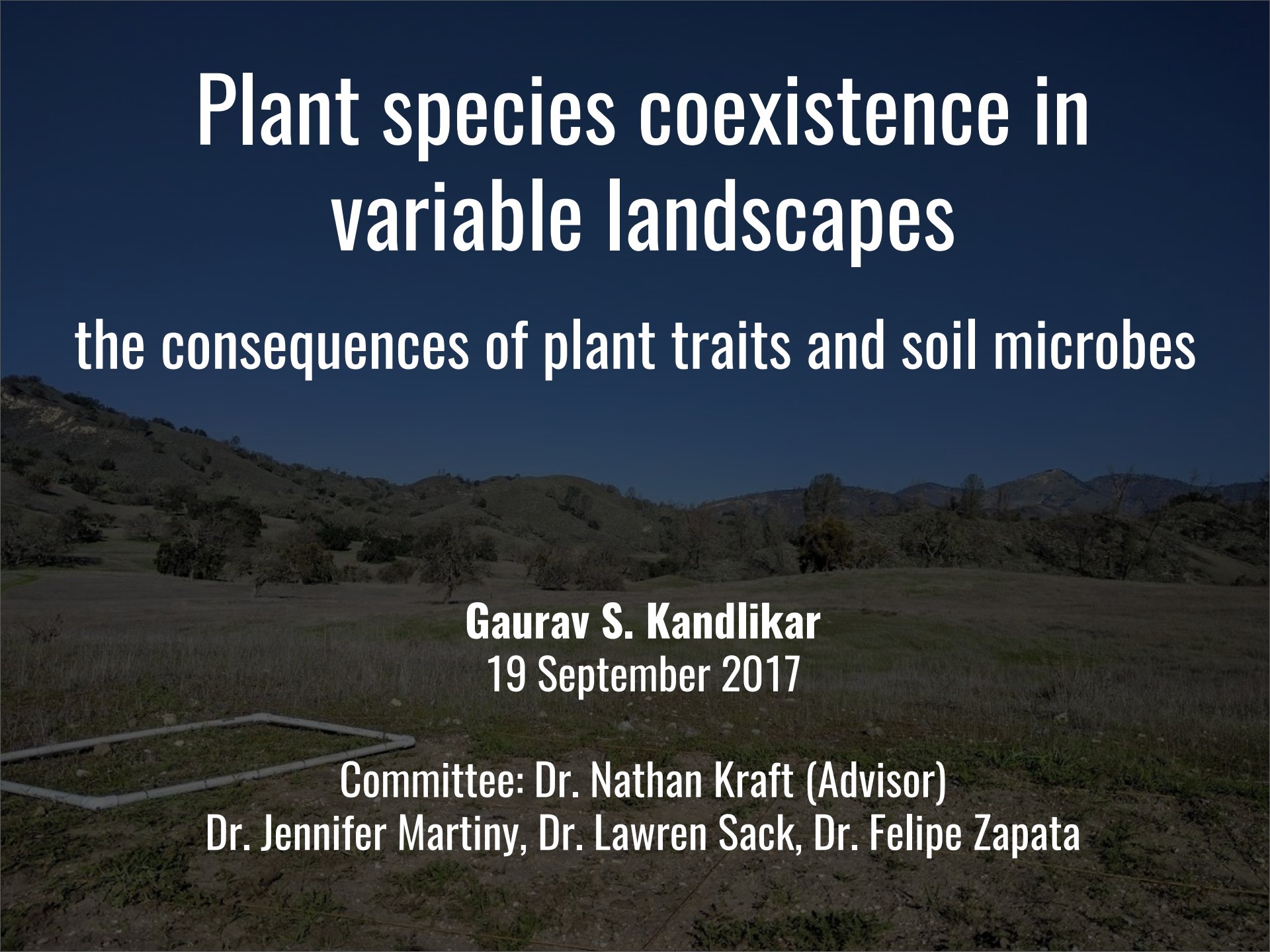
Plant species coexistence in variable landscapes

the consequences of plant traits and soil microbes



Gaurav S. Kandlikar

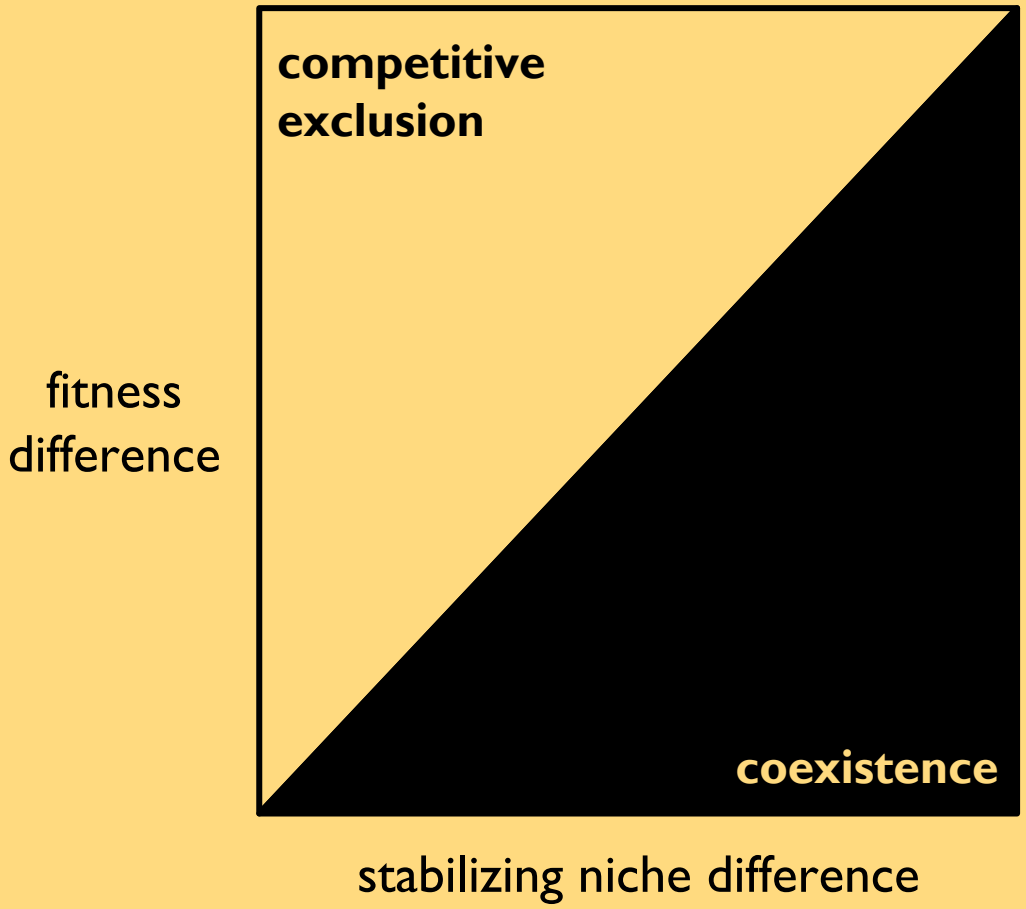
19 September 2017

Committee: Dr. Nathan Kraft (Advisor)
Dr. Jennifer Martiny, Dr. Lawren Sack, Dr. Felipe Zapata

