Predator-Prey Dynamics & Coevolution

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Outline

- Background theory on P-P interactions

- Build a mathematical model w/ P-P interaction
  - Demonstration in R
  - Add complexity to our model

- Coevolution

- Cool examples throughout

Types of species interactions

		Species 1	
		+	-
Species 2	+		
	-		

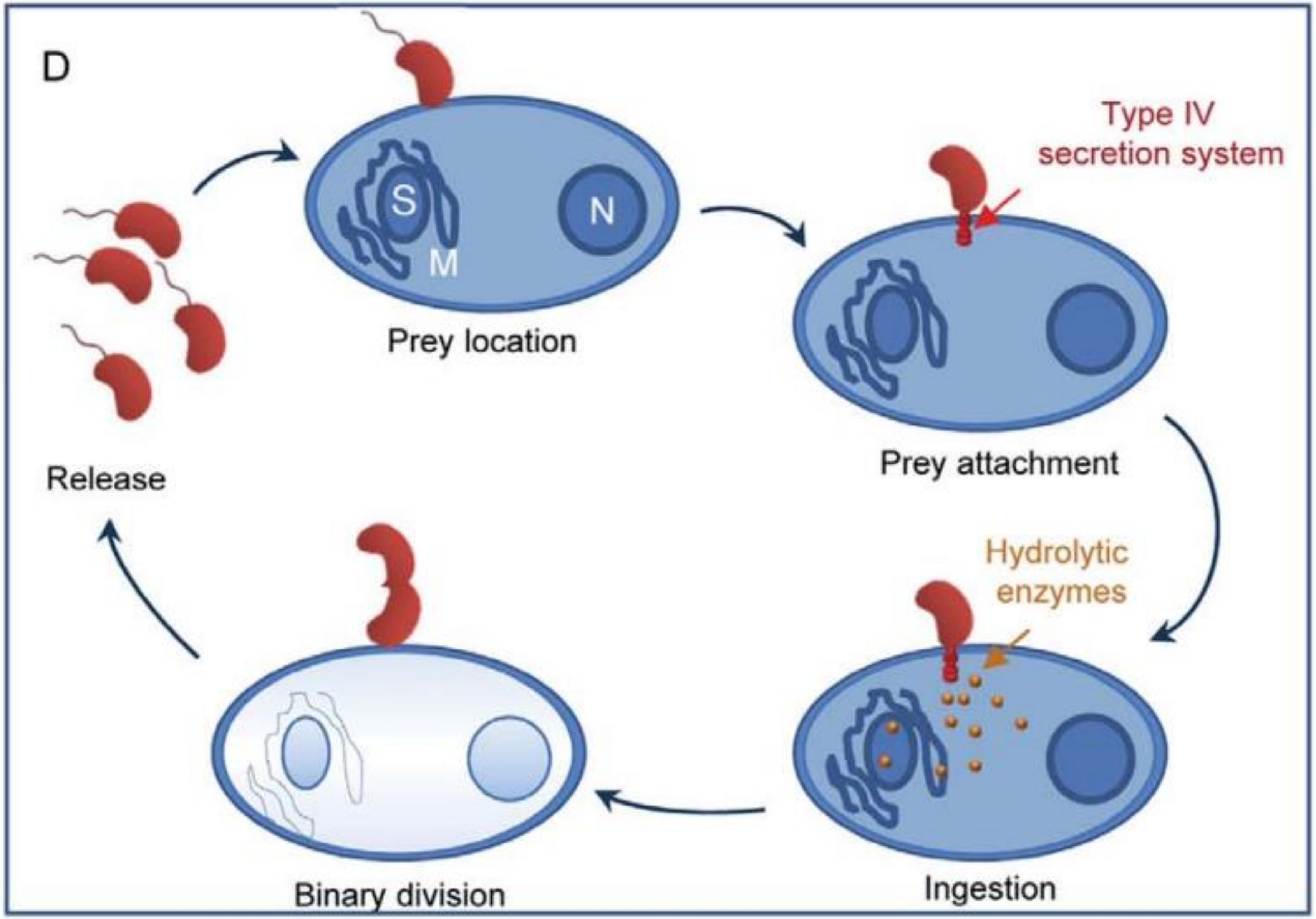
Types of species interactions

		Species 1: +	Species 1: -
Species 2	+	Mutualism	Predation / Parasitism / Herbivory
	-	Predation / Parasitism / Herbivory	Competition

(Commensalism
+ 0 (neutral) interaction)

Buffalo being attacked
by lions in Serengeti Nation
al Park in Tanzania

Photo: Nick Dale https://www.nickdalephotography.com/blog/lions-of-the-serengeti-and-masai-mara



Pérez et al. Environmental Microbiology (2016)
Adapted from Guerrero and colleagues (1986)

