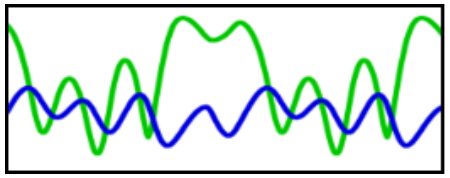

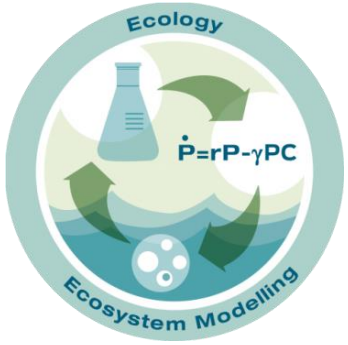

Predator coexistence through emergent fitness equalization

Ellen van Velzen

Ecology and Ecosystem Modelling, University of Potsdam

MPDEE, 28-04-2021

Annu. Rev. Ecol. Syst. 2000. 31:343–66

MECHANISMS OF MAINTENANCE OF SPECIES DIVERSITY

Peter Chesson
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→ coexistence of consumers competing over the same resources?

Competitive exclusion

The Competitive Exclusion Principle

An idea that took a century to be born has implications in ecology, economics, and genetics.

Garrett Hardin

Competitive exclusion

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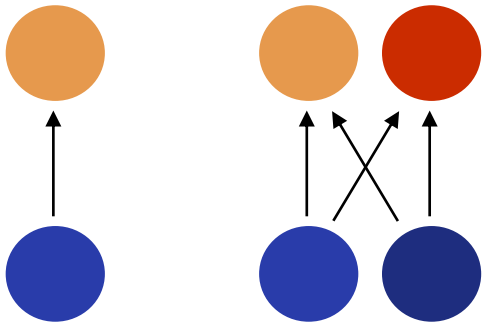

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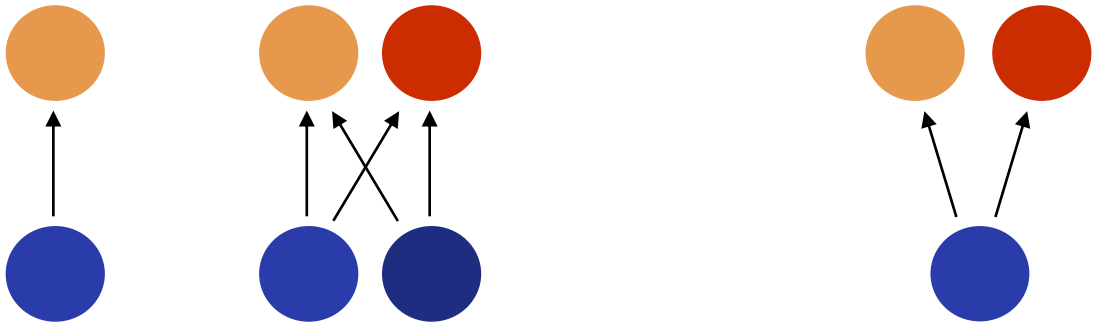

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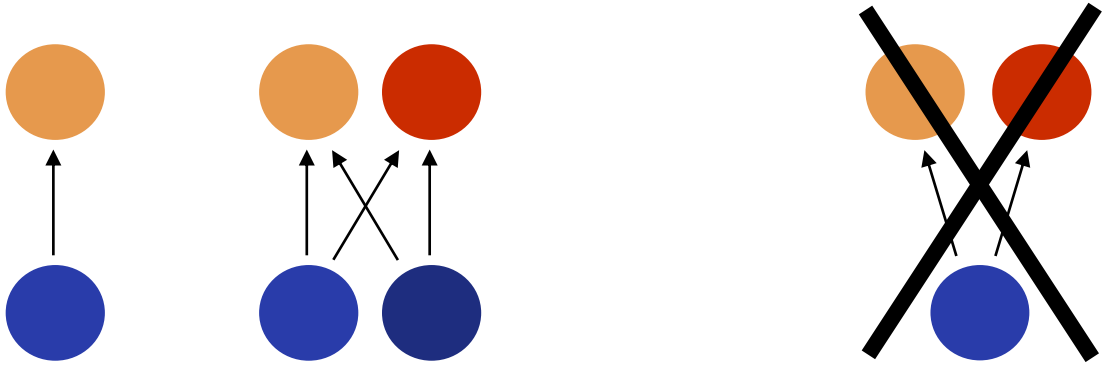
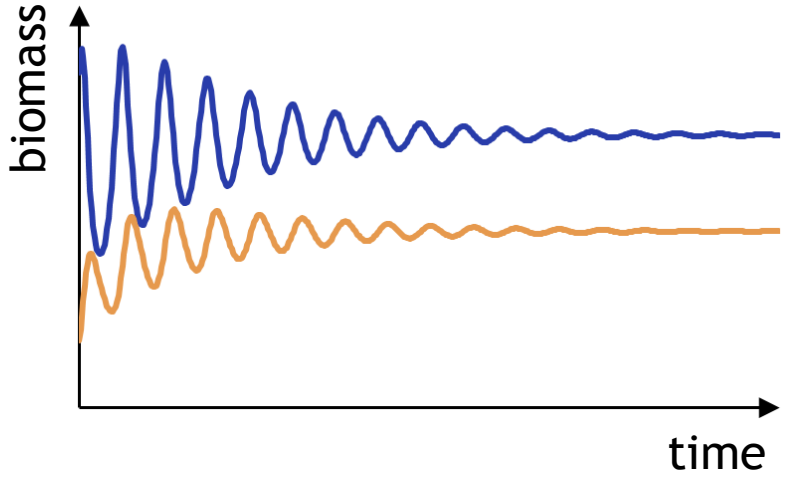


Competitive exclusion: the R^* rule



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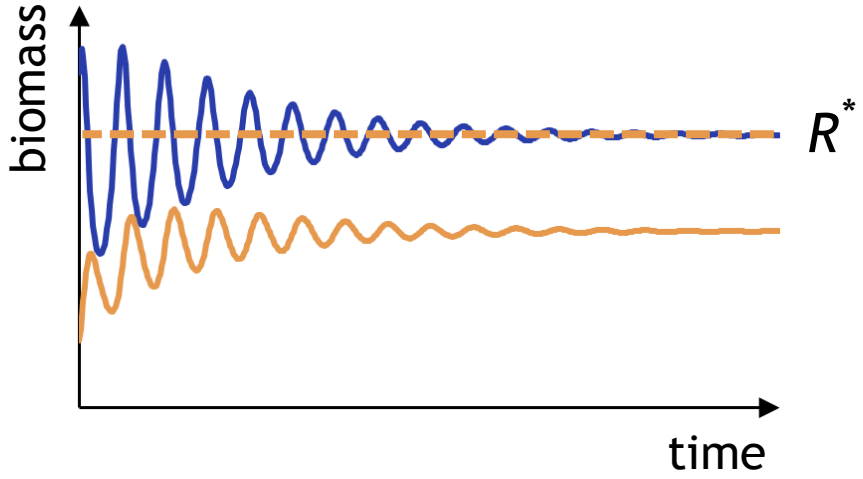

*R**: lowest prey biomass on which predator can survive

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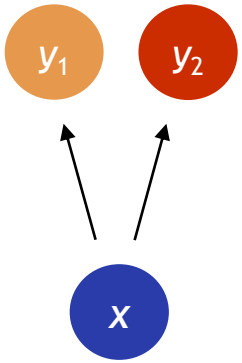
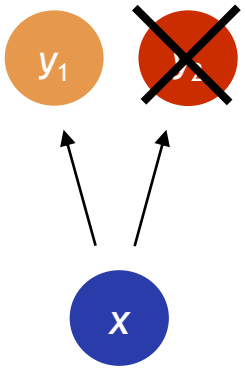
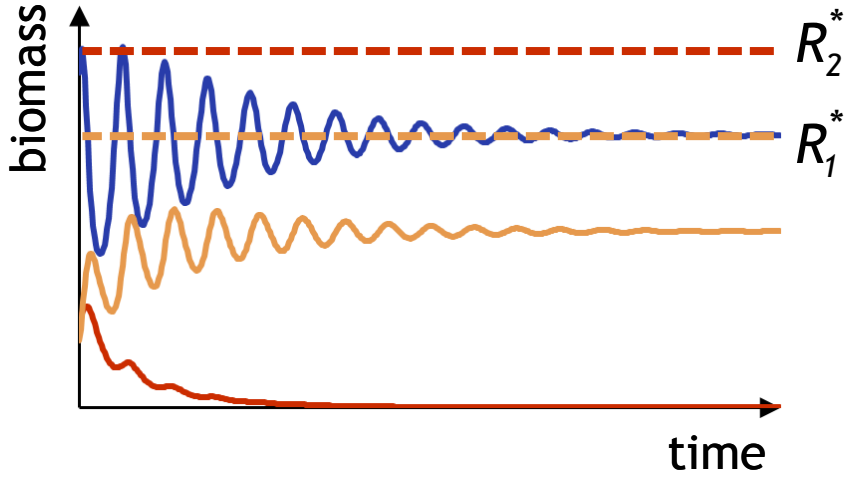


