How do you avoid being eaten?

Readings for today

- Oshanin, G., Vasilyev, O., Krapivsky, P. L., & Klafter, J. (2009). Survival of an evasive prey. Proceedings of the National Academy of Sciences, 106(33), 13696-13701

Topics

- The predator-prey dynamic
- The advantage of being a lazy prey

The predator-prey dynamic

Predators and prey

ecological “arms race”

Prey (2022)

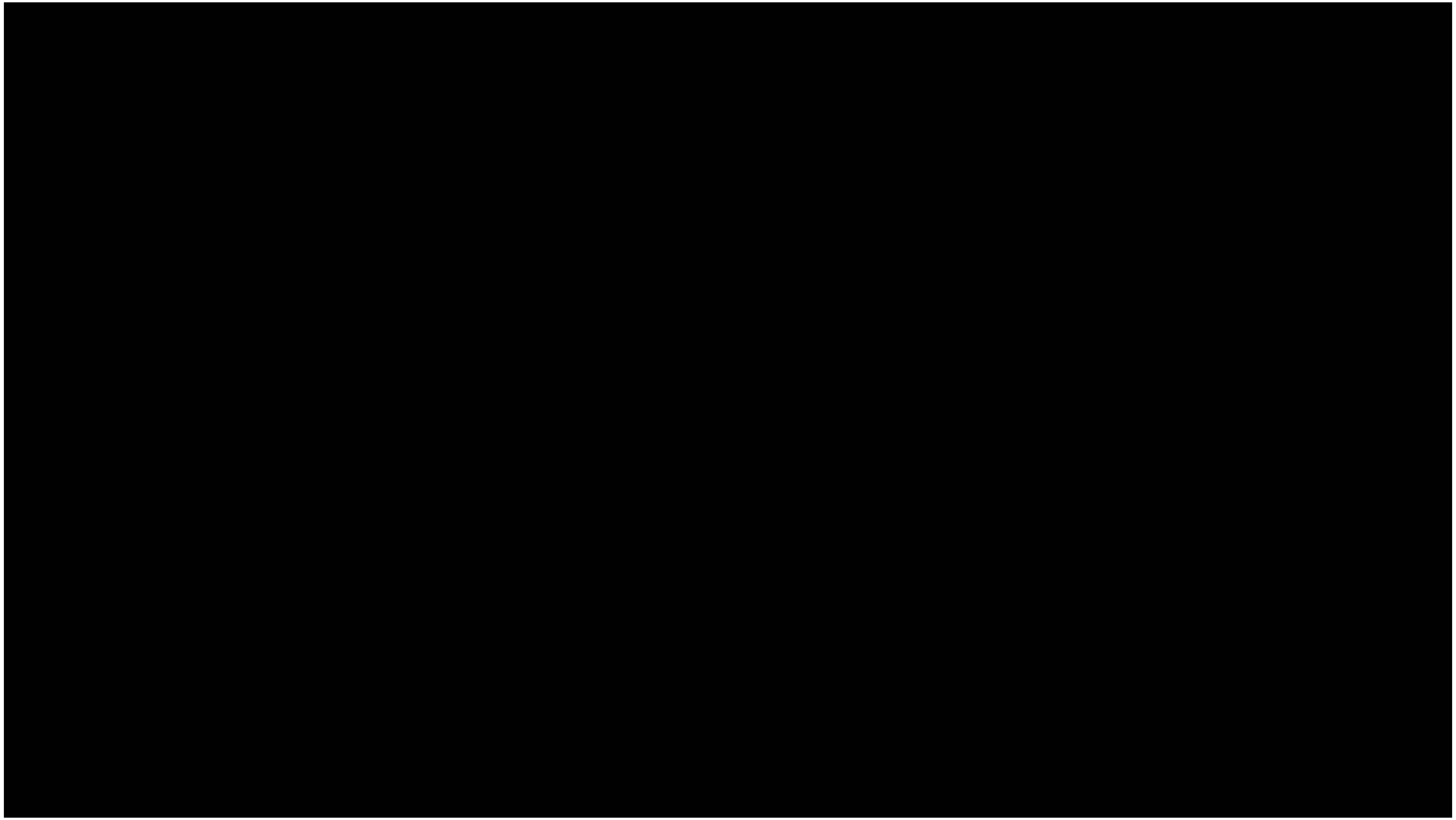
Predator

An organism that actively hunts, kills, and consumes other organisms for sustenance. Predators can be carnivorous, feeding on animals, or herbivorous, feeding on plants. Carnivorous predators are typically what come to mind when we think of this term, but herbivores, which consume plants, are technically predators of plants

