Pollination Biology

. . . real story of the birds & bees . . .
and beetles, bugs, butterflies, bats
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
Sexual Reproduction in Plants

Pollination and seed/spore dispersal important aspects of biosystematics in plants:

- Gene flow
- Outcrossing vs. inbreeding
- Reproductive isolation
- Speciation
- Co-speciation (coevolution)
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

- insect lineages diversified prior to **angiosperms**, but co-opted by and responded to by angiosperms

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Labandeira et al., 2001
Divergence vs. Convergence

• classic example of both divergence and convergence in pollination is the family Polemoniaceae (phlox family)

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

V. Grant
B. Grant
Is hummingbird ancestral?

Fouquieraceae sister to phlox family
Is hummingbird ancestral?

Fouquieraceae sister to phlox family

No! bee pollinated

Ph.D. Work by Jeff Rose
Divergence vs. Convergence

• another example is evolution of orchid floral form in *Platanthera* of Northern Hemisphere

*Platanthera leucophaea*  
Prairie-fringed orchid
Divergence vs. Convergence

• DNA relationships indicate remarkable divergent and convergent shifts - 3 separate shifts to nocturnal hawkmoth pollination

Platanthera
**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 *Archaefructus* (and in all gymnosperms)
Evolution of the Flower

- closed carpel for protection of ovules and seeds

*Drimys* - basal angiosperm
Evolution of the Flower

• fusion of carpels into one pistil - efficient deposition of pollen and movement of pollen tubes down one or few 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

Protogyny in *Asimina* - pawpaw (Annonaceae)
Evolution of the Flower

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

• **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 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

*Nuphar* - yellow water lily

Longitudinal view of beetle flowers illustrating various methods of protecting pistils
Beetle Pollination

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

Nuphar - yellow water lily
Beetle Pollination

- carrion beetle pollination is more advanced - coprophily

- flowers have spicy, fruity, or rotten smell attracting beetles

Hydnora africana

Araceae

Xanthosoma sp.
Araceae
George K. Linney

Cyclocephala 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)
Fly Pollination

- two specialist families - **Aristolochiaceae** (birthwort) and **Araceae** (arum)
Fly Pollination

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

- many parasites and saprotrophs utilize carrion flies

*Rafflesia* (Rafflesiaceae)

*Burmanniaceae*

*Heliosis* (Balanophoraceae)
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
Bee & Wasp Pollination

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- strong UV light patterns
- “nectar guides”
Bee & Wasp Pollination

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- fragrant (perfumes, pheromones)
- poricidal anthers - buzz pollination

*Eulaema* (euglossine)

*Solanum* - Solanaceae

Perfume industry
Bee & Wasp Pollination

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

*Ophrys ciliatum* - orchid in the Mediterranean pollinated by wasp – *Scolia ciliata*
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?
**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 pileatum*
sexual dimorphism in Venezuela
**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

Romero & Nelson (1986) *Science*
**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

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### Male A

### Female A

### Female B

### Male B

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**Wt (mg) of pollinia**

Romero & Nelson (1986) *Science*
The pollination biology story of *Ficus* (figs) and their obligate pollinators, the fig wasps, is classic

- monoecious syconium (Fig. 3) is best studied

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Fig. 1. Gynodioecious seed figs containing long-styled pistillate florets

Fig. 2. Gynodioecious gall figs containing short-styled pistillate florets and staminate florets

Fig. 3. Monoecious species with pistillate florets and staminate florets
Fig Wasp Pollination

- Host specificity by female wasps who lay eggs in gall forming fig ovaries but pollinate other ovaries.
Fig Wasp Pollination

- 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
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

Hummingbird Clearwing Moths
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
Moth Pollination

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*Adansonia* - Madagascar

*Brighamia* - Hawaii
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
Bird Pollination - Ornithophily

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

• **NOT a one way shift to bird pollination**

Van der Niet & Johnson (2012)
*Phylogenetic evidence for pollinator driven diversification of angiosperms*
Bird Pollination - Ornithophily

- **NOT** a one way shift to bird pollination

Few shifts to birds in *Salvia* followed by many reversals to bee pollination
Bird Pollination - Ornithophily

- Read . . .

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

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

Bat pollinated flowers

- Parkia (Fabaceae)
- Lecythis (Lecythidaceae)
- Tacca (Taccaceae)

Musa - banana

baobab
cactus
Other Mammal Pollination

- Marsupials, mice, primates - rarer

Kinkajou with *Ochroma* pollen
Other Mammal Pollination

- Marsupials, mice, primates - rarer
- Humans

Ken Wood pollinating *Brighamia*

Honey possum on *Banksia*

Honey possum on coral gum

Neotropical mice

*Combretium* (Combretaceae)