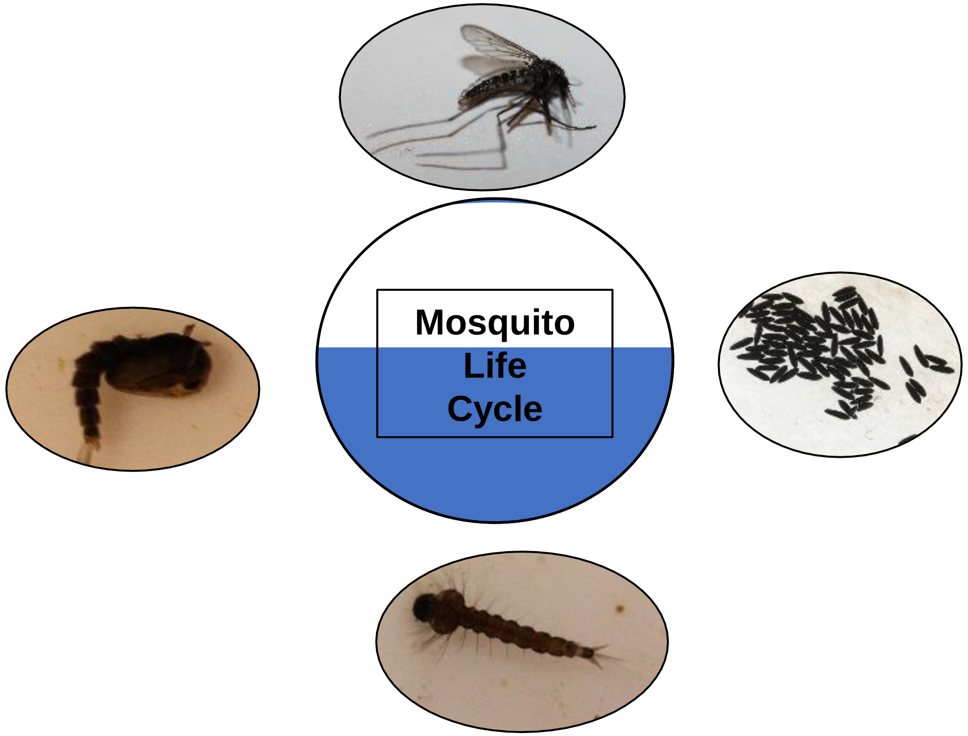
Vampirovibrio chlorellavorus

parasitic bacterium attaches to the surface of green algae

Chlorella vulgaris

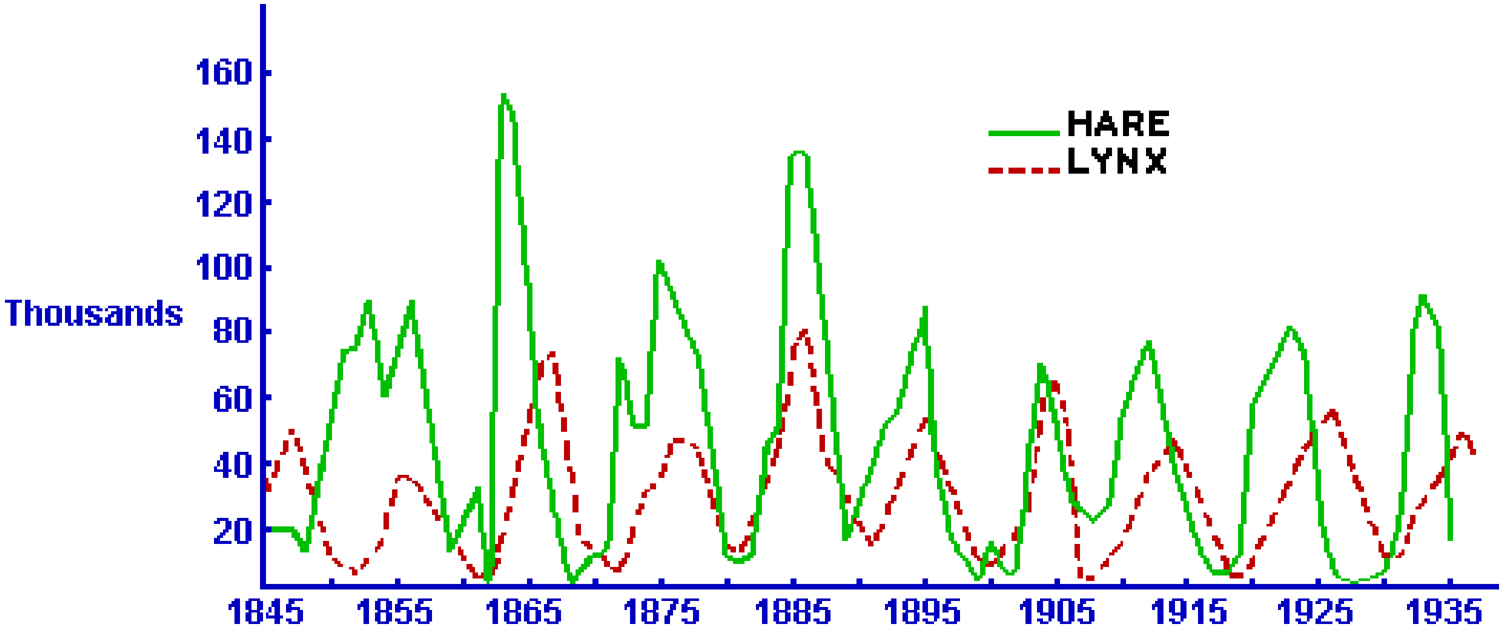
Sucks out cellular contents of its prey

Larval stage Arctic mosquito *(Aedes nigripes)* and predaceous diving beetles (*Colymbetes dolabratus)*



Newly emerged Arctic mosquito adults (*Aedes nigripes)* and wolf spiders (*Pardosa glacialis)*

