

Plant of the day!



Ophrys speculum

Ophrys European genus of orchids

Practices 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)



Questions

What is co-evolution?

Why is it important?

Examples



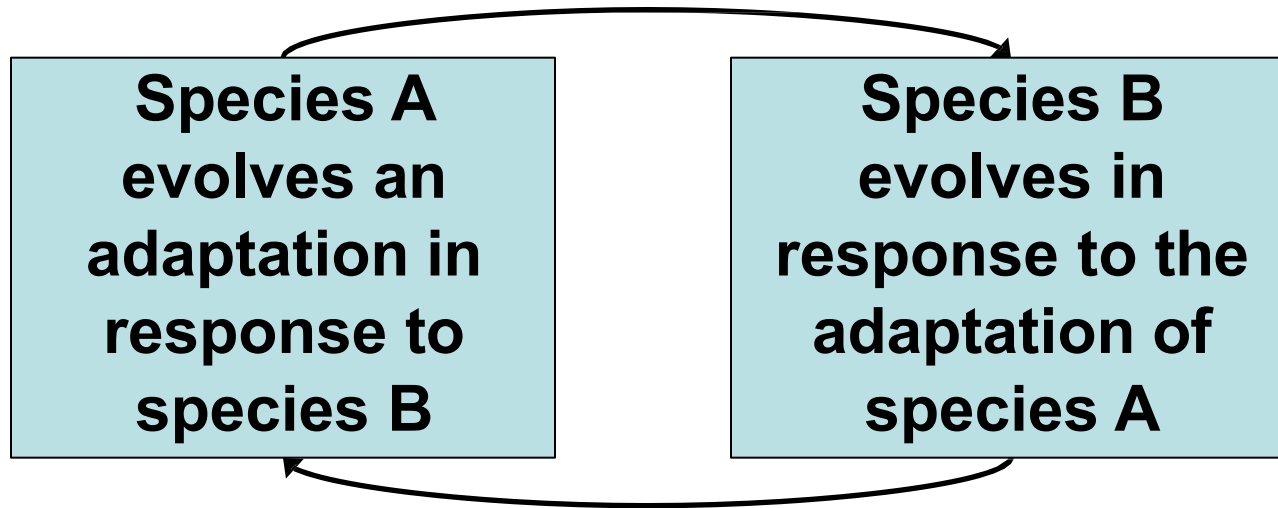
What is co-evolution?

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

-trait centered

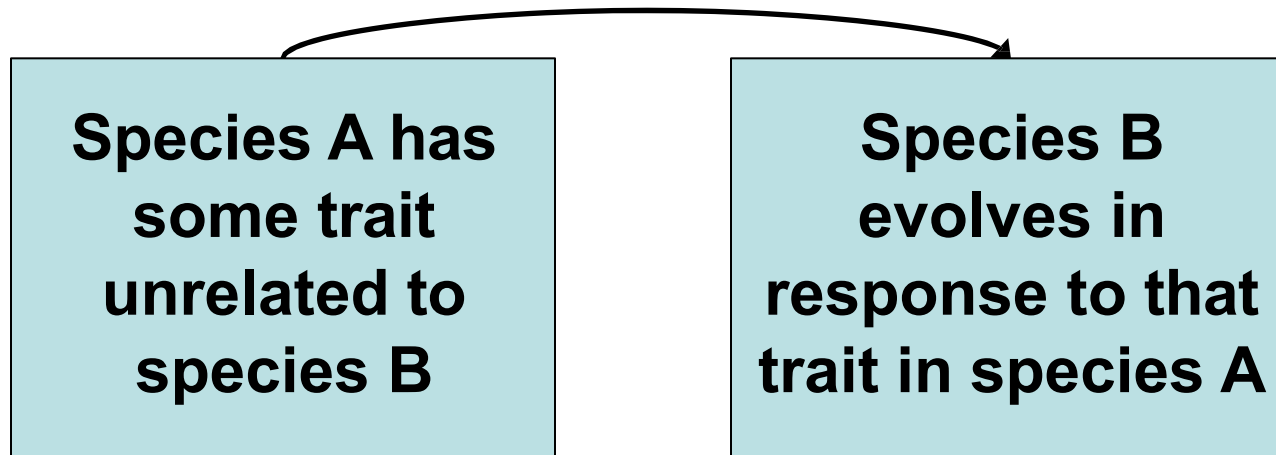


What is co-evolution?





