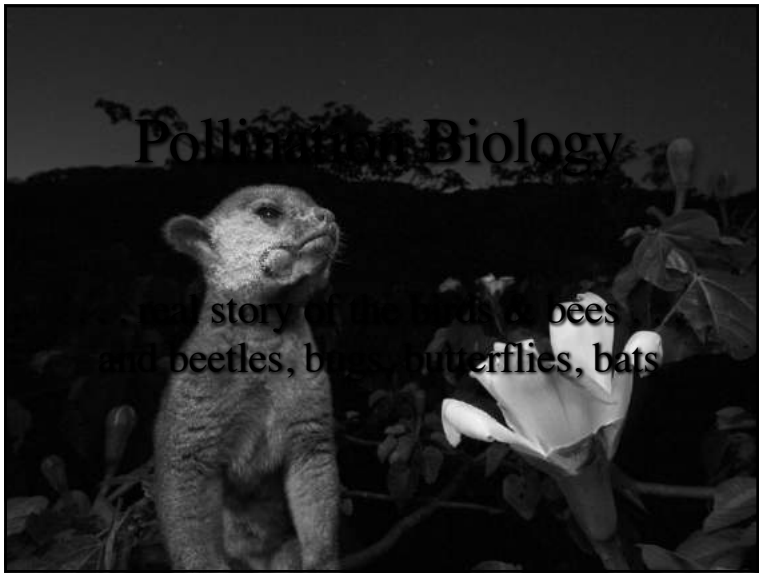


Sexual Reproduction in Plants

- 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:

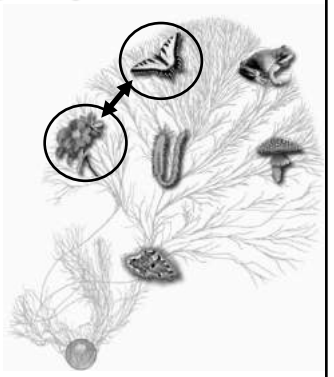
- Gene flow
- Outcrossing vs. inbreeding
- Reproductive isolation
- Speciation
- Co-speciation (coevolution)

Coevolution

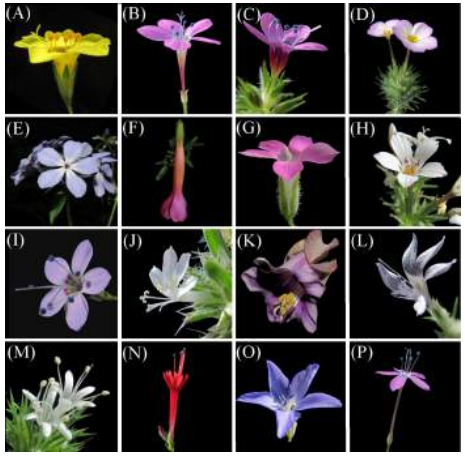
Coevolution – interactions between two different clades as selective forces on each other, resulting in adaptations that increase their interdependency

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



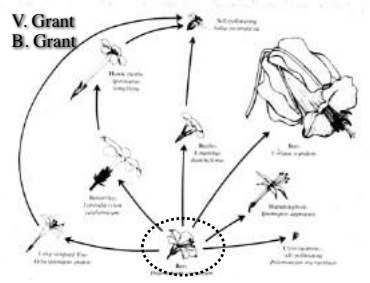
Coevolution

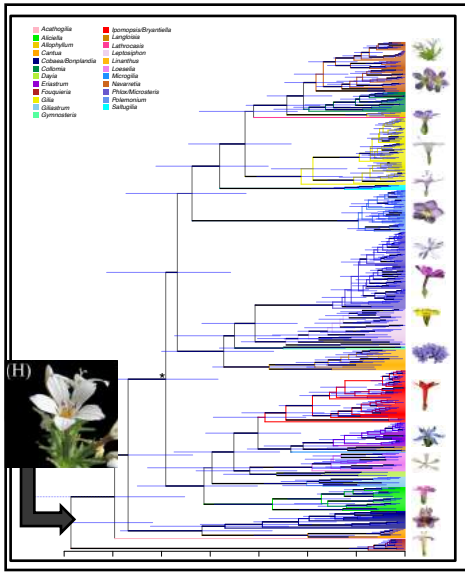


- coevolution with pollinators often leads to convergence and divergence in flowers
- best studied has been the phlox family: Polemoniaceae

