ESRM 350

Competition

Autumn 2016

“The early bird gets the worm, but the second mouse gets the cheese”

- Willie Nelson

Population Growth

- So far, we've focused on the growth of single populations
  - Exponential growth
  - Logistic growth
    - with density dependence

- In reality, populations don't grow in isolation; rather, they are subject to the influence of other populations
  - Competition
  - Predation
  - Parasitism/disease

Competition

- Can be defined as
  - active demand by two or more organisms for a common vital resource
  - any use or defense of a resource that reduces the availability of that resource to other individuals

- Competition can be
  - within species (*intra-specific*)
    - contributes to density-dependence (worse with crowding)
  - between species (*inter-specific*)
    - depresses carrying capacity (K) for both competing populations

Types of Competition

- **Exploitation competition**
  - Competition through reduced availability of a shared resource
    - does not involve direct interaction
    - winner is the forager that turns resources into offspring the quickest (i.e., that forages most efficiently)

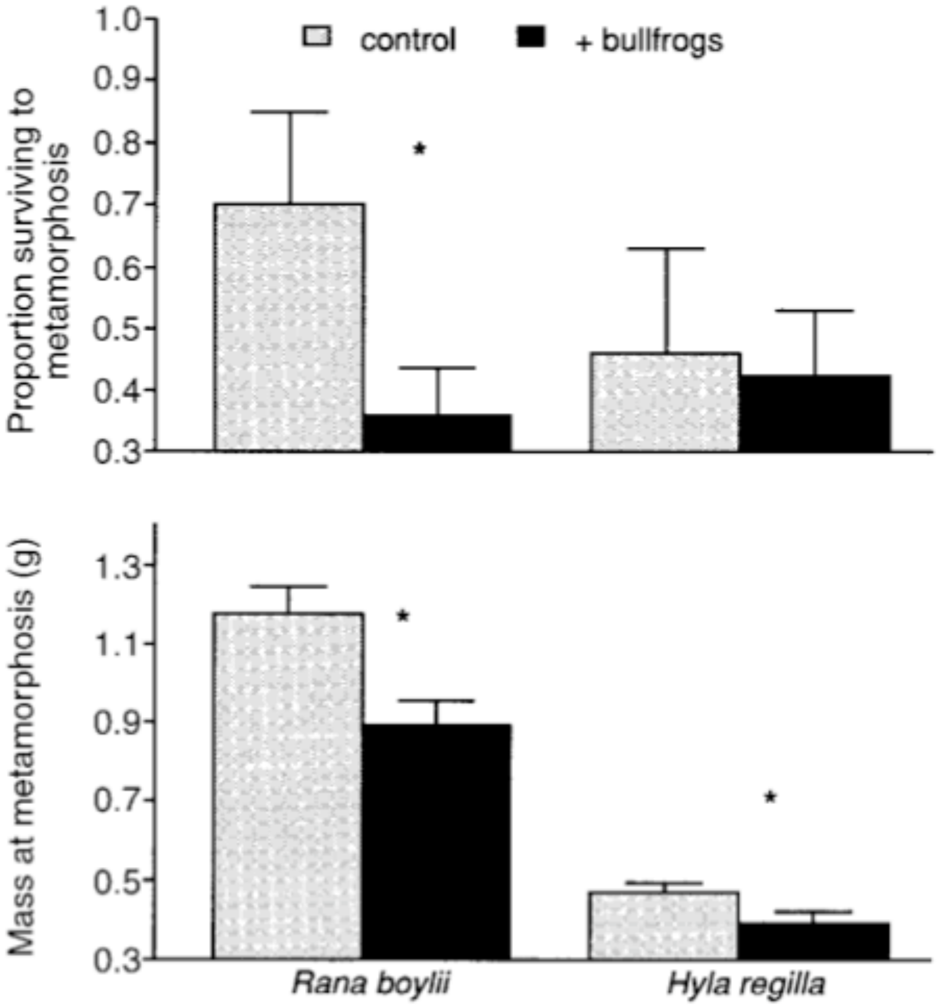


FIG. 6. Survival to and mass at metamorphosis for native tadpoles in the presence (dark bars) or absence (light bars) of bullfrog tadpoles in 2-m² enclosures of natural river substrate (means and 1 SE; Experiment III). Asterisks indicate significance ($P < 0.05$). For *R. boylii*: control $n = 85$ metamorphs; treatment $n = 41$. For *Hyla*: control $n = 35$ metamorphs; treatment $n = 32$.

Yellow-legged frog (*Rana boylii*)

Pacific tree frog (*Hyla regilla*)

Effect of bullfrogs – reduction of benthic algae, a shared resource

Kupferberg (1997) *Ecology*

Types of Competition

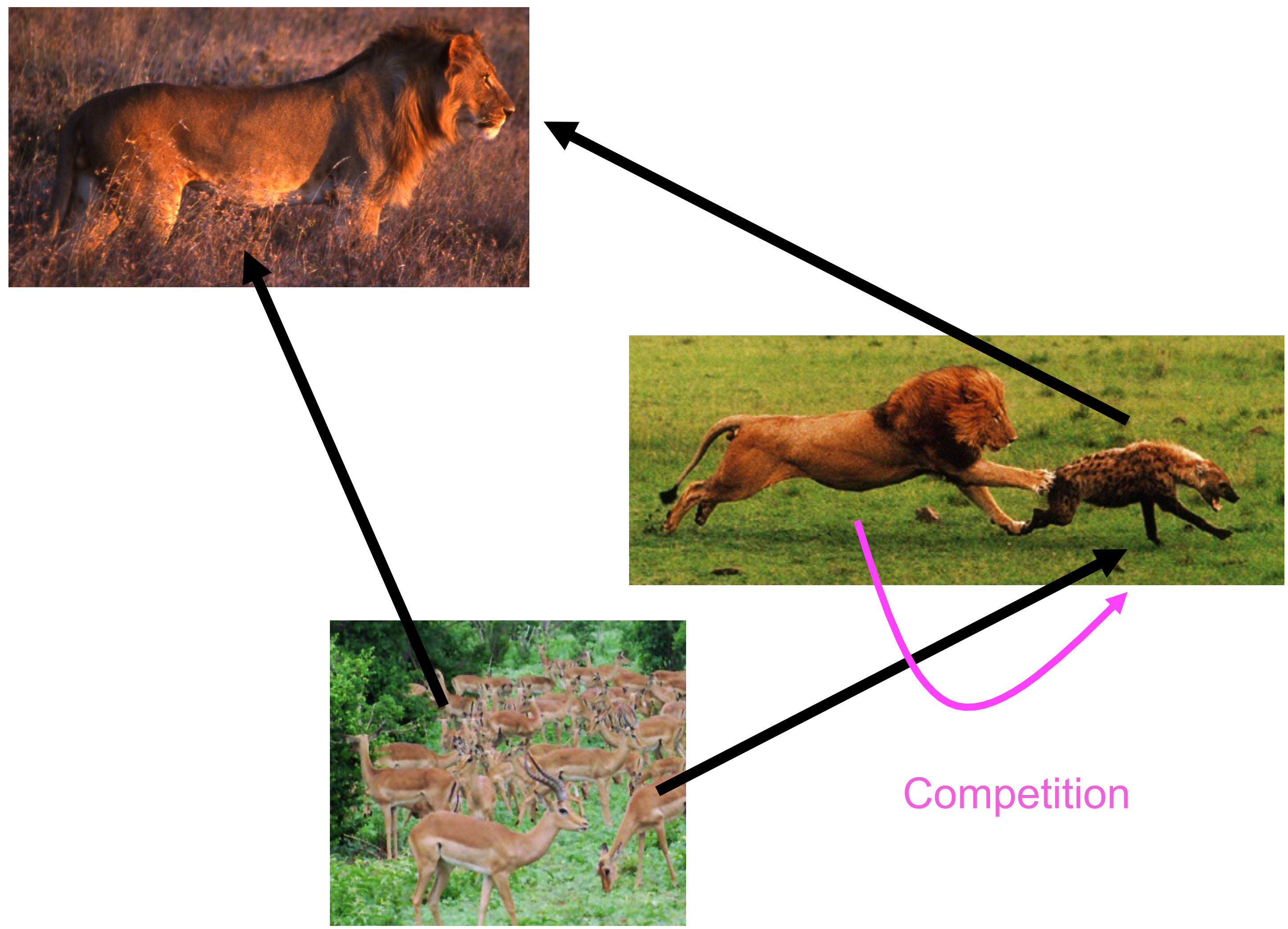
- **Interference competition**
  - Competition with direct interactions between individuals
    - may involve contests or fights over food
    - may involve physical obstruction (getting in another individual’s way)
    - winner often individual that gets to resource first
    - resource doesn’t have to be in short supply, but interference competition is more likely if shortages exist

- Hummingbirds exclude other hummingbirds (as well as bees and moths) from flowering plants

Intraguild Predation (IGP)

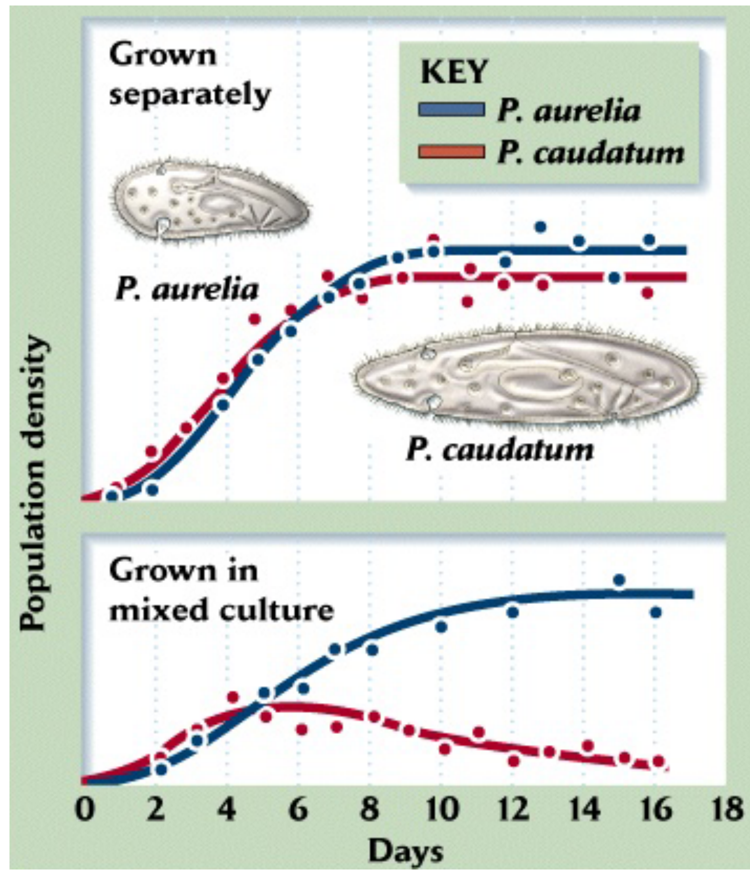
- An extreme form of competition where predator and prey are also competitors
  - Cannibalism is when IGP occurs within a species

Intraguild Predation (IGP)



Competitive Exclusion

- Gause's Exclusion Principle (Principle of Competitive Exclusion)
  - two species that are too similar in their ecological requirements cannot coexist for long *or*
  - two species cannot coexist forever on the same limiting resource
  - the lesser competitor will be **excluded** from an area or go extinct



Competitive Exclusion

- How similar is too similar?
  - i.e., how do we determine the outcome of a competitive interaction between any two populations?
- Lotka-Volterra model for competing species
- $\alpha_{i,j}$ is the **competition coefficient**
  - Quantifies effect of species j on the population growth of species i (expressed in terms of number of species i individuals that would have to be added to have same competitive impact as one individual of species j; value of 1 signifies equivalence)
  - $\alpha_{i,j}$ **(e.g., 2)** $\alpha_{j,i}$ **(e.g., 0.5)**

Alfred Lotka, US mathematician; **Vito Volterra**, Italian mathematician

Lotka-Volterra Model

$$\frac{dN_1}{dt} = r_1 N_1 \left(1 - \frac{N_1}{K_1} - \frac{\alpha_{12} N_2}{K_1}\right)$$

