectativa teórica



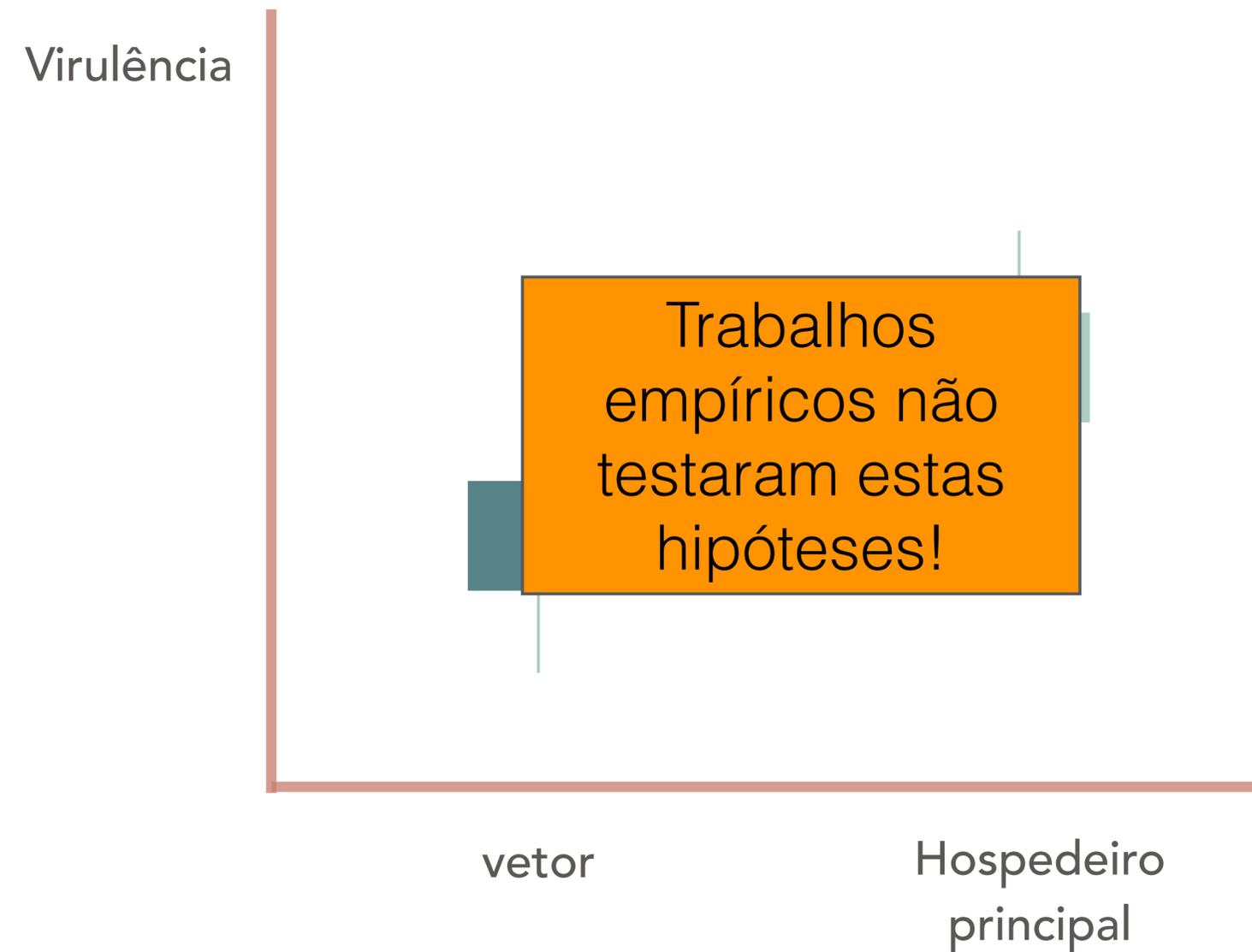
Transmissão por vetor- expectativa teórica



Transmissão por vetor- expectativa teórica



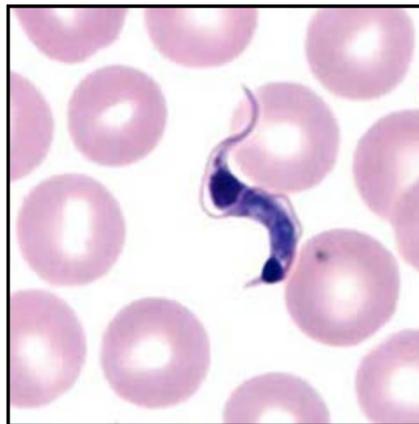
Transmissão por vetor- expectativa teórica



Doença de Chagas

Parasita

Trypanosoma cruzi



Vetor

Triatoma infestans



Hospedeiro definitivo

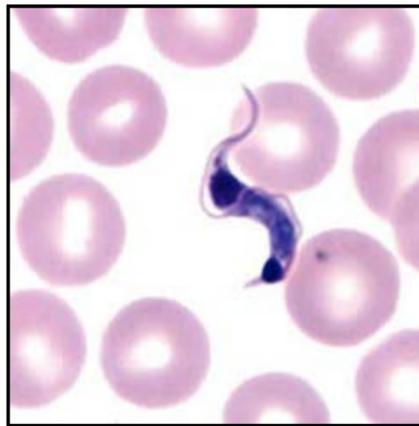
Homo sapiens



Doença de Chagas

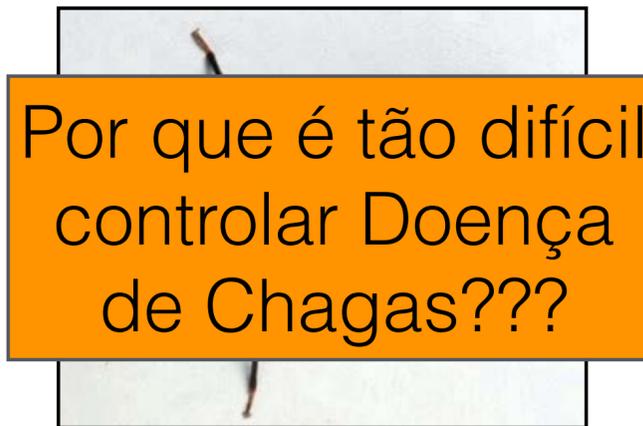
Parasita

Trypanosoma cruzi



Vetor

Triatoma infestans



Hospedeiro definitivo

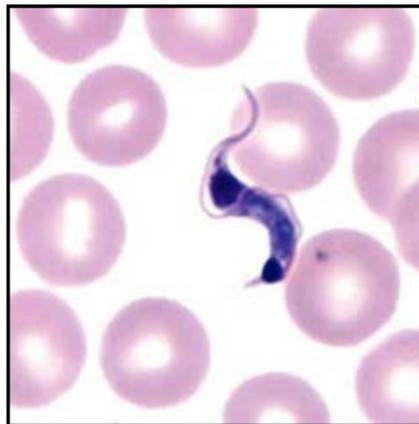
Homo sapiens



Doença de Chagas

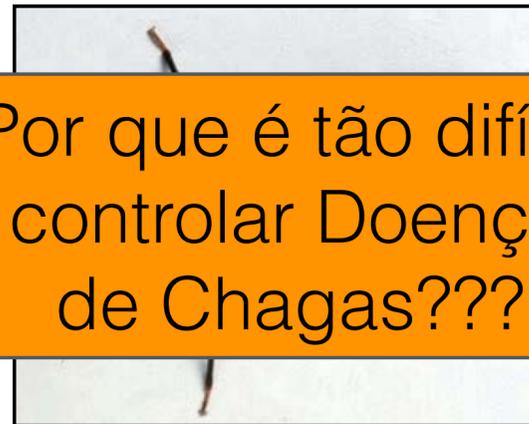
Parasita

Trypanosoma cruzi



Vetor

Triatoma infestans



Por que é tão difícil controlar Doença de Chagas???

Doença de terceiro mundo?

Hospedeiro definitivo

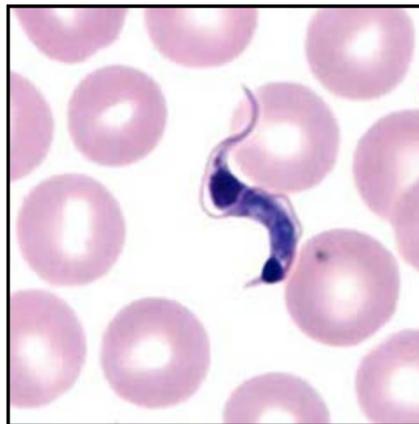
Homo sapiens



Doença de Chagas

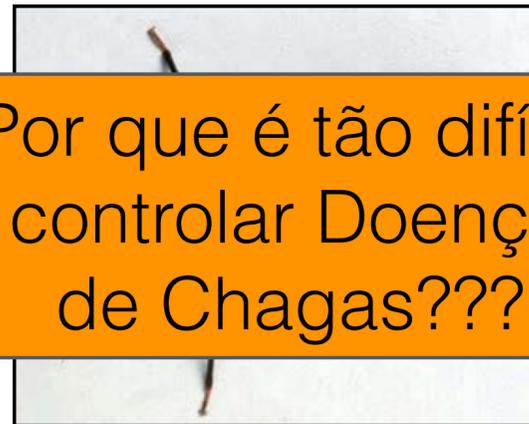
Parasita

Trypanosoma cruzi



Vetor

Triatoma infestans



Por que é tão difícil controlar Doença de Chagas???

Hospedeiro definitivo

Homo sapiens

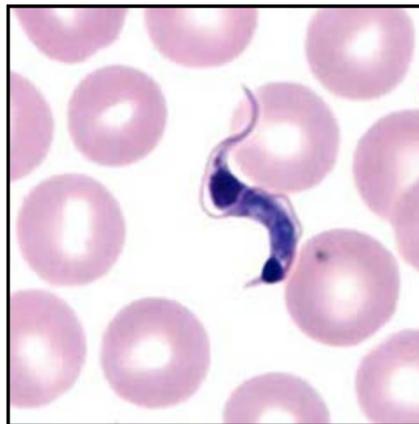


Como eliminar um protozoário?

Doença de Chagas

Parasita

Trypanosoma cruzi



Vetor

Triatoma infestans



Hospedeiro definitivo

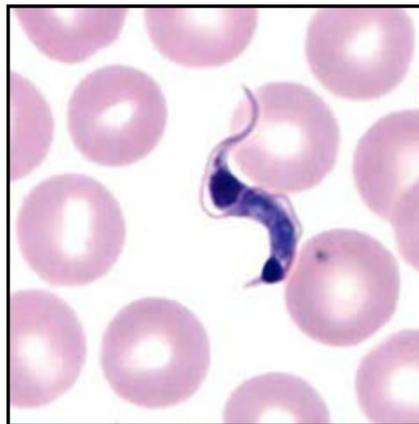
Homo sapiens



Doença de Chagas

Parasita

Trypanosoma cruzi



Vetor

Triatoma infestans



Aumento de
resistência a
inseticida!!!!