Coevolution

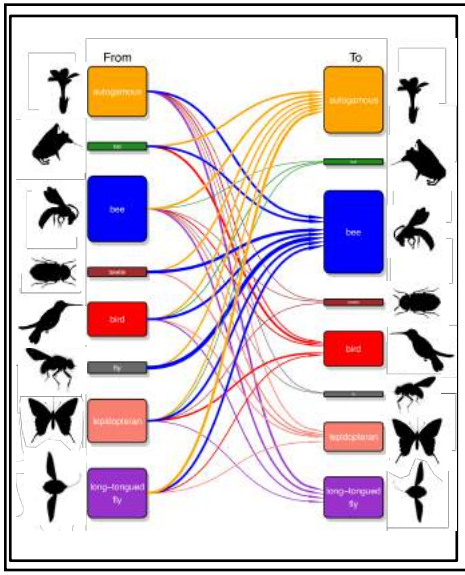
- frequent shifts to different "pollination syndromes" from ancestral bee pollination





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

Ph.D. Work by Jeff Rose

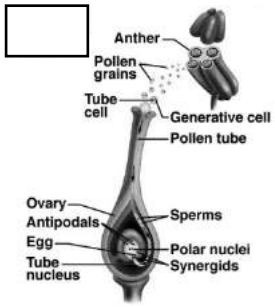


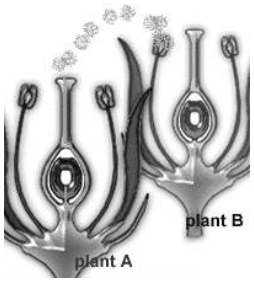
- tested with genomic data (400 nuclear genes)
- bee pollination confirmed as ancestral
- a lot of transitions in pollinators!

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 *Archaefructus* (and in all gymnosperms)

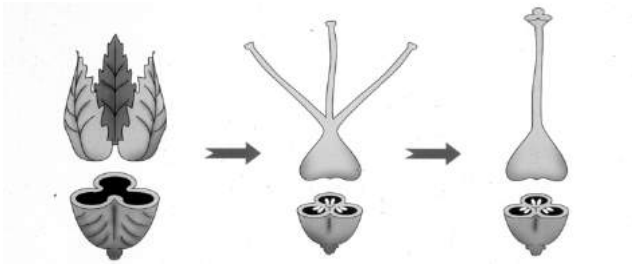
Evolution of the Flower

• 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

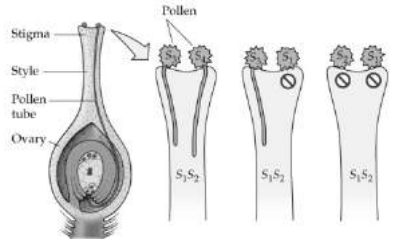
• protogyny or protandry - temporal sequence of anthesis or stigma receptivity

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)

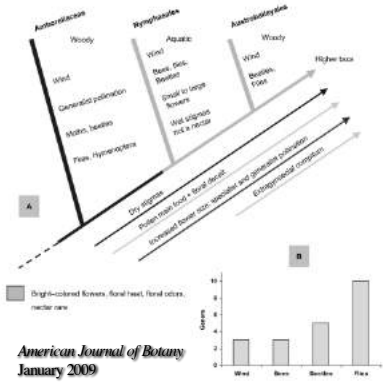
Insect Pollination - Entomophily

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 Pollination



American Journal of Botany
January 2009

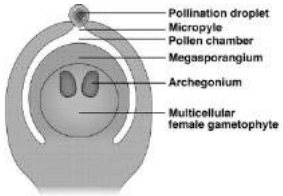
ANA grade has surprising number of pollination types . . .