Prey

An organism that is hunted, killed, and consumed by a predator. Prey can include animals, plants, or other organisms. In some cases, prey have evolved specific adaptations or behaviors to avoid or deter predation, such as camouflage, toxins, or defensive structures.

Predator-prey dynamics



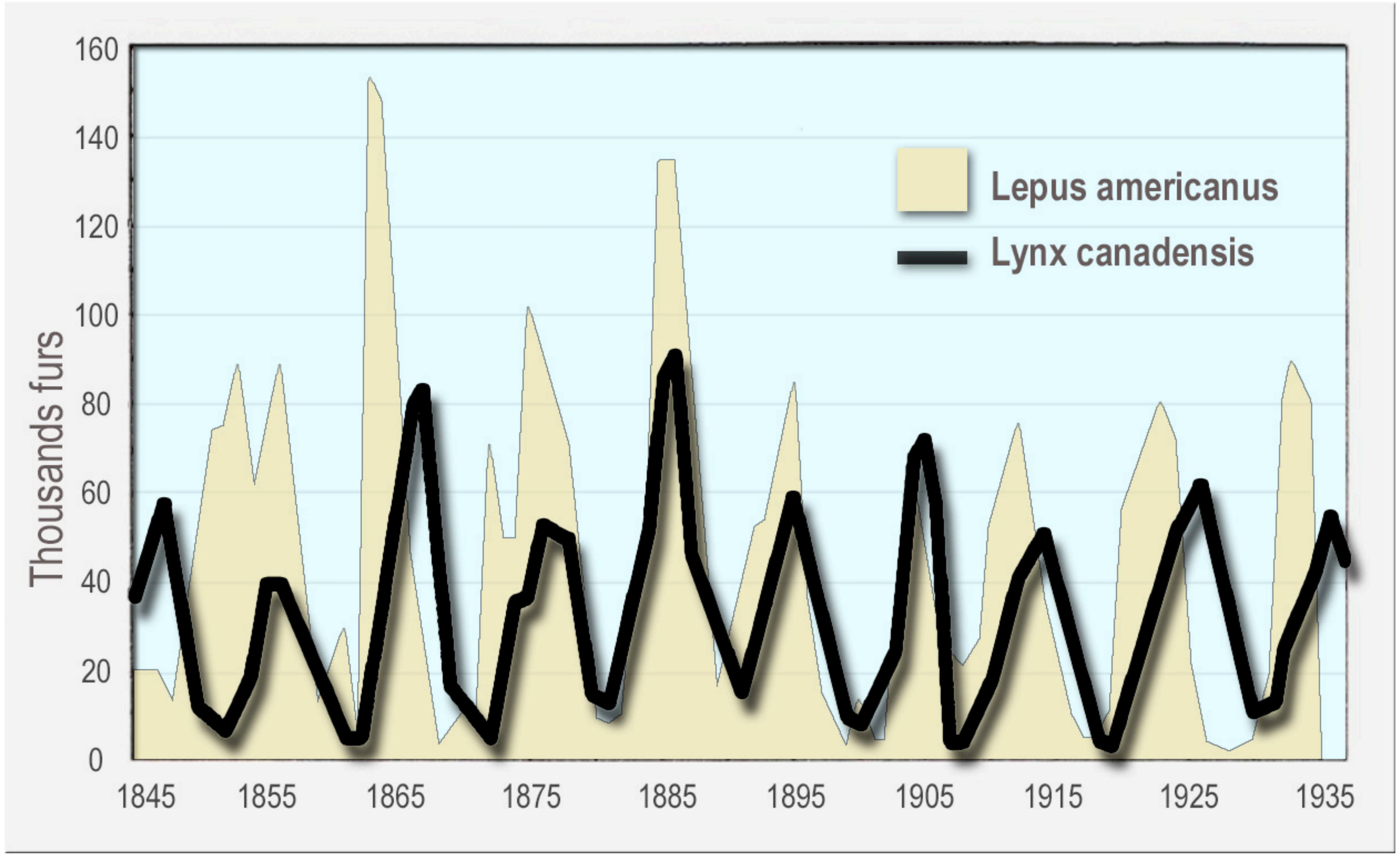
https://www.youtube.com/watch?v=NYq2078_xqc