What isn't co-evolution?





Why is it important?

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)



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*





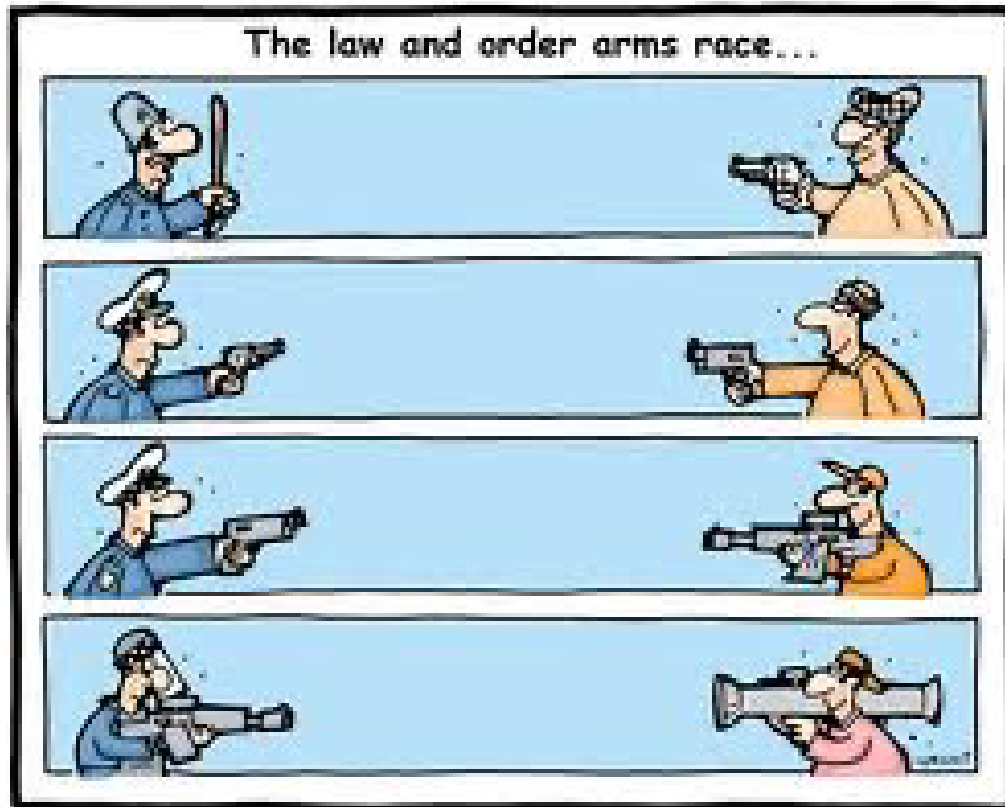
Red Queen Hypothesis

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

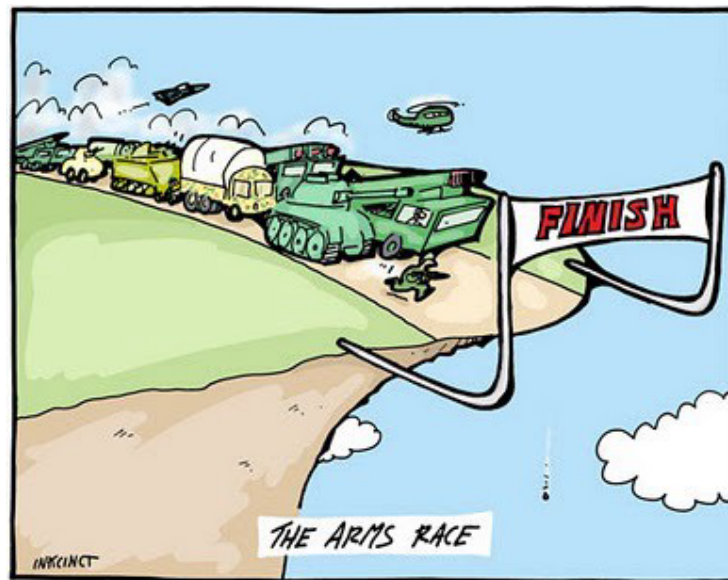
Arms race: The escalating and reciprocal coevolution between the offensive ability of a predator/parasite and the defensive capability of its prey/host