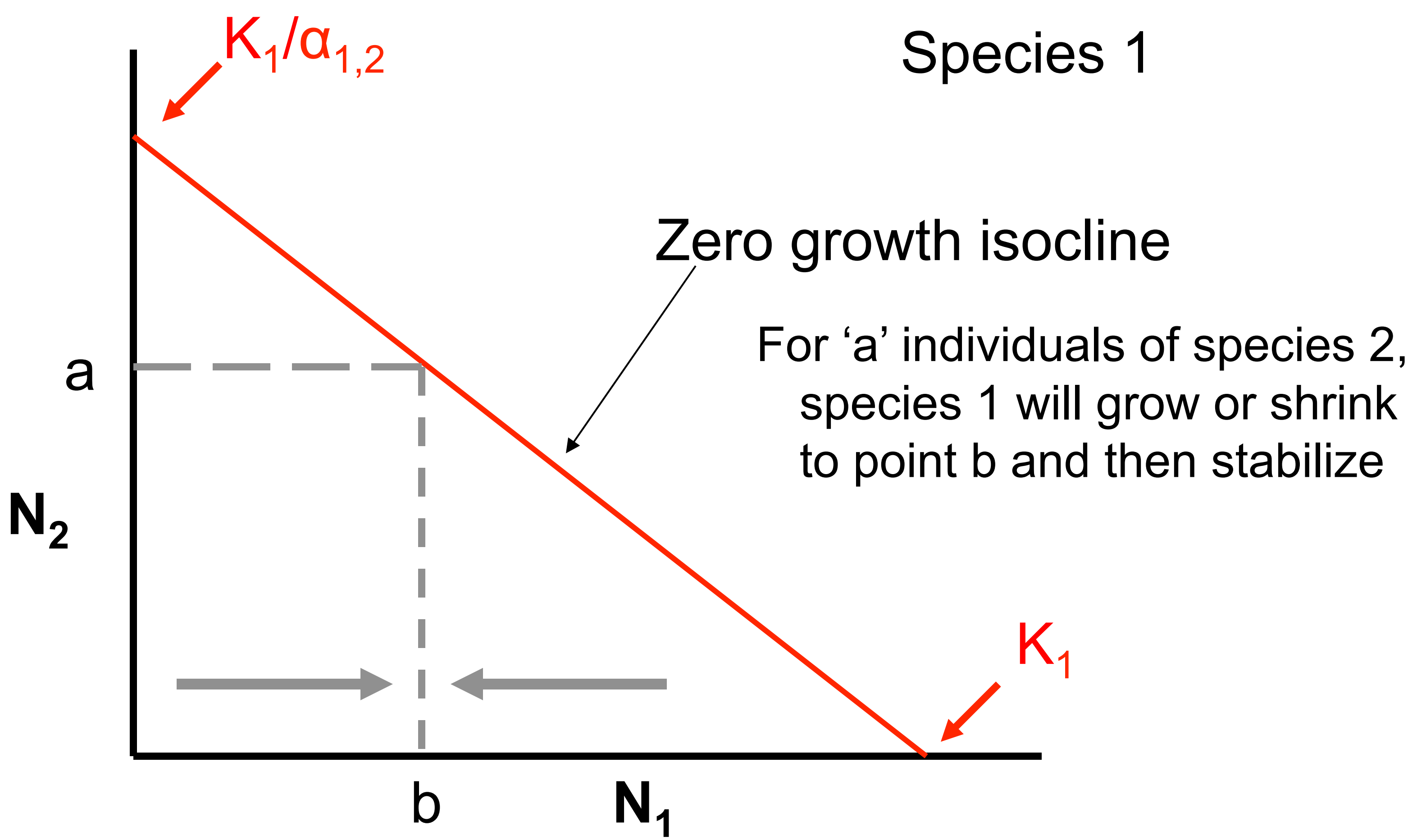
$$\frac{dN_2}{dt} = r_2 N_2 \left(1 - \frac{N_2}{K_2} - \frac{\alpha_{21} N_1}{K_2}\right)$$

How do these differ from logistic growth?

Model Assumptions

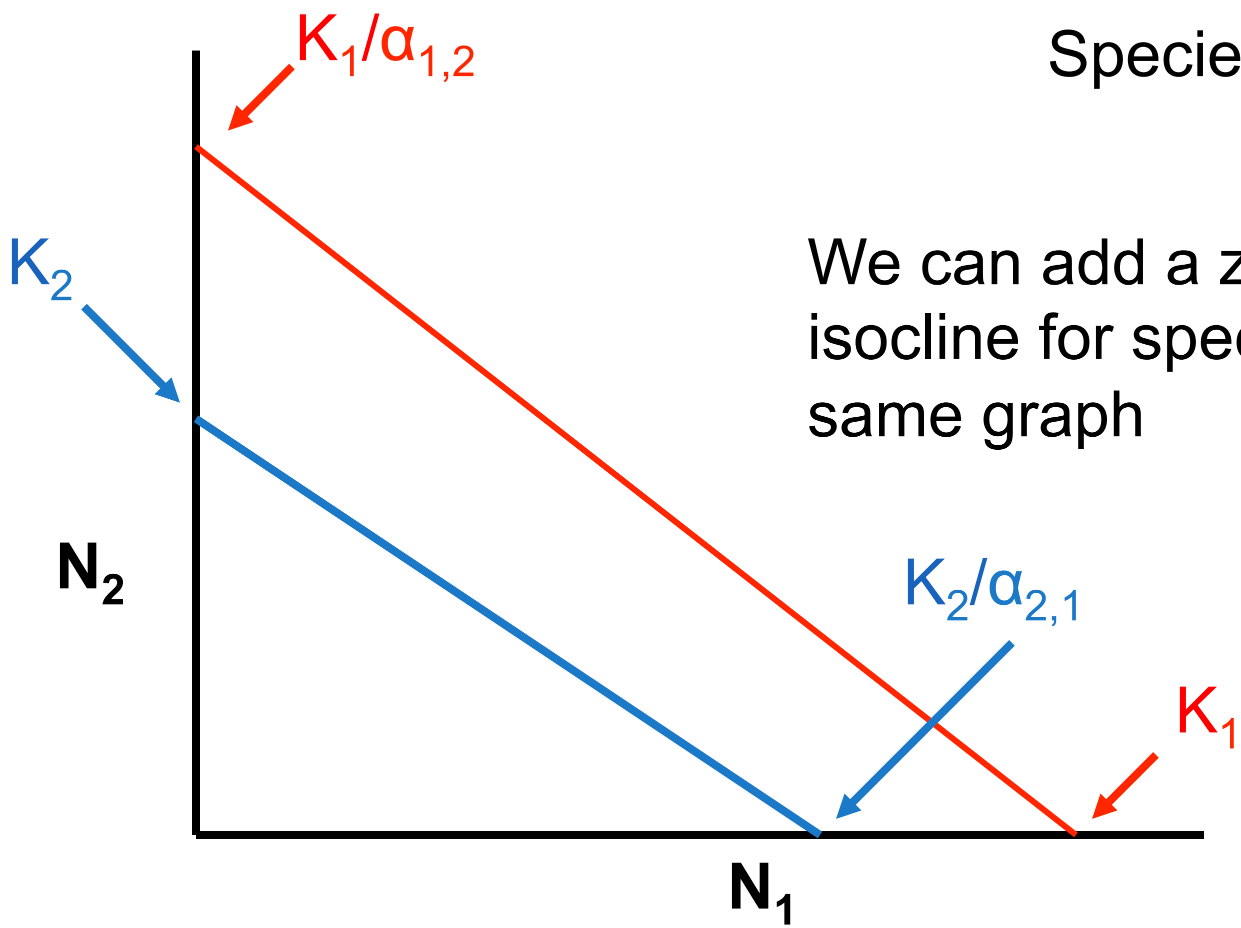
- All individuals are the same
- Competition coefficients are constant
- Linear effect of competition
- Density dependence
- Simple, yes, but this model nevertheless allows us to solve for the growth trajectory of a population subject to competition from a second population of specified size
  - Facilitates prediction of competitive outcomes

Determining the Outcome of Competition: Coexistence vs. Exclusion



The **zero-growth isocline** describes expected equilibrium population sizes of one species if abundance of the second species is held constant, and vice versa

Determining the Outcome of Competition: Coexistence vs. Exclusion

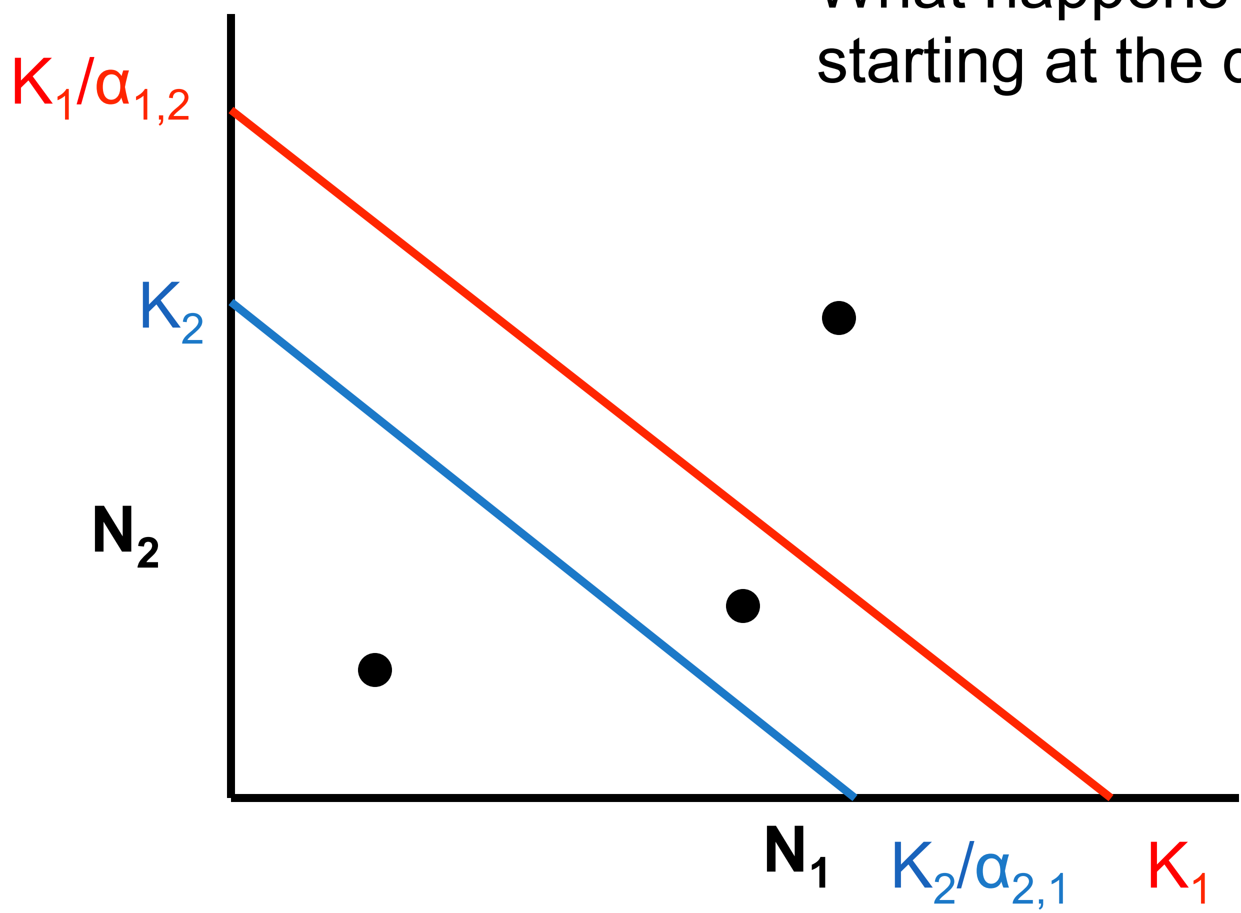


Species 1

We can add a zero growth isocline for species 2 on the same graph

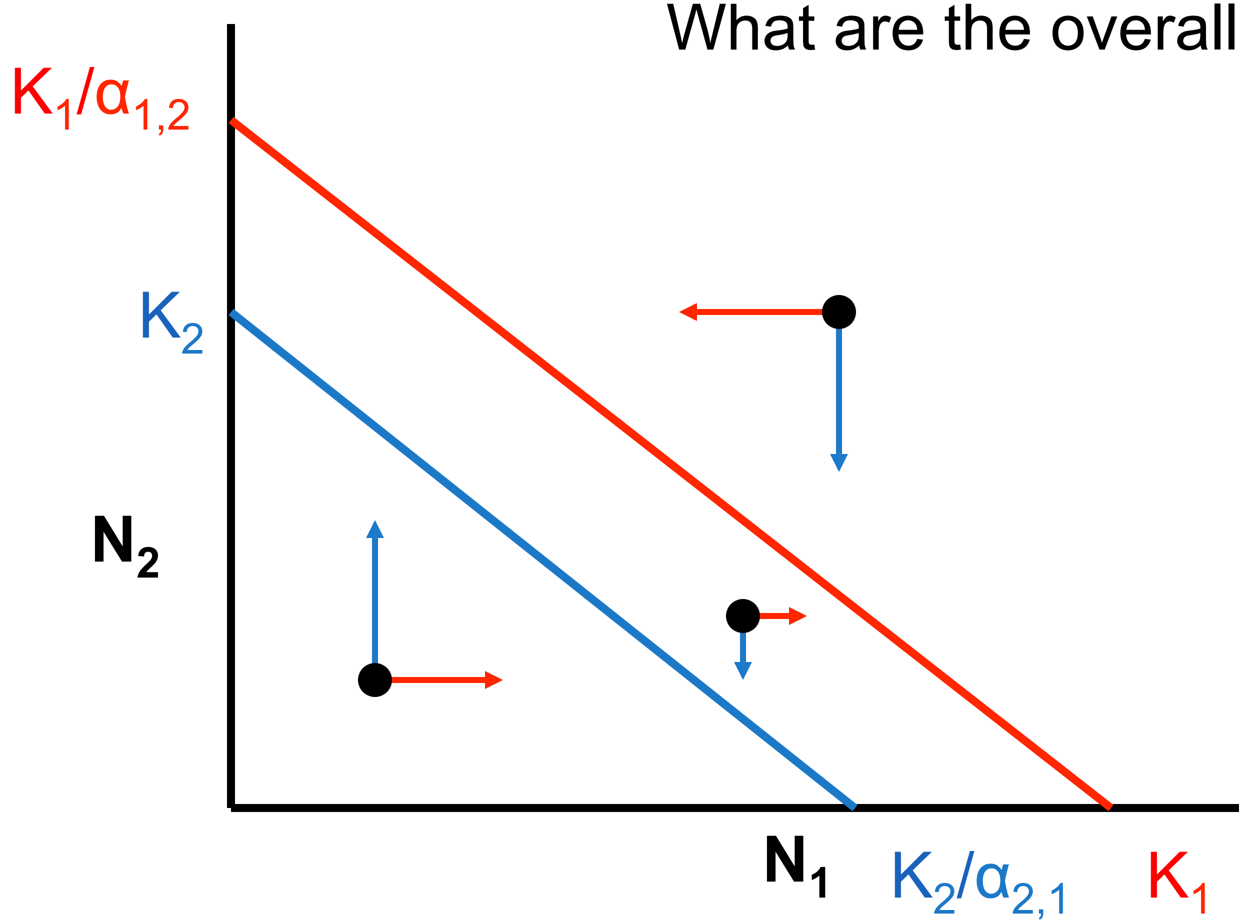
Case 1: Competitive Exclusion of Species 2 by Species 1

What happens to populations starting at the dots?



