Pollination Biology

Sexual Reproduction in Plants

- Movement onto land is an issue for sexual reproduction in plants - unlike for animals
  - rely on movement of (1) pollen, (2) young embryo encased in a seed (or fruit), or (3) spores

Coevolution

- Interactions between two different clades as selective forces on each other, resulting in adaptations that increase their interdependency

Animal-flowering plant interaction is a classic example of coevolution:
- Plants evolve elaborate methods to attract animal pollinators
- Animals evolve specialized body parts and behaviors that aid plant pollination
Coevolution

- coevolution with pollinators often leads to convergence and divergence in flowers
- best studied has been the phlox family: Polemoniaceae

Ph.D. Work by Jeff Rose

Coevolution

- frequent shifts to different “pollination syndromes” from ancestral bee pollination

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- tested with genomic data (400 nuclear genes)
- bee pollination confirmed as ancestral

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- a lot of transitions in pollinators!

Ph.D. Work by Jeff Rose
What is Pollination?

- Pollination: The transfer of pollen from the male anther to the female stigma, in same plant or between two plants.

Evolution of the Flower

Evolution of the flower is linked with evolution of pollination syndromes and why divergence/convergence is pervasive in floral features

- bisexual flowers to bring male and female parts closer
- primitive flowers had separate pollen- and carpel-bearing structures such as in Archaeafructus (and in all gymnosperms)

Evolution of the Flower

- closed carpel for protection of ovules and seeds

Evolution of the Flower

- fusion of carpels into one pistil - efficient deposition of pollen and movement of pollen tubes down one or two style lobes
Evolution of the Flower

- **epigyny** - protection of ovules from probing animals
- **fusion of floral parts** - tubular structures for restricting nectar access

Evolution of the Flower

- **exotic landing platforms, spurs, nectaries, etc** - specialization for specific pollinators

Evolution of the Flower

Placement of both stamens and carpels in the same flower causes inbreeding - subsequent selection for outcrossing

- **protogyny or protandry** - temporal sequence of anthesis or stigma receptivity

1. female phase
2. male phase

Protogyny in *Asimina* - pawpaw (Annonaceae)

Evolution of the Flower

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- **self incompatibility** - chemical on surface of pollen and stigma/style that prevent pollen tube germination on the same flower (S allele incompatibility system)
Evolution of the Flower

Placement of both stamens and carpels in the same flower causes inbreeding - subsequent selection for outcrossing

- heterostyly - reciprocal separation of anthers & stigmas
- unisexuality - reversal back to separate sexes in flowers

Primula - primrose  Cucurbita - zucchini

Pollination Syndromes

- morphologically convergent adaptive trends exhibited by the floral features of pollinated plants and, in animal pollination, the mouthpart structure and other flower-interactive features of the pollinators

Passive
1. Wind - anemophily
2. Water - hydrophily

Active
3. Animal - zoophily (ornithophily, entomophily)

Insect Pollination - Entomophily

Modern insect pollinators
- Beetles -- Coleoptera
- Flies -- Diptera
- Ants -- Hymenoptera
- Butterflies -- Lepidoptera
- Moths -- Lepidoptera
- Bees -- Hymenoptera

Primitive type of insect pollination appears to be beetle or fly pollination

ANA Pollination

ANA grade has surprising number of pollination types... including thermophily (heat to volatize scents for fly pollination) in Illicium floridanum
Beetle Pollination

• likely that beetles first visited the female cones of conifers and fed on the pollination droplet exudates
• function of pollination droplet originally for capture of wind-blown pollen — shift as food attractant for beetles as in Welwitschia

Beetle Pollination

• beetle flowers usually have numerous parts - flowers provide stamens, petals as food for chewing beetles

Beetle Pollination

• beetle flowers are pale or dull in color, but with strong odor

Beetle Pollination

• carrion beetle pollination is more advanced - coprophily
• flowers have spicy, fruity, or rotten smell attracting beetles
Fly Pollination

- carrion/dung flies have special pollination system (sapromyophily) with no reward - flies attracted to flowers to lay eggs
- flowers brownish/purple, often mottled, with foetid odor

Asarum canadense - wild ginger (Aristolochiaceae)

Fly Pollination

- two specialist families - Aristolochiaceae (birthwort) and Araceae (arum)

Jack-in-the-pulpit

Amorphophallus titanum - titan arum
Fly Pollination

- many parasites and saprotrophs utilize carrion flies

Rafflesia (Rafflesiaceae)
Heliosis (Balanophoraceae)
Burmanniaceae

Fly Pollination

- advanced fly pollination can be similar to bee pollination - ecologically similar ("bee flies")

Syrphid on Anemone
Xanthogramma on morning glory

Bee & Wasp Pollination

- most important group of flower pollinators
- attracted to flower mainly for food (pollen, nectar, oils, etc.)

