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

Sexual Reproduction in Plants

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

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

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

Fig. 1. Floral diversity in Polemoniaceae. (A) Leptosiphon aureus subsp. aureus; (B) Saltugilia splendens subsp. grantii; (C) Navarretia hamata subsp. hamata; (D) Leptosiphon montanus; (E) Phlox divaricata subsp. laphamii; (F) Cantua buxifolia; (G) Aliciellla latifolia subsp. latifolia; (H) Linanthus orcutii; (I) Saltugilia caruifolia; (J) Loeseliastrum schottii; (K) Cobaea scandens; (L) Eriastrum eremicum subsp. eremicum; (M) Navarretia leucocephala; (N) Ipomopsis tenuifolia; (O) Dayia scabra; (P) Gilia leptantha subsp. leptantha.

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

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 *Archaeofructus* (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

• fusion of floral parts - tubular structures for restricting nectar access

• 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

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)

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

1. Wind - anemophily
2. Water - hydrophily
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

Welwitschia

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

**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

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**Beetle Pollination**

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

**Fly Pollination**

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

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Fly Pollination

- many parasites and saprotrophs utilize carrion flies

Fly Pollination

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

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

Perfume industry

Eulaema (euglossine)
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

Bee & Wasp Pollination

Two European bee mimic orchids pollinated by different species of bees

Bee & Wasp Pollination

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 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

**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

**Catsetum 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

**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)

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**

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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

Few shifts to birds in Salvia followed by many reversals to bee pollination

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

- Read...

Birds are known for their pollination habits, with many species relying on hummingbirds for pollination. 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 plants often have features that attract bats, such as being white and aromatic, with robust flowers that bats can cling to.

Other Mammal Pollination

- Marsupials, mice, primates - rarer
- Humans

Other mammal pollinators include marsupials, mice, and primates, which are often considered rarer pollinators.

Ken Wood pollinating Brighamia

Pollinators like Ken Wood play a crucial role in the pollination of Brighamia flowers, showcasing the diversity of mammal pollinators.