Hospedeiro definitivo

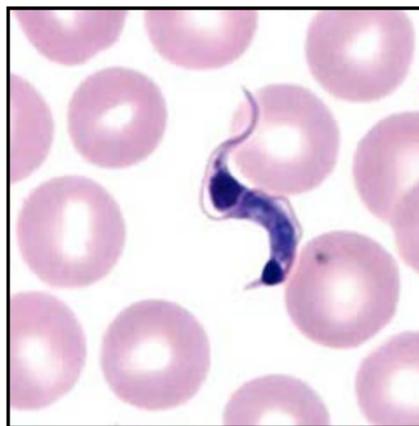
Homo sapiens



Doença de Chagas

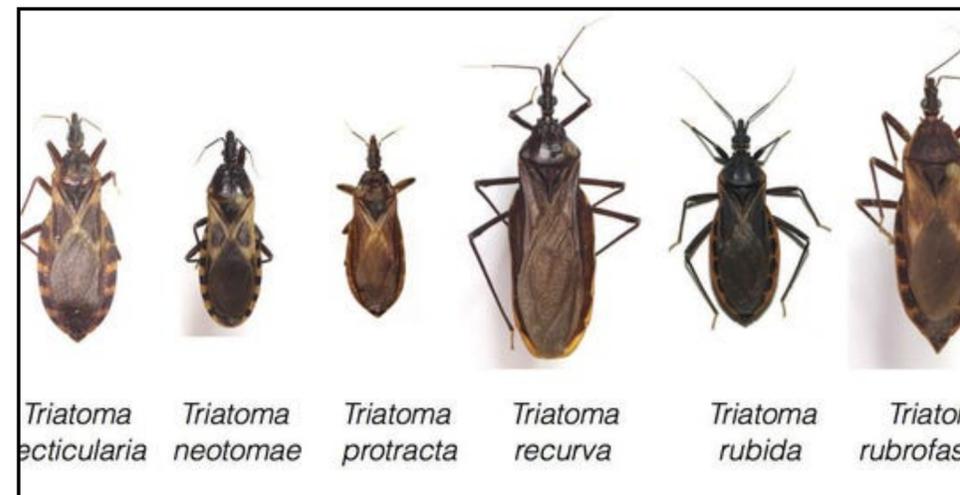
Parasita

Trypanosoma cruzi

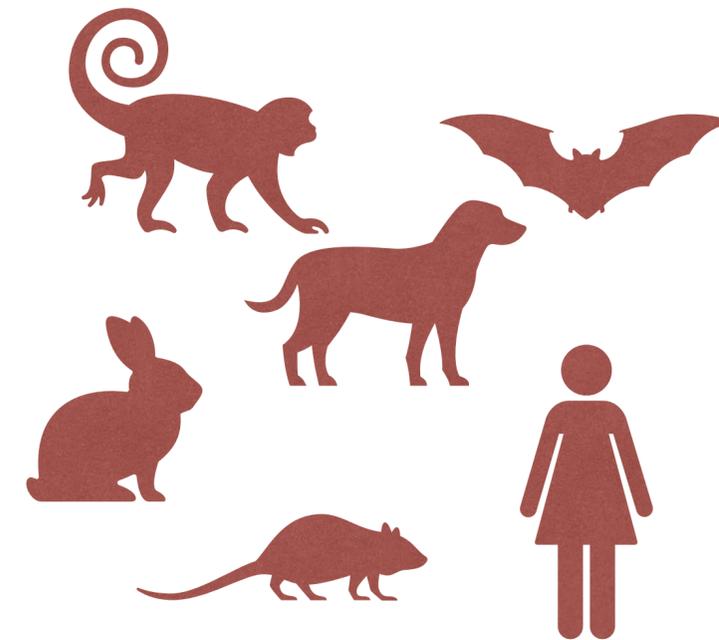


Vetor

Triatominae

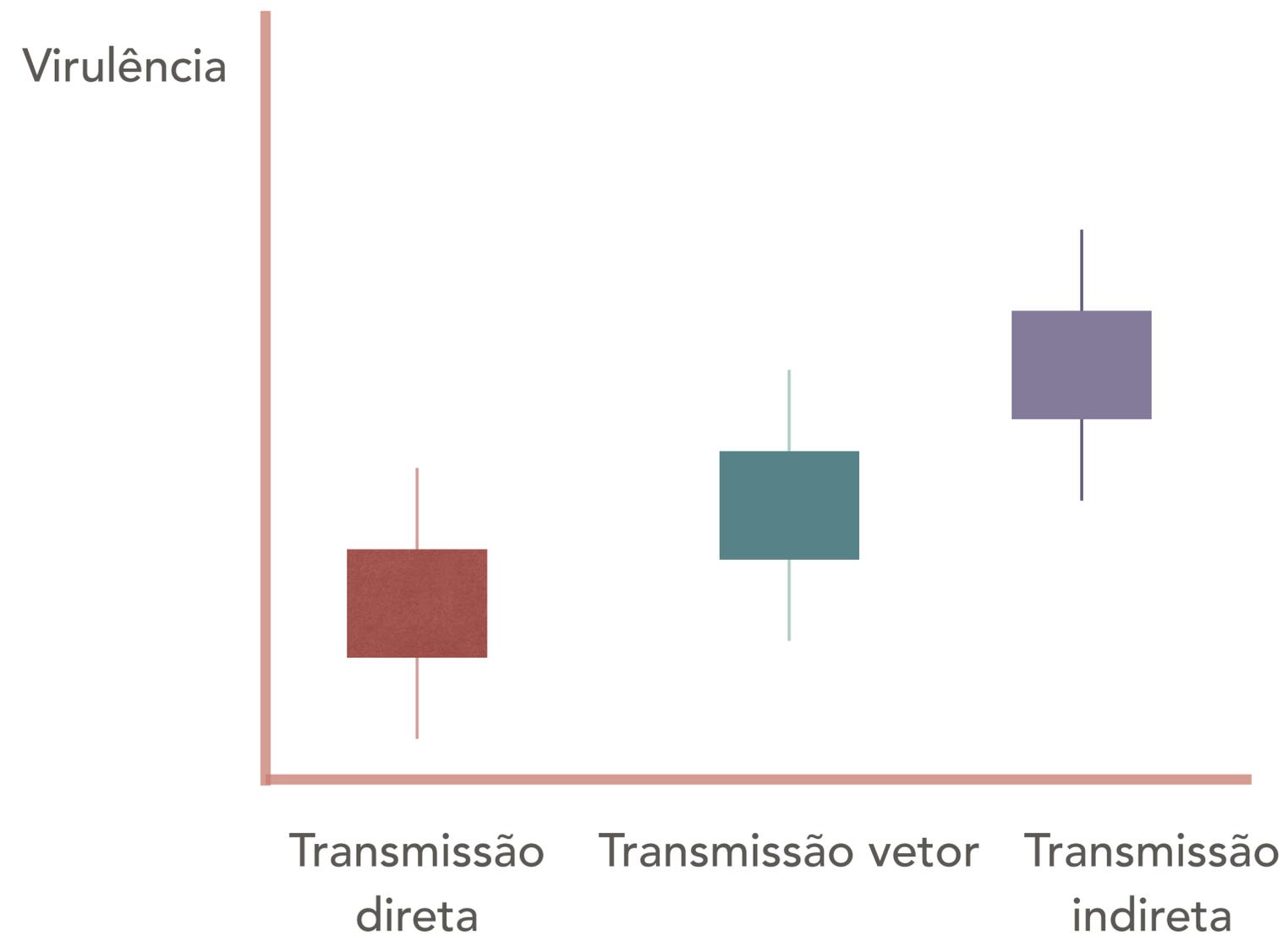


Hospedeiro definitivo



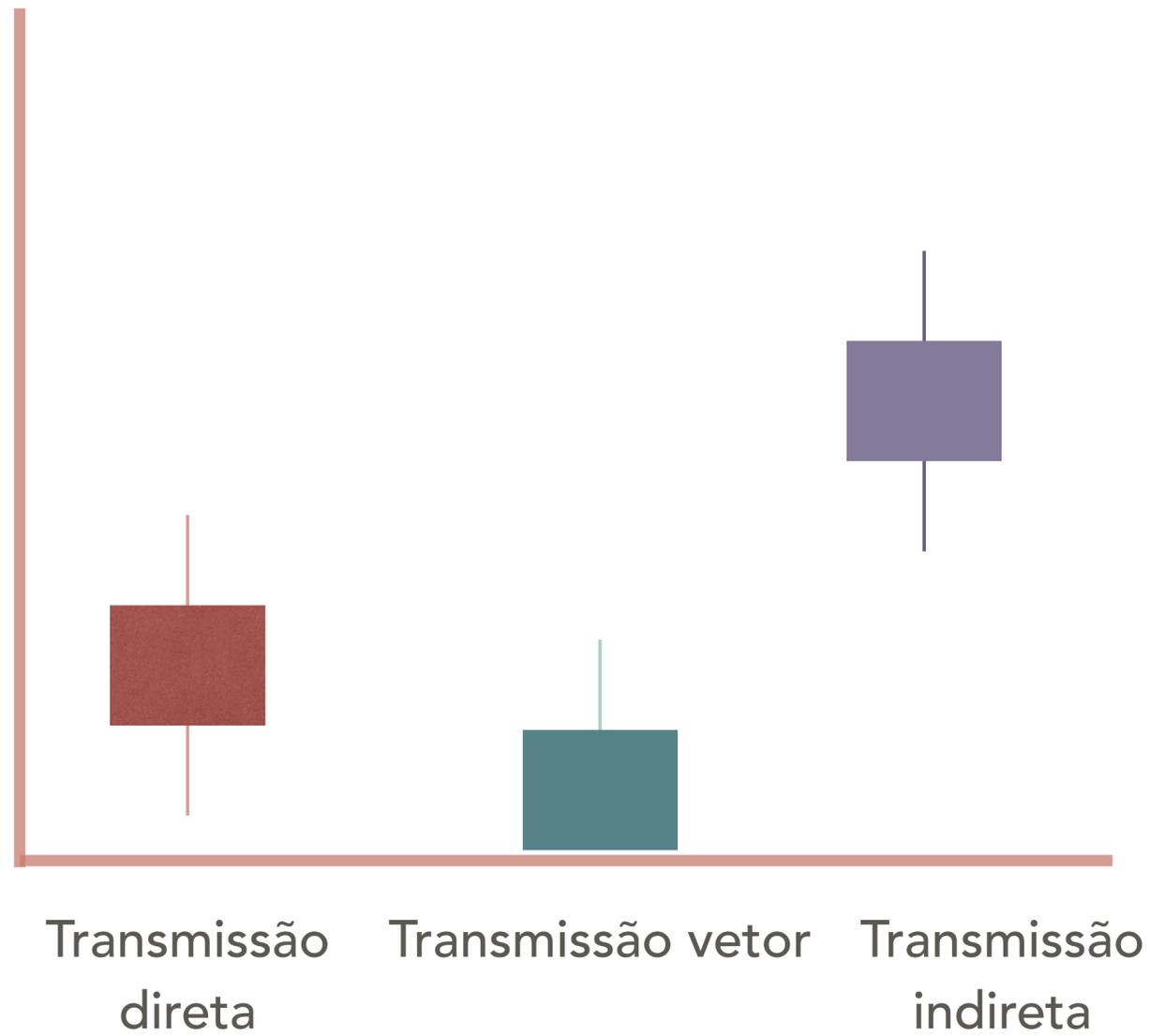
Rede complexas
de vetores e
hospedeiros!!!!

Doença de Chagas- expectativa teórica

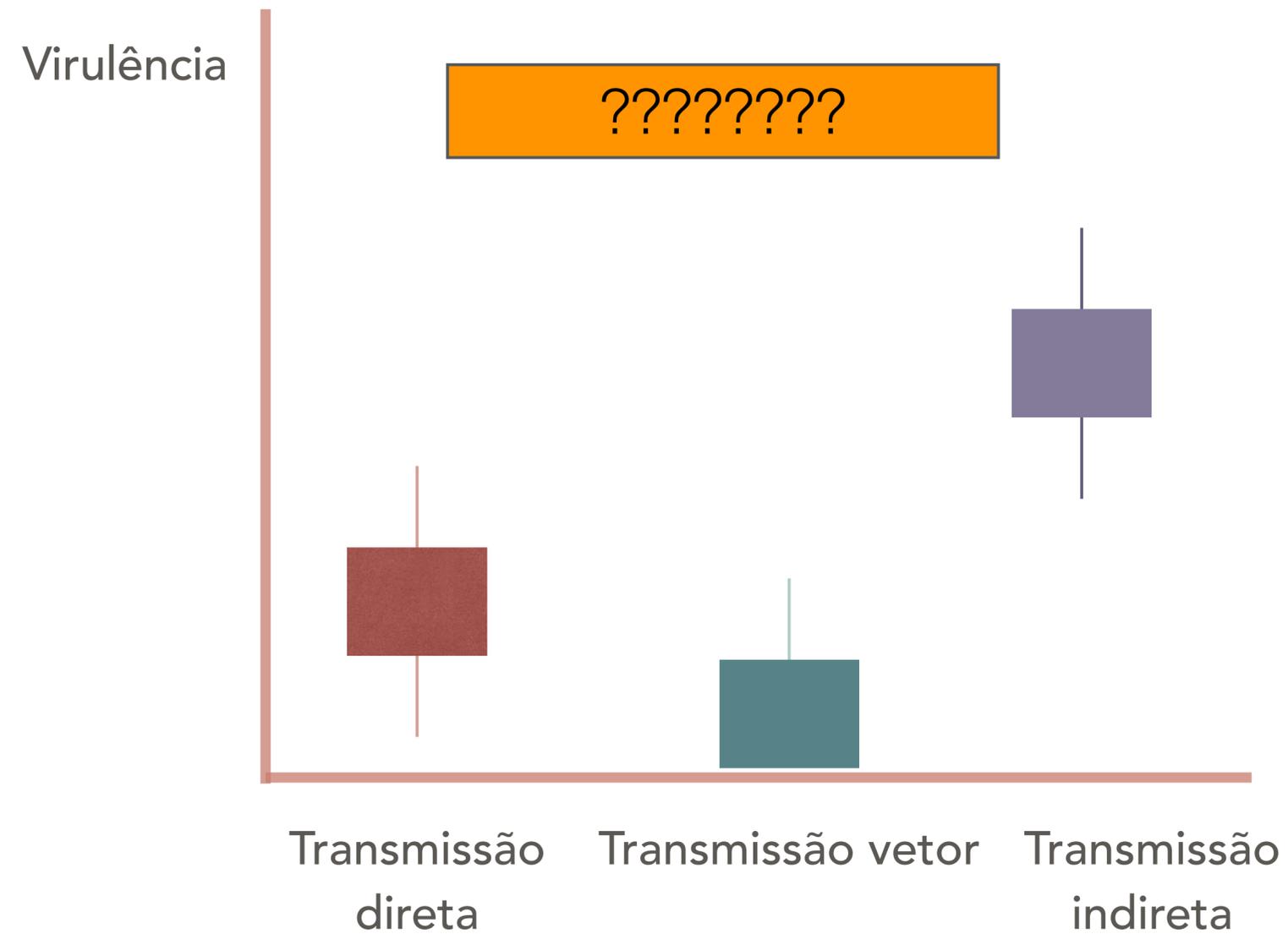


Doença de Chagas

Virulência



Doença de Chagas



Doença de Chagas

Virulência

?????????

The **Bill & Melinda Gates** Foundation today announced four grants totaling **\$68.2 million** to help accelerate research on **neglected tropical diseases**, including hookworm, leishmaniasis, and **trypanosomiasis**, which kill or disable millions of people in the world's poorest countries every year.