Kahn Academy

Lotka-Volterra equations

Lotka-Volterra equations

Differential equations used to describe the oscillations observed in predator and prey populations over time.



https://en.wikipedia.org/wiki/Lotka%E2%80%93Volterra_equations

(Lotka 1910)

Lotka-Volterra equations

Lotka-Volterra equations

Differential equations used to describe the oscillations observed in predator and prey populations over time.

Δ Predator

predator pop. density

$$\frac{d\mathbf{y}}{dt} = \sigma\mathbf{x}\mathbf{y} - \gamma\mathbf{y}$$

effect of prey

max predator

Δ Prey

prey pop. density

$$\frac{d\mathbf{x}}{dt} = \alpha\mathbf{x} - \beta\mathbf{x}\mathbf{y}$$

max prey

effect of predator

(Lotka 1910)

Competing decision goals

Predator

How do I used sensory signals to find my prey?

↓

Pursuit

Prey

How do I used sensory signals avoid being eaten?

↓

Avoidance

The advantage of being a lazy prey

Survival strategies

Goal: Choose a deterministic motion strategy, given the predator and prey's velocities and sighting ranges, that optimizes their respective chances of successful pursuit or evasion.

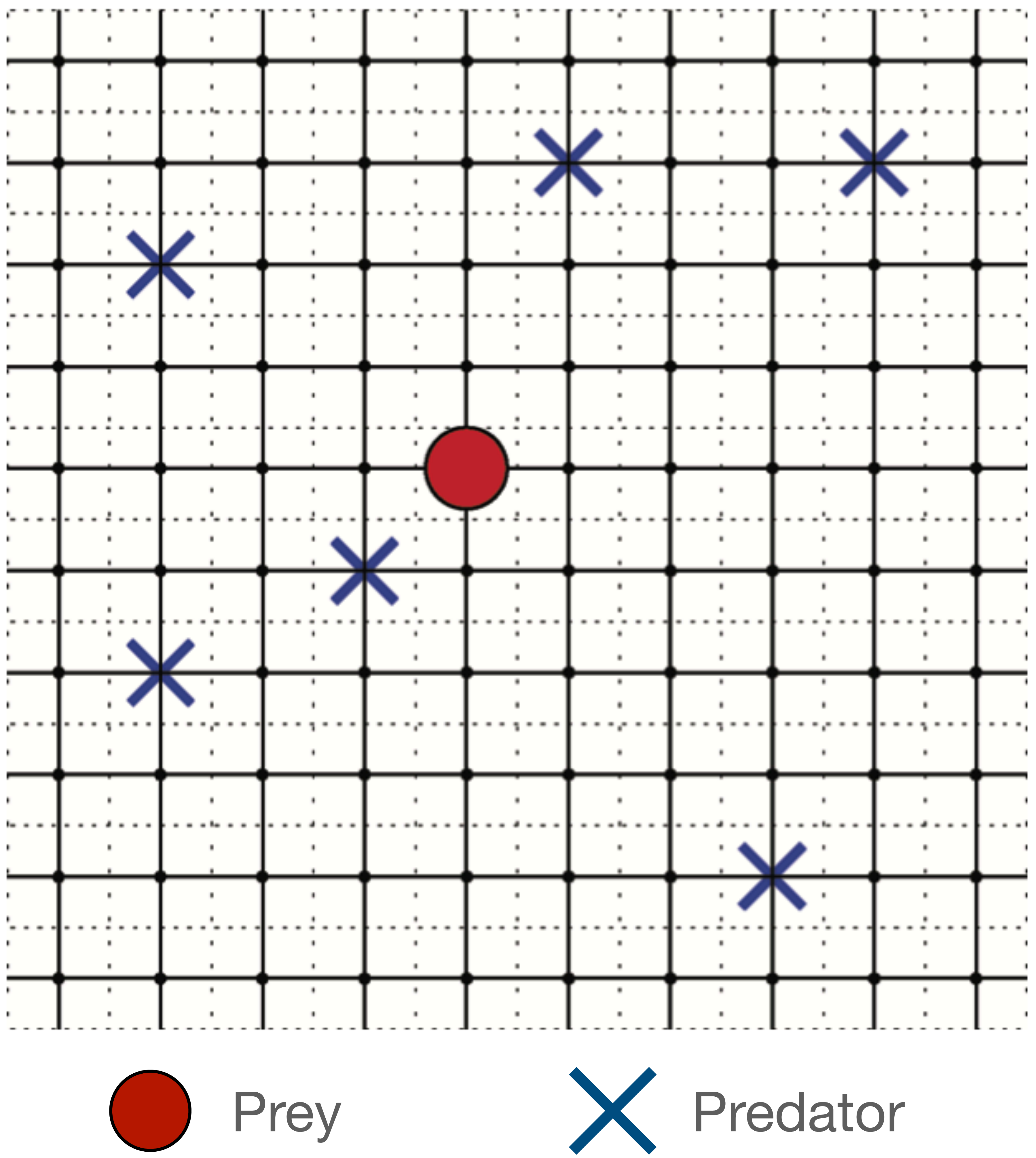
How should the prey move in order to maximize its chances of not being caught up to time t?

