



Why do species cooperate?

**A card-based simulation of the ant-
acacia mutualism**

11/12/14

Biotic Interactions

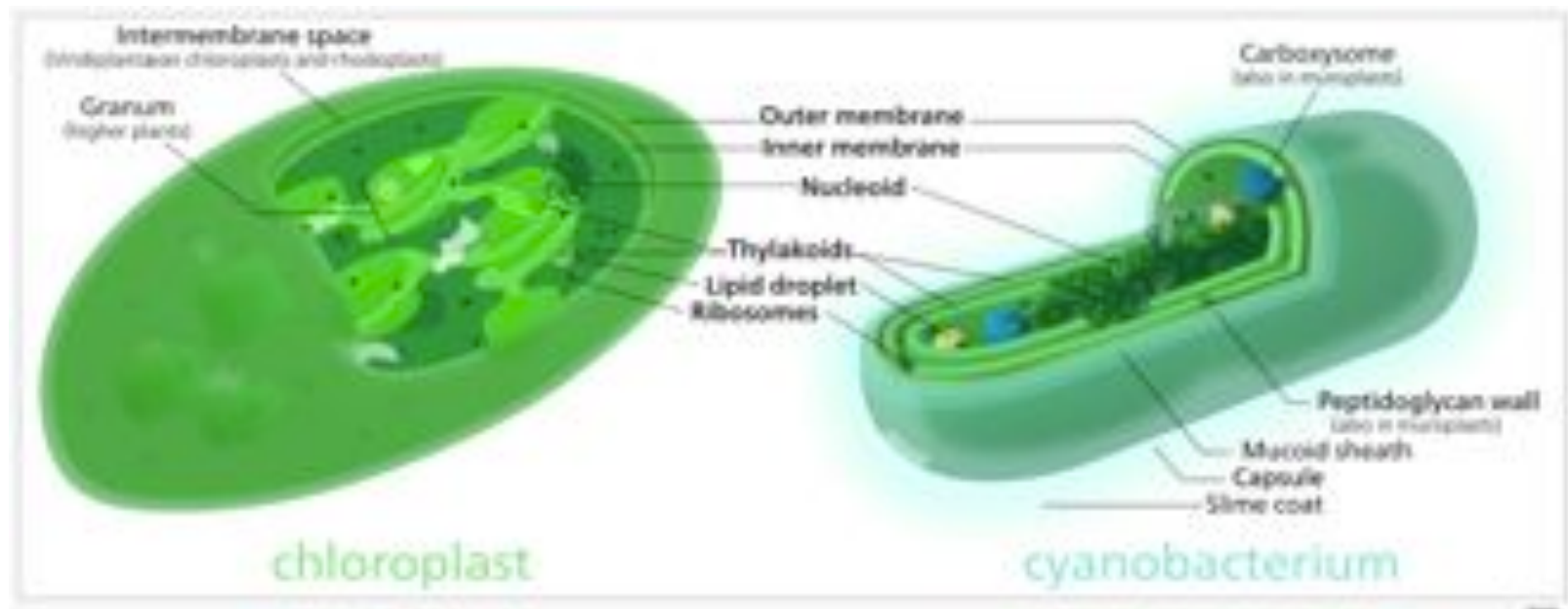
- Competition – both species have reduced fitness in presence of another
- Exploitation/Parasitism – one species benefits at the expense of another
- Commensalism – one species benefits without affecting the other
- Mutualism – each species benefits from the activity of the other



Why are mutualisms cool/important?

- Relevant to all of biological life
- Many practical applications
- Much is still unknown!

“Life did not take over the globe by combat, but by networking” (i.e., by cooperation) – Lynn Margulis and Dorion Sagan



Endosymbiotic theory

Medical Applications- Gut Bacteria

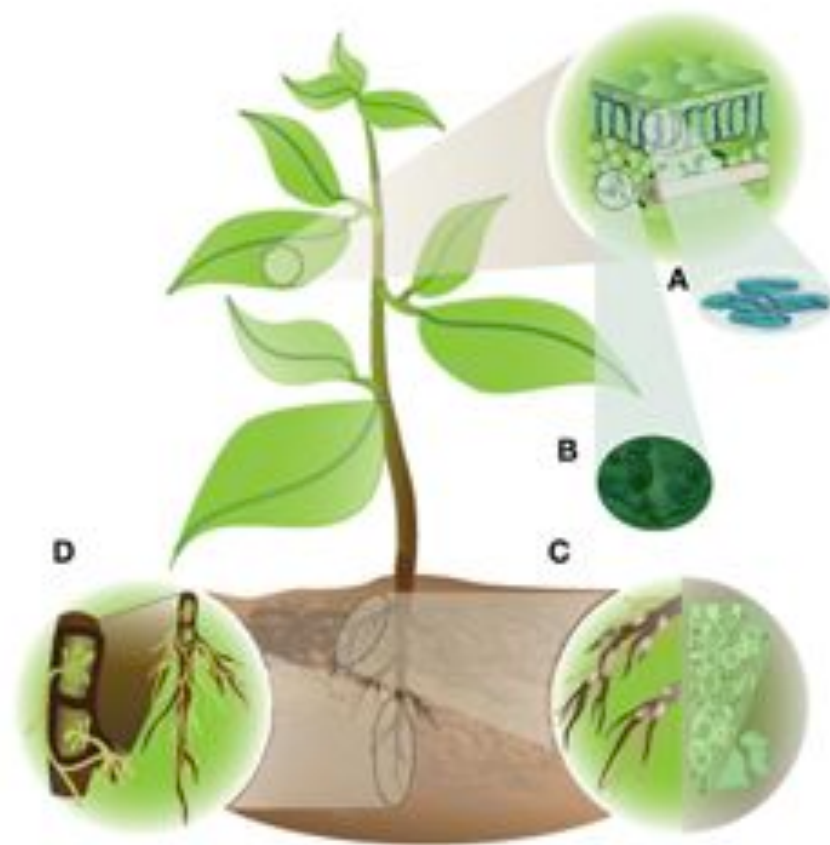
Ongoing research into the effects of probiotics on:

- Immune function and infections
- Vitamin production
- Allergies- lactose intolerance



Agricultural applications - Endophytes

- Stress tolerance
- Enhance growth
- Resistance to pathogens
 - Many produce secondary compounds with herbicidal, antibacterial, or antifungal activity
 - Competition for space in the plant (“barrier effect”)



Cheating

Cheating

- Cleaner fish



Cheating

- Cleaner fish
- Nectar robbers



Cheating

- Cleaner fish
- Nectar robbers
- Plants



How do mutualisms evolve when
natural selection favors cheating?

Whistling thorn tree (*Acacia drepanolobium*)



Ant-Acacia mutualism

- Acacia provides shelter and food for the ants
- Ants provide protection against herbivores (such as elephants)





<https://www.youtube.com/watch?v=Xm2qdxVVRm4>

The co-evolution game

You are the ANTS

- 1) If your ant **EXPLOITS** and the acacia **EXPLOITS**...
Your ant starves! (discard your **EXPLOIT** ant)
- 2) If your ant **EXPLOITS** and the acacia **COOPERATES**...
Reproduce twice (add two **EXPLOIT** ants to your population)
- 3) If your ant **COOPERATES** and the acacia **EXPLOITS**...
Your ant starves! (discard your **COOPERATE** ant)
- 4) If your ant **COOPERATES** and the acacia **COOPERATES**...
Reproduce once (add one **COOPERATE** ant to your population)



Vs.