image: https://www.flickr.com/photos/rejik/
Kabani River, Kerala, India


image: https://www.flickr.com/photos/14723335@N05/

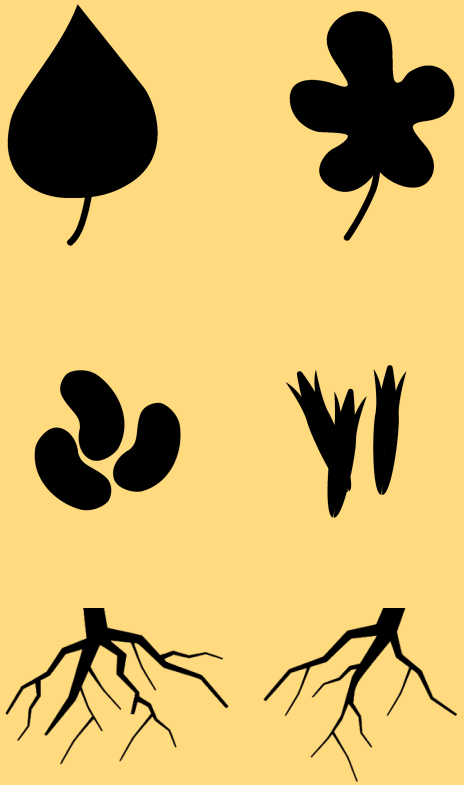

image: https://www.flickr.com/photos/14723335@N05/



Adler et al. 2007 Ecol. Letters

fitness
difference

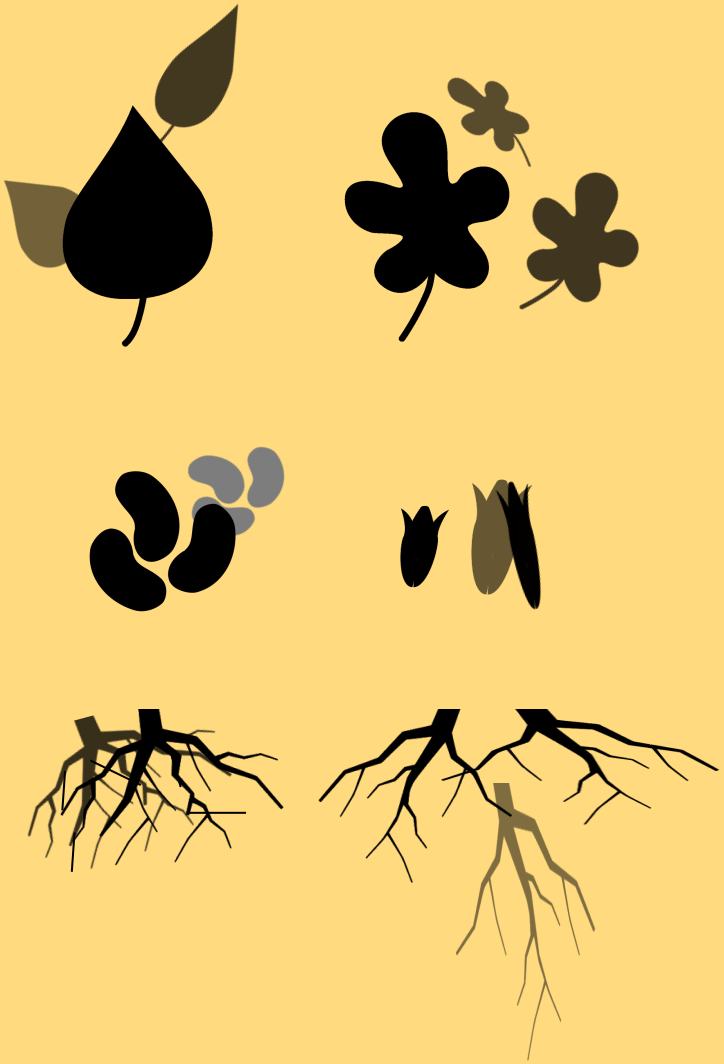
stabilizing niche difference



Adler et al. 2013 Ecol. Letters

fitness
difference

stabilizing niche difference



To do: make ITV part look nicer, kinda blurry rn

Turcotte & Levine 2016 TREE

Fierer 2017 Nature Reviews

Bever et al. 2015 AREES

Dissertation Questions

1. How do differences in species functional traits relate to their demographic variation in patchy landscapes?

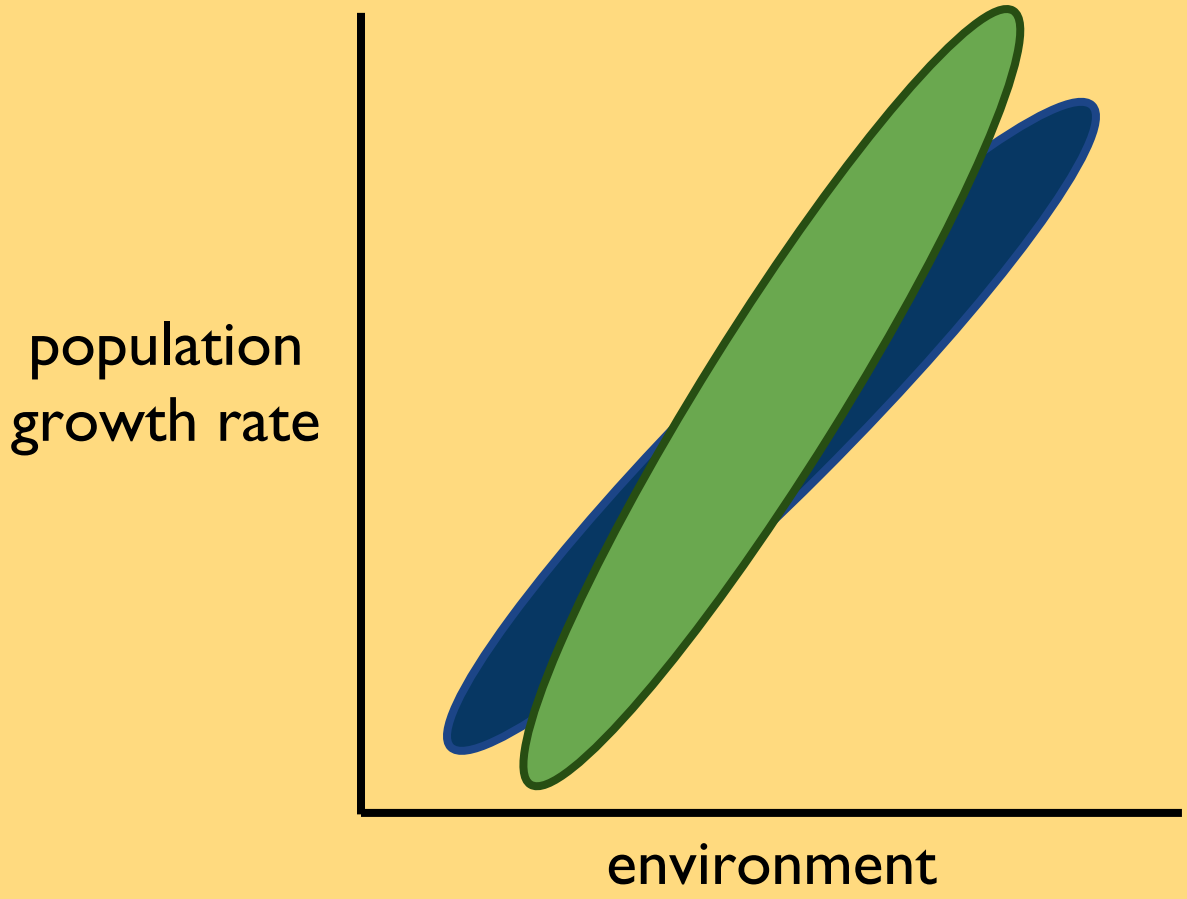
2. How does intra-specific trait variation influence competitive dynamics?

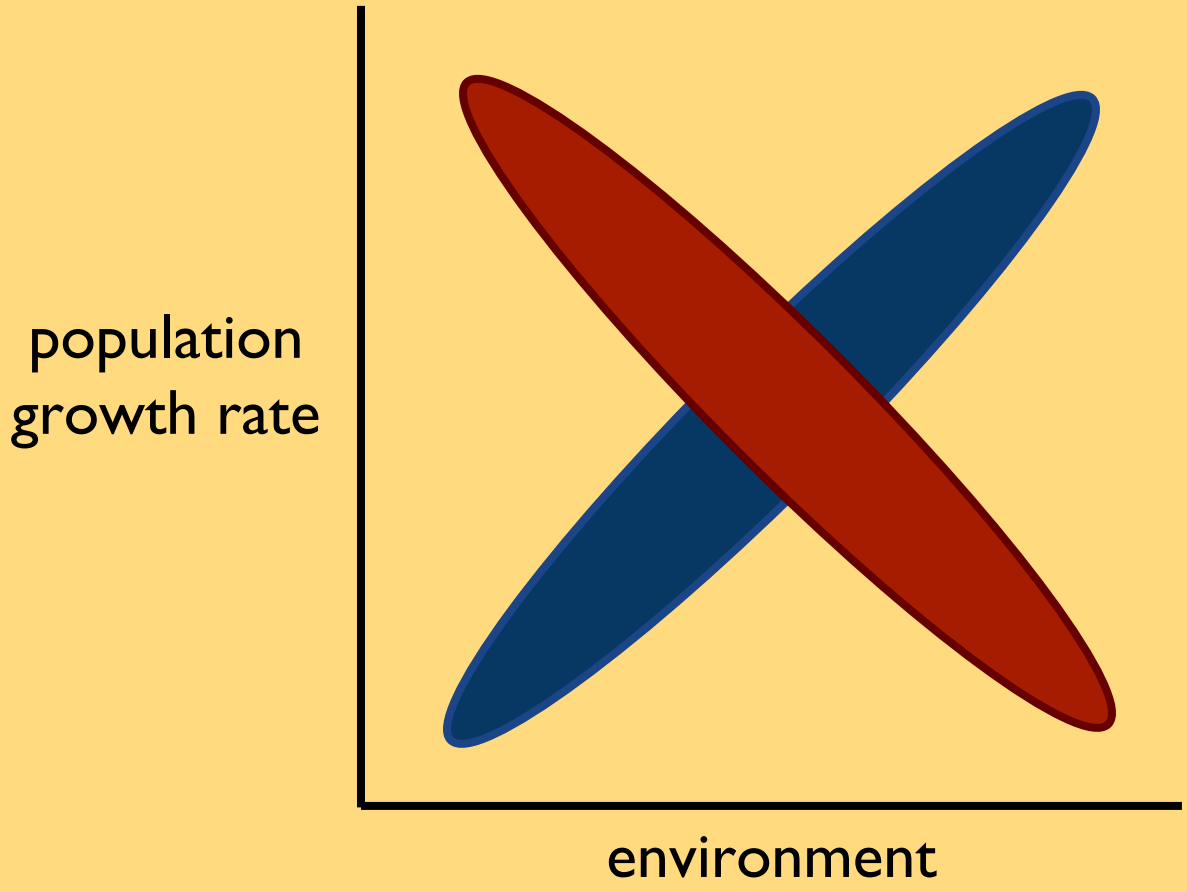
3. How can we jointly consider the consequences of resource competition and plant-microbe interactions in a unified framework?

Chapter 1

How do functional traits shape plant demographic responses to heterogeneous environments?


population
growth rate
environment


population
growth rate
environment


population
growth rate
environment

Chapter questions

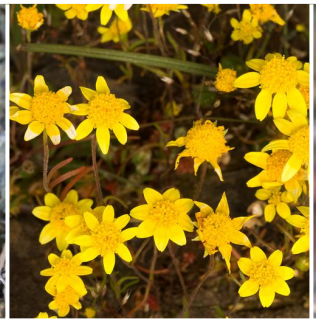
1. Which environmental factors drive variation in species responses to spatial heterogeneity?

