These are the notes on what I didn’t have time to say in class. I will try to add more notes on what I actually said during class.

Notes are numbered by slide number in the presentation, beginning where I left off.

Slide 93. The caterpillar of the Double-toothed Prominent moth. Birds often locate caterpillars on the basis of the holes in leaves that they leave when they feed. This caterpillar conceals the leaf damage it makes by positioning itself in place of the leaf material it has just eaten. Note that the back of the caterpillar looks just like the serrated edges of the elm leaves that it is surrounded by, so it can replace the edge of a leaf very effectively.

94. The adult Double-toothed Prominent moth.

95. There is a Once-married Underwing hidden against the bark of this Paper Birch tree (I artificially induced this particular camouflage by putting the moth on the tree).

96. Close-up of the moth hiding.

97. The same moth, but with wings open, showing the bright red-and-black hindwings. Underwing moths like this one generally have brightly colored hindwings. If camouflage fails and a predator has discovered them, they flash their wings at the predator, hopefully startling it long enough that they can fly away.

98. Grasshoppers do this too. This is a Carolina Locust camouflaged against the ground. When it takes flight, it reveals black hindwings bordered with white. It also makes a loud “crack” noise in taking off that is additionally startling.

99. Here is a Blue-winged Grasshopper with bright blue hindwings.

100. And a Plains Yellow-winged Grasshopper with yellow hindwings.

101. And another species with bright red hindwings.

102. This is a Gaudy Sphinx moth, with the same trick. Camouflaging green forewings conceal startling hindwings. (Notice the little brown spots on the forewings that look like dead patches in a green leaf.)

103. Eye spots can replace bright colors in startling a predator. When this Io Moth opens its wings, it looks like the face of a big scary animal. Hopefully, a predator will run away.

104. This Small-eyed Sphinx is doing the same thing. When its wings are closed, the moth looks like a dead leaf. If camouflage fails, the eyespots can be displayed. (This moth is quite common near my house, and my house is what this individual is on.)

105. This is a harmless treehopper (a sort of true bug) called *Cyphonia clavata*. An outgrowth of its back is formed into a decoy that makes the bug look like a fierce ant from on top.

106. The same species from various angles.

107. This is a Scarlet-bodied Wasp Moth (Cosmosoma myrodora). It has what is called “aposematic coloration” – bright colors that warn predators not to eat it, because it is toxic. This particular moth is toxic because the adult male moth drinks poisonous sap that leaks from certain plants such as *Eupatorium capillifolium*. It manages not to be poisoned itself and uses the poison (an alkaloid) to make itself toxic. The male moth also puts some of the toxin in the sperm that he gives to a female and she then uses it to make their eggs toxic. Additionally, the male has two pouches on his belly filled with cottony fibers, and he saturates the fibers in the alkaloid. When he mates, he showers these toxic fibers upon his mate, so she becomes toxic as well as her eggs.

108. This is the Bella Moth (*Utetheisa ornatrix*). It also is toxic, this time because of alkaloids it ingested while it was a caterpillar. If attacked by a predator who has ignored the aposematic coloration, the moth emits from its thorax a distasteful froth filled with the alkaloid, which serves as an additional warning that the moth’s body is toxic.

109. The left photo shows a Bella Moth frothing – the froth is the white bubbly stuff coming out of the thorax. The right side shows a spider that has just eaten a Bella Moth. The moth was eaten because it was raised on a diet free from the toxic alkaloids. The spider was not deterred by the coloration or by the froth, since neither froth nor moth proved to be distasteful.

110. This is a caterpillar in the genus *Tarchon*. It is so brightly colored that Panama recently used it as the picture on the national postage stamps. A lot of furry caterpillars that one might want to stroke actually have irritating toxins on their hairs and are brightly colored to warn predators to stay away.

111. This is a Monarch caterpillar and two Red Milkweed Beetles. Both species are toxic because of the poisonous milkweed plants they eat.

