Lecture 27

Pollination

I. Pollination

A. Probably the most important contribution made by insects to human health and the most underappreciated: pollination. Not just honeybees but many insects, including butterflies and moths, beetles, flies.

B. Plants are rooted in the ground and incapable of movement. Sexual reproduction for plants is just as important as it is for animals but they can't just get up and find a mate. For most plants, sex is a matter of getting male gametes in contact with female gametes.

C. Plant classification. Kingdom Plantae.

1. Phylum (Division) Bryophyta: mosses and liverworts. **Nonvascular**-no specialized transporting tissues (mosses are low to ground, don't have to transport nutrients or water).
2. Phylum (Division) Tracheophyta: **Vascular** plants with special conducting tissues (how do trees get water to the top?). **The vast majority of plant species are the flowering plants** (= angiosperms). The vascular plants are divided into:
   a. Ferns
   b. Gymnosperms: Conifers (pines, spruces and similar).
   c. **Angiosperms: flowering plants**.
      1) monocots-grasses, corn, irises, orchids
      2) dicots-all other plants with flowers

D. **Types of plant sex**

1. Ferns and mosses-evolutionarily old plants. They have male gametes that have flagella and are motile like that of animals (sperm) and are unprotected by an type of coat. Alternating generations: one reproduces sexually by gametes, the other asexually by spores. The leaflike fronds are the spore-producing generation. When a spore germinates it forms another structure on the ground that develops the male and/or female organs. Sperm cells can swim actively to the female gametes on another one of these structures and fuse with one (especially in a film of rainwater or dew). Note that ferns and mosses are most common in very damp regions. (Ferns usually develop both sexes on one structure but self-pollination is prevented)
2. Majority of terrestrial plants have taken a different direction. The conifers and flowering plants. These vascular plants can live in dry regions and tower above the moist ground. **They produce male gametes called pollen. The genetic material is encased in a protective coating to protect the gamete and prevent drying out, but this precludes swimming to the female gametes**. When the male gametes meet up with female gametes, the fusion results in a seed. Seeds are the plant embryos, also protected by a covering.

E. Pollination =placing pollen (male) into receptive stigma (female) of a flower.

1. The basic structure of a flower. Outermost are the petals and sepals of the flower, usually the most conspicuous. Inside these are the reproductive organs.
2. Note that in the conifers, reproductive organs are contained within the pinecones rather than within flowers.

3. **Pollen** is produced by **anthers**, the plant equivalent of male genitalia. Anthers are borne on the **stamens**, which collectively make up the androecium. The structure of the pollen wall is characteristic of each particular group of plants and can be used in identification.
4. Female gametes are housed in the **carpel or pistil**. The pistil consists of the **stigma** (receptive surface, usually sticky), the **style** (a tube through which the pollen grain must grow to reach the waiting gamete) and the **ovary** which contains the **ovule** (the structure that will house the embryo resulting from fertilization) containing egg or ovum.
5. The pollen lands on the stigma and **germinates, producing a pollen tube** which grows down through the style. The male gametes move down pollen tube until the ovum or egg is reached, at which point fusion occurs. The result is a **seed**, a **resting plant embryo**.
6. For some plants, getting the appropriate parts together is easy because they can fertilize themselves. Usually this doesn't work because the pollen from the same plant is incompatible with the ovum or because other mechanisms to prevent self pollination are in place. Why should this be, when the male and female gametes are usually in close proximity on the same plant and it would be an easy way to produce seed? There is an advantage to mixing and recombination of the different hereditary material of two plants. Introduces additional variability into the progeny. Cross-pollination also increases the probability that unfavorable hereditary features that are recessive will be ineffective, for the genetic complement of the partners is likely to be different.
7. Thus the plant has to obtain pollen from other plants of the same species. Moving pollen to stigma of another plant is an operational problem requiring assistance.

F. Pollination can occur by:
   1. **Nonliving methods**. Example-wind pollination
      a. Conifers, grass, ragweed, many species of trees, wheat and corn are examples of plants that are pollinated by wind. Grains of pollen are shed in very large numbers into the wind and pollination is effected if one lands on the stigma of the appropriate species. Wind pollination is a risky business with a lot of pollen grains **wasted** by landing in inappropriate places.
      b. Produce a lot of small pollen grains, usually have separate male and female flowers.
      c. Usually **don't disperse well**, exist in stands (conifers)
   2. **Living methods**. Mechanical pollination.

      Many plants induce animals to carry around their pollen. They pick it up when feeding at one flower and then carry it with them to the next, where it is brushed off or becomes stuck to the stigma.