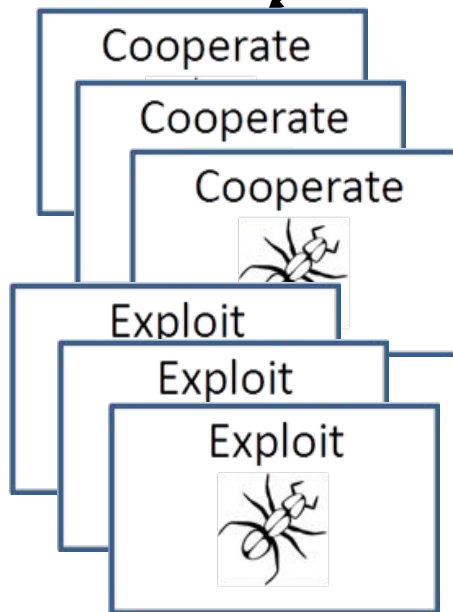
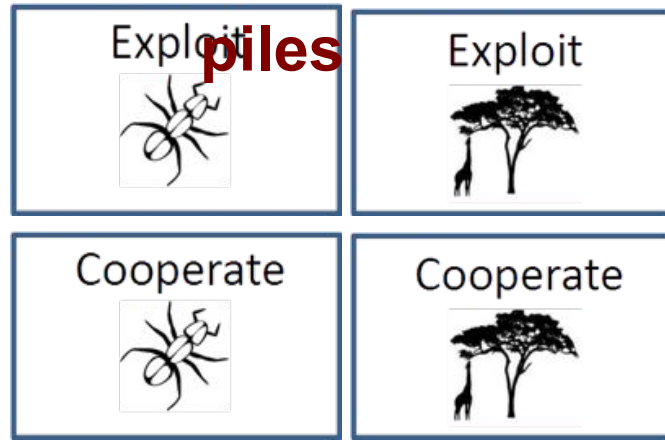
You are the ACACIA

- 1) If your acacia **EXPLOITS** and the ant **EXPLOITS**...
Your acacia is eaten! (discard your **EXPLOIT** ant)
- 2) If your acacia **EXPLOITS** and the ant **COOPERATES**...
Reproduce twice (add two **EXPLOIT** acacia to your population)
- 3) If your acacia **COOPERATES** and the ant **EXPLOITS**...
Your acacia is eaten! (discard your **COOPERATE** ant)
- 4) If your acacia **COOPERATES** and the ant **COOPERATES**...
Reproduce once (add one **COOPERATE** acacia to your population)



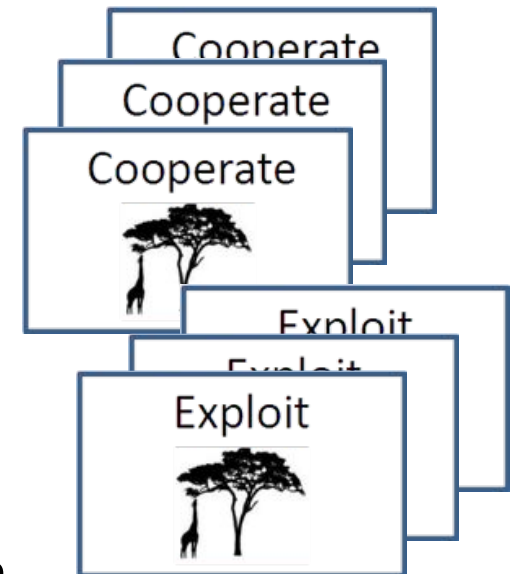
Setting up the game

**Draw
piles**

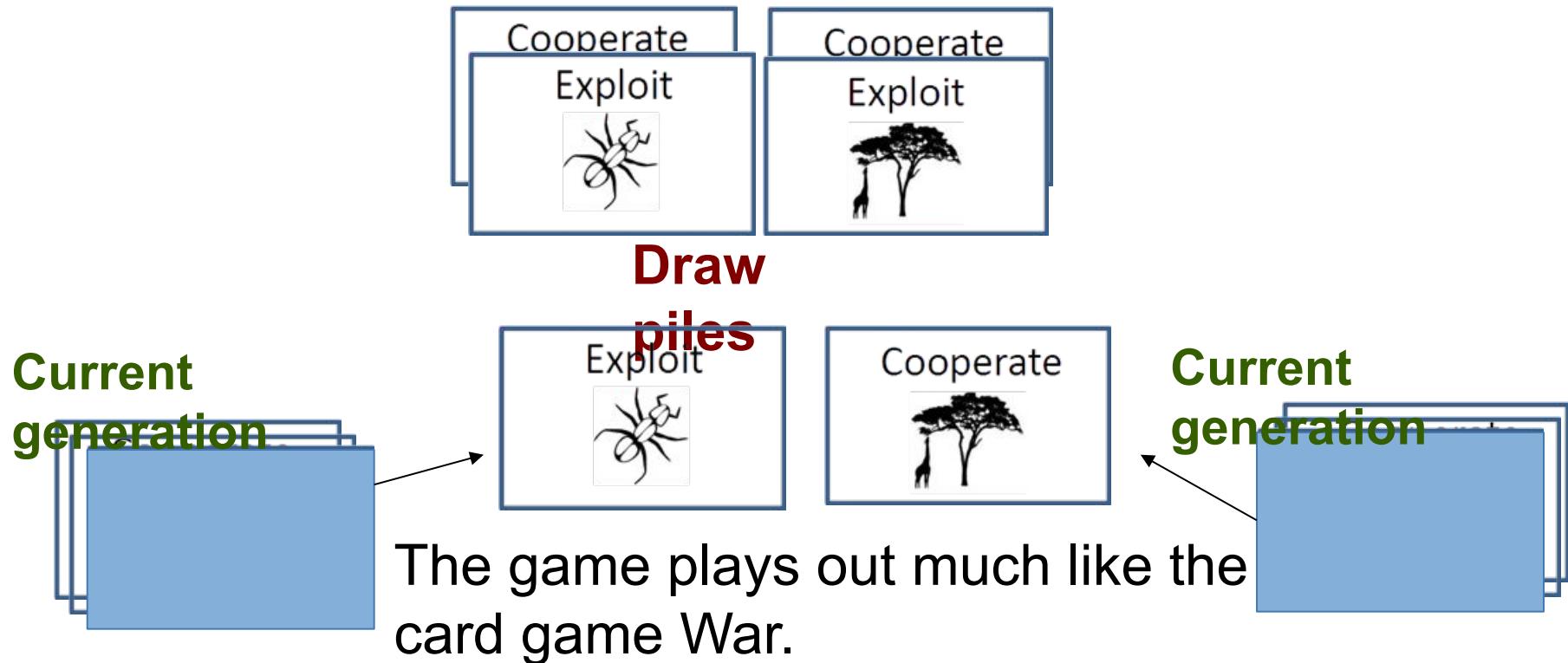


Each player draws their initial populations of **3 Exploit** and **3 Cooperate** cards