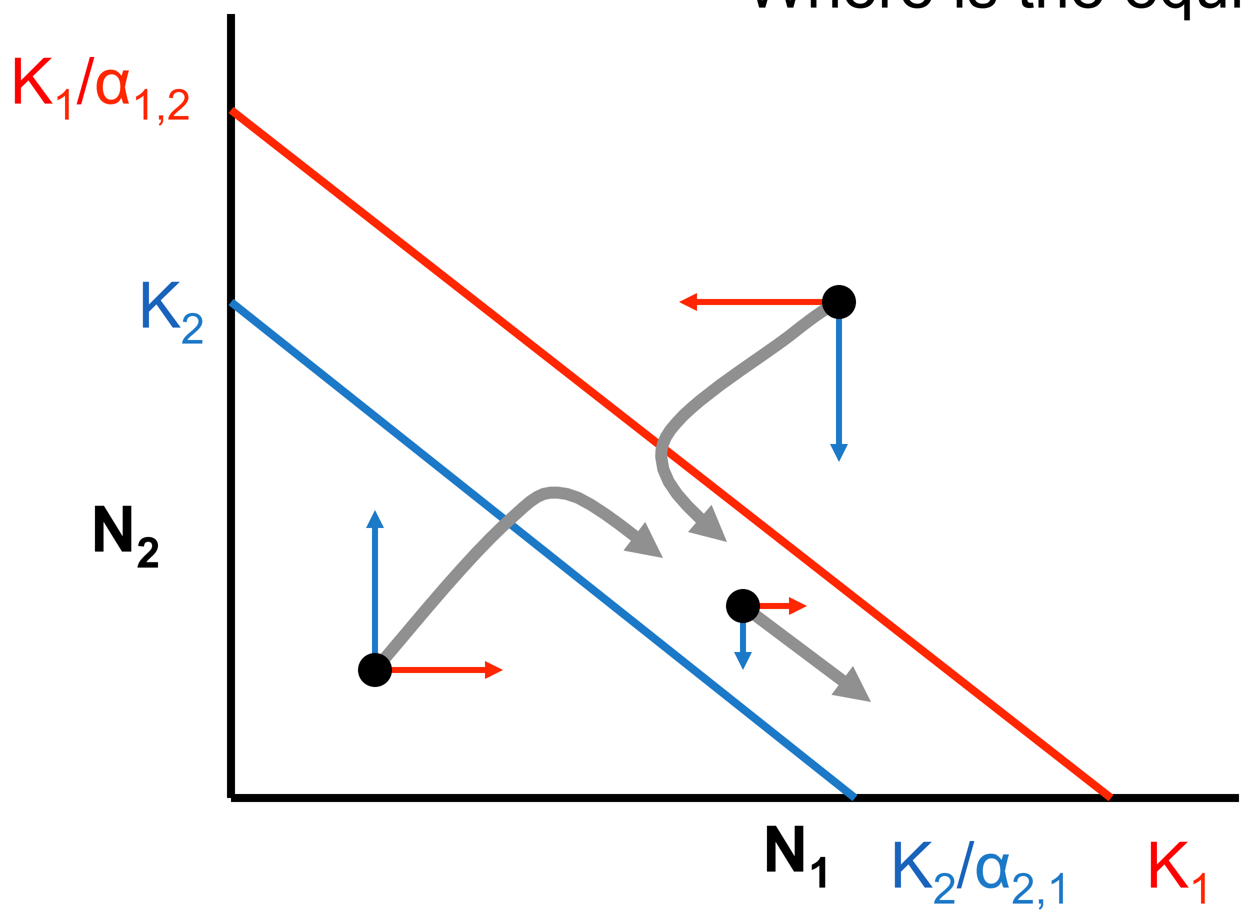
Case 1: Competitive Exclusion of Species 2 by Species 1

What are the overall trajectories?



Case 1: Competitive Exclusion of Species 2 by Species 1

Where is the equilibrium?



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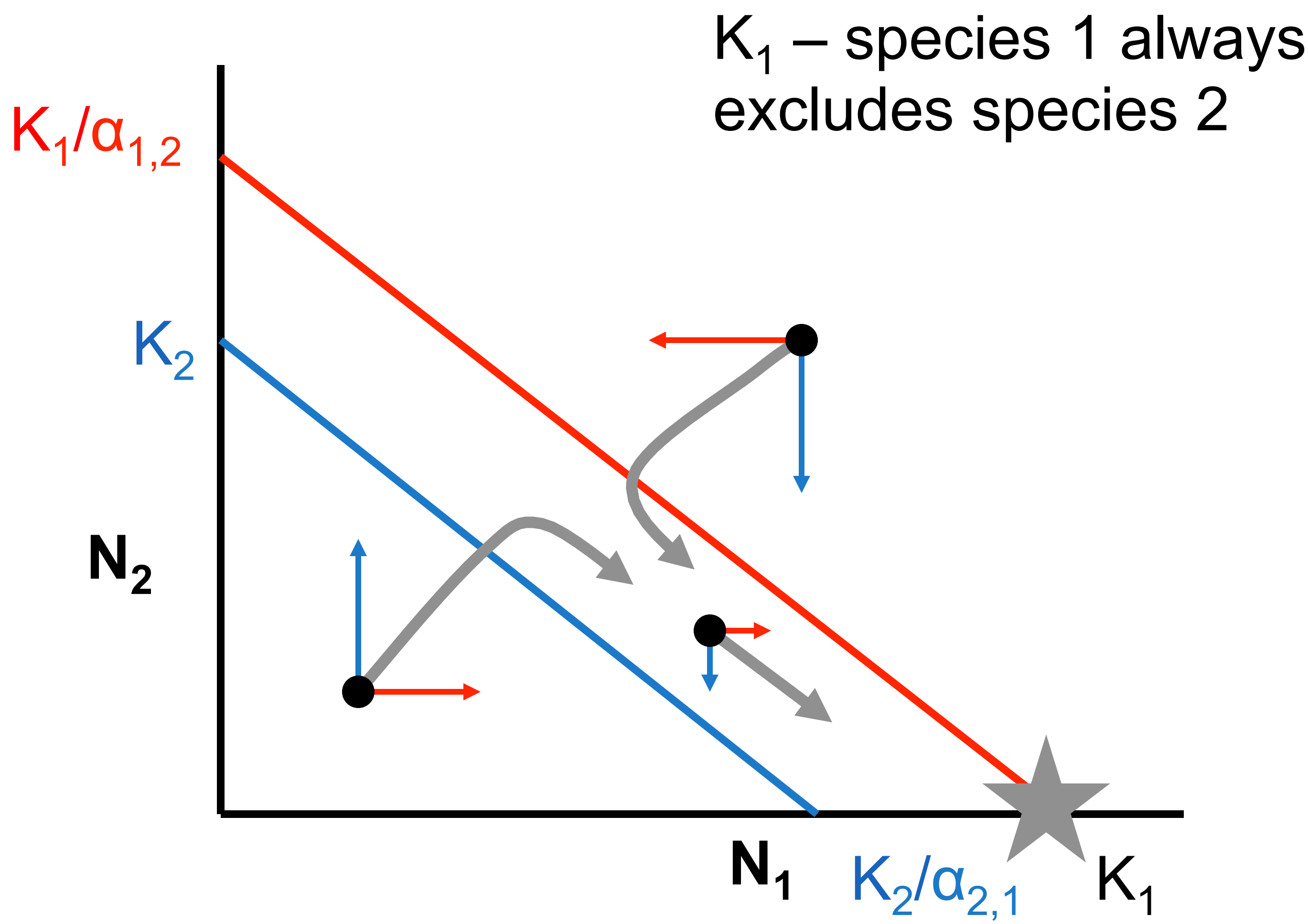
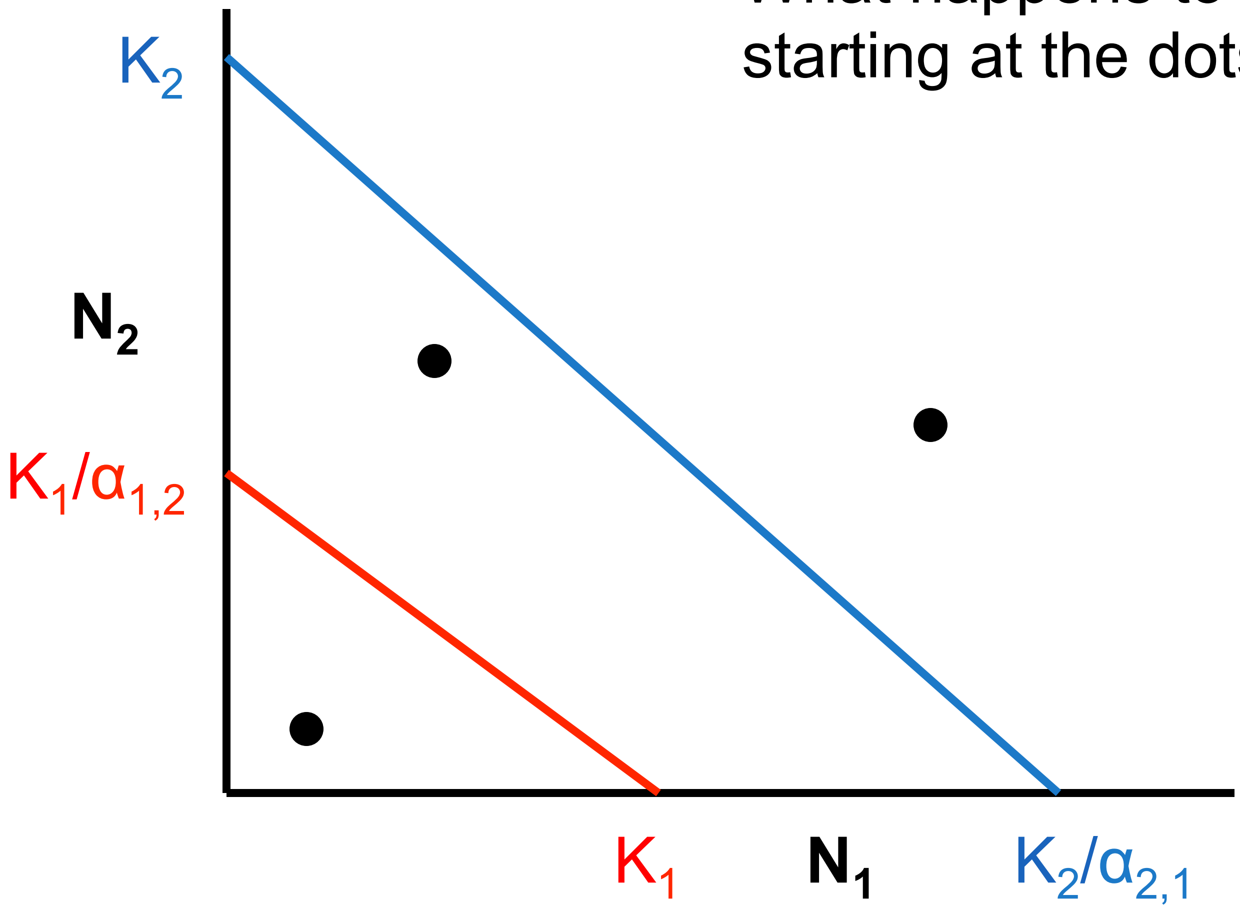


Case 2: Competitive Exclusion of Species 1 by Species 2

What happens to populations starting at the dots?



