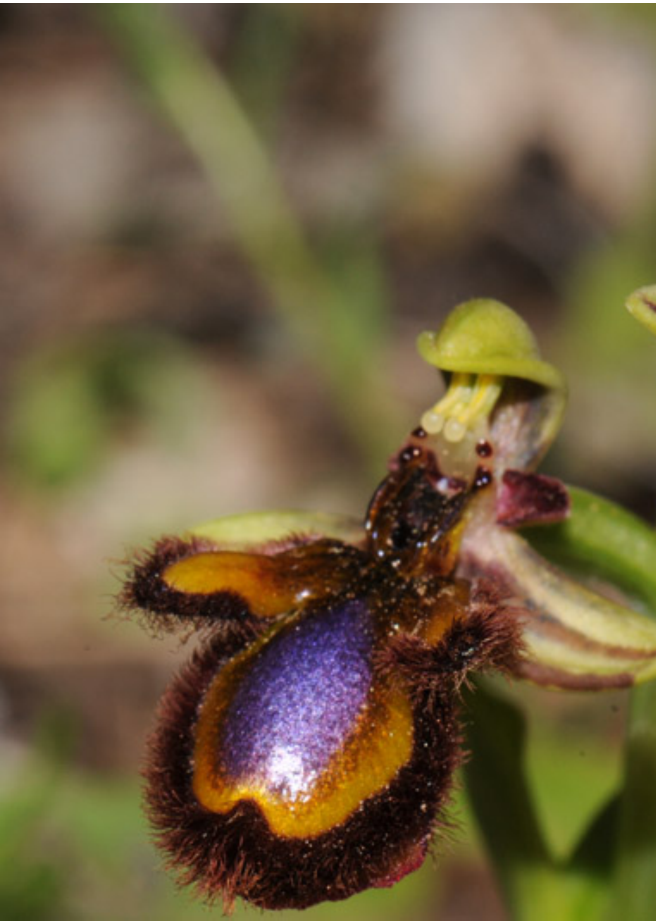
Plant of the day!



Ophrys speculum

Ophrys in Europe, 9 genera in Australia

Sexual deception where the flower attracts male pollinators by mimicking a female of the same species (e.g. scent, colour, “hair”)

Typically, pollination by sexual deception is highly specific and usually only involves one insect species

1/3 of the ~25k species of orchids are pollinated by deceit, giving no reward (only 400 are sexually deceptive)

What is co-evolution?

What is co-evolution?

Why is it important?

Examples

What is co-evolution?

Co-evolution: occurs when two (or more) ecologically interacting species exert reciprocal selection pressures on one another and the response is inherited
-trait centered

What is co-evolution?

Species A evolves an adaptation in response to species B

Species B evolves in response to the adaptation of species A

This isn’t co-evolution

Species A has some trait unrelated to species B

Species B evolves in response to that trait in species A

Important coevolved interactions in plants

Fabaceae host Rhizobium (bacteria) in their root nodules

They take up N_2 out of the air and convert it to a form of nitrogen that is usable to the host plant

This process is called nitrogen fixation

Mutualism - Rhizobium supply the usable nitrogen and plants give organic acids as an energy source

Why don't the bacteria cheat?

What is co-evolution?

Co-evolved interactions are important

Mitochondria (Eukaryotes and bacteria-cellular energy)
Chloroplasts (Eukaryotes and cyanobacteria-photosynthesis)
Mycorrhizae (Plants and fungi-nutrition in plants)
Rhizobia (Plants and bacteria-nitrogen fixation in soil)
Pollination (Plants and animals-sexual reproduction in plants)
Seed dispersal (Plants and animals-sexual reproduction in plants)
Parasitism (Hosts and parasites)
Competitors
Predators and prey

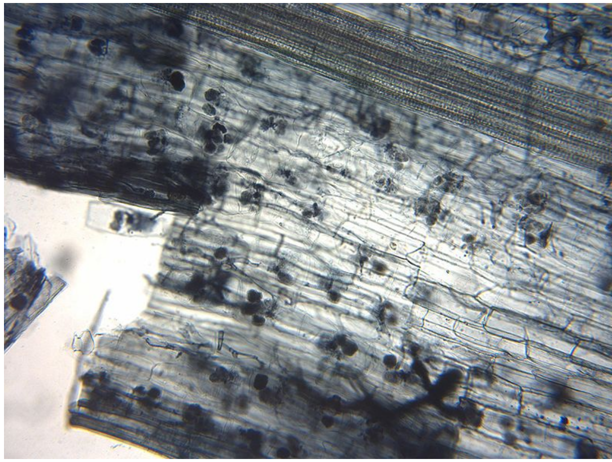
Complex organisms require coevolved interactions to survive and reproduce

Species rich ecosystems are dependant on coevolved interactions (especially mutualisms)

Important coevolved interactions in plants

A **mycorrhiza** is a symbiotic (mutualistic but can be pathogenic) association between a fungus and the roots of a plant.

