Lecture 9. Plant-Insect Interactions

The green world VS insects

What kinds of relationships?

- Friendly mutualism(+,+): help each other, both benefit and no one is harmed. No free lunch, but benefits > costs.

- Antagonism (+, -): one benefits, another is harmed.

- Commensalism (+, 0): one benefits, another is unaffected.

Mutualism

- Pollination: flowering plant / insect pollinator system

- Plant guard or seed dispersal: plant / ant system

Mutualism: plant / pollinator system

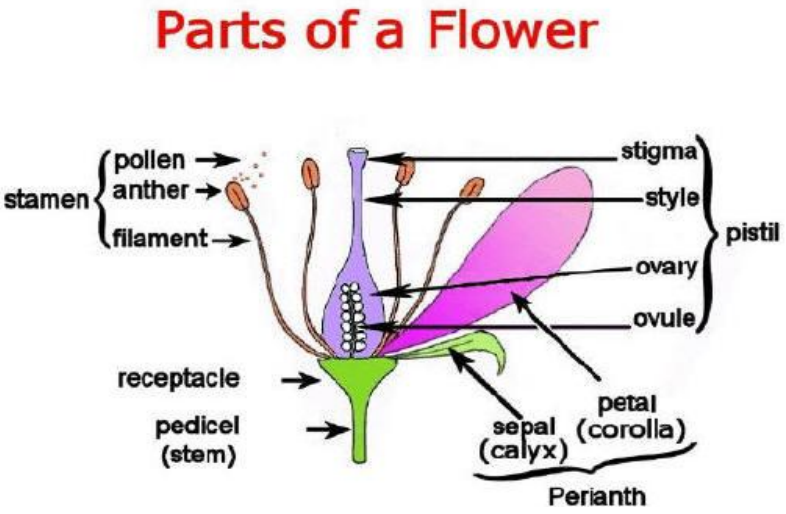
- Pollination: flowering plant (angiosperm) and animals have co-evolved (or at least affect each other to some degree) to use each other to accomplish feeding and reproductive needs. The plant feeds the pollinator and the pollinator accomplishes the pollen transfer for the plant.

Flowering plants

insect pollinators

Co-adaptations to maintain insect pollination systems

- Synchrony in time and space
- Plants provide attractive cues: flower color, fragrance, and shape
- Plants provide direct rewards: pollen, nectar, and fun/deceit
- Insect pollinators have morphological capacity to transport pollen and to get rewards
- Some degree of pollinator constancy (flower fidelity): visit the plant regularly




Bumblebee, Mexican Sunflower and Morning Dew 10/03/00 ©2000 Arlene Ripley

Attracting pollinators: visual cues

A “Bull’s eye” color pattern: stand out against a background of green foliage (*Rudbeckia, a black-eyed susan)*

A reversed bull’s eye (the daylily *Hemerocallis*)

Human & butterfly (*Gaillardia,* painted daisy)

Honey bee: orange/white

Nectar guide

Attracting pollinators: olfactory cues

- Butterfly & bird: more visual in behavior and not very olfactory

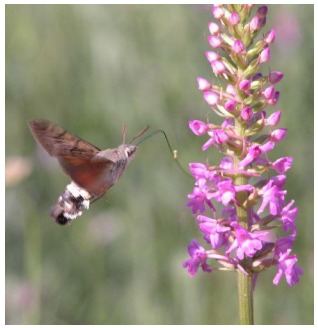
- Bees: sweet or spicy

- Moths and bats are very olfactory and not too visual in orientation

  Moth: very heady sweet fragrances
  Bats: Strong fruity or musky scents

Attracting pollinators: shape

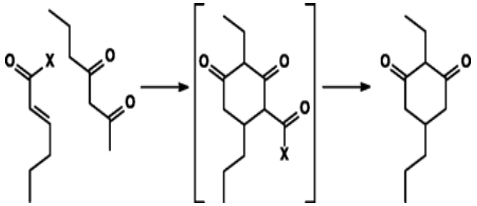
- Beetle: easy, open entrance, structural foods
- Hovering pollinators: generally hang down and have a long nectar tube
- Non-hovering insects and birds: need perches or landing platforms as part of the flower
- Mimicry of female



Rewarding pollinators

1. Nectar: primarily sugar solution (25-75%), variable amounts of amino acids and lipids
2. Pollen: the most direct reward; rich in protein and fat
3. Fun / deceit:

intoxication



pseudocopulation (Schiestl et al., 2003. Science)

Spectrum of co-evolution

- Co-evolution: reciprocal adaptive changes.