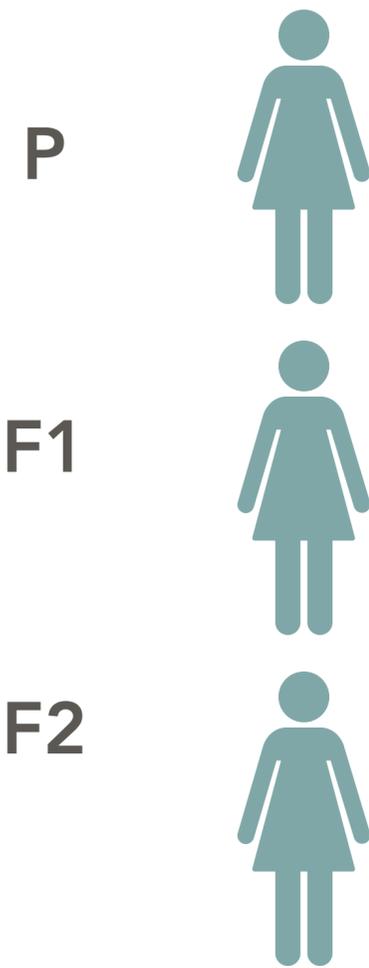
Transmissão
direta

Transmissão vetor

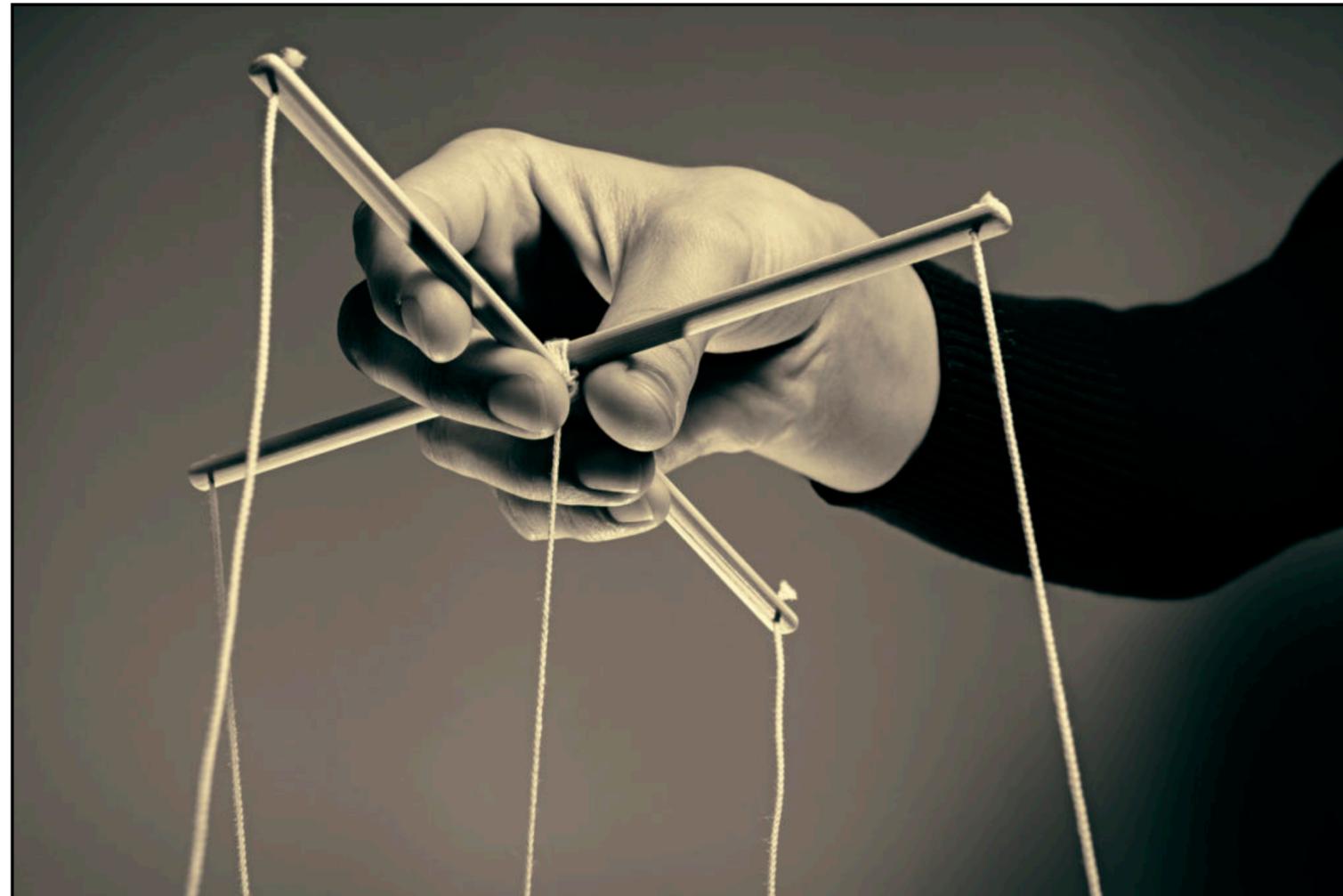
Transmissão
indireta

Transmissão vertical

Transmissão vertical



Wolbachia - the puppet master

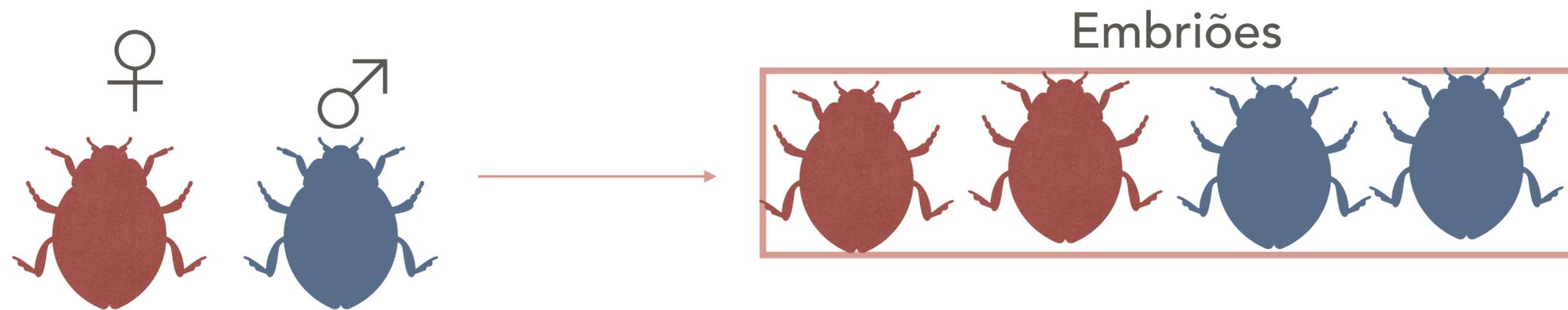


Wolbachia - the puppet master

65% das espécies de insetos!!! Ocorrem também em crustáceos, aracnídeos e nematodos

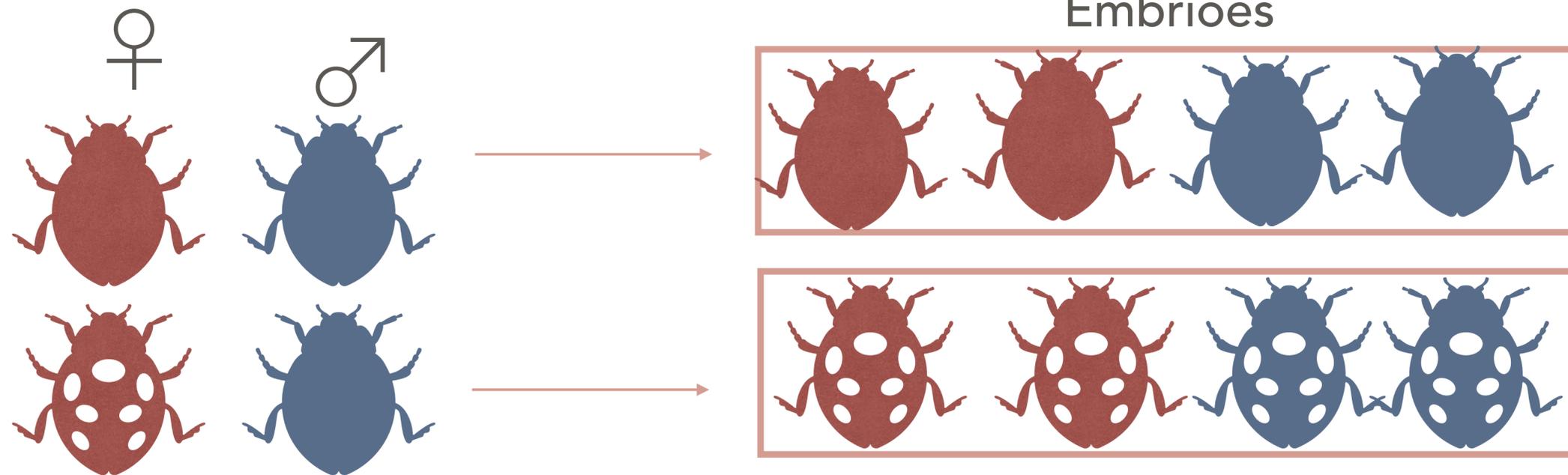
Wolbachia - the puppet master

Manipula a reprodução dos infectados!!!



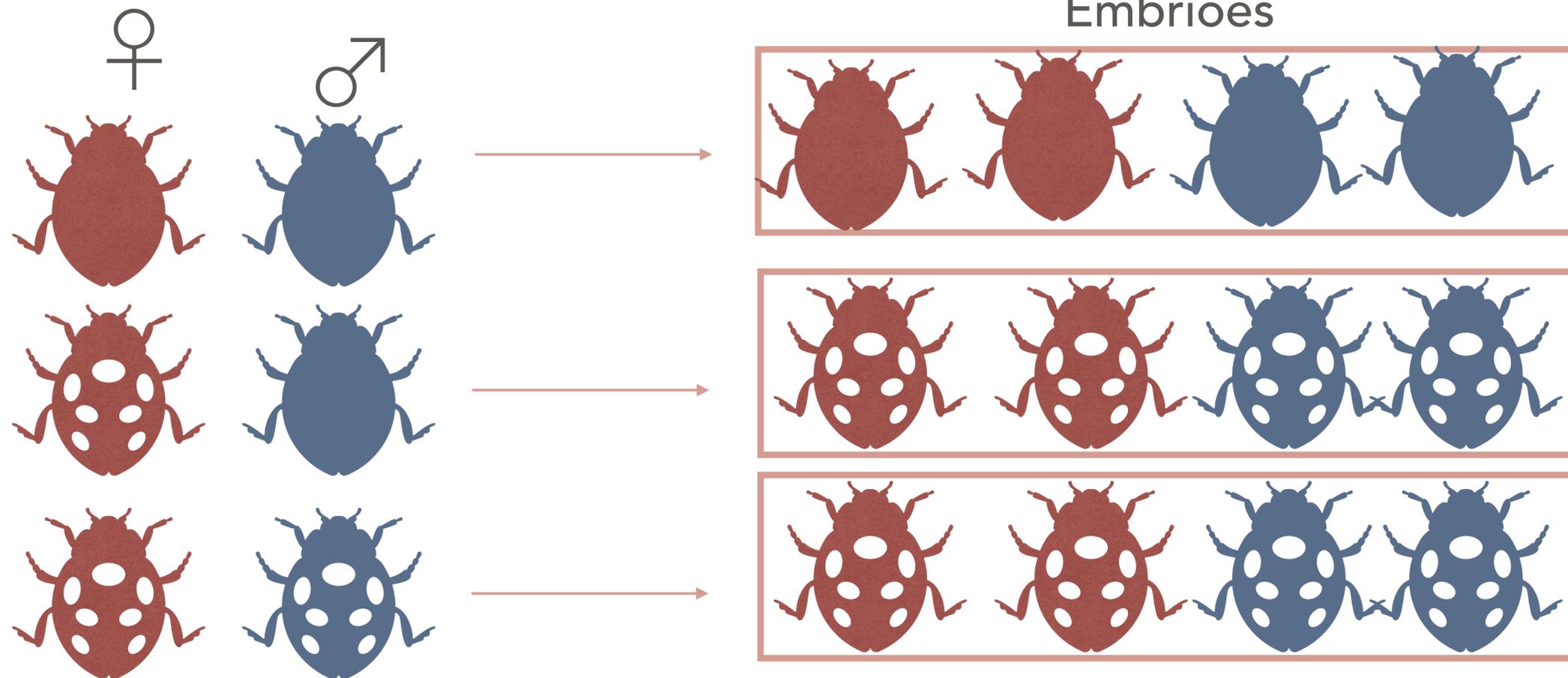
Wolbachia - the puppet master

Manipula a reprodução dos infectados!!!



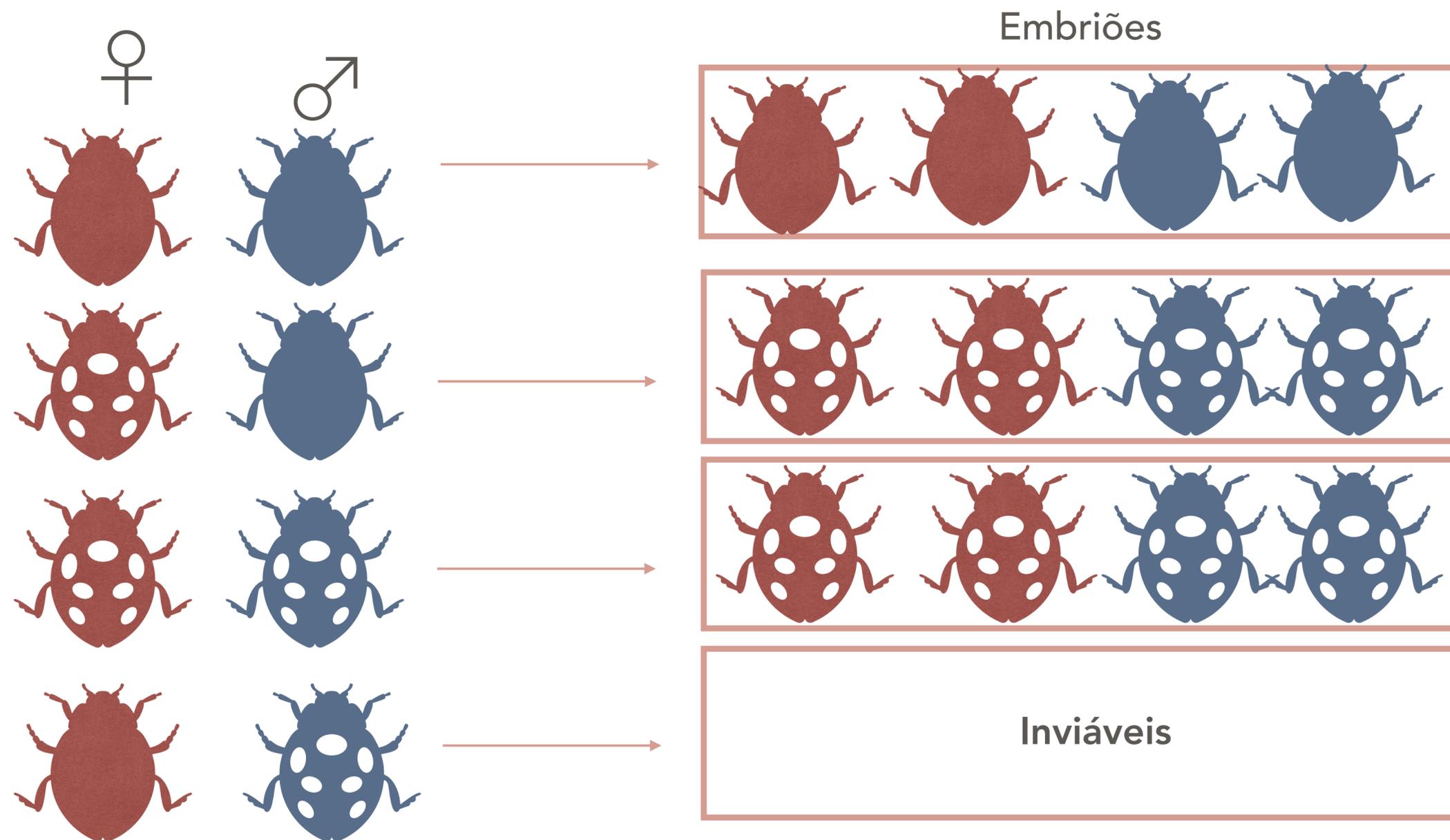
Wolbachia - the puppet master

Manipula a reprodução dos infectados!!!