The fungus colonizes the host plants' roots either intracellularly as in arbuscular mycorrhizal fungi (AMF), or extracellularly as in ectomycorrhizal fungi.



root cells containing hyphae

The fungus gets carbohydrates

The plant gets higher absorptive capacity for water and mineral nutrients (due to comparatively large surface area of mycelium:root ratio).

Red Queen hypothesis

They were running hand in hand, and the Queen went so fast that it was all she could do to keep up with her: and still the Queen kept crying 'Faster! Faster!' but Alice felt she could not go faster, though she had not breath left to say so. The most curious part of the thing was, that the trees and the other things round them never changed their places at all: however fast they went, they never seemed to pass anything…

'In our country,' said Alice, still panting a little, 'you'd generally get to somewhere else – if you ran very fast for a long time, as we've been doing.' 'A slow sort of country!' said the Queen. '*Now, here, you see, it takes all the running you can do, to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that!*'

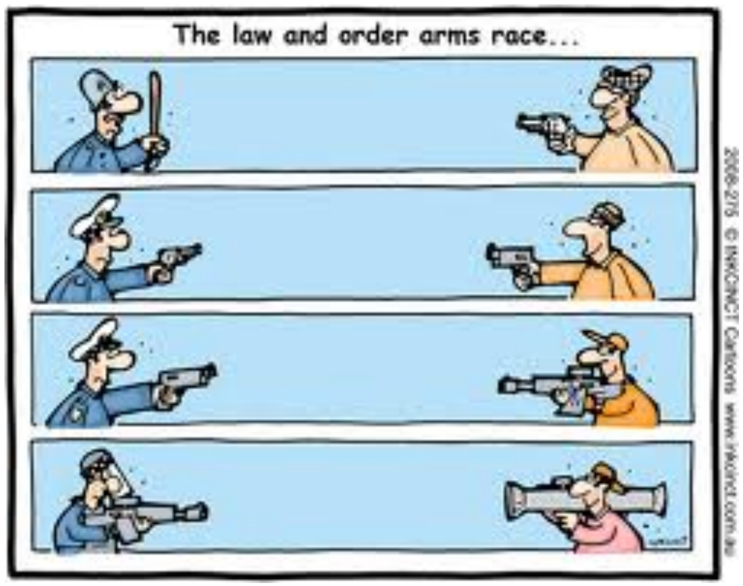
Lewis Carroll's *Through the Looking Glass*

Red Queen hypothesis

The continual evolutionary change by a species that is necessary to retain its place in an ecosystem because of ongoing co-evolution by other species

Arms race

Arms race: The escalating and reciprocal coevolution between the offensive ability of a predator/parasite and the defensive capability of its prey/host



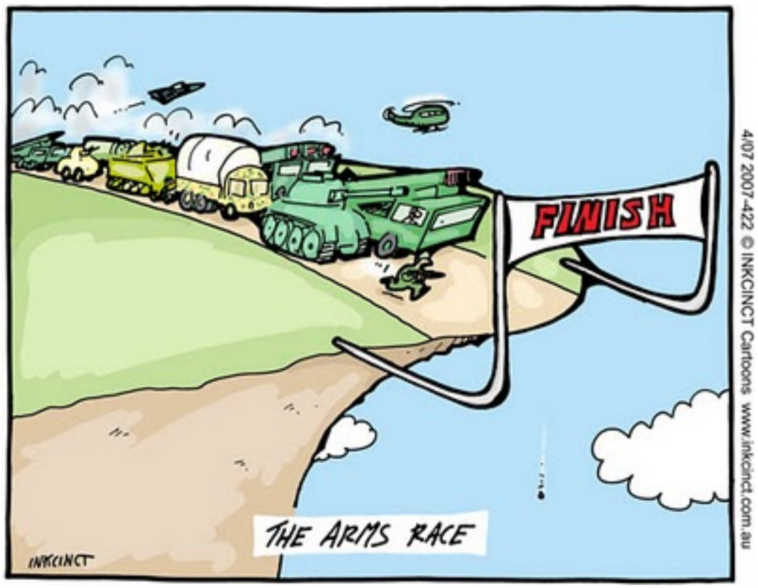
Arms race

<u>THINK – PAIR - SHARE</u>

How could you tell if an evolutionary arms race had occurred? What would be the signal and how would you detect it?