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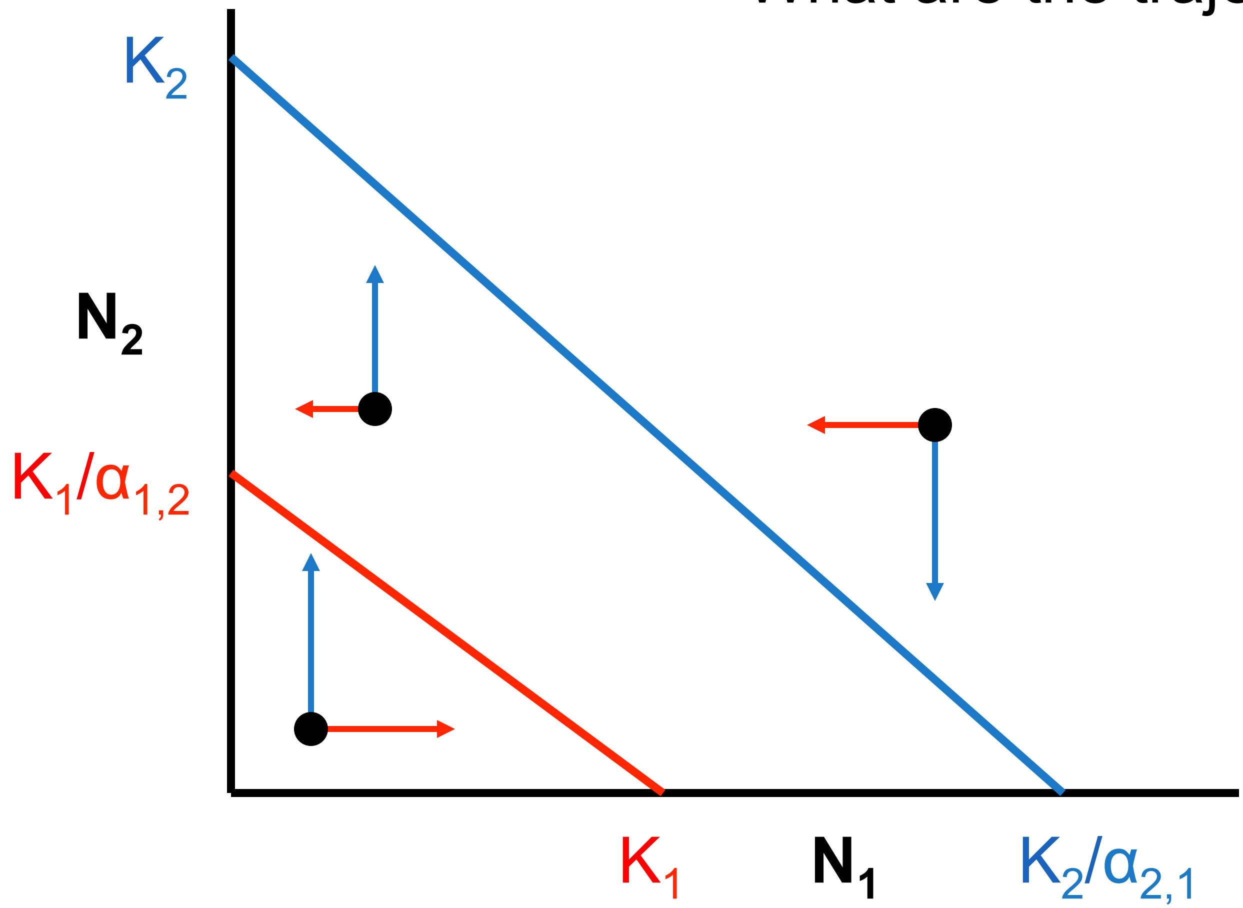
What are the trajectories?



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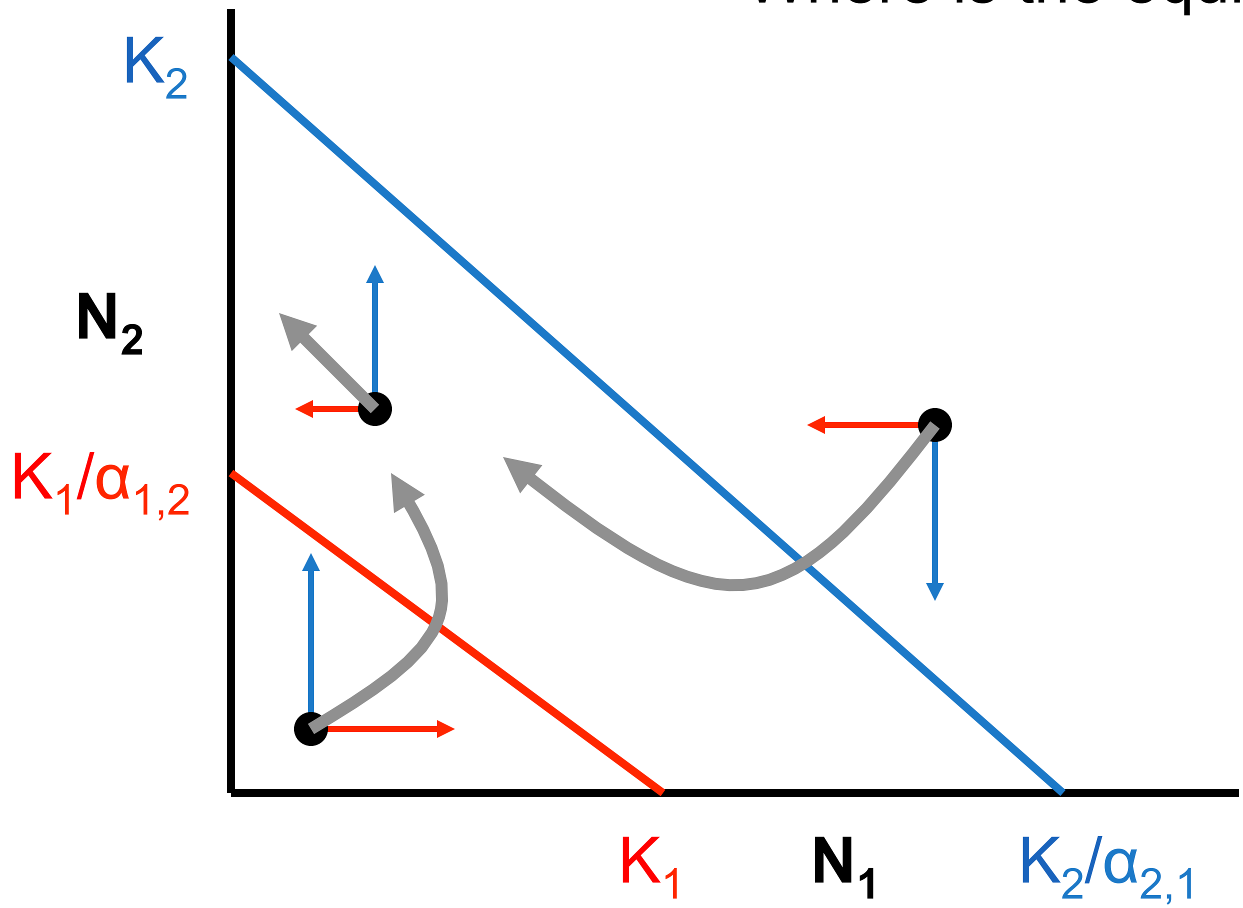

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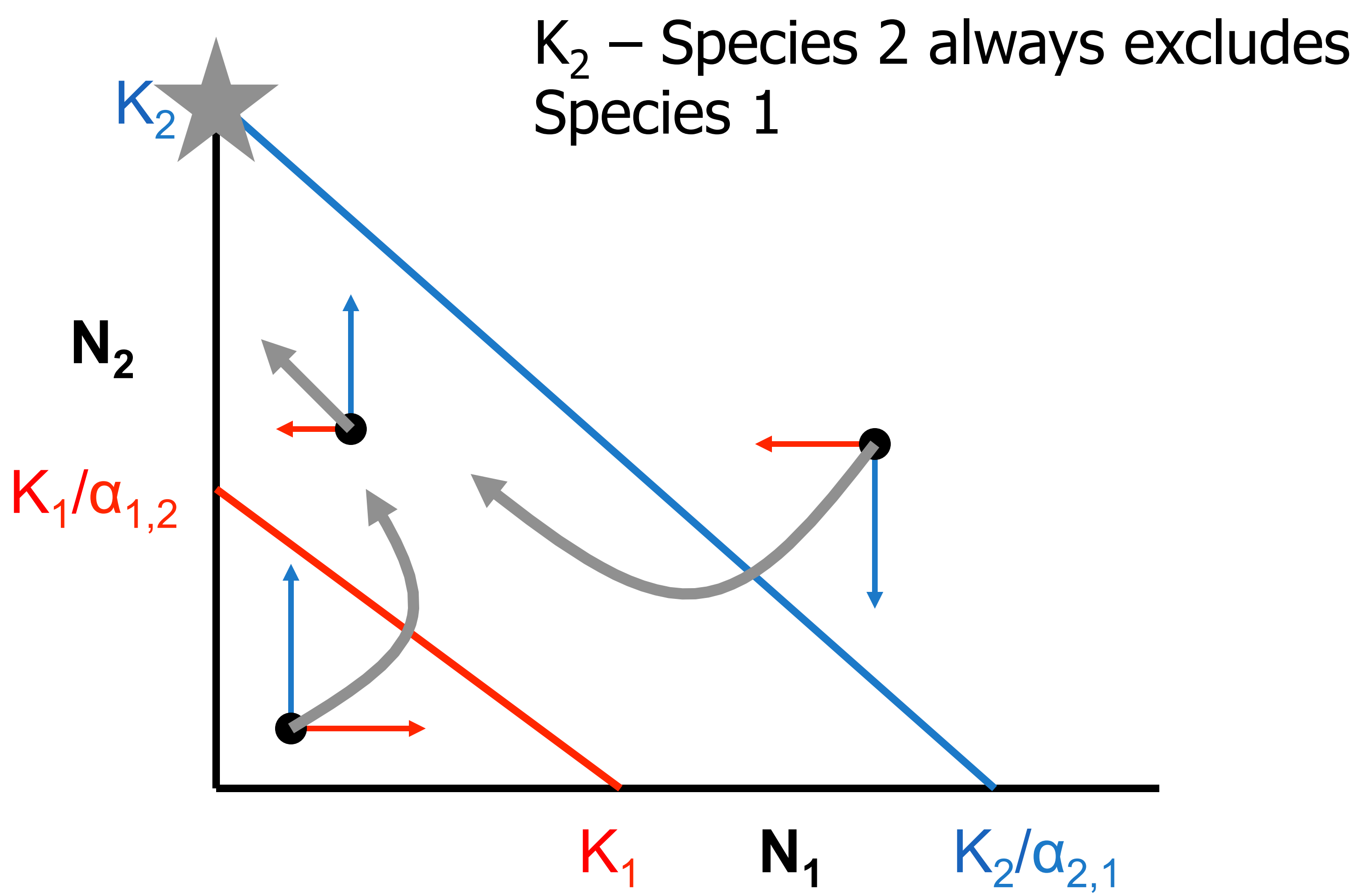
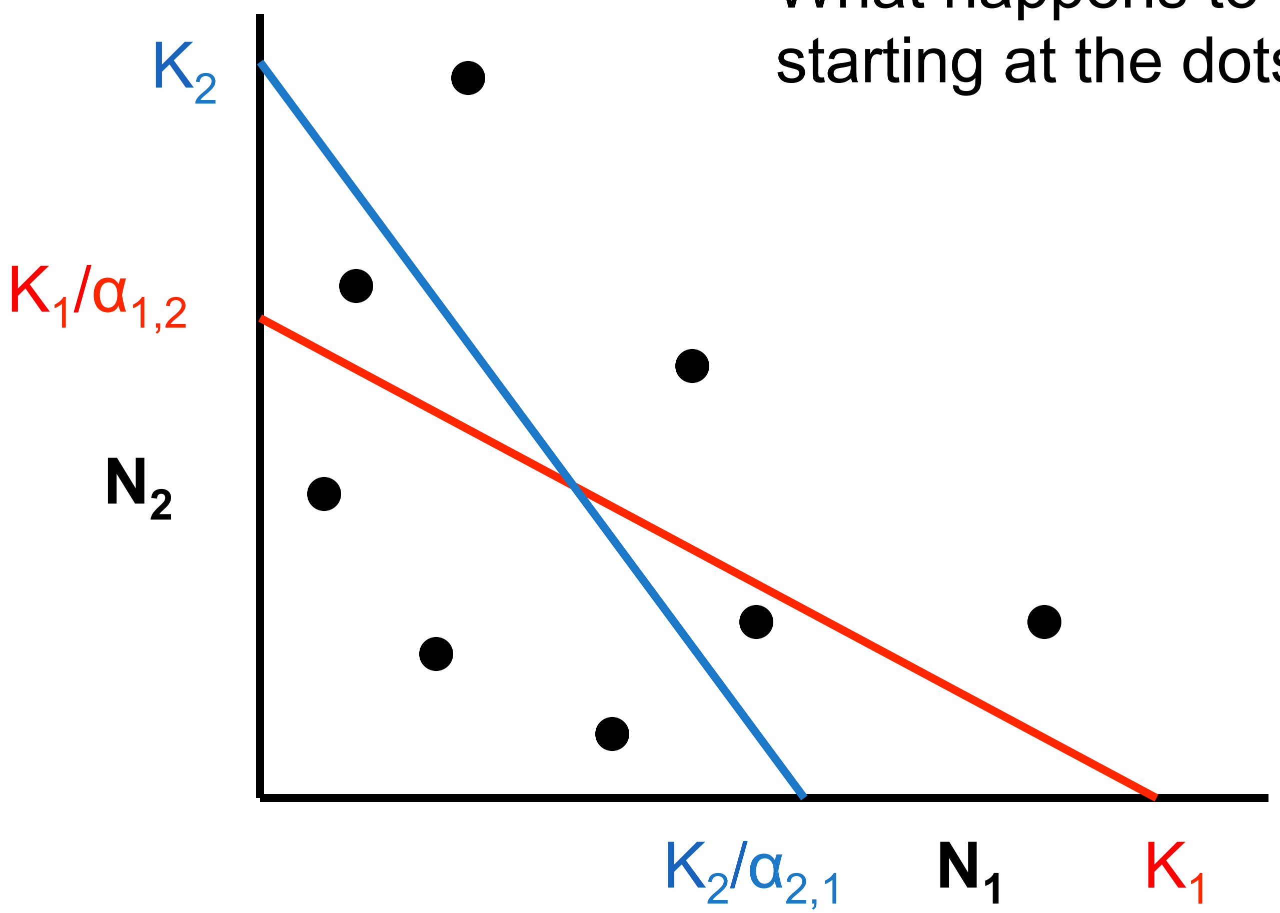