- Pairwise co-evolution: Co-adaptation of two species. The adaptive responses between two species lead to evolutionary changes in each other. Also called "specific co-evolution"

  1. figs-fig wasps 2. yuccas-yucca moths

- Diffuse co-evolution: Co-adaptation of two groups of species. This sort of diffuse co-evolution, by guilds of interacting species, has produced a range of so-called pollination syndrome, or collection of traits characterizing plants sharing similar pollinators.

  1. cantharophily: beetle pollination 2. myophily: fly pollination

  3. phalaenophily: moth pollination 4. psychophily: butterfly pollination 5. melittophily: bee pollination

Pollination syndrome: cantharophily

- Beetle pollination: beetles are pollen chewers, not very specialized for pollination; flowers are not very specialized for pollinators--large, open, dish and bowl type, no nectar guide, easy access.

Pollination syndrome: myophily

Fly pollination: flowers produce fly attracting odors (dung or decaying carrion) and frequently trap fly inside flowers. Usually dark red, purplish-green, hide sexual organs, no nectar

Skunk cabbage

Pollination syndrome: myophily

lady-slipper orchid (*Cypripedium*) produce “alcohol” in yellow petal pouch

Pollination syndrome: phalaenophily

Flower: Mostly white with long nectar (corolla) tube or spurs, heavy sweet odor, bloom at night, blossom rim with deep dissection or fringed, blossom horizontal or tilting downward

Moth: long thin proboscis, tend to hover below the flower and point its proboscis upward to insert it in the long nectar spurs

Gymnadenia conopsea (Fragrant Orchid)
Pollinated by Hummingbird Hawkmoth

Pollination syndrome: psychophily

Gaillardia (painted daisy)

Flower: red/yellow color patterns, the large landing platform, wide flower, bloom at day time, weak odor, blossom erect and blossom rim without dissection.

Butterfly: long thin proboscis, but tend to alight on flowers

Pollination syndrome: melittophily

Flower: strong landing platform, vivid color present, UV-reflectance pattern, subtle odor

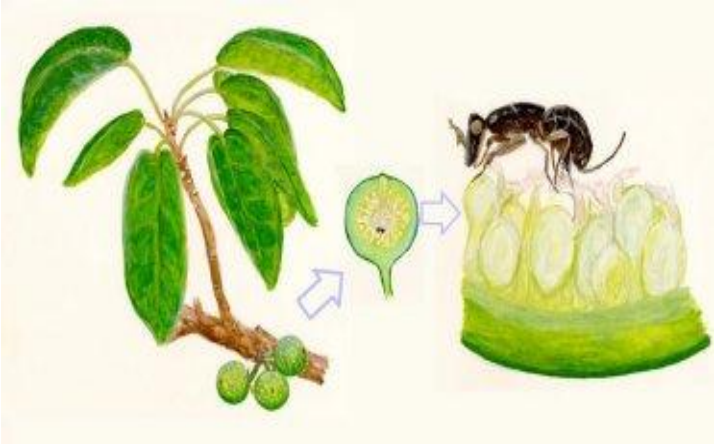
Bumblebee, Mexican Sunflower and Morning Dew 10/03/00 ©2000 Arlene Ripley

Bees: pollen chewers, morphologically well adapted for pollen transfer, some with advanced learning capacity