R^*: lowest prey biomass on which predator can survive

Competitor with lower R^* wins, other goes extinct

Competitive exclusion: the R^* rule





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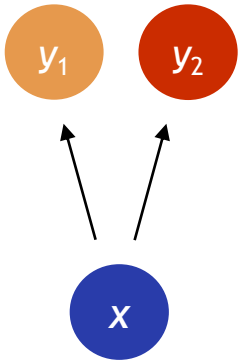

$$\frac{dx}{dt} = rx - a_1 x y_1 - a_2 x y_2$$

$$\frac{dy_1}{dt} = e_1 a_1 x y_1 - d_1 y_1$$

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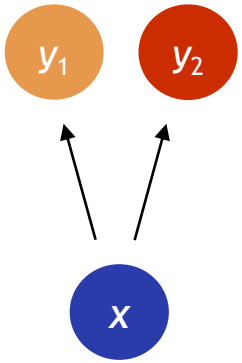

$$\frac{dx}{dt} = rx - a_1 x y_1 - a_2 x y_2$$

$$\frac{dy_1}{dt} = e_1 a_1 x y_1 - d_1 y_1 \quad \Rightarrow \quad R_1^* = x^* = \frac{d_1}{e_1 a_1}$$

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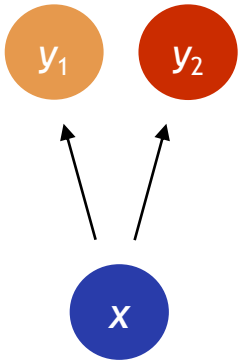

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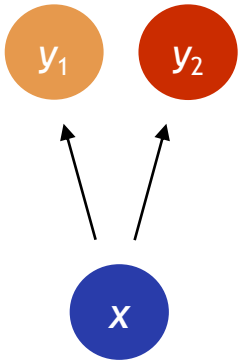

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To get coexistence: $R_1^* = R_2^* \quad \Rightarrow \quad \frac{d_1}{e_1 a_1} = \frac{d_2}{e_2 a_2}$

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self-limitation in predators

spatial variability in prey biomass

temporal variability in prey biomass

differences in stoichiometry

chaotic dynamics

mutualism between predators

niche differentiation within prey

What if...

...predators could coexist because they **do** have the same R^*?

What if...

...predators could coexist because they **do** have the same *R**?

$$\frac{d_1}{e_1 a_1} = \frac{d_2}{e_2 a_2}$$

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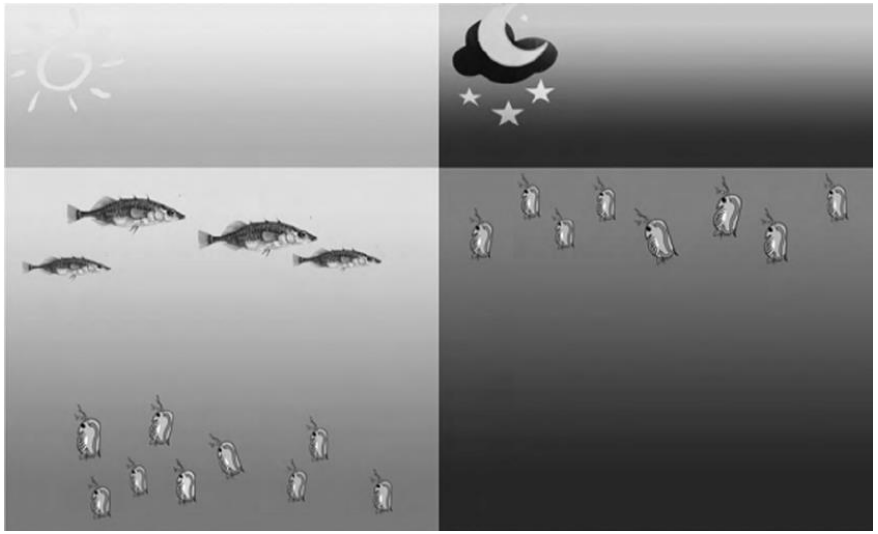

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"Attack rates": how well can predators capture the prey

- Prey defense traits affect the attack rates

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- Defense traits can change adaptively over time
  - rapid evolution
  - inducible defenses

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"Attack rates": how well can predators capture the prey

- Prey defense traits affect the attack rates
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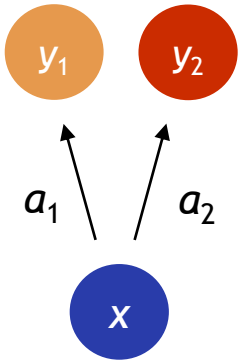
→ R_1^* and R_2^* change over time

Can defense adaptation in prey **equalize** R_1^* and R_2^* and thereby **enable coexistence**?

Coexistence through prey adaptation?



$$\frac{dx}{dt} = rx - a_1xy_1 - a_2xy_2$$

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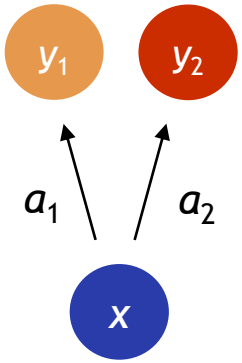

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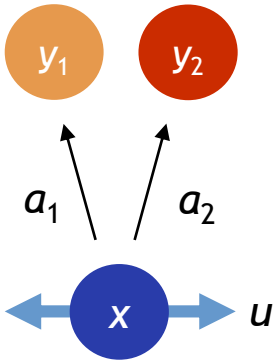
To get coexistence: $\frac{d_1}{e_1a_1} = \frac{d_2}{e_2a_2}$ ➡ $a_1 = a_2$

Coexistence through prey adaptation?



$$\frac{dx}{dt} = rx - a_1 x y_1 - a_2 x y_2$$

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$$\frac{du}{dt} = v \frac{\partial}{\partial u}\left(\frac{1}{x}\frac{dx}{dt}\right)$$

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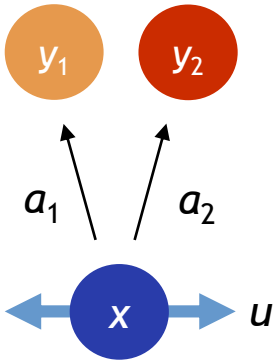

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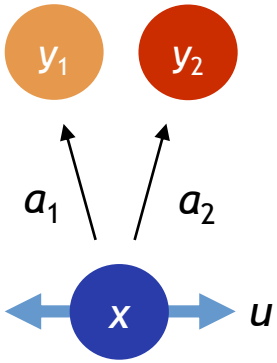
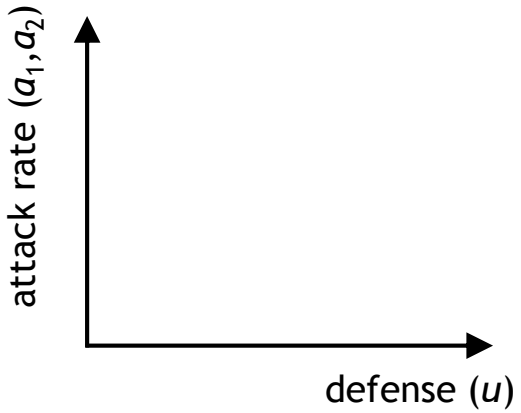
$$\frac{dy_2}{dt} = e a_2 x y_2 - d y_2$$

$$\frac{du}{dt} = v \frac{\partial}{\partial u}\left(\frac{1}{x}\frac{dx}{dt}\right) = v\left(\frac{\partial r}{\partial u} - \frac{\partial a_1}{\partial u} y_1 - \frac{\partial a_2}{\partial u} y_2\right)$$

Coexistence through prey adaptation?