G. Pollination of most flowering plants is by insects.
   1. Insect pollination is an example of a true mutualism, plant benefits reproductively and plant usually provides reward which benefits pollinator.

2. For a long time scientists believed that a key reason for the success of flowering plants (that is, why there are so many more species of this group than of other types of plants) is because of this mutualistic relationship. But the discovery that insects had mouthparts adapted for feeding on plants before this radiation occurred suggests that this might not be true.
3. **Types of insects that pollinate in order of importance**: **Bees, flies, butterflies and moths, beetles.**
   a. **Bees**. Honeybees the most important.
      1) Significance due to vast numbers in a colony-50,000 or more individuals.
      2) Capacity for learning and transmitting information about nectaries and pollen sources.
      3). Pollination industry
         a) Most heavily used commercially is honey bees. When bees visit flowers they often get covered with pollen grains, which adhere to the branched hairs all over their bodies. The grains are combed out and packed onto a flattened segment of their hind legs called the corbicula, or pollen baskets.
         b) 10$ billion worth of plants pollinated by bees annually. Most vegetables, fruits, forage crops like alfalfa and clover.
         Almonds, apples, avocados, blueberries, cherries, cranberries, cucumbers, citrus fruits, kiwifruit, melons, nectarines, peaches, pumpkins, squash, strawberries.
         Asparagus, broccoli, carrots, cauliflower, celery, onions.
         30% of all food eaten is honeybee-pollinated.
         c) To make a full-time living from honeybees, about half of the nation's 2000 commercial beekeepers pull up stakes each spring, migrating north to find flowers for their bees. Big business to move bees from field to field, region to region during early season of cropping, especially in California's fertile Central Valley.
         d) **Solitary bees** are also important. Solitary bees are responsible for tomato pollination. Live in rows of single burrows in a block of wood, transported around from place to place. (See clip in Alien Empires).

   b. **Other bees:** Bumblebees are regular and important pollinators which live entirely on nectar and pollen and feed broods on them. Bumblebee proboscis is longer than honeybee and can reach flowers too deep for honeybees. But season of activity is shorter and bumblebee colonies do not survive winter so they need not collect winter stores.

   c. What about other social Hymenoptera like ants and wasps? Ants are classic "nectar thieves" because their small bodies can reach nectar without touching the anthers at all. They are not hairy and are not morphologically very

suited for pollen transfer. Wasps/Hornets produce large broods but feed them predominantly animal material. Nectar they draw is usually eaten by themselves.

d. Flies: hover flies and bee flies among the most important pollinators, second only to the bees.

1) Hover fly larvae parasitize eggs and young of other insects, adult live on nectar and pollen. Often look like bees or wasps in coloration. Batesian mimicry-found in same type of situations as bees.

2) Bee flies are very hairy and look like bumblebees. They also feed on pollen and nectar. Both are expert fliers, hovering and very agile in directional changes.

e. Butterflies and moths. Many are regular visitors to flowers. Butterflies have a wedge or button like thickening at end of antennae, moths do not. Moths are far more numerous but are often active in the evening. Good example is the hawk or sphinx moth you are rearing, *Manduca sexta.* Only adults feed on flowers. They have a very long proboscis for sucking up nectar.

f. Beetles: relatively less important but may have been the first evolutionarily. Mouthparts are chewing, so usually can only lick up nectar from exposed surfaces. Certain longhorn beetles, soldier beetles, checkered beetles and metallic wood boring beetles.

4. How do plants attract insects? Enticements and cues include:

a. **Pollen** as an attractant. Insects eat some of the pollen itself. Pollen is high in protein and fat which makes it a very desirable food for insects. However it is encased in a tough protein coat that is called the exine that makes it hard to digest. This makes sense as the plant would want to protect the gametes from ending up as food. The exine is so tough that pollen grains persist for long periods of time. Especially in bogs, sometimes pollen grains persist for tens of thousands of years. Nonetheless, some primitive plants use pollen as their means of attracting insects. The water lily makes far more pollen than it needs so that insects can feed on some and transfer some.

b. Nectar is a key attractant for pollinators. Nectar made for insect consumption playing no other role than to attract pollinators is called floral or nuptial nectar.

1) Nectars range up to 60% in concentration. Anything more concentrated would be stickier and undrinkable through the narrow proboscis of bees and butterflies.

a) Nectar is some combination of sucrose, glucose and/or fructose. Varying amounts but never much of other things.

2) Nectar is usually presented in particular regions or specialized structures called **nectaries.** Nectaries vary widely in appearance and can be found in

all flower parts in different species. The position of the nectary in the flower may be concealed at the base of the flower so that is accessible to only certain species of pollinators.