. . . 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*

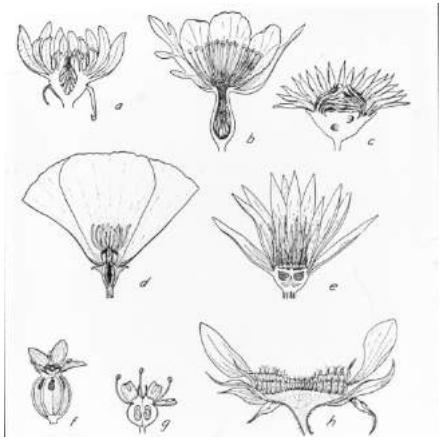



Welwitschia

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


Cyclocepha beetle

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)

Aristolochia species

Fly Pollination

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

Jack-in-the-pulpit

Skunk cabbage

Dragon-root

Fly Pollination

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

Amorphophallus titanum - titan arum

Fly Pollination

• many parasites and saprotrophs utilize carrion flies

Burmanniaceae

Rafflesia (Rafflesiaceae)

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

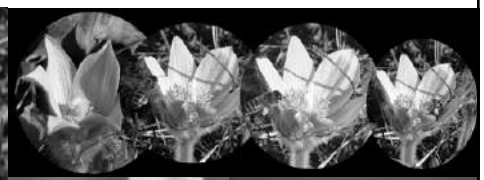
Halictid after nectar

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

- flowers are white, blue, yellow - generally not red
- strong UV light patterns
- "nectar guides"







Bee & Wasp Pollination

- flowers are white, blue, yellow - generally not red
- strong UV light patterns
- "nectar guides"
- 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


mint


Calceolaria


Ophrys

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*


Ophrys

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

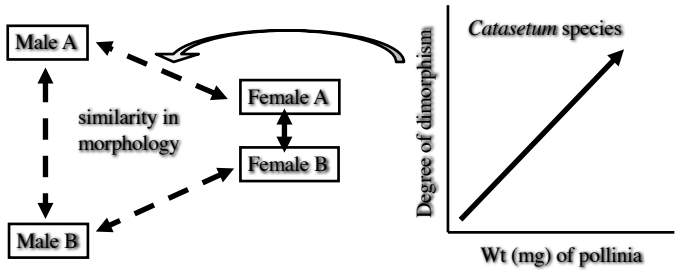
- male euglossines collect pheromones from flowers
- male *Catasetum* flowers discharge pollinia (323 cm/sec)
- euglossine bees learn to avoid male flowers
- female flowers must be different looking to attract the euglossine bees - often upside down requiring new behavior

Male flower triggered

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



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

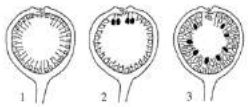


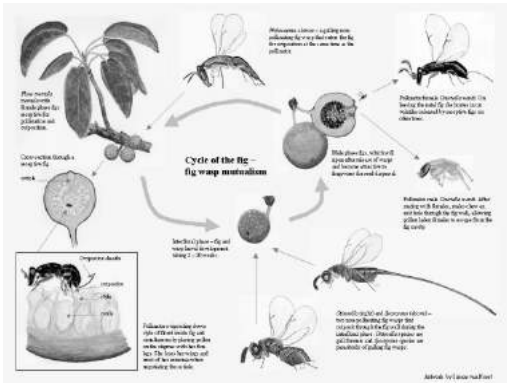
Fig. 1. Gynodioecious seed figs containing long-styled pistillate florets

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



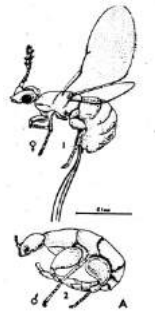
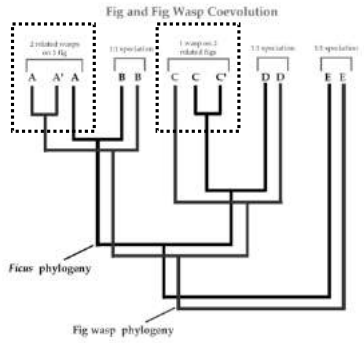