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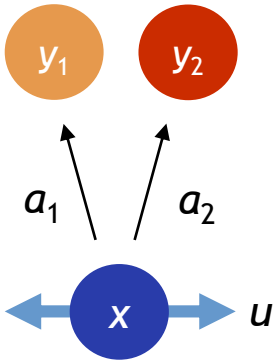

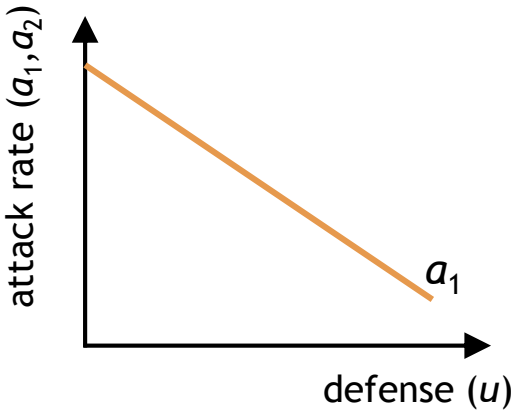

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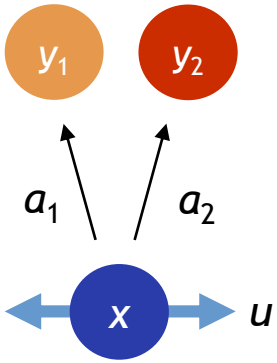

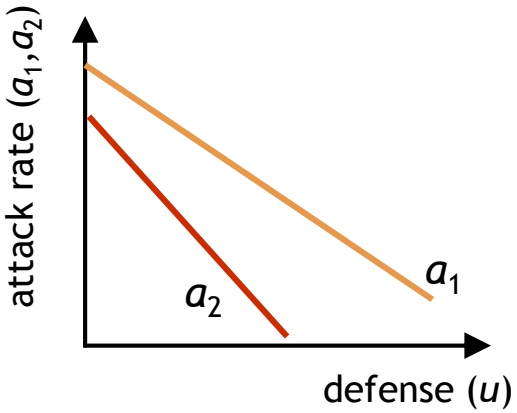

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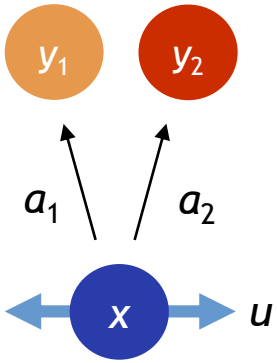

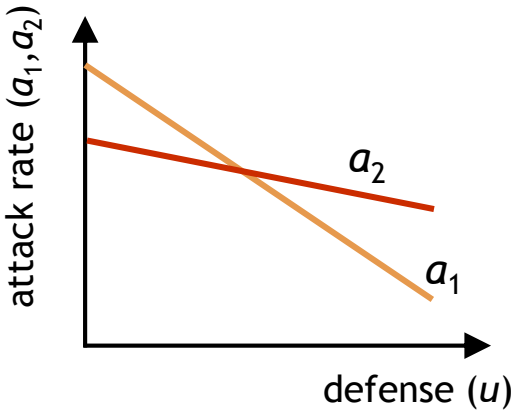

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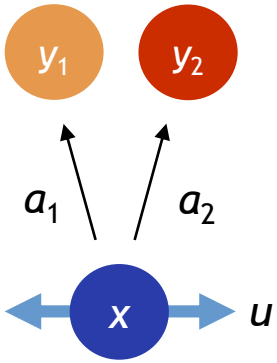
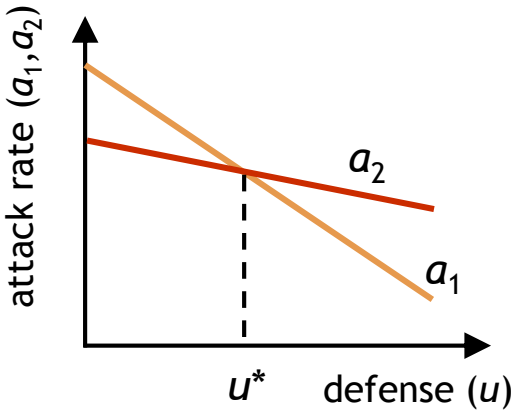
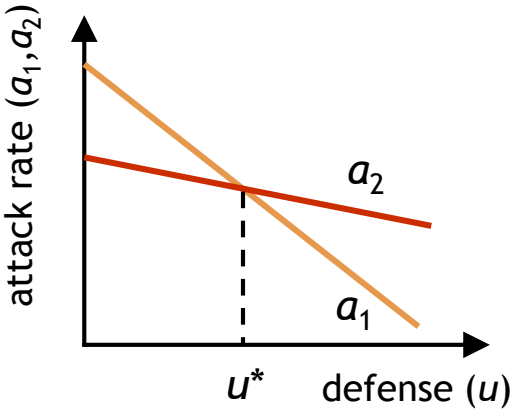




if there exists a defense level $u = u^*$ where the attack rates cross, coexistence may be possible

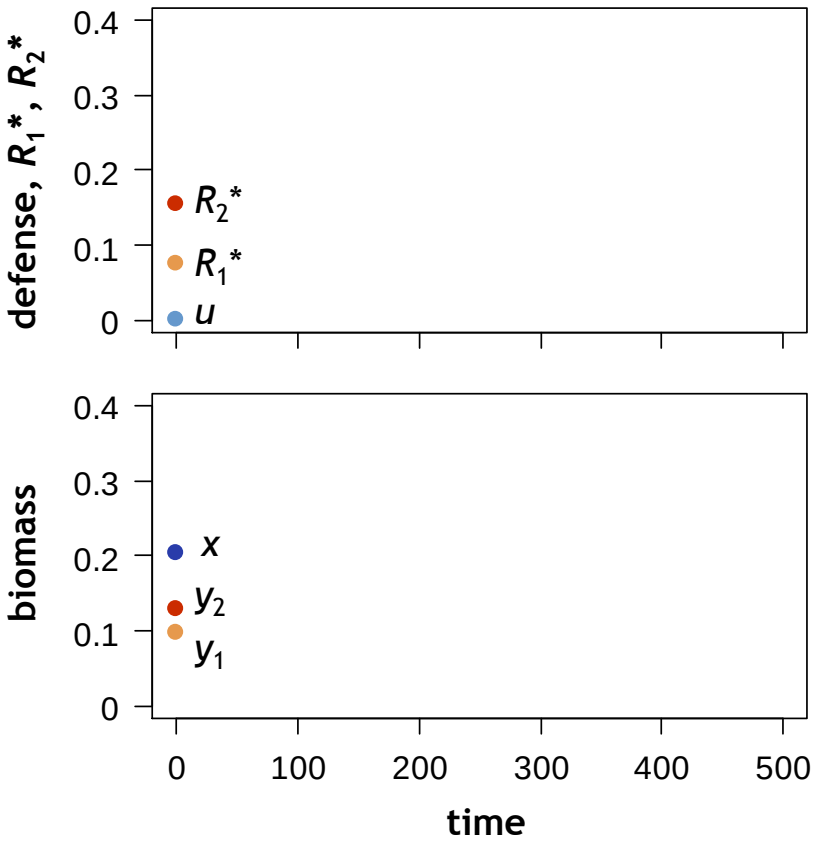
Does it actually work?

Results (I): coexistence through prey adaptation?



Initial conditions:

- defense = 0
- $a_1 > a_2$
- $R_1^* < R_2^*$



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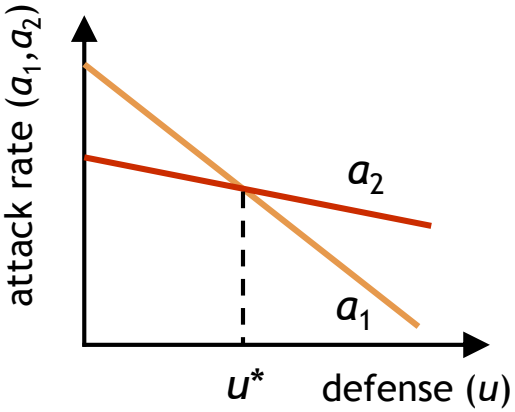

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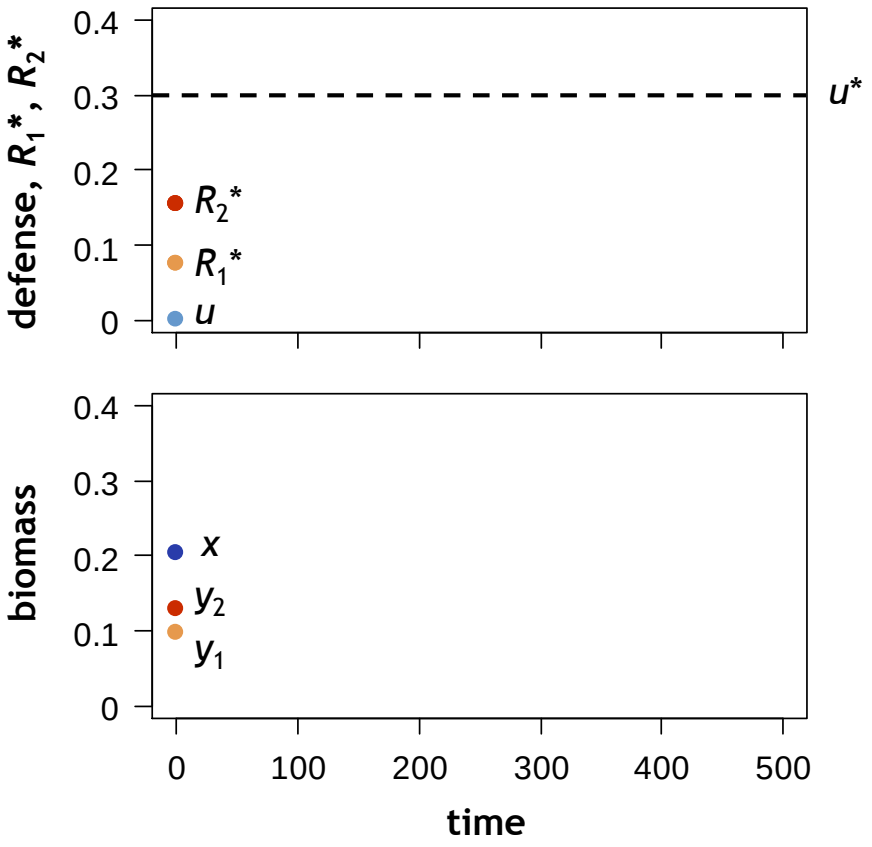