Population cycles of Lynx and Hare in Boreal forest

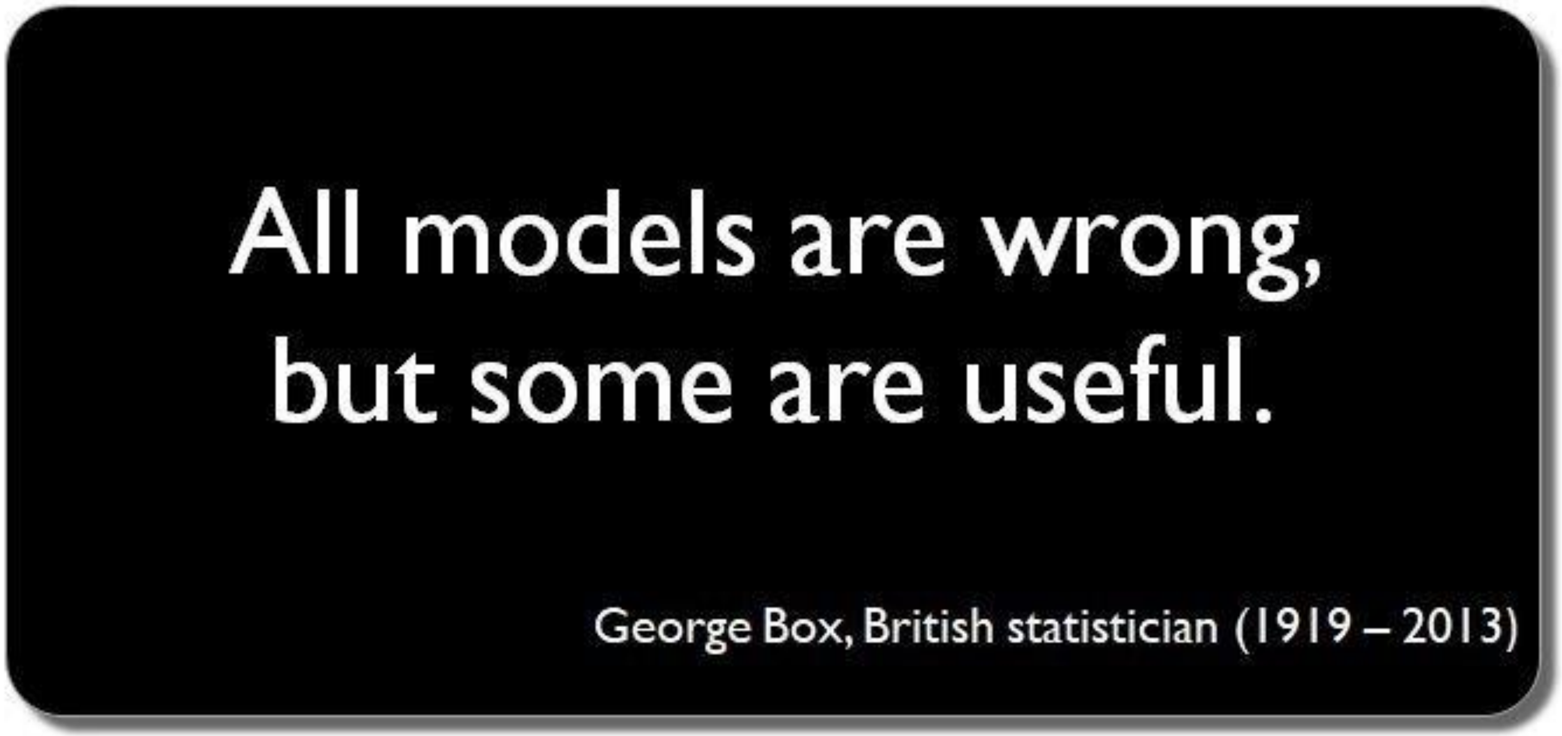


Adapted from Odum, *Fundamentals of Ecology*, Saunders, 1953

Photo: Jeff Lepore, Science photo library

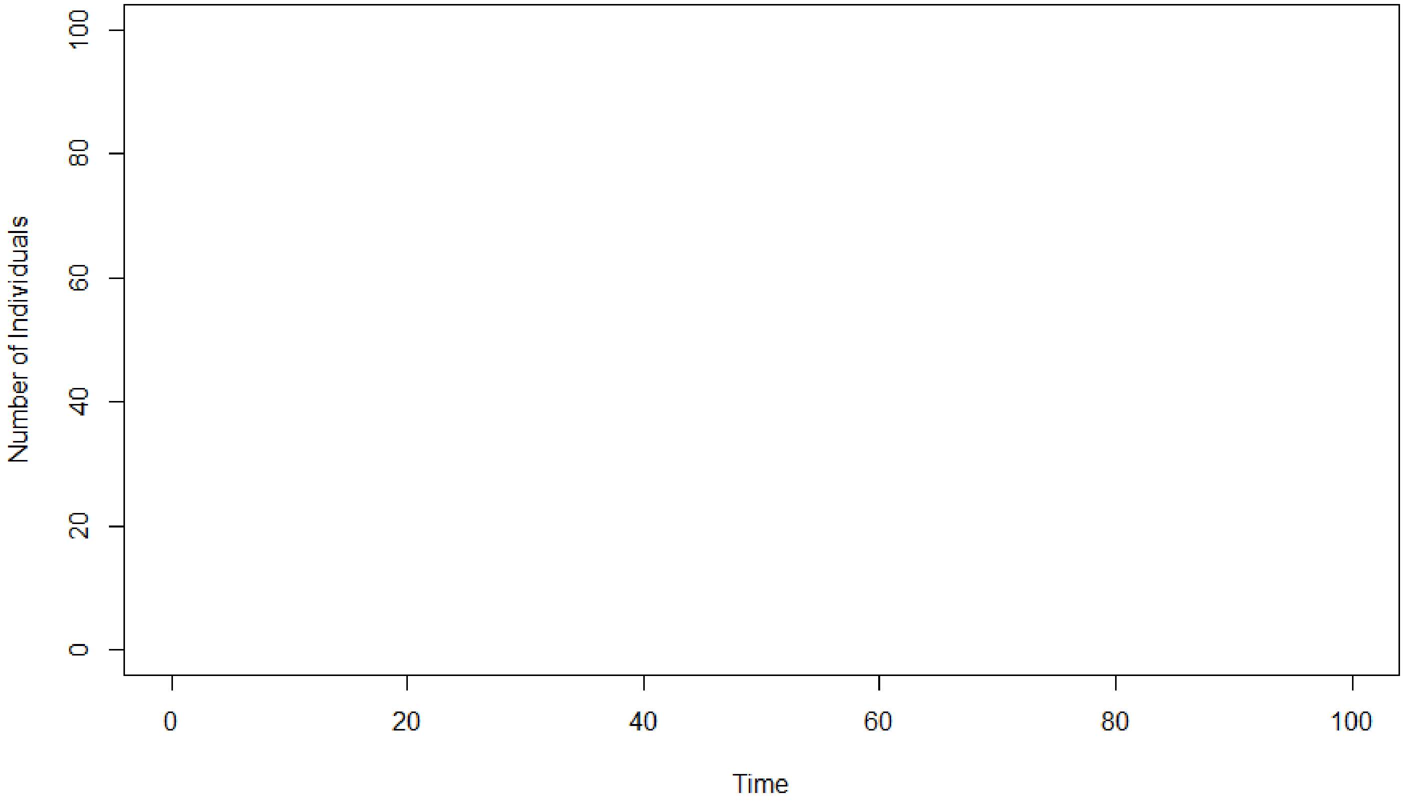
- Cool dataset from Hudson bay fur trade records

Build a mathematical model for predator-prey dynamics



- Models = abstractions of real-world phenomenon

Build population model for Prey (N)



Build population model for Prey (N)