Then **shuffles** their cards and places them **face down** in a pile

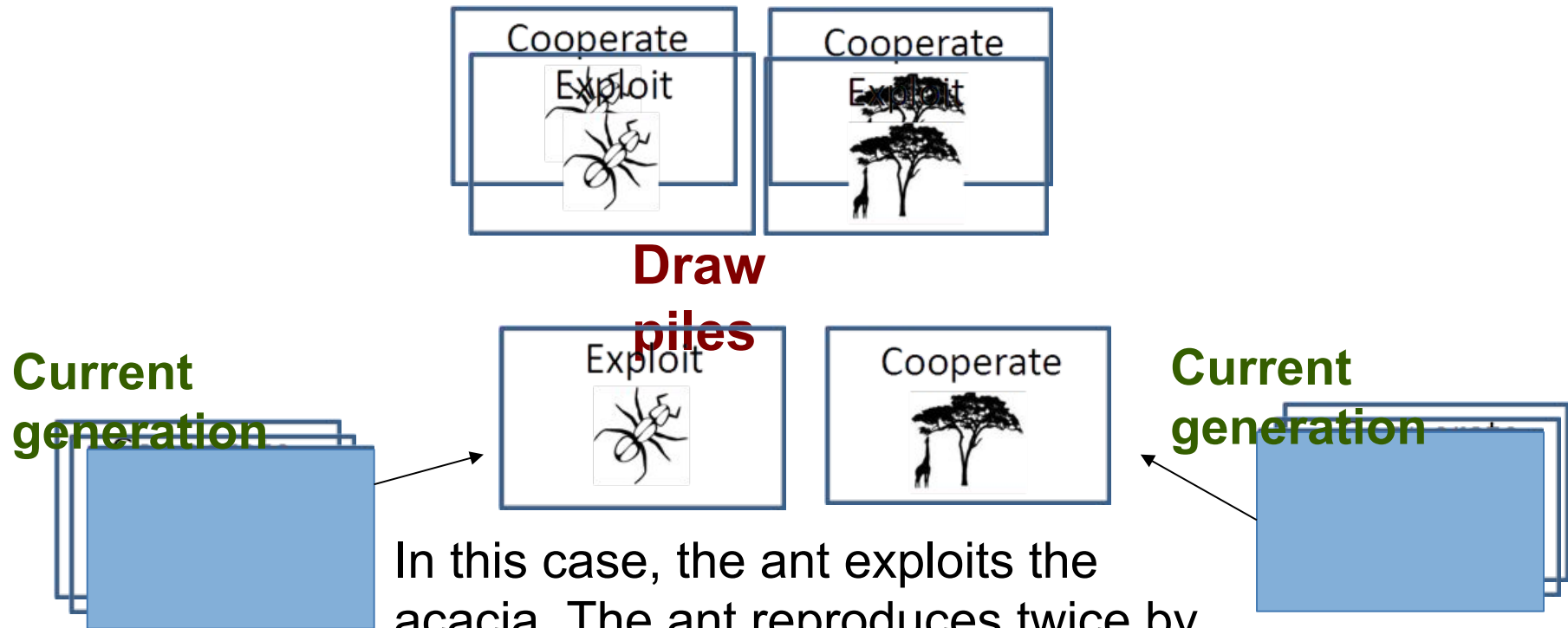


Playing the game



Each player reveals the top card of their deck and plays out the interaction as described on their species cards

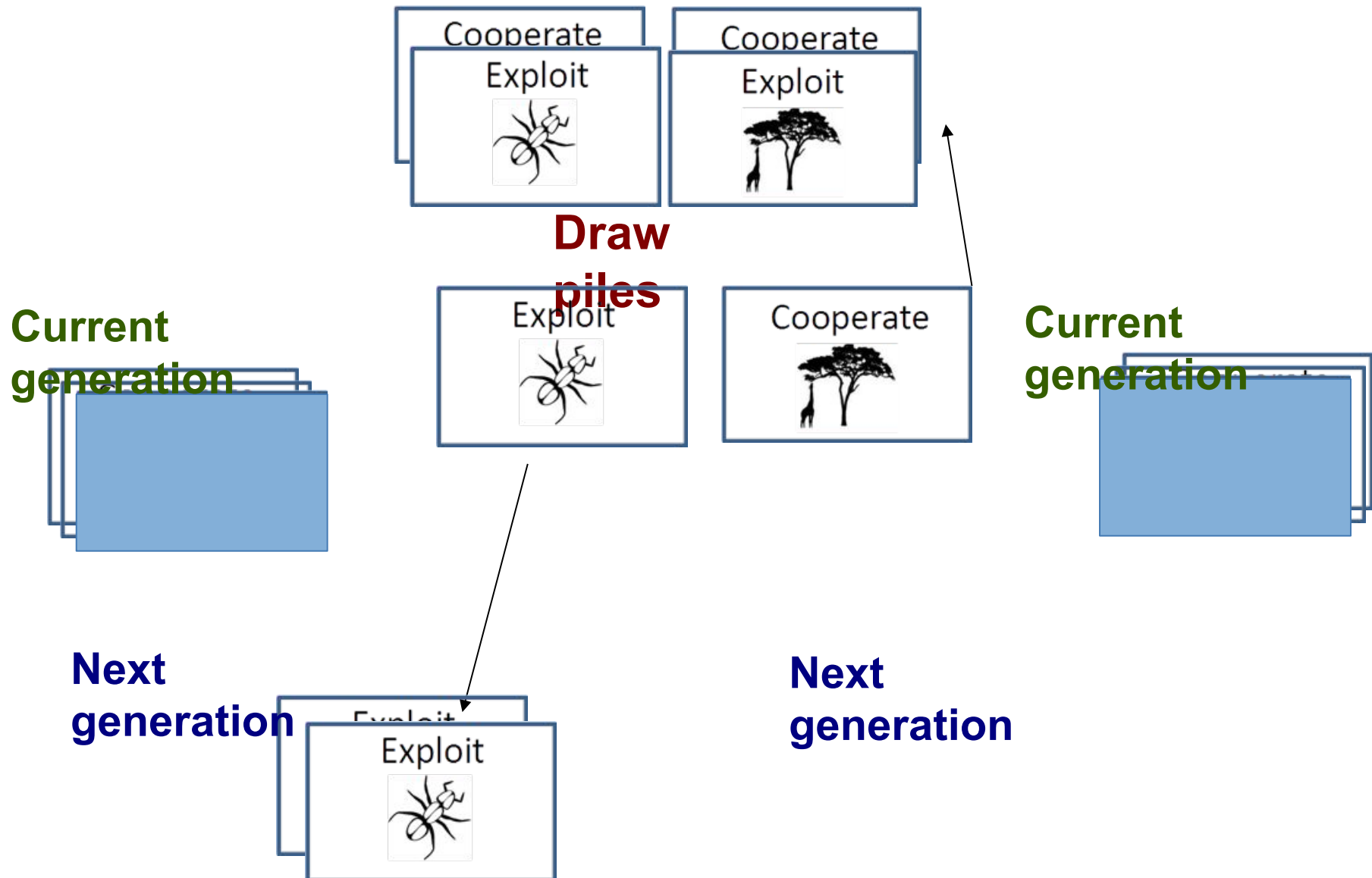
Playing the game



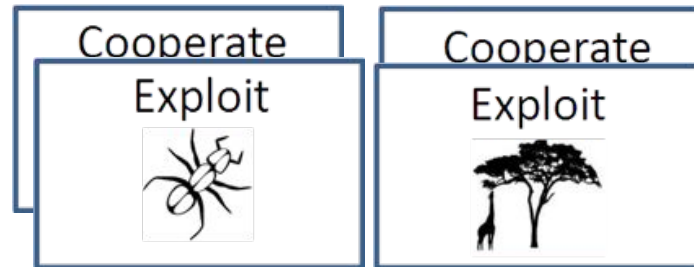
In this case, the ant exploits the acacia. The ant reproduces twice by taking two **Exploit** ants from the draw pile.

The acacia is unprotected and dies and so the played card returns to the draw pile.