Case 3: Unstable Equilibrium



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Case 3: Unstable Equilibrium

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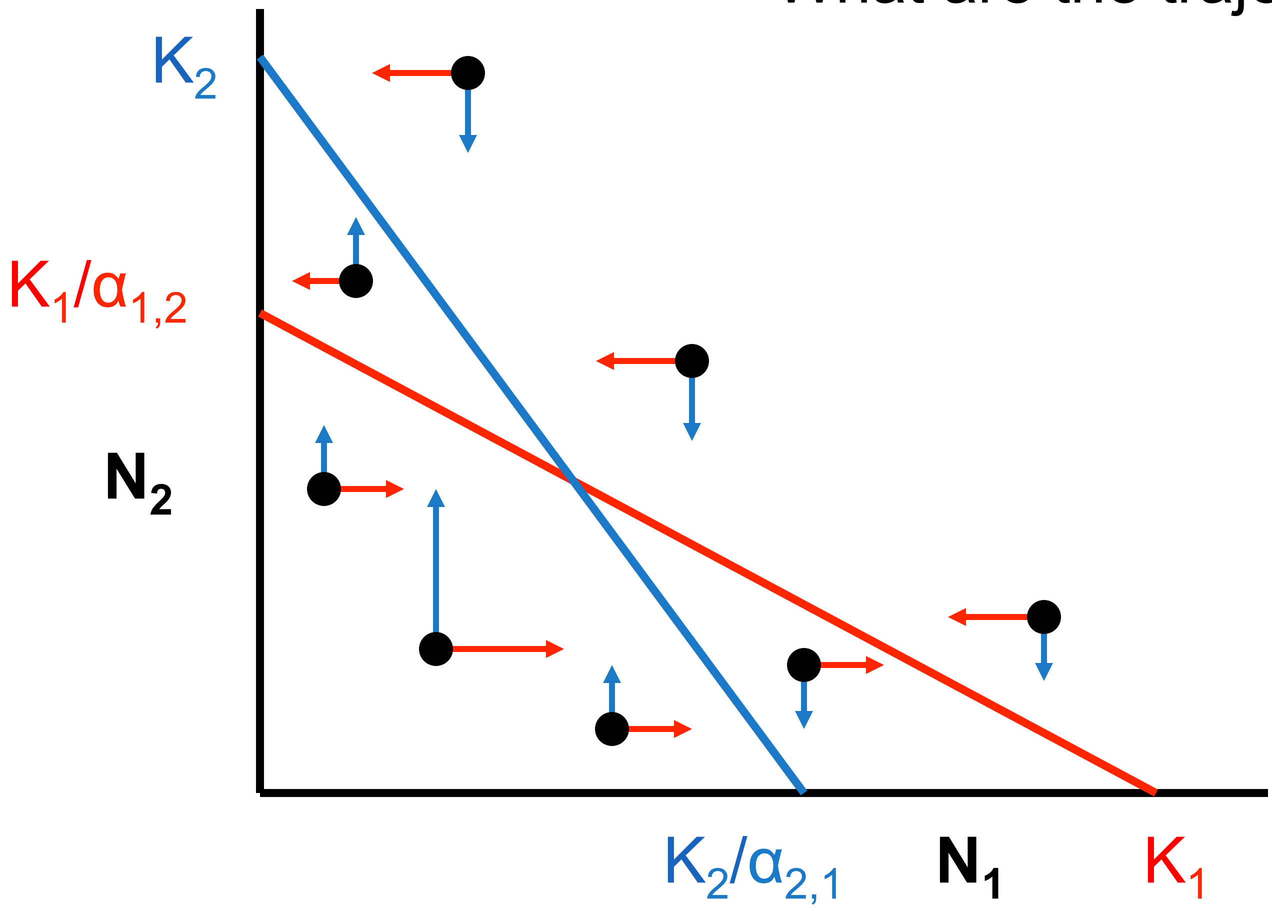

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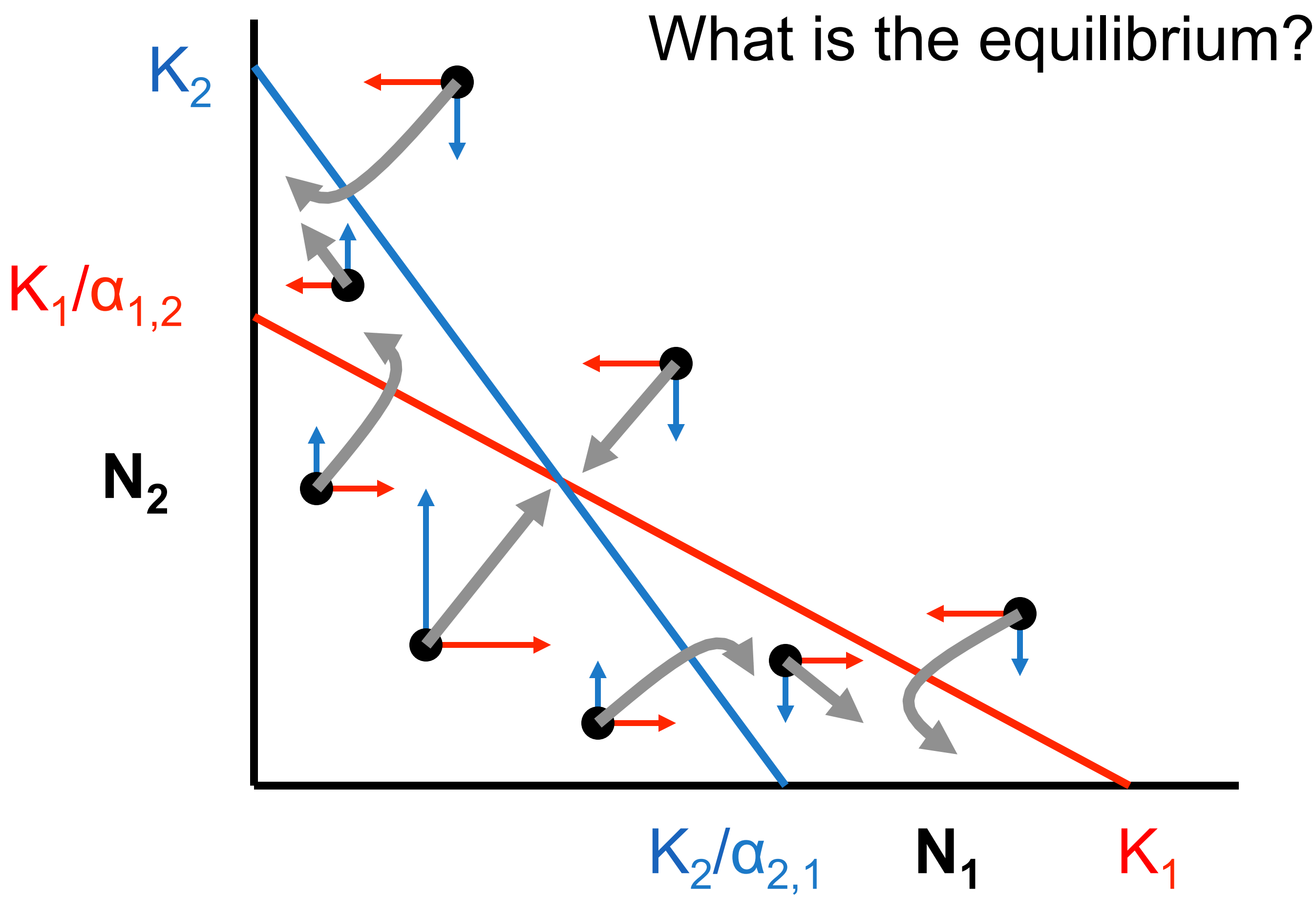

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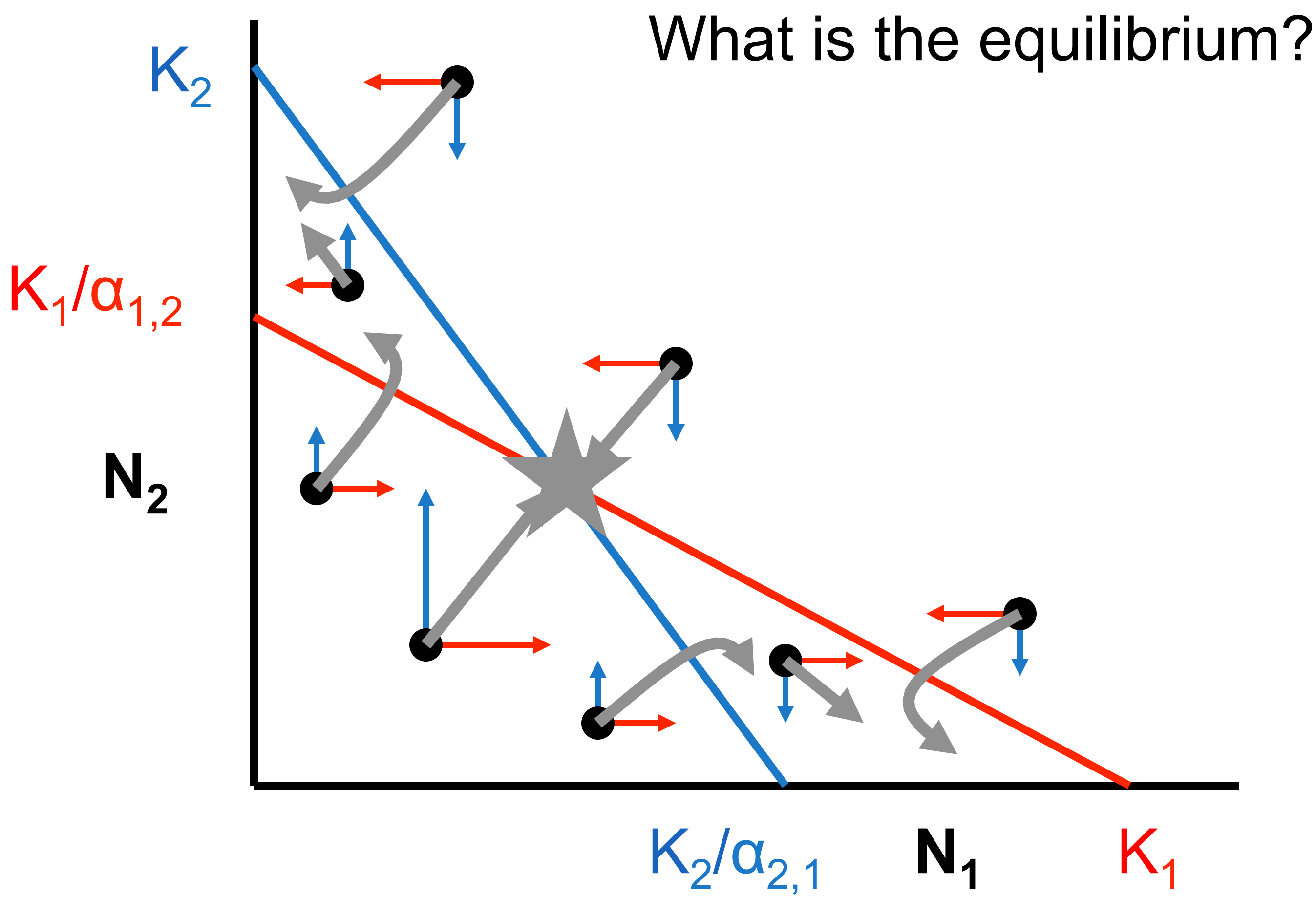
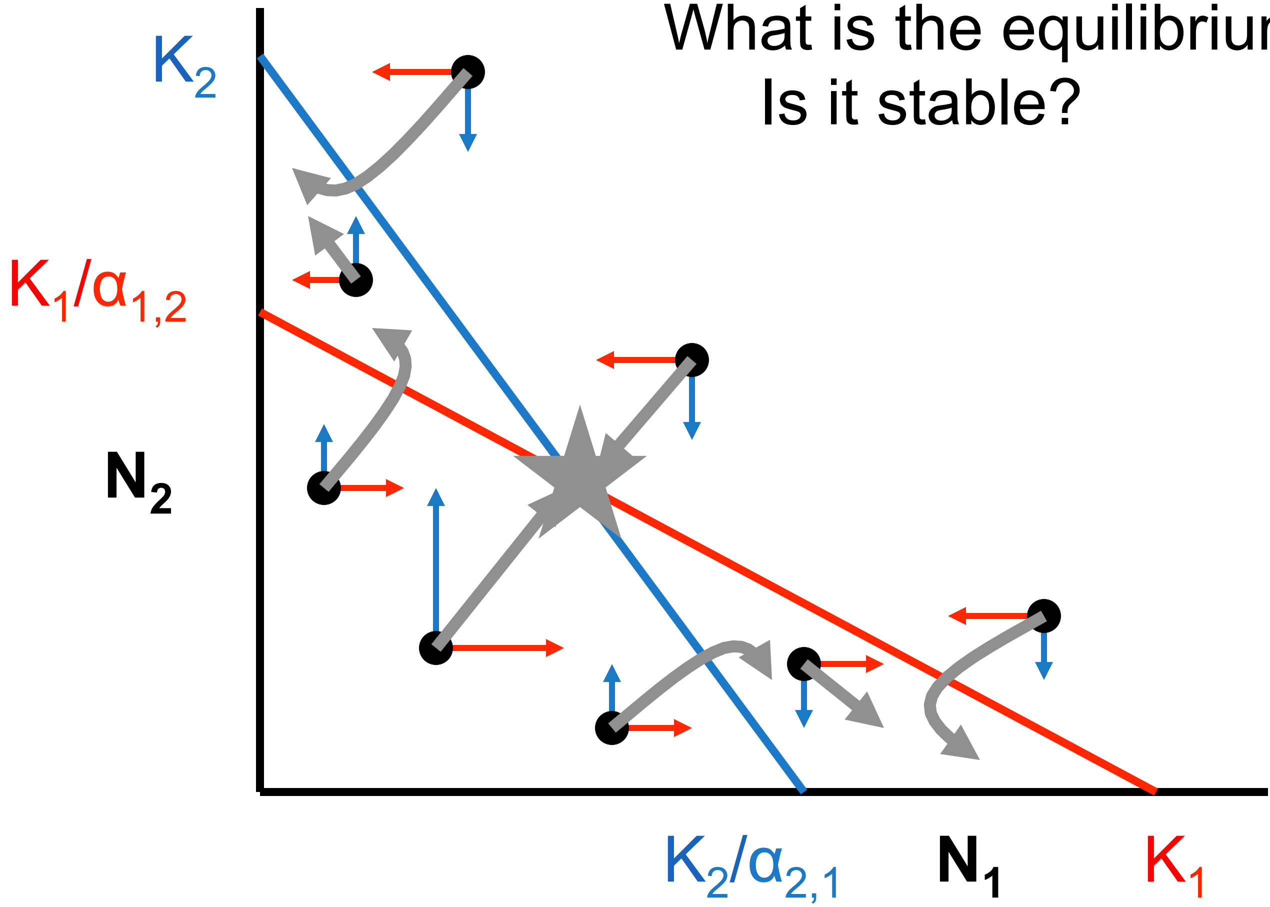