Arms race

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 interactions



Mutualisms

Plant herbivore interactions
Plant pathogen interactions
Competition

Plant pollinator interactions



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





Antagonistic interactions: plant herbivore interactions

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

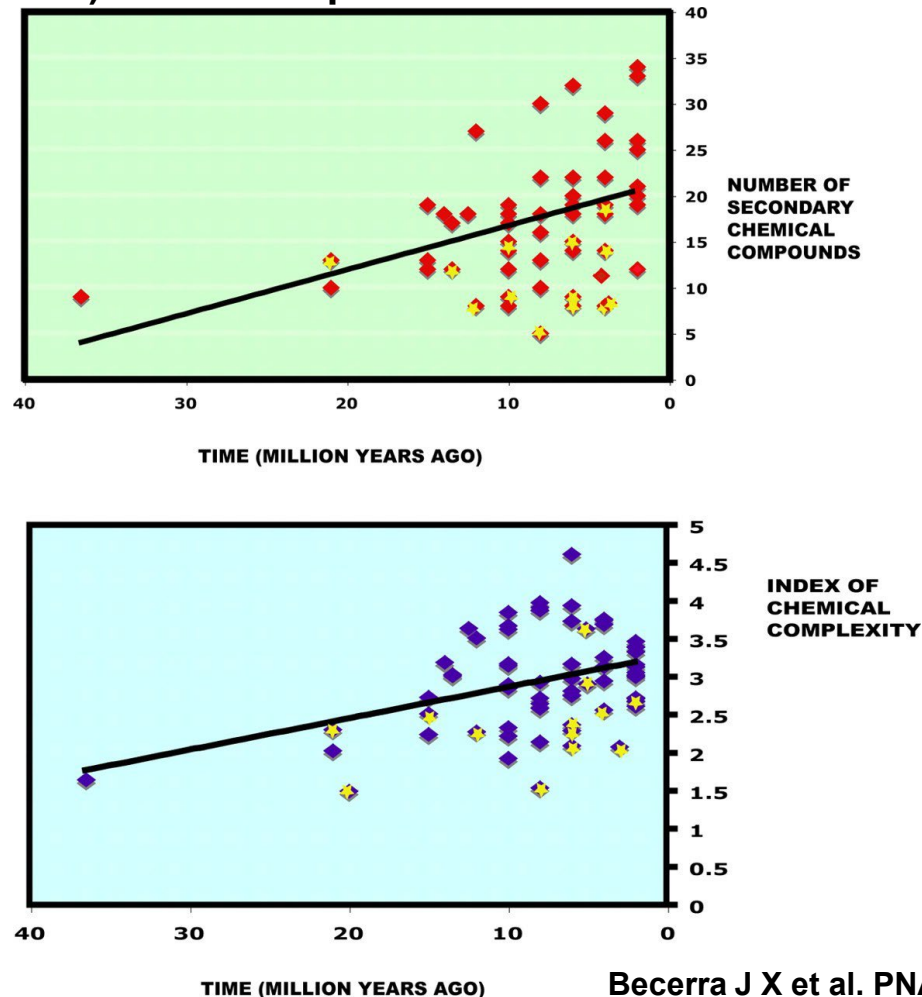
Is the increase lower in those species with mechanical (squirting) means of defense?