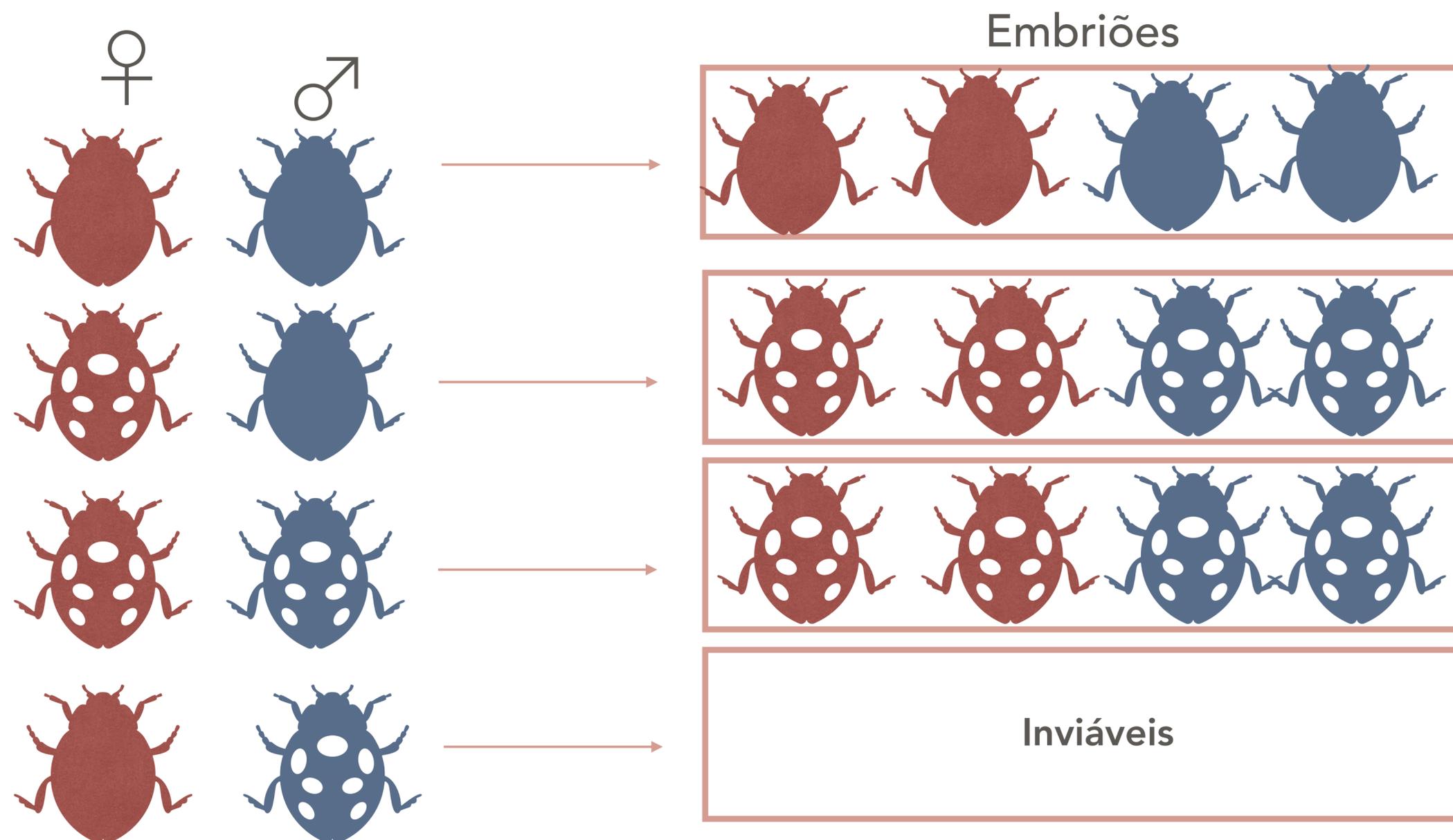
Wolbachia - the puppet master

Manipula a reprodução dos infectados!!!



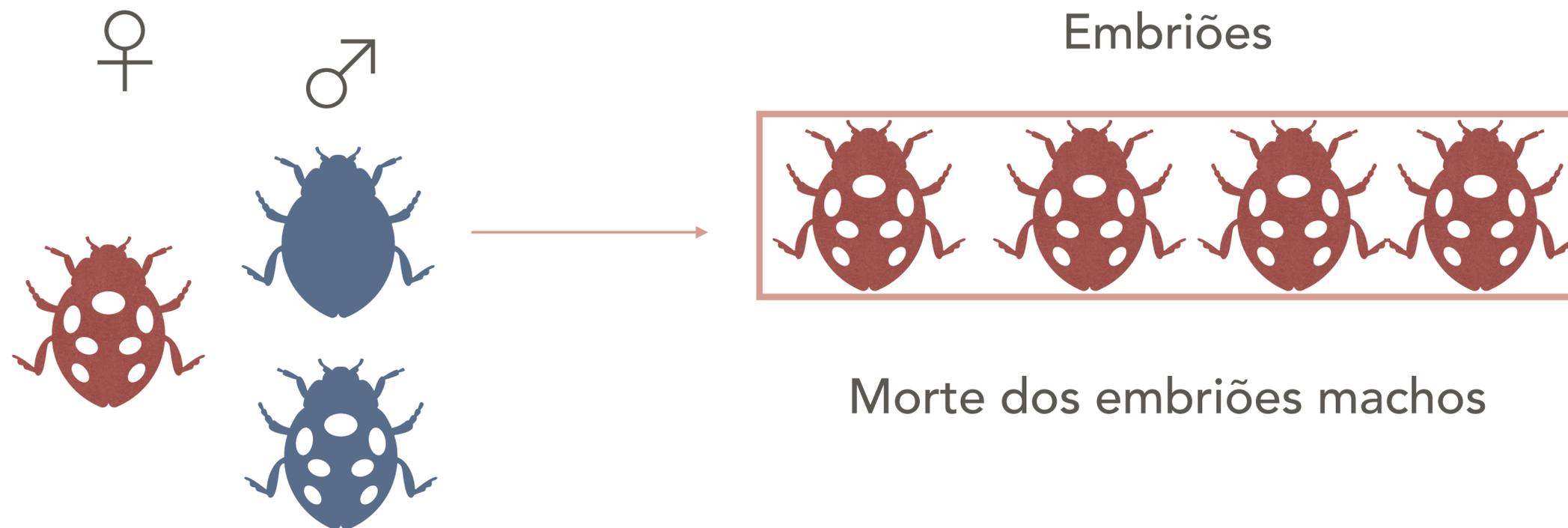
Wolbachia - the puppet master

Manipula a reprodução dos infectados!!!



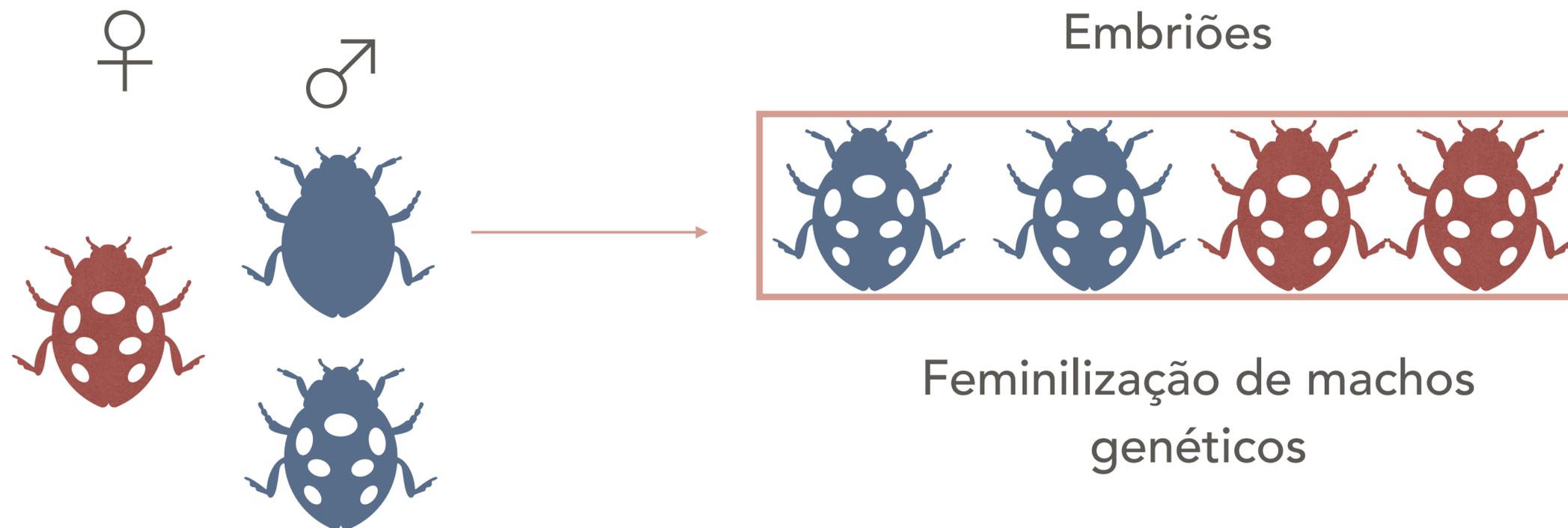
Wolbachia - the puppet master

Manipula a reprodução dos infectados!!!



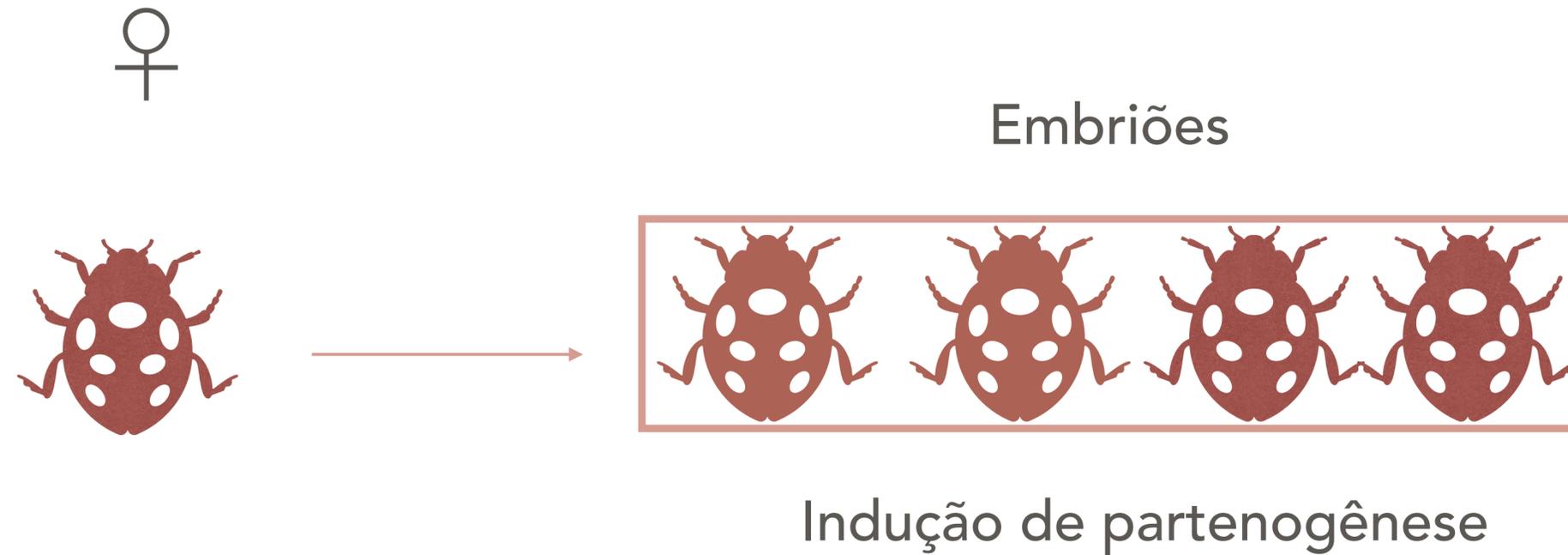
Wolbachia - the puppet master

Manipula a reprodução dos infectados!!!



Wolbachia - the puppet master

Manipula a reprodução dos infectados!!!

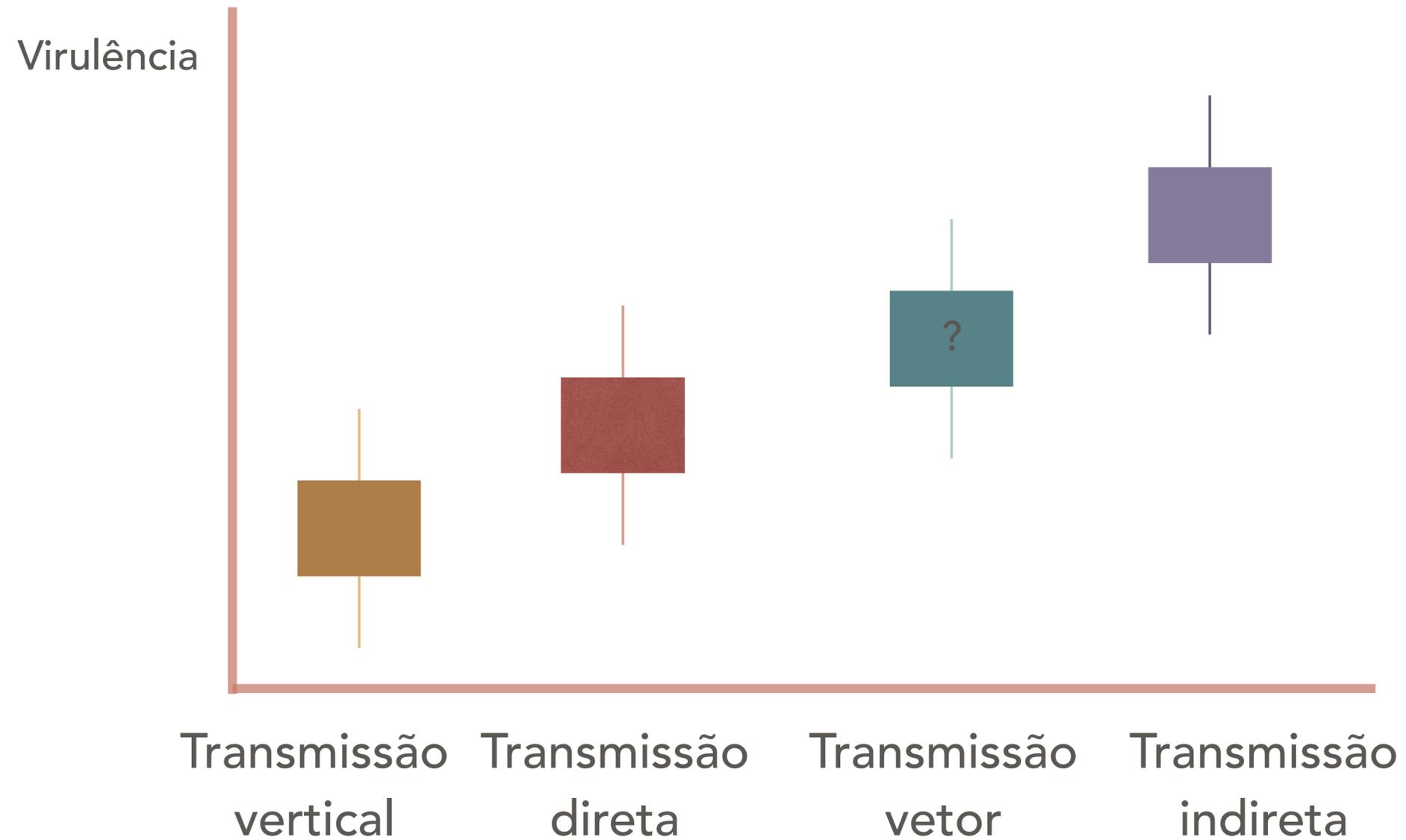


Wolbachia - Controle da dengue

Testes preliminares parecem bastante promissores!