Arms race

Darwinian extinction-a decline in mean fitness that occurs as a result of adaptation by natural selection which reduces the size of the population until it becomes inviable



example: increase in individual fitness for predator attack rates can lead to increased extinction risk for predator and prey

Types of coevolution

Specific: one species interacts closely with another. Changes in one species induce adaptive changes in the other, and vice-versa

Diffuse: selection imposed reciprocally by one interacting species on another is dependent on the presence or absence of other species

Types of coevolution

Coevolution takes multiple forms and generates a diversity of ecological outcomes

Antagonistic interaction	⟷	Mutualisms
Plant herbivore interactions		Plant pollinator interactions
Plant pathogen interactions		
Competition		

Antagonistic interactions: plant herbivore interactions

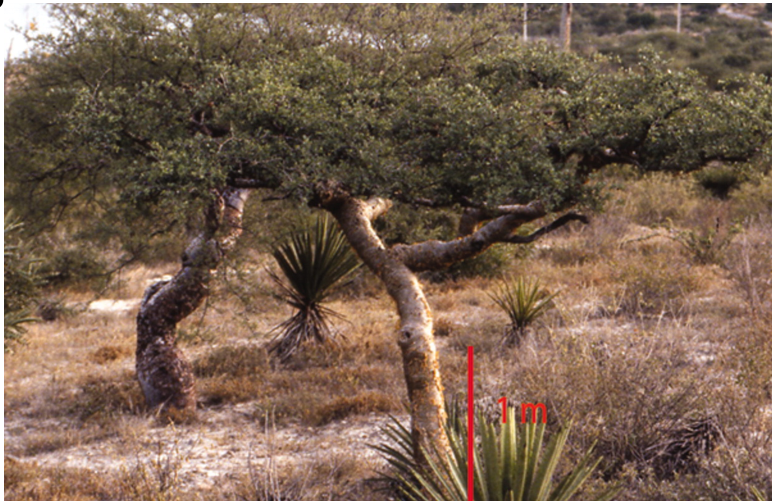
Plant-herbivore coevolution

- Plants produce toxic "secondary" chemicals (not directly involved in growth and reproduction such as terpenoids, alkaloids and phenols) that reduce herbivory

- Some herbivores have evolved to detoxify the toxic chemicals.
  - herbivores may specialize on the hosts whose defenses they have overcome
  - plants may evolve new defenses, and the cycle continues (Red Queen)
  - is there evidence of chemical escalation in plants?

Antagonistic interactions: plant herbivore interactions

Bursera spp. produce an array of terpenes



-toxic or repellent to insect herbivores

-decrease the survival and growth of their specialized herbivores, genus Blepharida

-some species have pressurized resin canals and can entomb their attackers

Antagonistic interactions: plant herbivore interactions

Squirt defense in Bursera

Becerra J X et al. PNAS 2009;106:18062-18066

Antagonistic interactions: plant herbivore interactions

Did the number of new secondary chemicals in the genus increase over time?

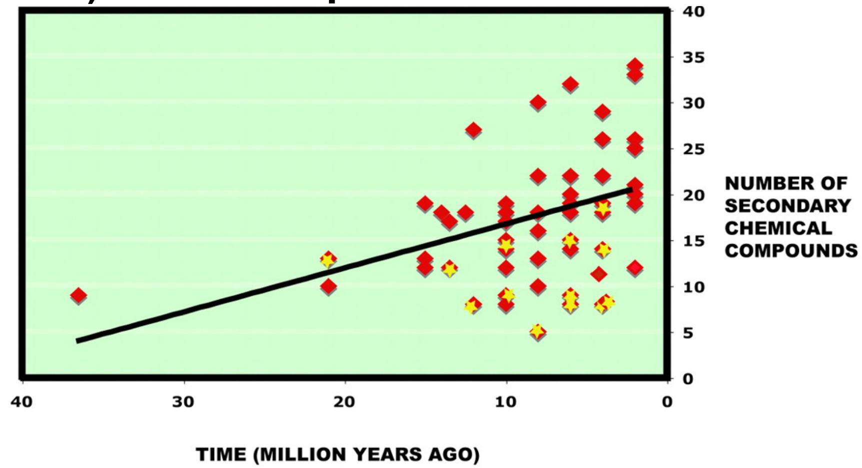
Is the increase lower in those species with mechanical means of defense?