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



Antagonistic interactions: plant herbivore interactions

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





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

Pseudomonas syringae pv. *tomato*

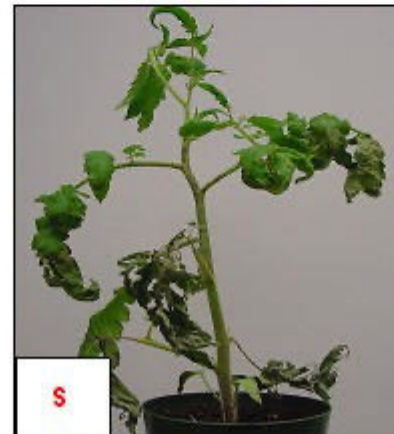
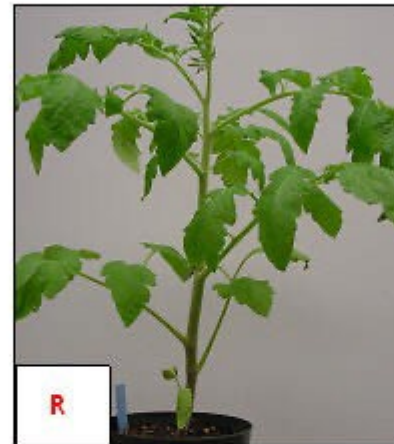
race 0
avrPto