- Mosquitos infectados por *Wolbachia* tem uma custo maior para se reproduzir o que diminui o tamanho populacional
- Competição entre *Wolbachia* e vírus da dengue leva a uma diminuição da frequência do vírus

Evolução de virulência



Evolução sexo

Evolução sexo

**Reprodução
sexuada**

**Reprodução
assexuada**

Evolução sexo

**Reprodução
sexuada**

**Reprodução
assexuada**

Vamos debater????

O custo do macho

O custo do macho



MANSPLAIN
THE MAGAZINE FOR WOMEN, WRITTEN BY MEN

The *truth* about sexism

Confused by politics?
Find out what to think

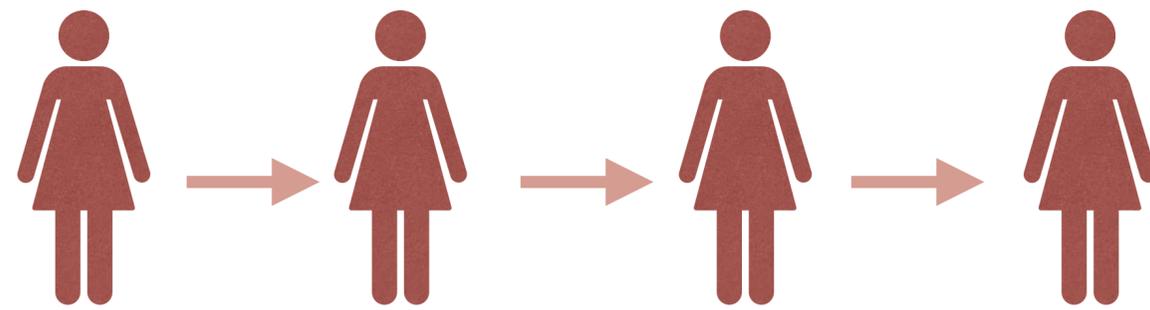
EVERYTHING YOU KNOW IS WRONG

but don't worry your pretty little head about it

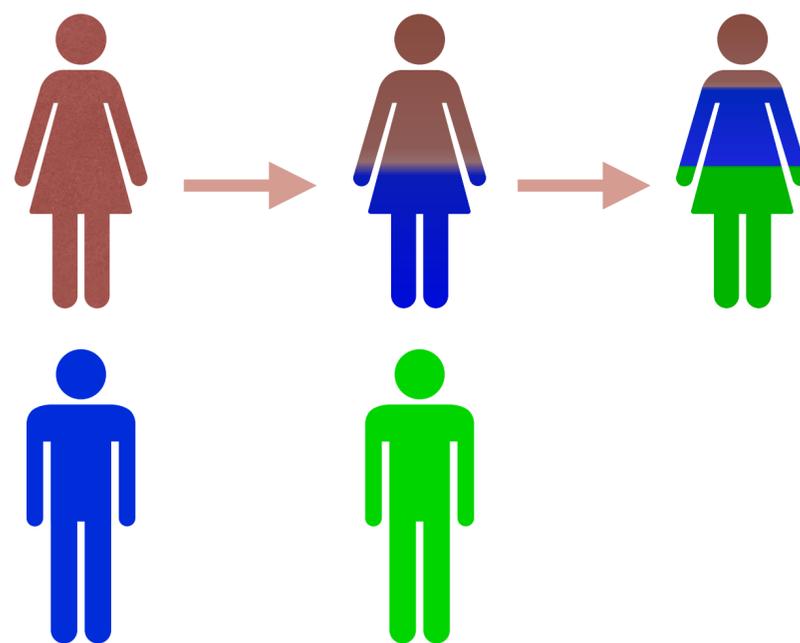
158 facts & opinions you *must* listen to

NEW from the makers of *Actually*, the monthly look at ethics in games journalism

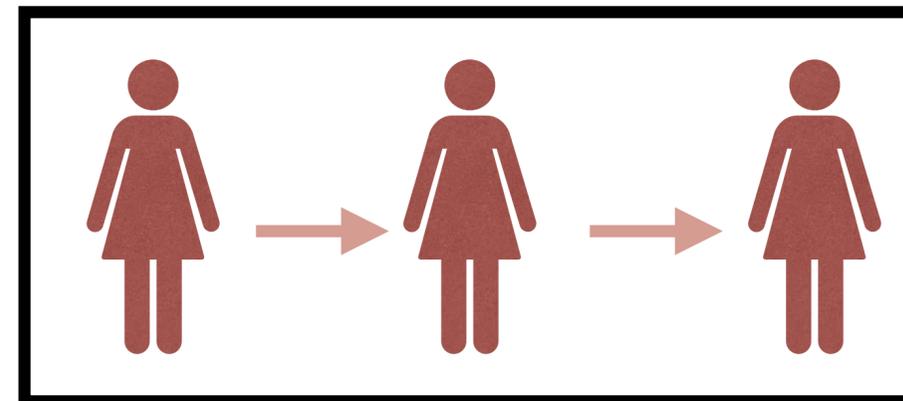
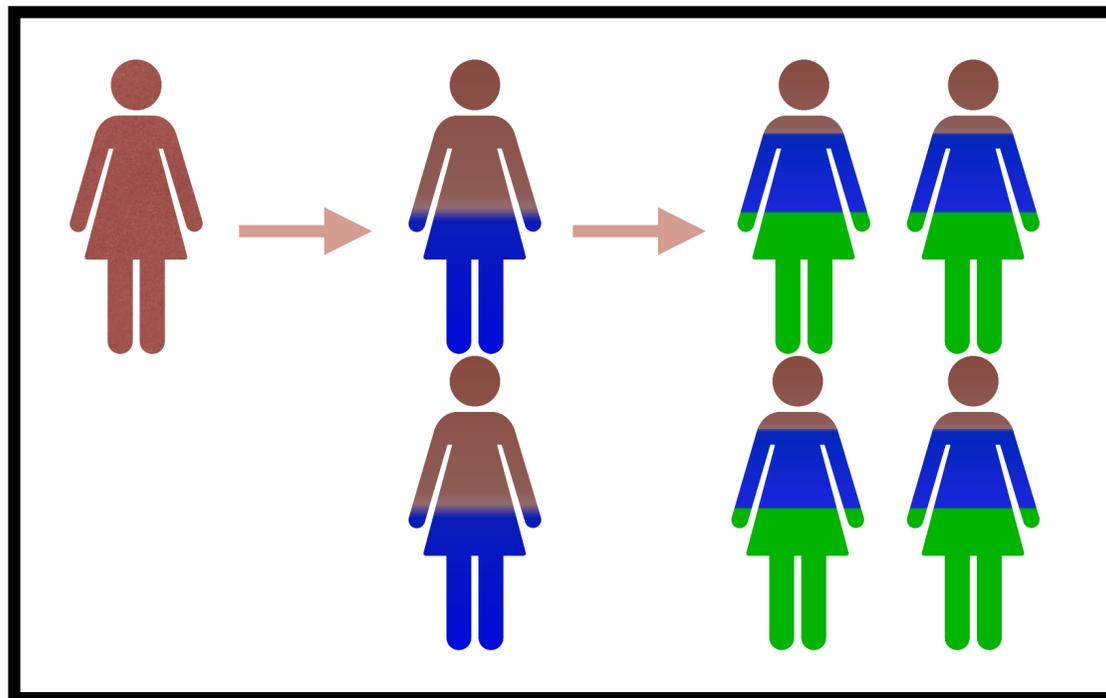
O paradoxo do sexo