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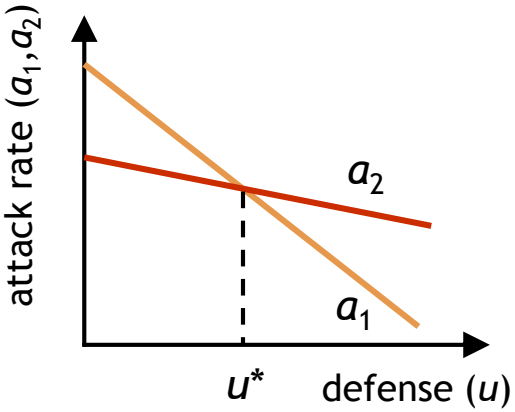

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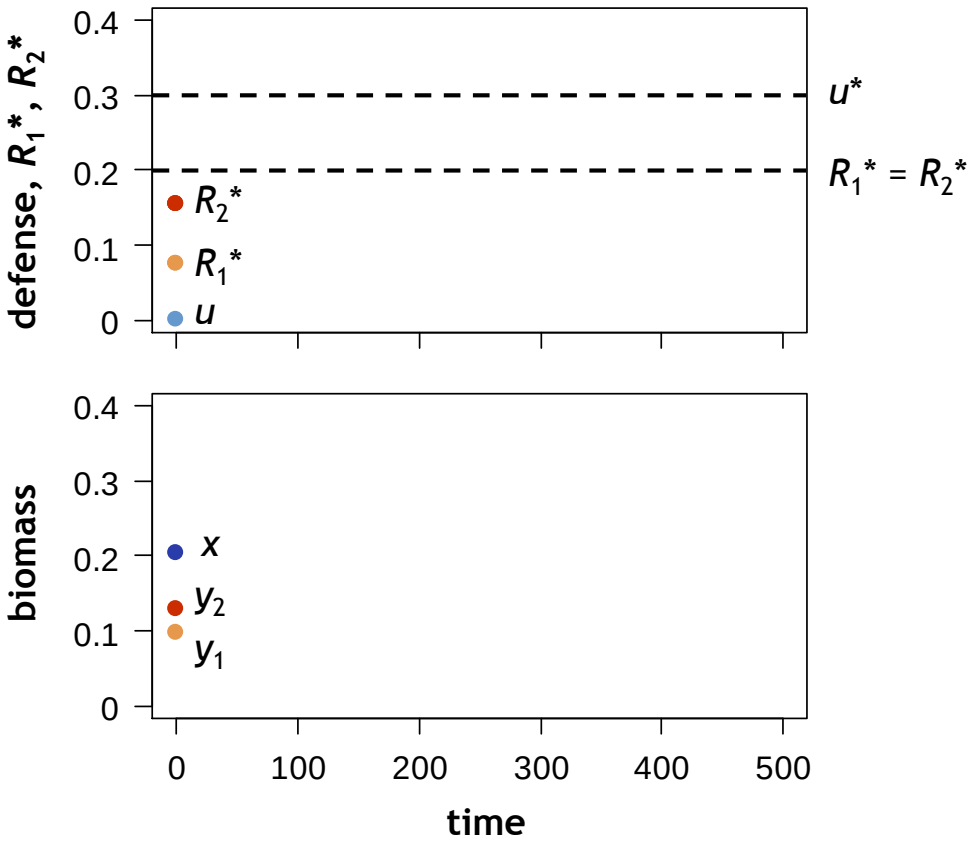

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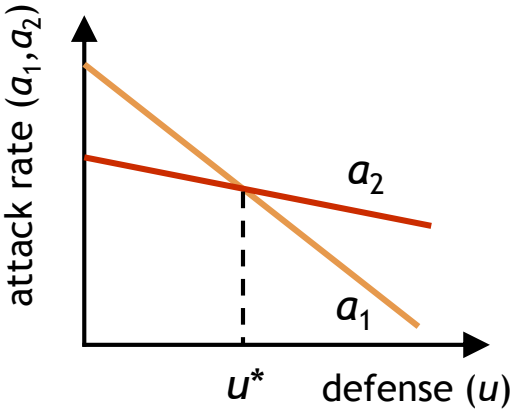

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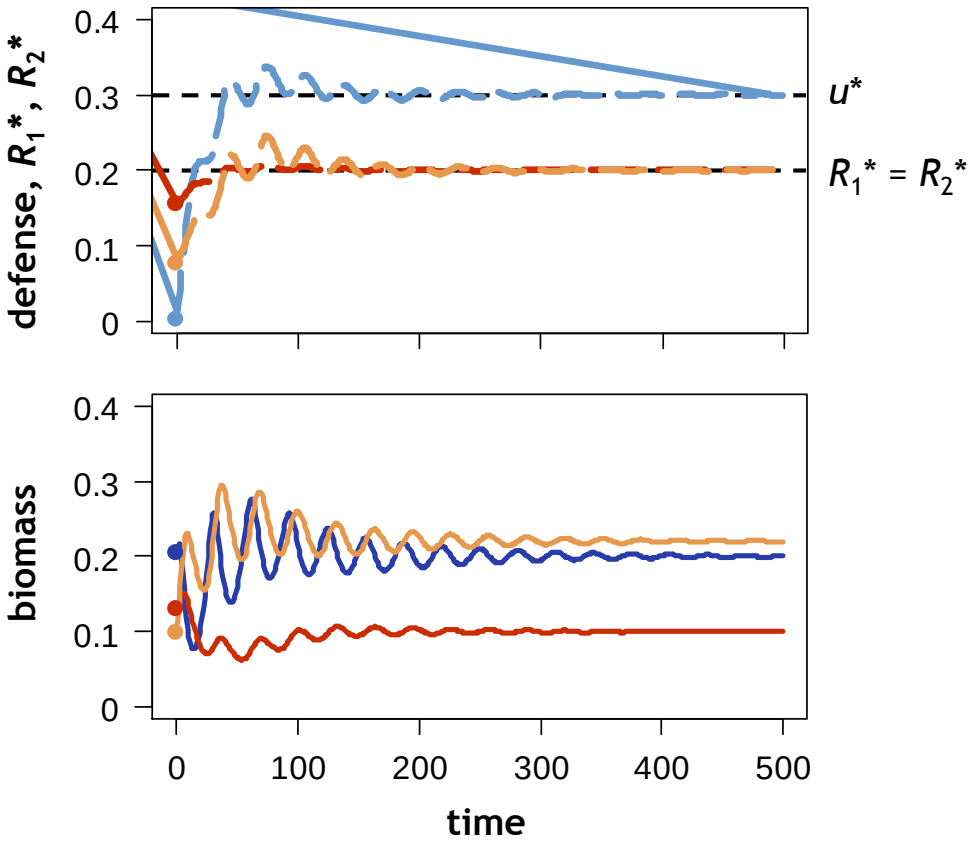