race 1
-

Tomato near-isogenic lines

Pto / *Pto*

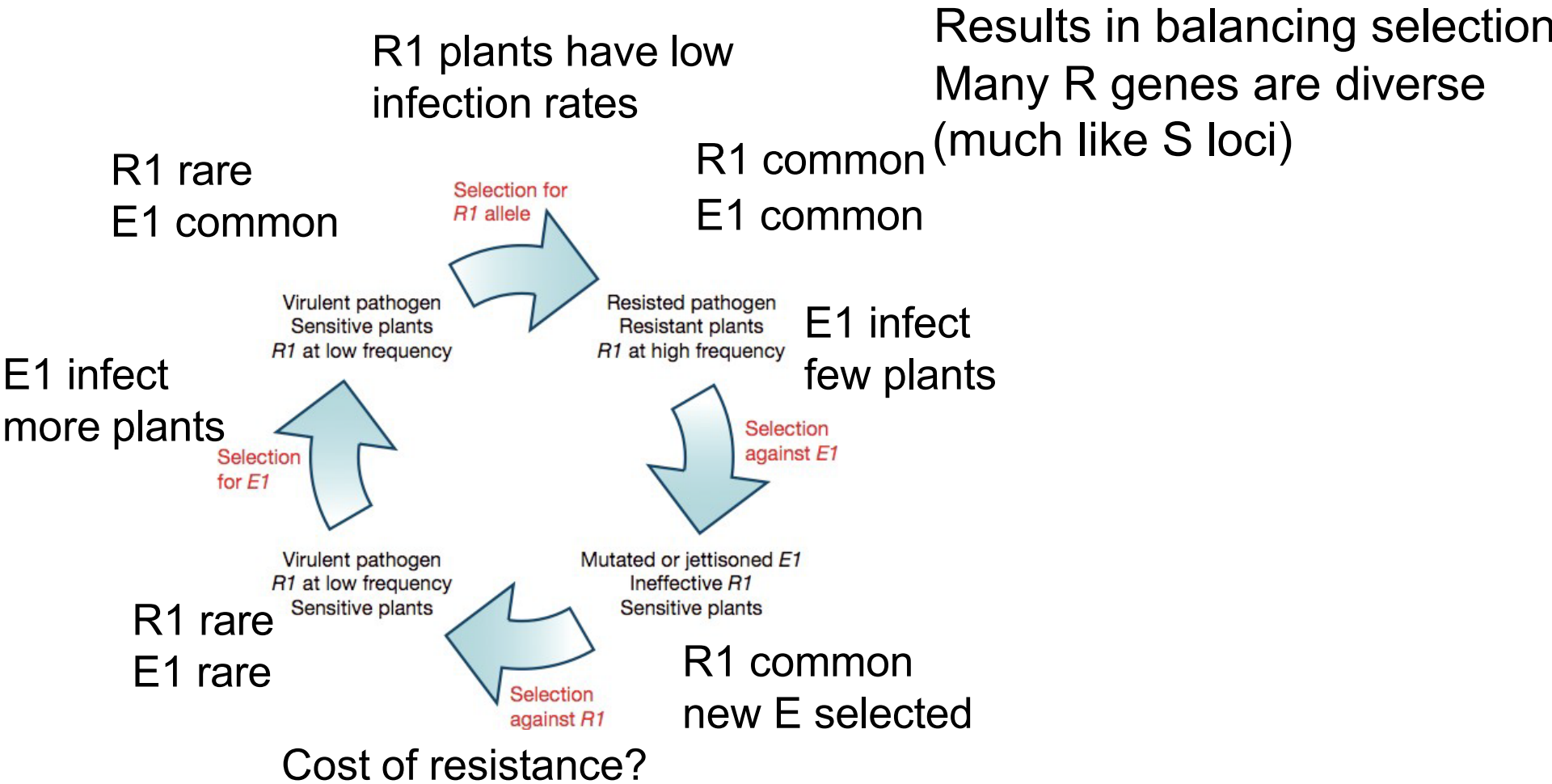
pto / *pto*



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



Antagonistic interactions: host and parasite systems





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

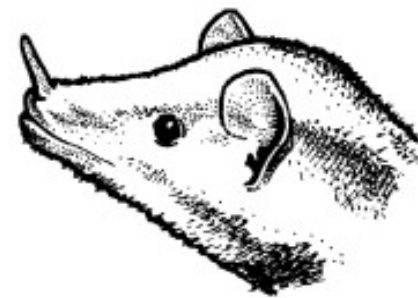


Antagonistic interactions: competition

Bats visit *Burmeistera* spp. indiscriminately

Anther/stigma exertion influences pollen placement/deposition

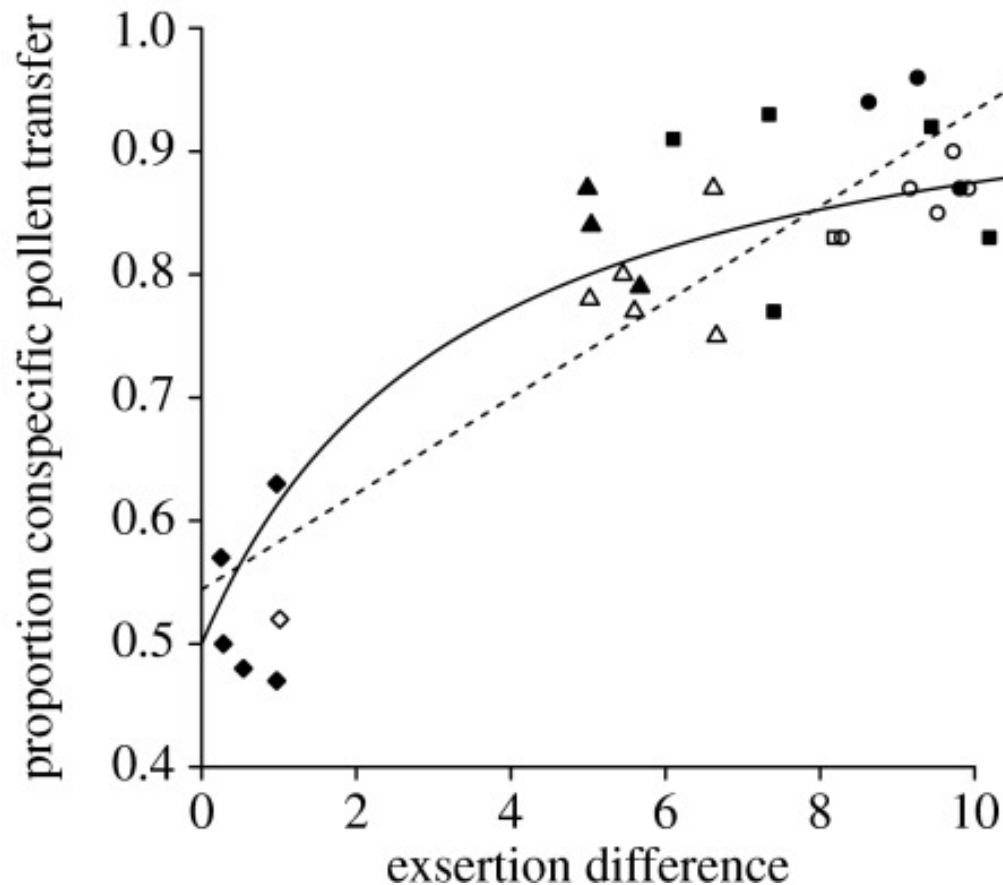
Prediction:
Greater divergence
in exertion length
reduces pollen
transfer