2. Which functional traits mediate species responses to the environmental drivers?


Uropappus lindleyi


Centaurea melitensis


Chaenactis glabriuscula


Lasthenia californica


Hemizonia congesta


Micropus californicus


Amsinckia menziesii


Clarkia purpurea


Clarkia bottae


Euphorbia peplus

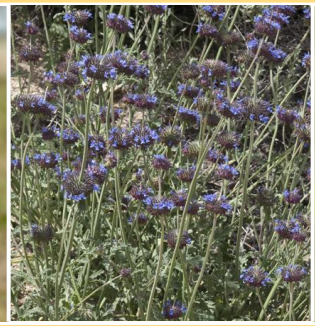

Medicago polymorpha


Acmispon wrangelianus


Bromus madritensis

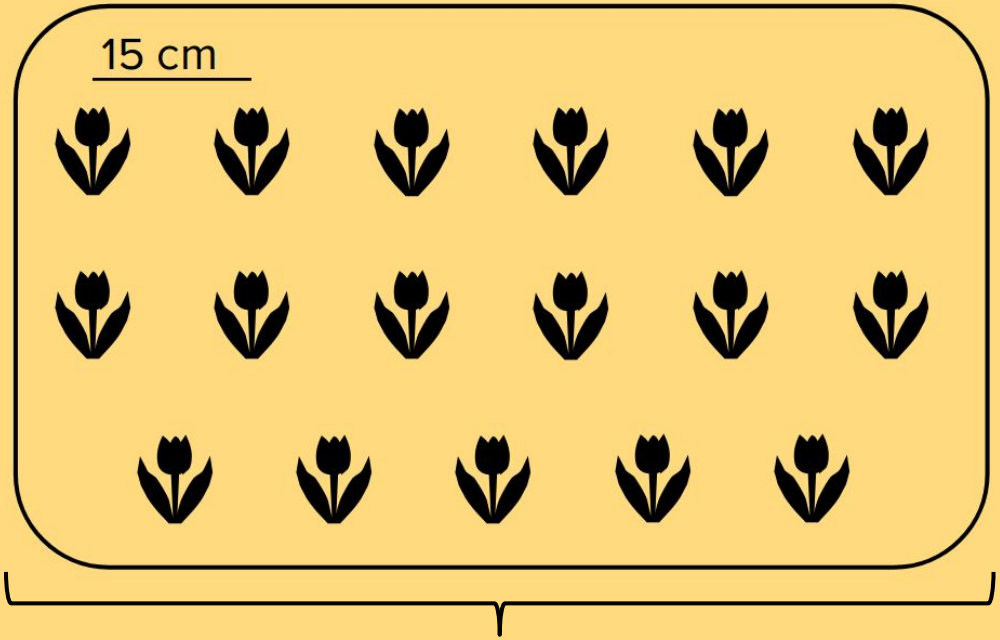

Hordeum murinum


Vulpia microstachys

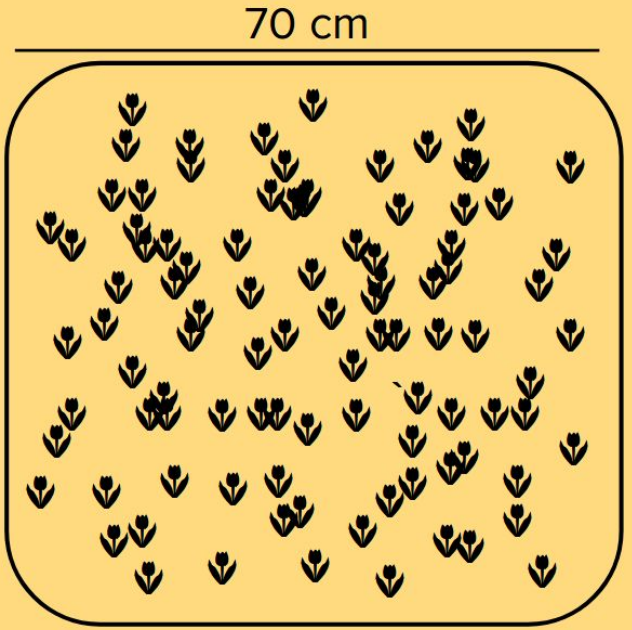

Salvia columbariae


Plantago erecta

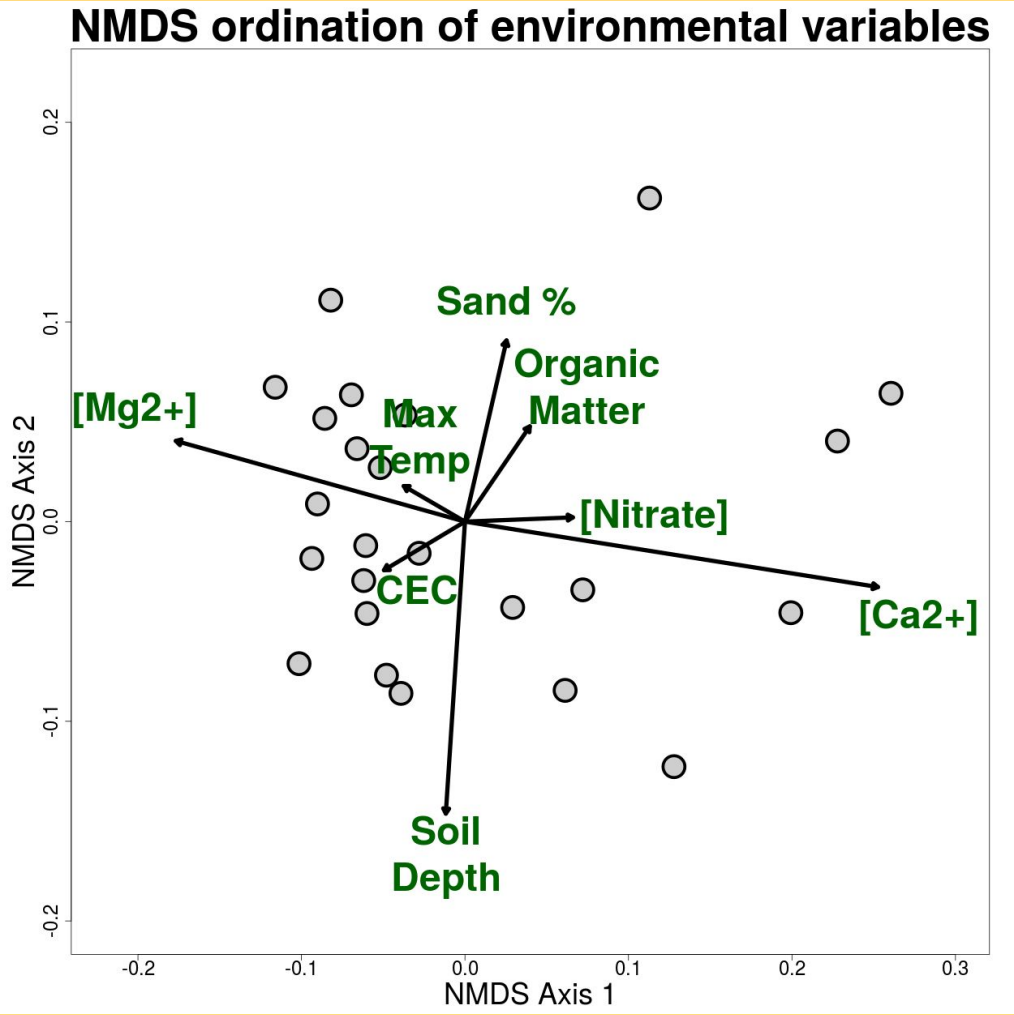
Images from CalPhotos (http://calphotos.berkeley.edu/)



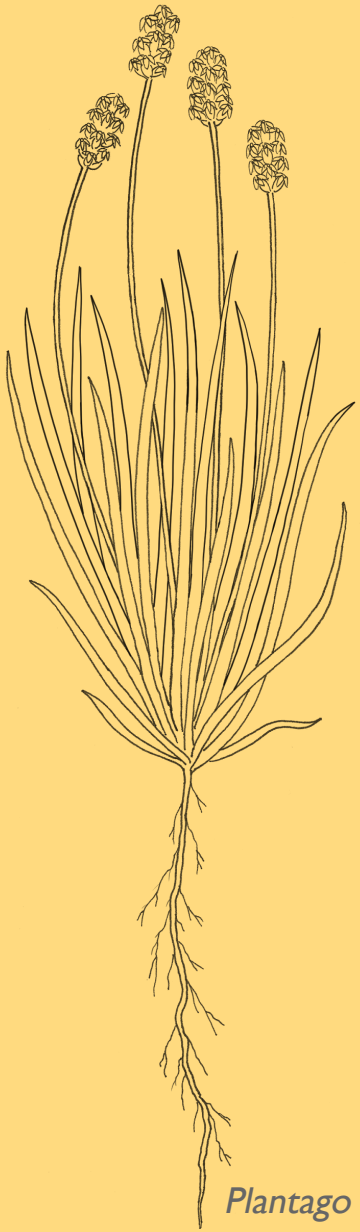
x 5 replicates/site



$$\frac{N_{i,j,T+1}}{N_{i,j,T}} = (1 - g_{i,j})s_i * \frac{\lambda_{i,j}}{1 - r_{i,j}(\eta_j)}$$


NMDS ordination of environmental variables
Sand %
Organic Matter
[Mg2+]
Max Temp
[Nitrate]
CEC
[Ca2+]
Soil Depth
NMDS Axis 1
NMDS Axis 2
0.2
0.1
0.0
-0.1
-0.2
-0.2
-0.1
0.0
0.1
0.2
0.3

Leaves
Leaf size
Specific leaf area
Leaf dry matter content
δC^{13}
Leaf N concentration
Leaf osmotic potential



Plantago erecta

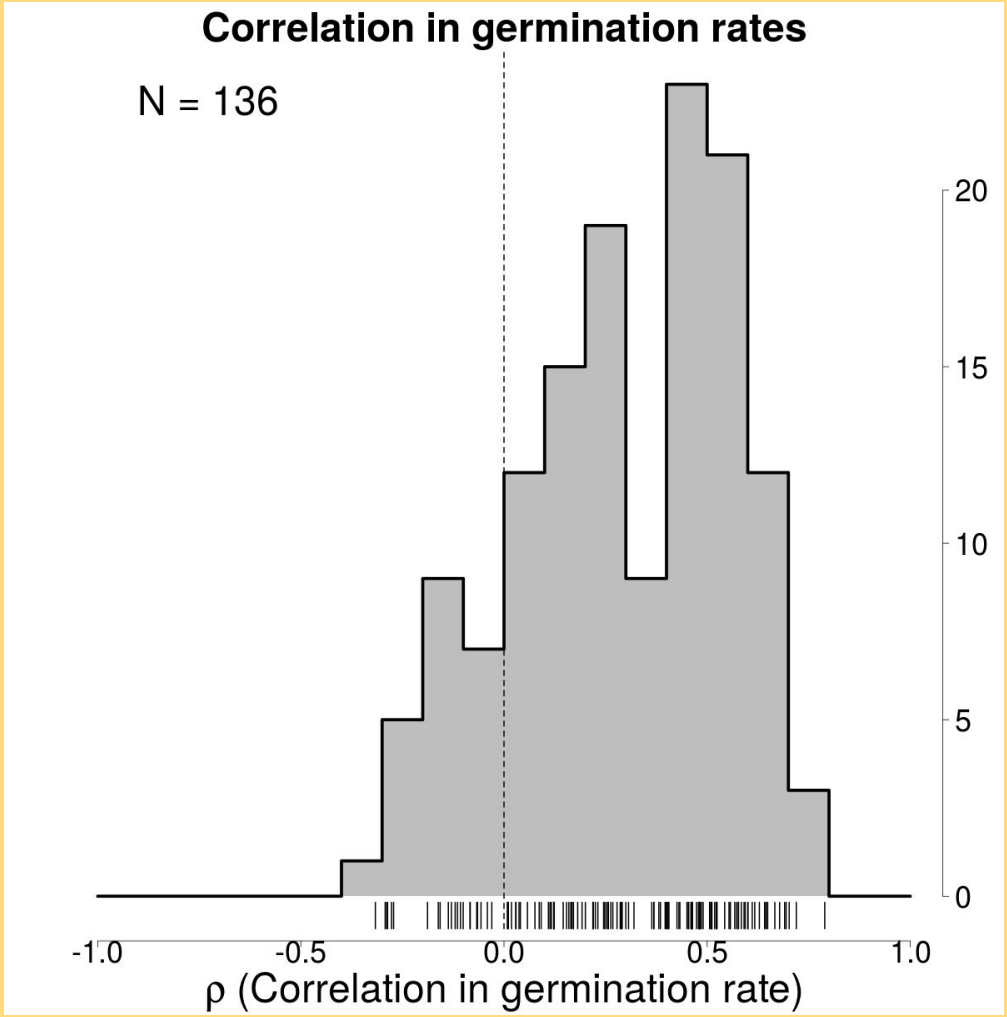
Reproduction
Seed mass
Fruiting phenology

Roots
Specific root length
Rooting depth

Whole-plant
Maximum height
Canopy shape index

Illustration: Joanna Shih (UCLA)

Species pairs tend to have distinct demographic responses to environmental gradients



$$p_{i,j} \sim \overbrace{a_0}^{species\ effect} + \underbrace{a_1 z_j}_{trait\ effect} + \overbrace{b_0 x_i}^{environment\ effect} + \underbrace{b_1 z_j x_i}_{interaction} + \overbrace{\epsilon_{\alpha j} + \epsilon_{\beta i} + \gamma_i}^{error\ terms}$$

To do- figure out why equation is blurry

Jamil et al. 2012 J. Veg. Sci

$$p_{i,j} \sim \overbrace{a_0}^{species\ effect} + \underbrace{a_1 z_j}_{trait\ effect} + \overbrace{b_0 x_i}^{environment\ effect} + \boxed{\underbrace{b_1 z_j x_i}_{interaction}} + \overbrace{\epsilon_{\alpha j} + \epsilon_{\beta i} + \gamma_i}^{error\ terms}$$

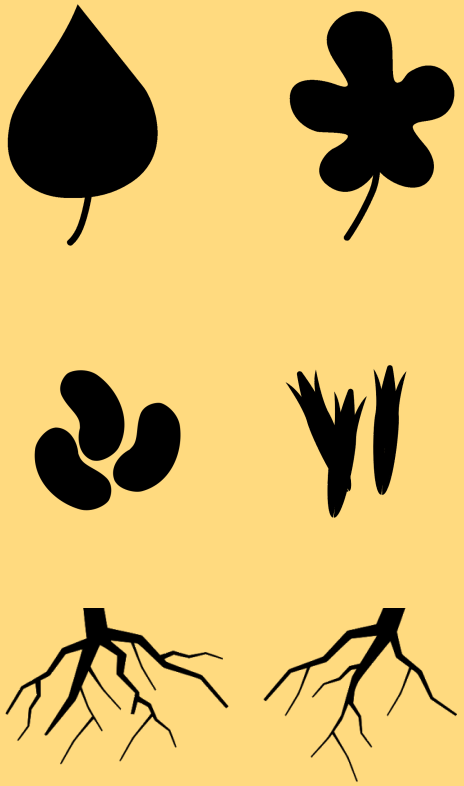
$$C_\beta = 1 - \frac{\hat{\sigma}^2_{\beta,\ no\ interaction\ term}}{\hat{\sigma}^2_{\beta,\ with\ interaction\ term}}$$

To do- figure out why equation is blurry

Jamil et al. 2012 J. Veg. Sci

fitness
difference

stabilizing niche difference



Chapter 2

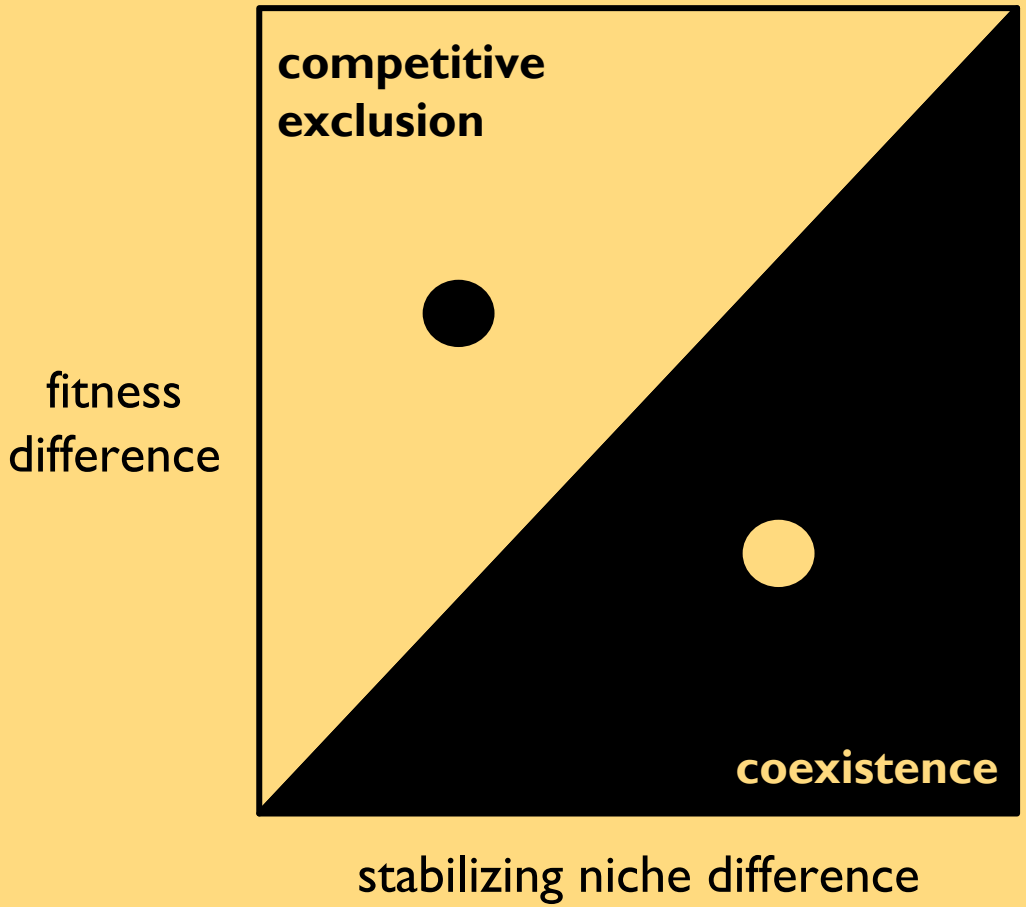
What is the nature of intra-specific trait variation and how does it influence species coexistence?

