Pollination Biology

...real story of the birds & bees...
and beetles, bugs, butterflies, bats

Sexual Reproduction in Plants

Pollination and seed dispersal important aspects of biosystematics 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
Divergence vs. Convergence

- the dual issue of divergence of closely related taxa, and convergence of distantly related taxa, is important in biosystematic studies of seed dispersal and pollination biology.

- classic example of both divergence and convergence in pollination is the family Polemoniaceae

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

- DNA relationships indicate remarkable divergent and convergent shifts - what kinds of floral changes have been involved with 3 separate shifts to nocturnal hawkmoth pollination?

- neater example is evolution of orchid floral form in Platanthera of Northern Hemisphere - read Hapeman & Inoue paper!
Mullerian & Batesian Convergence

- interesting example of convergence in pollination among three genera of unrelated families in American tropics

  - orange and yellow pigments used as animal signalling
  - coloration pattern used by unrelated, nectar-bearing genera to attract butterflies and bees
  - Mullerian mimicry - reinforcing signal

- a third genus shares the pollination signal but offers no nectar reward
  - Batesian mimicry - exploiting the signal

Seed vs. Pollen Dispersal

- Seed dispersal more important in field of plant geography - the study of distributions of plant taxa

What is Pollination?

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

Why do Animals Pollinate Plants?

- Food reward - in exchange for moving their pollen to another flower
- Nectar - a sugary solution produced in special flower glands called nectaries
  - Nectar concentration matches energy requirements of the pollinator; bird- and bee-pollinated flowers have different sugar concs.
- Pollen - is high in protein, some bees and beetles eat it
  - Flowers sometimes produce two kinds of pollen: a normal and a sterile, but tasty, kind, for the insect

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 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)

**Pollination Syndromes - Caveats**

- not all visitors are pollinators

\[ \text{‘robber’ hummingbird on } Campsis \quad \text{‘robber’ lycanid on } Lotus \]

**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

**Pollination Syndromes - Caveats**

- many plant species with a specific “syndrome” have a surprising “suite” of effective pollinators

\[ \text{Sunbird on bee-pollinated } Asclepias \quad \text{Halictidae bee and vespid wasp pollinating moth-pollinated } Silene \]
Pollination Syndromes - Caveats

- Insect lineages diversified prior to angiosperms, but co-opted by and responded to by angiosperms.

Insect Pollination - Entomophily

Modern insect pollinators

- Beetles -- Coleoptera
- Flies -- Diptera
- Ants -- Hymenoptera
- Butterflies -- Lepidoptera
- Moths -- Lepidoptera
- Bees -- Hymenoptera

ANITA Pollination

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

Primitve type of insect pollination appears to be beetle or fly pollination.

Beetle Pollination

likely that beetle 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 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.

**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

- two specialist families - Aristolochiaceae (birthwort) and Araceae (arum)
  - *Jack-in-the-pulpit*
  - *Skunk cabbage*
  - *Amorphophallus titanum - Titan arum*

- many parasites and saprotrophs utilize carrion flies
  - *Rafflesia* (Rafflesiaceae)
  - *Heliconia* (Heliconiaceae)
  - *Boronia* (Boroniaceae)

Fly Pollination

- two specialist families - Aristolochiaceae (birthwort) and Araceae (arum)
  - *Skunk cabbage*
  - *Amorphophallus titanum - Titan arum*

- 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
- strong UV light patterns
- “nectar guides”

**Solanum** - **Solanaceae**
- Eulaema (euglossine)
- poricidal anthers - **buzz pollination**

**Bee & Wasp Pollination**

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

**Klitheca (euglossine)**

**Perfume industry**
**Bee & Wasp Pollination**

- Flowers are white, blue, yellow - generally not red
- Strong UV light patterns
- *Irruption* (perfumes, pheromones)
- Poricidal anthers - *buzz pollination*
- Zygomatic often - landing platform

**Bee & Wasp Pollination**

- Some plants take advantage of the sex drive of certain insects
- Mirror or bee mimic orchids look like female bees or wasps, and even possess their pheromones
- Males try to mate with them, and in the process they pollinate the plant
- The orchid gets pollinated, but the male bee or wasp only gets frustrated

**Bee & Wasp Pollination**

Two European bee mimic orchids pollinated by different species of bees

**Bee & Wasp 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?
**Catsetum Pollination**

- Male euglossines collect pheromones from flowers
- Male *Catsetum* 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**
- 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.

**Larvae - angiosperms herbivory relationship** (chemical arms race) appear to be more important for coevolution.
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

Adansonia - Madagascar
Brighamia - Hawaii

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

- Darwin predicted a hawkmoth would be found with foot-long proboscis for the Malagasy Christmas Star
- Entomologists scoffed but 40 years later Xanthopan morgani praedicta was discovered on the island with a 12 inch tongue

Angraecum sesquipedale (Orchidaceae)

Bird Pollination - Ornithophily

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

Bird Pollination - Ornithophily

- Convergence of bird flowers around the world

Flower visiting birds are geographically disjunct

Convergence in bird pollination

Convergent structures in bill and body shape in flower visiting birds from four different continents: North America, Australia, South America, and Africa

- hummingbirds
- sunbirds
- honeyeaters

Other birds - Africa, Australia, Hawaii

- hummingbirds restricted to New World
- 13 licks/sec powered by hyoid apparatus
- differential placement of pollen

- honeycreepers
- Tawny-crowned honeyeater
- Yellow plumed honeyeater
- Redstarted sunbird
- Yellow-plumed honeyeater
- Kangaroo paw
**Bat Pollination - Chiroptirophily**

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

**Other Mammal Pollination**

- Marsupials, mice, primates - rarer
- Humans

Ken Wood pollinating *Brachypodium*

Honey possumpollinating *Banksia*

Neotropical mice

Combretum (Combretaceae)