Playing the game

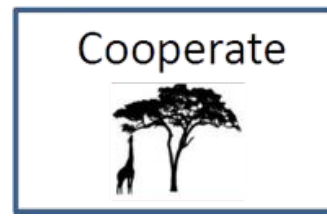
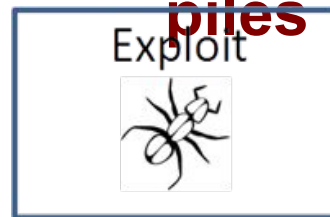


Playing the game

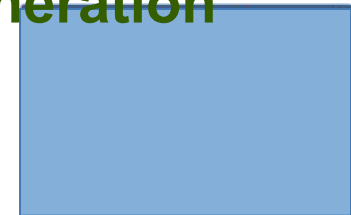


**Draw
piles**

**Current
generation**

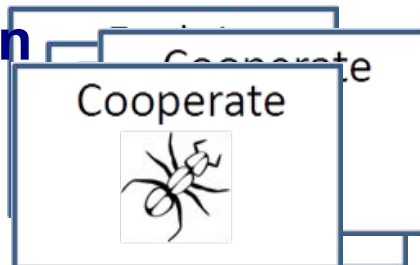


**Current
generation**

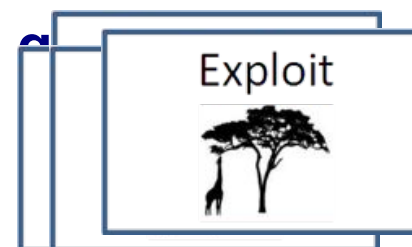


**Play continues until the population
of one or both species runs out**

**Next
generation**



**Next
generation**

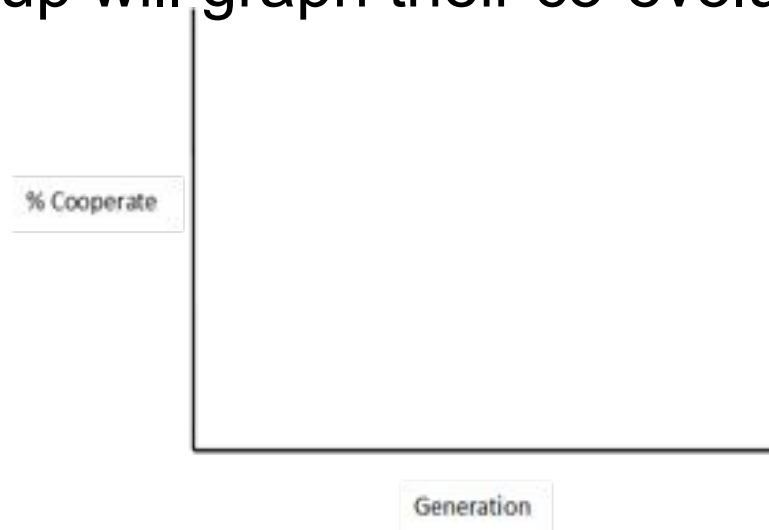


Recording our data

At the end of each generation, the ant player and the acacia player both tally the number of **Cooperate** and **Exploit** individuals in their data sheets:

Generation	# Cooperate cards	# Exploit cards	Total cards	% Cooperate	% Exploit
1					
2					
3					
4					
5					

And each group will graph their co-evolution results.




4 Ant species

- *Crematogaster mimosae*
 - *C. sjostedti*
 - *C. nigriceps*
 - *Tetraponera penzigi*
- Aggressive defender; relies on tree's resources
 - Less-aggressive defender, nests in stem cavities made by beetles
 - Good defender, but prunes buds
 - Intermediate protector, but does not feed at extrafloral nectaries

