Ecology 8310
Population (and Community) Ecology

Seguing from populations to communities

- Species interactions
- Lotka-Volterra equations
- Competition
- Adding in resources

Species interactions:

Competition (- , -)

Predation (+ , -)

(Herbivory, Parasitism, Disease)

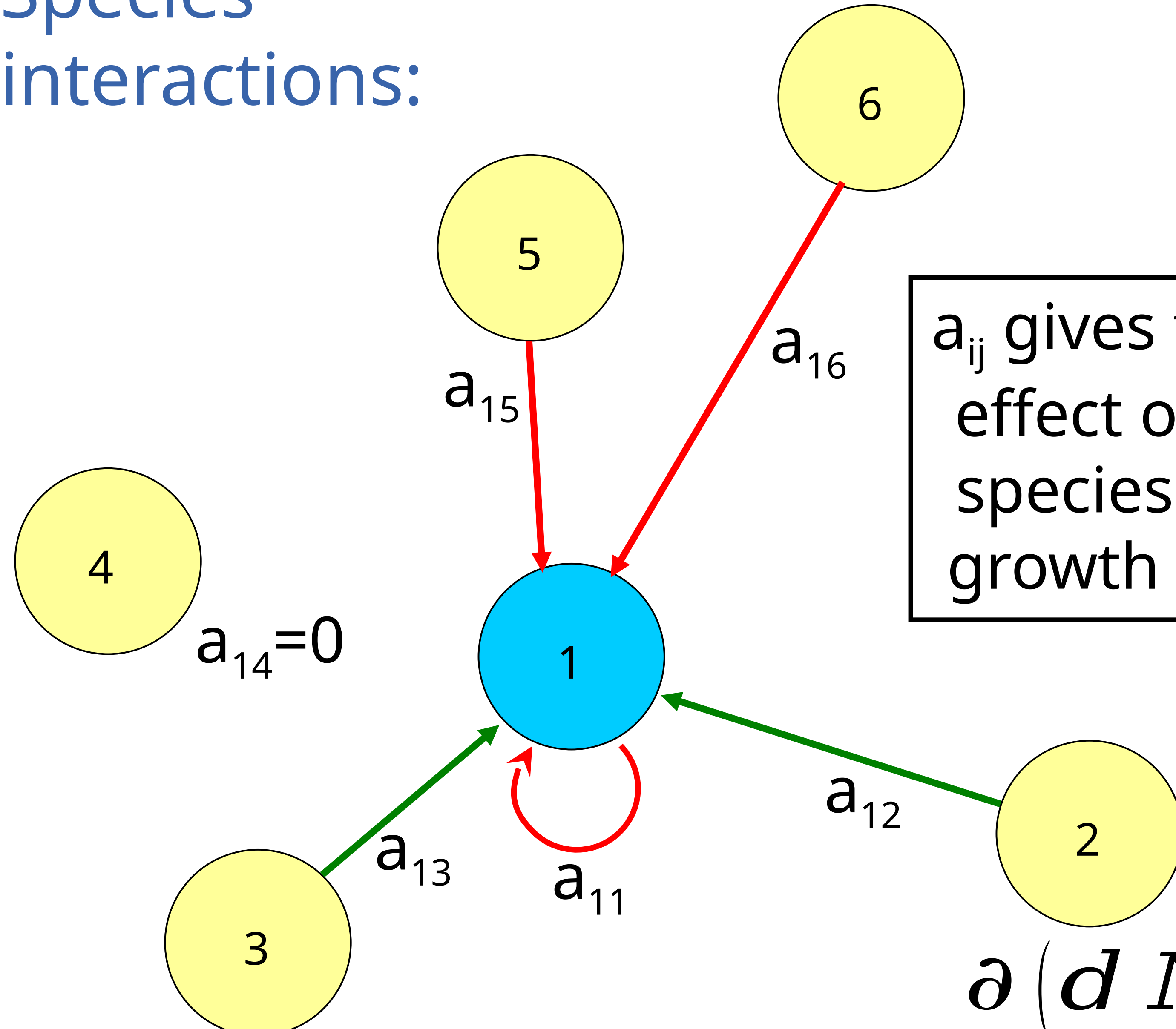
Mutualism (+ , +)

None (0 , 0)

Species interactions:

$a_{ij}>0$

$a_{ij}<0$



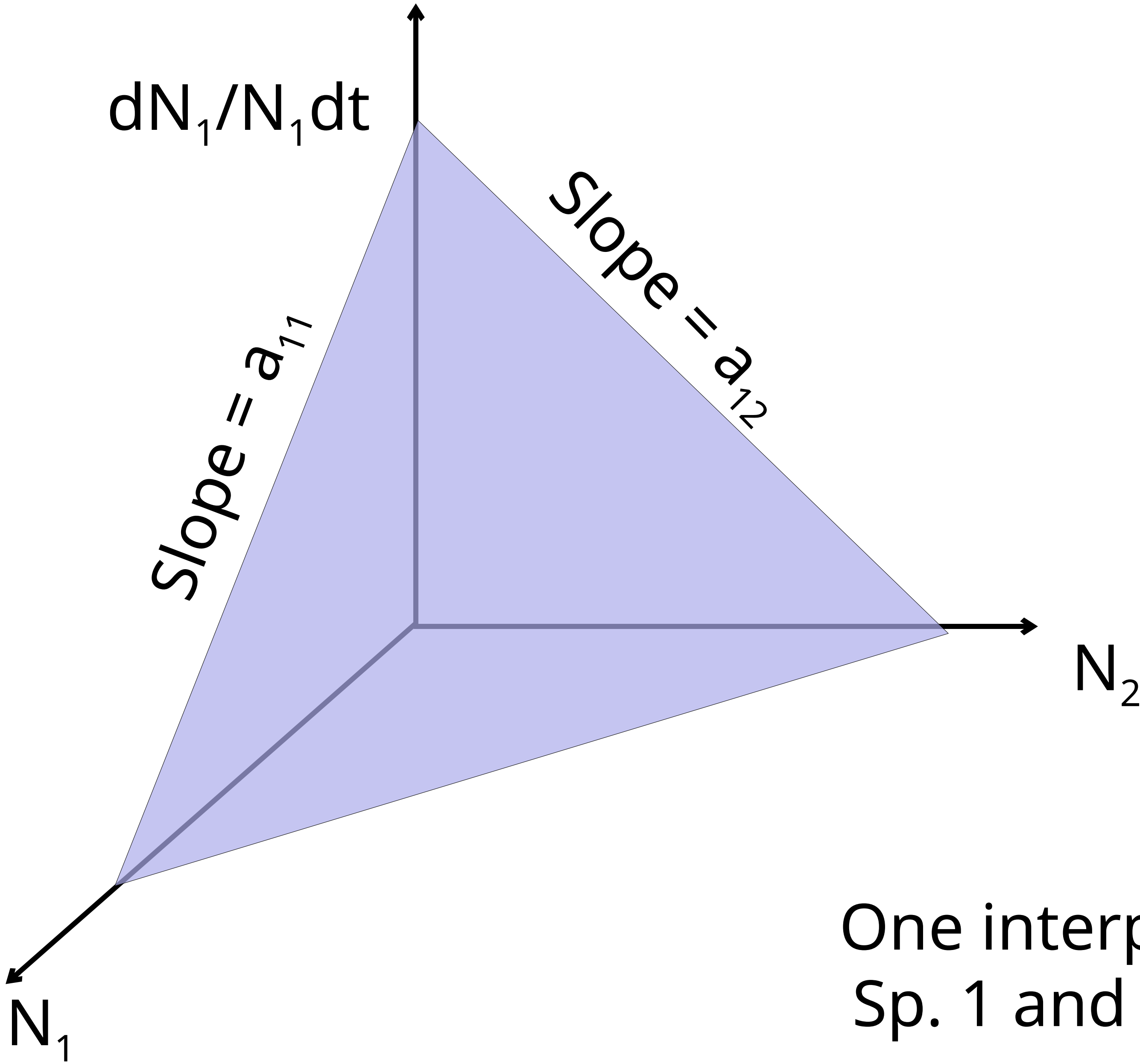
a_{ij} gives the per capita effect of species j on species i's per capita growth rate, $dN_i/N_i dt$

$$a_{ij} = \frac{\partial \left(dN_i / N_i dt \right)}{\partial N_j}$$

Generalized Lotka-Volterra system:

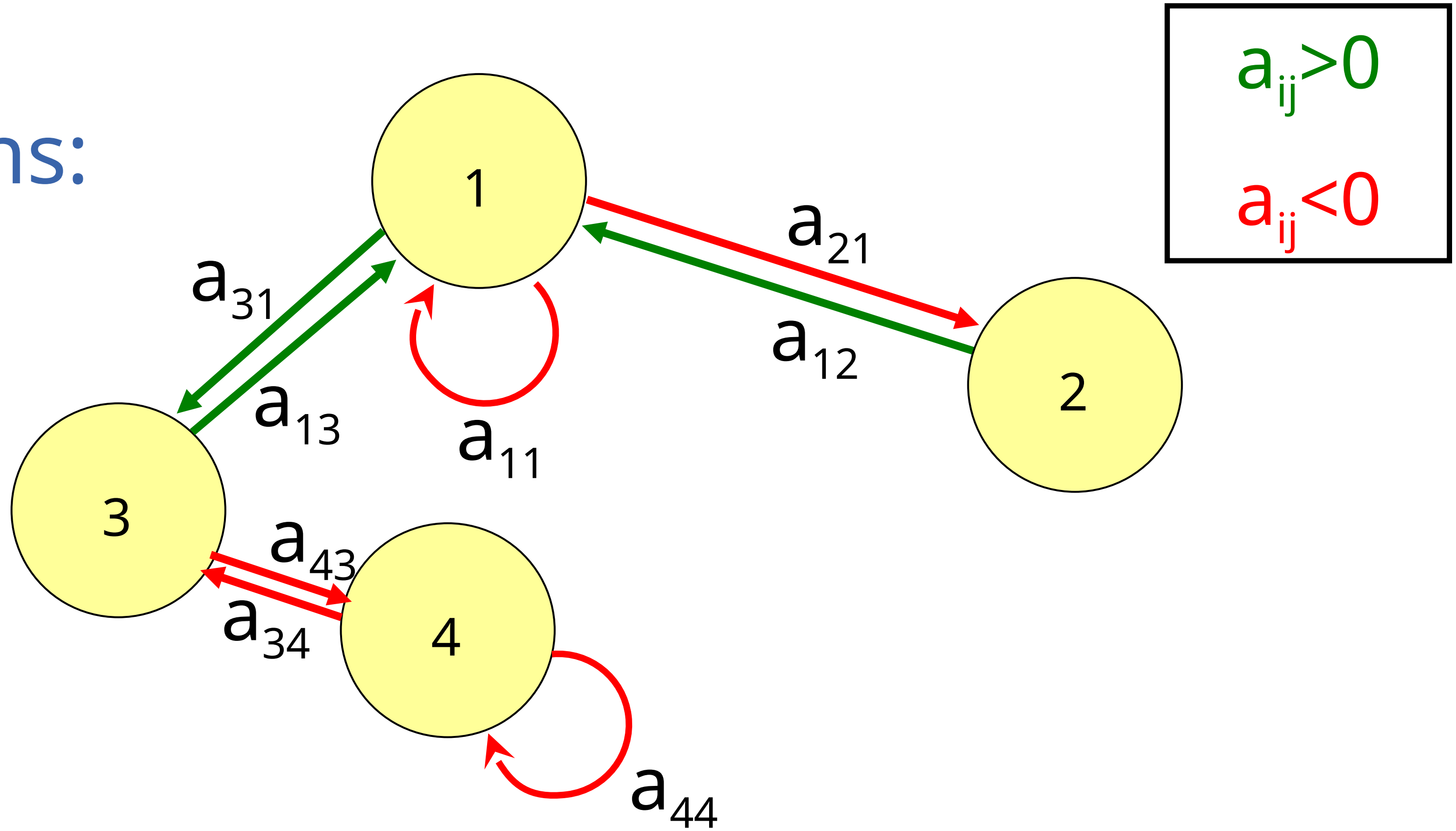
Special cases:

1. Exponential model: all a's=0
2. Logistic model: a_{ii}<0; others =0



One interpretation:
Sp. 1 and Sp. 2 are
competitors

Species interactions:



What can you say about the interactions between these species?

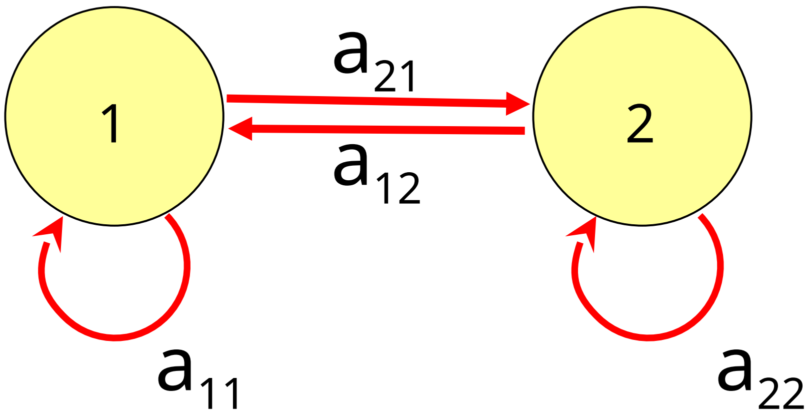
Which are interspecific competitors?

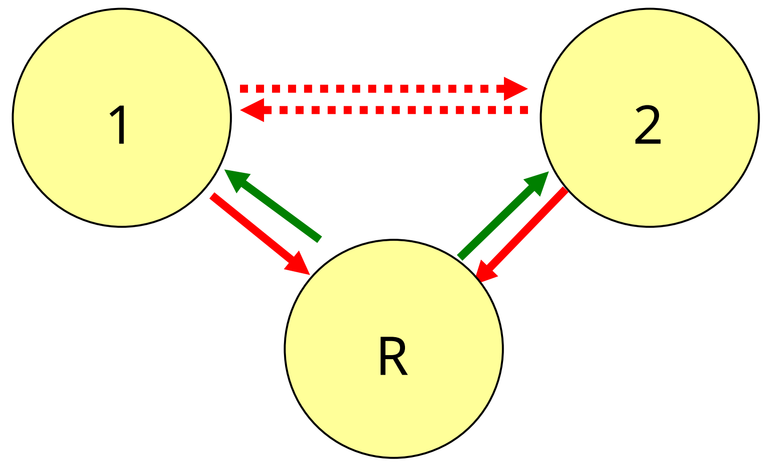
Which are predator and prey?

Which are mutualists? Which show self limitation?

Competition:

Arises when two organisms use the same *limited* resource, and deplete its availability (intra. vs. interspecific)

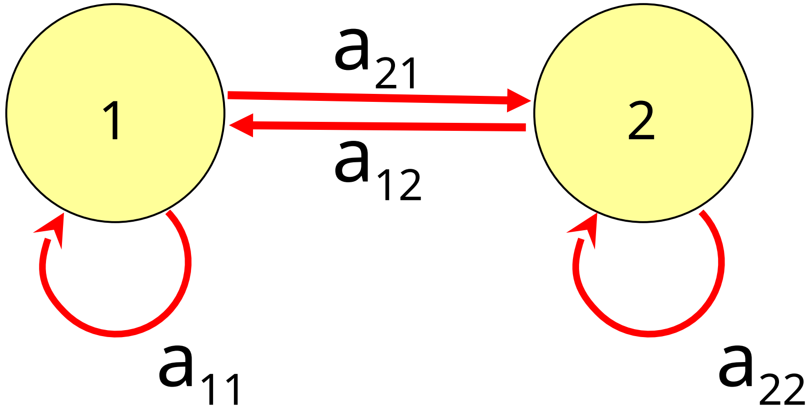




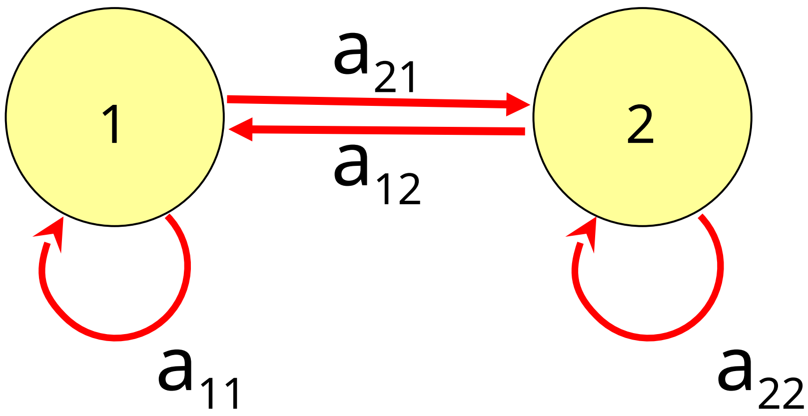
Alternate terminology:

$\alpha_{ij} = a_{ij}/a_{ii}$, the effect of interspecific competition relative to the intraspecific effect (e.g., how many of species i does it take to have the same effect as 1 individual of species j?)

Competition:



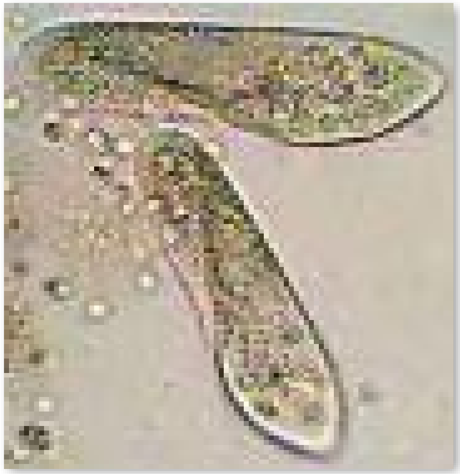
Competition:



Can we use this model to understand patterns of competition among two species (e.g., coexistence and competitive exclusion)?

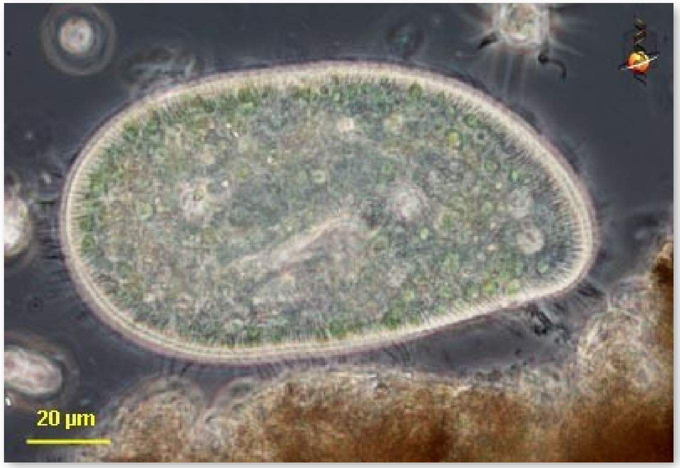
E.g., *Paramecium* experiments by Gause…

Classic studies of resource competition by Gause (1934, 1935)



