



Pollination Mechanisms and Plant-Pollinator Relationships

Pollination is one of the most fascinating processes in the natural world. Pollination is how flowering plants reproduce. The process involves the transfer of pollen from the male parts to the female parts of the same or another plant. For some plants, this movement of pollen requires the action of another organism, a pollinator. Plants and their pollinators form a mutualistic relationship, a relationship in which each benefits from the other. In the plant-pollinator relationship, the pollinator benefits by feeding on food rewards provided by the flower, primarily nectar and pollen. In return, the plant benefits as the pollinator moves from flower to flower, transferring pollen as it forages for the food rewards. This movement of pollen allows the plant to reproduce and to exchange genetic information with other plants. Most flowering plants require relationships with pollinators to reproduce.

Unfortunately, pollinator populations worldwide are in decline, which negatively affects the flowering plants that depend on them. It also means trouble for humans, as we all depend on the services of pollinators in many different ways, from the food we eat to the air we breathe. This decline in pollinator populations is due in part to human practices that have contributed to a loss of wild and flower-rich habitat. By changing some of our practices, such as how we manage flowering plants in our gardens and farms, we can help conserve these vital pollinator species.

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Taxonomy basics

Taxonomy is the field of study concerned with identifying, naming and classifying organisms. An understanding of taxonomy can help you select plants that are beneficial to the pollinators in your area.

Plants and animals are often called by different names in different locations. The mountain lion (*Puma concolor*) is also known by the common names puma, cougar and catamount. Conversely, the same common name may refer to completely different species. For example, pileated woodpeckers (*Dryocopus pileatus*) are called woodcocks in some areas, but the American woodcock (*Scolopax minor*), or timberdoodle, is not a woodpecker at all. This ambiguity in how common names are applied is why knowledge of the scientific names of plants is necessary to ensure you are selecting the plants you meant to select.

Scientific naming system

Early botanists and zoologists realized that a system of identifying organisms that eliminated such confusions would be essential for communicating descriptions of flora and fauna. In the 1700s, Carl Linnaeus, a Swedish physician and botanist, popularized a naming system in which a species is identified with two Latin names, Latin being the scientific language of the time. In this system, each organism is given a unique combination of two names, one for the genus, which is a group of related species, and one for the species. This system is referred to as binomial nomenclature, which simply means “naming with two names.” Scientific names (Genus + species) are denoted in italics, by convention, so they are easily

Authors

Candace Galen and Levi Storks of University of Missouri, Biological Sciences; and Ela Carpenter, Jackie Dearborn, Julia Guyton and Sean O’Daniels of University of Missouri, Fisheries and Wildlife Sciences

recognizable in publications, as illustrated in the paragraph above. Subsequent uses of the same genus name within a publication are often abbreviated to the first letter, for example, *D. pileatus*.

Taxonomic levels

The Linnaean binomial system gives us a way to identify and communicate species names across geographic regions and languages, but the field of taxonomy deals with classifying organisms from the broadest of shared characteristics down to those found only in each unique species. Traditionally, there are seven main taxonomic levels, or hierarchies: kingdom, phylum, class, order, family, genus and species. To examine each level more in depth, consider the taxonomy of a very well-known insect pollinator, the common, or European, honey bee (*Apis mellifera*) (Table 1).

Taxonomic levels

High school biology students often learn some variation of the mnemonic “King Phillip Came Over From Germany Sunday” as a means of remembering the order of the taxonomic levels.

- K**ingdom
- P**hylum
- C**lass
- O**rders
- F**amily
- G**enus
- S**pecies

Table 1. Taxonomy of the European honey bee.

| Taxonomic level | Scientific name | Common name |
|-----------------|------------------|-----------------------------------|
| Kingdom | Animalia | Animals |
| Phylum | Arthropoda | Insects, spiders, crabs, lobsters |
| Class | Insecta | Insects |
| Order | Hymenoptera | Ants, bees, wasps |
| Family | Apidae | Social bees (hive or colony) |
| Genus | <i>Apis</i> | Honey bees (four species) |
| Species | <i>mellifera</i> | European honey bee |

The variety of organisms narrows at each level of the taxonomy, as indicated by the associated common names. Organisms are grouped at each level based on shared features. As the number of features they have in common increases, fewer organisms exist that share them all. This description of how closely related organisms are to one another is the central theme of taxonomy. Shared features that are useful for taxonomy are often physical traits, such as number of wings or legs; however, in some cases, behaviors can also be useful, as in the family Apidae, which consists of hive-nesting or social bees.

Cultivated plant species are additionally classified as varieties. Different varieties have been modified through crop-breeding programs to either enhance or eliminate traits present in the native, or wild-type, organism. The taxonomy of the wild cabbage (*Brassica oleracea*) serves as an example (Table 2). It and several other of our common vegetables are varieties of the same species.

Table 2. Taxonomy of the wild cabbage.

| Taxonomic level | Scientific name | Common name |
|-----------------|-----------------|---|
| Kingdom | Plantae | Plants |
| Phylum | Magnoliophyta | Flowering plants (angiosperms) |
| Class | Magnoliopsida | Dicotyledons (dicots) |
| Order | Capparales | |
| Family | Brassicaceae | Mustard family |
| Genus | <i>Brassica</i> | Mustards |
| Species | <i>oleracea</i> | Cabbage, broccoli, Brussel sprouts, cauliflower, collard greens, kale, kohlrabi |

Naming systems for plants and animals are similar, but have a few differences, especially at the family level. Animal family names end with *-idae* (for example, Apidae, Nymphalidae), whereas plant family names end with *-aceae* (for example, Fabaceae, Rosaceae). This chapter mainly discusses plant-pollinator relationships at the family level, so a general understanding of these naming conventions will be helpful.

The usefulness of taxonomy

To gain an understanding of how knowledge of taxonomy can be useful, examine the following plant-pollinator relationships.

Traits shared at the family level are often the most useful in recognizing and describing related organisms. For plants, these traits are not always visible. For example, plants of the Fabaceae family are excellent soil nitrogen fixers, making them ideal cover crops. Honey bees can often be found — and stepped on — in patches of white clover (*Trifolium repens*) (Table 3). However, white clover is not native to North America, so producers interested in using cover crops in their fields may want to investigate native Fabaceae, such as purple prairie clover (*Dalea purpurea*), which may also better support native pollinators such as bumble bees (*Bombus* spp.). Bumble bees share the Apidae family with honey bees (*A. mellifera*) and carpenter bees (*Ceratina* spp. and *Xylocopa virginica*), among others.

Taxonomy also reveals that species that may outwardly appear to be unrelated, actually have more in common than is first apparent. People are often surprised to learn that watermelons (*Citrullus lanatus*) and cucumbers (*Cucumis sativus*) are in the same family, Cucurbitaceae, which also includes cantaloupe, honeydew, pumpkins and squash (Table 4).

All members of this family have imperfect flowers, meaning flowers that have either male or female reproductive organs, and they make pollen grains that are too heavy and sticky to be moved by wind. Thus, pollinators are required for these plants to produce fruits. Honey bees can provide this service, but our native bumble bees may be better suited for this task early in the season because they remain active during cooler, wetter weather unlike honey bees.

Apples (*Malus domestica*) also require pollinators to produce fruits. Although apple blossoms have perfect flowers, that is, flowers that contain both male and female structures, most varieties are self-sterile, meaning a tree cannot pollinate its own flowers. Thus, for trees to produce apples, pollen must be transferred from one tree to another, a process called cross-pollination. As is the case with cabbage (*B. oleracea*), the many varieties of apple are all *Malus domestica* (Table 5).

Table 3. Taxonomy of the white clover.

| Taxonomic level | Scientific name | Common name |
|-----------------|------------------|--------------------------------|
| Kingdom | Plantae | Plants |
| Phylum | Magnoliophyta | Flowering plants (angiosperms) |
| Class | Magnoliopsida | Dicotyledons (dicots) |
| Order | Fabales | |
| Family | Fabaceae | Pea family (legumes) |
| Genus | <i>Trifolium</i> | Clovers |
| Species | <i>repens</i> | White clover |

The abbreviation spp.