Andrena after pollen
Halictid after nectar
Macropis europea on Lysimachia vulgaris
- oil is essential for juvenile development

Bee & Wasp Pollination

- flowers are white, blue, yellow - generally not red
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- strong UV light patterns
- "nectar guides"
- fragrant (perfumes, pheromones)
- poricidal anthers - buzz pollination
- zygomorphic - landing platform

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Bee & Wasp Pollination

- Some plants take advantage of the sex drive of certain insects
- Mirror or bee mimic orchids - pheromones
- Male insect mates with flowers
- Orchid pollinated

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**Bee & Wasp Pollination**

Two European bee mimic orchids pollinated by different species of bees

*Ophrys lutea* | *Ophrys sicula*

What pollinates this tiger orchid from Colombia? *Mrs. Santa Claus?*

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**Catasetum Pollination**

- exotic type of euglossine (*Eulaema, Euglossa*) bee pollination
- *Catasetum* orchid flowers unisexual and strongly dimorphic
- why this strong dimorphism?
- why do males of different species of *Catasetum* appear more different than do the females?

*Catasetum pulcherrimum*

sexual dimorphism in Venezuela

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**Catasetum Pollination**

- male euglossines collect pheromones from flowers
- male *Catasetum* flowers discharge pollinia (323 cm/sec)
- euglossine bees learn to avoid male flowers
- female flowers must be different looking to attract the euglossine bees - often upside down requiring new behavior

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**Catasetum Pollination**

- pollination biology drives sexual dimorphism and male-male differentiation and female-female similarity
- and explains relative degree of sexual dimorphism within an orchid species

Romero & Nelson (1986) *Science*
Fig Wasp Pollination

The pollination biology story of Ficus (figs) and their obligate pollinators, the fig wasps, is classic

- monoecious syconium (Fig. 3) is best studied

- host specificity by female wasps who lay eggs in gall forming fig ovaries but pollinate other ovaries

- DNA cladograms of host (fig) and pollinator (fig wasp) show co-speciation or co-evolution

  - exceptions occur but generally fit the co-evolution model
  - 1 fig wasp species for two closely related fig species geographically separated
  - 2 related fig wasp species on one geographically widespread fig species

  George Weiblen (University Minnesota)

Co-evolution of the pantropical figs and their wasp pollinators

Cruad et al. (2012) Co-speciation of figs and fig wasps. Systematic Biology
**Fig Wasp Pollination**

- Multiple inter-continental dispersals of figs and their wasp have started new rounds of co-speciation or co-evolution

**Butterfly Pollination**

- Butterflies interact with plants most dramatically in longer-lived larval stages

**Butterfly Pollination**

- Guided by sight and smell
- Butterflies can see red and orange flowers
- Usually shaped as a long tube because of insect’s proboscis – to get nectar
- Flat inflorescences - butterflies land

**Moth Pollination**

- Day-active (diurnal) moths visit flowers similar to that of bees
Moth Pollination

• Night-active (nocturnal) moths visit flowers that are dusk or night blooming, white or pale yellow, fragrant, and with long tubular structures for long proboscis
• no landing platform - moths hover

Platanthera - prairie fringed orchid

Bird Pollination - Ornithophily

• Birds have a good sense of color, they like yellow or red flowers...
• . . . but do not have a good sense of smell, so bird-pollinated flowers usually have little odor
• Flowers provide fluid nectar in greater quantities than for insects
• Hummingbird-pollinated flowers usually have long, tubular corolla
• Pollen is large and sticky

Other birds - Africa, Australia, Hawaii
• Convergence is the rule
**Bird Pollination - Ornithophily**

- NOT a one way shift to bird pollination
- Few shifts to birds in *Salvia* followed by many reversals to bee pollination

![Image of bird pollination]

**Bat Pollination - Chiroptirophily**

- Night-blooming (nocturnal)
- White and aromatic
- Robust flowers - bats can cling
- Often hanging below crown - access for sonar

![Image of bat pollination]

**Other Mammal Pollination**

- Marsupials, mice, primates as carers

![Image of other mammal pollination]

**Phylogenetic evidence for pollinator driven diversification of angiosperms**

- Eocene
- Oligocene
- Miocene
- Pliocene
- Pleistocene
- Holocene

**Pollinator Clade**

- Calosphace
- Atdartria
- Dorystaechas
- Meriandra
- Zhumeria
- Glutinaria
- Sclarea
- Salvia
- Heterosphace
- Riosma
- Pervolka
- outgroup

**Hummingbird stem crown**

- Not a one way shift to bird pollination
- Few shifts to birds in *Salvia* followed by many reversals to bee pollination

Does speciation occur more frequently in hummingbird OR in insect pollinated clades AND how much more (e.g., 2X, 5X, 100X)

**Read...**


- Other Mammal Pollination: Marsupials, mice, primates as carers.

- Night-blooming (nocturnal)
- White and aromatic
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Other Mammal Pollination

- Marsupials, mice, primates - rarer
- Humans

Ken Wood pollinating *Brighamia*

Honey possum on *Banksia*

Honey possum on coral gum