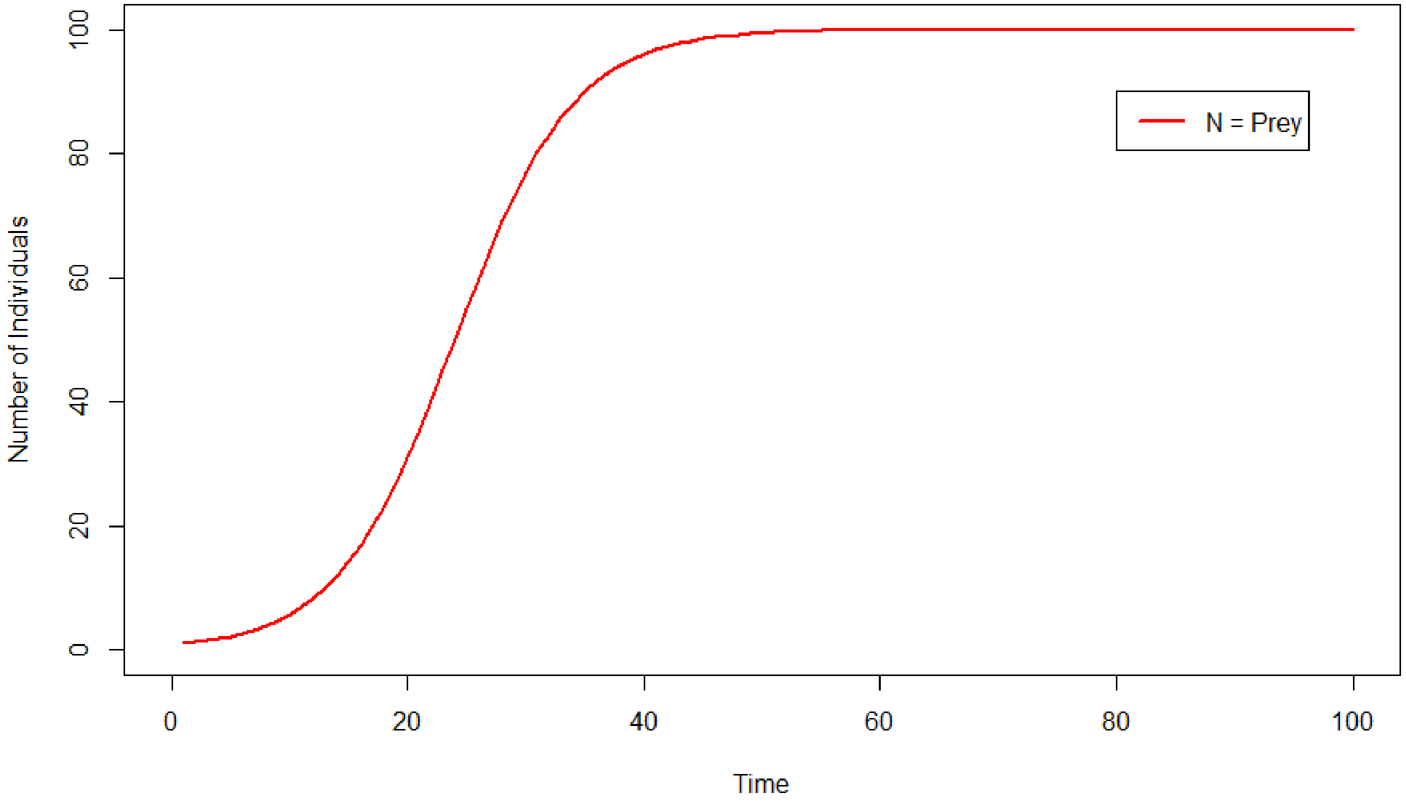
dn/dt = Population growth of prey w. respect to time

r = intrinsic growth rate of prey

K = Carrying capacity of prey

$$\frac{dN}{dt} = \underbrace{rN}_{\textbf{Births}}\underbrace{\left(1 - \frac{N}{K}\right)}_{\textbf{Deaths due to limited resources}}$$

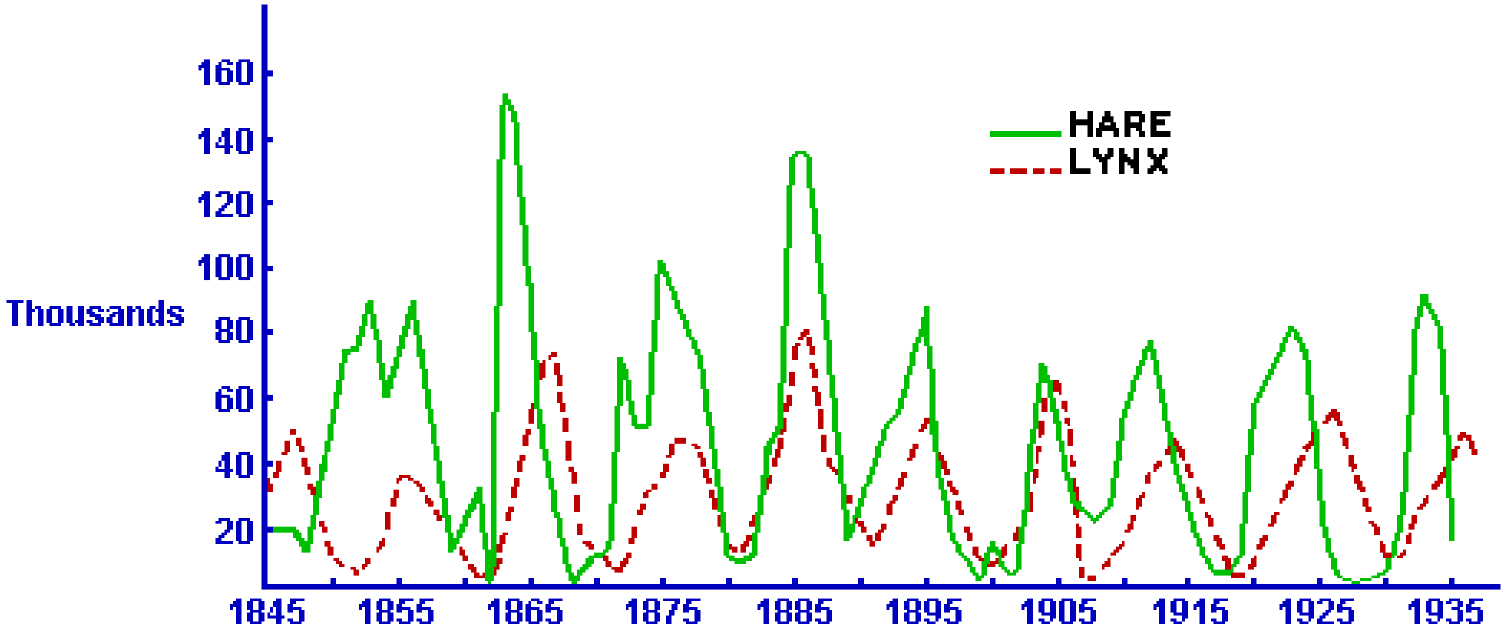
Build population model for Prey (N)



r = 0.2
K = 100

Build population model for Prey (N) and Predator (P)

Lotka-Volterra P-P model



Build population model for Prey (N) and Predator (P)

r= growth rate of prey

a = attack rate of predator on prey

$$\frac{dN}{dt} = \underbrace{rN}_{\textbf{Births}} - \underbrace{aNP}_{\textbf{Deaths due to predator}}$$

Lotka-Volterra P-P model

**we simplified our prey model so they only receive deaths from predators (no (1-N/K) term for intraspecific density dependence

dp/dt = Population growth rate of predators

b = conversion efficiency

a = attack rate of predator on prey

d = predator death rate

$$\frac{dP}{dt} = \underbrace{baNP}_{\textbf{Births from eating prey}} - \underbrace{dP}_{\textbf{Deaths}}$$

Build population model for Prey (N) and Predator (P)

a = **attack rate** of predation (prey captured/prey•time•predator)