O paradoxo do sexo

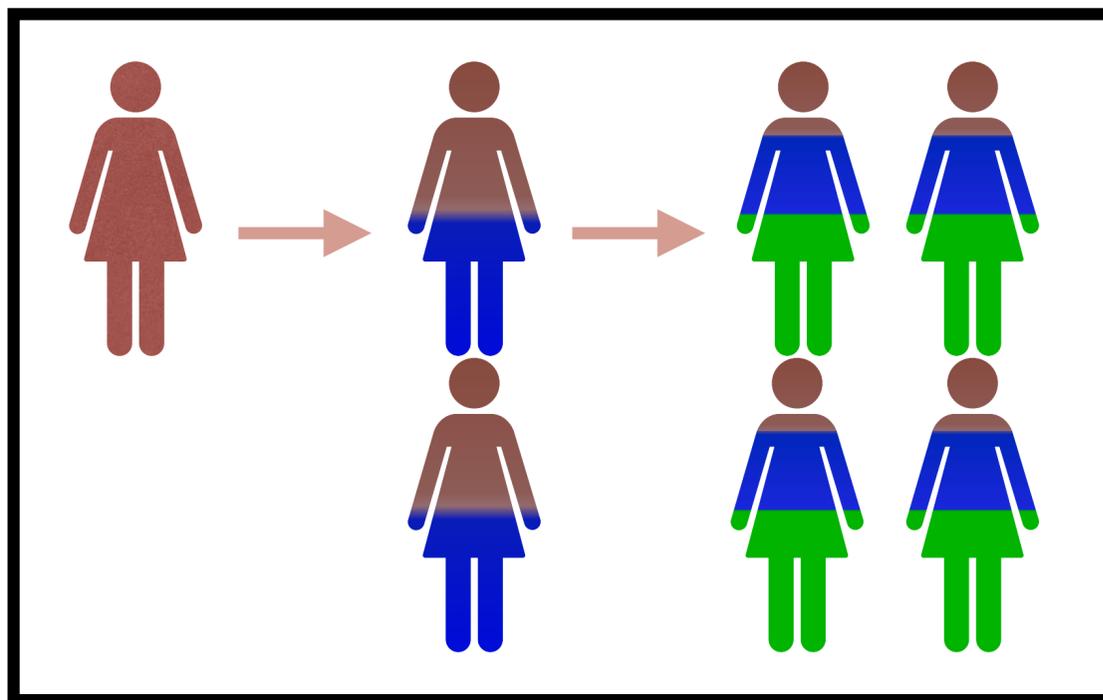


O paradoxo do sexo

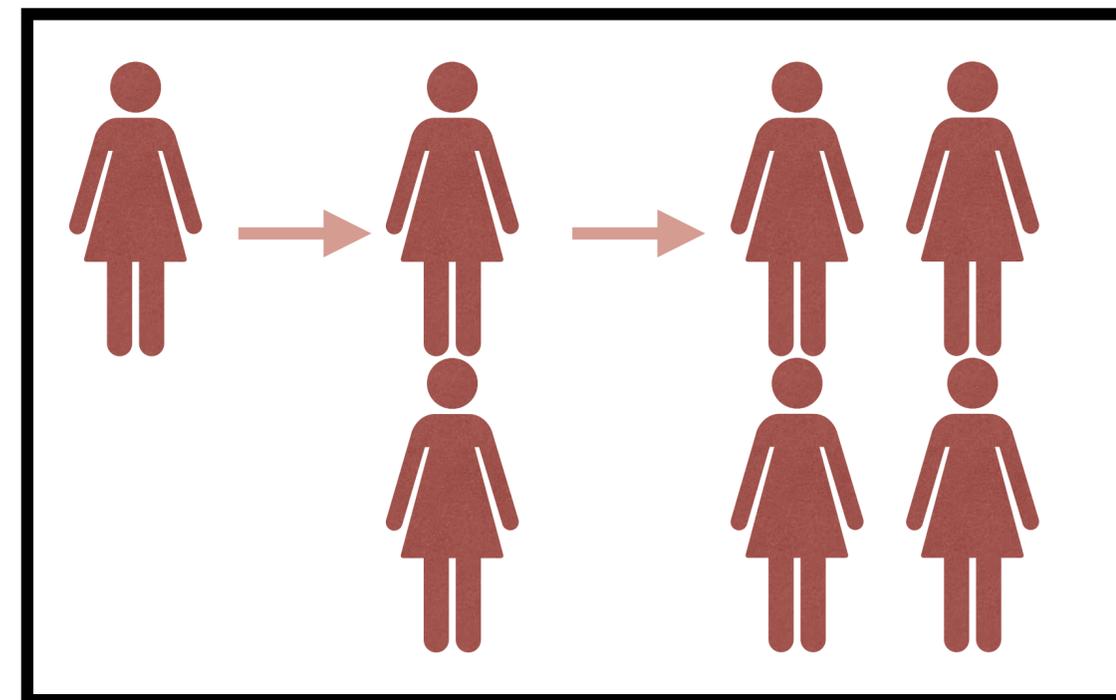


O paradoxo do sexo

Reprodução sexual

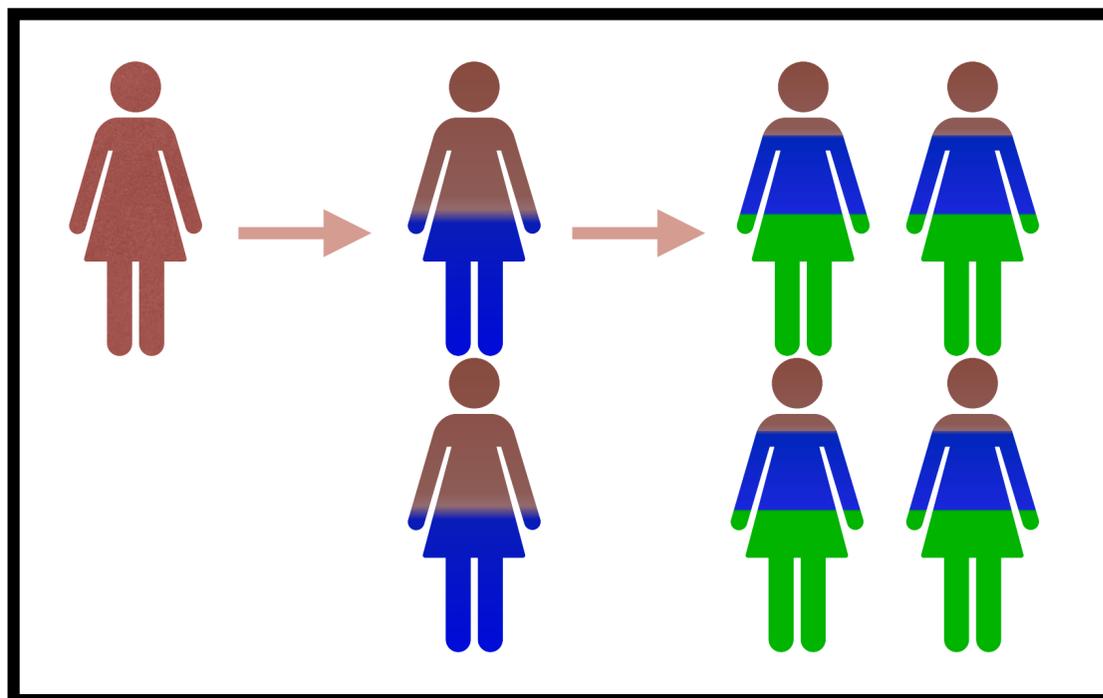


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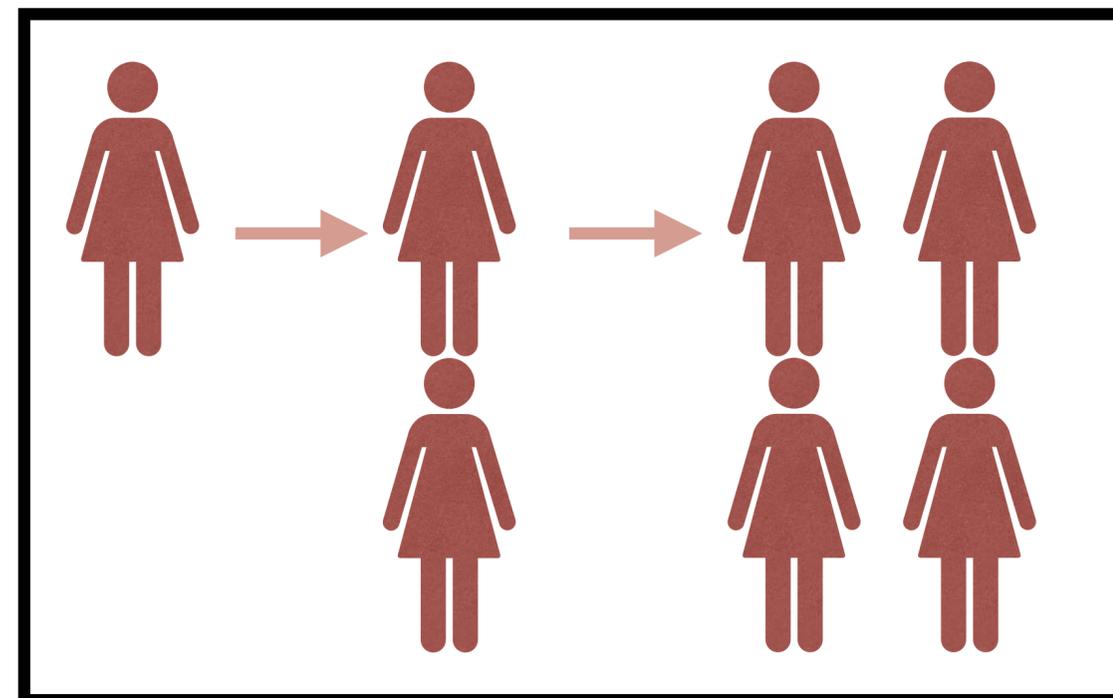