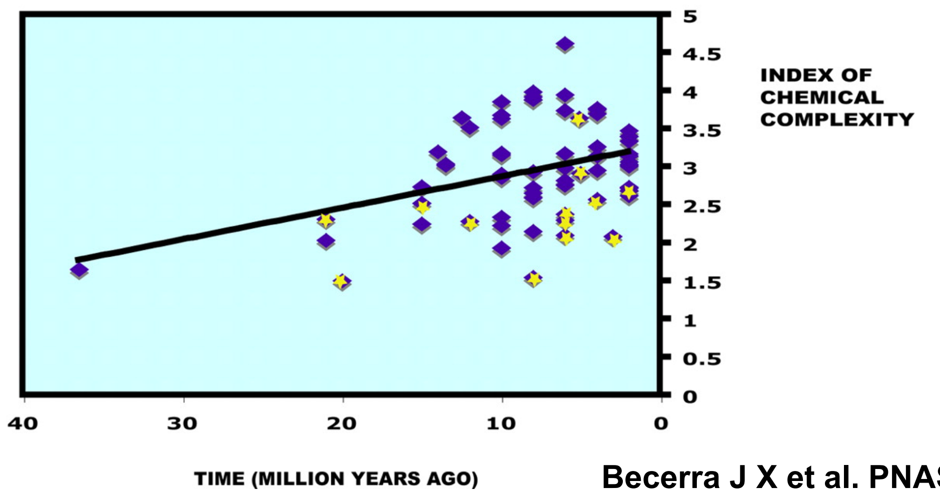
Examined the number and relative concentration of chemical compounds in 70 Bursera species and used a phylogeny to determine if the number and complexity have increased over time

Becerra J X et al. PNAS 2009;106:18062-18066

Antagonistic interactions: plant herbivore interactions

Diversity of secondary compounds (Upper) and complexity of chemical mixtures (Lower) of extant species of Bursera over time.





Becerra J X et al. PNAS 2009;106:18062-18066

Antagonistic interactions: host and parasite systems

- Parasites are constantly evolving into new forms to avoid host resistance

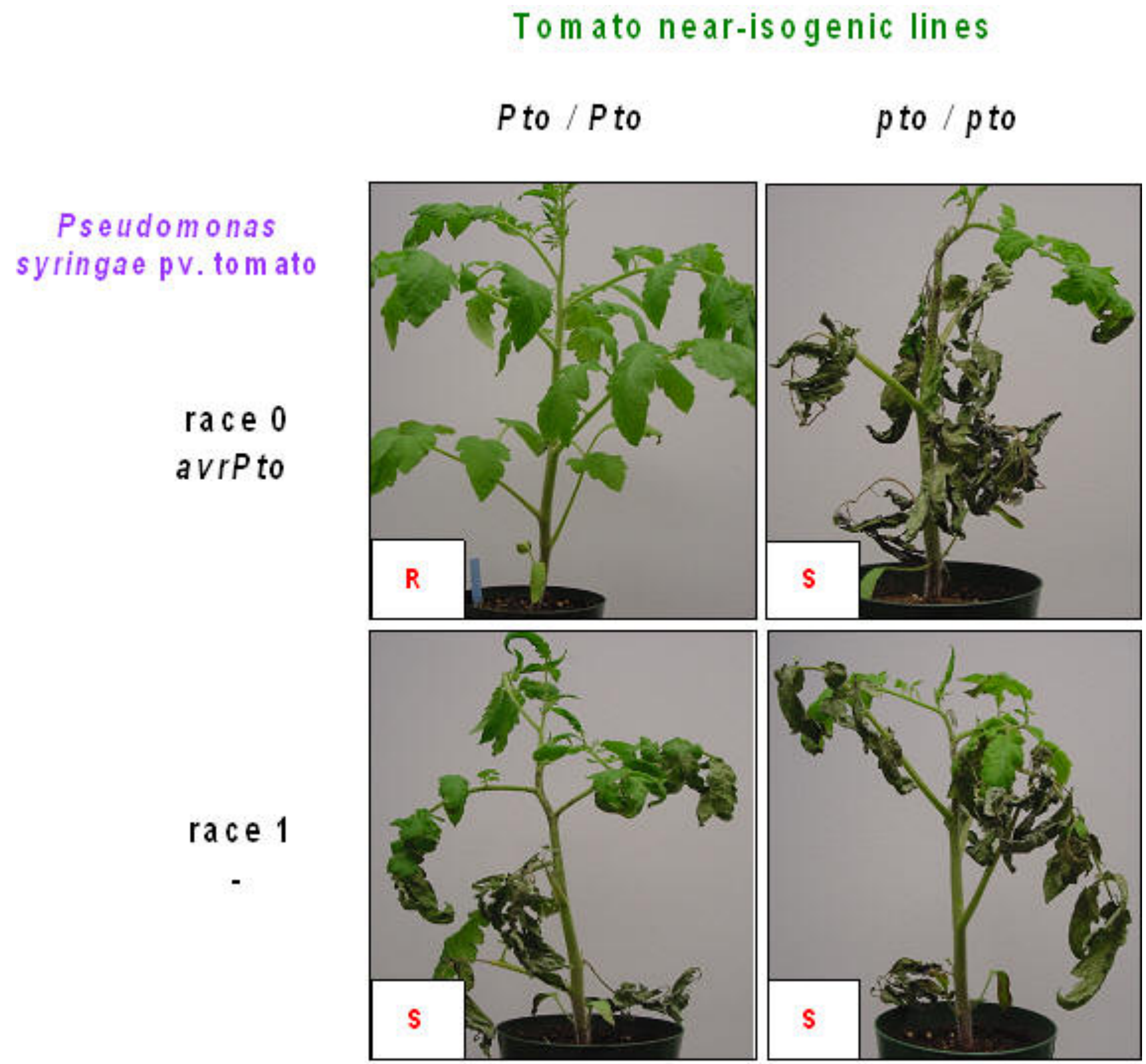
- Hosts are constantly under selective pressure to evolve new resistance genes