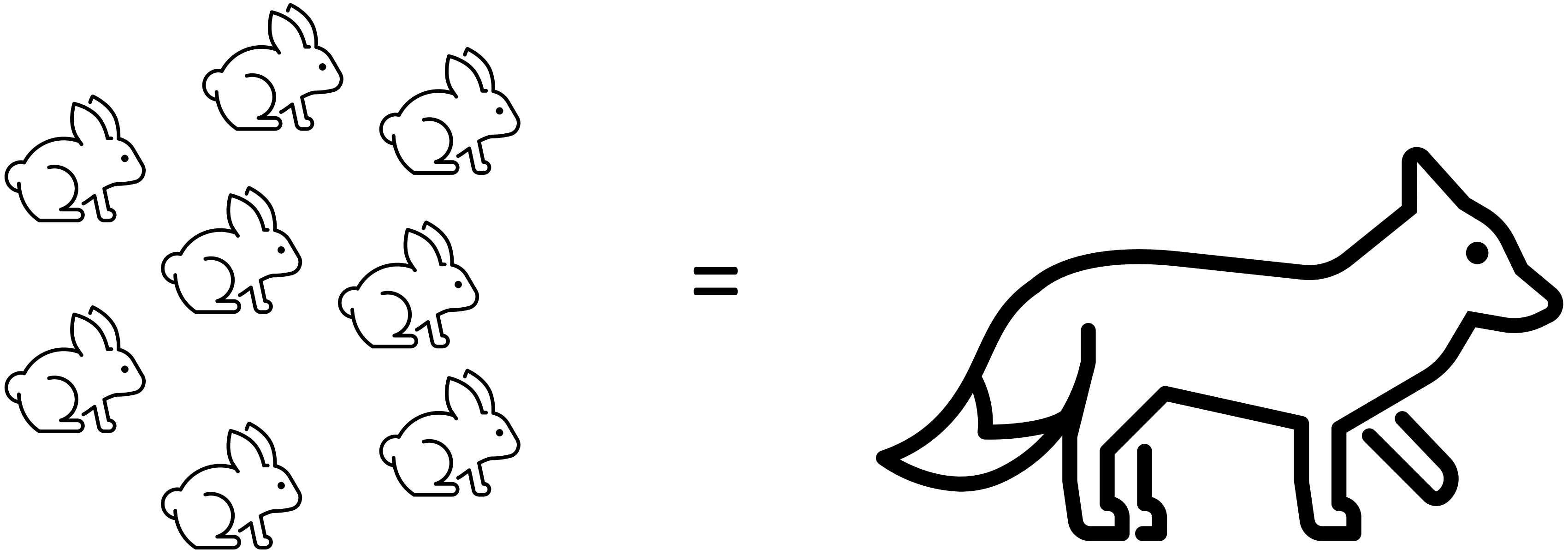
"Mass action"

The rate at which predator (solid balls) and prey (striped balls) bump into each other at random

Build population model for Prey (N) and Predator (P)

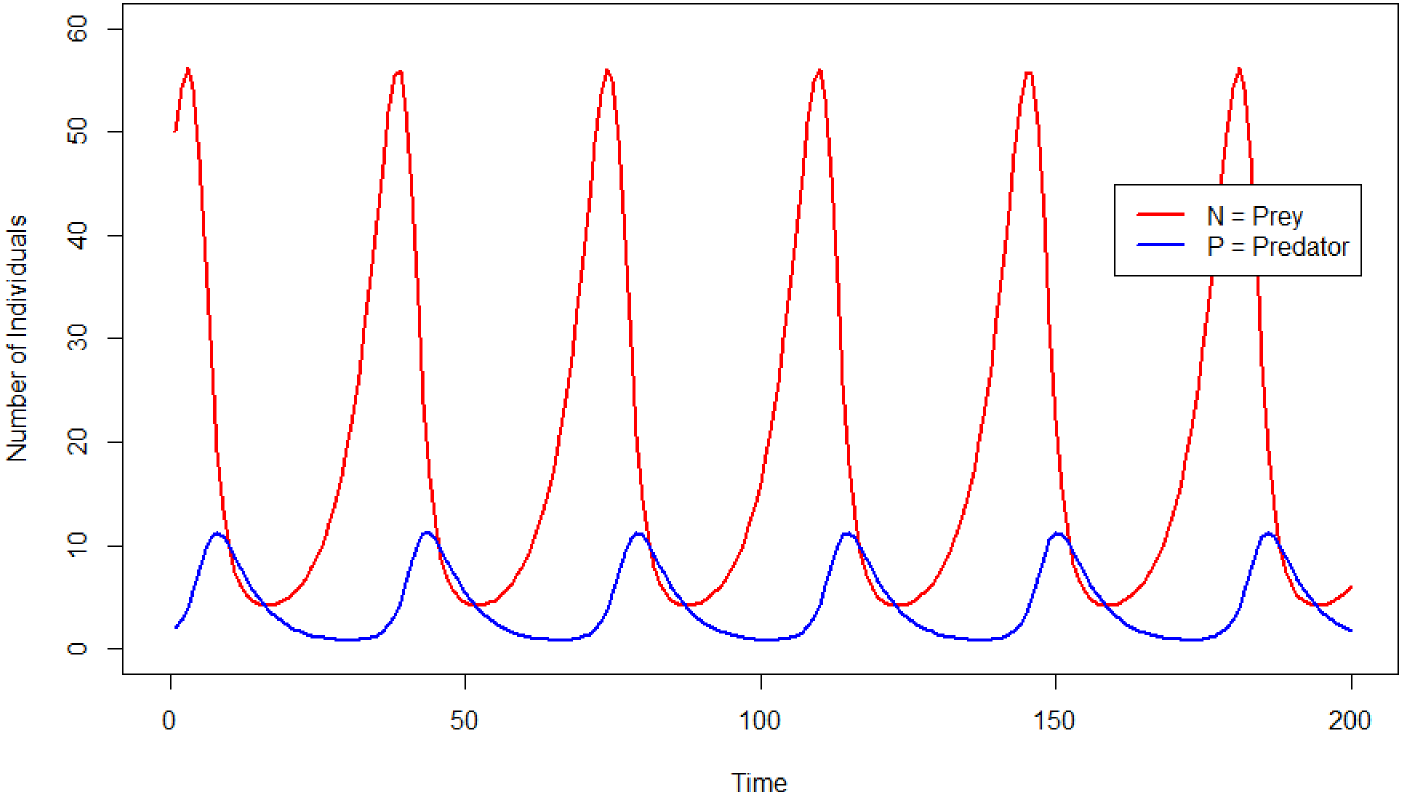
b = **conversion efficiency**

How many babies of predator does each prey represent?



Build population model for Prey (N) and Predator (P)

Build population model for Prey (N) and Predator (P)



$r = 0.2$
$a = 0.05$
$b = 0.2$
$d = 0.2$

What assumptions did we make?