O paradoxo do sexo

Reprodução sexual



Reprodução assexual



O paradoxo do sexo

Alelo da anemia falciforme



O paradoxo do sexo

Alelo da anemia falciforme



O paradoxo do sexo

Alelo da anemia falciforme



SS



Ss

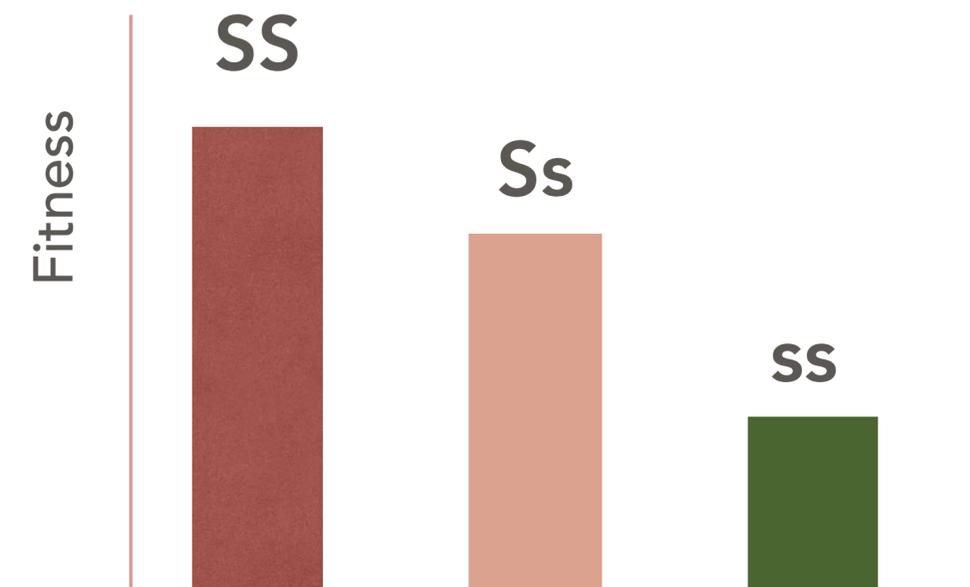


ss



O paradoxo do sexo

Alelo da anemia falciforme



O paradoxo do sexo

Alelo da anemia falciforme



SS



Ss



ss



O paradoxo do sexo

Alelo da anemia falciforme



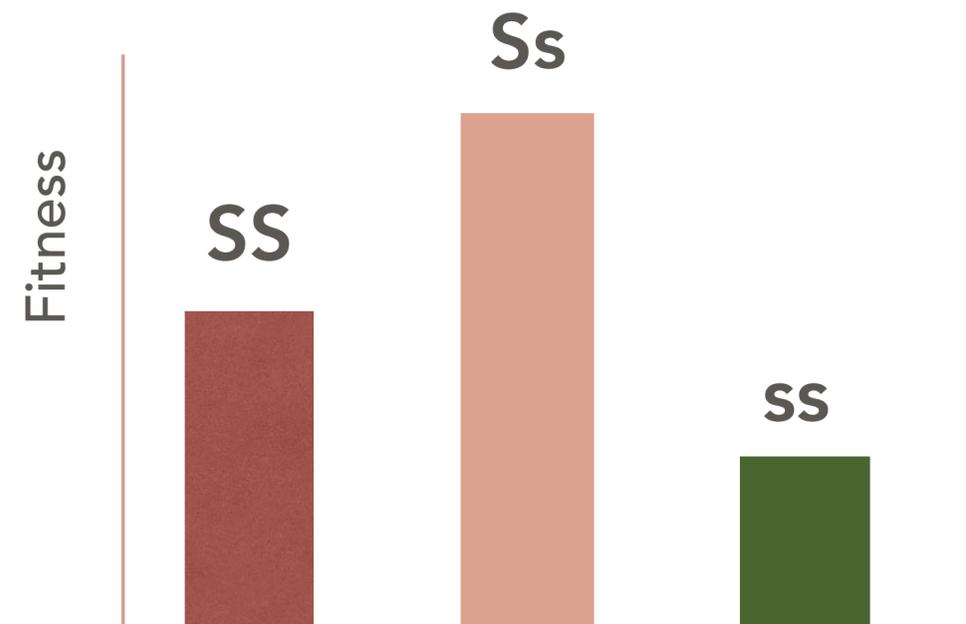
SS



Ss

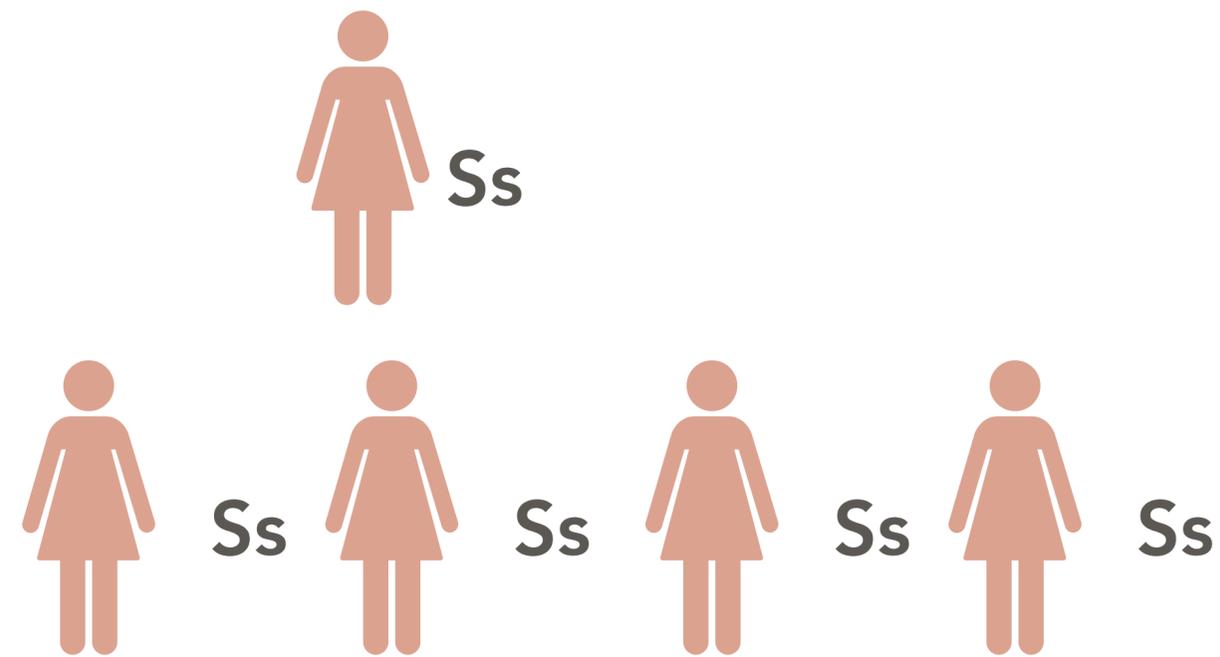


ss



O paradoxo do sexo

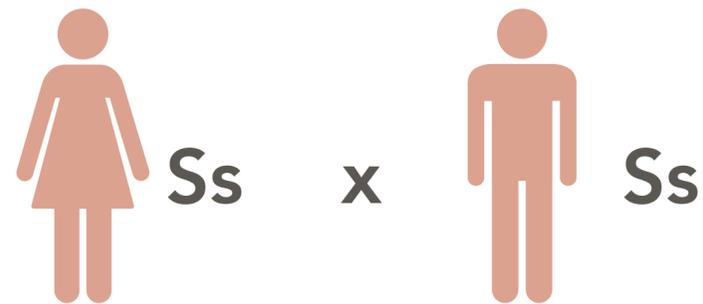
Alelo da anemia falciforme



Custo da segregação

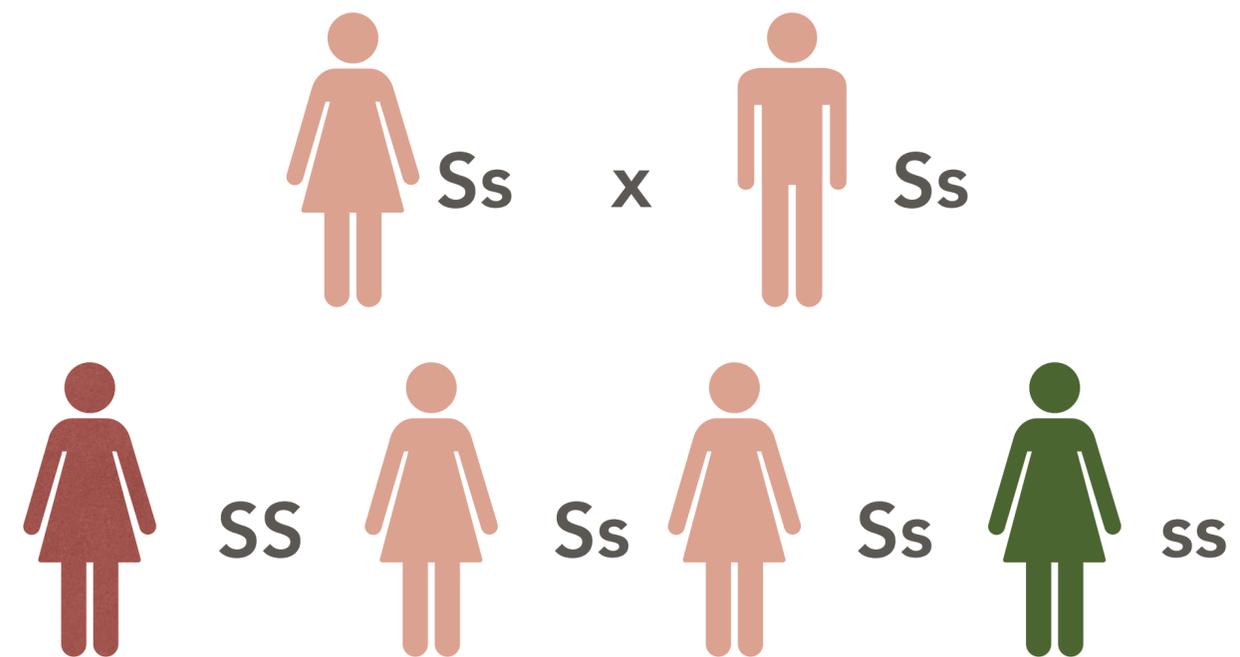
O paradoxo do sexo

Alelo da anemia falciforme



O paradoxo do sexo

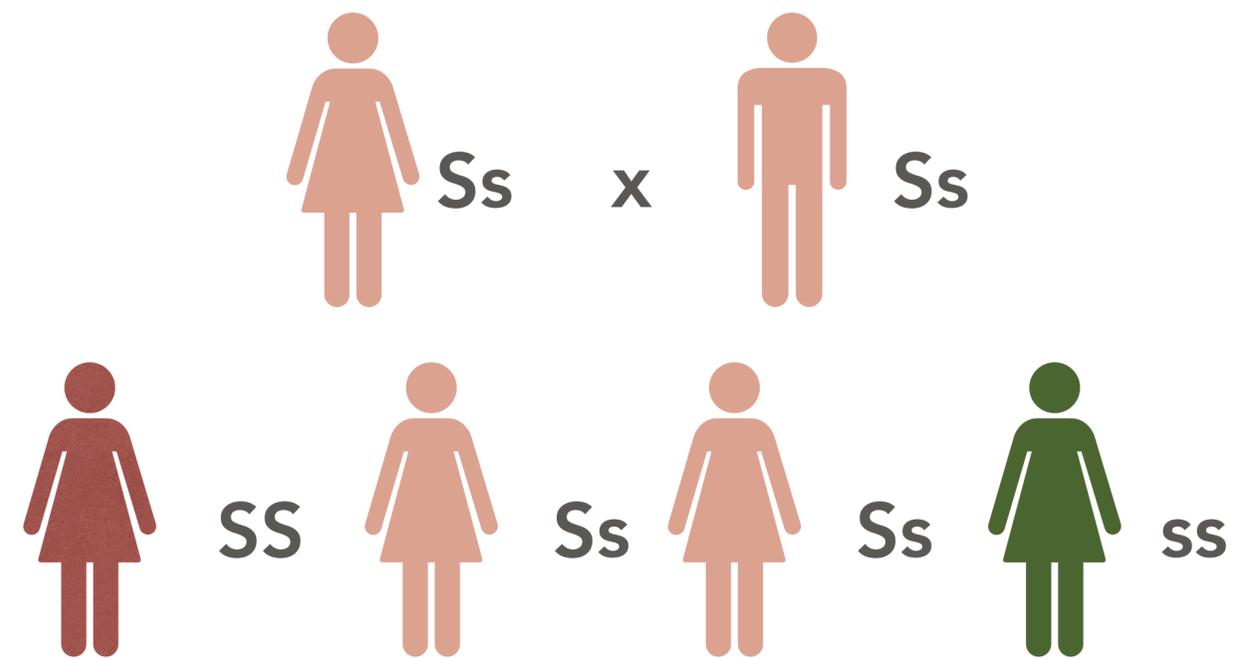
Alelo da anemia falciforme



Custo da segregação

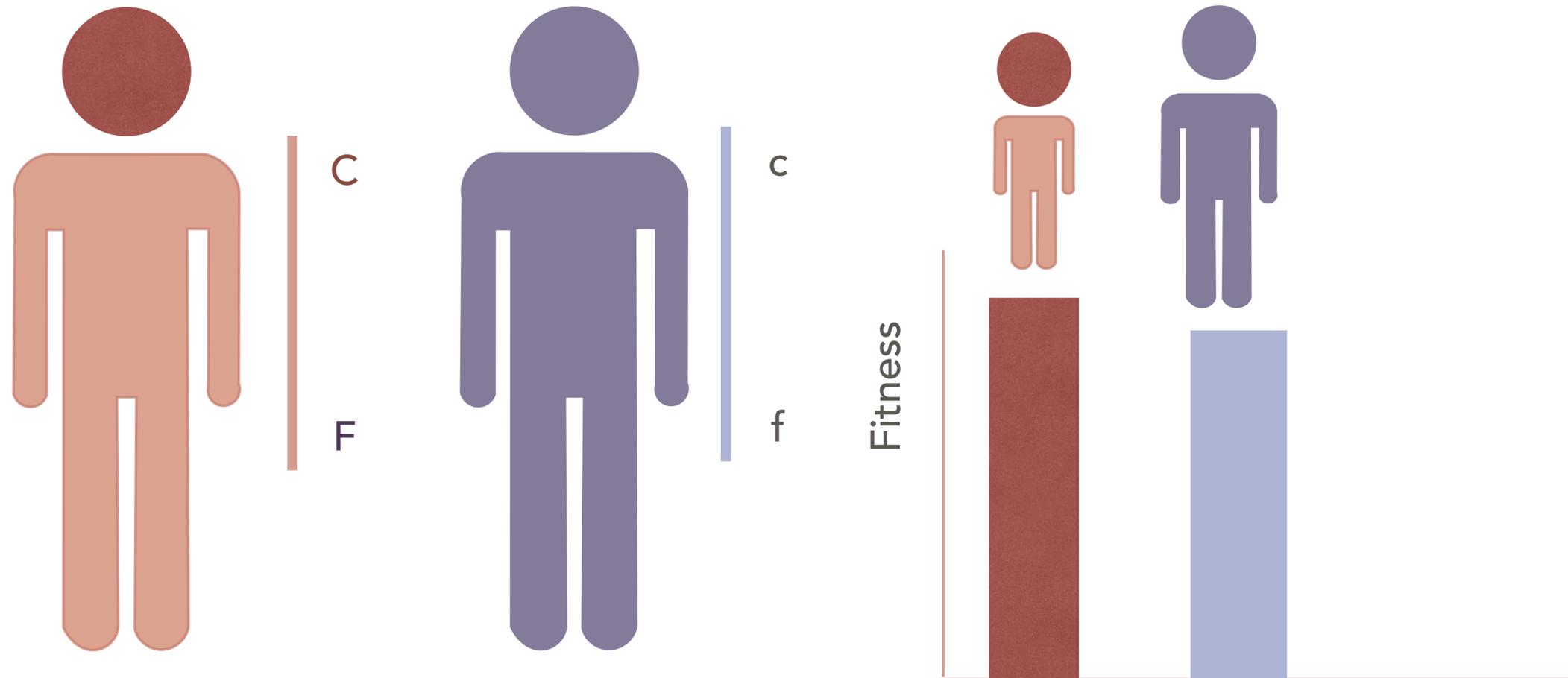
O paradoxo do sexo

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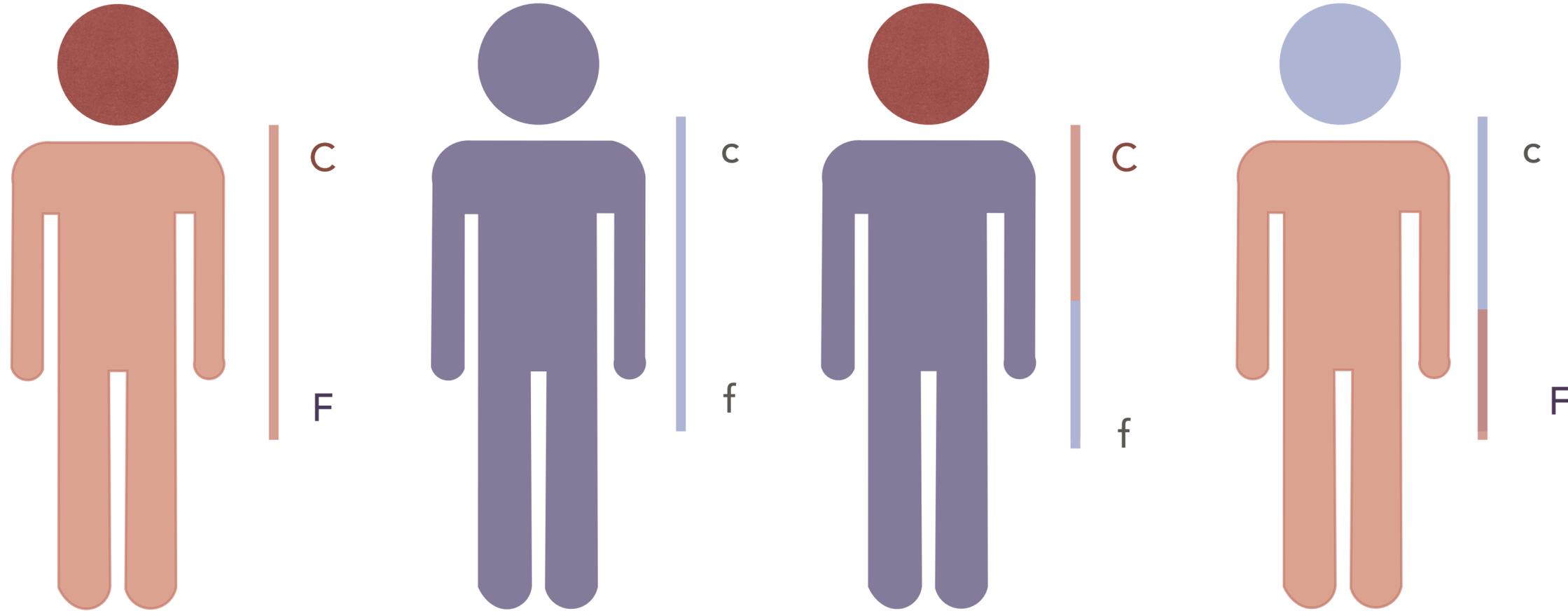
Custo da segregação

O paradoxo do sexo



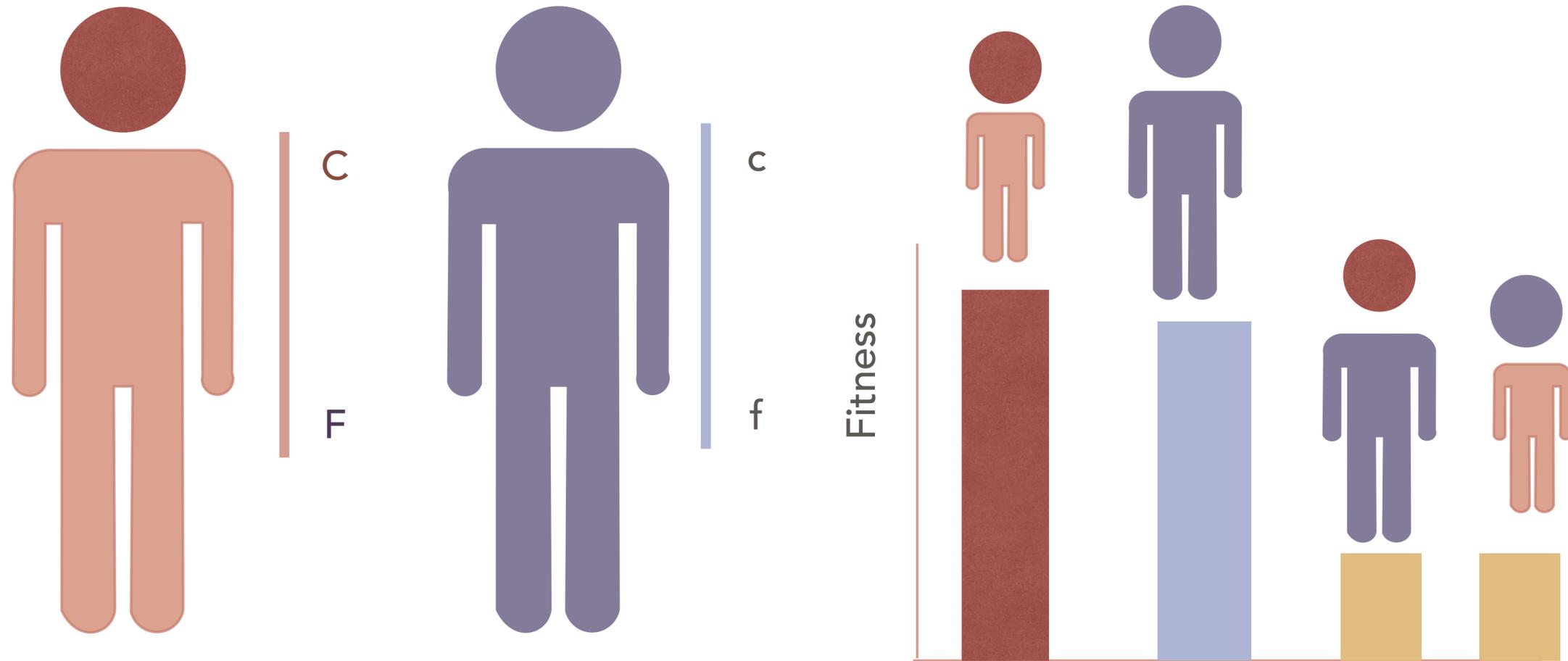
Custo da recombinação

O paradoxo do sexo



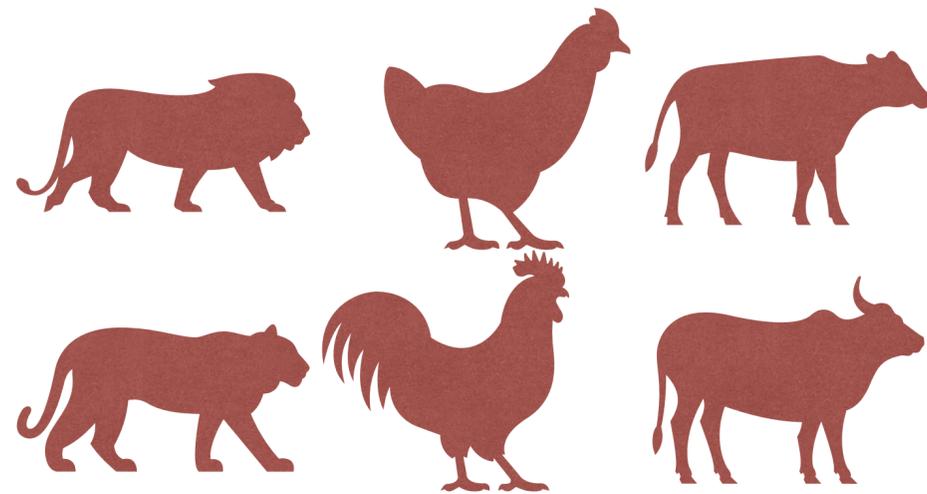
Custo da recombinação

O paradoxo do sexo



Custo da recombinação

O paradoxo do sexo



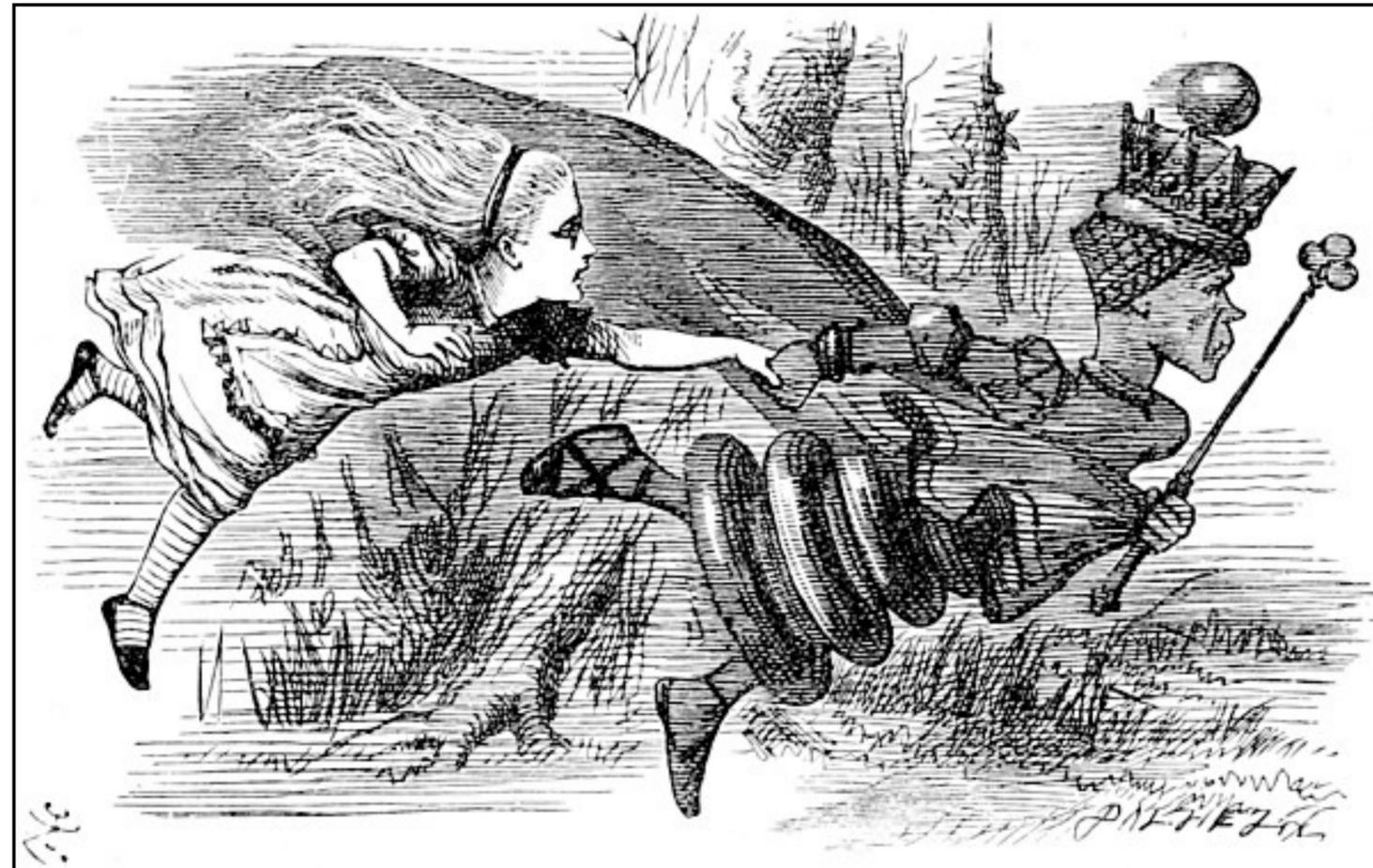
Porque raios existe sexo?????