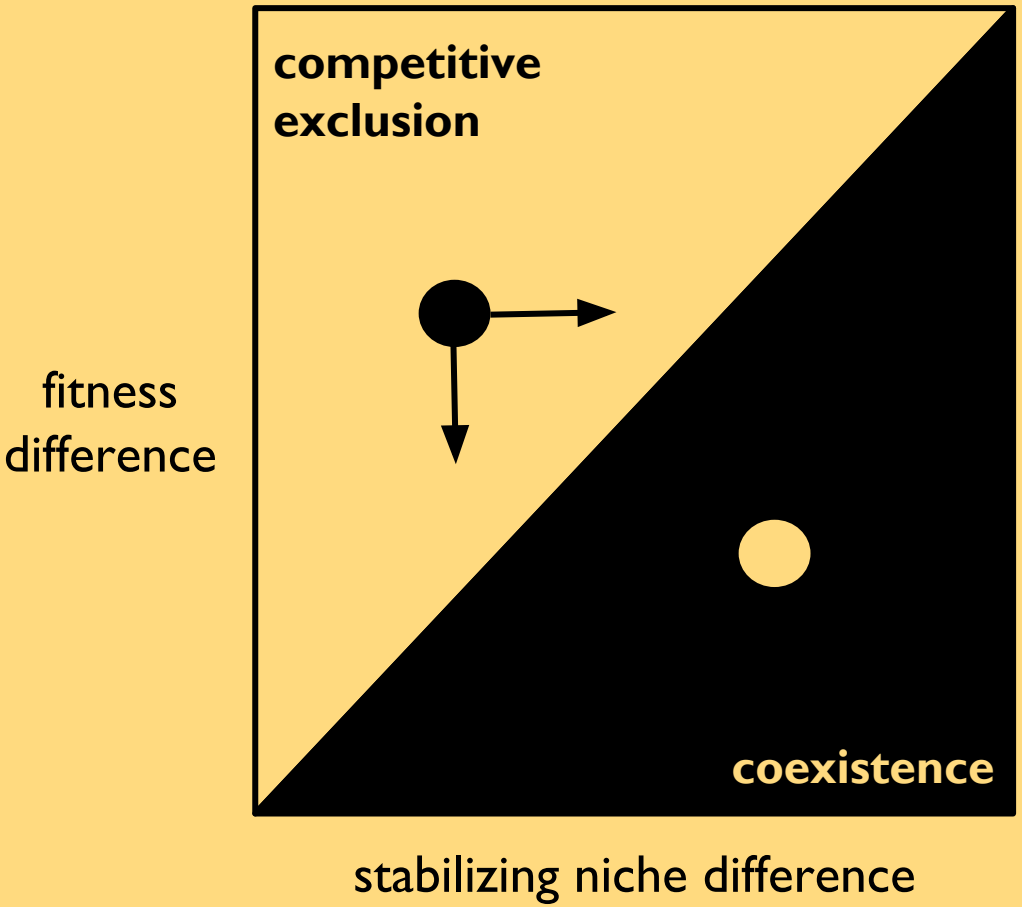
chapter 2 background

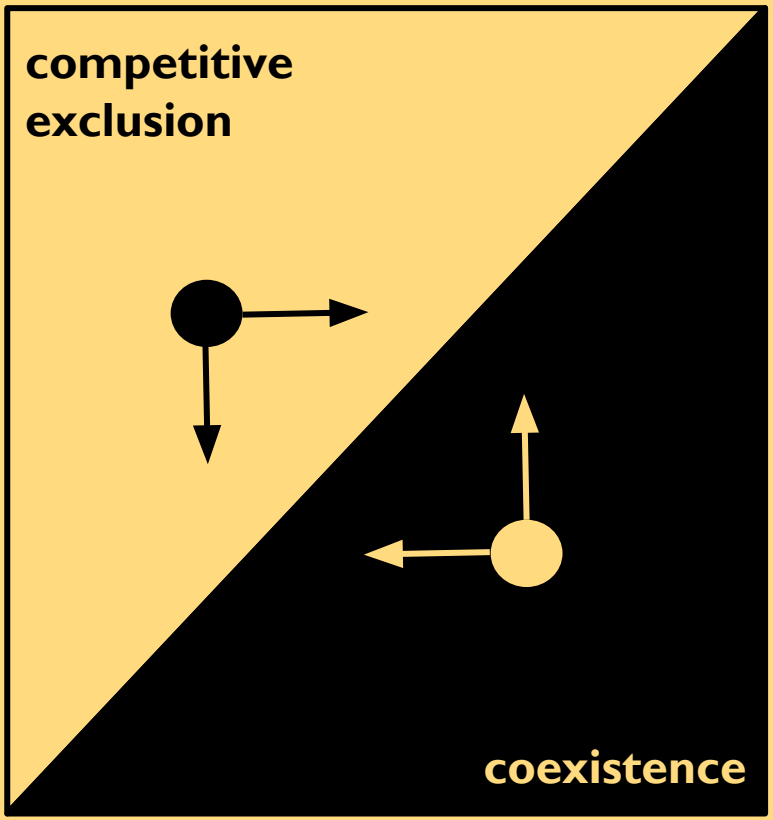
ITV within individuals

ITV within individuals

ITV between populations


competitive
exclusion
coexistence
fitness
difference
stabilizing niche difference


competitive
exclusion
coexistence
fitness
difference
stabilizing niche difference



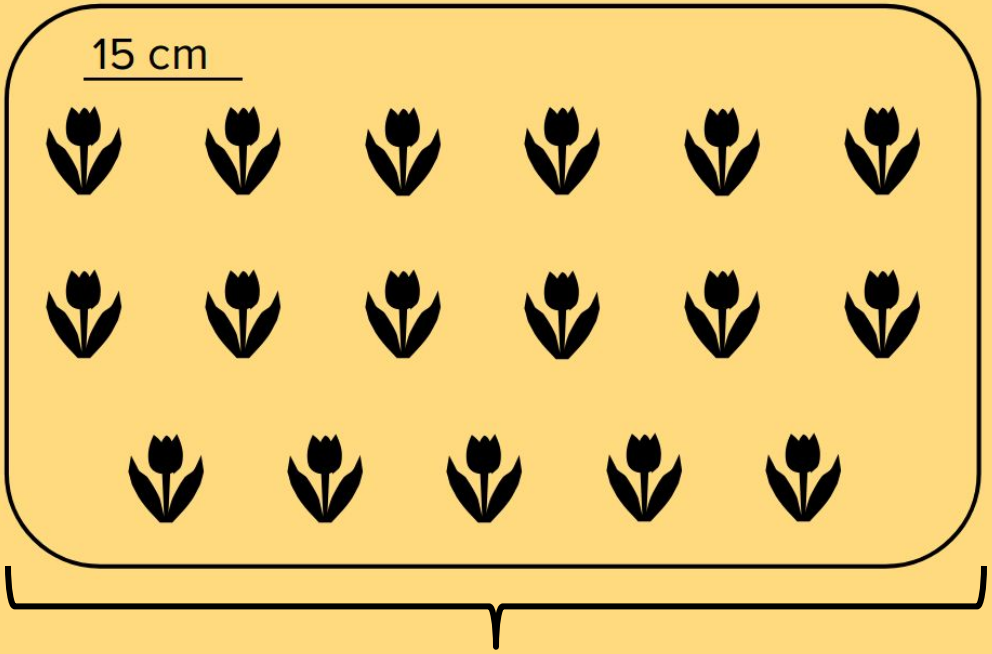
Hart et al. 2016 Ecol Letters

Chapter questions

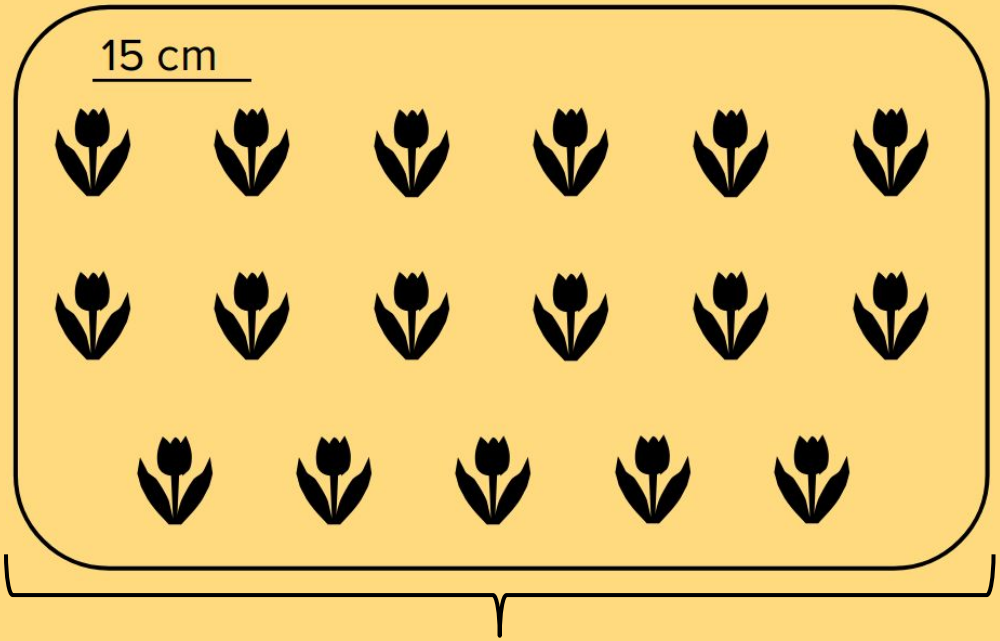
1. What is the structure of trait variation across an environmental gradient?

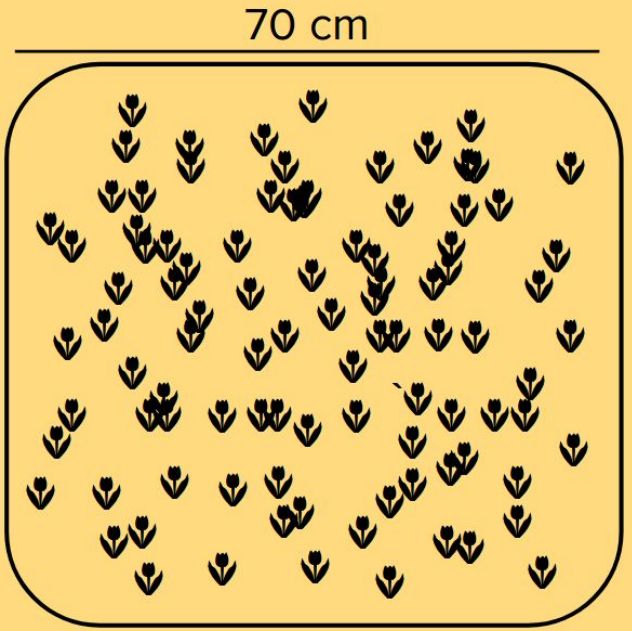
2. Do species shift their ecological strategies in competition, and how might this influence the outcome of competition?