10 mm



Antagonistic interactions: competition



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



Mutualisms: plant pollinators

Mutualism: a symbiotic relationship where both species benefit from the interaction

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

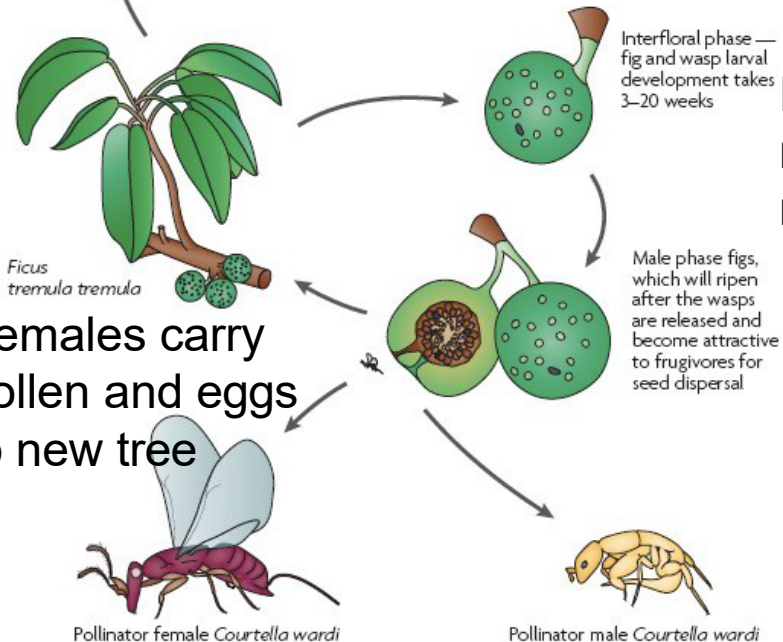
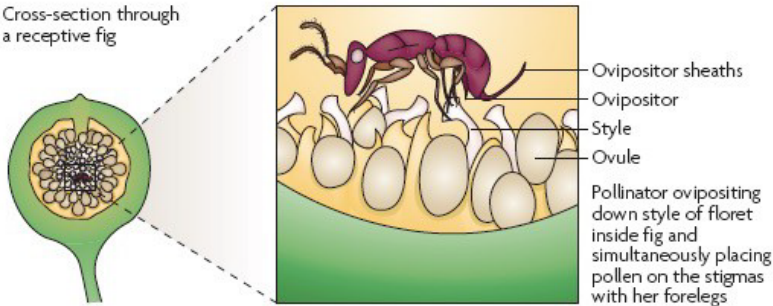
The obligate mutualisms between flowering plants and their insect pollinators constitute extreme cases of interspecific mutualisms





Reciprocal co-evolution examples: plant pollinator mutualisms

Cross-section through
a receptive fig



Female wasps
mate with
males in fig

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)

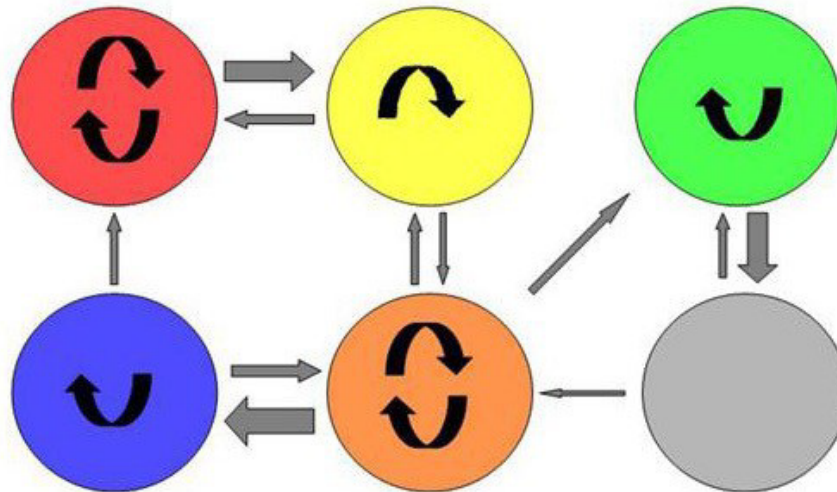
<https://www.youtube.com/watch?v=alyLXrfSLc0>