When spp. follows a genus name, it simply indicates that the name refers to multiple species in that genus.

Table 4. Taxonomy of the watermelon and the cucumber.

| Taxonomic level | Watermelon | Cucumber |
|-----------------|------------------|----------------|
| Kingdom | Plantae | Plantae |
| Phylum | Magnoliophyta | Magnoliophyta |
| Class | Magnoliopsida | Magnoliopsida |
| Order | Cucurbitales | Cucurbitales |
| Family | Cucurbitaceae | Cucurbitaceae |
| Genus | <i>Citrullus</i> | <i>Cucumis</i> |
| Species | <i>lanatus</i> | <i>sativus</i> |

Table 5. Taxonomy of the apple.

| Taxonomic level | Scientific name | Common name |
|-----------------|------------------|--------------------------------|
| Kingdom | Plantae | Plants |
| Phylum | Magnoliophyta | Flowering plants (angiosperms) |
| Class | Magnoliopsida | Dicotyledons (dicots) |
| Order | Rosales | |
| Family | Rosaceae | Rose family |
| Genus | <i>Malus</i> | Apple and crab apple |
| Species | <i>domestica</i> | Apple ("orchard", domestic) |

Other fruit trees within the Rosaceae family include peach (*Prunus persica*) and cherry (*P. avium*), both of which also come in many varieties.

Mason bees (*Osmia* spp.) are solitary nesting, native pollinators that specialize in pollinating Rosaceae fruit trees. Because of this specialization, they are often called orchard bees. There are 140 species of mason bee in North America. The blue orchard bee (*Osmia lignaria*) is one of the few native bees managed for agriculture due to its efficiency as a pollinator. Mason bees belong to the family Megachilidae, as do leafcutter bees (*Megachile* spp.), another common orchard pollinator that shares the solitary nesting trait (Table 6).

Table 6. Taxonomy of the blue orchard bee and the leafcutter bee.

| Taxonomic level | Blue orchard bee | Leafcutter bee |
|-----------------|------------------|--------------------------------|
| Kingdom | Animalia | Animalia |
| Phylum | Arthropoda | Arthropoda |
| Class | Insecta | Insecta |
| Order | Hymenoptera | Hymenoptera |
| Family | Megachilidae | Megachilidae |
| Genus | <i>Osmia</i> | Megachile |
| Species | <i>lignaria</i> | 242 species (in North America) |

Shared family traits

Pumpkins (*Cucurbita pepo*) belong to the Cucurbitaceae family, as do watermelon and cucumber. Therefore, pollinators will be required for plants to produce pumpkins. If your pumpkin plants are not producing as expected, try raising honey bees on your farm.

Multipurpose plants

Planting cover crops, such as clovers, between rows of cash crops can not only improve soil nitrogen levels but also increase cash crop yields as a result of the presence of pollinators attracted by the cover crops.

Selecting plants for pollinators

Research the family, genus or species names on plant tags before buying plants for your garden and flower beds. Beware, some tags are more informative than others.

Bees are by no means the only insect pollinators worthy of mention. Flies (order Diptera), beetles (order Coleoptera), butterflies and moths (order Lepidoptera), and wasps (order Hymenoptera) are important pollinators as well, and some have developed specialized relationships with their preferred host plants. Some of these specialized plant-pollinator relationships are described in later sections.

Applying taxonomical knowledge

An understanding of plant and pollinator taxonomy can be valuable for mastering knowledge of pollination and improving your property's capacity to support pollinators and thus your harvest.

Taxonomy can help you recognize that plants that may outwardly appear unrelated, such as watermelons and cucumbers, are in fact closely related and thus may share a need for the same animal pollinators.

Taxonomy can also inform sustainable agriculture practices. For example, plants in the Fabaceae family can help replace soil nitrogen levels between crop rotations while benefiting native pollinators, such as bumble bees.

With a basic knowledge of taxonomy, a quick glance at the taxonomic hierarchy of an organism provides information on its pollination or host plant requirements, and thus on benefits of its presence on your land.

To practice applying your taxonomical knowledge, fill in the chart below with the complete taxonomy of the golden northern bumble bee (*B. fervidas*) and the red clover (*T. pratense*) using only information presented in this section.

| Taxonomic level | Red clover | Golden northern bumble bee |
|-----------------|------------|----------------------------|
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Flower anatomy

Flowers are the reproductive structures of angiosperms, or flowering plants. Angiosperms comprise most of our food and fiber crops. Nearly all flowering plants require pollination to produce seeds and fruits; these include most of our edible fruit and vegetable crops.

In pollination, pollen is transported from the male parts of a flower to the female parts of the same flower or a different flower of the same species. Pollen is a fine, powdery substance made up of microscopic particles or grains. Pollen, especially the small light grains adapted to wind pollination, is usually the cause of spring allergies.

Plants have evolved many different shapes, sizes and colors of flowers to attract animal pollinators. These animal-pollinated flowers are typically brightly colored and fragrant, whereas wind-pollinated flowers are typically smaller, dull in color and unscented.

From a pollinator's perspective, a flower provides food, typically in the form of nectar and pollen. Nectar is produced by glands called nectaries, which can be located on any part of the plant but are commonly found in the flower. These floral nectaries are typically located near the base of the flower, requiring pollinators to contact the flower's reproductive structures while sipping the nectar and, thus, facilitating pollination.

Basic flower anatomy

A knowledge of basic flower anatomy can aid in understanding how plants reproduce (Figure 1). Flowers are generally comprised of four whorls of parts: the calyx, corolla, androecium and gynoecium. Each whorl contains a set of organs: sepals, petals, stamens and carpels, respectively.

Calyx. Sepals of the calyx look similar to leaves and surround the unopened bud. The sepals protect the flower before it opens and may remain attached to the base of the flower afterward. Sepals are typically green and smaller than the petals, but they can also be large and brightly colored, resembling petals. When sepals and petals are identical in appearance, they are called tepals.

Corolla. The corolla typically encircles the reproductive parts of the flower and may be continuous, lobed, or divided into separate petals. Petals also help protect the reproductive organs of the flower, but primarily serve to attract pollinators. To succeed in attracting pollinators, petals are often brightly colored and fragrant.

Androecium. The next whorl in, the androecium, is comprised of stamens, the male reproductive organs of the flowering plant. Stamens are made up of two parts: a thin stringlike stalk called a filament and the pollen-producing organ at its tip, called the anther.

Gynoecium. The innermost whorl of the flower, the gynoecium, contains the female reproductive parts of the flowering plant. The carpels that make up the gynoecium may be separate or fused to form a compound pistil. The pistil is made up of three parts: the ovary, the style and the stigma. The ovary holds the unfertilized seed, or ovules, and typically develops into a fruit once pollination takes place. The stigma is the uppermost section of the pistil at the tip of the style, and receives the pollen. To catch the pollen, the stigma is commonly sticky, or covered with small hairs or grooves.

Other structural parts. At the base of a flower are two more structural parts, the receptacle and pedicel. The receptacle is simply the base of the flower, and it is supported by the pedicel, or flower stalk.

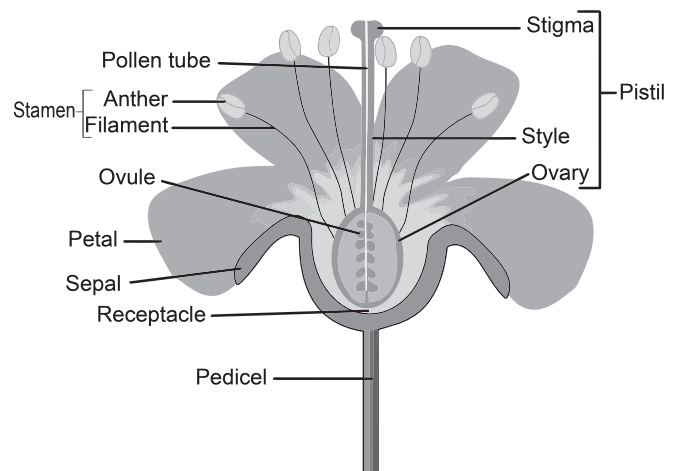


Figure 1. Basic flower anatomy: a perfect flower containing male and female organs.