- Assumed that predators randomly bump into prey

- Assumed that predators never stop eating

- Assumed that predators take no time to consume prey

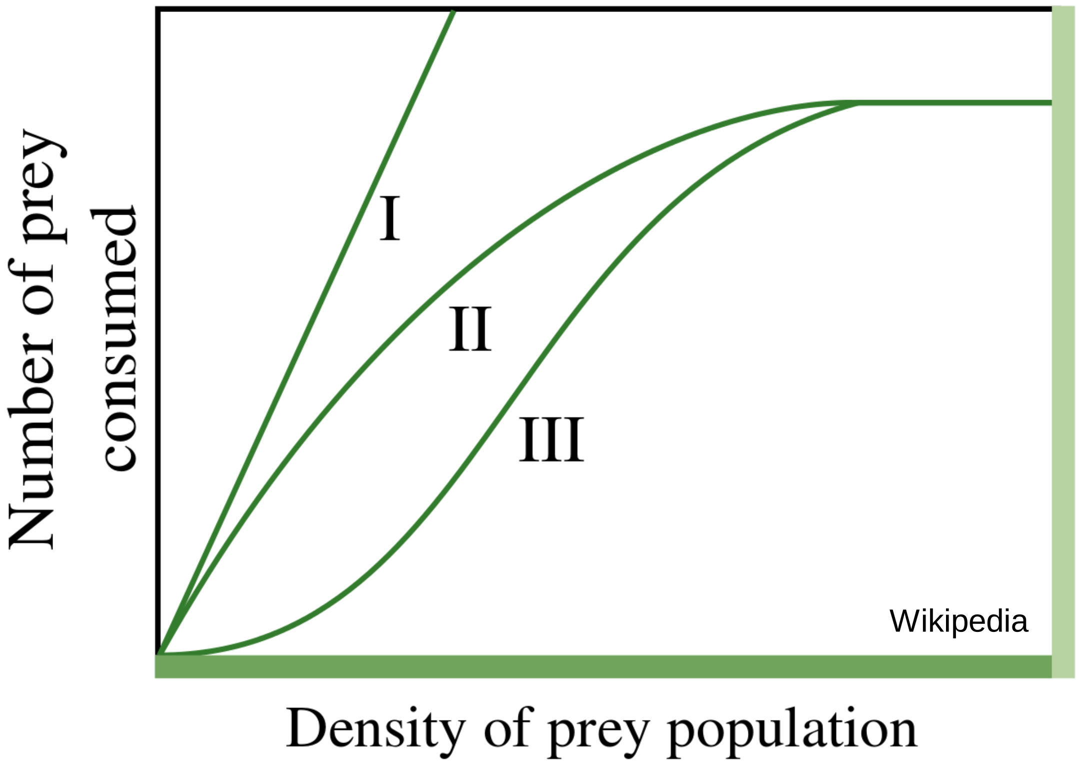
(and more…)

Photo: Amaury Laporte

Add complexity to our model…

Functional Response : Relates a single predator's prey consumption rate to prey population density

Handling time: time spent by predator subduing and consuming prey



- C.S. Hollling's Type II and III functional response

https://www.youtube.com/watch?v=AnHiAWlrYQc&t=87s

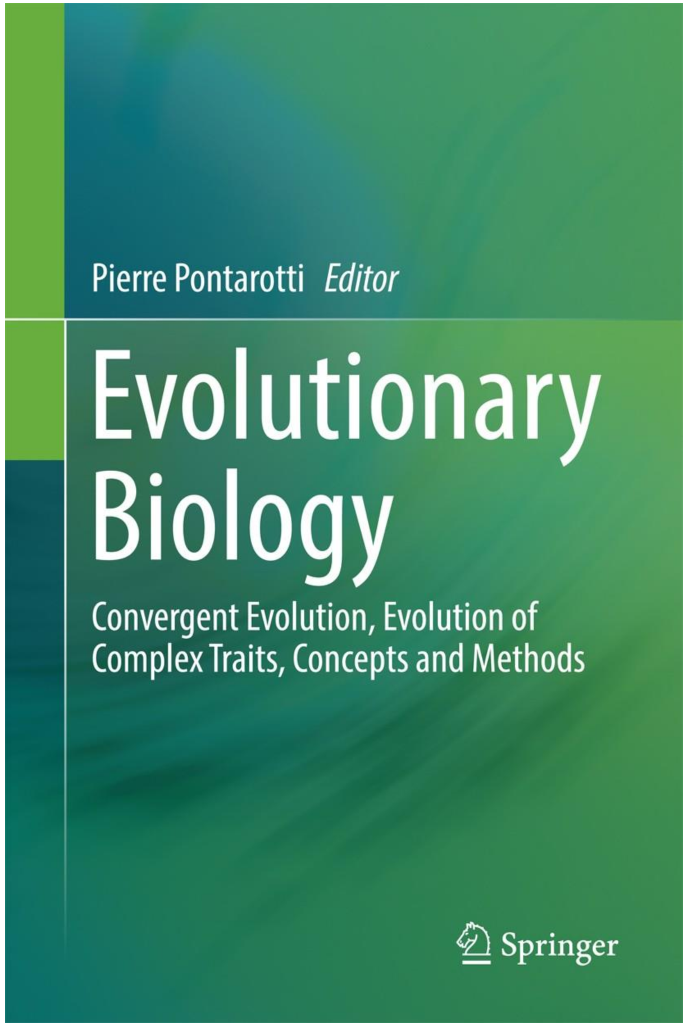
Cicadas benefit from
predator satiation

https://www.post-gazette.com/life/outdoors/2021/05/13/cicada-brood-x-periodical-pennsylvania-lifecycle-predation/stories/202105120040

https://www.thayerbirding.com/do-birds-eat-cicadas/

What assumptions did we make?

- Assumption that species don’t change in response to one another



Coevolution: evolution in more than one organism brought about by reciprocal selective effects between the entities

https://upload.wikimedia.org/wikipedia/commons/9/91/Bertholdiatrigona.jpg

https://upload.wikimedia.org/wikipedia/commons/7/77/Big-eared-townsend-fledermaus.jpg

ARTICLE

https://doi.org/10.1038/s41467-019-12140-6 OPEN

Bacterial predator-prey coevolution accelerates genome evolution and selects on virulence-associated prey defences

Ramith R. Nair[1,3], Marie Vasse[1,3], Sébastien Wielgoss[1], Lei Sun[1,2], Yuen-Tsu N. Yu[1] & Gregory J. Velicer[1]