Obligate pollination

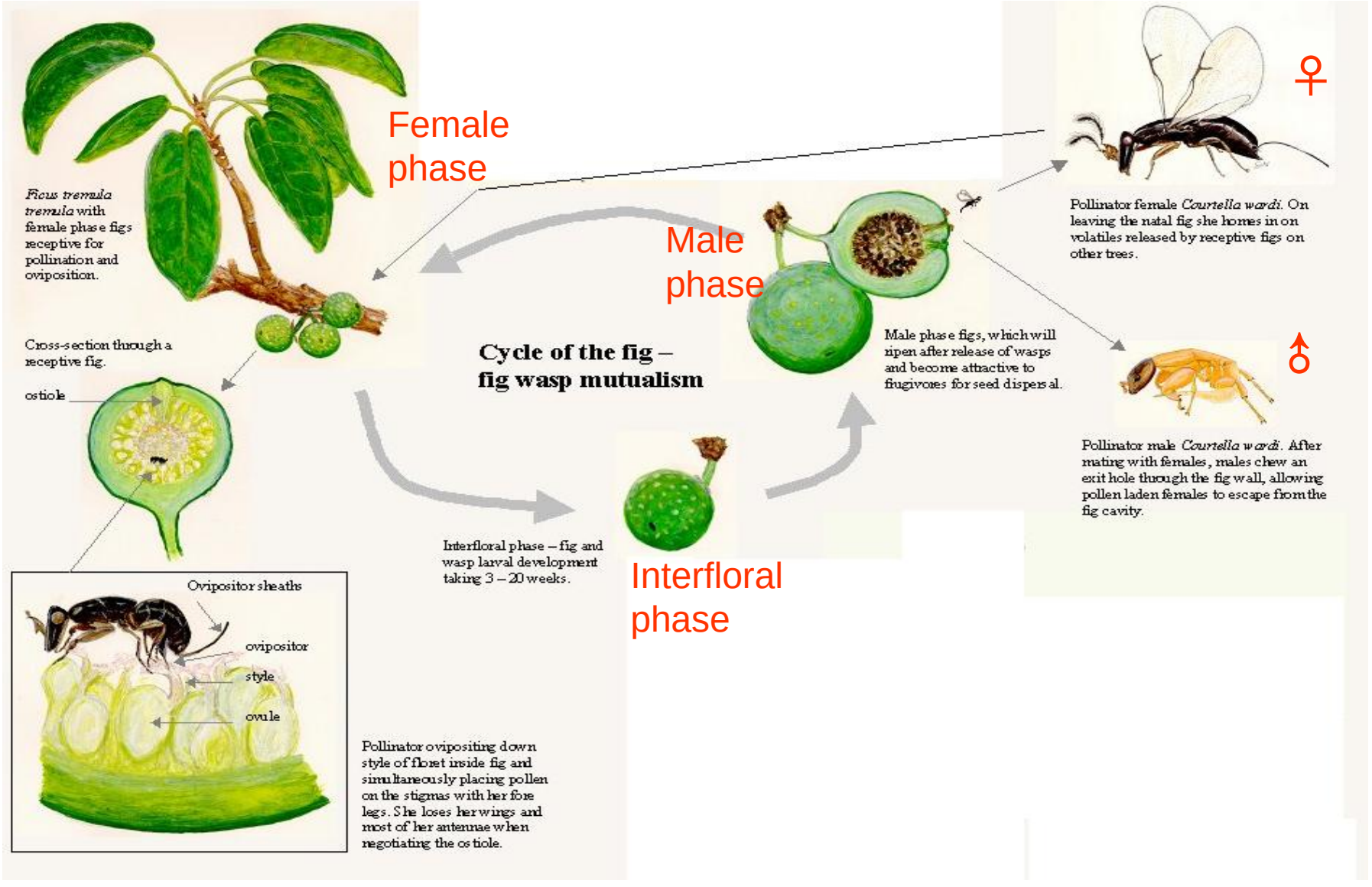
- Obligate pollination: neither party can survive without the other. Pairwise co-evolution. Two of the most famous are figs-fig wasps and yuccas-yucca moths (*Tegeticula)*
- Tightly coevolved mutualism, in which the plant relies exclusively on the insect for pollination, and the insect relies exclusively on the plant for food
- In both cases, the larvae are seed/flower eaters

Obligate pollination: figs-fig wasps

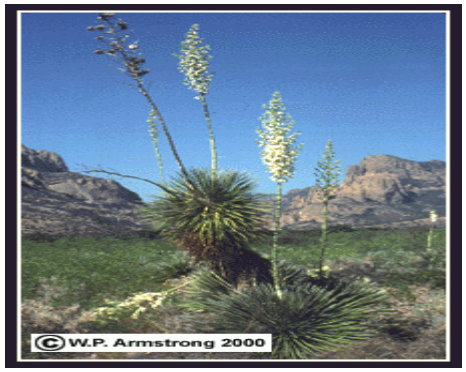


- One to one rule: one fig tree species is usually pollinated by one fig wasp species that is only associated with that fig species.
- Such one-to-one rule may not always hold: 750 species of *Ficus* in the world, but only 300 fig wasp pollinator species currently known.
- Figs: flowers hidden inside fig; 3 development phases--female, interfloral, and male, no synchrony between trees; olfactory cue
- Fig wasps: flattened and elongated head and thorax, backward pointing teeth on female mandibular appendage

Obligate pollination: figs-fig wasps



Obligate pollination: yuccas-yucca moths



- One to one rule
- Yuccas: moth larvae can feed on about 20 of 300 seeds per flower; if too many larvae hatched, the flower will be aborted (thus the larvae will die).
- Yucca moths: Female collect pollen from one flower, fly to another flower, inspect the flower for the scents of previous female visitors, actively stuff pollen into stigma; typically inject 3-5 eggs into one flower's ovary, leave her own scent as a warning to future visitors

Mutualism: Ant / plant systems

Acacia-ant system

A *Pseudomyrmex* ant feeds on nectar from an Acacia extrafloral nectary (=EFN). (Photo by the Max Plank Institute)

Pseudomyrmex Ants: body guard for acacia against herbivores and other plants by biting and stinging

Acacia: provide shelter (enlarged hollow thorns) and food (EFN, Modified leaflet tips called Beltian Bodies) for the ant.