Paramecium caudatum

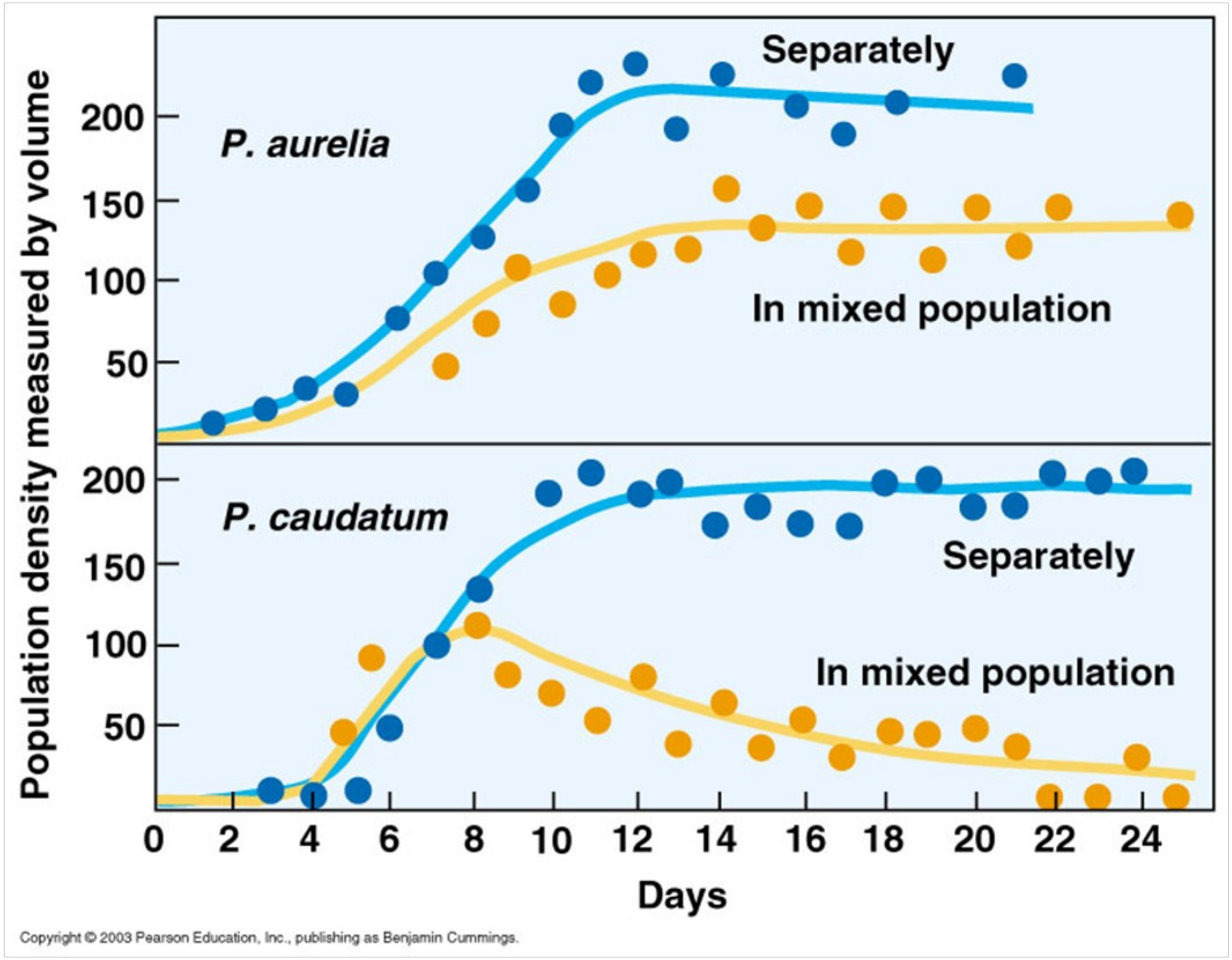
Paramecium aurelia



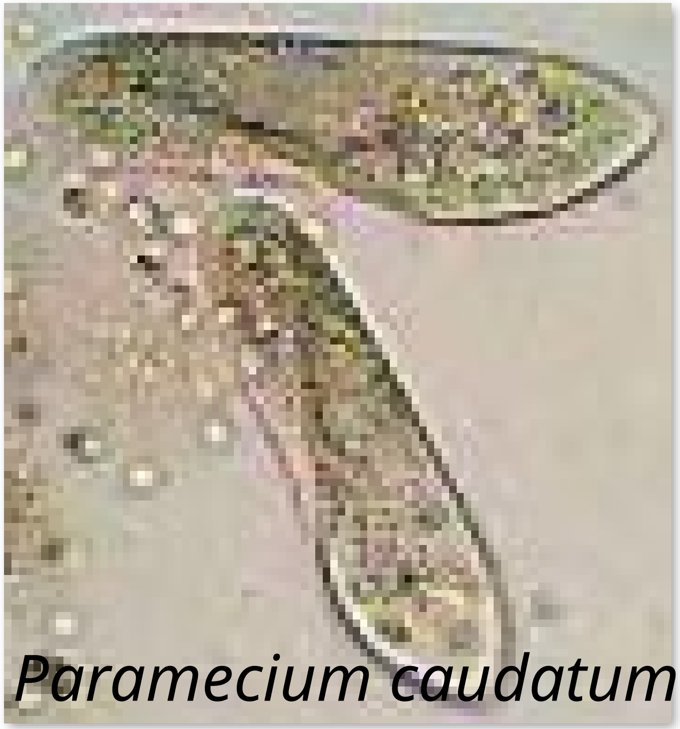
Paramecium

Competitive exclusion:

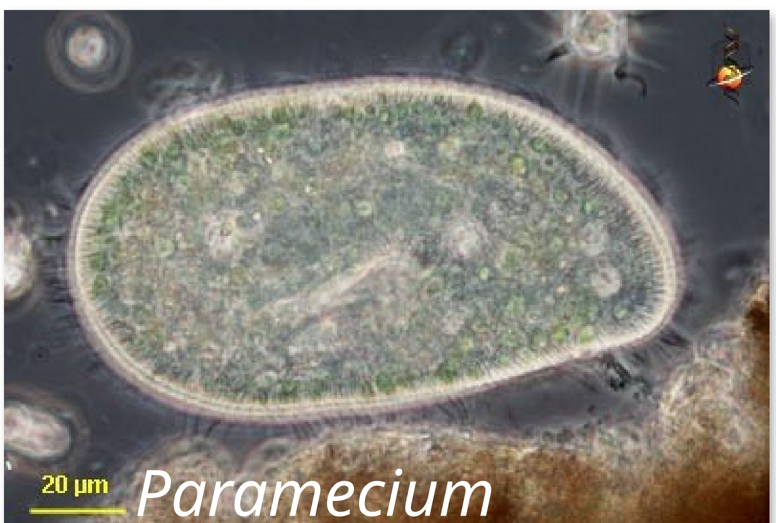
P. aurelia excludes *P. caudatum*



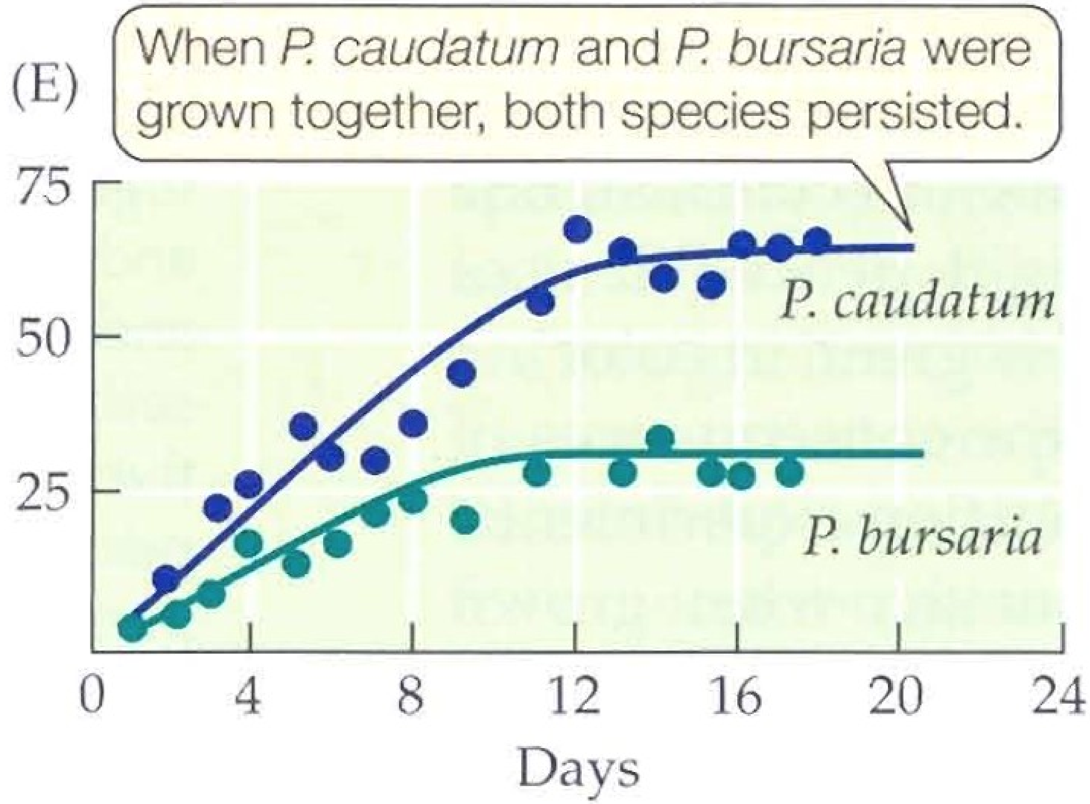
In contrast…



Paramecium caudatum



Paramecium



Why this disparity, and can we gain insights via our model?

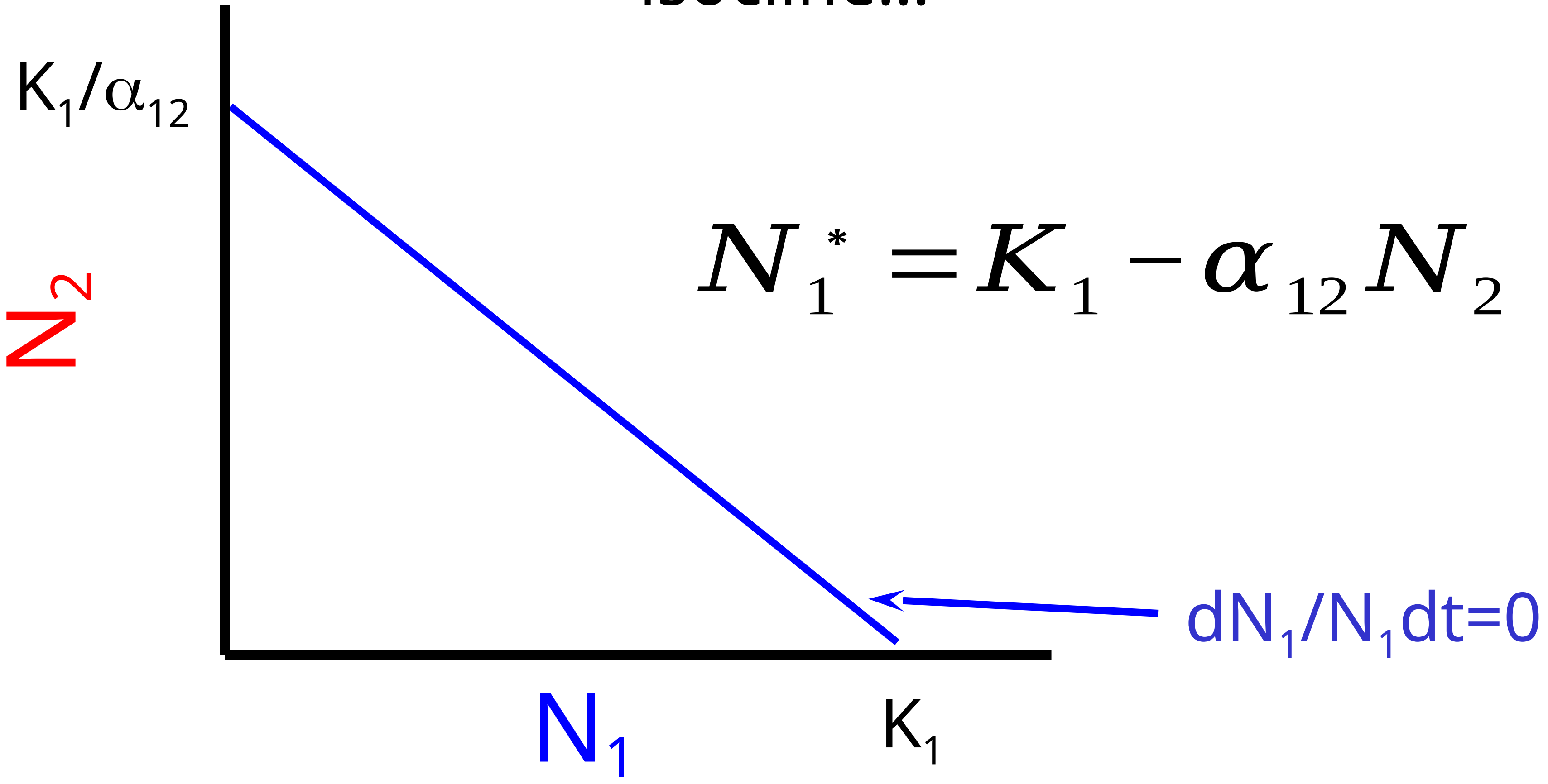
Competition:

At equilibrium, dN/Ndt=0:

Phase planes:

Graph showing regions where dN/Ndt=0 (and +, -); used to infer dynamics

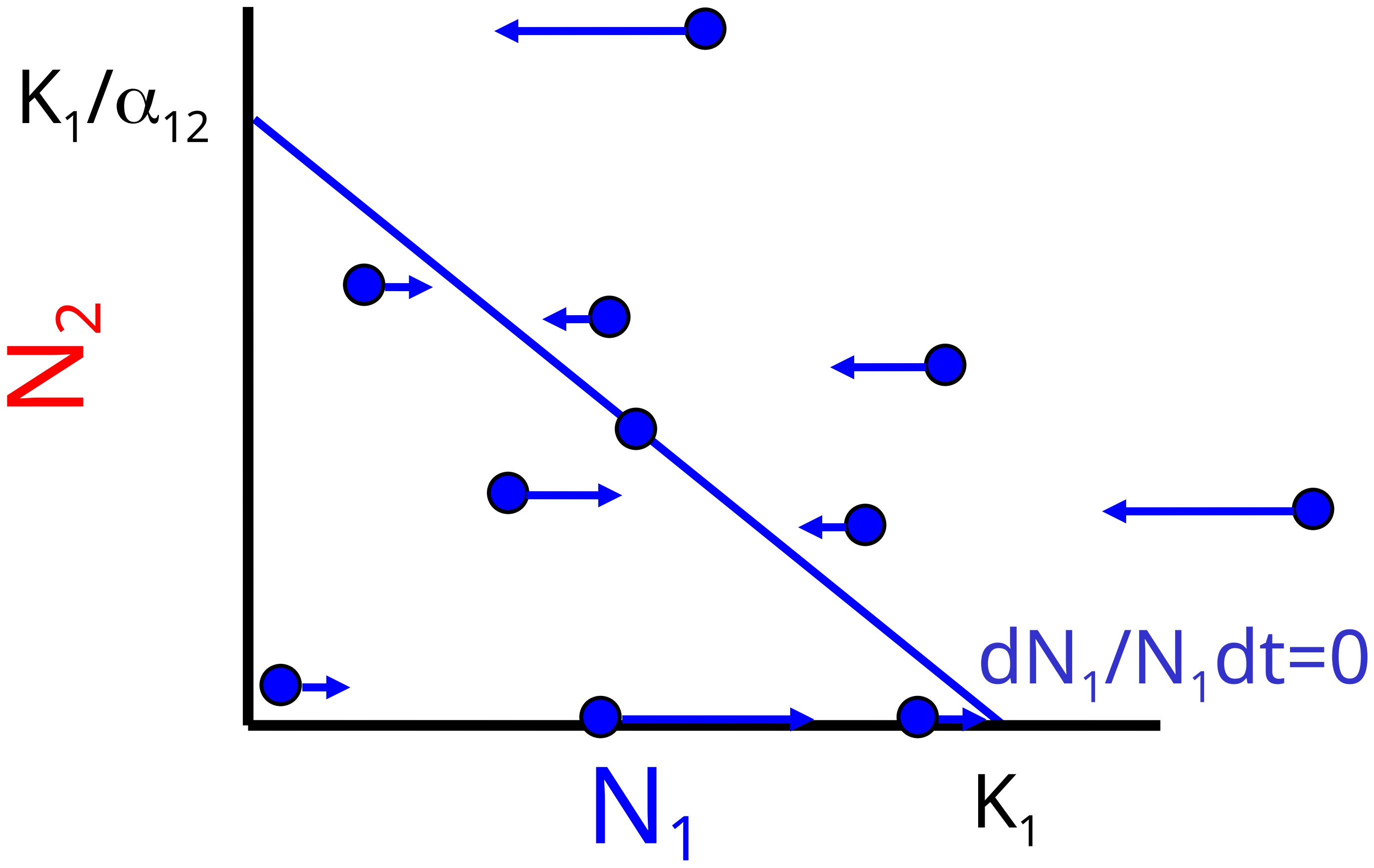
Species 1's zero growth isocline…



$$N_1^* = K_1 - \alpha_{12} N_2$$

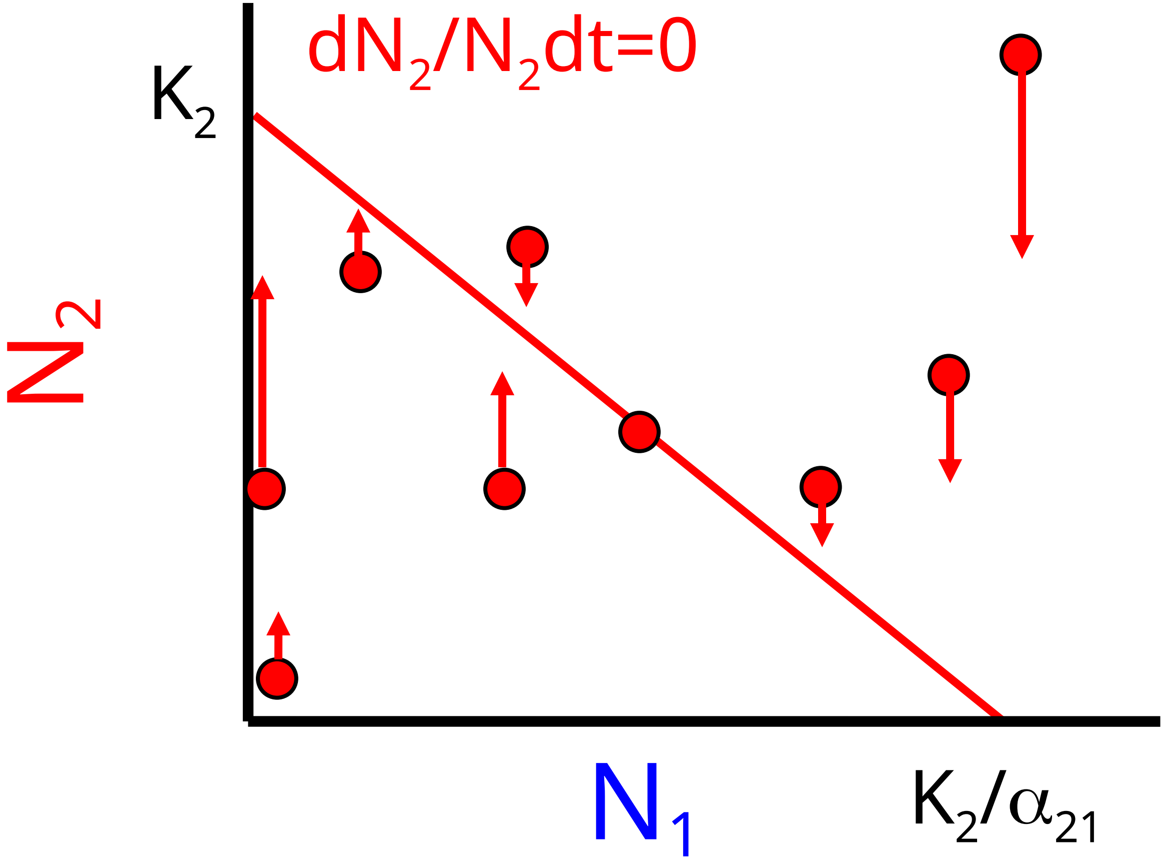
Phase planes:

What if the system is not on the isocline. Will what N_1 do?



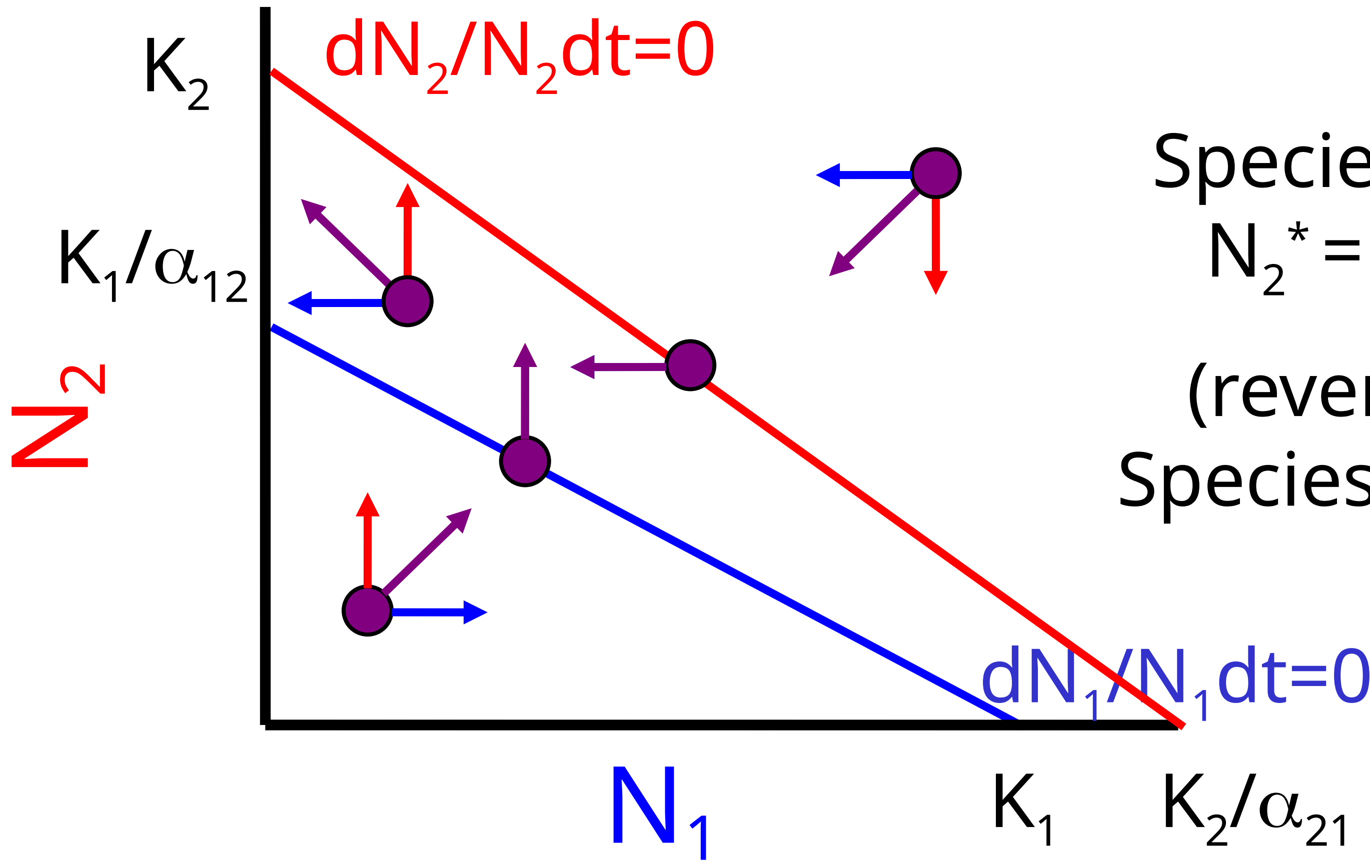
Phase planes:

$$N_2^* = K_2 - \alpha_{21} N_1$$



Phase planes:

Putting it together...