Pollination's role in reproduction

Pollination is the first step in sexual reproduction of seed plants. Most angiosperms have perfect flowers, but some produce imperfect flowers. A perfect flower contains male and female reproductive organs (Figure 1). An imperfect flower has only male or only female reproductive organs (Figure 2).

To describe a plant as a whole, botanists use the terms monoecious and dioecious (Figure 2). A monoecious plant has male and female reproductive organs on the same plant. Monoecious plants can have either perfect or imperfect flowers. Examples of monoecious species in Missouri are wild plum (*Prunus americana*), with perfect flowers, and pumpkins, with imperfect flowers. Dioecious plants have male and female flowers on separate plants. The native persimmon (*Diospyros virginiana*) is a dioecious plant commonly found in Missouri. Because dioecious plants have male and female flowers on separate plants, two plants of different sexes need to be near each other for fruit production to occur. Keep this need in mind when selecting plants for your garden, and make sure you have ample space for plants of both sexes.

Pollination Q&A

Q: Why aren't my trees producing fruit?

A: It could be that the plants are dioecious and you have only females in your yard.

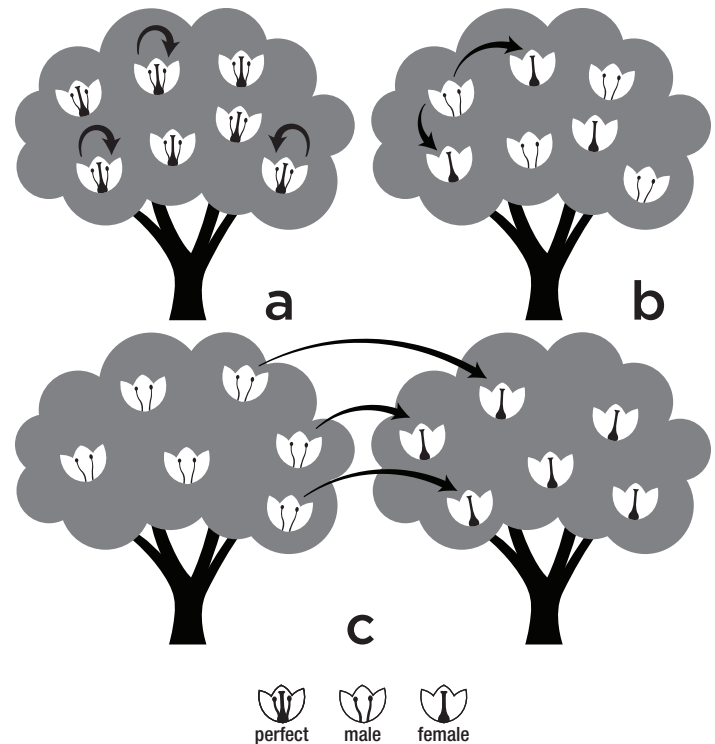


Figure 2. Monoecious plants have either (a) perfect flowers or (b) imperfect flowers. Dioecious plants have (c) male and female flowers on separate plants.

Other terms used to describe flowers

- Complete — Flowers with sepals, petals, stamens and pistil
- Incomplete — Flower lacking one or more whorls of parts
- Pistillate — Flowers with only female parts
- Staminate — Flowers with only male parts

Flower shapes

Flowers come in various shapes and sizes (Figure 3). These differences are often related to their mode of pollination.

Flowers of wind-pollinated plants typically have very small or no petals, making it easier for airborne pollen to come in contact with the stigma.

Flowers of animal-pollinated plants usually have larger showy petals of different shapes and sizes to attract pollinators. Flower shape can provide a clue as to what animals might serve as pollinators for a plant. For example, lipped, or labiate, flowers usually provide a platform on which bumble bees can land before entering the flower, whereas long tubular flowers are frequented by hummingbirds, who hover while probing the deep flowers with their long beaks. Some common flower shapes are described below.

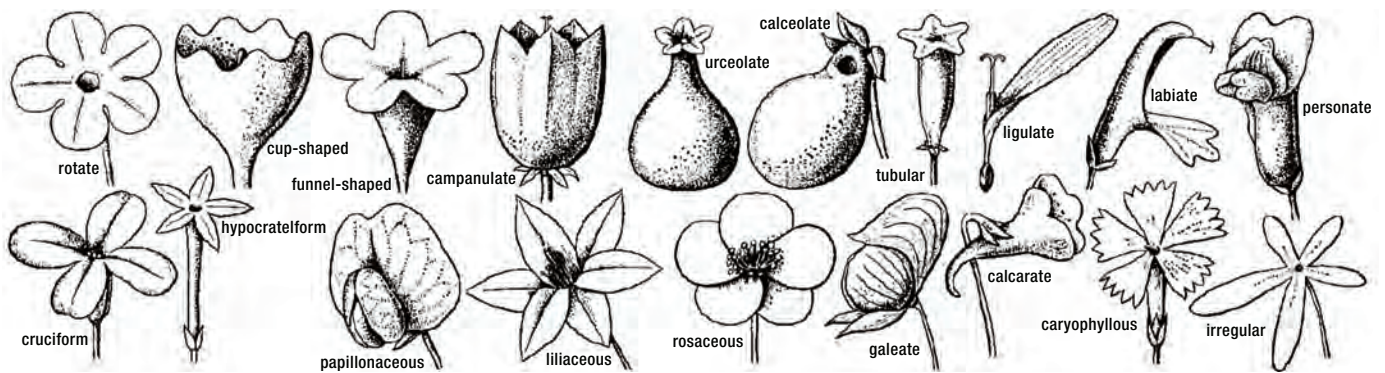


Figure 3. Flower shapes.

- Campanulate — Bell-shaped flower
- Cruciform — Cross-shaped flower with four petals
- Cupuliform — Cup-shaped flower without spreading petal tips
- Funnelform — Funnel-shaped flower that broadens from the base to the tip
- Labiate — Flower with liplike petals
- Reflexed — Flower with petals that are curved backwards
- Salverform — Tubular flower that spreads at the tip
- Spurred — Flower with petals formed into spurs that usually contain nectar
- Stellate — Star-shaped flower, usually with five petals
- Tubular — Cylindrical, tube-shaped flower

Inflorescence

Flowers can be arranged singly or in clusters attached to a central stem. When flowers are arranged in clusters, or groups, on a central stem, they form an inflorescence. The main stem of an inflorescence is called the peduncle. Inflorescences come in many shapes and arrangements (Figure 4).

The flower head of a sunflower (genus *Helianthus*, family Asteraceae) is actually an inflorescence, not a single flower. Sunflowers are made up of hundreds of tiny flowers called florets. This multitude of florets is very effective at attracting pollinators, producing hundreds of seeds that provide food for various animals.