Myxococcus xanthus (soil microbe) swarms E. Coli prey

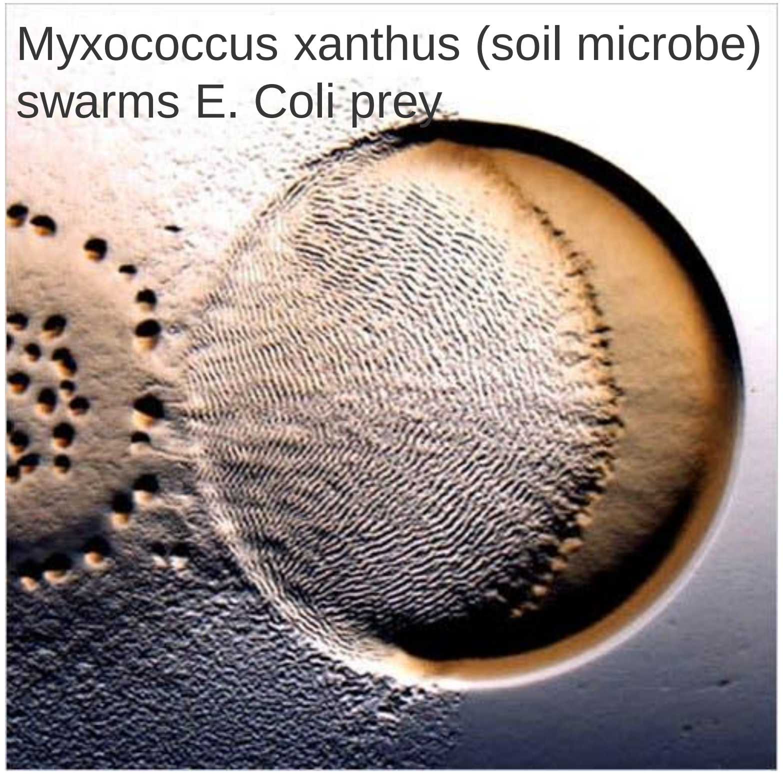


Photo: John R. Kirby/University of Iowa Carver College of Medicine

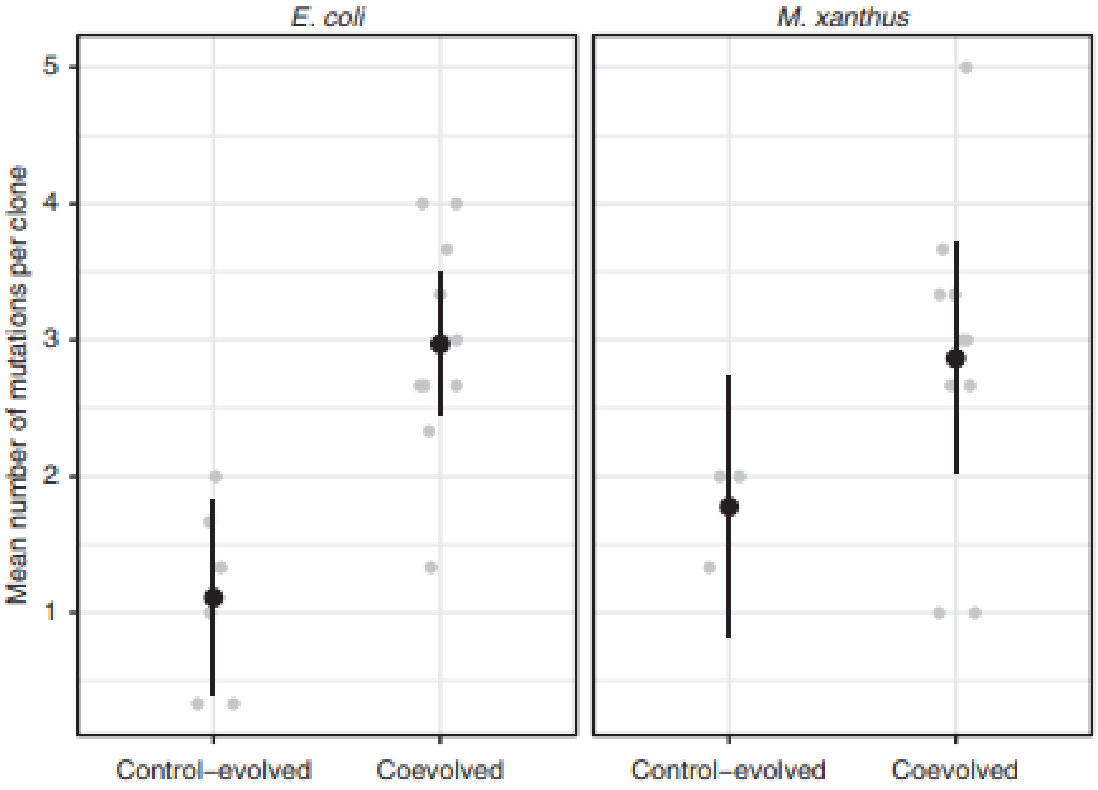


Photo: Masaki Hoso

Pareas iwasakii is a snail-eating specialist

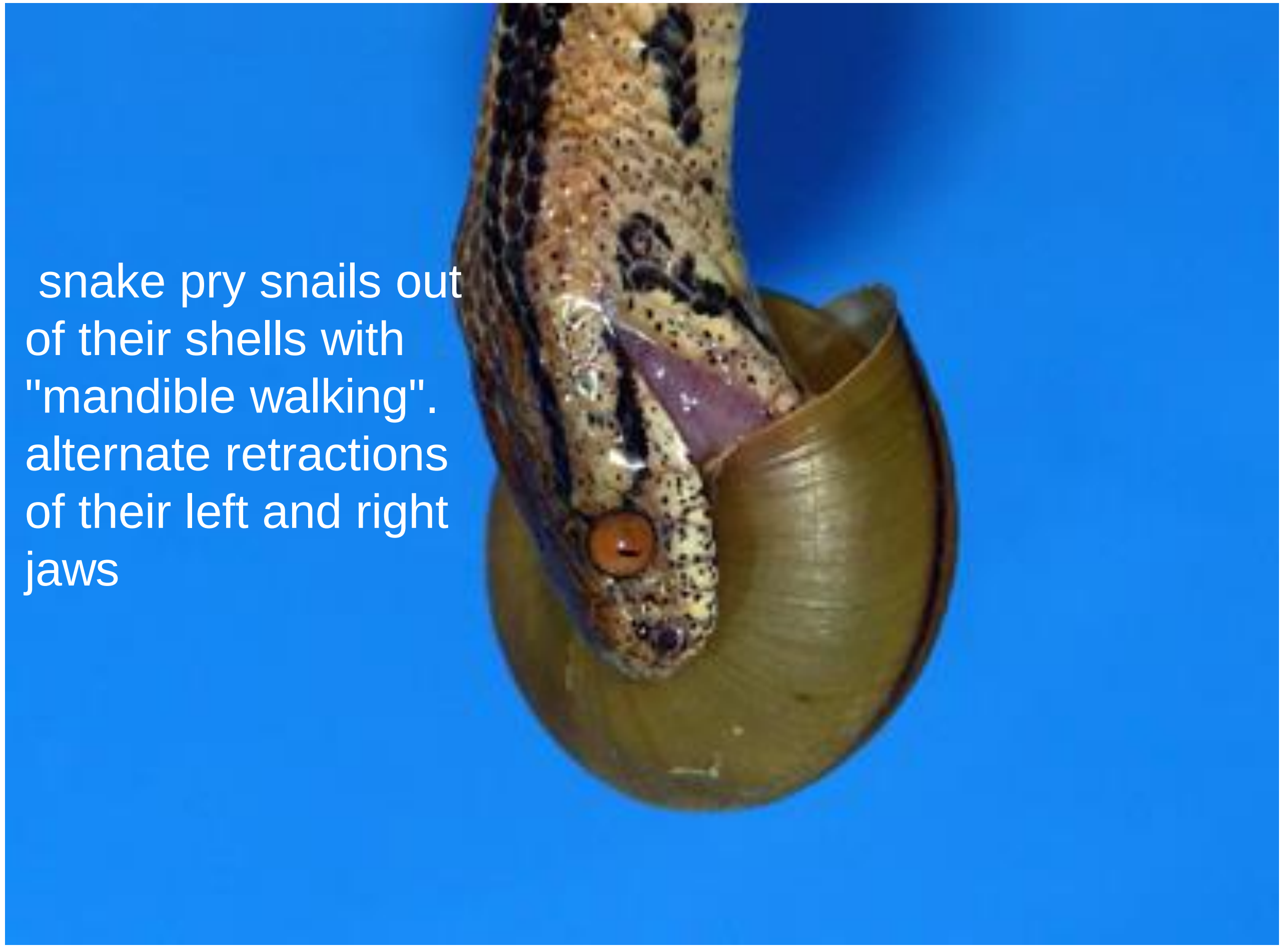
Endemic to the Yaeyama Islands in southern Japan