Species 2 "wins":
$N_2^* = K_2$, $N_1^* = 0$

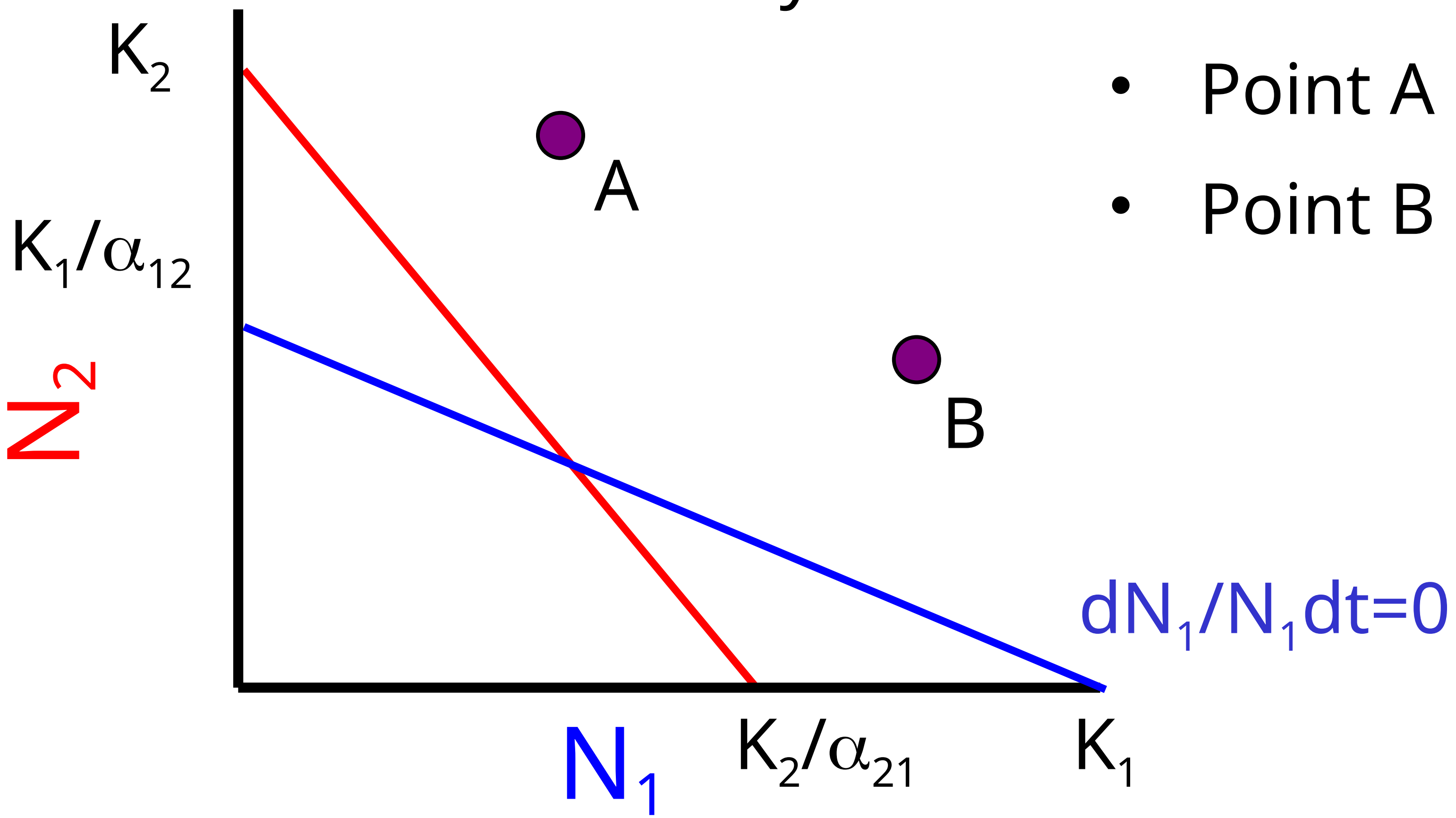
(reverse to get Species 1 winning)

Phase planes:

Your turn….

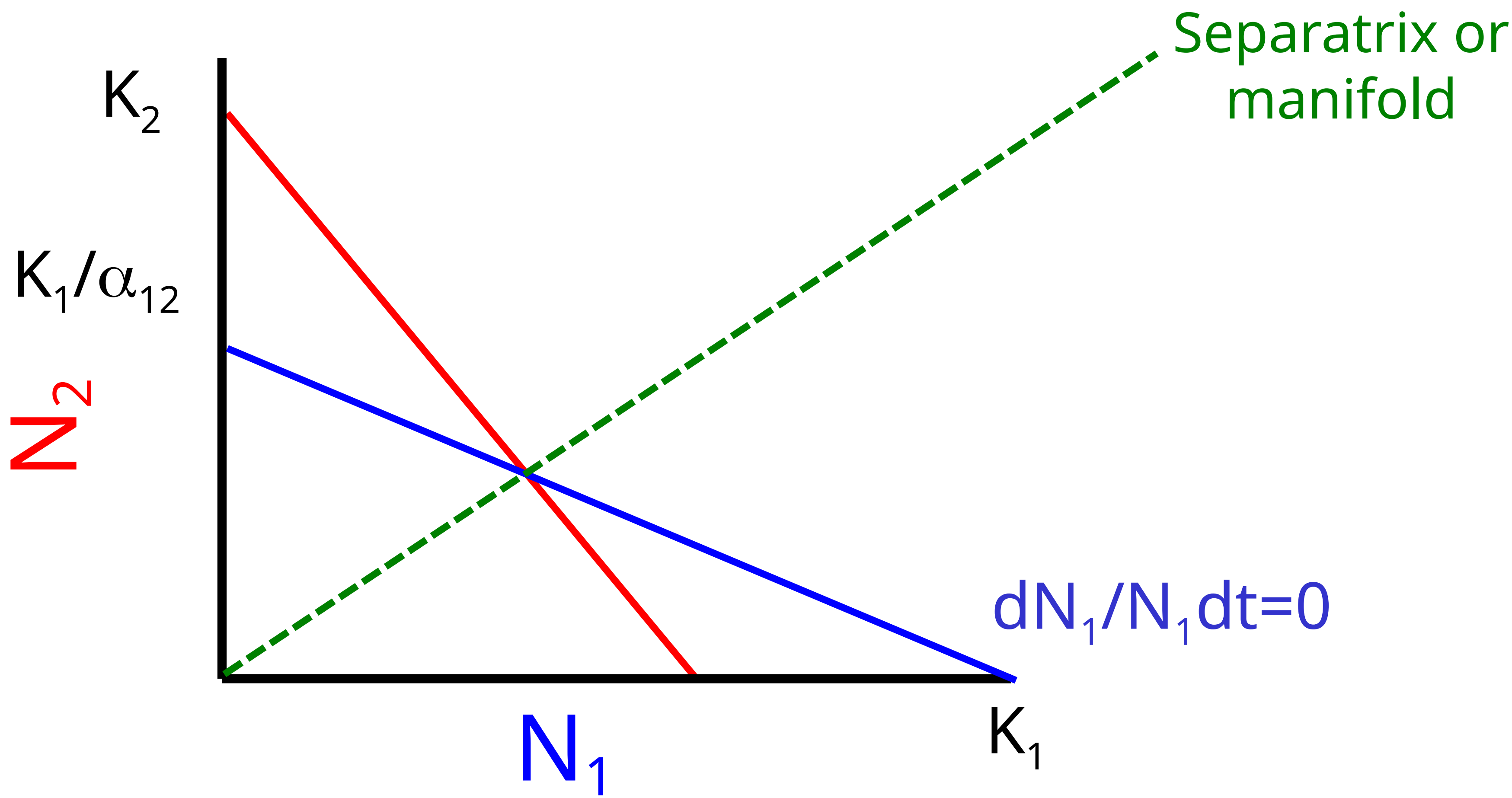
Draw the trajectors on the phase plane; then draw the dynamics (N vs. t)…for the system that starts at:

- Point A
- Point B



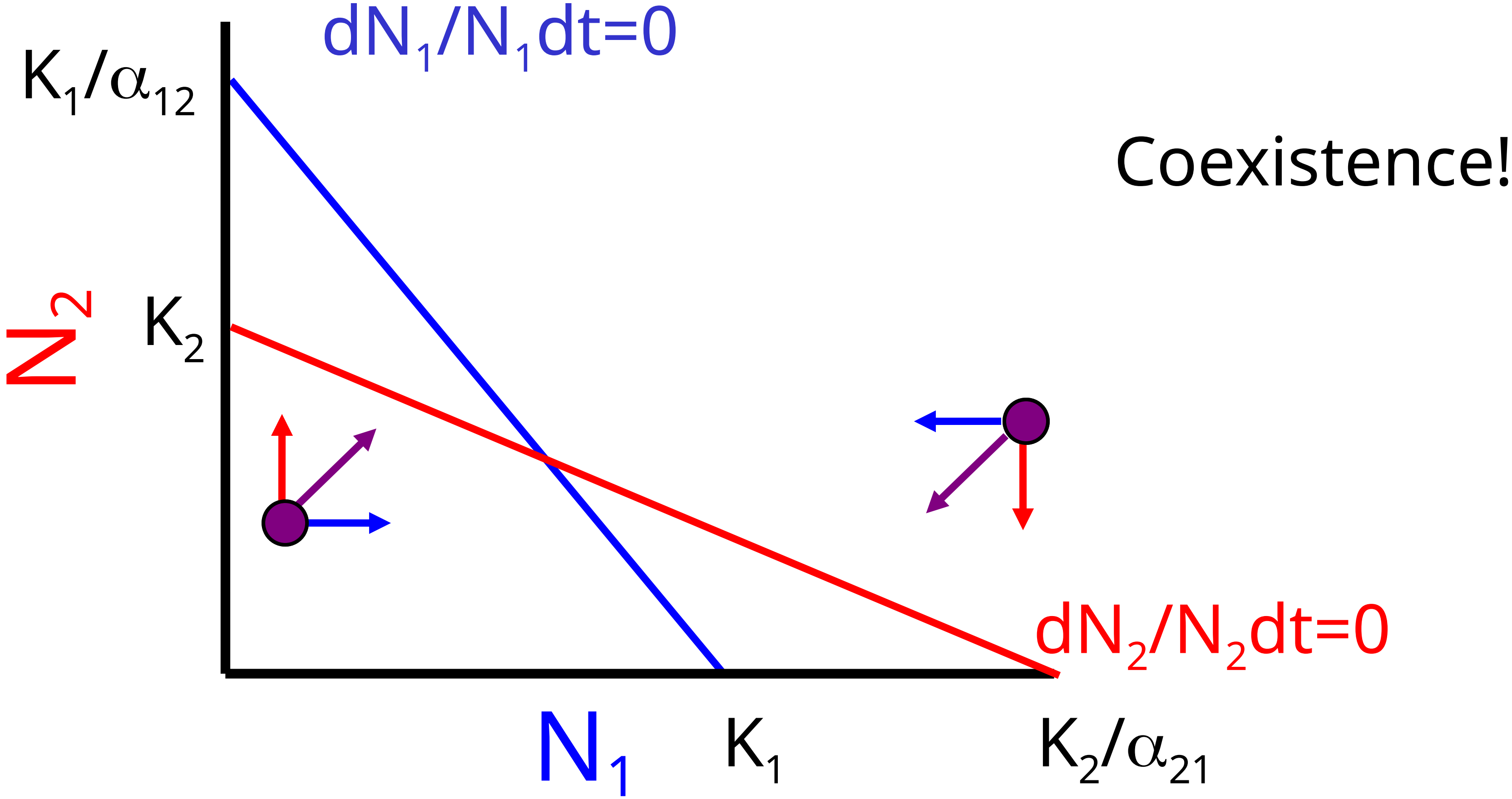
Phase planes:

Now do it for many starting points:



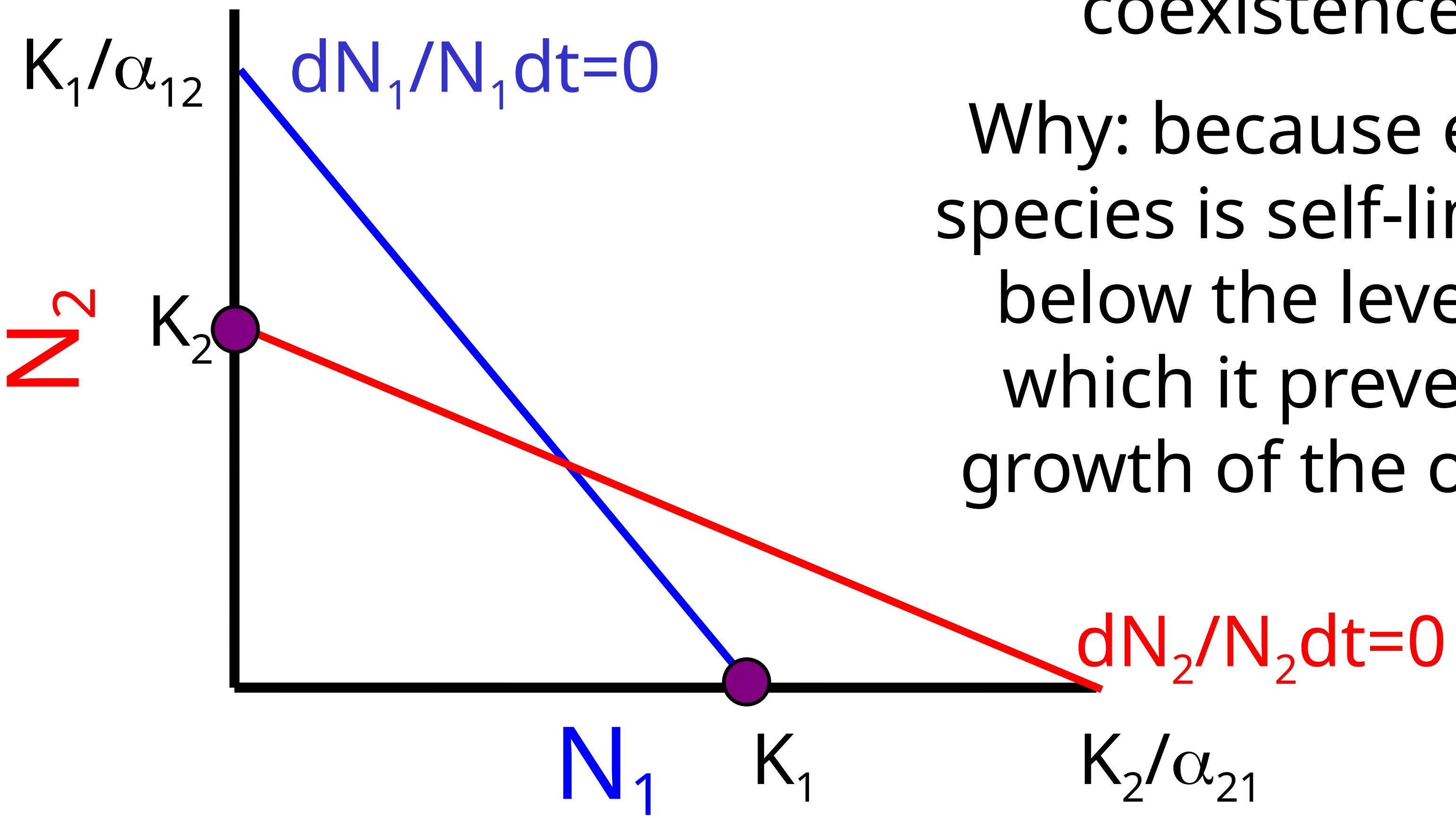
Phase planes:

A final possibility…map out the trajectories:



Phase planes:

"Invasibility"…

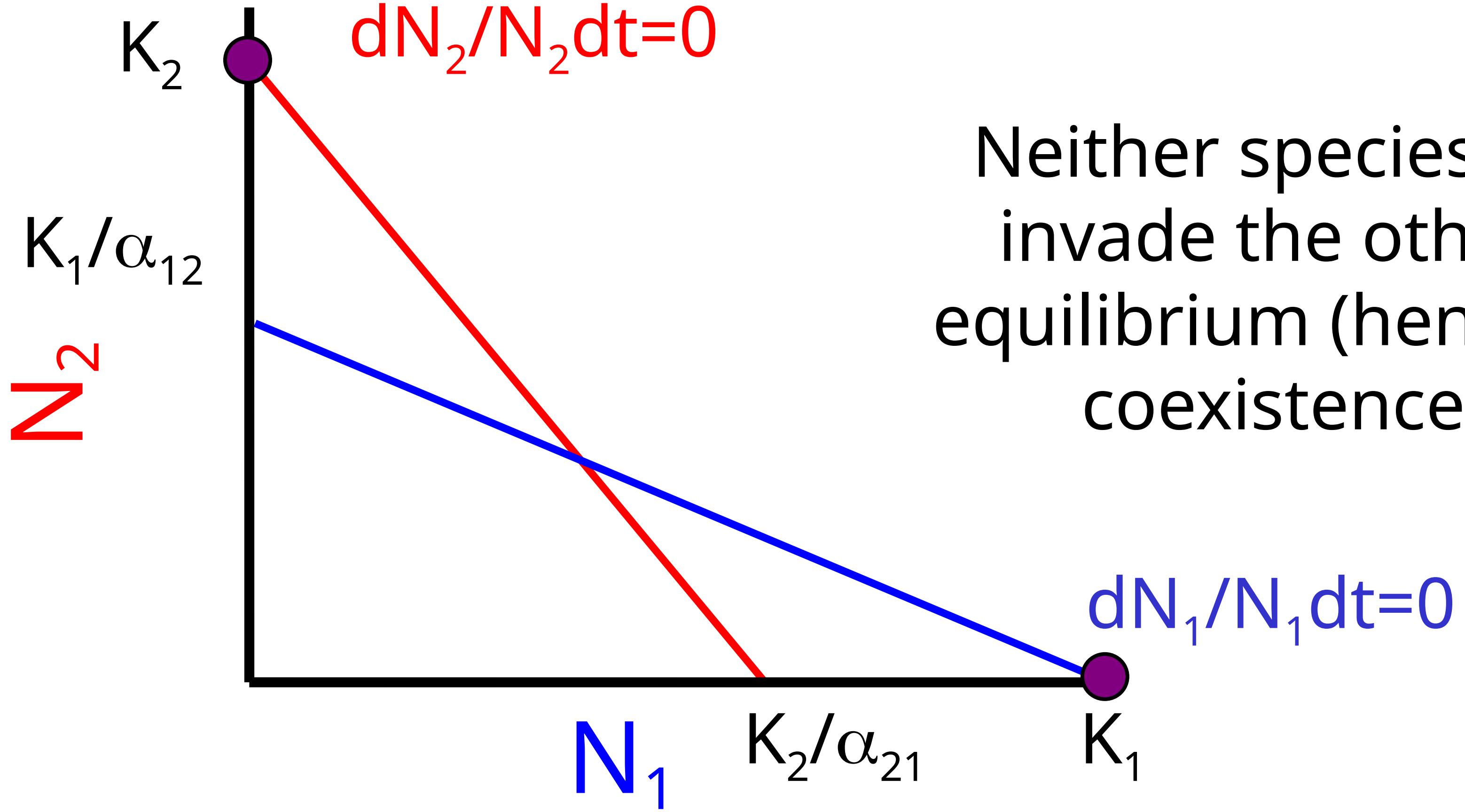


Mutual invasibility ➔ coexistence!

