Why Flowers Are Beautiful
An Example of Coevolution

Coevolution

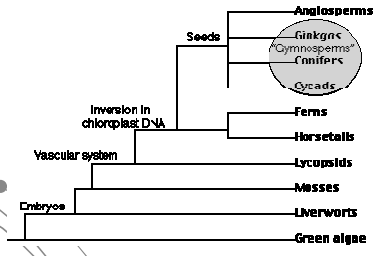
Coevolution is the the mutual evolutionary influence between two species (the evolution of two species totally dependent on each other). Each of the species involved exerts selective pressure on the other, so they evolve together.

Coevolution is often seen in a number of species of flowering plants that coevolved with specific pollinators (insects, bats, etc). The pollinator gets a reward such as nectar for pollinating the plant.

Moth-pollinated plants often have spurs or tubes the exact length of a certain moth's "tongue." For example, Charles Darwin predicted the existence of a moth in Madagascar based on the size and shape of a flower he saw there.

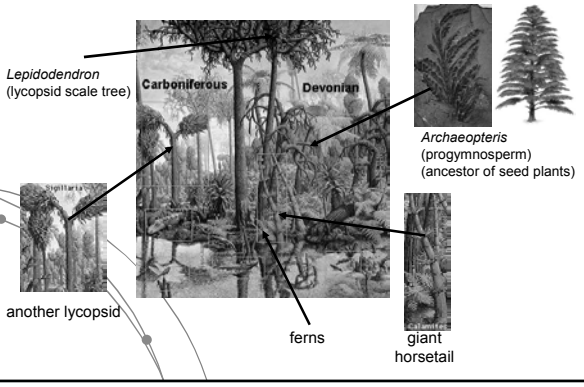
The moth was actually discovered about 40 years later..

Evolution of Plants: Cladogram



First appearance of groups agree fairly well with interpreted clades

Devonian-Carboniferous
First Widespread Forests
(mostly horsetails, scale trees, progymnosperms)



Permian

Widespread extinction of scale trees and many ferns
(although some did survive)
Appearance of gymnosperm* plants related to conifers

Lepidodendron
(scale tree)

Lebachia
(relative of conifers)

* High school review: Gymnosperms include plants whose seeds are not enclosed in an ovule (like a pine cone). Gymnosperms *usually* have needles that stay green throughout the year. Examples are conifers such as pines, cedars, spruces and firs. Some gymnosperms do drop their leaves - ginkgo, dawn redwood, and bald cypress.

Triassic

Lower Storey: Ferns, cycads, gingkos
Upper Storey: Conifers & Tree Ferns
Two new gymnosperm plant groups become important : **Ginkgos and Cycads**

Conifer

Tree Fern

Gingko: leafy, tree-forming plant with "vomit" fruit.

Cycad:
palm-like leaves, fibrous knotty "bark".

Jurassic

Much the same as Triassic but a little more diverse at generic and species level.

Lower Storey: Cycads, Ginkgos, Ferns
Upper Storey: Conifers

conifer

cycad

cycad

horsetail

fern

The Angiosperm Radiation: angiosperms are spectacularly diverse today.

Angiosperms first appear in the early to middle Cretaceous

At the species level, in both pollen and macrofossil counts, they become increasingly diverse through the Cretaceous.

Their initial center of diversity was in the tropics, but they spread towards the poles through the Cretaceous.

By the end Cretaceous, angiosperm species dominated tree floras in many places.

Ground cover is rarely preserved. One ash-fall covered flora from Wyoming shows a strange pattern. Angiosperm herbs do dominate the species list. However biomass, the amount of plants as measured by weight (or abundance), is still dominated by cycads and ferns (typical early Mesozoic plants).

We don't know how common this pattern is, but it is certain that after the Cretaceous-Tertiary extinction, biomass of low vegetation is dominated by angiosperms in most places.

Cretaceous

Lower Storey: Angiosperms* appear and become dominant over Cycads, Ginkgos, & Ferns

Upper Storey: Conifers continue, but experience some replacement by Angiosperms

* High school review: Angiosperms have a seed surrounded by an ovule (think of an apple). Angiosperms are trees have broad leaves that *usually* change color and die every autumn. Oaks, maples and dogwoods are examples of deciduous trees. Some angiosperms that hold their leaves include rhododendron, live oak, and sweetbay magnolia.

Dale Russell (Canadian Paleontologist Who Has Defected to the U.S.):

"Before flowering plants appeared, the world was like a Japanese garden: peaceful, somber, green; inhabited by fish, turtles, and dragonflies. After flowering plants, the world became like an English garden, full of bright color and variety, visited by butterflies and honeybees. Flowers of all shapes and colors bloomed among the greenery."