112. The adult Monarch butterfly retains the toxin that it ate as a caterpillar.

113. The Viceroy butterfly looks like a Monarch so predators will think it is toxic and avoid it. In fact, Viceroys are perfectly palatable. The mimicry of a poisonous species by a non-poisonous species is called Batesian mimicry. Sometimes, also, two toxic species will look alike so as to reinforce the impression on predators that a particular pattern means poison. This type of mimicry is called Mullerian. Viceroys in some parts of Florida are actually distasteful, like Monarchs, and are, in this case, Mullerian mimics, not Batesian mimics.

114. This harmless moth (the Maple Callus Borer Moth) is a clear-winged moth (family Sesiidae). Clear-winged moths have patches of their wings free from scales and therefore transparent. The moths are often Batesian mimics of bees and wasps and the clear wings help them in their disguise.

115. This is a paper wasp, which can sting.

116. This is the harmless Grape Root Borer Moth, one of the clear-winged moths, which mimics a paper wasp. (In this case, it looks like the wings of the moth do have reddish scales on them, since the wings of a paper wasp aren’t clear, but have a reddish tint.)

117. This is a syrphid fly. Syrphid flies (also called flower or hover flies) typically feed from flowers and are Batesian mimics of bees or wasps. This fly appears to be mimicking a yellowjacket.

118. Here is a yellowjacket to compare.

119. This is a Bald-faced Hornet.

120. This is a harmless syrphid fly, *Spilomyia fusca*, that mimics a Bald-faced Hornet.

121. This Locust Borer beetle also mimics a wasp. It is often found feeding from goldenrod flowers.

122. These two mating beetles are buprestids in the genus *Acmaeodera*. Unlike most other beetles, who stick out their hard elytra (wing cases) laterally like airplane wings when they fly, *Acmaeodera* can slip their transparent hindwings out from under the elytra, without taking the elytra off the back, and, by means of a little notch at the base of each elytron, can fly using just the hindwings. The advantage of this is that the beetles appear with transparent wings and can mimic wasps even as they are flying.

123. This tiger swallowtail caterpillar, like quite a few other caterpillars, mimics a snake. The huge eyespots are nowhere near the caterpillar’s real eyes (the caterpillar’s head is that dark brown band on the bottom edge of the snake’s mouth). The eyespots are designed so that, like the Mona Lisa eyes, they always appear to be looking straight at you.

124. This is the adult tiger swallowtail butterfly. (This particular butterfly is a Canadian Tiger Swallowtail.)

 125. This is a bombardier beetle. “Bombardier” means somebody who sets off bombs, and this is just what this beetle does. It has a special chamber at the tip of its abdomen that is the explosion chamber. In this, hydrogen peroxide reacts with chemicals called hydroquinones, producing toxic benzoquinones – and also a lot of heat. The benzoquinones are released by a nozzle on the tip of the beetle’s abdomen. They come out in a jet with a popping noise, and they are boiling hot (about 100 degrees Celsius) as a result of the reaction. When attacked by a predator, the beetle shoots it with a jet of the boiling poison. The predator in this case is a pair of tweezers that are pinching the beetle’s left foreleg. The beetle has rotated its nozzle so that the jet points directly towards the tweezers (going through the beetle’s legs).

126. Pupae normally don’t move much, since the animal inside them is rearranging its body as it develops into an adult. However, if you touch a pupa, it will often wriggle so as to get away from you. This ladybug pupa does something more aggressive. If you are an ant (which you might be…) and you stick an exploratory antenna into one of those nice little grooves on the left side on the pupa, the pupa will immediately snap upright, closing the groove and pinching your antenna between the sharp edges of it. These grooves have been termed gin traps because of their resemblance to certain nasty traps of that name which humans set to catch animals.

127. These are Milkweed Aphids (*Aphis nerii*). They have little projections known as cornicles at the tips of their abdomens. When one of the aphids is disturbed, it produces a kind of wax from its cornicles. The wax emerges as a liquid, but congeals rapidly, acting as a sort of anti-predator superglue. Wasps that try to parasitize these aphids sometimes die – stuck to plants by hardened cornicle wax.