- **Resistance** – the ability of the host to combat the parasite
- **Virulence** – the ability of the parasite to harm the host

Antagonistic interactions: host and parasite systems

Effector genes (E) of pathogens suppress host plant defenses

Resistance genes (R) in plants detect effectors eliciting a defense response



'Gene-for-gene' model of plant disease resistance

Antagonistic interactions: host and parasite systems

R1 plants have low infection rates

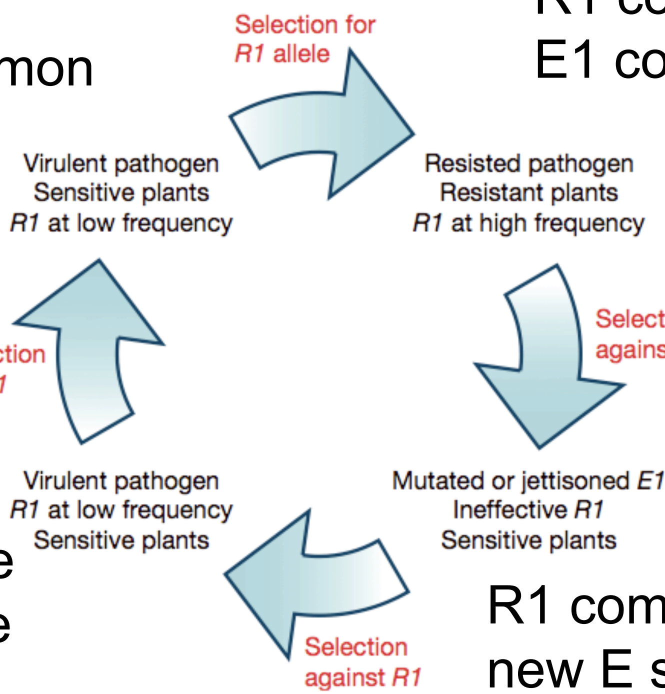
Results in balancing selection
Many R genes are diverse
(much like S loci)

R1 rare
E1 common

R1 common
E1 common

E1 infect
few plants

E1 infect
more plants

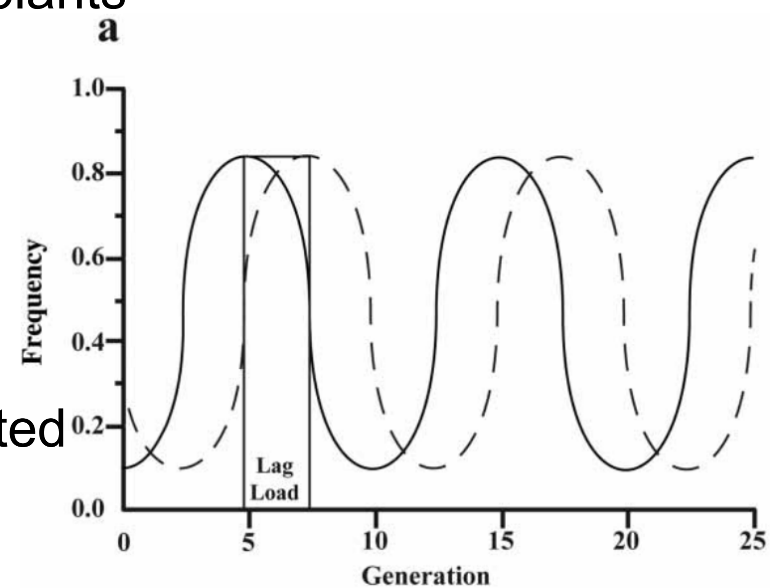


R1 rare
E1 rare

R1 common
new E selected

Cost of resistance?