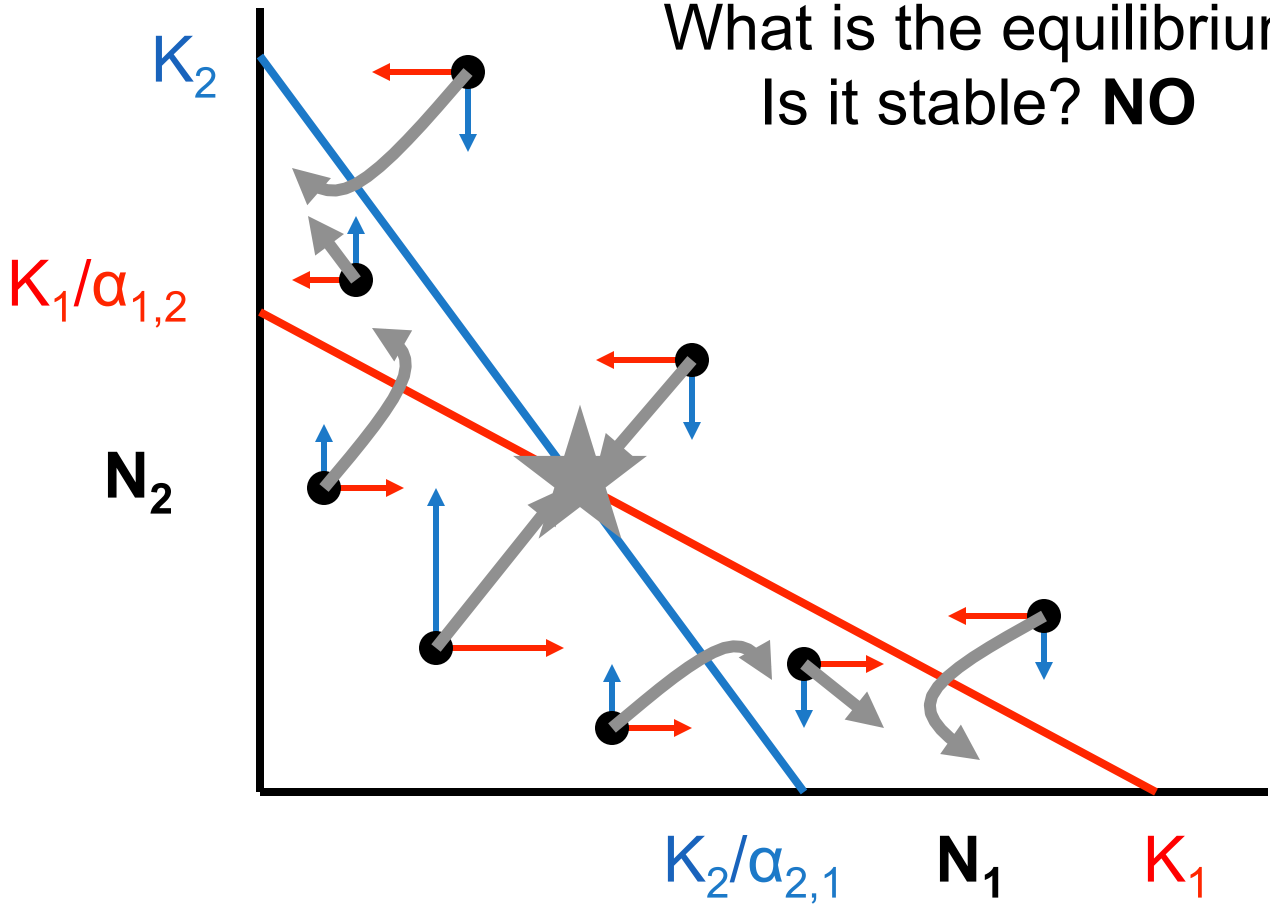
Case 3: Unstable Equilibrium

What is the equilibrium?
Is it stable?



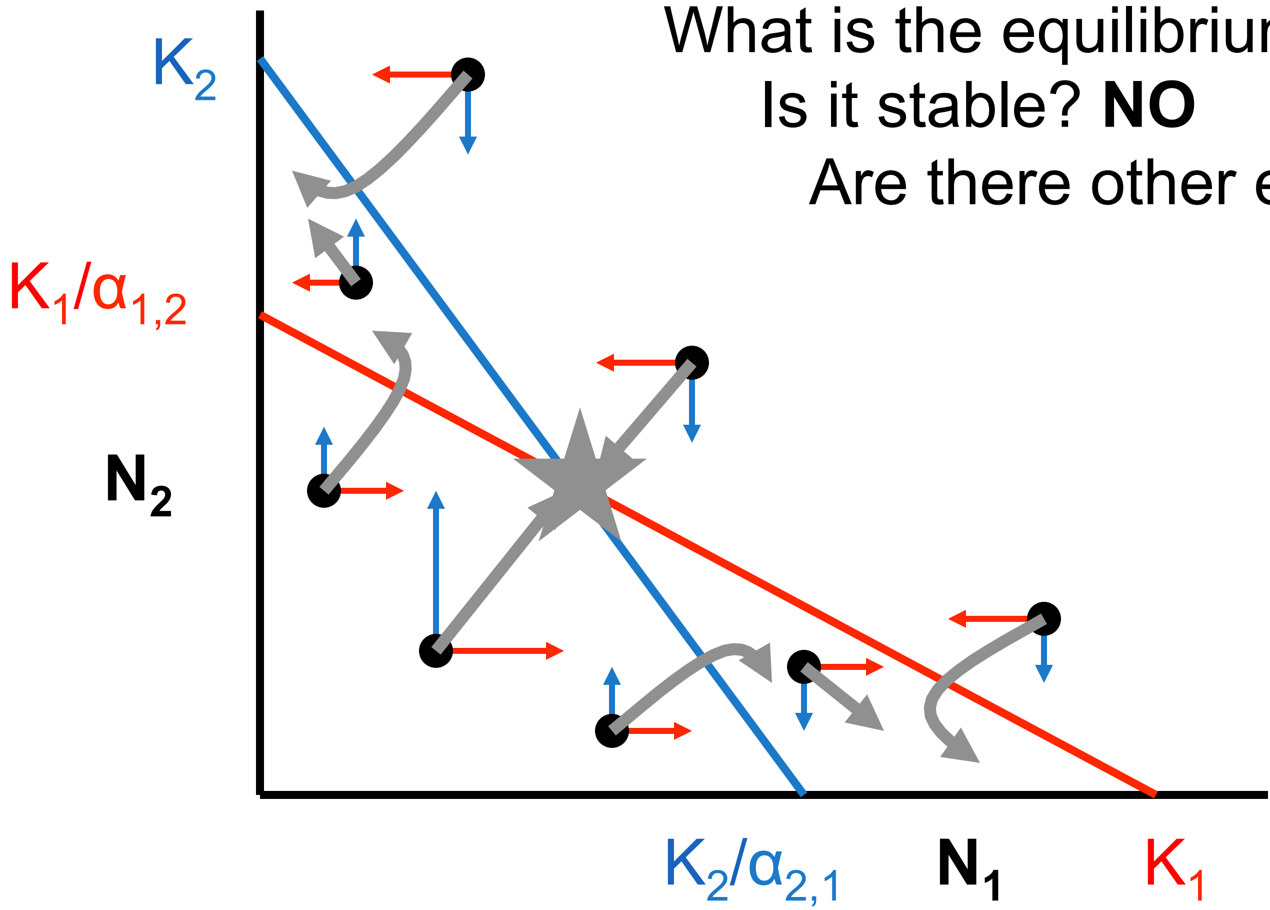
Case 3: Unstable Equilibrium

What is the equilibrium?
Is it stable? **NO**



Case 3: Unstable Equilibrium

What is the equilibrium?
Is it stable? **NO**
Are there other equilibria?