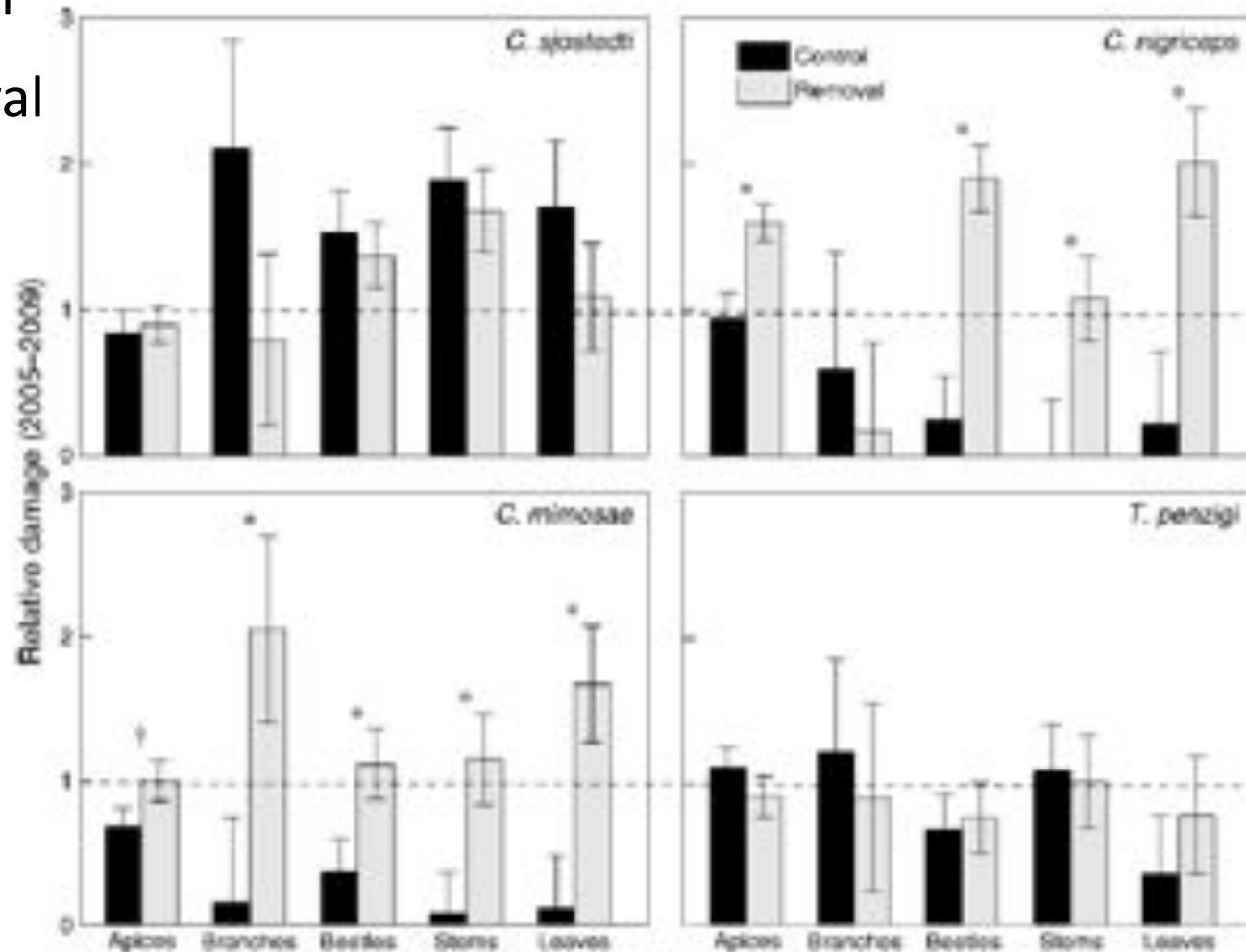
4 Ant species

Occupies 52% of
trees under normal
conditions

- *Crematogaster mimosae*  • Aggressive defender; relies on tree's resources
- *C. sjostedti* • Less-aggressive defender, nests in stem cavities made by beetles
- *C. nigriceps* • Good defender, but prunes buds
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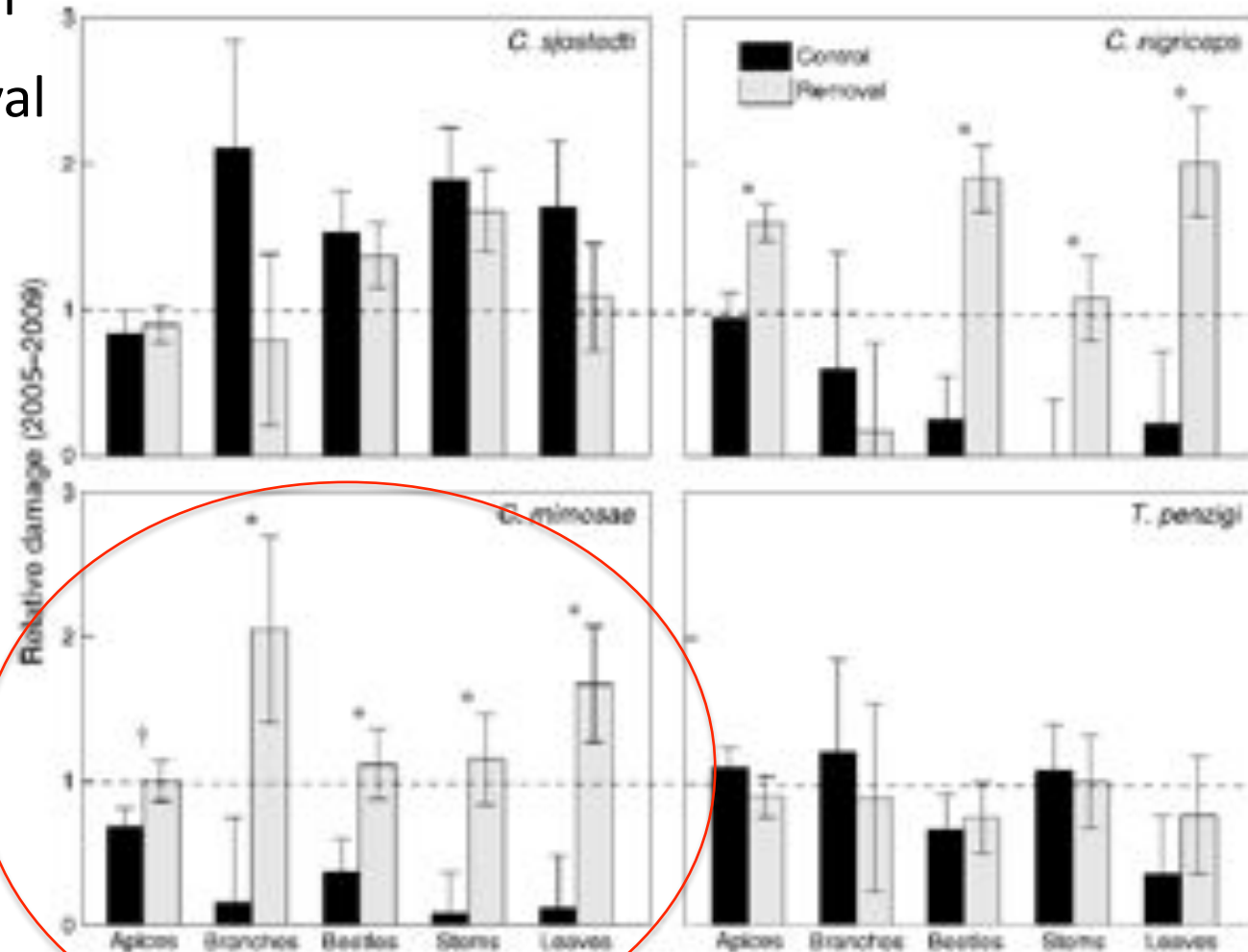
Ant removal experiment