At 24 sites, plants were grown with a very low density of competitors

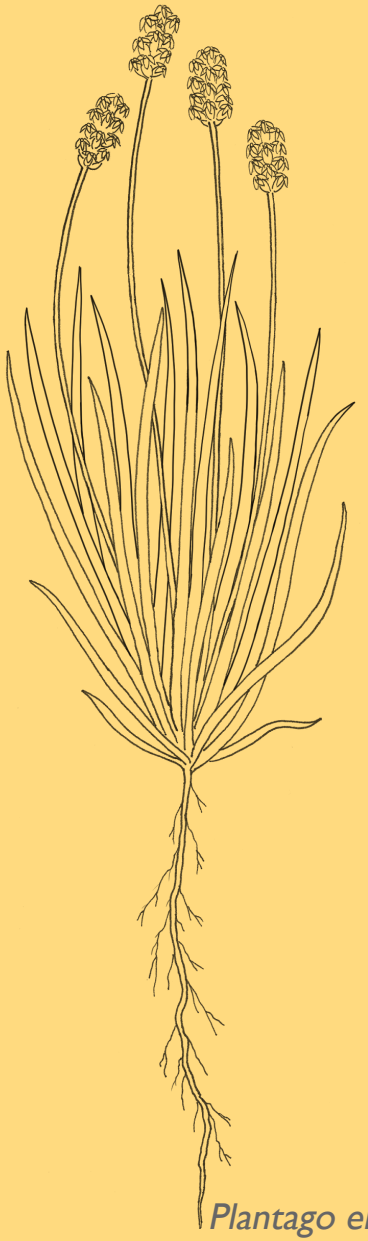


At one site, plants were grown with and without competitors





Leaves
Leaf size
Specific leaf area
Leaf dry matter content



Plantago erecta

Roots
Specific root length

Whole-plant
Canopy shape index

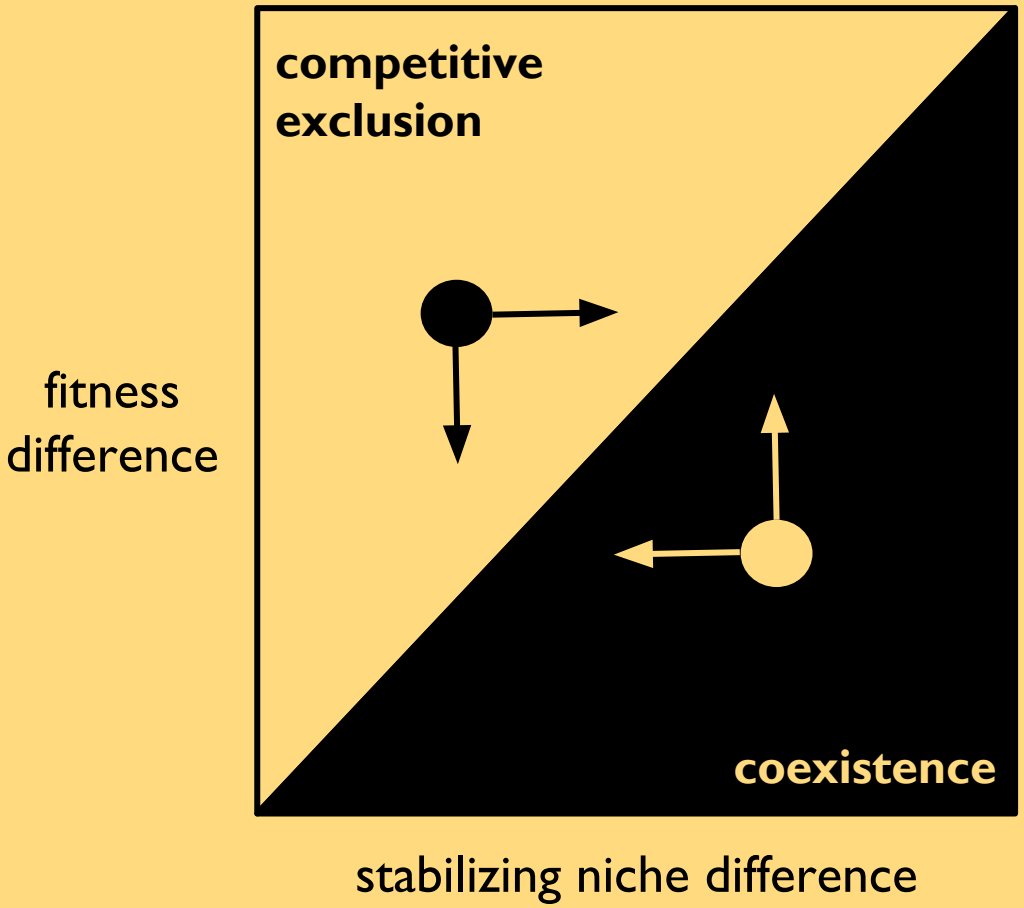
Illustration: Joanna Shih (UCLA)

Q1: What is the structure of trait variation across an environmental gradient?

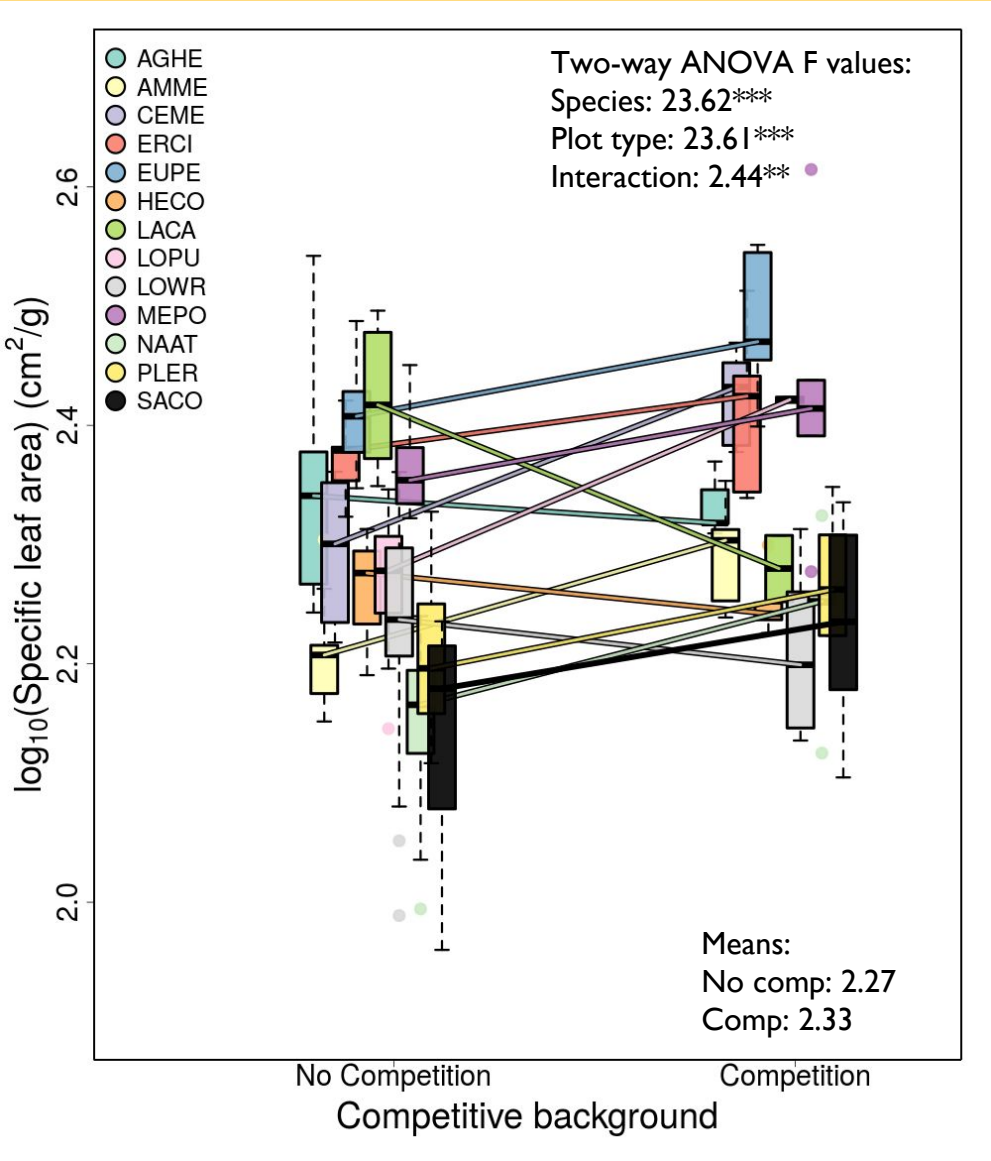
$$trait_{i,j} \sim \overbrace{a}^{\text{trait mean}} + \underbrace{b_0 x_i}_{\text{species effect}} + \overbrace{c_0 z_j}^{\text{environment effect}} + \underbrace{c_1 x_i z_j}_{\text{interaction}} + \overbrace{\epsilon_{\alpha j} + \epsilon_{\beta i} + \gamma_i}^{\text{error terms}}$$

To do- figure out why equation is

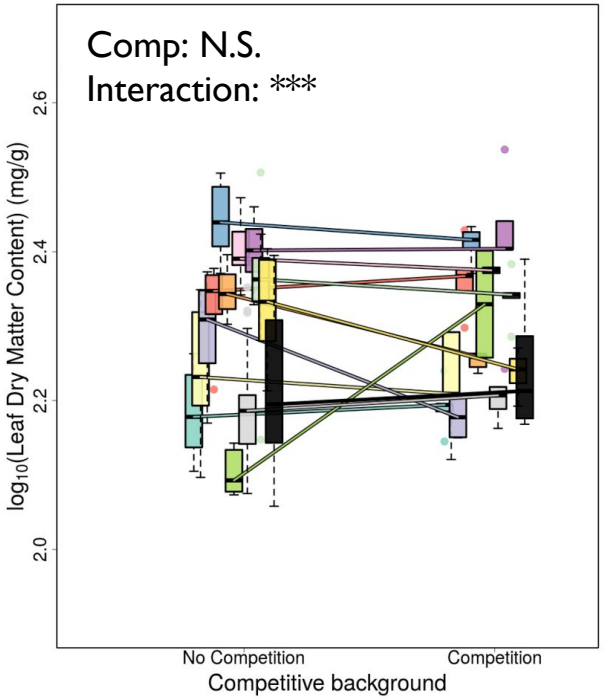
Q2: Do species shift their ecological strategies in competition, and how might this influence the outcome of competition?