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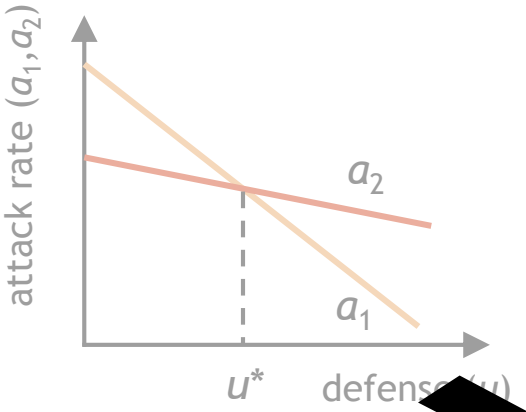
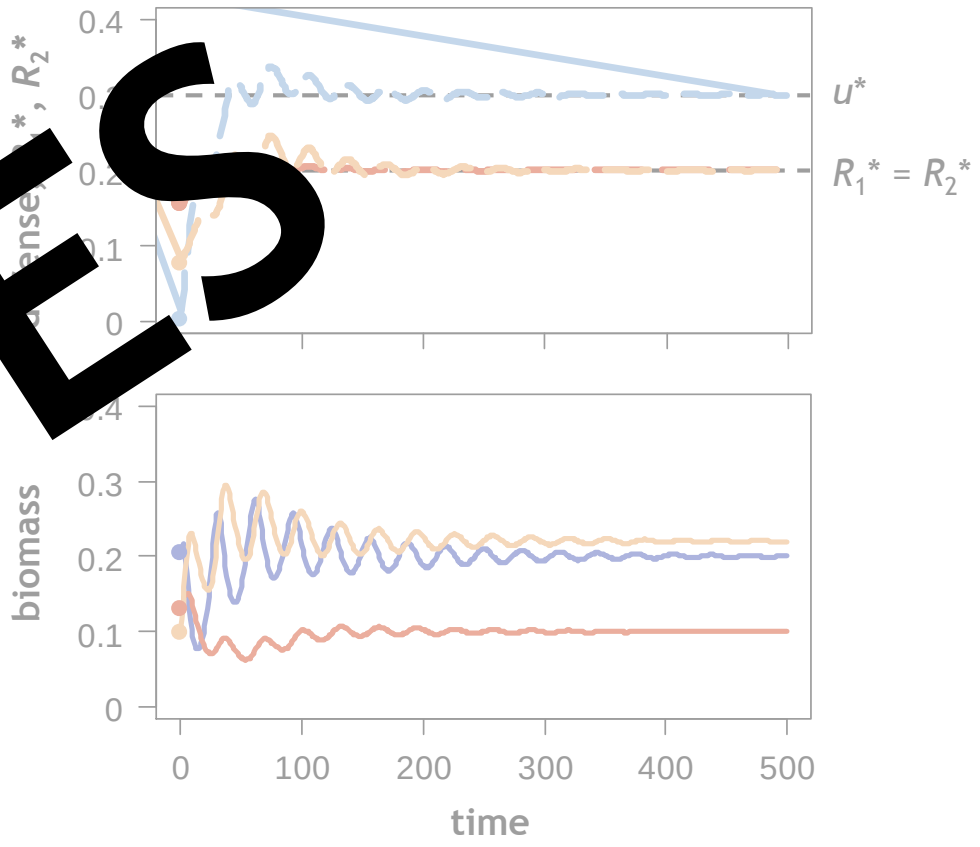


YES



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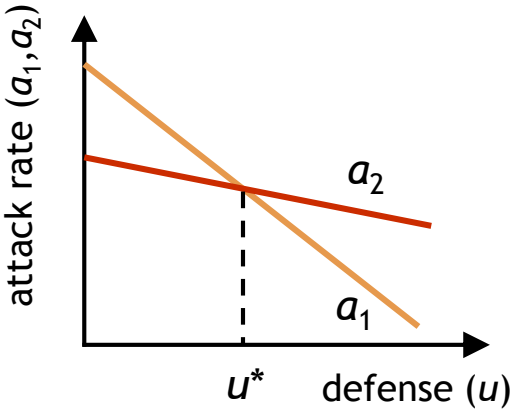
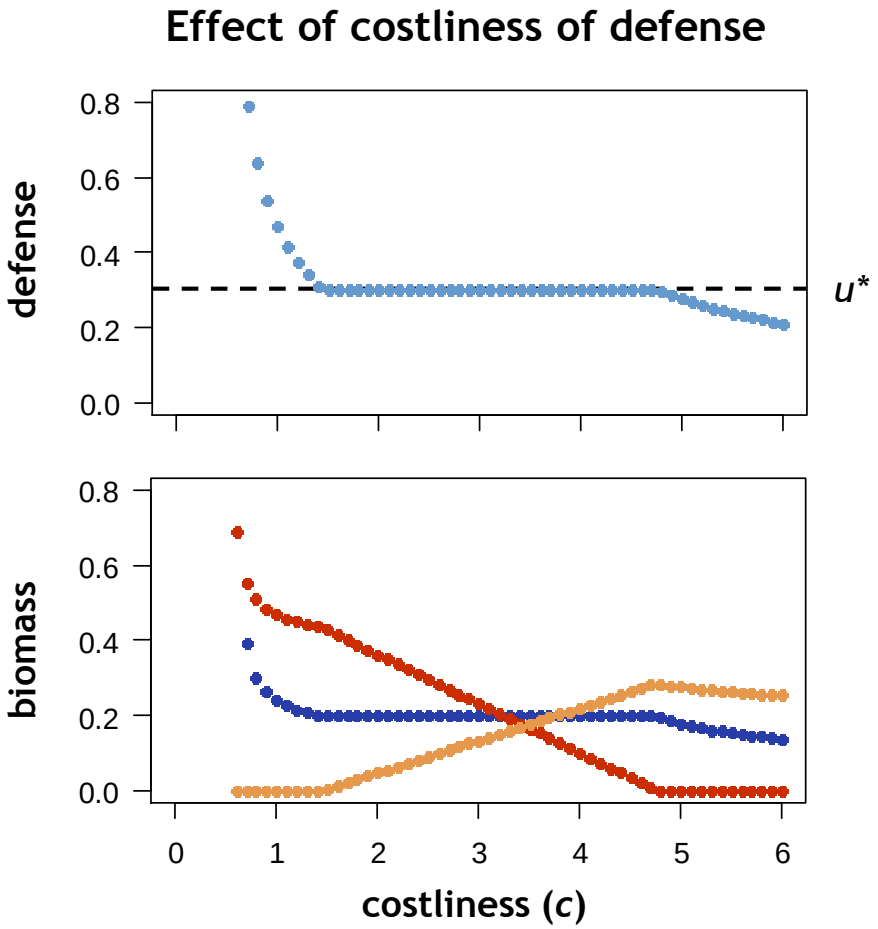
Results (II): when does it work?