(Oshanin et al. 2009

Princesses and monsters

Minimal model

1. On a square lattice with V sites and periodic boundaries, N predators are randomly placed; prey starts at the origin.
2. Predators execute a nearest-neighbor random walk (RW) simultaneously without interactions; multiple predators can occupy one site.
3. When a predator is next to the prey, it moves to the prey's site, capturing it.
4. Before predators move, the **evasive** prey checks adjacent sites. If all are empty, it stays put. If some are occupied, it moves to a randomly selected unoccupied site, given that its four neighbors are vacant. Predators still follow the initial prey's location.



(Oshanin et al. 2009

Survival probabilities

Immobile prey

$$P_{\mathrm{imm}}(t) \sim e^{-\alpha\rho t}$$

Evasive prey

$$P_{\mathrm{ev}}(t) \sim \begin{cases} e^{-B\alpha\rho^3 t} & \text{finite lattice} \\ e^{-B\rho^3 S(t)} & \text{infinite lattice} \end{cases}$$

Terms

N = number of predators

V = number of sites (nodes)

$\rho = N/V$, predator density

t = time

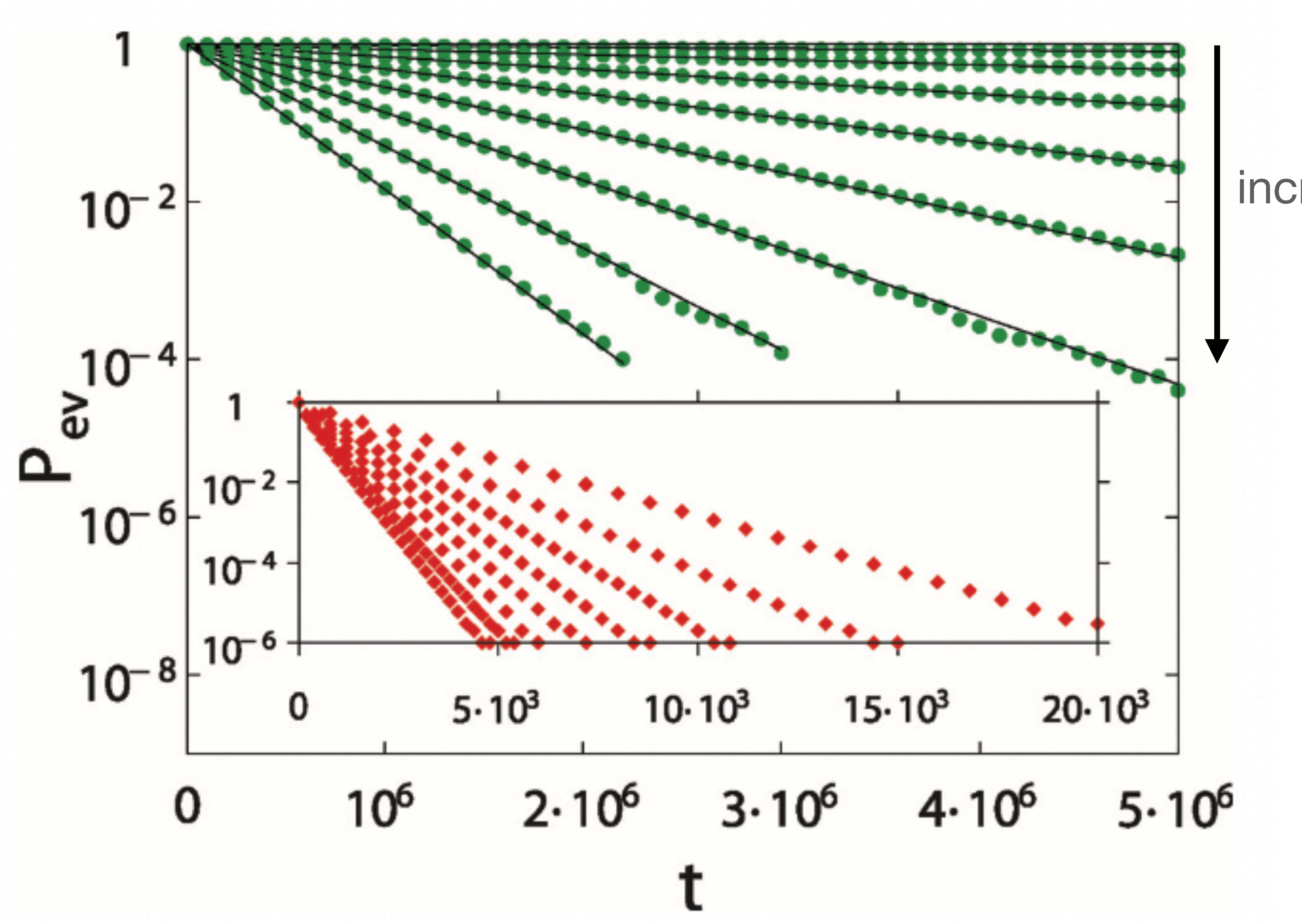
α = scalar that varies with diffusion coefficient of predators