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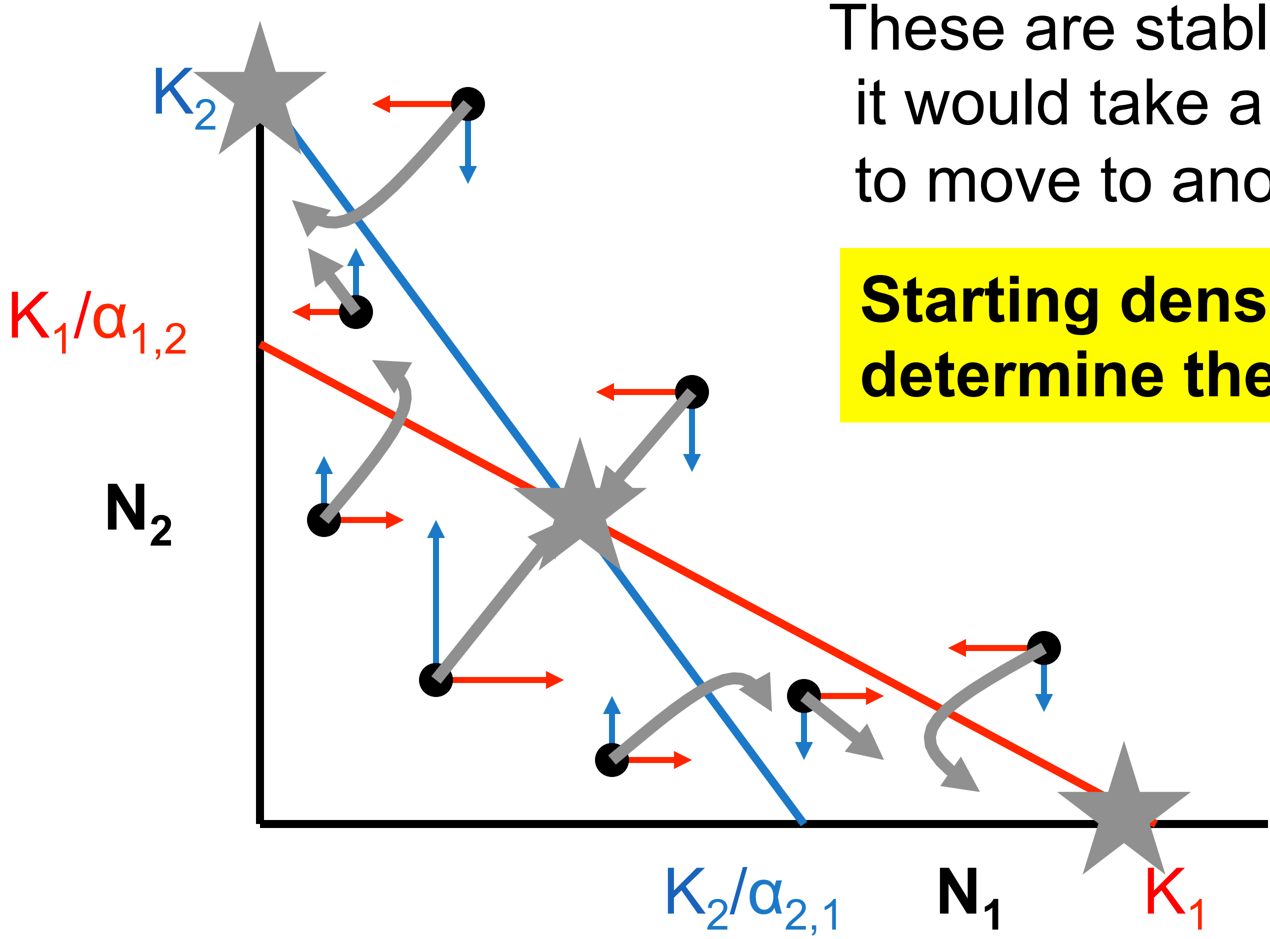
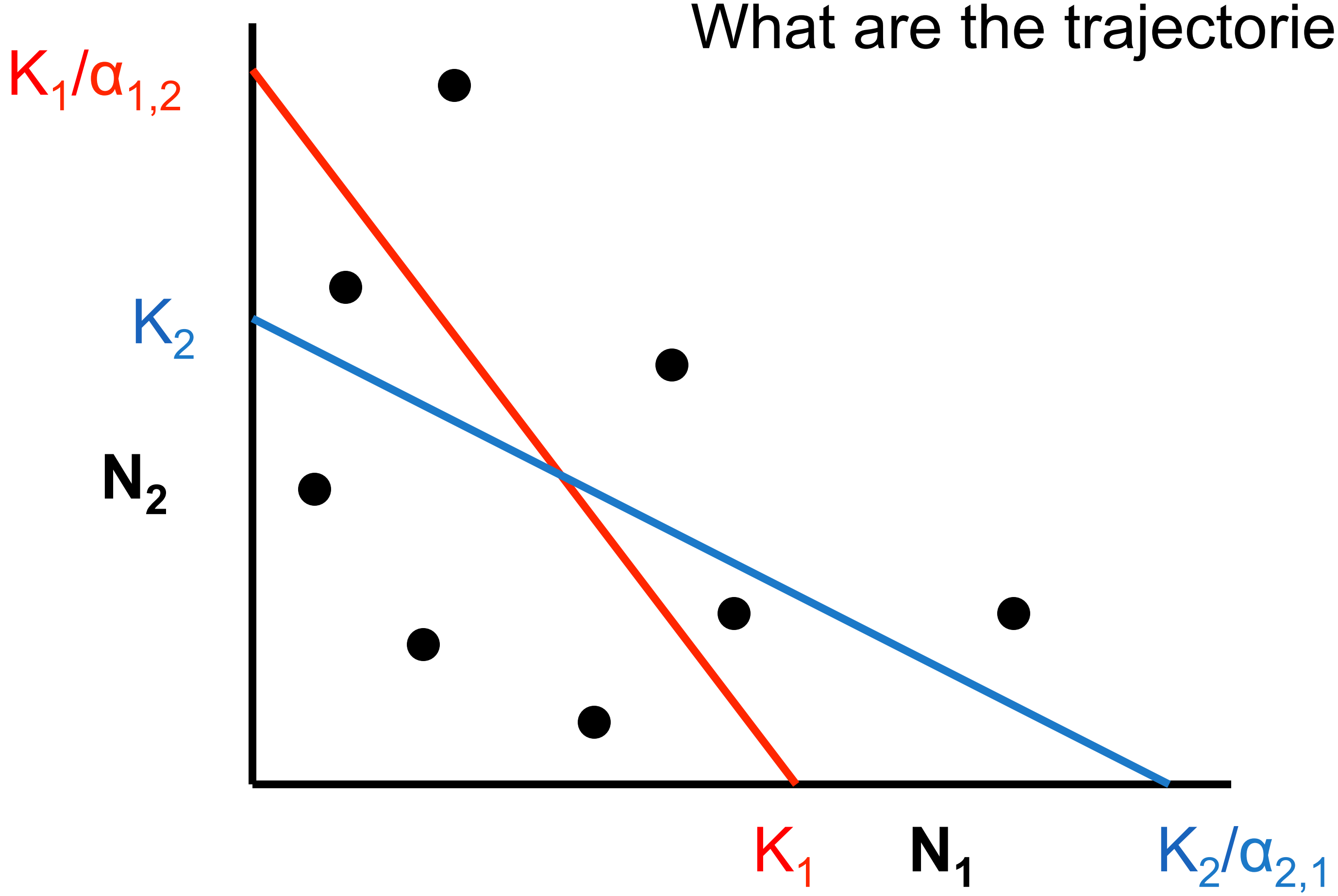


These are stable to a point; it would take a large change to move to another one

Starting densities determine the outcome

Case 4: Competitive Coexistence

What are the trajectories?



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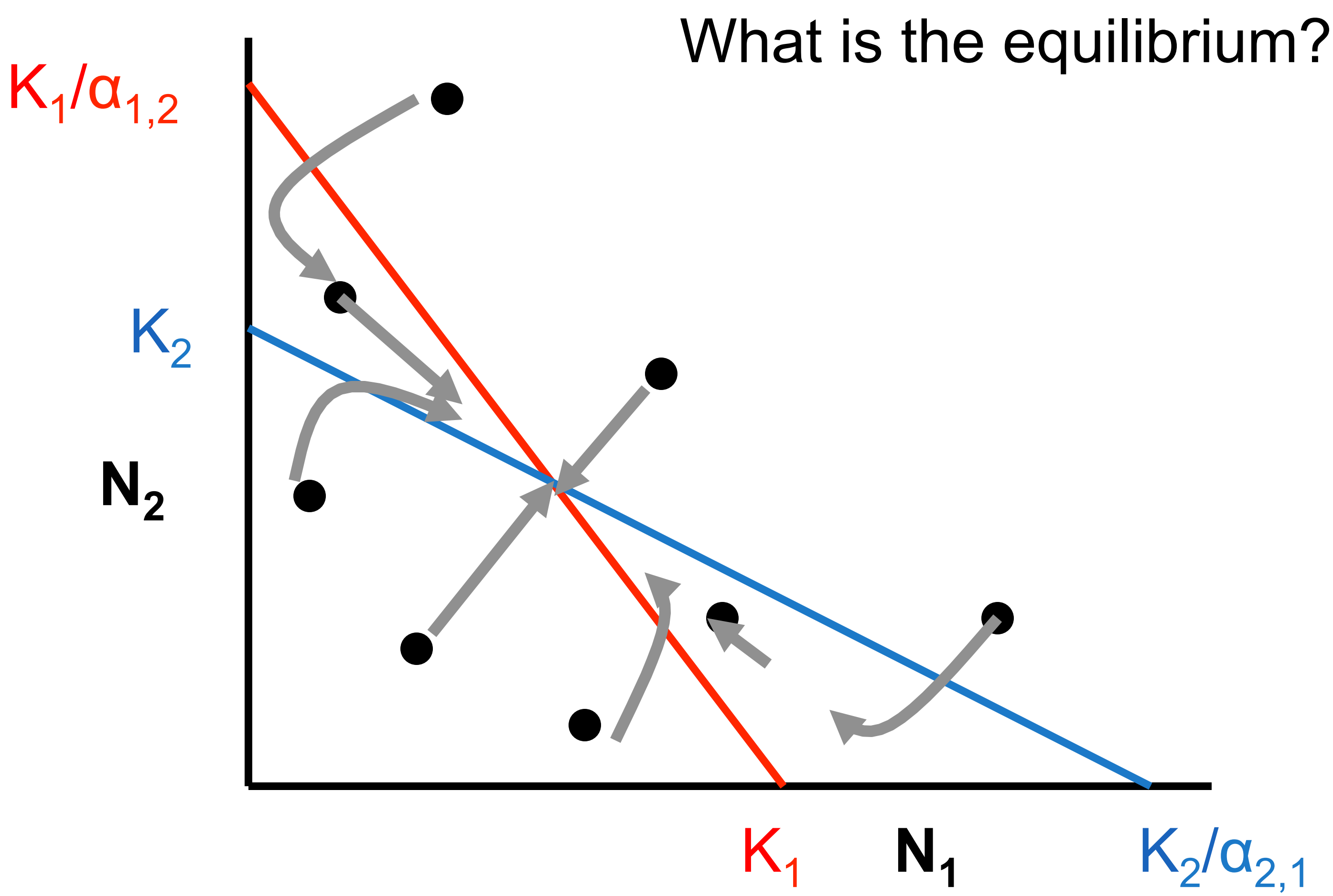

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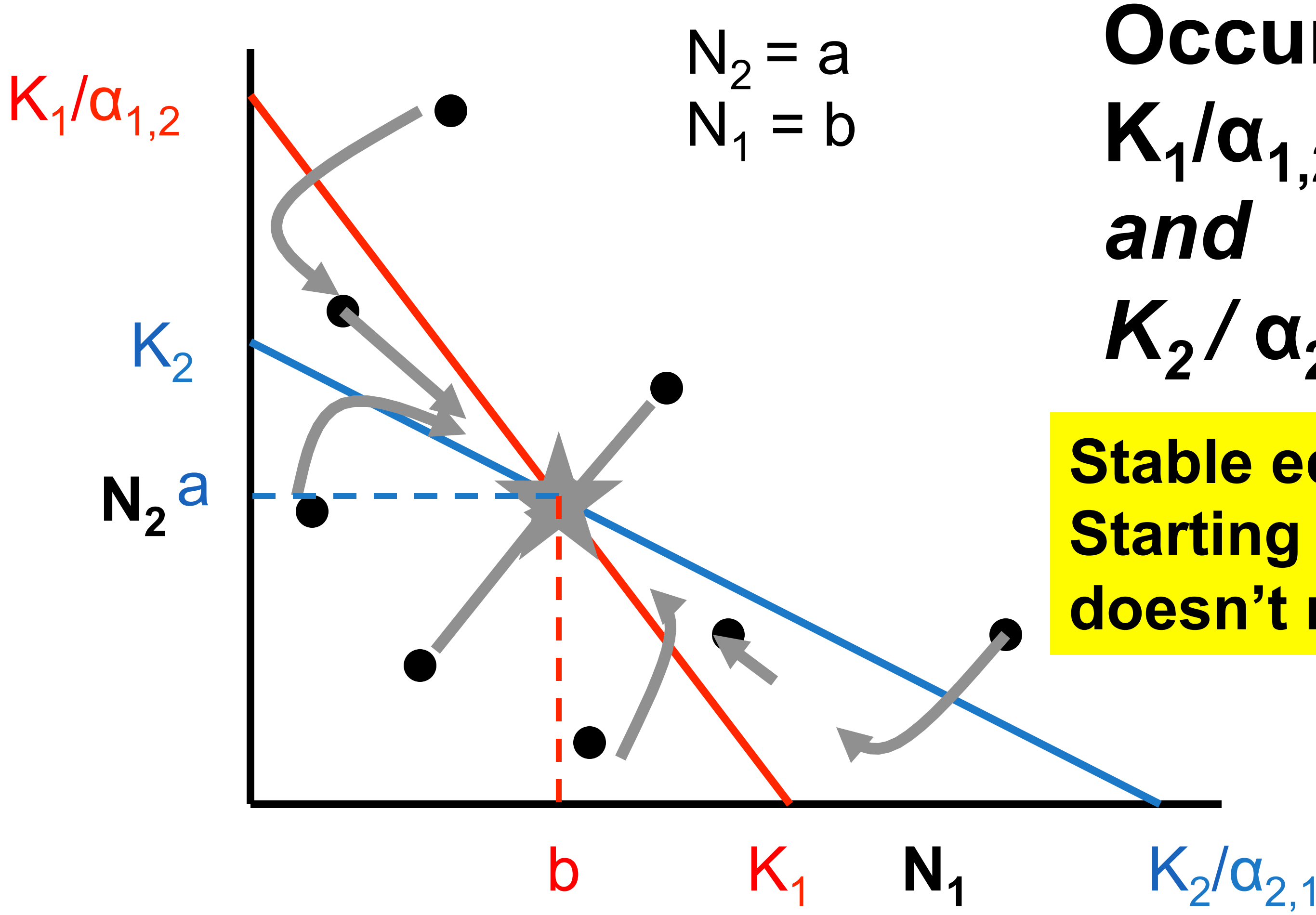
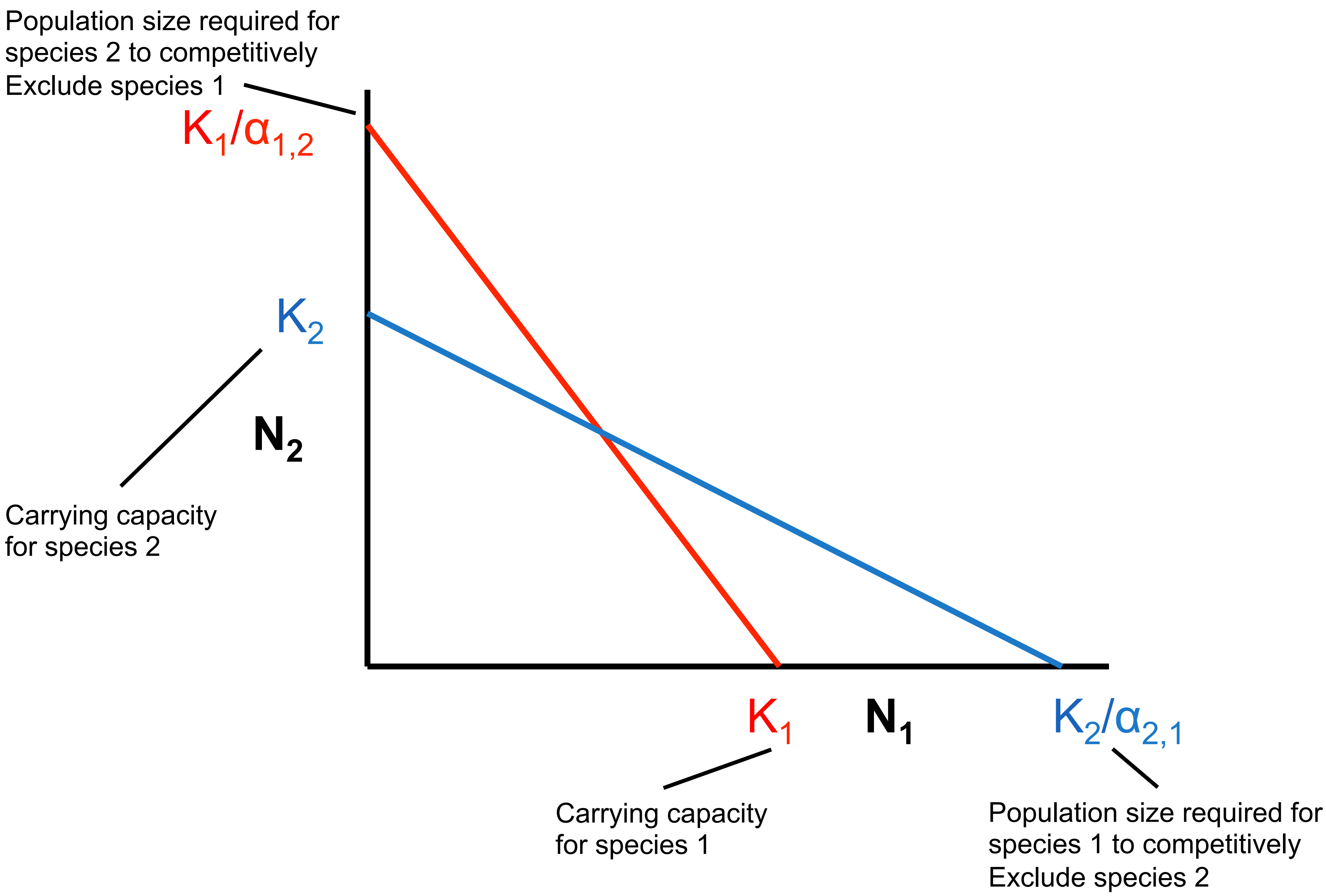