Jones & Dangl Nature 2006



Occhipinti 2013

Antagonistic interactions: competition

Competition for pollination can lead to reproductive interference that imposes fitness costs

e.g. pollen loss to foreign stigmas and stigma blockage by foreign pollen

-specialization of pollinators
-differences in flowering time
-divergent flower morphology

Antagonistic interactions: competition

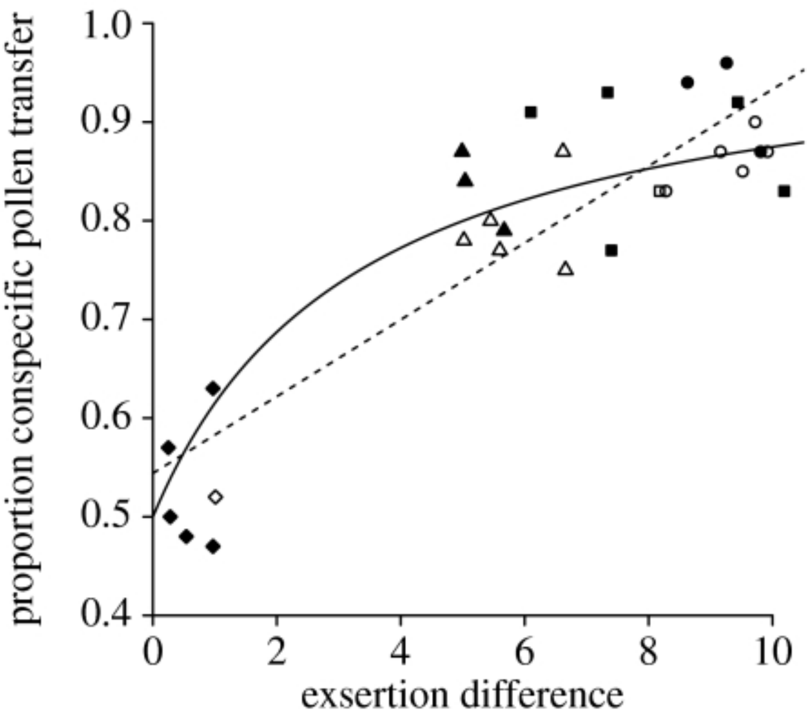
Bats visit *Burmeistera* spp. indiscriminately

Anther/stigma exertion influences pollen placement/deposition

Predictions:
Greater the divergence in exsertion length between a pair of flowers, the less pollen that bats would transfer interspecifically

Observed differences in exsertion length between sympatric species would be significantly greater than those of randomly generated null assemblages

Antagonistic interactions: competition



Munchhala and Potts 2007

Larger exsertion difference resulted in more conspecific pollen transfer (less interference)

Exsertion difference of sympatric populations was greater than chance (null assemblage)

Local adaptation via character displacement accounted for most of the exsertion difference between sympatric populations