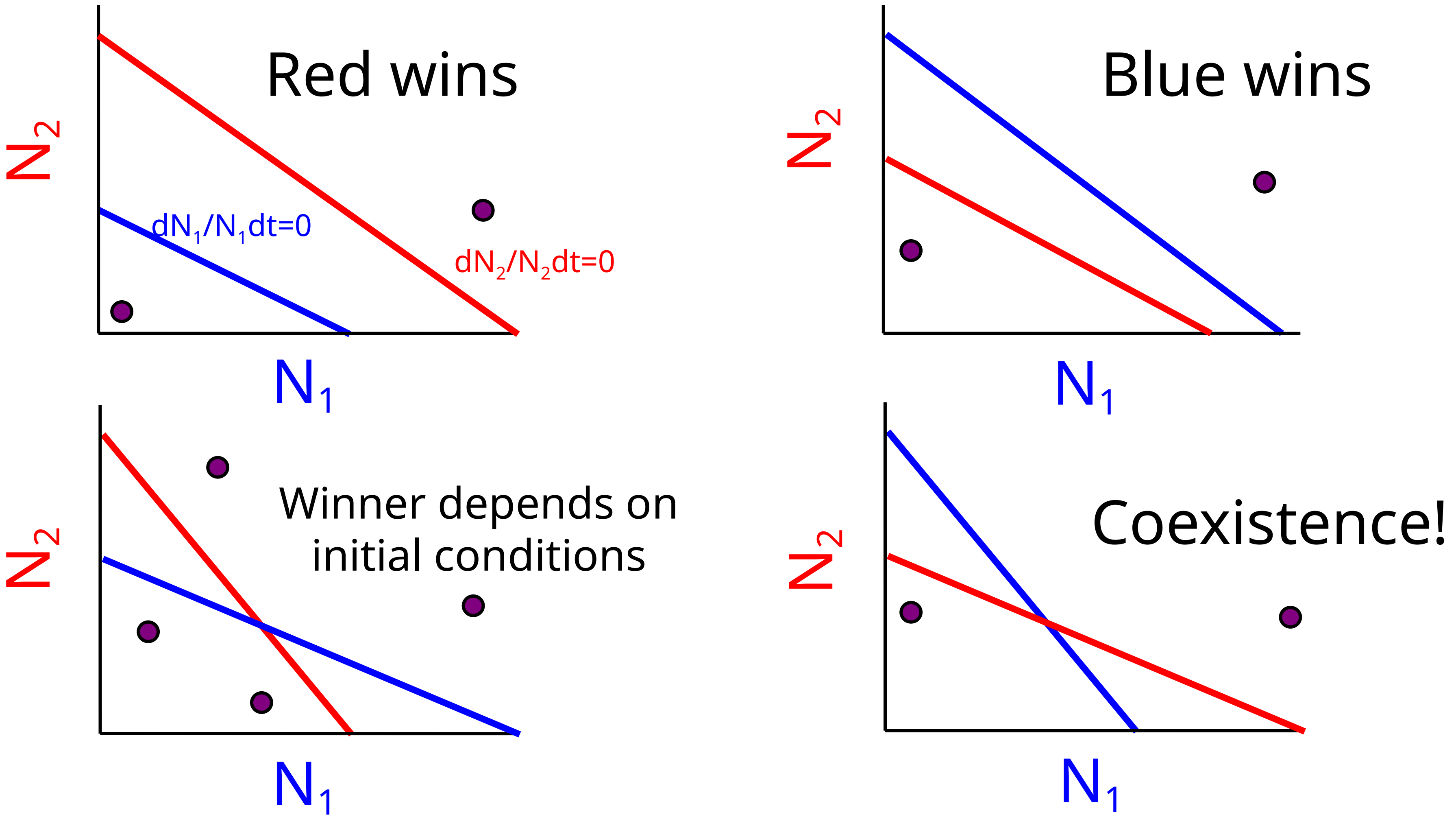
Why: because each species is self-limited below the level at which it prevents growth of the other

Invasibility:

Contrast that with…



Neither species can invade the other's equilibrium (hence no coexistence).

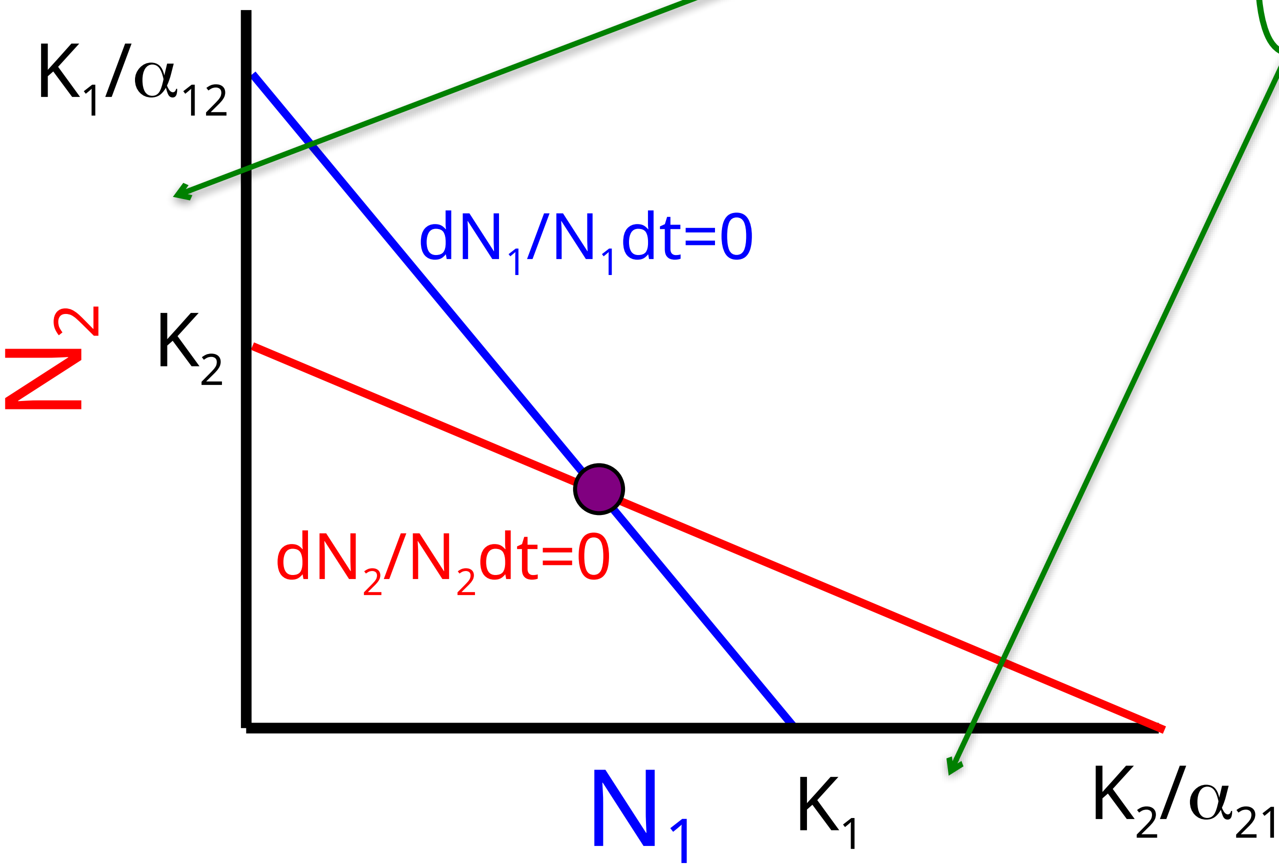

Red wins
dN1/N1dt=0
dN2/N2dt=0
N2
N1
Blue wins
N2
N1
Winner depends on
initial conditions
N2
N1
Coexistence!
N2
N1

Let's "look at the math"...

Coexistence:

$$\frac{K_1}{\alpha_{12}} > K_2$$

$$\frac{K_2}{\alpha_{21}} > K_1$$



or

Coexistence requires that "intra > inter"

- Resource partitioning
- "Competitive exclusion principle"

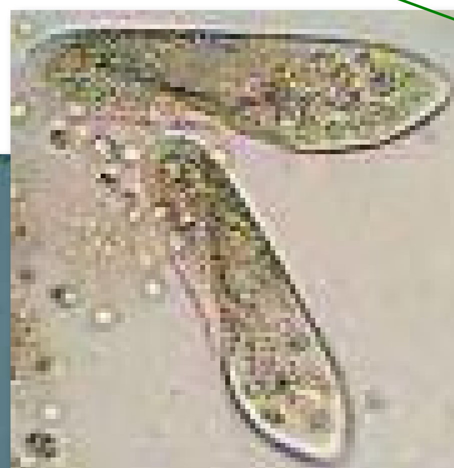
(2 species cannot coexist on a single limiting resource)

Can we now explain Gause's results?

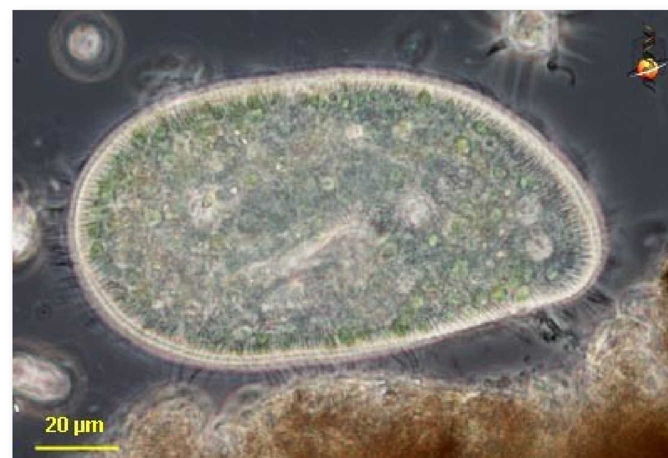
Bacteria in water column

Yeast on bottom

Paramecium aurelia



Paramecium caudatum

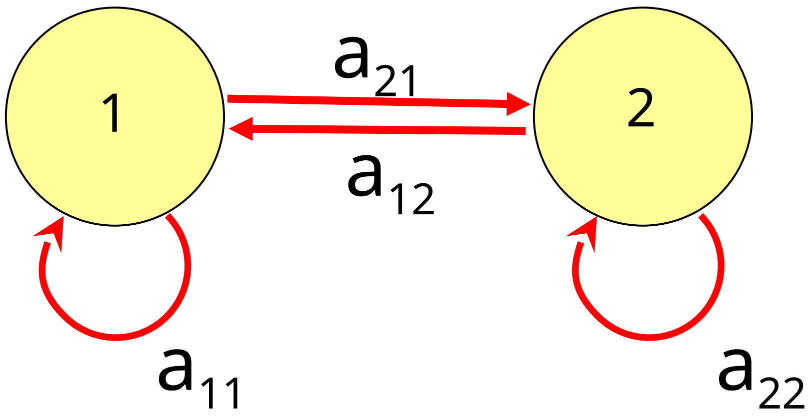


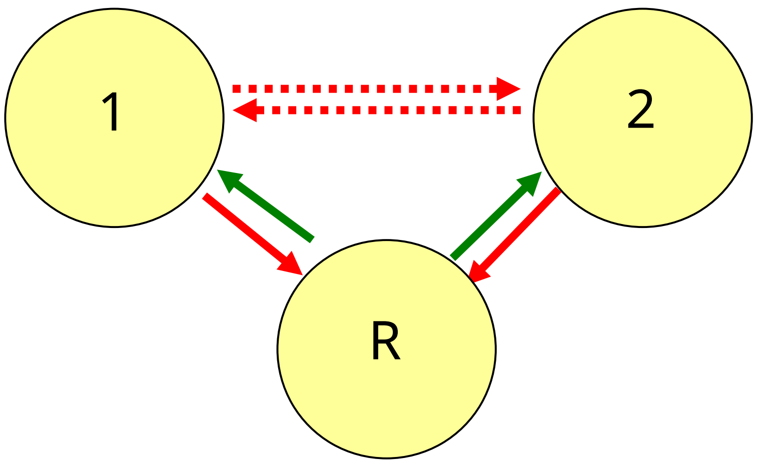
Paramecium bursaria

The missing link: resources

Competition:

Arises when two organisms use the same *limited* resource, and deplete its availability

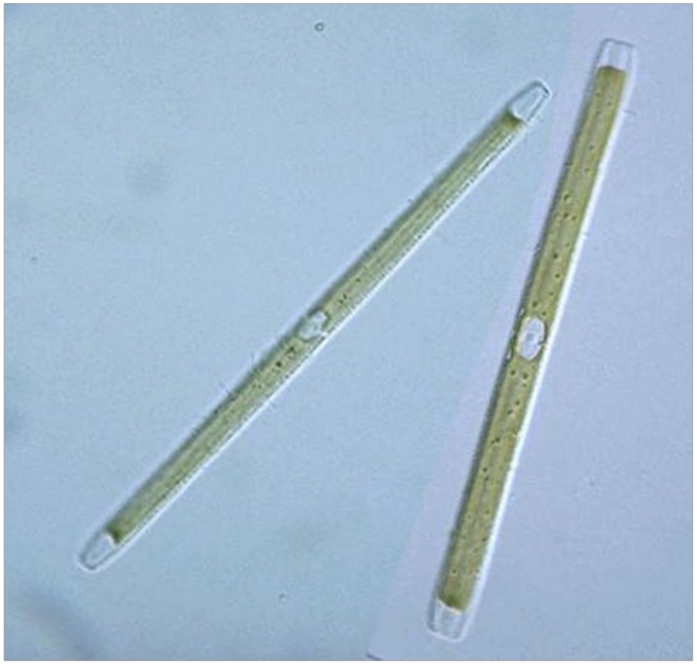




Let's explicitly consider resources

The competitors: diatoms

Synedra ulna



Asterionella formosa

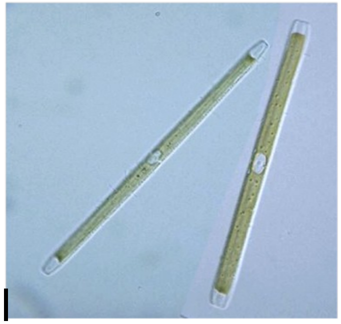
The shared resource: silicate (SiO_2)

Research by David Tilman

Resources:

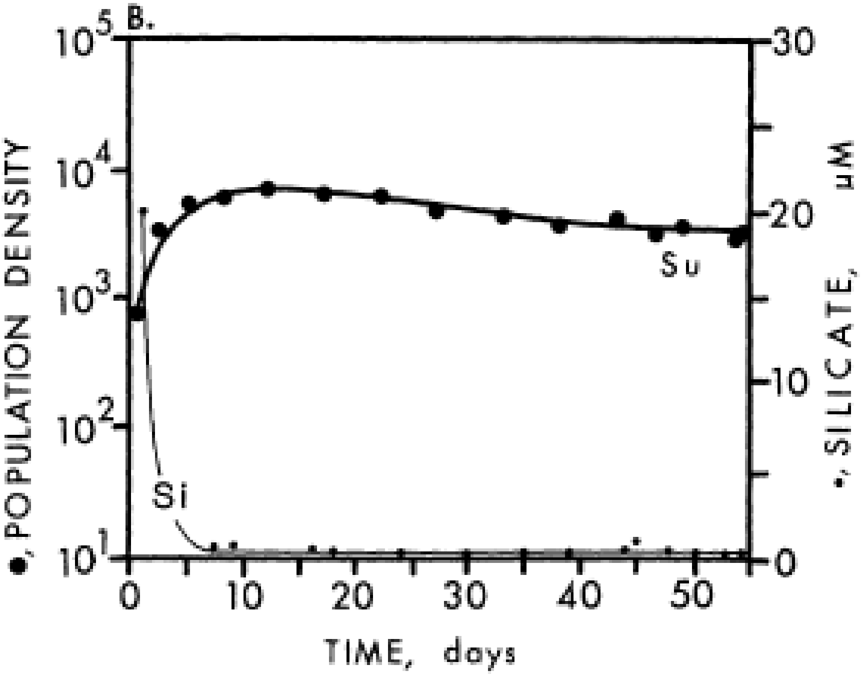
Followed population growth
and resource (silicate) when alone:

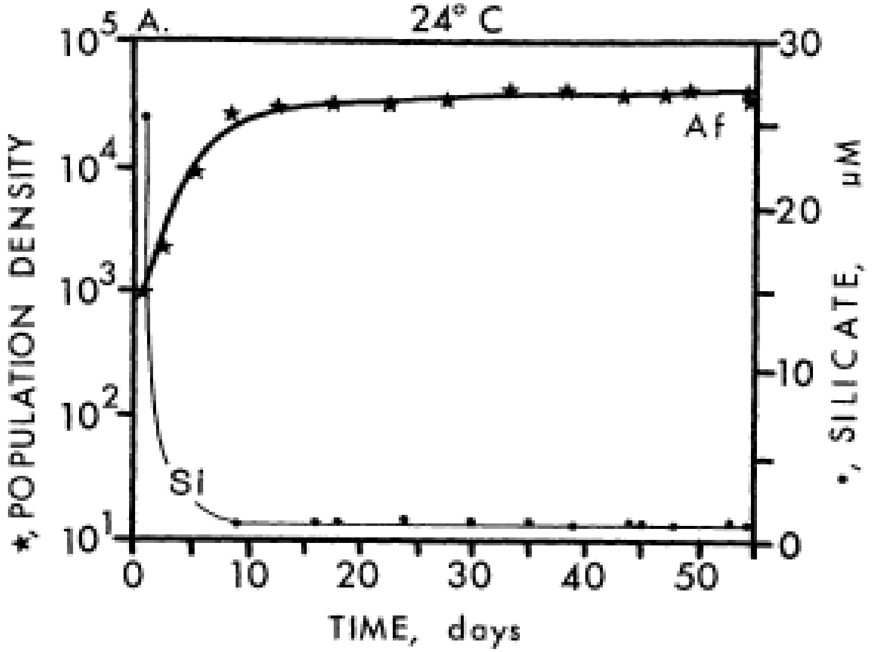
Synedra ulna



Asterionella formosa

Data = points.
Lines = predicted from model

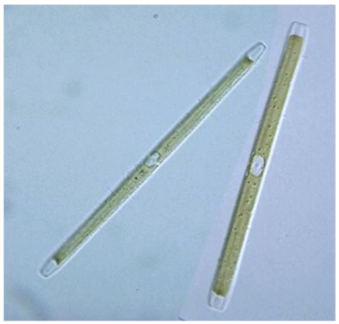




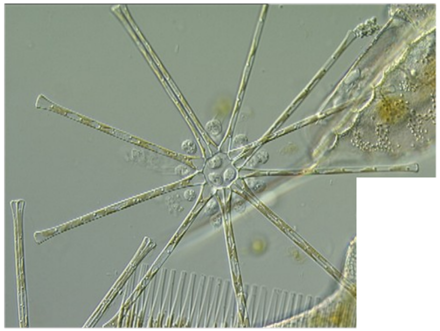
Resources:

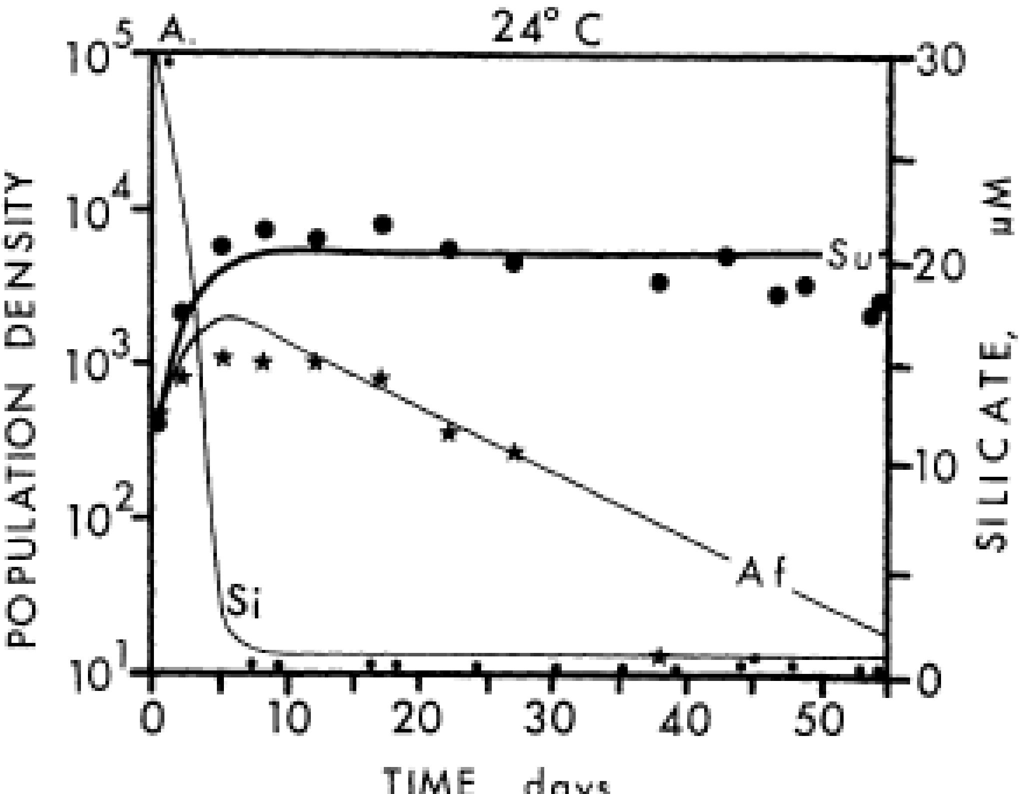
What will happen when growth together: why?

Synedra ulna



Asterionella formosa





Resources:

R*: resource concentration after consumer population equilibrates (i.e., R at which Consumer shows no net growth)

Species with lowest R* wins (under idealized scenario: e.g., one limiting resource).

If two limiting resources, then coexistence if each species limited by one of the resources (intra>inter): trade-off in R*s.

Next time: Tilman's R* framework for two consumers & two resources