Control
Removal



Ant removal experiment

■ Control
■ Removal

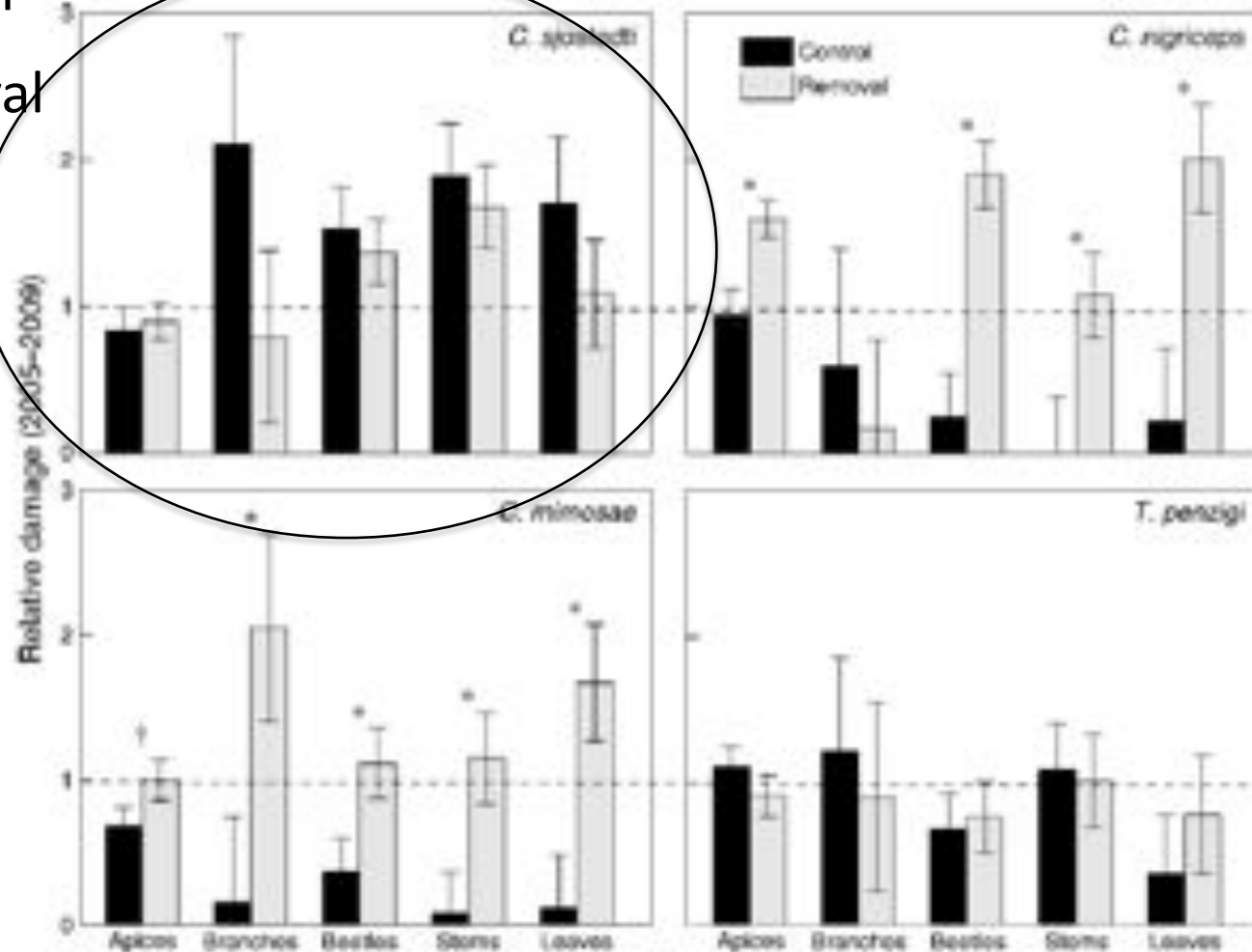


Cm

Ant removal experiment

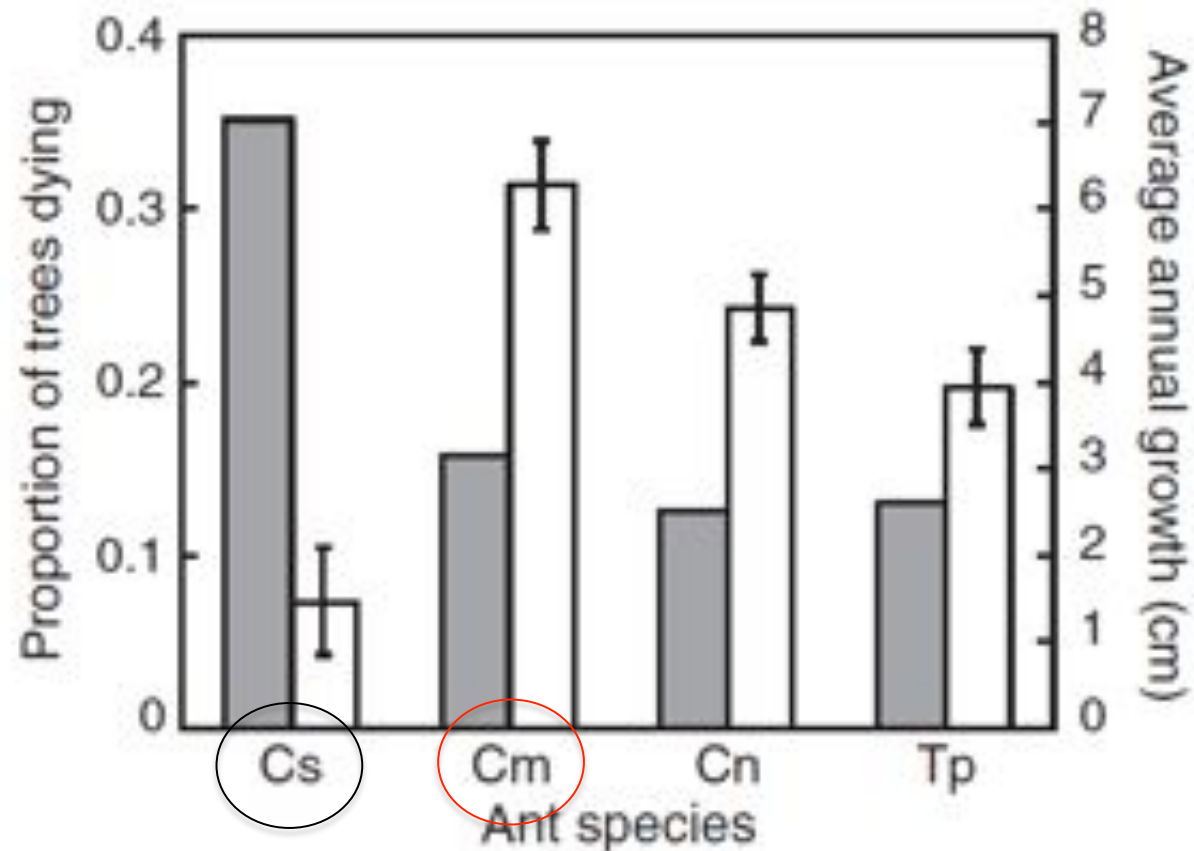
■ Control
■ Removal

Cs



Long-term experiment

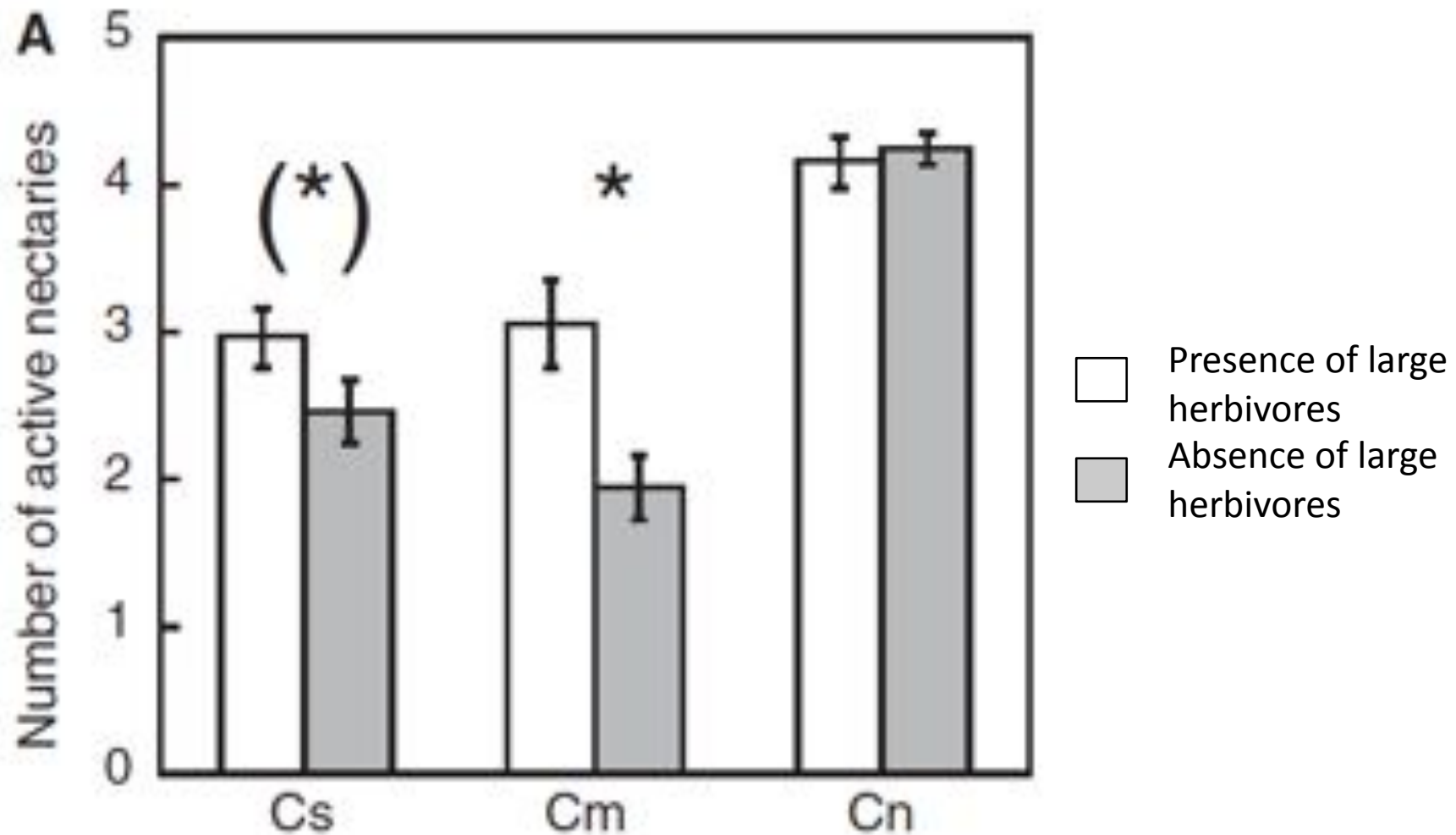
- Proportion of trees dying
- Average annual growth