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

squirrels are absent

hotspot for crossbills
and pine

-selection for larger
longer cones and
large bills

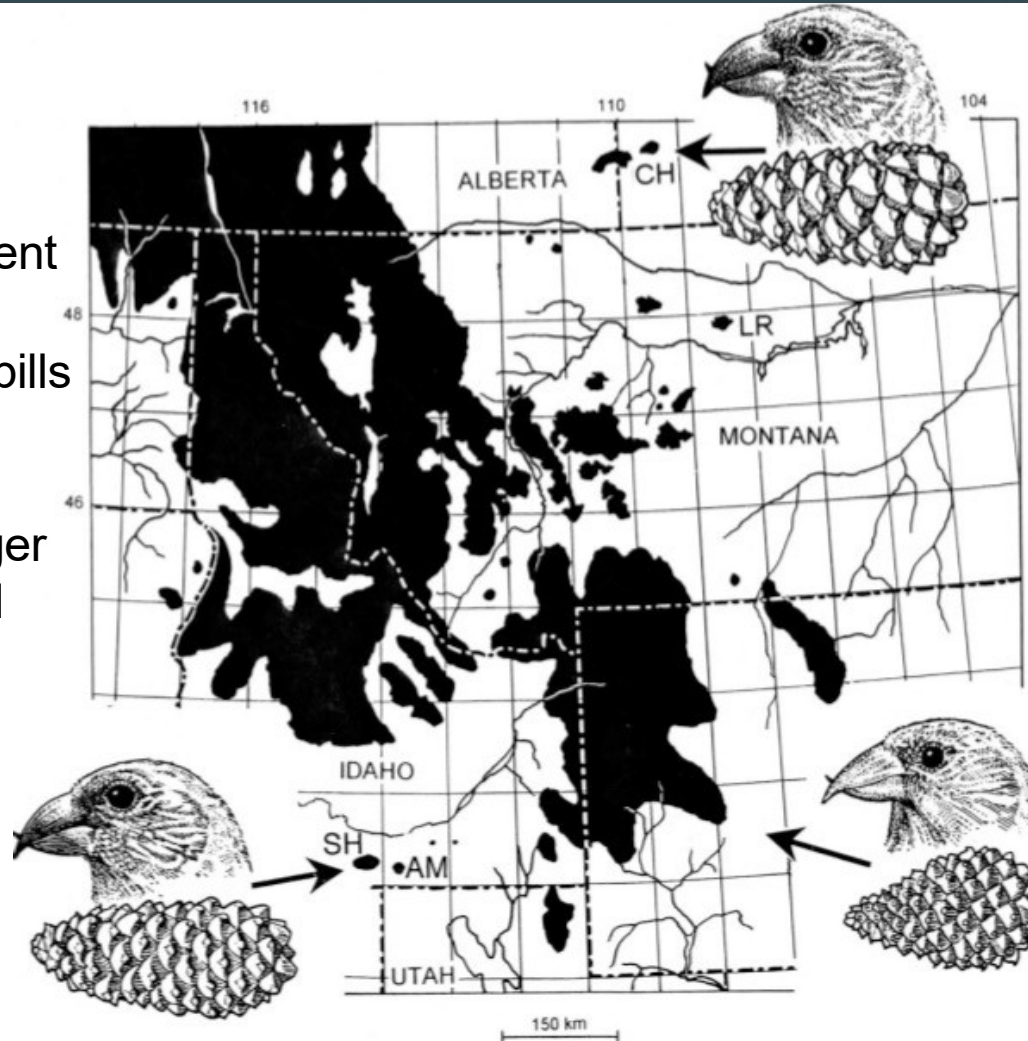
squirrels were recently
introduced

squirrels present

-selection for short
wide cones by squirrels

coldspot for crossbills
and pine

-selection for smaller
bills





Coevolution: summary

Complex organisms require coevolved interactions to survive and reproduce

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Interactions coevolve as constantly changing geographic mosaics