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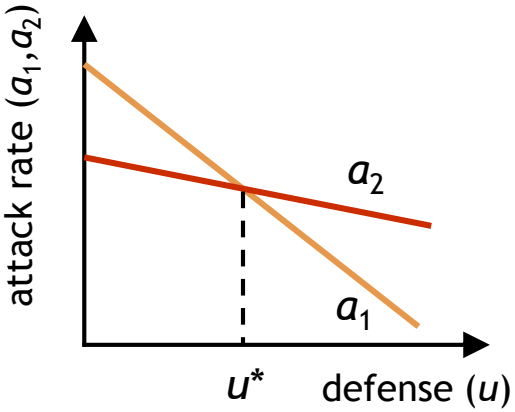
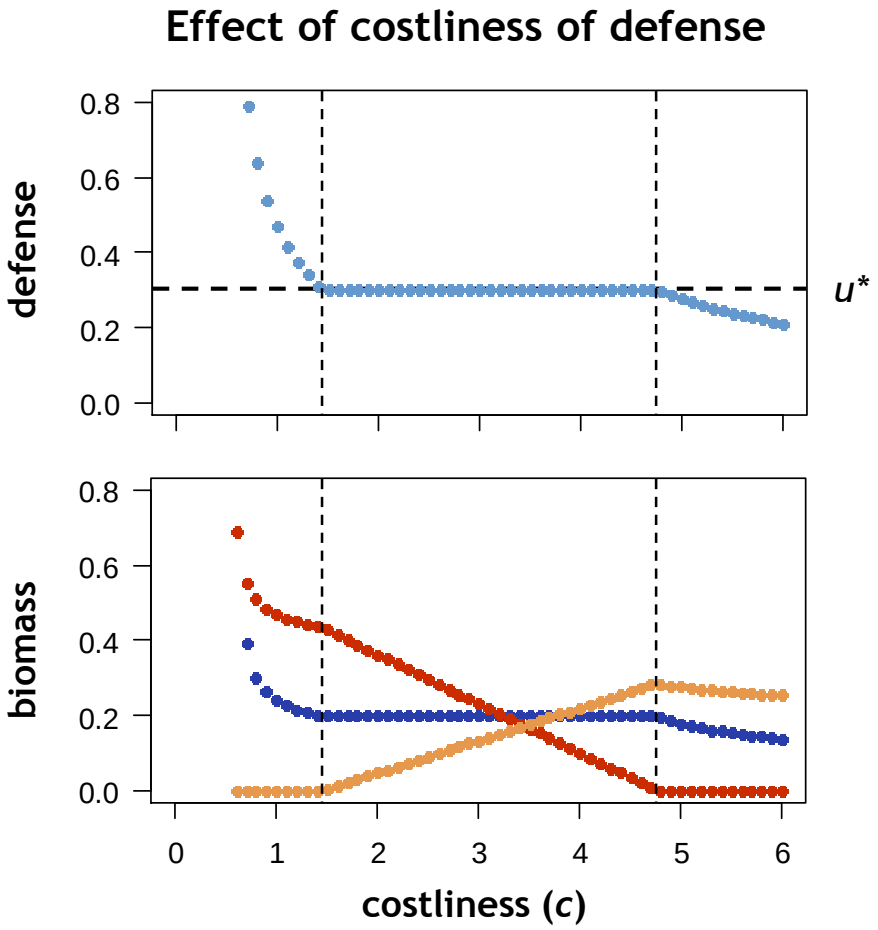
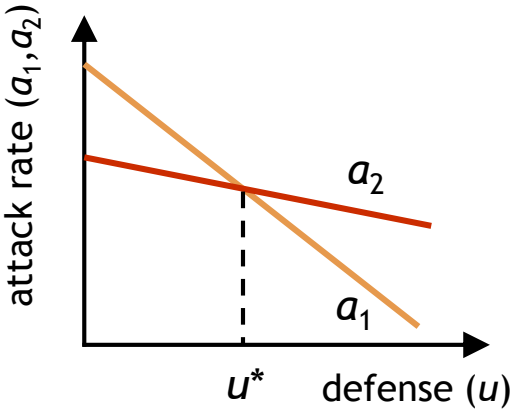
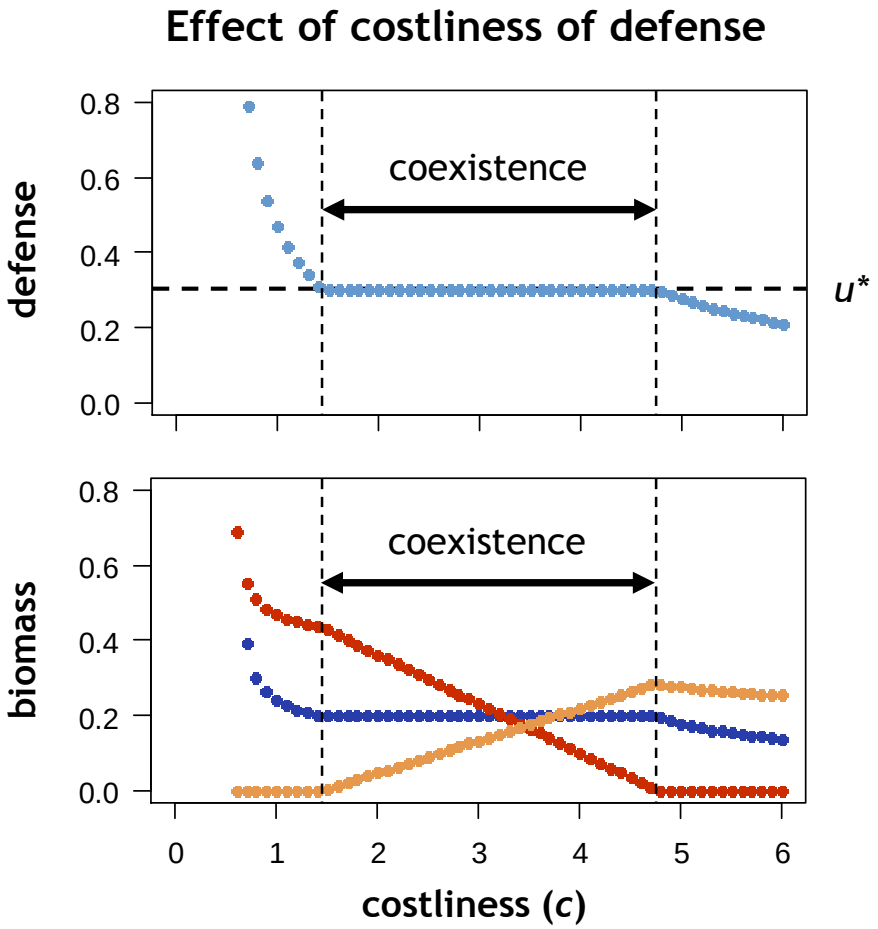


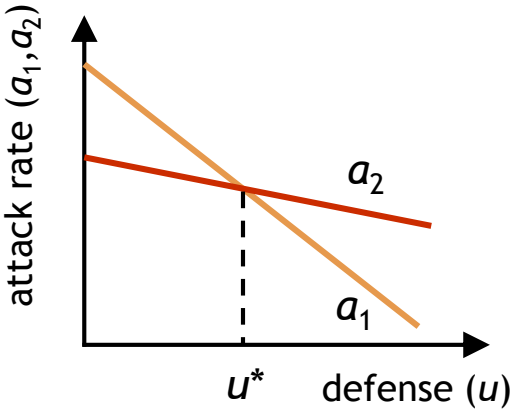


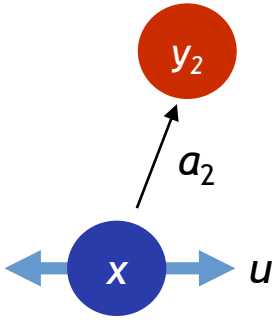
Results (II): when does it work?

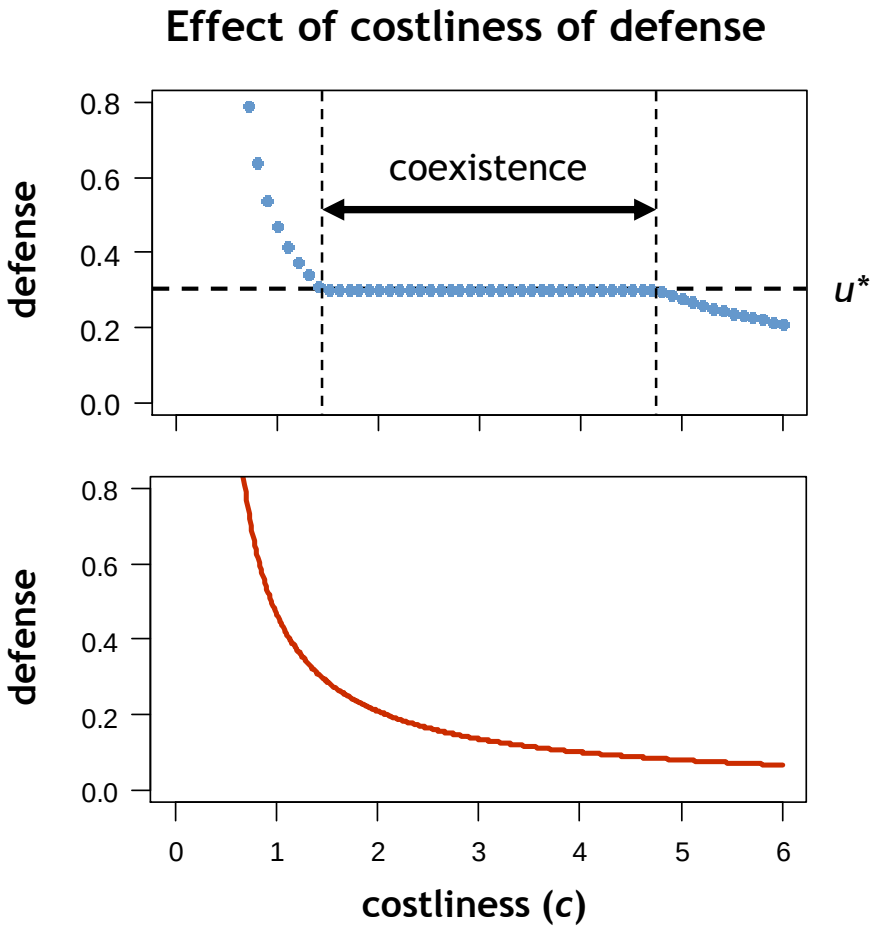




Results (III): how does it work?