128. Tortoise beetles are built rather like turtles or tortoises. They are covered, from above, with a hard shield formed by thin extensions of the elytra and the pronotum (a plate on the thorax). With head and legs underneath this shield, a tortoise beetle does not present those handholds which ants find useful on insects that they wish to carry off as prey. Shown here is a Mottled Tortoise Beetle (*Deloyala guttata*). The bright, iridescent gold is typical of tortoise beetles.

129. Some species of tortoise beetles, which live on succulent leaves, use claws on their legs to pierce the leaf tissue and further anchor themselves against being carried off. But the species shown here, the Palmetto Tortoise Beetle (*Hemisphaerota cyanea*) lives on palmetto leaves, which are too hard to be pierced by claws. Therefore, it has, in addition to its hemispherical “tortoise shell”, large, padded feet, each with about 10,000 bristles underneath. From glands on the feet, oil is drained to the bristle tips, each of which is forked into pads. When the beetle is attacked, it simply presses its feet flat against what it is resting on. The oil, compressed into a fine film on the beetle’s 120,000 tiny pads, produces tremendous suction, so that the beetle is able to remain fixed even when pulled at for 2 minutes with a force 60 times its body weight. This is roughly equivalent to me being able to hang from the ceiling while an elephant dangles from me. To release its feet from their suction, the beetle rolls them off the substrate. The disadvantage of the defense, however, is that a large amount of oil is expended. To prevent further and unnecessary use of oil, the beetle walks on tiptoe.

130. Photo A shows this beetle withstanding a 2 gram weight that has been attached, by pulley, to its back. B shows the beetle’s feet (tarsi). C is a closeup of one of the tarsi. F shows some of tiny pads, each tipped with an oil droplet. G shows the oil droplets left on a sheet of glass after the beetle has pressed down its tarsus on it. Here is the description given by an article on the subject:

(A) Beetle withstanding a 2-g pull; brush strokes are causing the beetle to adhere with its tarsi. (B) Ventral view of beetle, showing yellow tarsi. (C) Tarsus (numbers refer to tarsomeres). (D) Tarsus in contact with glass (polarized epi-illumination). (E) Same as preceding, in nonpolarized light; contact points of the bristles are seen to be wet. (F) Bristle pads, in contact with glass. (G) Droplets left on glass as part of a tarsal “footprint.” (H and I) Apparatus diagrammed in Fig. 1. In H, beetle is on platform, before lift is applied (horizontal trace on oscilloscope); in I, the lift has been applied (ascending green trace) to point where beetle has detached (return of trace to baseline). [Bars = 1 mm (B), 100 μm (C), 50 μm (D), 10 μm (F), and 50 μm (G).]

131. Details of the pads. Here are the details from the article:

(A–C) Normal tarsus, and details thereof; the pads are stuck together in clusters (C), which are arranged in rows (A). (D–F) Comparable with preceding, but of a tarsus cleaned of oil by treatment with methanol/chloroform solution. (G) Comparable with E but with some of the bristles clustered where a droplet of oil has been applied. (H) Portion of tarsus where tips of bristles have been cut off, showing how bristle shafts are stuck together in groups; a substance, presumed to be oil, is seen between the bases of the bristles (upper arrow). Lower arrows point to pores from which tarsal oil is presumed to be secreted. (I) Bristles, in profile view, showing the component parts (shaft, bifurcated tip, pads) and oil pores between their bases. [Bars = 100 μm (A), 20 μm (B), 5 μm (C), 10 μm (I).]

132. The beetle walking.

133. A, B, C show the larva of a species of tortoise beetle that sports a slender, two-pronged fork, nearly as long as it is, attached near the tip of its abdomen. While most insects abandon their poop, the larva attaches its poop, together with its molts, to the fork on its abdomen. It then is able to use the poop as a distasteful shield, able to be positioned in any direction to block its body from a predator.

The remaining photos show the adult Palmetto Tortoise Beetle (again) and its larva. The larva defends itself by excreting its poop in long curling strands, which it glues to the tip of its abdomen. The strands gradually form a sort of protective thatch over the larva. The thatch presumably acts as disguise, as well as a distasteful covering that predators do not want to probe into. One sort of beetle, however, *Calleida viridipennis*, habitually feeds upon the larva and doesn’t mind extracting it from the covering of poop.