B = numerical scaling factor

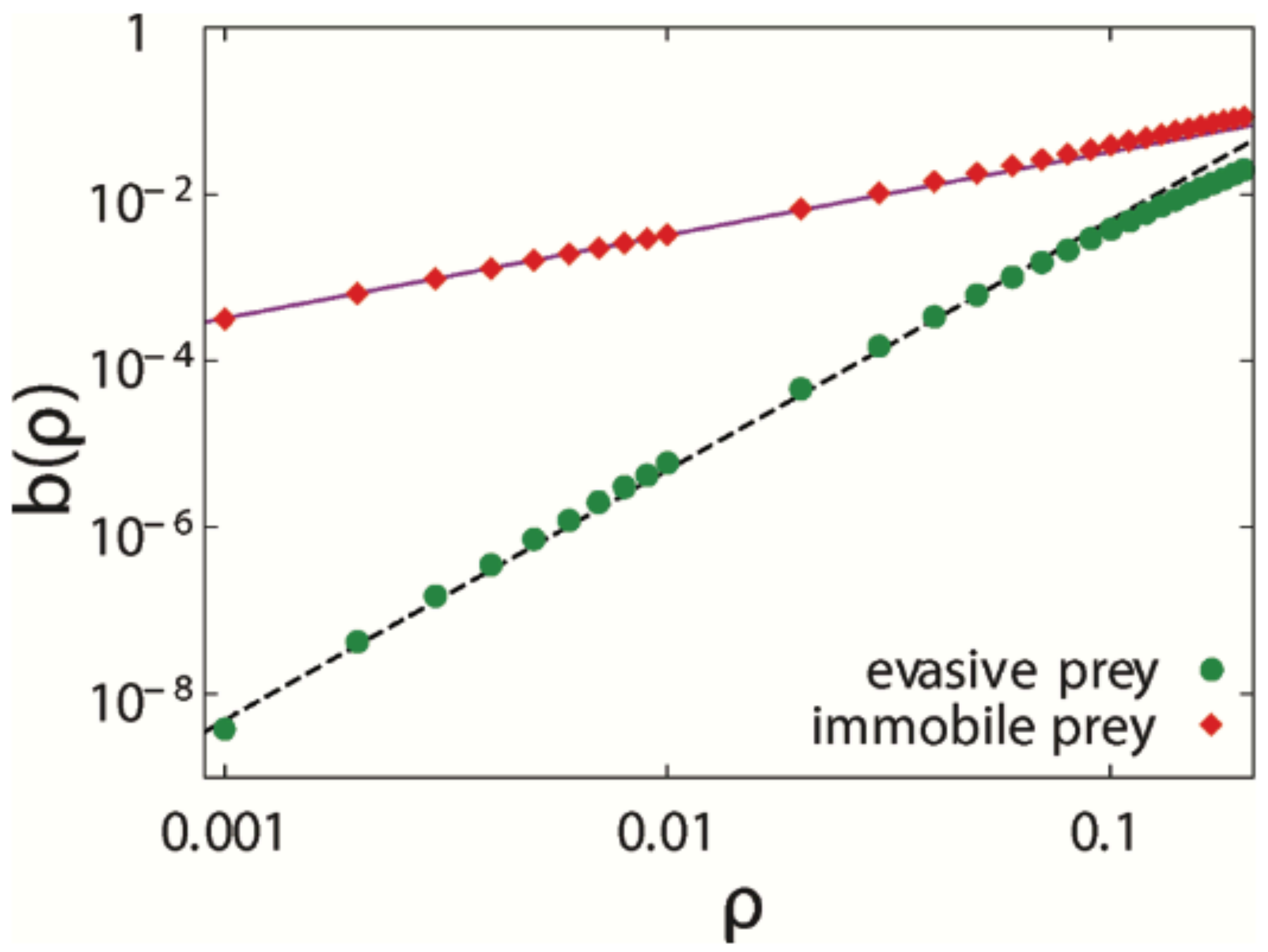
$S(t)$ = mean # of distinct sites visited by a predator up to time t