O paradoxo do sexo

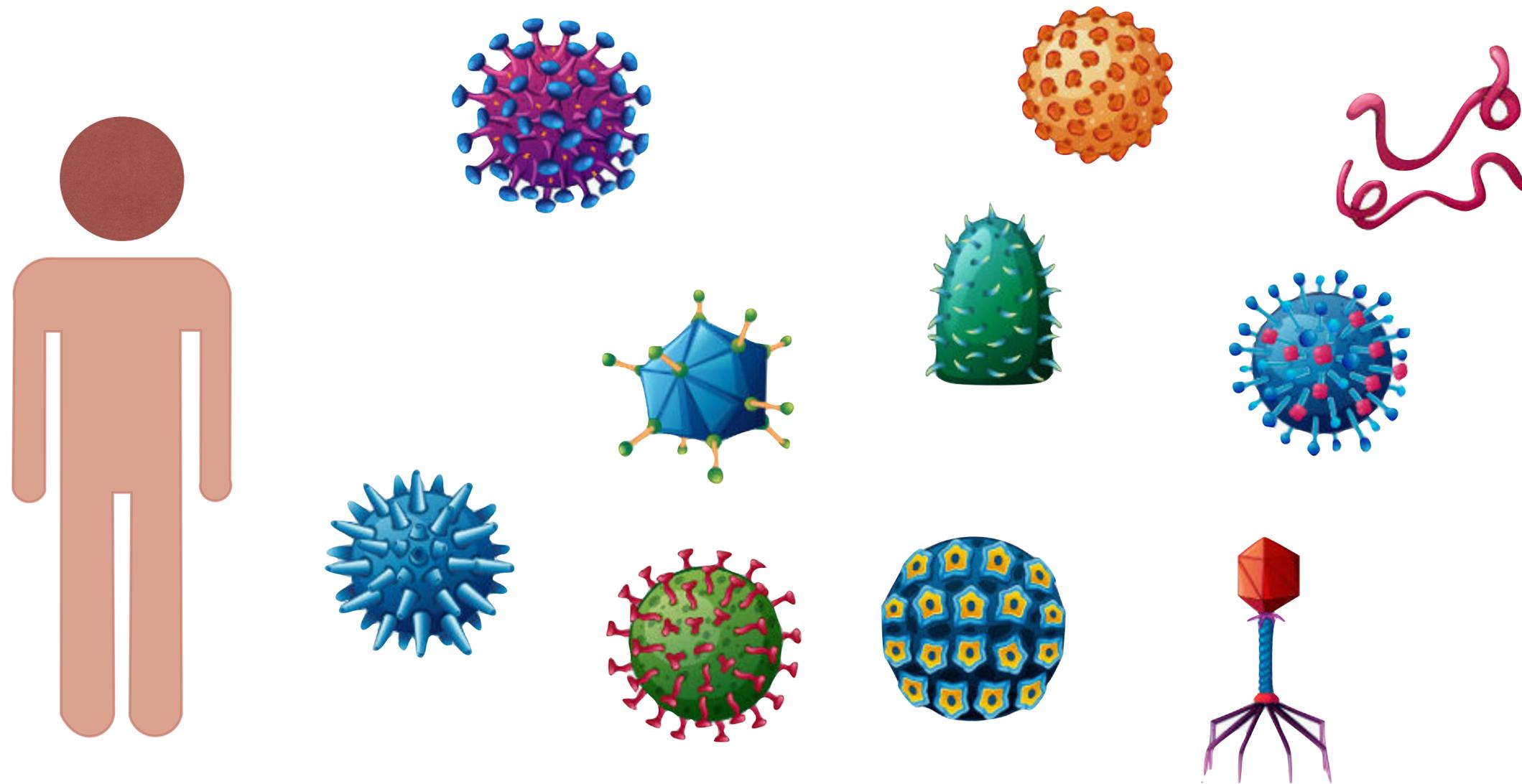
99% dos eucariotos se reproduzem sexuadamente!

O paradoxo do sexo

99% dos eucariotos se reproduzem sexuadamente!



Pressões seletivas mudando o tempo inteiro



Sofre mais quem tem o genótipo mais
comum

Science

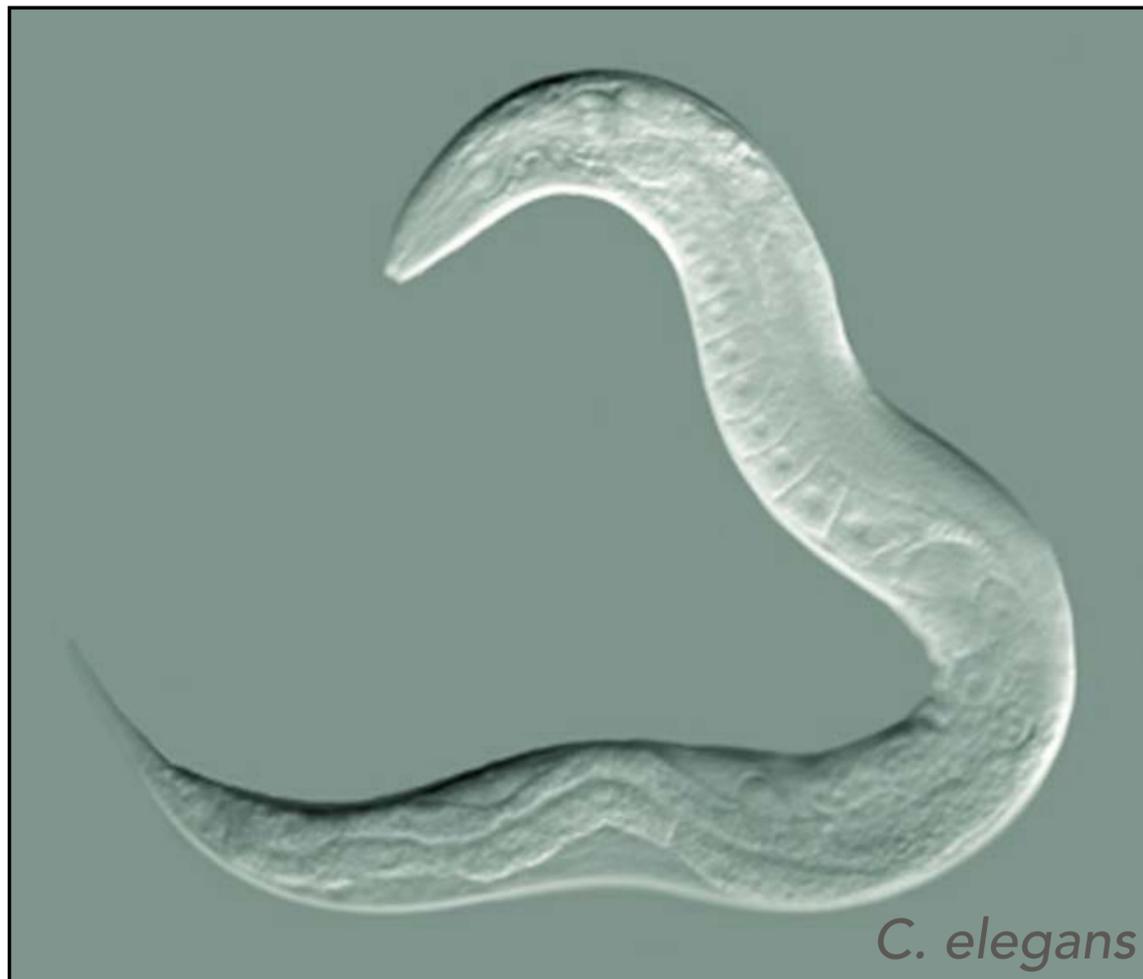
REPORT

Running with the Red Queen: Host-Parasite Coevolution Selects for Biparental Sex

Levi T. Morran^{*}, Olivia G. Schmidt, Ian A. Gelarden, Raymond C. Parrish II, Curtis M. Lively

+ See all authors and affiliations

Evolução do sexo



POPULAÇÕES ASSEXUADAS

POPULAÇÕES SEXUADAS

Evolução do sexo



Serratia marcescens



Evolução do sexo



Serratia marcescens



Evolução do sexo

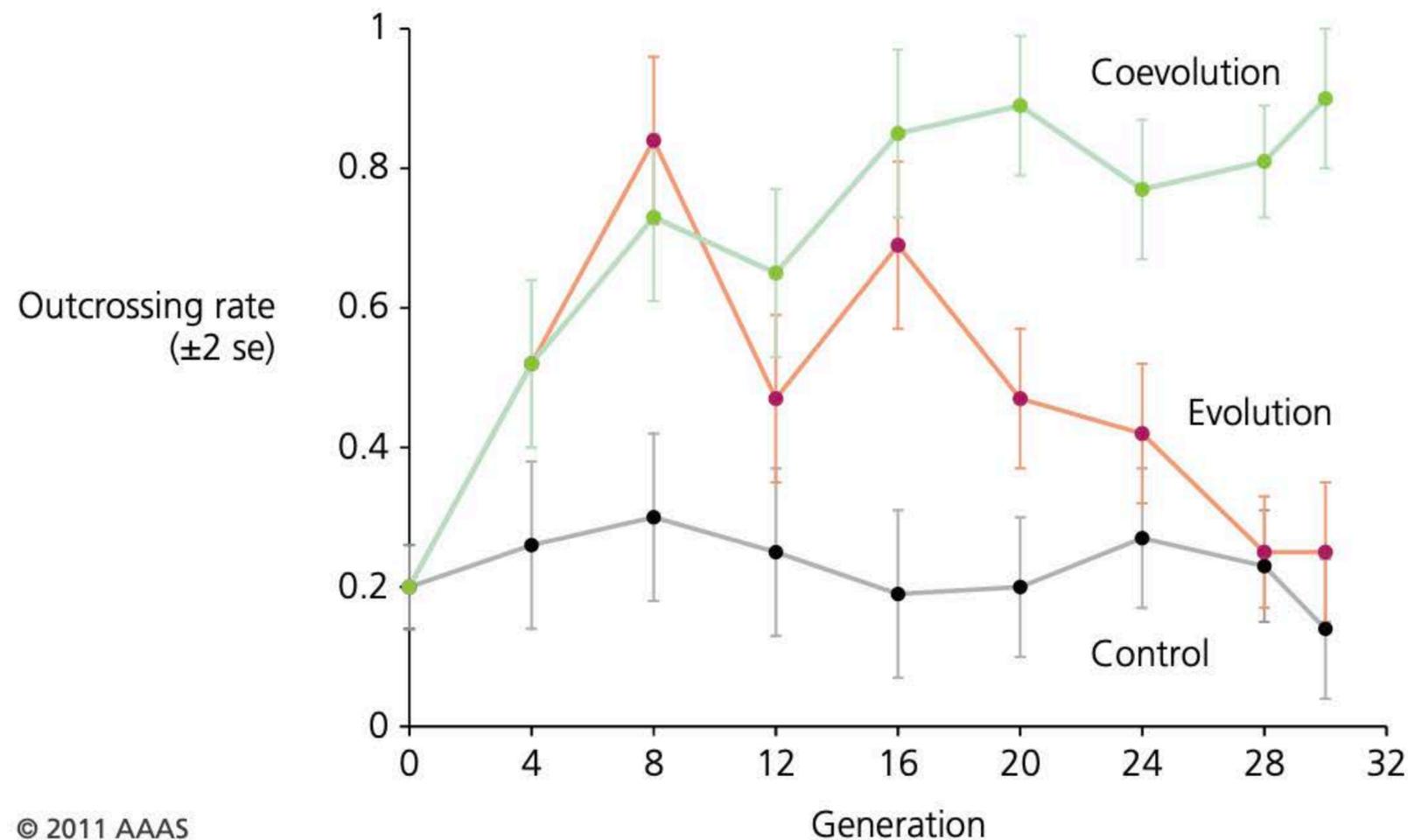


Figure 8.29 Pathogens select for outcrossing in *C. elegans* Frequency of outcrossing in *C. elegans* populations evolving by natural selection in the lab. *Control* populations were exposed to heat-killed pathogenic bacteria, *evolution* populations to pathogenic bacteria from a stock population, and *coevolution* populations to pathogens under selection for their ability to infect and kill the worms. From Morran et al. (2011).

From "Running with the Red Queen: host-parasite coevolution selects for biparental sex." *Science* 333: 216–218. Reprinted with permission from AAAS.

Evolução do sexo

**Reprodução
sexuada**

**Compensa em um
mundo com muitos
inimigos**

Conclusões

- Interações antagonistas são (foram) extremamente importantes na história evolutiva
- Evolução da virulência depende do modo de vida do parasita
- Entender coevolução é importante para qualquer pessoa que trabalhe com saúde humana