Cretaceous

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Conifer

Angiosperm (this one is forerunner to sycamore)

Angiosperm (look for these this spring If it ever warms up)

Angiosperm (palm)

Advantages of Being an Angiosperm

Gymnosperms rely on wind to carry pollen from plant to plant (lottery 6-49 approach)

Angiosperms have flowers to attract animal pollinators. Pollination no longer exclusively by wind.

Allows plants to more carefully controlled delivery of pollen to the same species.

An intimate relationship (but not in that kind of way)

The common snapdragons that many people plant in their gardens are designed for a bumblebee of just the right weight to trip the opening mechanism

Possible Scenario for Evolution of Angiosperms

Early gymnosperms and angiosperms were wind-pollinated.

Like modern gymnosperms, the ovule exuded droplets of sap to catch pollen grains.

Insects (beetles) on the plant found this protein/sugar mix and used it as food.

Insects became dependent on this food source and started carrying pollen from plant to plant.

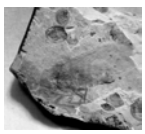
Beetle-pollination must have been more efficient than wind for some species, so there was natural selection for plants that attracted insects.

Next to occur would have been the evolution of **nectaries**, nectar-secreting structures, to lure the pollinators.

Development of white or brightly-colored, conspicuous flowers to draw attention to the nectar and/or other food sources would also have occurred.

The carpel (female reproductive structure) was originally leaf-shaped. It became folded on itself to enclose and protect the ovule from being eaten by the pollinators (hence Angiosperms). Plants with protected ovules would have been selected over ones with ovules that got eaten.

By the beginning of the Cenozoic Era (65 mya), the first bees, wasps, butterflies, and moths had evolved. The significance in this is that these are insects for which flowers are often the only source of nutrition for the adults.

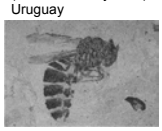


Cretaceous bee from Liaoning, China

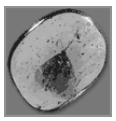
Fossil beehive made by soil-nesting bees (Late Cret-Early Tert.) Uruguay

Fossil wasp (Oligocene) In volcanic ash

Fossil wasp (Neogene) In amber



Fossil wasp (Paleogene) In volcanic ash



Fossil butterfly (Neogene) In amber

From this point on, certain plant and insect species have had a profound influence on one another's evolution. A flower that attracted specific pollinators on a regular basis had an advantage (less wasted pollen) over flowers that attracted "promiscuous" pollinators. It is also an advantage for the pollinator to have its own "private" food source because there is, thus, less competition. The varied shapes, colours, and odors of flowers allowed sensory recognition by pollinators and excluded unwanted, indiscriminate pollinators.

Today, over 65% of Angiosperms are insect-pollinated and 20% of insects, at least at some stage, depend on flowers for their food.

How Did Insects Start Pollinating ?

For pollination to work, to be effective, a relationship must be established between the pollinator and the blossom to be pollinated, involving regular visits by pollinator:

These visits (whatever the cause) should constitute a regular part of the life activities of the animal.

The visitor must perform or at least try to perform certain tasks that are tied in with the structure and function of the blossom. Insects that happen to visit a couple flowers and transfer pollen don't count as pollinators of that species unless they regularly visit that species of plant for some specific reason.

While the exact role as pollinators played by such visitors is unclear, the possibility exists that a more direct insect-blossom relation may develop out of such a behaviour.

This may be true of hummingbirds. They eat small insects and spiders (you can't live on sugar alone) and may have originally been attracted to flowers to eat the insects on them.

The plant must supply:

A. Some kind of reward (food?) for the pollinator (nectar, pollen).

B. Some kind of attractant to advertise the presence of the reward. This could be a direct attractant such as odour, colour, shape, or texture, or an indirect attractant such as providing prey for predators.

C. A means of putting pollen onto the pollinator such that it is effectively transferred to the next flower visited.

Adaptations of Flowers Depends on the Type of Pollinator

Bees don't see red, but do see yellow, blue, and UV. Thus, bee-pollinated flowers are mostly yellow or blue with UV nectar guides (landing patterns) to guide the bee. They usually have a delicate, sweet scent, and a small, narrow floral tube to fit the tongue-length of that species of bee. The flowers are sturdy and irregularly-shaped with a specifically-designed landing platform. For example, snapdragons will only open for a bee of the right weight.

Butterflies are diurnal and have good vision (can see red) but a weak sense of smell. They are perching feeders.

Butterfly-pollinated flowers are brightly-colored but odourless. Often, these flowers occur in clusters (Compositae, milkweed) and/or are designed with a "landing platform."