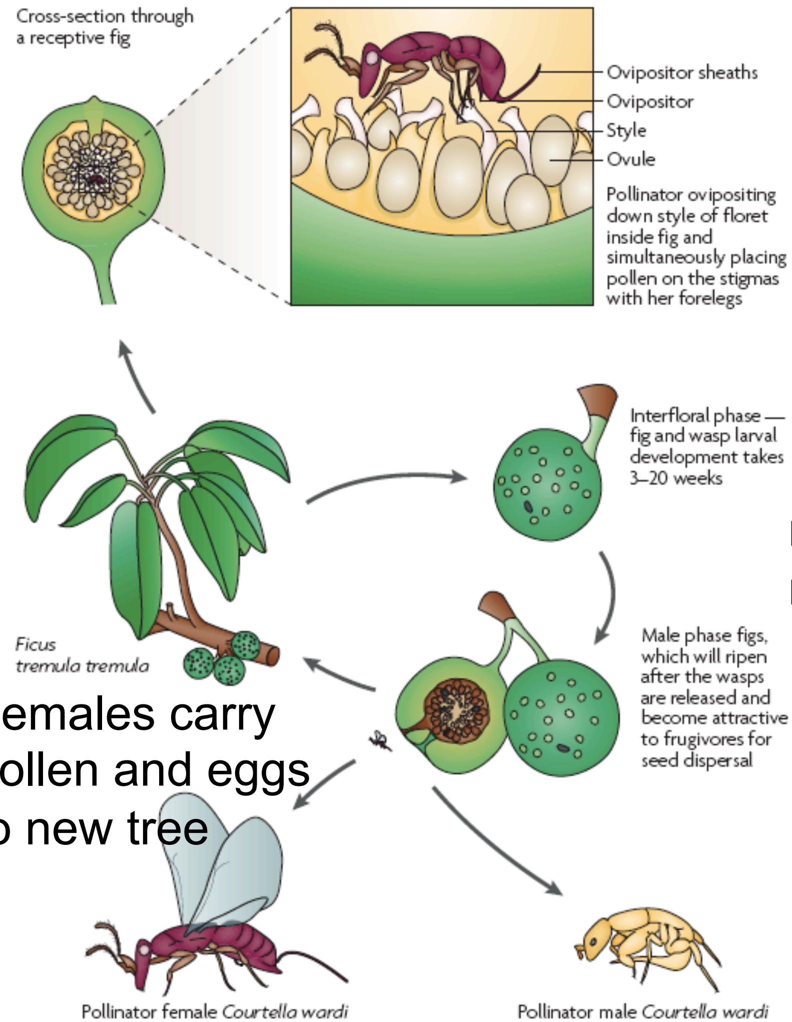
Mutualisms: plant pollinators

Mutualism: a symbiotic relationship where both species benefit from the interaction (e.g. the shrew and the pitcher plant)

Mutualisms represent one of the most influential of all biological interactions, with fundamental consequences for the evolution and maintenance of biotic diversity

The obligate mutualisms between flowering plants and their insect pollinators constitute extreme cases of interspecific mutualisms

Reciprocal co-evolution examples: plant pollinator mutualisms



Female wasps mate with males in fig

Females carry pollen and eggs to new tree

The fig-wasp mutualism is ancient and diverse, originating ≈80-90 million years ago

750 described species of *Ficus*

>300 wasp species

-One species of wasp thought to pollinate one species of fig (many exceptions)

The coevolutionary vortex

Extreme specialization in mutualistic interactions is uncommon in free living species. Why?

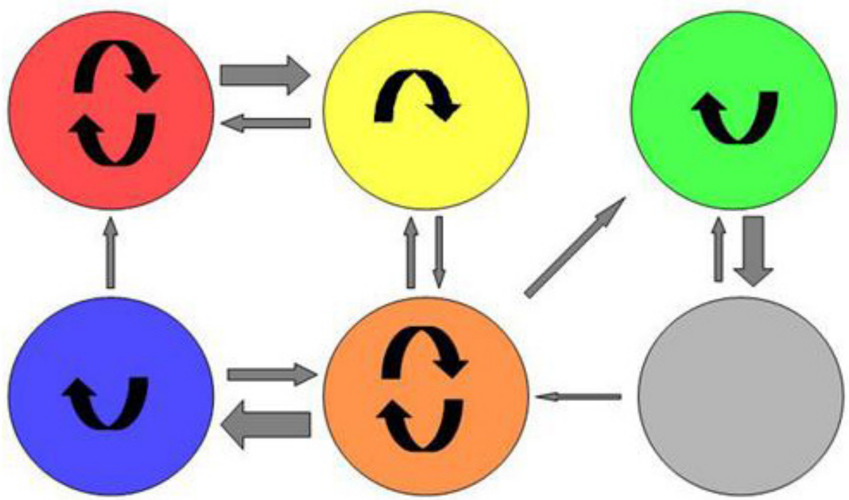
The coevolutionary vortex!