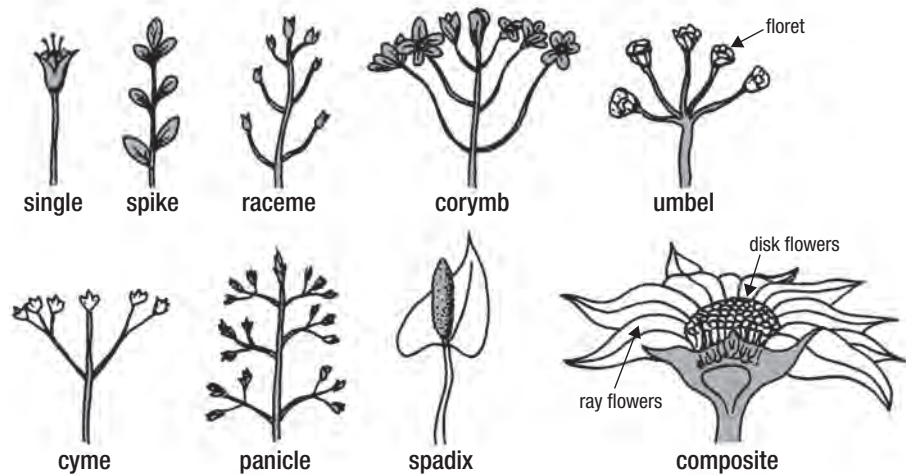


Figure 4. Kinds of inflorescences.

Applying floral knowledge

Flowers come in many different shapes, with different organs, and in different arrangements. This diversity of flower designs has evolved to accomplish the task of pollination. The plants that require animal pollinators have in turn evolved to attract specific pollinators that can provide this service. Knowledge of how flowering plants reproduce is valuable for any gardener to ensure that ovules can be fertilized, seeds set, and delicious fruit produced for harvest. A basic knowledge of flower anatomy can also be helpful for commercial farmers in choosing which crop plants to grow and how many might be needed for adequate pollination. Plus, as illustrated by the tubular flowers of hummingbird host plants, knowing the shape of a flower can give you a clue about its special pollinators.

Pollination Q&A

- Q:** How can I attract hummingbirds to my garden?
- A:** Include plants with long tubular flowers — preferably in shades of red, orange or yellow — that are easy for hummingbirds to drink from.

All sorts of pollinators

Pollinators can take many different forms. Worldwide, more than 100,000 species of invertebrates and more than 1,000 species of vertebrates act as pollinators. About 80 percent of the world's flowering plants, including one-third of our food crops, depend on these animal pollinators to reproduce. Many types of animals can be pollinators for a wide range of different plants. In Madagascar, for example, lemurs are the sole pollinators for a few species of trees, transferring pollen from tree to tree as they feed on nectar-rich flowers. Many bats are pollinators, including some species in southwestern United States that pollinate agave and saguaro cactus. Even some lizards pollinate plants in the forest canopy as they travel between flowers, lapping up nectar. However, most pollinators, including most of those found in Missouri, are insects.

Pollinator species can be categorized as either dietary specialists or generalists. Specialist pollinators are picky, collecting pollen from a narrow range of closely related plants. The specialist pollinators are called oligoleges, or oligolectic species. Generalist pollinators are more flexible and collect pollen from a variety of unrelated plants. The generalist pollinators are called polyleges, or polylectic species.

Pollinators are a key part of healthy ecosystems. A wider diversity of pollinators in many ecosystems is related to greater overall biodiversity, or variety among living organisms. These living organisms include our cultivated plants, which depend on pollinators. As native pollinators lose more and more habitat, they need our support if we want to continue to benefit from the vital pollination services they provide.

Pollinators of Missouri

A wide diversity of native bees pollinate wildflowers, cultivated flowers, orchards and vegetables in Missouri. These bees are just as diverse as the plants they pollinate. And although bees are probably the most important pollinators, other animal species also contribute to pollination in Missouri. In addition to bees, Missouri has seven other main groups of pollinators: wasps, ants, butterflies, moths, beetles, flies and hummingbirds.

Bees (order Hymenoptera)

Bees are the most well-known pollinators in North America and usually the most influential in pollinating both our native and our cultivated plants. The honey bee immediately comes to most people's minds when thinking about bees. However, many native bee species are important pollinators.

Bees are the most efficient pollinators for many crops, pollinating flowers as they forage for the nectar and pollen they collect to feed to their young. All bees start their life cycles as larvae that eventually pupate and develop into winged adults. Depending on the sociality of the bee species, the larvae are cared for by the colony or provisioned by their mother. Bees usually lap up nectar with their tongues and store pollen in special baskets, called corbiculae, located on their hind legs. When a bee stops at a flower to gather nectar and pollen, it contacts the anthers. Pollen from the anthers attaches to hairs on the bee's body. When the bee moves on, it carries that pollen to the stigma of the next flower it visits. This transfer of pollen between flowers results in pollination.

Different bee species in Missouri play slightly different roles in pollination and require slightly different conditions to thrive. Apidae is the largest family of bees and contains many species that commonly visit Missouri flowers. Most of these bees are polylectic, meaning they visit a wide variety of flowers.

Honey bee (*Apis mellifera*)

The official state insect of Missouri, the honey bee (*Apis mellifera*), is in the family Apidae (Figure 5). Honey bees were brought here from Europe nearly 400

Insects are spineless

The key difference between vertebrates and invertebrates is that vertebrates have a backbone, or spinal column. More than 95 percent of animal species are invertebrates. The largest group of invertebrates is the insects, which includes beetles, bees and butterflies.

Pollinator insects are either generalists or specialists

Some pollinator insects collect pollen from a variety of unrelated plants. These generalists are called polyleges, or polylectic species. Other insects are picky eaters that collect pollen from a narrow range of closely related plants. These specialists are called oligoleges, or oligolectic species.

When are bees active?

Most bees are active during the day. The adjective meaning "active in the daytime" is *diurnal*. Some bees are active around dawn and dusk; these bees are *crepuscular*. Bees that are active at night are *nocturnal*.

years ago and are now found throughout North America. Honey bees are extremely social insects and establish nests, or hives, above ground in tree cavities or in managed bee boxes. A colony has a single queen, hundreds of fertile male drones, and tens of thousands of infertile female workers. The queen produces all of the young; the drones mate with fertile queens from other colonies; and the workers collect food, brood young, and tend the hive. Worker bees are the ones most often seen outside the hive, foraging for nectar and pollen, which they bring back to the nest to feed the brood. Honey bees forage intensively due to the large size of their colonies. Their foraging results in a lot of pollination and makes the honey bee one of the most important pollinators in North America and Europe. Honey bees overwinter as a colony, sustained during the cold winter months by a supply of stored honey and pollen.



Figure 5. Honey bee (*Apis mellifera*).

Bumble bees (*Bombus* spp.)

The family Apidae also contains social bee species native to North America, such as the bumble bees (*Bombus* spp.) (Figure 6). Unlike honey bees, bumble bees typically nest below the ground. They too have colonies comprised of a single fertile queen, fertile male drones, and infertile female workers. However, bumble bee colonies are much smaller, rarely exceeding a few hundred bees. Bumble bee colonies do not last through the winter. Only young, mated queens overwinter, and each goes on to establish a new colony in the spring.



Figure 6. Bumble bee (*Bombus* sp.).

Bumble bees partake in a unique pollinating behavior known as buzz pollination, in which they use the sonic vibrations of their wings to release pollen from the anthers of the flower.

Carpenter bees (*Xylocopa* spp. and *Ceratina* spp.)

Also in the family Apidae are the carpenter bees (*Xylocopa* spp. and *Ceratina* spp.), a lesser-known group of native Missouri bees (Figure 7). The Eastern carpenter bee (*Xylocopa virginica*) resembles the bumble bee but has a noticeably darker abdomen. These solitary or weakly social bees make their nests in wood, hence their name. Like other bees, they pollinate flowers as they feed on nectar and pollen, which females also collect to line their nests with as a food source for the young. The young hatch in the summer, overwinter as fully formed bees, and mate the following spring.

Carpenter bees cause direct damage when they tunnel into wooden human structures and can cause indirect damage in winter, when woodpeckers will chisel through wood to get to the bees, a favorite food. In nature, carpenter bees promote decomposition of dead wood, recycling nutrients back into the soil.



Figure 7. Carpenter bee (*Xylocopa* sp.)

Is it going to sting me?

Bees, wasps and hornets are feared for their painful stings. However, not all bees and wasps sting, and some don't even possess stingers. In bees and wasps, only the females have a stinger.