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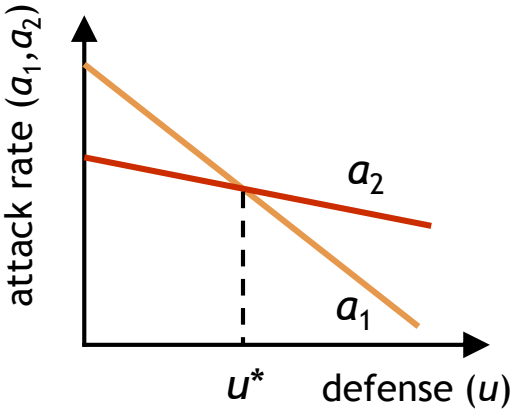

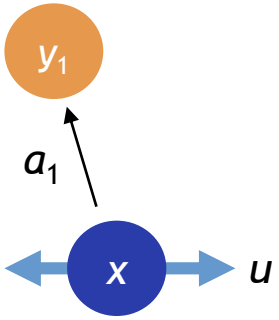

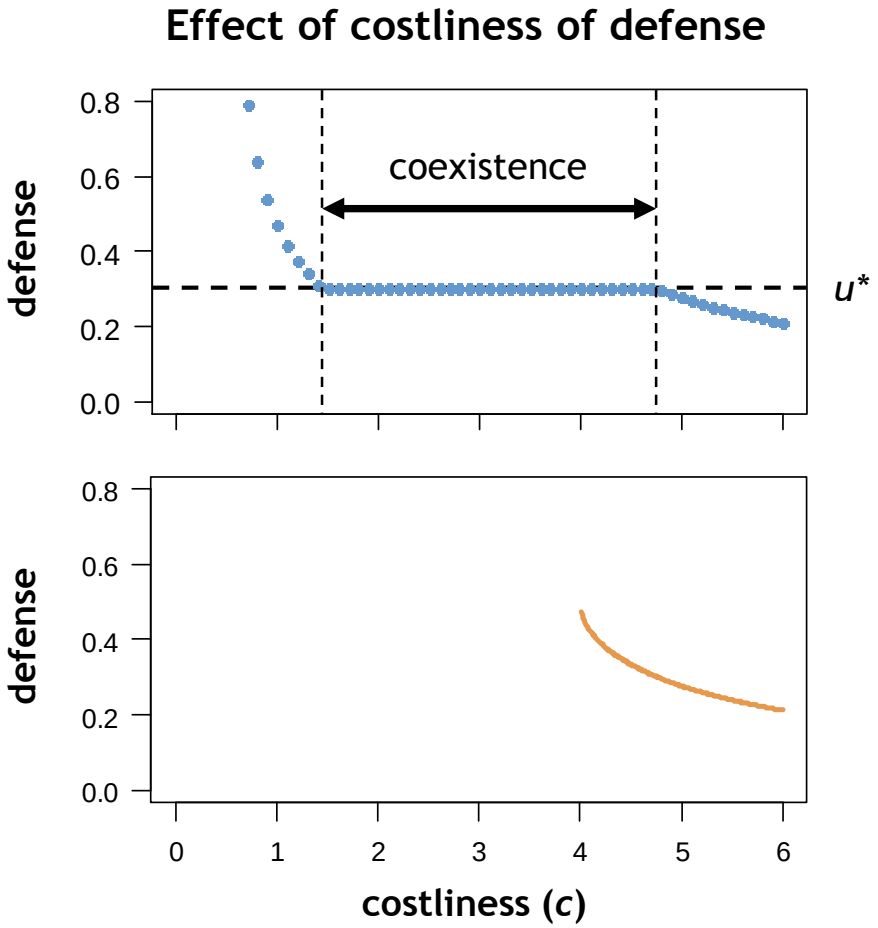

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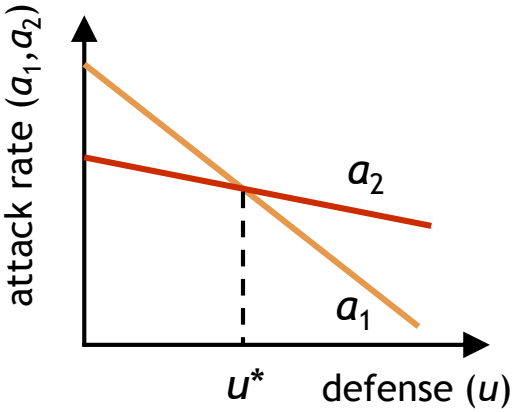
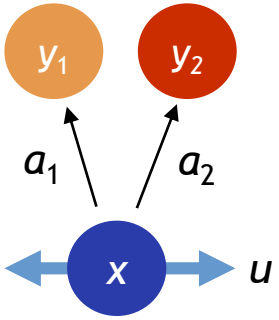
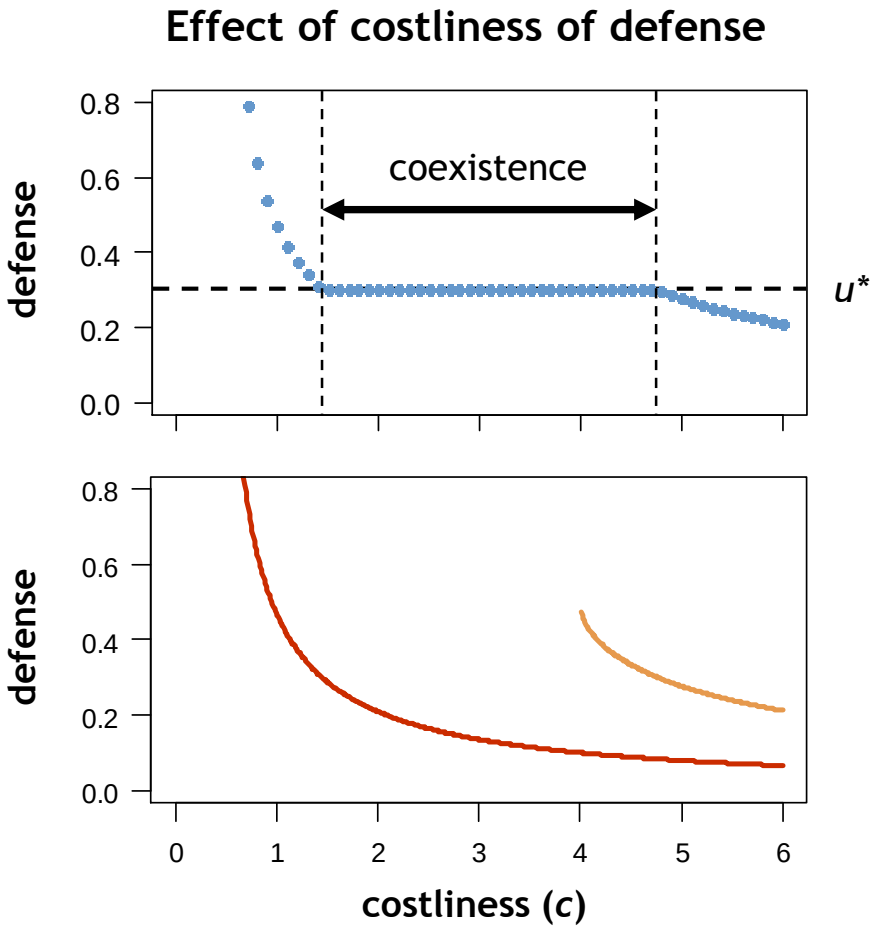
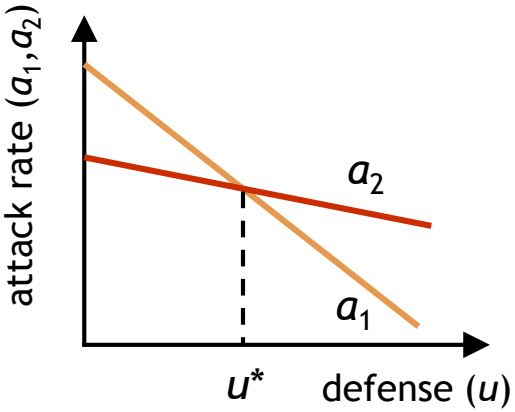
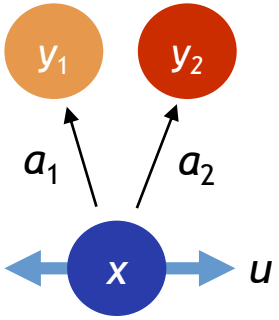


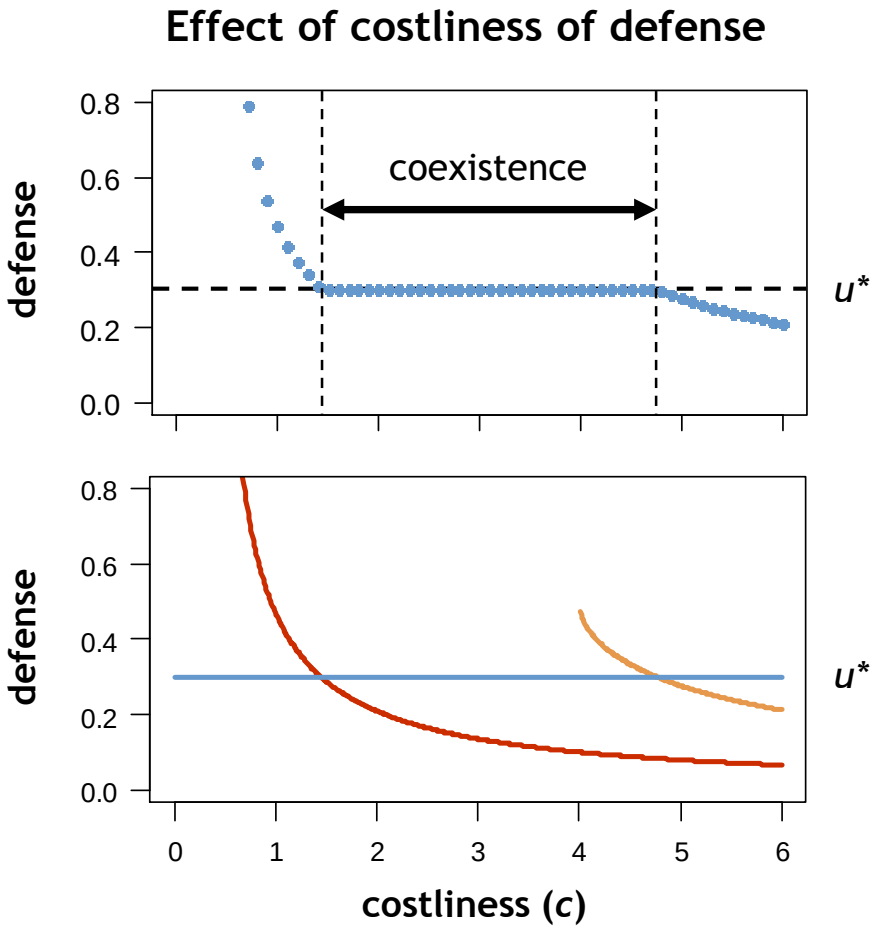




Results (III): how does it work?