Butterflies walk around on flower clusters probing the blossoms with their tongues. Each flower has a tube of suitable length for the butterfly's tongue.

Moths are nocturnal, have a good sense of smell, and are hover-feeders.

These flowers pollinated by moths are white or pale coloured so they are visible at night, and may only be open at night.

Typically, these flowers have a strong, sweet scent (again, maybe only at night) and deep tubes to match the length of the appropriate moth's tongue.

The petals are flat or bent back (recurved) so the moth can get in.

MOONFLOWER
Ipomoea alba

Birds, especially hummingbirds have good eyes which expecially can see red but poor senses of smell. These flowers are brightly-colored, especially red, but have no smell, and have recurved petals so they are out of the way.

Hummingbirds are hover-feeders, and these flowers (for example, columbine or fuchsia) are designed to dust the bird's head (and back) with pollen

Some flies are attracted to rotting flesh. These flowers may be nondescript or may be brownish-red with a bad, rotten smell as their main attractant.

Some flowers, near the ground, are pollinated by **ants** or **ground beetles**.

Skunk cabbage

On the other hand, some plants have not specifically coevolved with a certain pollinator.

Canada thistle flowers are visited by a wide variety of bees, beetles, and butterflies.

Similarly, goldenrod flowers attract a variety of beetles, wasps, and other small insects which, in turn, may be food for waiting spiders.

…But Life Isn't Always Fair

Some orchids use sexual deception

They exude a chemical similar to the pheromone of a female native wasp. This scent attracts a male wasp.

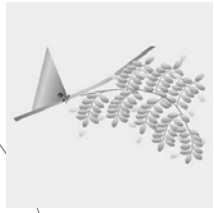
A male who smells a flower of this orchid, thinks it's a female wasp, gets closer and the flower looks like a female, lands on it and it feels like a female, tries to copulate, gives up in frustration, and goes on to the next thing that smells like a female, and ends up transferring pollen.

When it lands on the labellum (the tongue of the flower), a trigger mechanism tips it towards the column which houses the pollen and the receptive stigma. Pollen is either removed or deposited in this process .

Another Example of Coevolution

Acacia ants and acacia trees

Acacias are small, Central American trees in the Leguminosae. They have large, hollow thorns. The acacia ants live in the thorns. On the tips of its leaflets, the plant makes a substance used by the ants as food. The ants defend the tree from herbivores by attacking/stinging any animal that even accidentally brushes up against the plant. The ants also prune off seedlings of any other plants that sprout under "their" tree



Seed Dispersal

Angiosperms also have **fruits** covering their seeds:

Use animals to disperse seeds, rather than the wind (via feeding, fur-sticking burrs and other methods)

Unusual example: The Cashew Apple has irritating resin just below seed coat (similar effect to poison ivy- but in your mouth !)

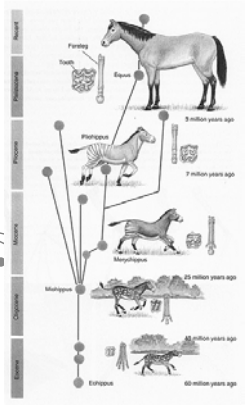
- animal takes off with succulent "fruit" (actually not a true fruit because it does not contain the seed), but leaves seed alone

Still, some plants held on to wind as a pollinator But…this also involved coevolution

Grasses are flowering plants (Angiosperms), but their flowers are very small, simple, not very attractive to pollinators -- grasses instead rely on **winds** to disperse their pollens and seeds. As global climate dried beginning in the Late Oligocene Epoch, grasses spread into what had previously been forested regions, and various herbivores began evolving toward specialization on grass diets.

Hyracotherium, the first horse (Eocene), was a browser about the size of a small dog. It had simple low-crowned teeth, and used four toes on each foot for getting around.

Coevolution of Grazers and Grasses



Grasses contain cellulose reinforced by silica

Since tooth enamel is softer than silica, herbivore teeth wear down during grazing.

Modern ungulates thus evolved hard, continuously growing cheek teeth and distinctive stomachs for processing this new kind of food.

Grasses, in turn, evolved to continue growing even after severe grazing or cropping.

Since grasses produce open terrains, herbivores developed greater mobility, and their carnivores followed suit, evolving modern fauna more adapted
for speed.

All of this co-evolution accelerated during the last 15 MYa, when grasslands came to dominate many of the earth's ecosystems.

Ancient Example of Coevolution: Platycerid snails co-occur with Devonian and Carboniferous crinoids

Benefit to snails: food (ate crinoid's faeces), as indicated by attachment to anal tube region

Benefit to crinoid: prevention of fouling by own faeces

Some platycerid species are only found with certain species of crinoid, presumably coevolving with the crinoids.

END OF LECTURE