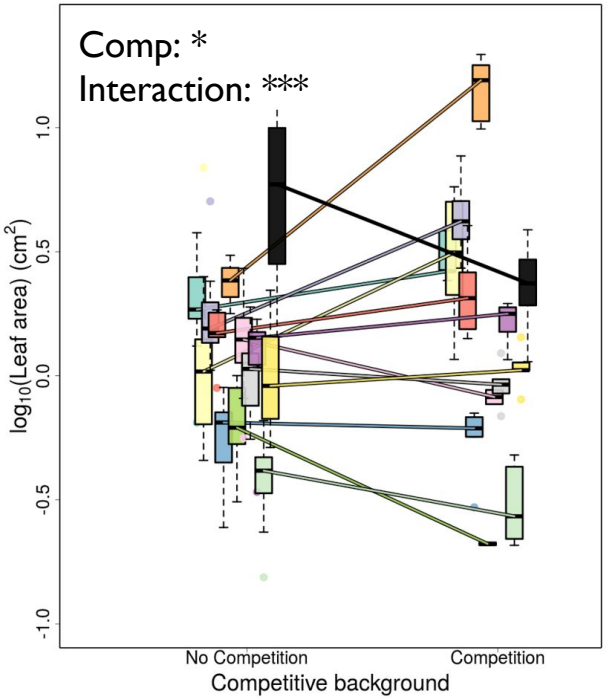


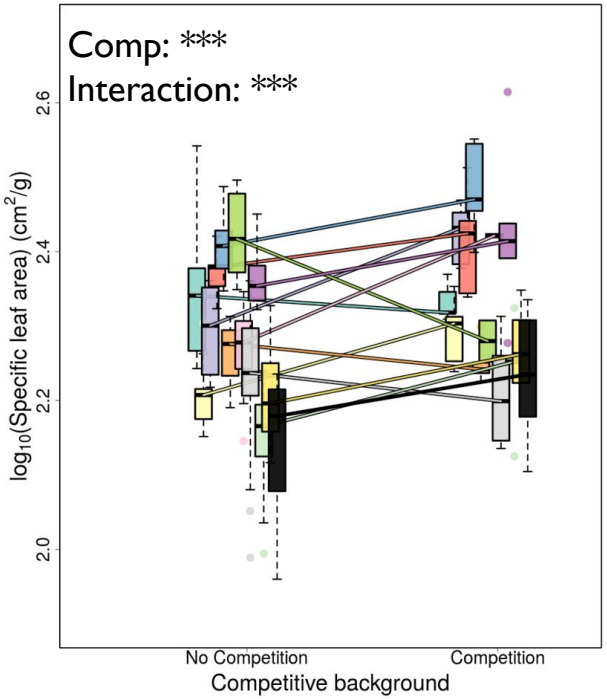
chapter 2 preliminary results



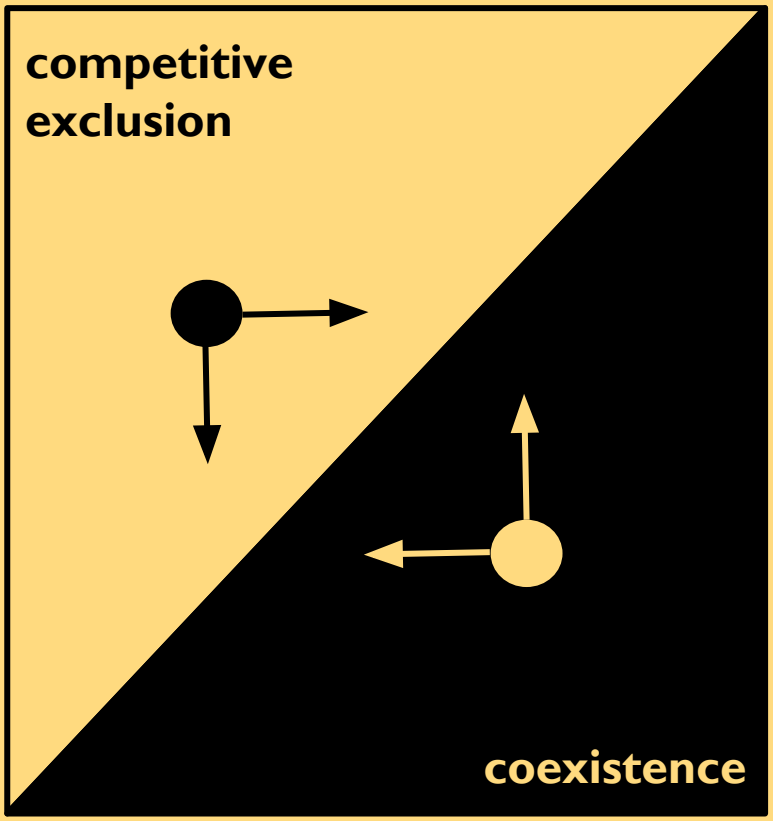
chapter 2 preliminary results







To do- figure out better way to show this

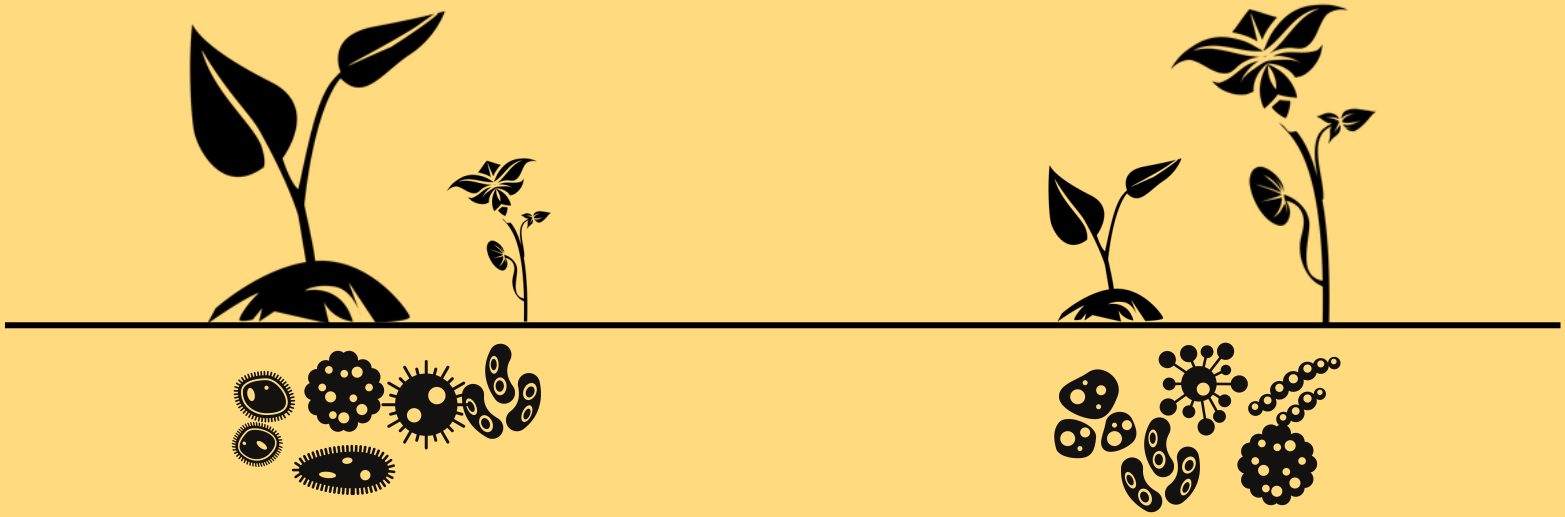


To do- not a big fan of this slide rn

Chapter 3

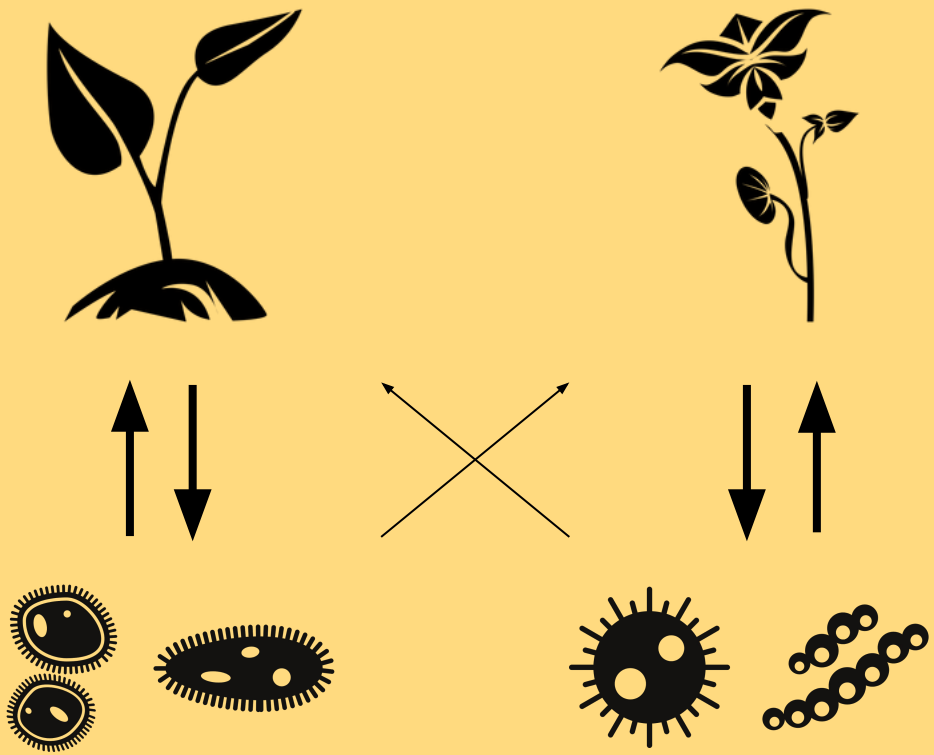
How can we better investigate the joint effects of plant competition and plant-microbe interactions?

Microbes are ubiquitous and varied, and they can have dramatic impacts on plant community dynamics.



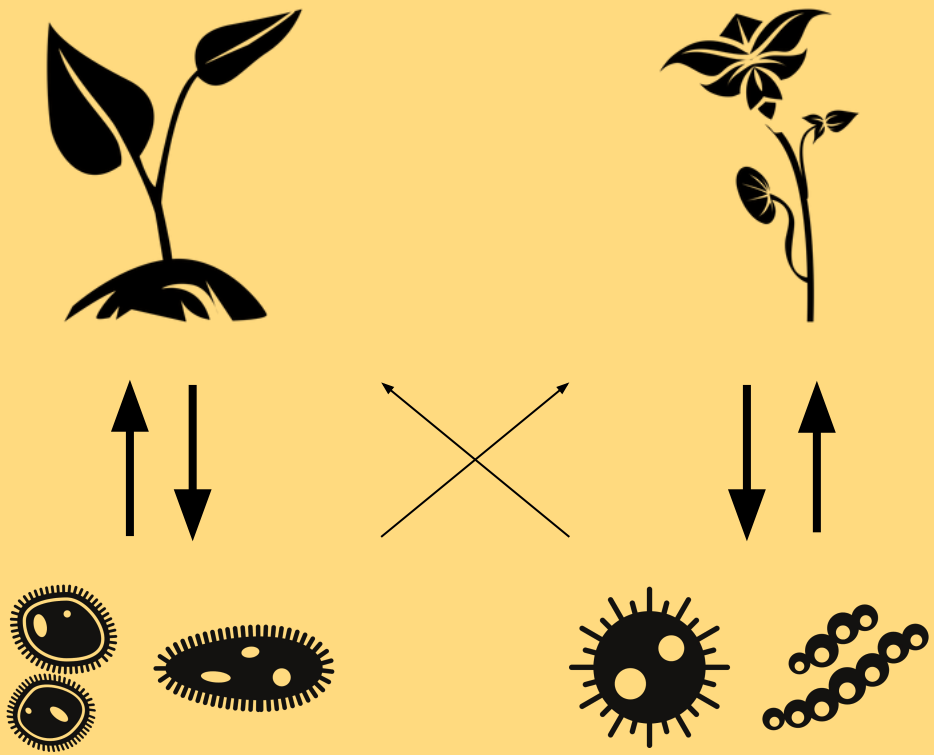
Bever et al. 2015 AREES

Plant-soil feedbacks can promote plant species coexistence

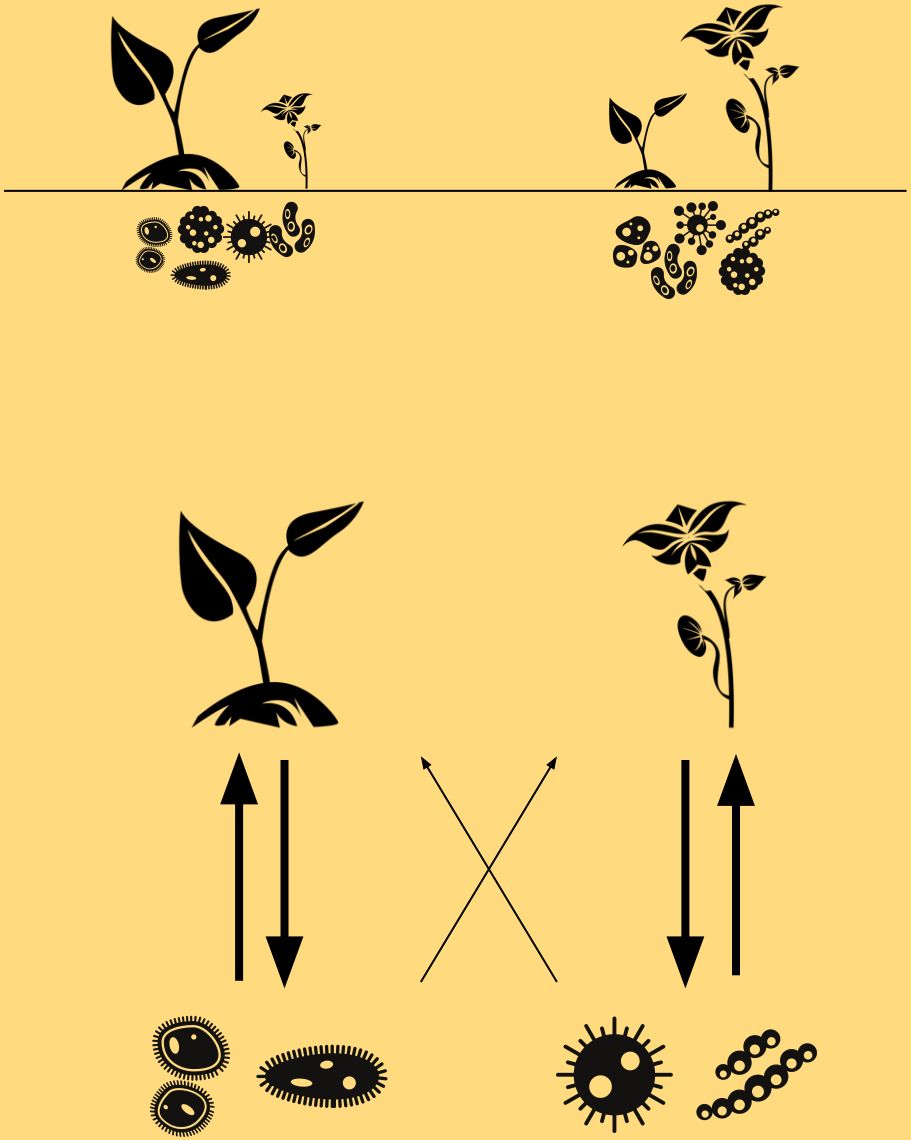


Bever et al. 1997 J Ecology

Plant-soil feedbacks can promote plant species coexistence



What is the relative importance of
microbes and competition to plant coexistence?