(Oshanin et al. 2009

Survival probabilities

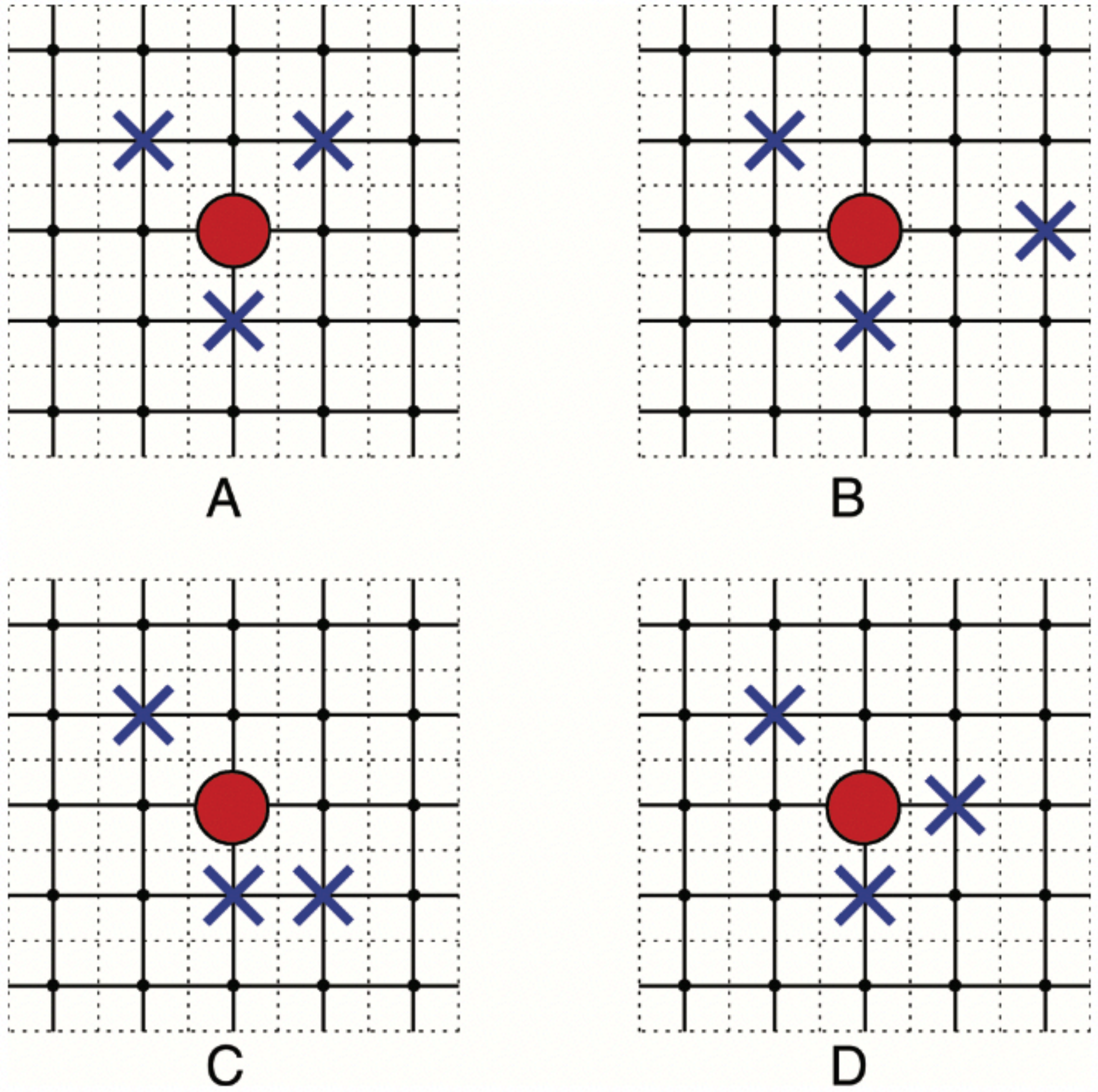


- Survival rates vary linearly with ρ
- Immobile prey: $b(p) \sim \rho$
- Evasive prey: $b(p) \sim \rho^3$



(Oshanin et al. 2009

Stalemate configurations



- Evasive prey cannot be captured by a single predator
- Evasive prey can only be captured with predators in positions where no safe move is available to the prey: ***stalemate configurations.***
- On a square lattice, 3 predators are sufficient to achieve these configurations.