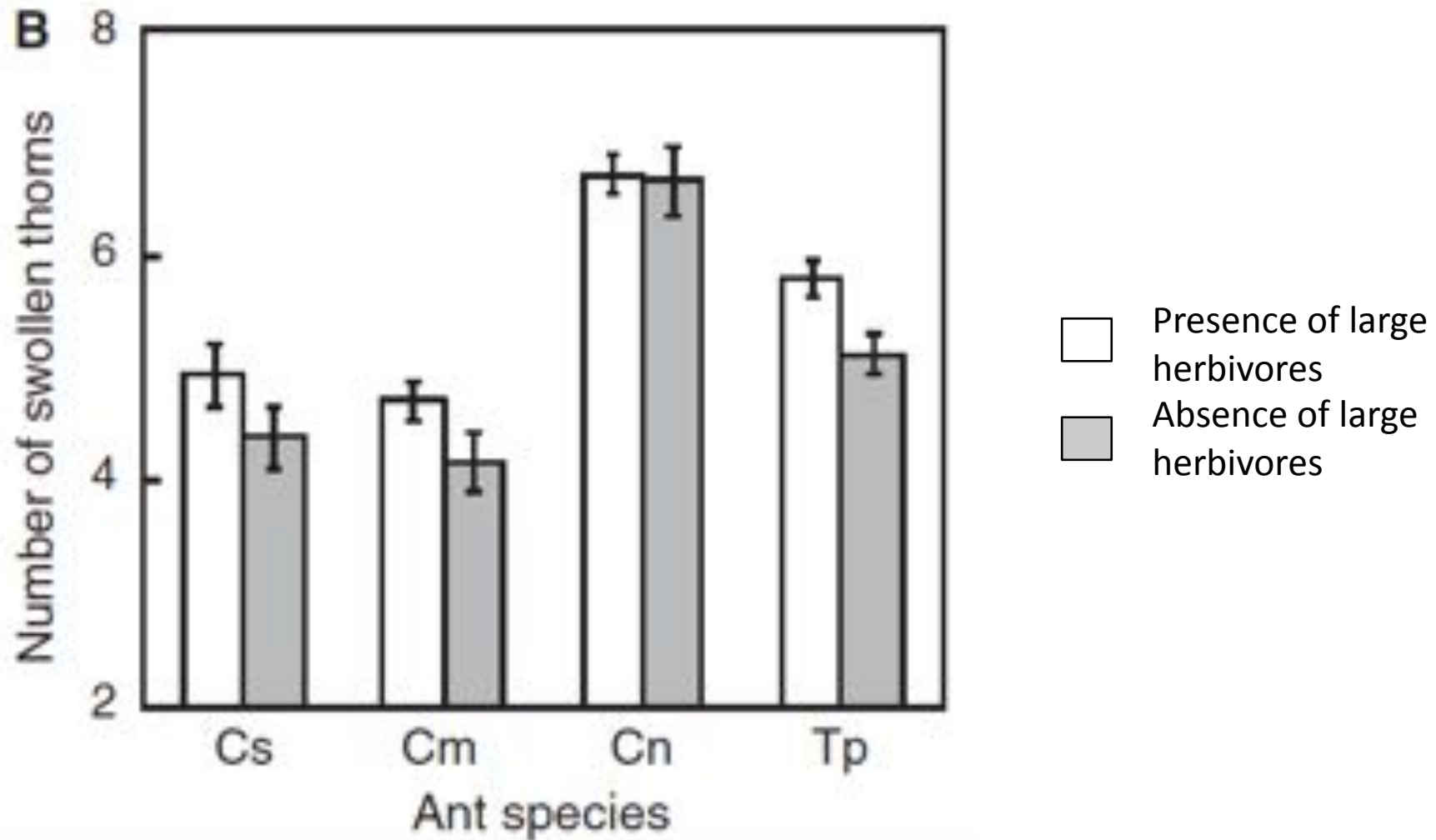
Long-term exclusion experiment

- 10 years
- Replicate blocks, half of which excluded large herbivores with the presence of electrified fences
- What do you think likely occurred in the herbivore exclusion treatments?