Mutualisms among free-living species tend to draw other species in as other species try and exploit the interaction (convergent "one-sided" evolution)

Geographic mosaic theory

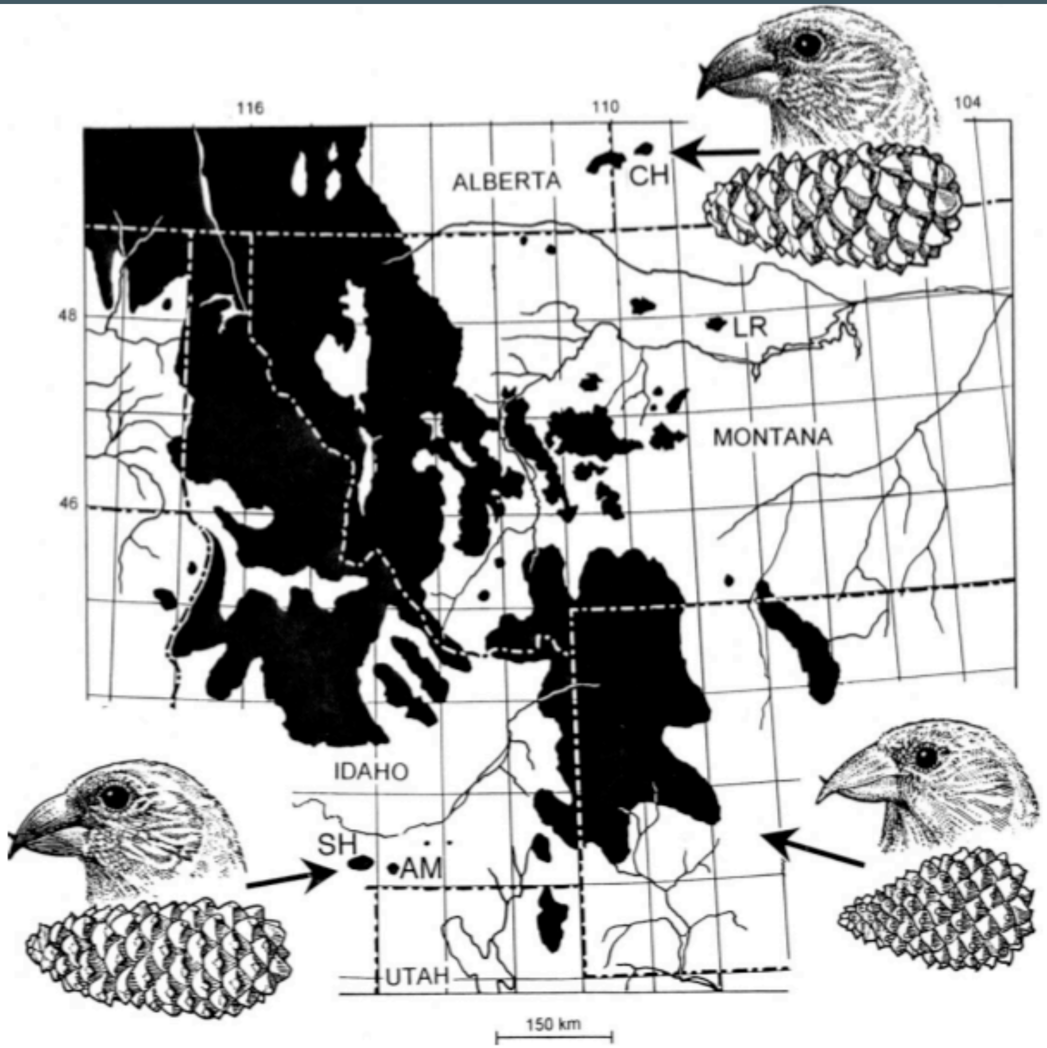
Interactions coevolve as constantly changing geographic mosaics

Coevolution is prominent in some areas (coevolutionary hotspots) but not others (coevolutionary cold spots) that the outcome of an interaction can vary between areas and that gene flow can affect the outcome of interactions



Hypothetical example of a Geographic Mosaic of Coevolution between two species: The coloured circles stand for biological communities; the arrows within the circles show interactions within local communities and represent selection on one or both (or none) species (truly reciprocal selection = hotspot). Selection among communities is generated from disparities in biotic or abiotic habitat quality. The arrows between the communities indicate gene flow (thicker arrows = more gene flow).

Reciprocal coevolution and geographic mosaics: pines and crossbills



Benkman et al. 2003

Reciprocal coevolution and geographic mosaics: pines and crossbills

Thin scales
-Easy for crossbills
-Hard for squirrels

Thick scales
-Hard for crossbills
-Easy for squirrels

Reciprocal coevolution and geographic mosaics: pines and crossbills

 +  +  = 

 +  = 

Reciprocal coevolution and geographic mosaics: pines and crossbills

 +  +  = 

More curved bill

 +  = 

Less curved bill

Coevolution: summary

Complex organisms require coevolved interactions to survive and reproduce

Species rich ecosystems are dependant on coevolved interactions (especially mutualisms)

Coevolution takes multiple forms and generates a diversity of ecological outcomes

Interactions coevolve as constantly changing geographic mosaics