Bever et al. 2015

fitness
difference

stabilizing niche difference

chapter 3 background

$$\text{Niche overlap} = \frac{\sum_l \frac{C_{jl} V_l C_{kl}}{r_l^R \alpha_I^R} + \sum_m \frac{a_{jm} w a_{km}}{r_m^P \alpha_m^P}}{\sqrt{\left(\sum_l \frac{c_{jl}^2 v_l}{r_l^R \alpha_l^R} + \sum_l \frac{a_{jm}^2 w}{r_m^P \alpha_m^P}\right)\left(\sum_l \frac{c_{kl}^2 v_l}{r_l^R \alpha_l^R} + \sum_l \frac{a_{km}^2 w}{r_m^P \alpha_m^P}\right)}}$$

$$\text{Species fitness} = \frac{\sum_l \frac{C_{jl} v_l}{\alpha_l^R} - \sum_m \frac{a_{jm}}{\alpha_m^P} - \mu_j}{\sqrt{\left(\sum_l \frac{c_{jl}^2 v_l}{r_l^R \alpha_l^R} + \sum_m \frac{a_{jm}^2 w}{r_m^P \alpha_m^P}\right)}}$$

Due to natural enemies

Due to resource use

Chesson & Kuang (2008) Nature

chapter 3 preliminary results

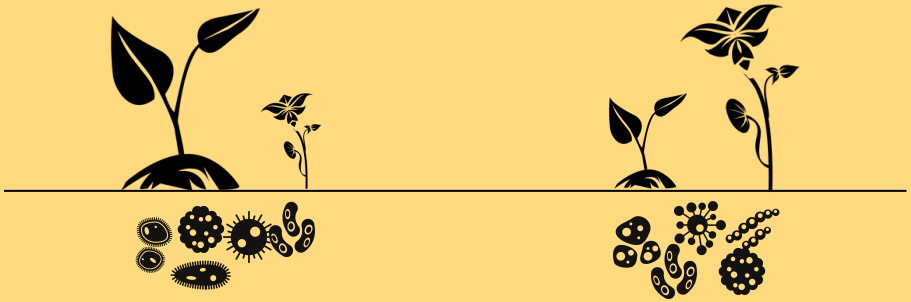
a_{jm}	a_{jn}	a_{km}	a_{kn}	r_l	r_g	r_m	r_n	ρ_{net}	$\rho_{competition}$	$\rho_{enemies}$	$\frac{\kappa_j}{\kappa_k}$	coexist?
0.001	0.00	0.00	0.001	2	2	0.1	0.1	1.00	1	1.00	1	no
0.015	0.00	0.00	**0.015**	2	2	0.1	0.1	0.95	1	0.13	1	yes
0.015	0.00	0.00	0.015	**0.4**	**0.4**	0.1	0.1	0.99	1	0.13	1	yes- but lot less stable
0.015	0.00	0.00	0.015	2	2	**1**	**1**	0.99	1	0.13	1	yes- but lot less stable

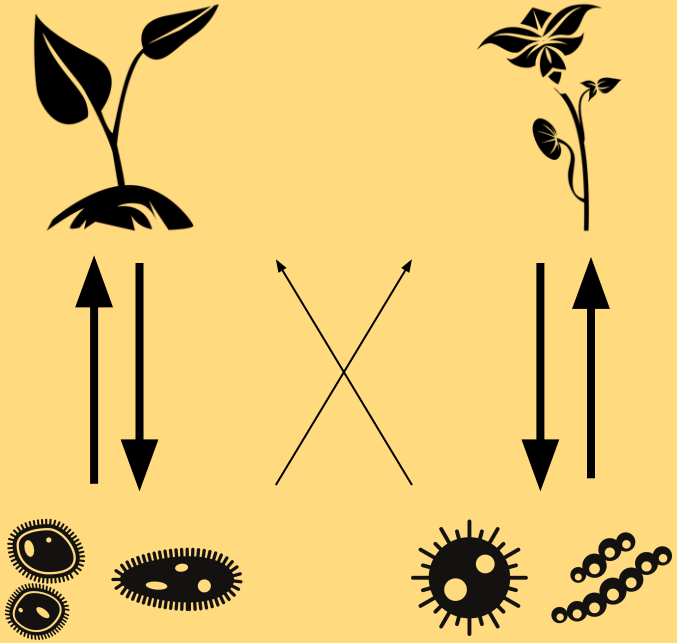
Ask for feedback on how best to present this part, seems messy right now!

To do: replace table with graph

a_{jm}	a_{jn}	a_{km}	a_{kn}	r_l	r_g	r_m	r_n	ρ_{net}	$\rho_{competition}$	$\rho_{enemies}$	$\frac{\kappa_j}{\kappa_k}$	coexist?
0.001	0.00	0.00	0.001	2	2	0.1	0.1	1.00	1	1.00	1	no
0.015	0.00	0.00	**0.015**	2	2	0.1	0.1	0.95	1	0.13	1	yes
0.015	0.00	0.00	0.015	**0.4**	**0.4**	0.1	0.1	0.99	1	0.13	1	yes- but lot less stable
0.015	0.00	0.00	0.015	2	2	**1**	**1**	0.99	1	0.13	1	yes- but lot less stable

To do: replace table with graph





Bever et al. 2015

fitness
difference

stabilizing niche difference

image: https://www.flickr.com/photos/rejik/
Kabani River, Kerala, India

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Mirjam von Rutte

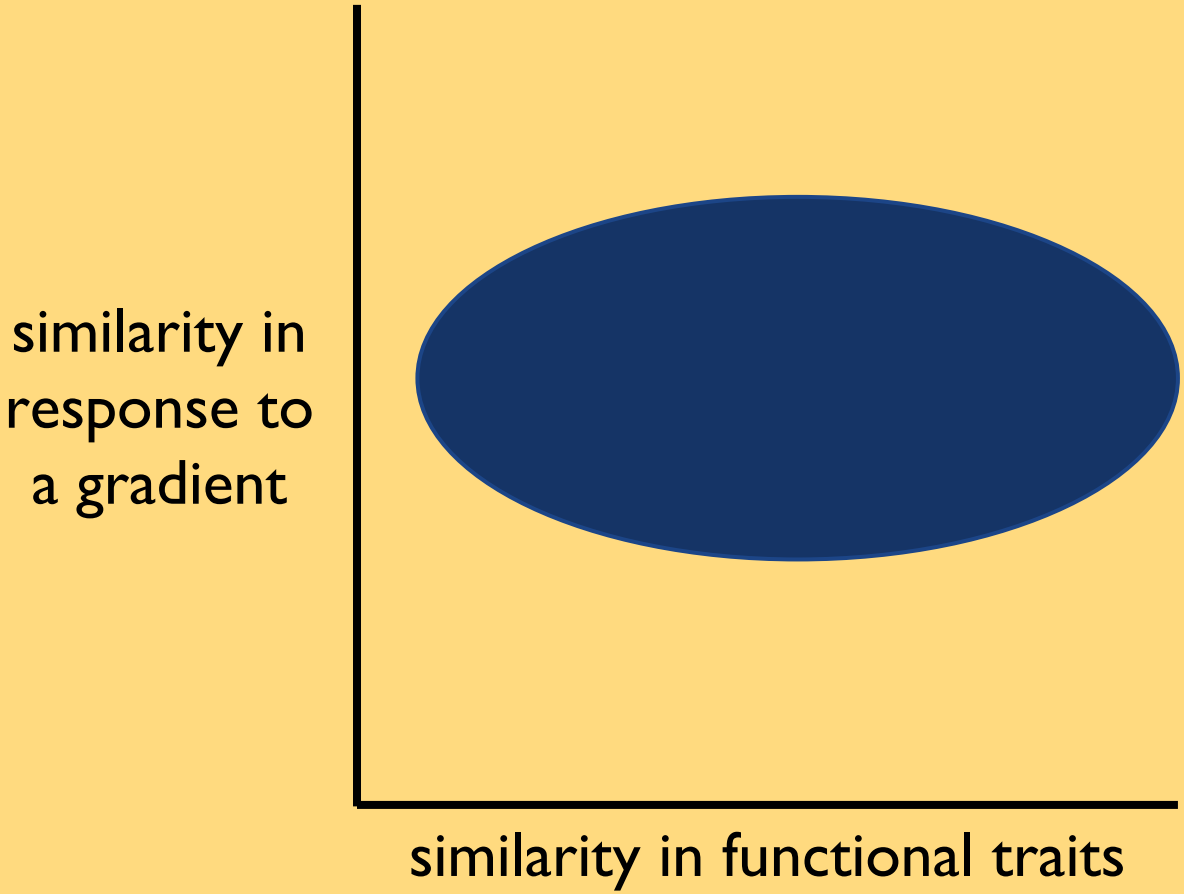
Committee
Jennifer Martiny
Lawren Sack
Felipe Zapata