3) The proboscis of insects feeding on nectar runs the gamut of very long to very short. *Manduca* has one of the longer probosci of the insects but it is dwarfed by one of its cousin in the tropics with a proboscis about 8 times longer.
4) Plants will regulate amount of nectar per flower Have enough nectar to reward insect but not so much that the insect won't have to visit other flowers.

c. Floral cues

1). **Odor** cues

a) Scent production is often important in attracting pollinators and determining behavior. Flowers pollinated by flies which often breed in dung and carrion, may smell like dung or rotten meat. Butterfly and moth flowers have a sweet smell.
b) Two types of odor
   i. highly volatile, dispersed for some distance
   ii. slightly volatile, produced in strips for the bee to follow once it finds the flower. Not a general scent perceptible to humans but scent patterns as in odor spots, odor gradients or an odor mosaic. The flower can be cut up into parts and each part put into a glass container. After closing it off for about 10 minutes, the experimenter can judge the quality and intensity of the smell in the jar. Scent marks are very common and may or may not be associated with visual marks. The visual marks often have a different odor from that of their surroundings. The visual strips on the flowers give off more of a smell that guides the insect towards the areas where the nectar is stored. These are by far the most common of all attractants.

2) **Visual** cues. Fewer species of plants use these. Visible color has a role in attracting insects but more importantly, UV absorbance or reflectance. Petals often have UV reflecting properties while other parts absorb UV light. The lines that absorb UV light are considered guides that draw the insect inward. Petals were actually pulled out and reversed, bees walked outwards instead of inwards. Few flowers in the temperate zone are red, reflecting the fact that most insects are red-blind-red would appear black if not for UV reflected.
3) **Structura**l cues. A few species of flowers are cheats and trick insects into visiting without providing a reward.
   a) Orchids in the genus *Ophrys* look and smell like a female wasp or bee. Males of many of these wasps or bee species emerge a few days earlier than females. Desperate for action, these males notice the orchid flowers, land on them and try to mate with them. In the process they

pick up the sperm package (pollinia) prepared for them by the orchid. The bee or wasp departs and repeats the process with another mimic flower, depositing the pollinia in the right place.

b) other species have reproductive structures that look and smell like hosts of parasitic wasps. A parasitic wasp tries to parasitize flower but actually pollinates

5. Plant species can be categorized on the basis of their flowers and how it relates to the transfer of pollen and the position of the nectary.
   a. **Disk flowers**: Petals spread out in a flat circle. Insects have no trouble landing on them. Pollen and nectar easily accessible. Many unspecialized visitors, potential pollinators, including bumblebees, beetles, flies, butterflies. This type of flower is common. Marsh marigold, rose.
   b. **Funnel flowers**: insects must find their way to the bottom of the flower. Pollinators: smaller insects that can climb inside the funnel. Crocus and Gentian
   c. **Bell flowers**: Bell flowers are inverted funnels, bells with the opening pointed downward. Insect must get into flower from below as nectar is at the top of the flower. Has to crawl up inside and gravity causes pollen shower. Strong fliers. Snowdrop, Turk's cap lily, Bellflowers, Columbine.
   d. **Stalked plate flowers**: these have a disk-shaped, flattened part set on a tubular stalk. The entrance is so narrow that insects must have long slender proboscis to feed deep in the bottom of the long slender corolla. Mostly butterflies and moths. Starry campion. Tobacco, nightshade.
   e. **Lip flowers.** These have an upper and lower lip. The lower lip forms a platform on which the insect can stand to dip its proboscis into the nectar tube. Stable hairs on the lower lip may press the insect against the pistil and stamens located above them. Touch-me-nots, monkshood, many orchids.
   f. **Butterfly flowers**: Name is derived from the flowers shape and doesn't mean only butterflies pollinate them. There is a large petal and two petals called wings. These cover the keel within which the stamens and pistil are hidden. The flower is shut until a heavy bodied insect lands. The pollen is pushed out or exposed when the insect lands on the wings or keel. Heavy bodied insects capable of tripping mechanism. Pea family.
   g. **Head or basket** flowers: An assemblage of many flowers. Food containers are densely packed which means tall thin tubes, so that a long proboscis is required. Lepidoptera. Thistle, daisy.
   h. **Insect trap** flowers: Petals form a chamber that allows no escape by flying out. Instead forced by slippery sides to take a small path outward that is less slippery. As the insect climbs out, pollen is sprinkled on it. Strong flying insects. Orchids, especially Lady Slippers.