Photo: Masaki Hoso

Pareas iwasakii asymmetric jaw

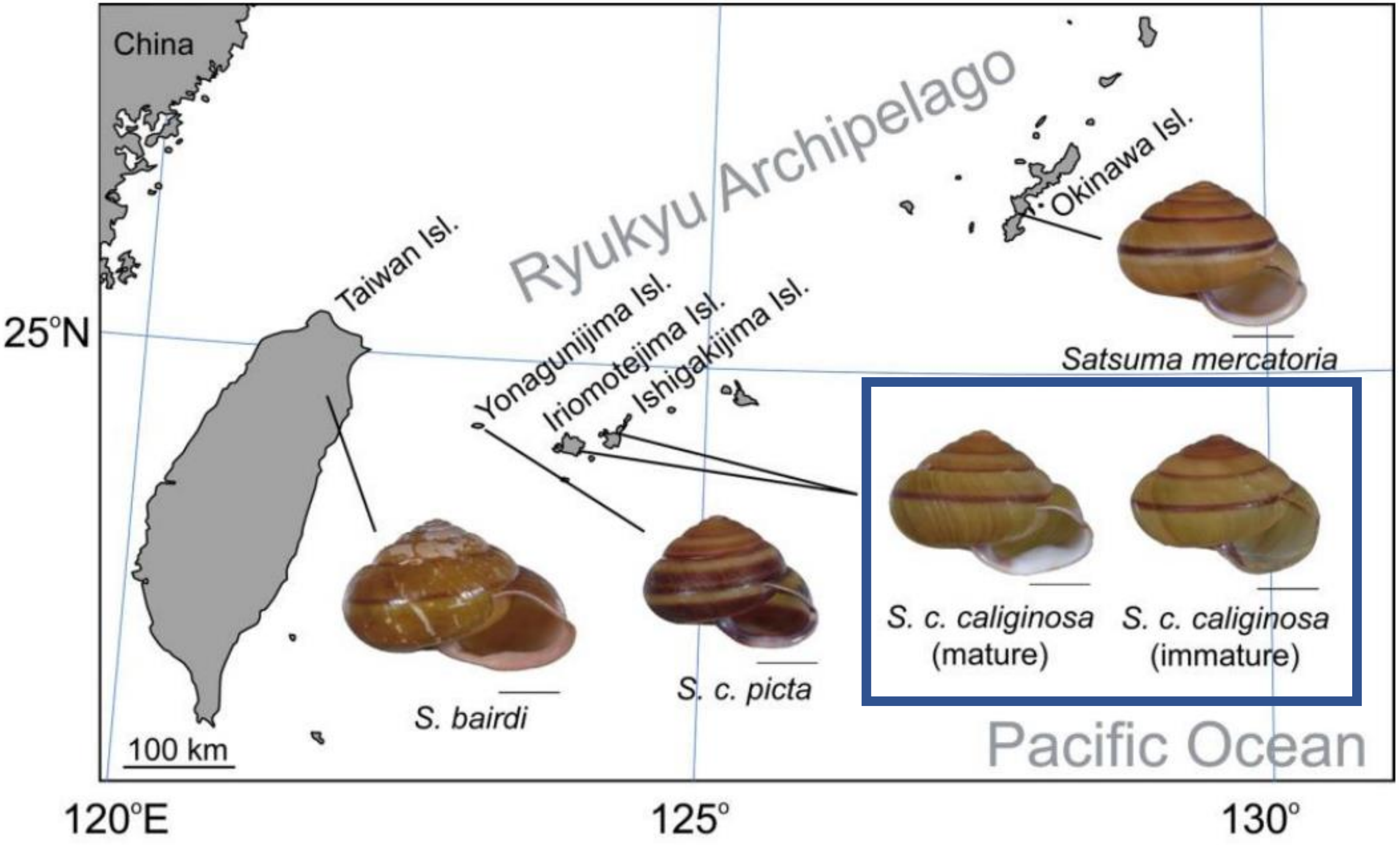
(16 on the left, 24 on the right)

Photo: Masaki Hoso



How do prey co-evolve?

Photo: Masaki Hoso



Increase handling time!

On islands where Satusma snails live w/ Pareas snakes, shell bottom has different aperature

Hoso et al. Biology Letters. 2007

How Being a "Lefty" Can Save Your Life – a Lesson from Snakes and Snails

By Lauren Koenig

ARTICLE

Received 1 Sep 2010 | Accepted 10 Nov 2010 | Published 7 Dec 2010

DOI: 10.1038/ncomms1133

A speciation gene for left-right reversal in snails results in anti-predator adaptation

Masaki Hoso[1], Yuichi Kameda[2], Shu-Ping Wu[3,4], Takahiro Asami[5], Makoto Kato[2,6] & Michio Hori[7]

Figure 1. The sinistral shell of *Dyakia salangana* (left) and the dextral shell of *Cryptozona siamensis* (right).

"The snakes drop left coiling snails because the shell gets in the way of their grasp. When the researchers fed snails to the snakes, the snakes consumed nearly all of the righty snails, but ate only 12.5% of the lefty snails. "

Questions?

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Predator-Prey ppt and exercise on Github…

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