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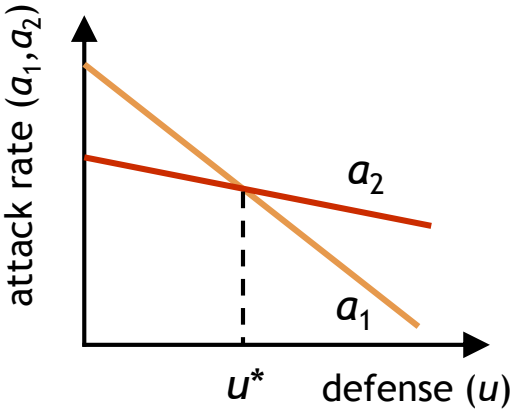

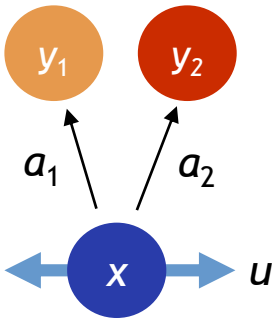

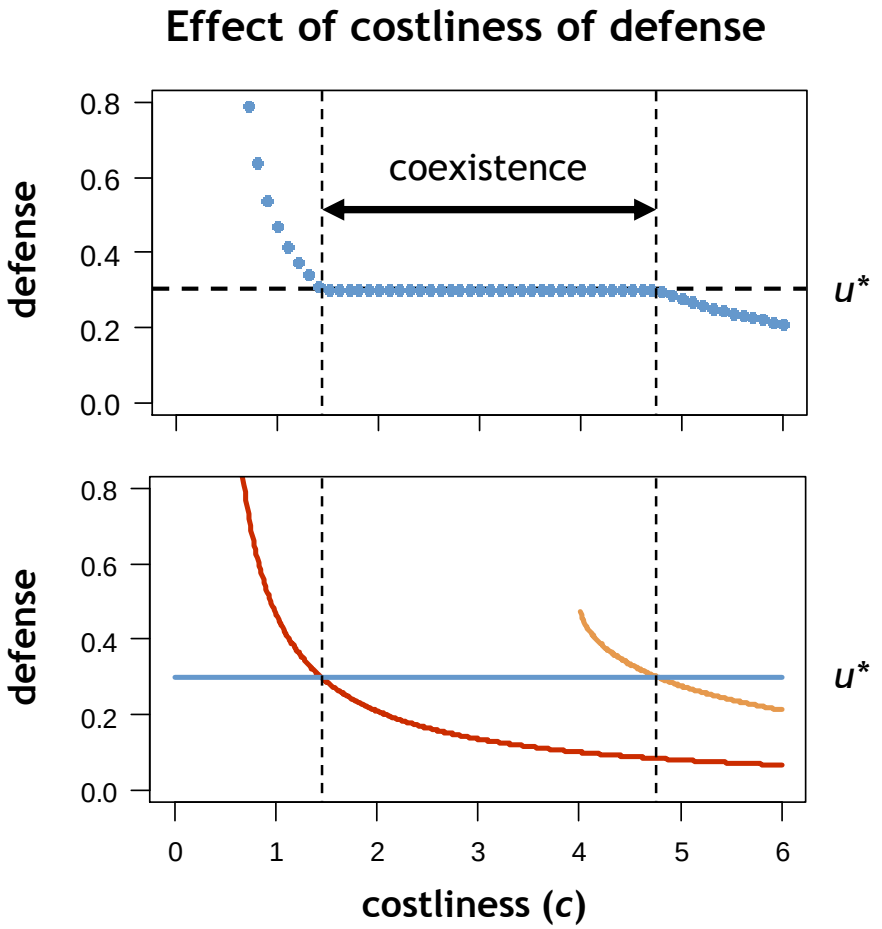

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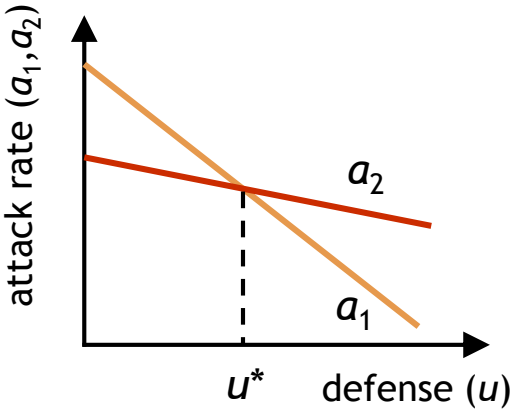

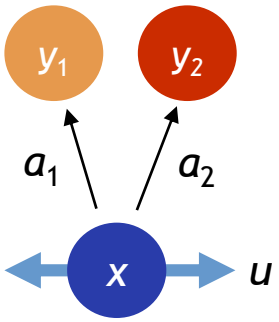

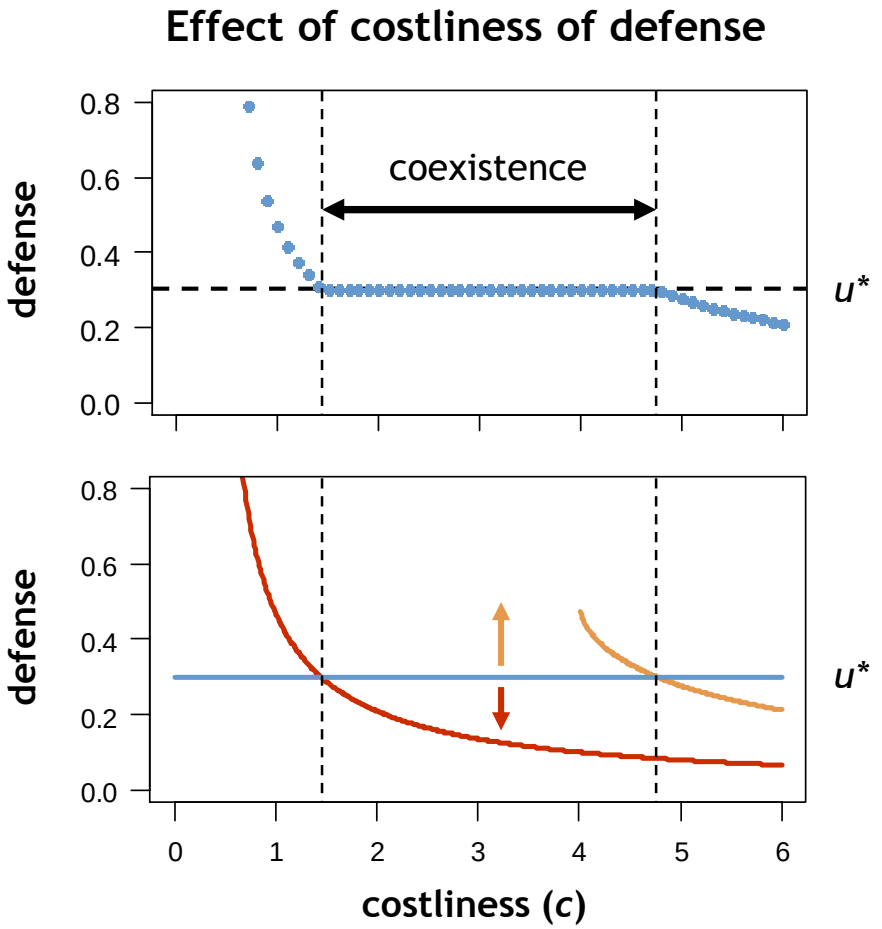

Summary

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- Costs of defense must not be too high or too low
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  - there must exist a defense level $u = u^*$ where R^* values are equal
  - at $u = u^*$ the predators must exert opposing selective pressure
- **Eco-evolutionary feedback loop** causes defense to converge to u^*, enabling stable coexistence

Thank you!

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