UCLA
Emily Curd
Zack Gold
Sack Lab
Rachel Meyer

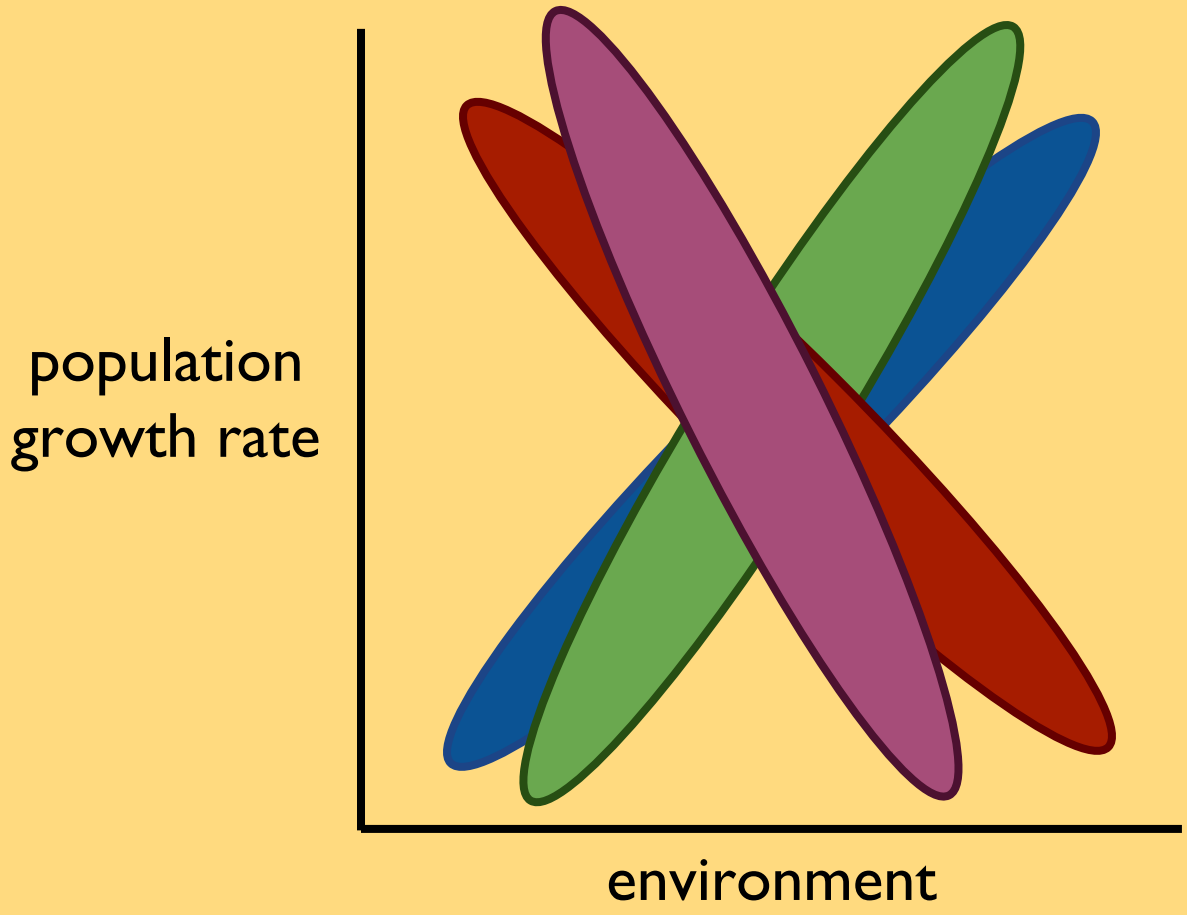
UCLA Undergrads
Clare Camilleri
Angela Chen
Bastien Dehaut
Aoife Galvin
Xin Yi Yan

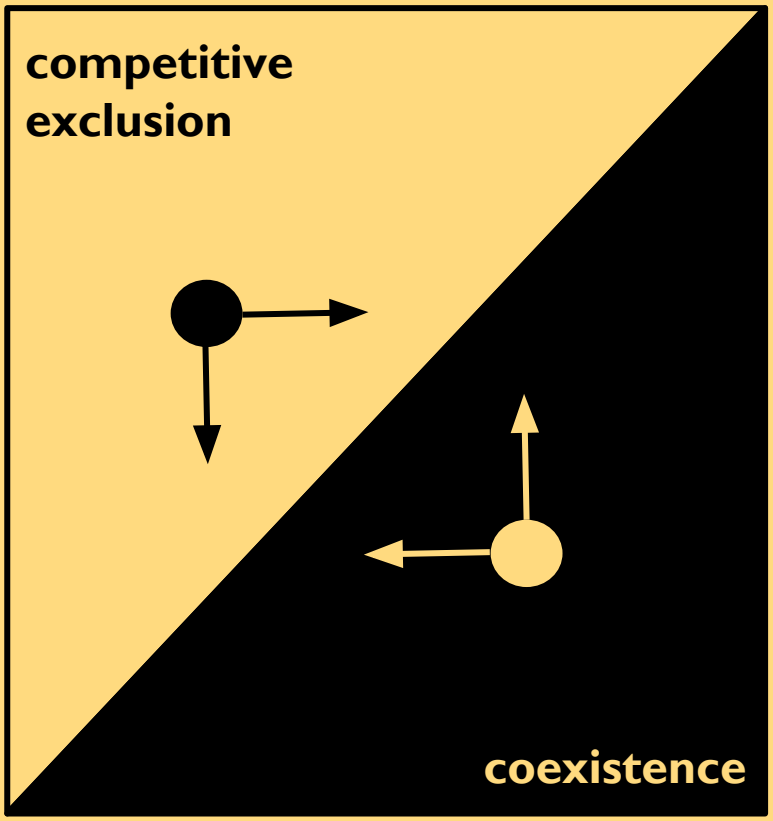
Funding

H_1- Similarity in species' demographic response is unrelated to similarity in traits




population
growth rate
environment


population
growth rate
environment



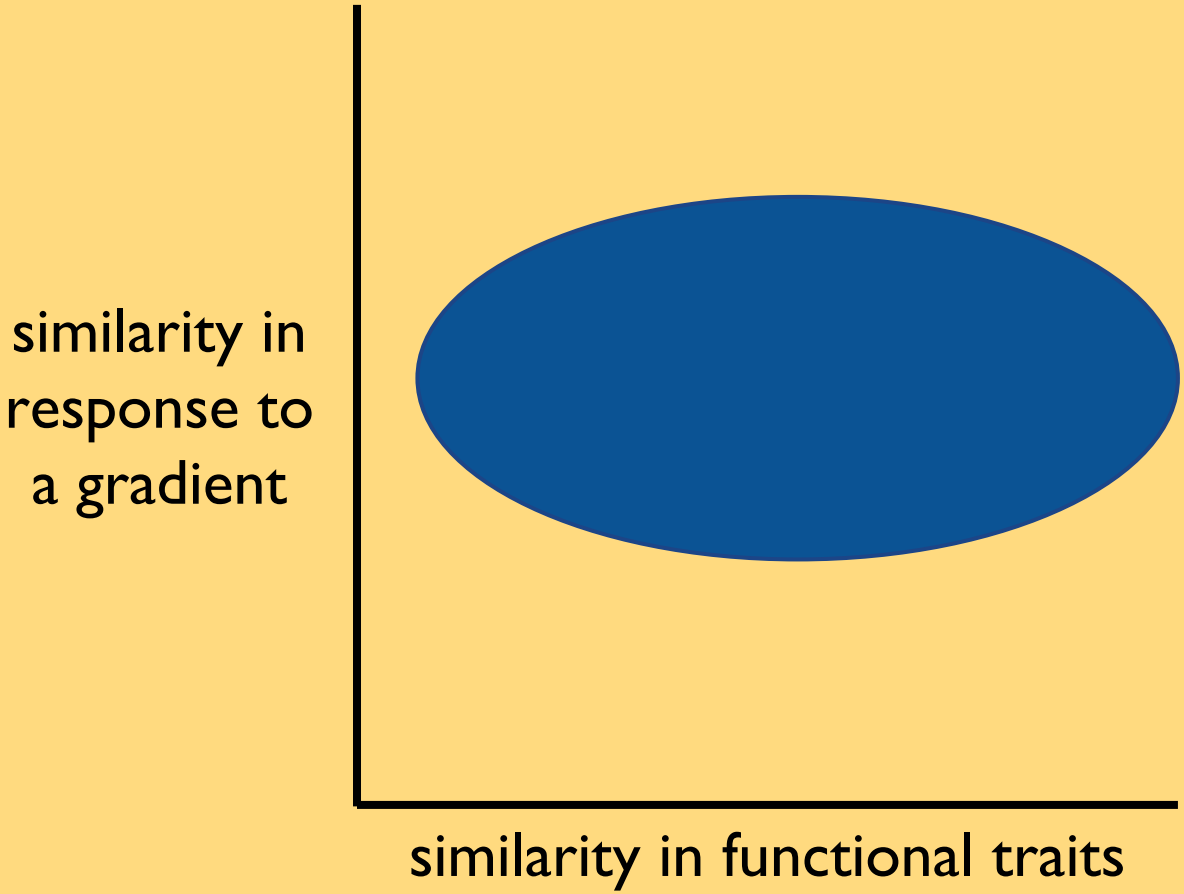
fitness
difference

stabilizing niche difference

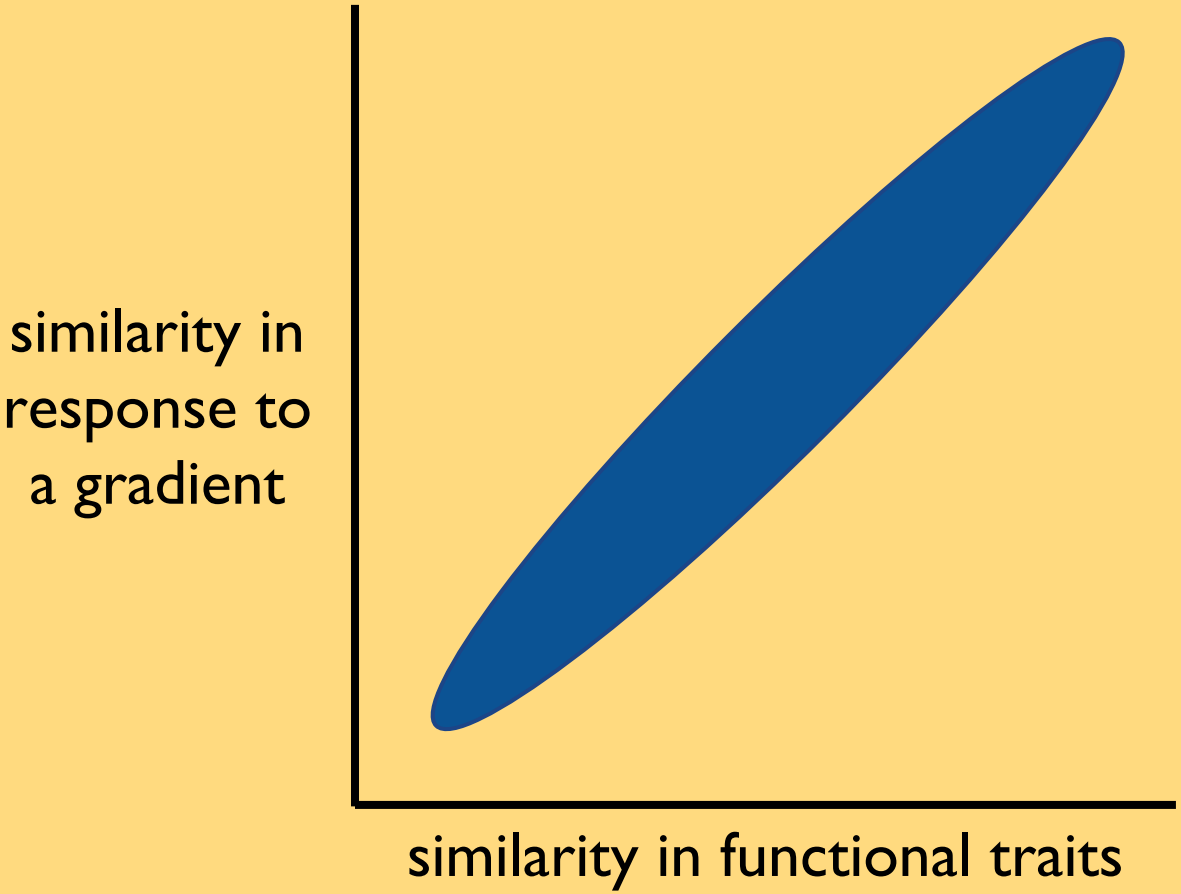
$$\rho = \frac{\Sigma_l \frac{C_{jl} V_l C_{kl}}{r_l^R \alpha_I^R} + \Sigma_m \frac{a_{jm} w a_{km}}{r_m^P \alpha_m^P}}{\sqrt{\left(\Sigma_l \frac{c_{jl}^2 v_l}{r_l^R \alpha_l^R} + \Sigma_l \frac{a_{jm}^2 w}{r_m^P \alpha_m^P}\right)\left(\Sigma_l \frac{c_{kl}^2 v_l}{r_l^R \alpha_l^R} + \Sigma_l \frac{a_{km}^2 w}{r_m^P \alpha_m^P}\right)}}$$

$$\kappa_j = \frac{\sum_l \frac{C_{jl} v_l}{\alpha_l^R} - \sum_m \frac{a_{jm}}{\alpha_m^P} - \mu_j}{\sqrt{\left(\sum_l \frac{c_{jl}^2 v_l}{r_l^R \alpha_l^R} + \sum_m \frac{a_{jm}^2 w}{r_m^P \alpha_m^P}\right)}}$$

H_1- Similarity in species' demographic response is unrelated to similarity in traits



H_2- Similarity in species' demographic response is predicted by similarity in traits



H_3- Species vary in their response to different environmental gradients, and similarity in response is predicted by similarity in different traits