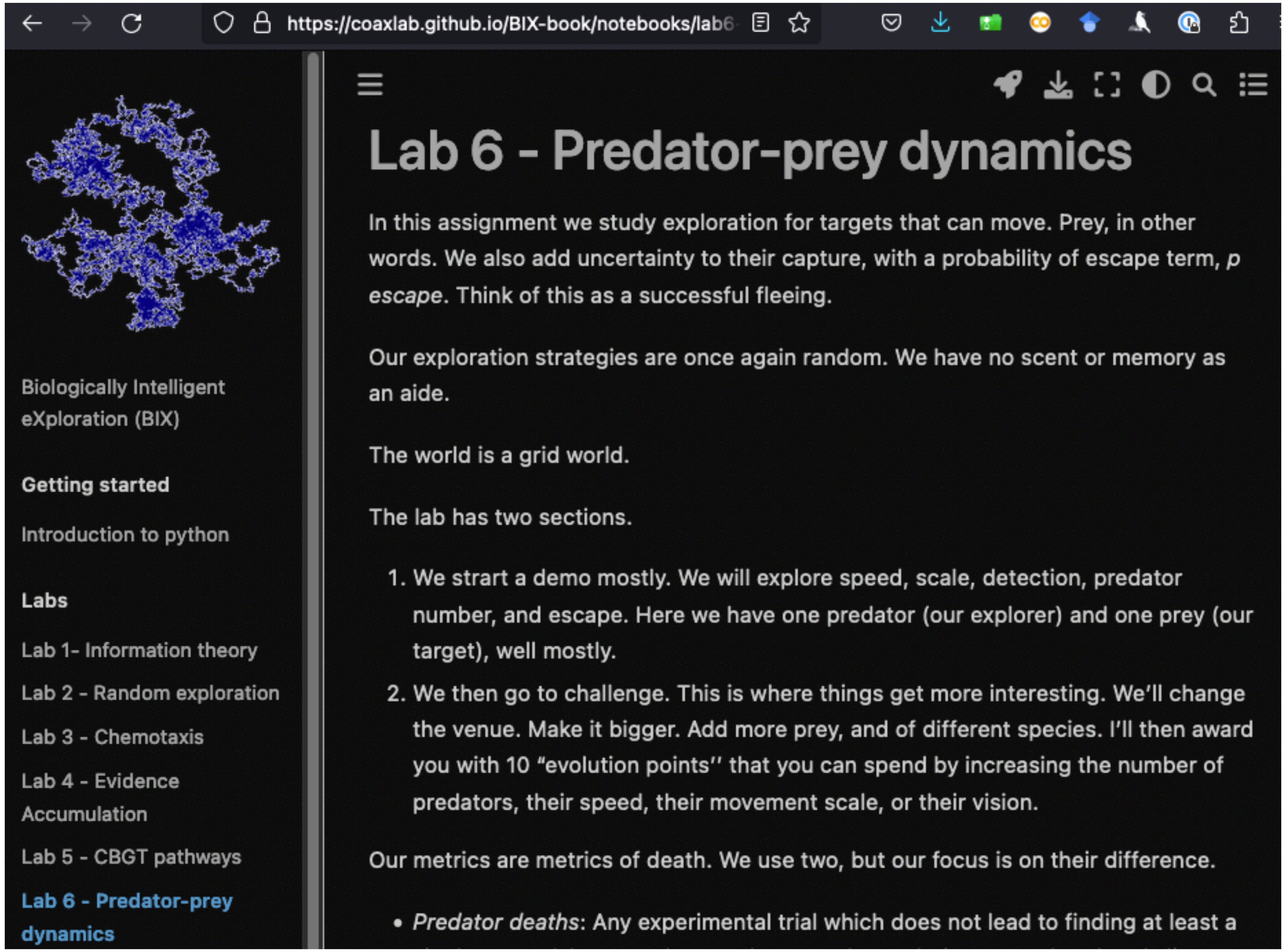
(Oshanin et al. 2009

Take home message

- Predators and prey form a balanced system that can be described by simple oscillator dynamics.
- A simple “lazy” evasive approach, where prey waits to jump to safe positions only when predators are sufficiently close, represents an effective and simple strategy for survival.
- The only way predators can effectively target these prey is via stalemate configurations that close off all avenues of approach.

Lab 6: Predator-prey dynamics

URL: https://coaxlab.github.io/BIX-book/notebooks/lab6-predator_prey.html


https://coaxlab.github.io/BIX-book/notebooks/lab6

Biologically Intelligent eXploration (BIX)

Getting started

Introduction to python

Labs

Lab 1- Information theory

Lab 2 - Random exploration

Lab 3 - Chemotaxis

Lab 4 - Evidence Accumulation

Lab 5 - CBGT pathways

Lab 6 - Predator-prey dynamics

Lab 6 - Predator-prey dynamics

In this assignment we study exploration for targets that can move. Prey, in other words. We also add uncertainty to their capture, with a probability of escape term, *p escape*. Think of this as a successful fleeing.

Our exploration strategies are once again random. We have no scent or memory as an aide.

The world is a grid world.

The lab has two sections.

1. We strart a demo mostly. We will explore speed, scale, detection, predator number, and escape. Here we have one predator (our explorer) and one prey (our target), well mostly.
2. We then go to challenge. This is where things get more interesting. We'll change the venue. Make it bigger. Add more prey, and of different species. I'll then award you with 10 "evolution points" that you can spend by increasing the number of predators, their speed, their movement scale, or their vision.

Our metrics are metrics of death. We use two, but our focus is on their difference.

- *Predator deaths*: Any experimental trial which does not lead to finding at least a