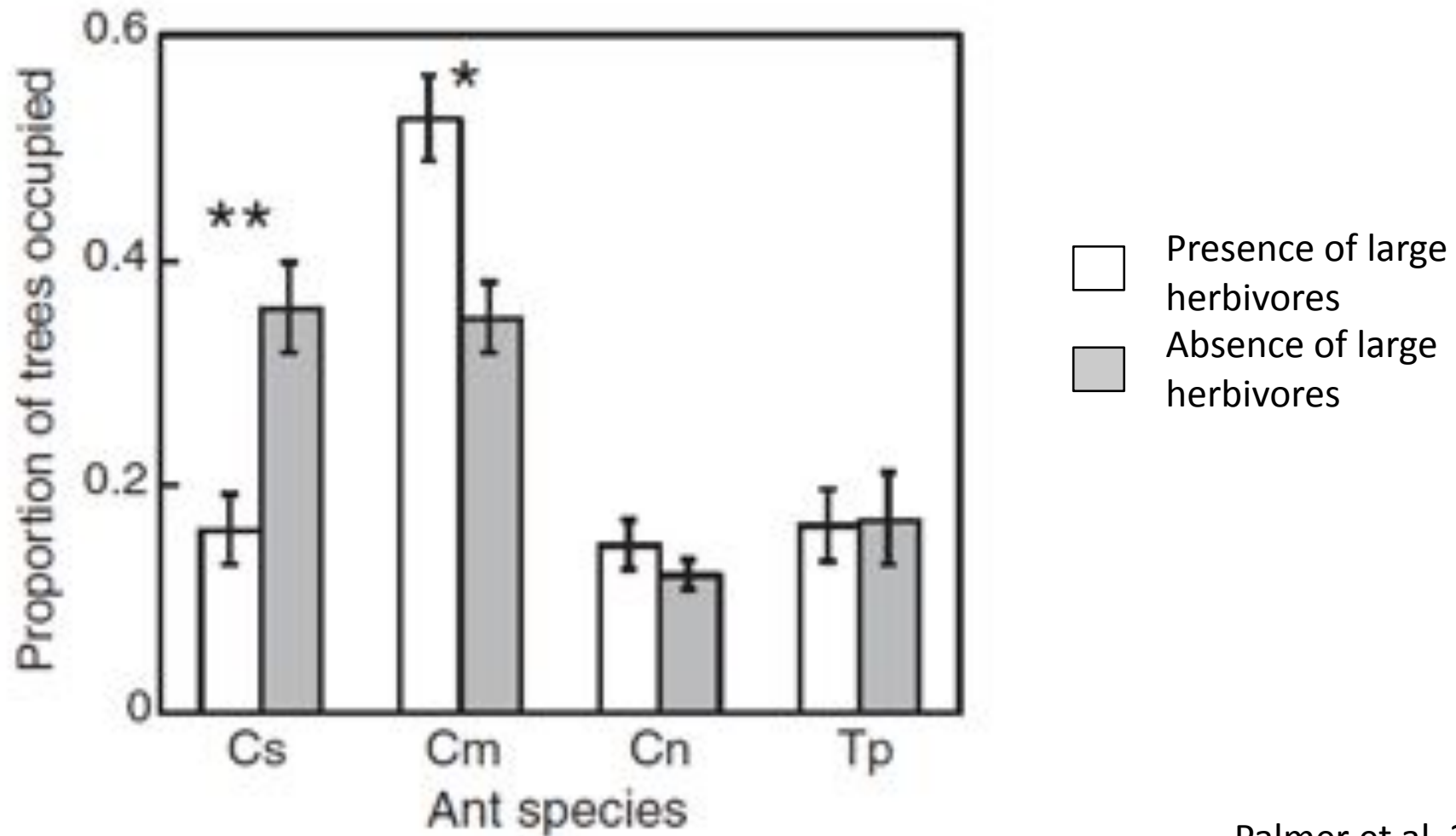
Acacias produced fewer nectaries



And fewer domatia

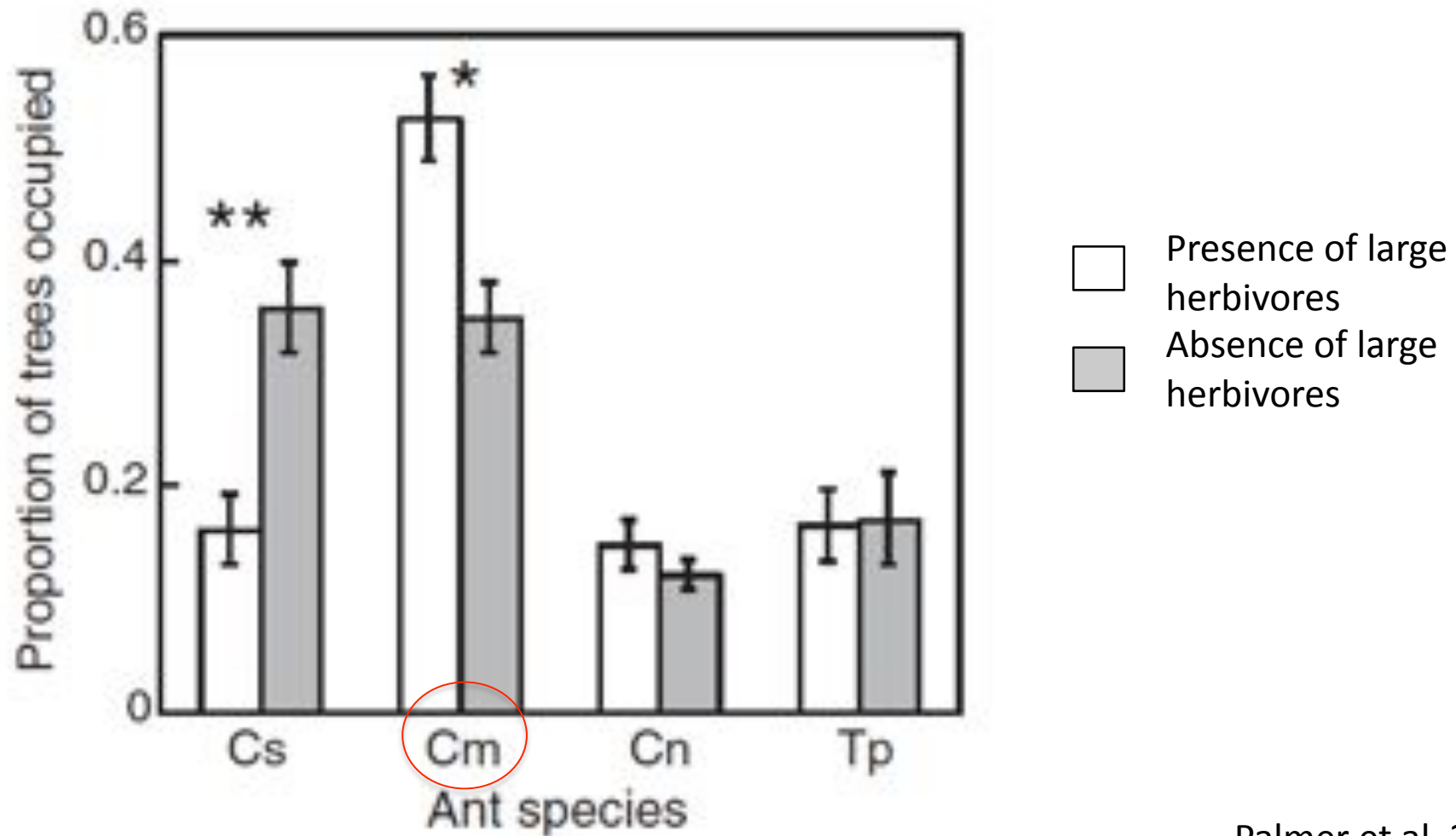


Change in ant species community



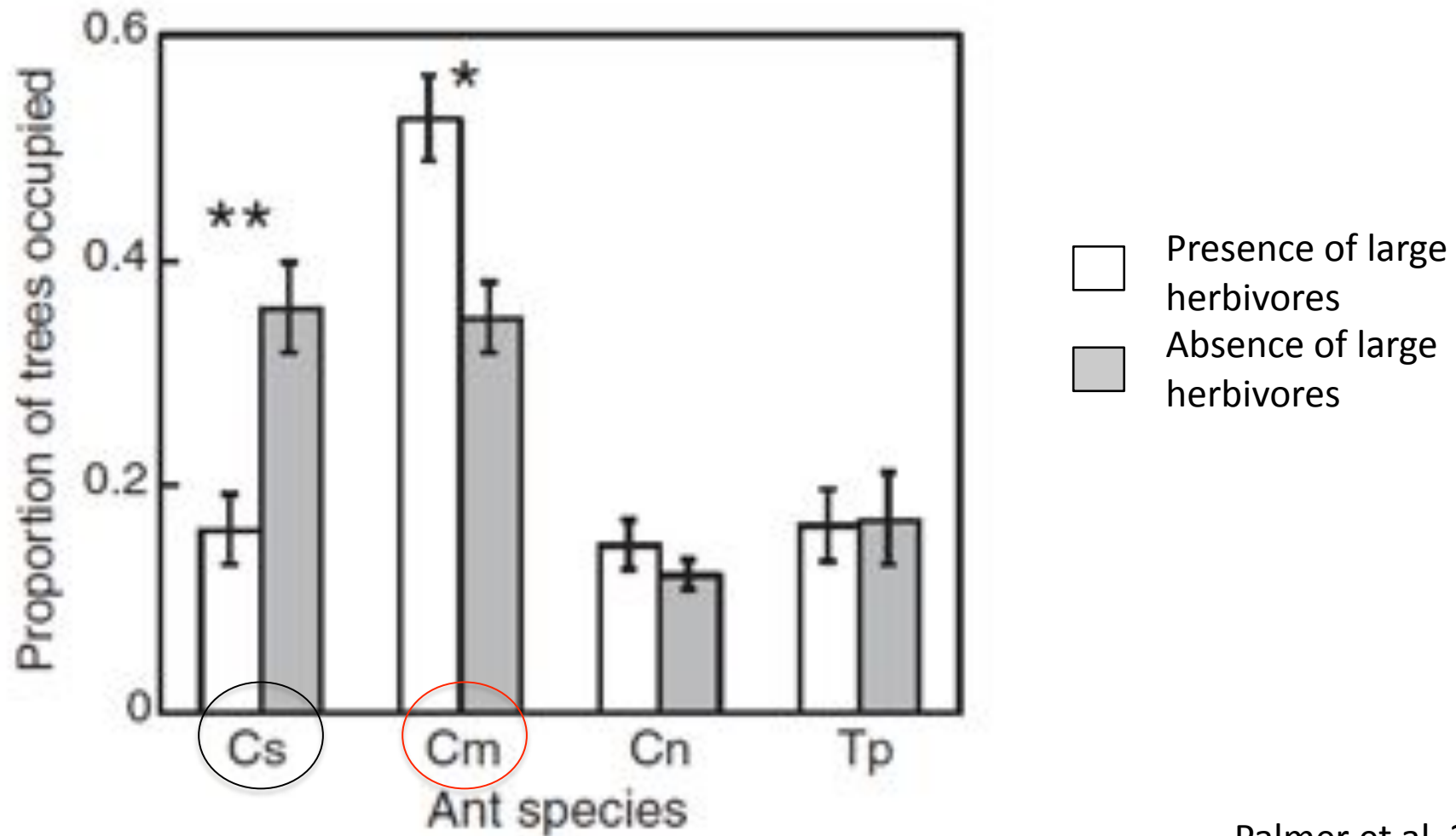
Palmer et al. 2008

Change in ant species community



Palmer et al. 2008

Change in ant species community



The removal of large predators
shifts the balance of symbionts
from mutualists to antagonists!