Acacia-ant system

Beltian bodies: protein- and lipid-rich

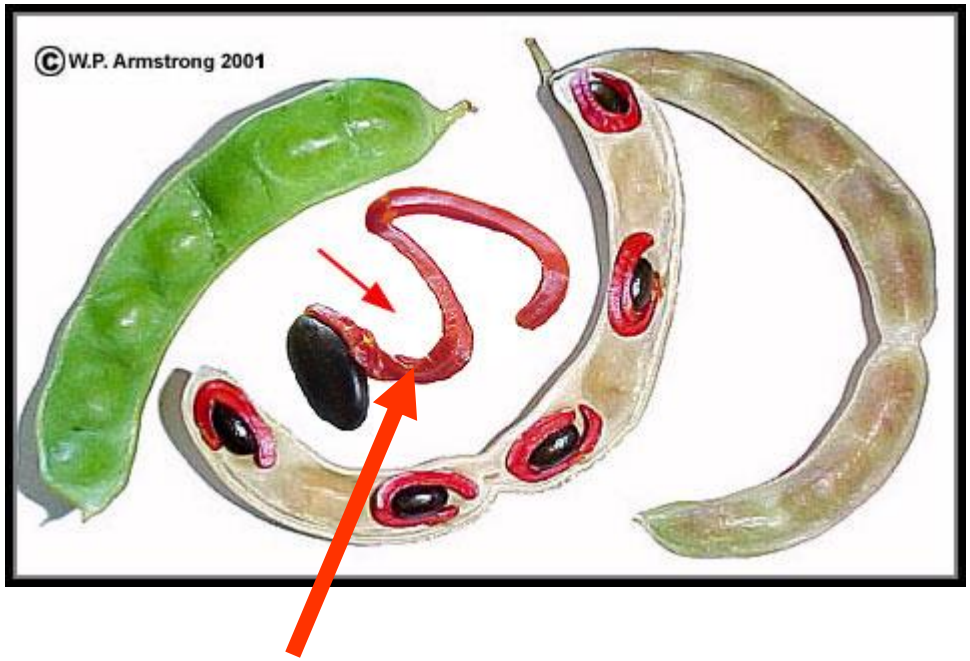
Thorn: shelter

EFN: extrafloral nectar, carbohydrate-rich

Mutualism: Ant / plant systems

Plants provide nutritional elaiosomes

Insects disperse seeds to favorite sites



Elaiosome = fatbody attached to seeds

Antagonistic interactions

- Antagonistic (+,-): not win-win situation, but one benefits, another harmed.
- Herbivory: insects eat plants
- Can plants turn the tables on insects and eat them instead of the reverse?

Yes!! call insectivory

Antagonistic insectivory

- How many? over 600 types of carnivorous plants grouped under Venus's-flytrap, pitcher plant, sundew, butterwort.

- Why eat insects? No chlorophyll? live in swampy nitrogen poor wetlands, which does not provide enough of the nutrients that plants need.

- How to eat? passively attract, trap, and digest (eat) unsuspecting victim with plant juices

Insectivore: Venus's fly trap

- The two-lobbed trap: 3 trigger hairs on the inner face of each lobe, fringed with teeth-like projections
- when one trigger hair is touched twice or when two are touched in succession, the trap closes. The teeth-like projections interlock, trapping the unsuspecting victim inside
- The struggling victim stimulates the secretion of digestive juices.
- The trap reopens in about 10 days

Insectivore: Sundew

- More than 100 species of sundews (*Drosera*)
- leaves are covered with tiny (usually red) hairs, which exude a clear, sticky fluid (dewdrops)
- The sticky droplets attract and trap insects.
- The struggling insect stimulates the hairs to bend inward towards the center of the leaf, to wrap it in a neat, tight package

Insectivore: butterwort

- leaves with a very sticky surface. Greasy to the touch, but deadly to any small insect that may land on or try to cross one of the leaves

Insectivore: pitcher plants

- leaves or leave parts modified into pitcher-like structures.
- Pitchers contain plant juice that smells like sweet nectar and attracts insects. Pitchers are topped with a hood or lid
- When insect try to drink from the pitcher, it loses its footing on the smooth interior, slides to the bottom, lands in a pool of liquid, which digests the victim