Most bees and wasps have a smooth or weakly barbed stinger that allows them to sting repeatedly. Honey bees, however, have a strongly barbed stinger that lodges in skin. When the bee tries to fly away, its abdomen rips open, killing it.

Bees and wasps usually sting in defense of their colonies, and thus social bees and wasps are more likely to sting than their solitary counterparts, especially near their hives. Most wasp stings occur because wasps are attracted to sweet foods and their nests are hidden.

Only one true species of hornet is found in North America, the European hornet (*Vespa crabro*). These hornets don't play much of a role in pollination and are usually not a threat unless they nest in human dwellings. Generally, watching for and staying away from active nests will help you avoid getting stung.

Some people have life-threatening reactions to stings. If you are stung, immediately seek medical attention if you feel short of breath or your throat and tongue are swelling.



Figure 8. Long-horned bee (*Melissodes* sp.)



Figure 10. Leafcutter bee (*Megachile* sp.).



Figure 12. Sweat bee (*Agapostemon virescens*).

Other Apid bees

Some other notable Apidae bees in Missouri are the cuckoo bees (*Nomada* spp. and *Triepeolus* spp.), the long-horned bees (*Melissodes* spp. and *Svastra* spp.) (Figure 8) and the squash bee (*Peponapis pruinosa*) (Figure 9). Most of these have yellow-and-black-striped bodies covered in hairs, and all of them are solitary ground-nesters.

Cuckoo bees are parasites that lay their eggs inside the nests of other bees, not participating in brood care at all. These bees feed on nectar but do not collect pollen, as they do not feed their young. They look much like wasps, with very few hairs on their bodies, making them less efficient pollinators.

Long-horned bees are so-named for the long antennae of the males. Often pale in color, they are important pollinators of sunflowers and daisies (family Asteraceae).

Squash bees are specialized pollinators of squash and pumpkins (family Cucurbitaceae), making them vital for growing these and related plants.



Figure 9. Squash bee (*Peponapis pruinosa*).

Megachilid bees

Some other bees in Missouri are in the family Megachilidae, which includes the leafcutter bees (*Megachile* spp.) (Figure 10) and the mason bees (*Osmia* spp.) (Figure 11). These bees are exclusively solitary. This group contains polylectic and oligolectic species. They are unique among bees in that they collect pollen on the underside of their abdomen rather than in baskets on their hind legs.

Although they pollinate flowers in much the same way as other bees, they are usually less efficient foragers because pollen carried on the underside of their abdomen sheds more readily than that carried on the hind legs of other bees. This inefficient method of transporting pollen causes them to have to visit more flowers to provision their young, but they transfer more pollen in the process.

Leafcutter bees are dark with pale hairs and get their name from the circular holes they cut in plant leaves. They use these sections of leaf to line their nests, which are usually cavities in rotting wood. Females lay one egg in each cell in the nest and provision the cells with nectar and pollen. The young hatch, pupate and overwinter in these cavities, and then emerge in the spring.

Mason bees are dark bees with habits similar to those of leafcutter bees. Mason bees nest in small cavities, such as a hole in a hollow reed stem, that they provision with nectar and pollen and into which they lay their eggs. They then seal the cells with mud, giving them their name. Like leafcutter bees, young mason bees hatch, pupate and overwinter in these cells, and then emerge in the spring. Mason bees are also known as orchard bees because they are excellent pollinators of fruit trees and other early blooming flowers.



Figure 11. Blue orchard bee (*Osmia lignaria*).

Halictid bees

Another common group of bees native to Missouri is the family Halictidae, the sweat bees (*Agapostemon* spp., *Halictus* spp. and *Lasioglossum* spp.) (Figure 12). Sweat bees are usually a metallic yellow or green color and are much smaller than most other bees. They are attracted to the moisture and salts in sweat, so they often land on people, but they rarely sting. Some species are solitary, whereas others show

different levels of social behavior. Social members of this family nest underground in small colonies of one or more egg-laying females and other females that serve as workers. Some of their offspring become workers; others mate and overwinter to emerge as queens the following spring. Like other bees, sweat bees feed on nectar and pollen and pollinate flowers as they forage. Most are polylectic foragers. Sweat bees also include the only crepuscular and nocturnal species of bees.

Andrenid bees

Another group of native Missouri bees is the family Andrenidae, which includes the mining bees (*Andrena* spp.) (Figure 13). Mining bees are usually dark with reddish stripes. They are solitary and ground-nesting. The females dig a tunnel in the ground along which they make cells where they lay eggs. Each cell is provisioned with nectar and pollen and then sealed. The young develop and overwinter in these cells and emerge the following spring. Mining bees are commonly oligolectic, and like other bees, they pollinate flowers in the process of foraging for nectar and pollen.



Figure 13. Mining bee (*Andrena* sp.).

Colletid bees

The family Colletidae is the last group of native Missouri bees, including the masked bees (*Hylaeus* spp.) (Figure 14) and the polyester bees (*Colletes* spp.) (Figure 15). These bees are solitary and ground-nesting. They are usually dark with white or yellow stripes. Masked bees lay their eggs in cavities that they line with a cellophane-like material. Polyester bees lay their eggs in long tunnels that they have dug and lined with polyester. Most bees in this family pollinate flowers in the process of foraging for nectar and pollen; however, masked bees carry nectar and pollen internally, which means they do not aid in pollination. This family contains polylectic and oligolectic species.



Figure 14. Masked bee (*Hylaeus* sp.).



Figure 15. Polyester bee (*Colletes* sp.).

Wasps (order Hymenoptera)

The role that wasps (families Vespidae, Crabronidae, Mutillidae, Sphecidae, Scoliidae, Chrysididae, Tiphidae, Siricidae, Leucospidae and Pompilidae) (Figure 16) play in pollination is less clear than that of bees. As winged adults, most wasps visit flowers to drink nectar, but they have fewer hairs on their body than do bees, so they are much less efficient pollinators.

Most wasps in Missouri are predatory and feed insect prey they capture to their young. Due to their predatory nature, wasps play a much larger role in controlling garden and row crop pests than do bees. So, aside from any role they might have in pollination, they are beneficial insects because of the role they play as natural enemies of certain pests.



Figure 16. Yellowjacket (*Vespula* sp.).

Ants (order Hymenoptera)

Ants (family Formicidae) (Figure 17) often visit flowers to collect nectar, as anyone who has plucked peonies from a garden knows. However, ants are usually inefficient as pollinators. Their lack of wings limits their ability to move from flower to flower efficiently. Also, many ants have an antibiotic chemical on their bodies that degrades any pollen they are carrying. Therefore, most ants take nectar without contributing to pollination.

In some instances, however, ants do serve as pollinators. Low-growing rock garden plants often benefit from ant pollination, as do other plants that flower low to the ground where ants can easily travel between flowers, such as spurge (*Euphorbia* spp.).



Figure 17. Weaver ant (*Oecophylla* sp.).

Butterflies (order Lepidoptera)

Butterflies are some of the most beautiful pollinators that visit Missouri gardens. Most caterpillars, which are the larval stage of butterflies, are herbivores that voraciously devour plant tissues. When the caterpillars grow large enough, they pupate and form a chrysalis or cocoon from which they later emerge as adult butterflies. Adult butterflies visit flowers to feed on nectar. Some species form highly specialized relationships with certain plants, laying their eggs on one or a few closely related host plants that fulfill the caterpillar's unique feeding requirements. Other butterfly species are generalists and lay their eggs on a variety of plants. Butterflies can travel over wide areas to find their host plant species, and some species of plants, especially tropical ones, are exclusively butterfly-pollinated.