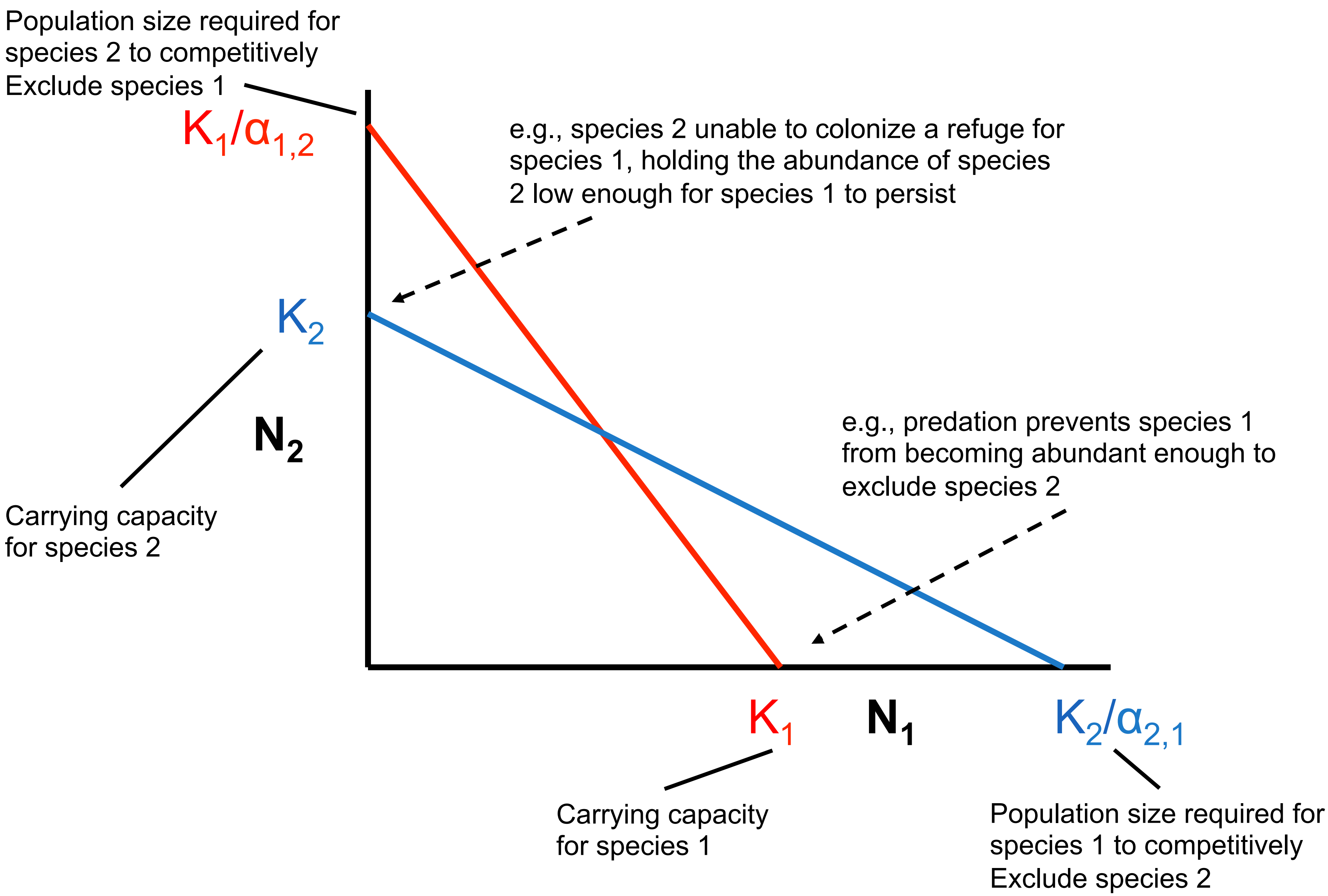
Occurs when
$K_1/\alpha_{1,2} > K_2$
and
$K_2/\alpha_{2,1} > K_1$

Stable equilibrium; Starting location doesn't matter

Competitive Coexistence



Competitive Coexistence

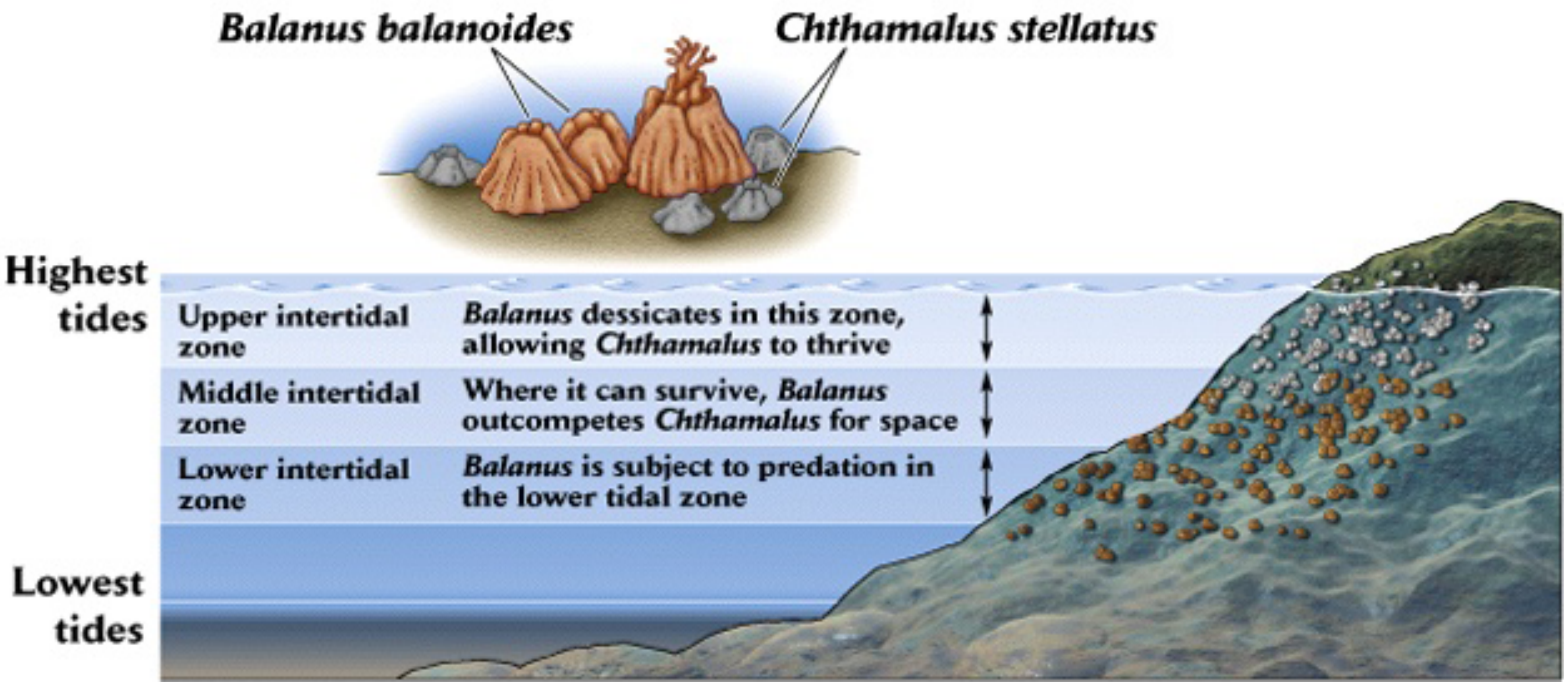


What Allows Competitors to Coexist?

- Competition coefficients are small (low dietary overlap)

What Allows Competitors to Coexist?

- Competitive refuge
  - There is a habitat where a superior competitor cannot exist
    - Barnacles in the intertidal zone

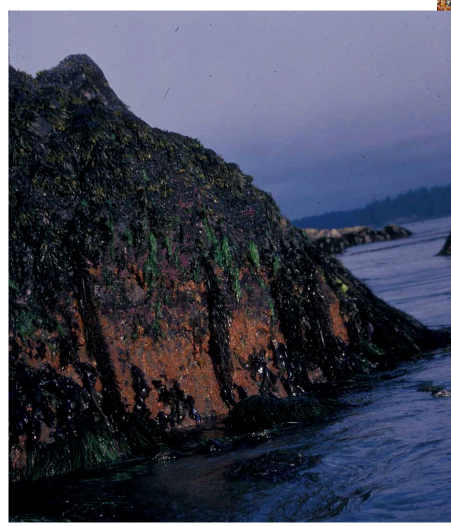


What Allows Competitors to Coexist?

- Temporal Heterogeneity
  - e.g. two species may do better at differing temperatures; winner dependent on that year’s conditions

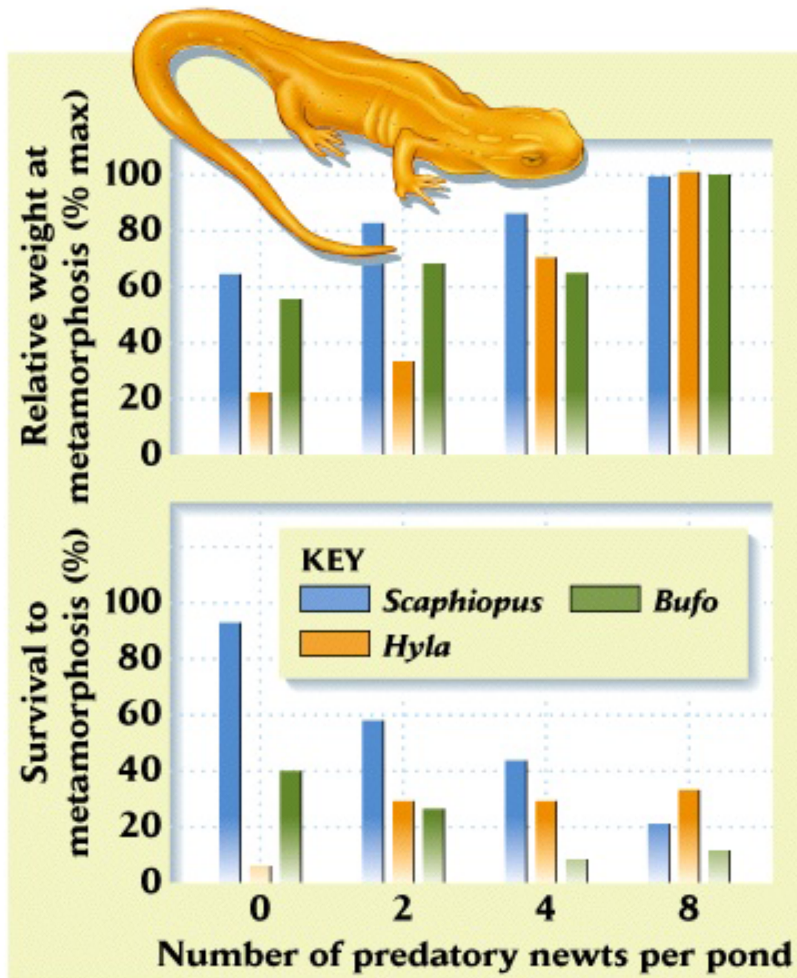
What Allows Competitors to Coexist?

- Predation and other mortality agents
  - If populations are kept low then there isn't really any competition and many species can coexist
    - Paine (1966) – starfish (mussel monoculture without them)



What Allows Competitors to Coexist?

- Predation and other mortality agents
  - If populations are kept low then there isn't really any competition and many species can coexist
    - Newts and anurans



Morin (1981) *Science*