Fig Wasp Pollination

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

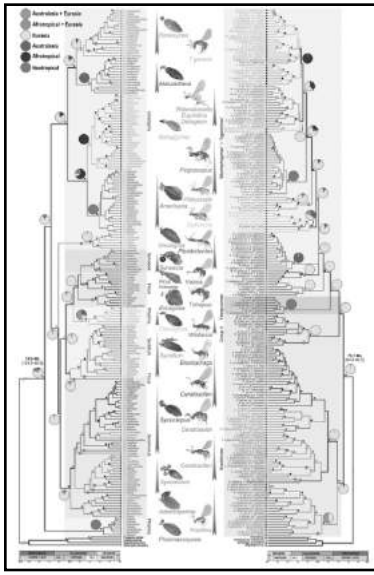


• exceptions occur but generally fit the co-evolution model

• 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)

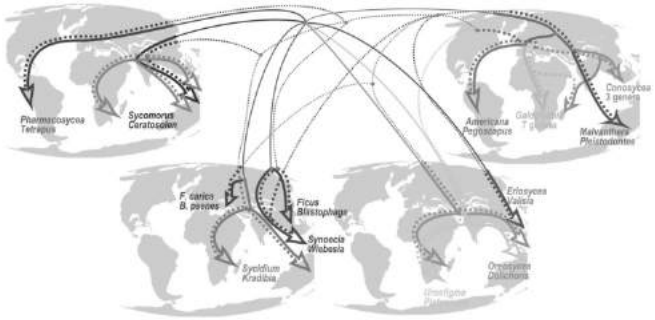


• Co-evolution of the pantropical figs and their wasp pollinators

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

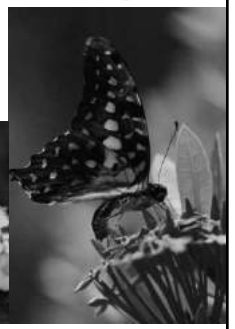
Fig Wasp Pollination

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



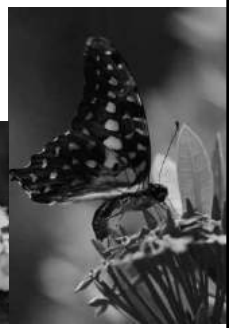
Butterfly Pollination

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

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

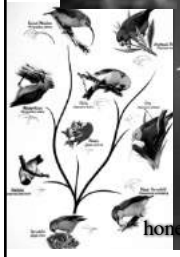
- Night-active (nocturnal) moths visit flowers that are dusk or night blooming, white or pale yellow, fragrant, and with long tubular structures for long proboscis
- no landing platform - moths hover

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

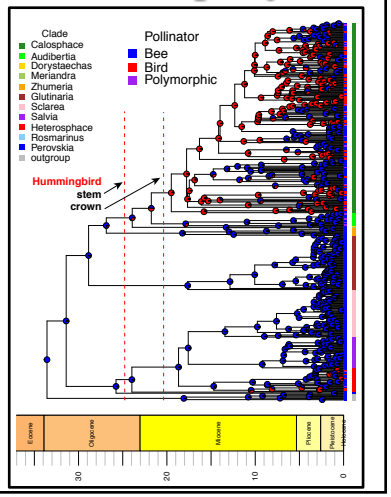


honeycreepers

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 . . .

Hummingbird pollination and the diversification of angiosperms: an old and successful association in Gesneriaceae

Martha Liliana Serrano-Serrano[1,2], Jonathan Rolland[3,4], John L. Clark[5], Nicolas Salamin[1,2,3] and Matthieu Perret[4,1]

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

Other Mammal Pollination

- Marsupials, mice, primates - rarer

Other Mammal Pollination

- Marsupials, mice, primates - rarer
- Humans

Ken Wood pollinating *Brighamia*

Neotropical mice

Combretum (Combretaceae)

Honey possum on *Banksia*

Honey possum on coral gum