The butterflies found in Missouri are the brush-footed butterflies (family Nymphalidae), the harvesters (family Lycaenidae), the metalmarks (family Riodinidae), the parnassians and swallowtails (family Papilionidae), and the skippers (family Hesperidae). The flower preferences of these species are diverse, but in general butterflies prefer plants with wide, flat flower surfaces that allow them to easily land and collect nectar. Their host plants are often found in open, sunny habitats. Butterflies, like many other insects, require different resources at each stage of their life cycle. To attract a butterfly species, a garden must support it at all of these stages by providing foliage for caterpillars and flowers for adult butterflies.

Perhaps the most well-known butterfly in Missouri is the monarch (*Danaus plexippus*) (Figure 18). These bright orange-and-black butterflies pollinate many types of wildflowers but cannot survive without milkweed. The adults gather nectar from a wide variety of plant species in addition to milkweed, but they lay their eggs only on milkweed plants (*Asclepias* spp.), and their caterpillars eat only milkweed. Monarchs overwinter in Mexico, completing one of the most amazing feats of animal migration. However, they are at risk due to eradication of their milkweed host plants in the United States and their breeding habitat in Mexico. You can help the monarch's continued survival by planting milkweed.



Figure 18. Monarch butterfly (*Danaus plexippus*).

Moths (order Lepidoptera)

Moths (families Erebidae, Noctuidae, Saturniidae, Geometridae, Crambidae, Notodontidae, Pterophoridae and Sphingidae) are similar to butterflies but are usually crepuscular and nocturnal. There are many more species of moths than of butterflies. Although moths, like butterflies, are not as efficient as bees at transferring pollen, there are a few striking examples of moth pollinators that are extremely specialized for flower foraging. One unique example in Missouri is the sphinx moth (family Sphingidae), a large hovering moth that is often mistaken for a hummingbird (Figure 19). The sphinx moth has one of the longest tongues for an insect. Its long tongue allow it to sip nectar from flowers with deep nectar tubes and spurs, such as columbines (*Aquilegia* spp.) and tobacco (*Nicotiana* spp.).

A moths rubs its head against the flower's anthers as it drinks from deep within the flower, collecting pollen that it then transfers to flowers of other plants. Although the caterpillars of many moths, such as the tomato hornworm (*Manduca quinquemaculata*) and the gypsy moth (*Lymantria dispar*), are agricultural pests, the winged adults are valuable pollinators for many native plants. To prevent them from devouring your garden plants, plant susceptible species, such as mustards (family Brassicaceae, which includes broccoli and cabbage), away from flowers that could attract the adult moths, or use trap plants. Trap plants are plants that act as decoys to entice garden pests away from the plants you want to harvest. For example, a good trap plant for tomato hornworms is dill (*Anethum graveolens*), which the hornworms will often go for preferentially, so should be planted on the other end of a garden, far from susceptible plants.



Figure 19. Hummingbird hawk-moth (*Macroglossum stellatarum*).

Beetles (order Coleoptera)

Beetles also serve as pollinators in Missouri (Figure 20). Beetles were among the first species to visit the earliest flowers, where they consumed pollen about 200 million years ago, and they are still important pollinators today. Beetles help pollinate about 90 percent of plants worldwide.

There are more than 30,000 species of beetles in the United States, which makes them the largest group of pollinators due to numbers alone. Beetles have a life cycle similar to that of bees, butterflies and moths, starting their lives as larvae, a life stage that can last up to several years in some beetle species. Most grubs are actually beetle larvae.

Some plants, such as magnolia (*Magnolia* spp.) and spicebush (*Lindera* spp.), rely on beetles for pollination. Beetles are much less efficient pollinators than bees and butterflies, as they are not as faithful to a single plant species and thus waste much pollen. They are also messier, eating their way through flowers with chewing mouthparts instead of the specialized tongue-like proboscides, or sucking mouthparts, seen in other pollinators. Plants pollinated by beetles tend to have large tough flowers, strong odors and exposed anthers. Beetles can be pests for certain plants. For example, the invasive Japanese beetle (*Popillia japonica*) is attracted to the sweet scent of plants such as linden trees (*Tilia* spp.) and rosebushes (*Rosa* spp.). Some beetles defecate in flowers and can thereby spread certain plant diseases; for example, the cucumber beetle (*Diabrotica* spp. and *Acalymma* spp.) can spread bacterial wilt in cucurbits (family Cucurbitaceae), including cucumbers, squash and melons. Other beetles, such as ladybird beetles (family Coccinellidae), are helpful predators in the garden because they eat aphids.

Flies and mosquitoes (order Diptera)

Despite their reputation as dirty insects, some flies are important pollinators (Figure 21). Many flies resemble bees. However, flies have a single pair of wings that they usually carry out to the side, whereas bees have two pairs that are usually carried over their backs. Like beetles, flies were among the earliest insects to feed from flowers. There are numerous genera of flies that visit a wide range of flowers. A few species of flies eat pollen like bees, although most only feed on nectar. In general, flies pollinate flowers that are small and grow in shady, moist environments. One popular example of this is the pawpaw, a low-growing Missouri native fruit tree; flies, typically carrion feeders, are attracted to its pungent smelling flowers that are purple-colored like meat. Houseflies and blowflies feed on nectar.

Because male mosquitoes feed on nectar — as opposed to female mosquitoes, who feed on blood — they can also aid in pollination. In fact, mosquitoes are the exclusive pollinators of some species of orchids found in northern regions of North America, even as far north as the Arctic.

Hummingbirds (order Apodiformes, family Trochilidae)

Hummingbirds are the only bird pollinators found in Missouri. They are important pollinators for tubular flowers, into which they insert their beaks and then use their tongues to lap up nectar. Pollen collects mainly on a hummingbird's head while it is feeding and is then transferred to the pistils of other flowers. Missouri's only resident hummingbird is the ruby-throated hummingbird (*Archilochus colubris*) (Figure 22), although other species may travel through Missouri during migration. Because they are larger than other pollinators, hummingbirds can move pollen over long distances. To attract hummingbirds to a garden, plant native wildflowers with bright and long-tubed flowers, such as cardinal flower (*Lobelia cardinalis*), jewelweed (family Balsaminaceae) and trumpet creeper (*Campsis radicans*). You can also use a hummingbird feeder to dispense sugar water for hummingbirds in the early spring as they return from their annual migration when flowers are scarce.



Figure 20. Goldenrod soldier beetle (*Chauliognathus pennsylvanicus*).

Thank flies for chocolate

In the tropics, flies are responsible for pollinating the cacao trees that produce chocolate.



Figure 21. Hover fly (*Syrphidae* sp.).



Figure 22. Ruby-throated hummingbird (*Archilochus colubris*).

Applying knowledge of pollinators

With knowledge of the variety of pollinators found in Missouri and the unique adaptations of each to a pollinator lifestyle, you can support different types of pollinators on your land, and best use them to ensure seed and fruit production through pollination. This information will be instrumental background knowledge as you educate others about the role and value of native pollinators in farm and garden environments. Table 7 summarizes traits of a good pollinator and provides examples of pollinators that have or lack each trait.

Table 7. Traits of a good pollinator.

| Trait | Usefulness to pollination | Example pollinators |
|---------------------------|---|--|
| More hair | <ul style="list-style-type: none">• Hairs allow pollen to stick to the pollinator and be transferred to other plants.• Without hairs, less pollen is collected and the pollen that is collected is much less likely to stick until the pollinator visits the next plant. | Have this trait: Bees, butterflies, moths Lack this trait: Wasps, ants, beetles |
| Larger size | <ul style="list-style-type: none">• Larger pollinators can usually carry more pollen.• Buzz pollination is usually only performed by larger bees. | Have this trait: Bumble bees, hummingbirds Lack this trait: Sweat bees |
| Flight | <ul style="list-style-type: none">• Pollinators that fly usually transfer more pollen than those that walk. | Have this trait: Butterflies, hummingbirds Lack this trait: Ants |
| Pollination behavior | <ul style="list-style-type: none">• Pollinators that visit a large number of flowers in a foraging trip are usually better pollinators.• Pollinators that visit a narrow range of plant species on a foraging trip are more successful at pollinating. | Have this trait: Bees Lack this trait: Beetles, ants |
| Pollen diet | <ul style="list-style-type: none">• Pollinators that eat pollen usually come into closer contact with pollen and can pick up more on their bodies. | Have this trait: Bees Lack this trait: Butterflies, flies, hummingbirds |
| Close contact with flower | <ul style="list-style-type: none">• More pollen sticks to pollinators that come into close contact with the flower. | Have this trait: Bees, ants, beetles Lack this trait: Butterflies, moths |

Pollination methods

In nature, gardens and farms, different plant species have a variety of methods to ensure their flowers are successfully pollinated. Some plants use abiotic pollination, which is pollination that is not caused by a living organism but by water or wind. However, most plants use biotic pollination, which requires the help of living organisms to move pollen from one flower to another.

Abiotic pollination

Water pollination is limited to aquatic plants. Pollen travels from one flower to another on or below the water's surface, depending on the plant.

In wind-pollinated species, the pollen is dispersed by air currents from the anthers, in hopes that some of it will land on the stigmas, or receptive tips, of the female pistils. Plants that use wind pollination have numerous tiny dull-colored flowers with little to no nectar or scent because they need not attract pollinators.

Wind-dispersed pollen is smoother and lighter than other types of pollen, making it readily airborne and mobile on air currents. Wind-pollinated plants produce massive amounts of pollen, a fact of which people with allergies are well aware.

Wind-pollinated plants usually grow in stands or close to each other to ensure that pollen can easily reach female flowers of the same species. Plants that use wind pollination include most conifer, or evergreen, tree species; cereal crops — wheat, rice, corn, rye, barley and oats; and most species of grass and sedge. Only about 18 percent of flowering plants use wind pollination.

Biotic pollination

Most plants — about 80 percent of flowering plants and over 33 percent of crop plants — depend on biotic, or animal-assisted, pollination. Plants have found various ways of attracting these animal species to their flowers to aid in pollination. They can attract pollinators by offering food, by having an appealing appearance or fragrance, or even by deception.

The plant-pollinator relationship is mutualistic, because both the plants and pollinators benefit from their interaction. While visiting flowers to gather food, pollinators unknowingly transfer pollen from one flower to another. This pollen transfer results in production of fruits and seeds and thus helps the plant reproduce.

Many flowers produce nectar, a sugary liquid located in the base of the flower, to attract pollinators to the flower. Hummingbird-pollinated flowers contain a large amount of nectar, which hummingbirds depend on for energy.

Some plants produce pollen of high nutritional value for ants and bees. These plants have to produce large amounts of pollen to ensure that not all pollen is eaten but that some is carried to receptive flowers. When a bee enters a flower and begins to gather pollen, some pollen will stick to the hairs on its body. The pollen on its body is then transferred to other flowers that it visits in the same foraging trip.

Visual attraction

Plants attract pollinators based on their flowers' shape, size, color and nectar guides. One of the easiest ways to get a sense of the types of pollinators that visit a flower is by looking at the flower's shape and size. Scarlet beebalm (*Monarda didyma*) has tubular flowers, and columbines (*Aquilegia* spp.) have spurred flowers. Both these shapes are suited to pollination by hummingbirds or butterflies with a long proboscis, which allows them to reach the nectar at the base of the corolla tube or spur. Shallow flowers with large open petals act as a landing pad for bumble bees (*Bombus* spp.), beetles (order Coleoptera) and butterflies (order Lepidoptera), whereas flowers with smaller landing pads and smaller openings may be visited by smaller bees, such as honey bees.

Flowers may be specialized as well. For example, long tubular flowers may prevent small-bodied or short-tongued insects from collecting nectar and thus specialize on larger pollinators like hummingbirds, moths and butterflies that have a long proboscis. Specialization can pose a problem; if no suitable pollinators occur in the area, the plant will be unable to produce seeds and fruit.

Generalists are more flexible. Sunflowers (*Helianthus annuus*), like many of the flowers in its family (Asteraceae), are visited by a variety of insect pollinators. Honey bees will pollinate many common fruit and vegetable plants and various types of wildflowers.

Pollinators show preferences for shapes that fit their foraging adaptations, such as body size and tongue length (Table 8).

A flower's color is also a clue to the types of pollinators it attracts (Table 9). Hummingbirds are attracted to red and yellow flowers. Butterflies are drawn to red, yellow, orange, pink and purple flowers. Nocturnal pollinators, such as bats and moths, will visit pale-colored or white flowers that remain open at night and are easiest to see in the dark. Some flies prefer flowers that are dark red, purple or

Table 8. Typical flower shapes associated with different pollinators.

| Flower shape | Pollinator | | | | | | |
|---|------------|-----------|-------------|------|-----|--------|-----|
| | Bee | Butterfly | Hummingbird | Moth | Fly | Beetle | Ant |
| Cup-shaped (campanulate, cupuliform, saccate or urceolate) | X | | | | | X | X |
| Bowl-shaped or open (coroniform, cruciform, ligulate or stellate) | X | X | | | X | X | X |
| Tube-shaped (funnelform, salverform or tubular) | | X | X | X | | | |
| Labiata | X | | | | | | |
| Papillionoid | X | | | | | | |
| Reflexed | | X | | | | | |
| Spurred | | X | X | | | | |



Figure 23. A yellow aster (*Asteraceae* sp.) as seen with human vision (top) and its UV-visible bull's-eye (bottom).

spotted because they resemble rotting flesh. Bees are attracted to whites, yellows, blues and purples and can even see ultraviolet (UV) patterns on flowers that humans cannot (Figure 23). These preferences are also something to keep in mind when buying hummingbird feeders; those with yellow plastic flowers will also attract bees.

Bees are also drawn to flowers by nectar guides, which are patterns on the petals that direct them to the center of the flower where the pollen and nectar are located. Nectar guides resemble a bull's-eye or stripes near the flower's center, and they often involve UV coloration.

Odorous attraction

In addition to producing visually attractive flowers, plants produce fragrant flowers to attract pollinators. Flowers that we normally think of as pleasant-smelling produce these scents to attract butterflies, bats and moths. Some flowers produce scents so strong they can be detected by insects more than half a mile away. When scent is the primary method of attracting pollinators, the flowers need not be as showy; thus, plants that use scent to attract pollinators may not have colorful flowers. Fragrant flowers are characteristic of summersweet shrub (*Clethra alnifolia*), roseshell azalea (*Rhododendron prinophyllum*, family Ericaceae), spicebush (*Lindera benzoin*, family Lauraceae) and magnolia (family Magnoliaceae) trees.

Some plants produce unpleasant smells that mimic the odors of rotting flesh or dung to attract flies and beetles. While inspecting the flower to locate the source of these odors, the insect comes in contact with pollen. Plants that depend on flies as pollinators include the pawpaw tree (*Asimina triloba*), skunk cabbage (*Symplocarpus foetidus*) and the world's largest flower, the corpse flower (*Amorophallus titanum*). Unlike the usual mutualistic plant-pollinator relationship, this relationship is commensalistic, in that the plant benefits from the interaction because pollen is transferred from one plant to another, but the pollinator receives no benefit.

Applying knowledge of pollination methods

By closely looking at, and smelling, a flower, you can often figure out what pollination method it uses to attract pollinators. Plants use color to attract hummingbirds, butterflies or bees; these pollinators are more visually oriented. A flower's shape may also suggest a plant's pollination method. Narrow or tube-shaped flowers usually have hummingbirds or long-tongued butterflies as pollinators, whereas wide open flowers attract bees and beetles. Flowers that are dull may use scent to attract pollinators or may be wind-pollinated. Plants may also imitate the appearance or smell, or both, of another insect or food source to trick insects into pollinating their plants.

Pollination Q&A

Q: What if flowers with a pollinator's preferred shape, size, color, or scent are unavailable?

A: Most Missouri pollinators are opportunistic and will make do with other, locally common flowers if their preferred flowers are unavailable.

Table 9. Flower colors that attract particular pollinators.

| Flower color | Pollinator | | | | | | | |
|------------------|------------|-----------|-------------|------|-----|-----|--------|------|
| | Bee | Butterfly | Hummingbird | Moth | Fly | Bat | Beetle | Wind |
| Red | | X | X | | X | | | |
| Orange | | X | X | | | | | |
| Yellow | X | X | | | | | | |
| Green | | | | | | | | X |
| Blue | X | | | | | | | |
| Purple | X | X | | | X | | | |
| Pink | | X | X | X | | | | |
| White or pale | X | | | X | | X | X | |
| Ultraviolet (UV) | X | | | | | | | |

Seasonal bloom times

Because most pollinators have a longer lifespan than flowers of a single plant can provide nourishment for, multiple plants, often of different species, need to be available for them over the course of the growing season. To meet their nutritional needs, animals must visit plants that bloom at different times. Although many plants bloom in late spring and early summer, there are plants that bloom during most times of the year. These varying bloom times allow pollinators to acquire food and nutrients from different plant species from early spring to late fall.

Spring bloomers

Several plants grown in Missouri bloom in early spring. One such plant is the wild plum (*Prunus americana*), which provides benefits to both wildlife and humans. As mentioned in the flower anatomy section, wild plum is a monoecious species with perfect flowers. Its flowers bloom in April and May, and are pollinated by various bee species, including honey bees (*Apis mellifera*) and bumble bees (*Bombus* spp.). Wild plums are also host to many butterfly (order Lepidoptera) species. As an added bonus, wild plum plants will provide you with a delicious source of fruit in the late summer that can be used for jams and pies.

Farmers growing corn or other row crops often plant a cover crop between rotations of the main crop to help keep the soil fertilized and make it as nutrient-rich as possible when the main crop is planted. Red clover (*Trifolium pretense*) is a commonly used cover crop in Missouri. A member of the Fabaceae family, red clover is a legume that will bloom in late May, providing food for bumble bees.

For a home garden, plants such as beardtongue (*Penstemon* spp., family Scrophulariaceae) and both false and wild indigo (*Baptisia* spp., family Fabaceae) can be planted in early spring and will bloom from late spring into summer. These plants will bring color to your garden and attract a variety of bee species for pollination.

For all of these plants, one of the biggest risks is frost. Because they bloom in the spring, a late frost could kill their flowers before the plants are successfully pollinated. Another risk is that many pollinators, such as bees, often have not had a chance to build up their populations by the time these early blooming plants flower. Therefore, spring bloomers run the risk of not getting enough visits from pollinators to reproduce.

Summer bloomers

In Missouri and the surrounding areas, several types of melons (family Cucurbitaceae), including watermelons (*Citrullus lanatus*), are grown, all of which

require pollinators to produce fruit. Watermelons have imperfect male and female flowers on the same plant, and their pollen is so heavy that it cannot be moved by wind. Due to these characteristics, watermelons require pollinators for sexual reproduction and fruit set. To produce a marketable watermelon, the female flower must receive 500 to 1,000 pollen grains.

Bumble bees, and other native bees, are the most effective pollinator of watermelons, as they can deliver more pollen on each flower visit. Watermelons typically bloom during the heat of the summer, in July and August.

Native persimmons (*Diospyros virginiana*, family Ebenaceae) bloom in early summer, from May to June, and are pollinated by honey bees and other native bees.

Many native perennials bloom in the summer months and are serviced by animal pollinators. One example is milkweed (*Asclepias* spp., family Apocynaceae), which has pinkish-purple flowers and blooms from June to August. Pollinated by a variety of insects, milkweed is important to monarch butterflies in particular. Monarch larvae feed exclusively on milkweed and the plant, in turn, is pollinated by the adult butterflies. Scarlet beebalm (*Monarda didyma* L., family Lamiaceae) is another plant that blooms from late June through late August. Because of its long narrow flowers, it is pollinated by long-tongued butterflies and hummingbirds. The presence of both of these plants in an ornamental or native plant garden could sustain a variety of pollinators over the summer.

In addition to plants that are visually pleasing, some herbs that are used as spices can be planted in a garden and provide resources for pollinators. Two examples are oregano (*Origanum vulgare*, family Lamiaceae) and fennel (*Foeniculum vulgare*, family Apiaceae). Oregano leaves can be eaten before the plant blooms, but if allowed to bloom in mid- to late summer, it will provide nectar for bees and hummingbirds. Fennel, which blooms from mid- to late summer, will attract bees, as well as flower-visiting wasps and hoverflies.

The risks for plants that bloom in the summer include loss of flowers and foliage to insect herbivores, and potential competition for pollinator visits with the many other species of plants also in bloom. The potential also exists for damage to flowers from hail and severe winds. In addition, the lifespan of a flower depends on both temperature and available water. Under summer heat and drought, nectar can dry up. When this happens, pollinators may lack sufficient energetic resources to raise their young.

Autumn bloomers

Although many people focus on their gardens only in late spring and early summer, a garden can be extended into the fall. Many species bloom late in the fall, and planting them in a garden will ensure flowers are available for pollinators whose life cycles extend late into the year. Some of these late-blooming plants include asters (genera *Symphyotrichum* and *Eurybia*., family Asteraceae) and gentian (*Gentiana* L. spp., family Gentianaceae). The plants bloom in late August through October and are pollinated by various bee species. Sunflowers also continue to bloom well into autumn and are visited by a variety of insect pollinators. One shrub common in Missouri that blooms from mid-November through mid-March, depending on the subspecies, is witch hazel (*Hamamelis* spp., family Hamamelidaceae). In mid-Missouri, honey bees can be seen visiting its flowers in mid-January.

Plants that bloom in the late summer through the autumn and winter months are at risk of storm damage and early frost. These natural events damage the flowers and prevent them from successfully reproducing. Late-blooming plants also suffer from low numbers of pollinators, as hummingbirds migrate south and bee colonies dwindle. This risk can be reduced if an abundance of flowering plants is available for pollinators earlier in the summer and fall.

Applying knowledge of bloom times

Using knowledge of the bloom times of various plants, you can choose to grow plants that flower at different times throughout the year, thereby ensuring that a variety of pollinators are available throughout the growing season to pollinate your fruit trees and garden vegetables.

Resources

- Attracting butterflies — National Wildlife Federation: <http://nwf.org/Garden-For-Wildlife/Wildlife/Attracting-Butterflies.aspx>
- Attracting hummingbirds — Missouri Department of Conservation: <https://nature.mdc.mo.gov/discover-nature/activities/bird-feeding/attracting-hummingbirds>
- Bee hotels — Open Air Laboratories network: <http://opalexplornature.org/Beehotels#/0>
- Flower shapes — University of Kentucky, Department of Horticulture: <http://dept.ca.uky.edu/PLS220/Flowershapes.pdf>
- Demonstration gardens — Missouri Botanical Garden: <http://www.missouribotanicalgarden.org/gardens-gardening/our-garden/gardens-conservatories/demonstration-gardens.aspx>
- Insectra spectra: Butterfly and bee vision (video) — Robin Noorda: https://youtube.com/watch?v=9CpEV9_7Ov8
- Monarch butterflies — Monarch Watch: <http://monarchwatch.org>
- Plants for pollinators: A collection of favorites — National Wildlife Federation: <http://nwf.org/News-and-Magazines/National-Wildlife/Gardening/Archives/2010/Native-Plants-for-Pollinators.aspx>
- Relationships of types of pollinators and flowers (two pollinator-flower matching games) — The Pennsylvania State University, Flowering Plant Reproduction Online Lab: http://personal.psu.edu/mnm14/blogs/biology_12_lab_flowering_plant_reproduction/lessons/03--.html
- Pollination game — Colours in NanoPhotonics: <http://www.colours.phy.cam.ac.uk/pollination-game>

Figure credits

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