134. These are some green tree ants from Australia.

135. The soil excavated by an ant colony living under a sidewalk.

136. The rather larger nest of a colony of European wood ants. I was wrong when I said in lecture that colonies have just one queen. Many ants, such as these wood ants, have multiple queens at one time.

137. A queen ant digging a new nest.

138. The emergence of the queens and drones of an ant nest. The ants with wings are the queens and drones.

139. Workers of the species *Pogonomyrmex maricopa* and *Aphaenogaster albisetosa* fighting in an Arizona desert. *Pogonomyrmex* are harvester ants. Some of these ants from the West cover their nests with pebbles so as to increase the amount of heat they absorb from the sun. Sometimes, fossil bones get mixed in too; paleontologists know to check the ant nests in an area they are investigating.

Moisture regulation also affects nest design in ants. In the arid Indian scrubland, Diacamma rugosum cover their nests with feathers and other absorbent materials; these catch dew in the morning and provide the ants with water. The opposite problem – that of too much water – is faced by Prionopelta amabilis, which lives in the Central American rainforest. These ants create desiccated chambers for their moisture-intolerant pupae by spreading absorbent old pupal cocoons over the walls of subterranean chambers.

Certain ants that live in mangrove swamps build nests that are partially submerged at high tide. After foraging for delicacies on the exposed ground at low tide, the ants move themselves (as well as their eggs, larvae, and pupae) into specially designed dead-end, bell-shaped chambers of the nest, in which, as the tide rises through the soil of the nest, spaces of air remain.

140. A honeypot ant, and an ant drinking the food stored within it.

141. A colony of leaf-cutter ants, which farm fungus, feeding it with leaf pieces that they take from trees. The ants have chosen a particular tree and are defoliating it (they can strip it completely in a single night). They cut out pieces of the leaves and carry them homeward. The pieces are really heavy compared to the ants – equivalent to a human carrying a 700-pound weight. Each ant carries this weight while it dashes homeward at a rate and for a distance equivalent to a human running 17 four-minute miles in a row.

Once back at the colony, the leaf pieces are processed. In one of the 1,000 chambers of an underground nest (of which the pyramidal mound of excavated earth can weigh 44 tons and the population of ants be 8 million), a class of smaller workers cuts the pieces into 1 millimeter-wide squares. Still smaller ants compress the pieces and place them in the underground garden of the colony – a gray, porous mass of moist, decomposing plant matter. Still tinier ants, one eighth of an inch long, clean the garden and remove some of the hyphal filaments of the single kind of fungus on which the entire colony feeds. The fungus feeds on the leaf material the ants harvest, and is immune to the fungicides the ants secrete to keep their colony clean. The mutual reliance of the ants on their fungus and vice versa is complete. A young queen raised in a mature colony carries a sample of the precious fungus with her, in her mouth, when she travels to found a new colony.

142. Some species of ants form mutualistic relationships with plants. Pseudomyrmex ants of the Americas are provided by acacia trees with nesting locations inside hollow thorns, together with nectar from the bases of the leaves, and Beltian bodies (packages of food) produced by the tips of the leaflets. The ants help the acacia tree, in turn, by driving away voracious herbivorous insects by biting and stinging, and by killing the seedlings of nearby competing plants before they can get established. Other ants, such as these, grow plants in their arboreal nests – the plants are given a safe habitat, while the ants get the structural support of the plants, as well as food the plants provide.

ARMY ANTS (143-145)

Army ants, such as the South American species Eciton burchelli, are itinerant raiders. Traveling too rapidly through the rainforest to build elaborate nests from or in natural materials, the army ants erect a bivouac. When the colony halts, 500,000 workers interconnect their claws, forming hanging chains of ants that are, in turn, interconnected, until a massive shelter is formed of solid ants. (A parasitic mite that lives on the feet of army ant workers provides its own claws for building purposes when the workers form their shelter.) The shelter is solid, and protects some of the workers, as well as the queen, eggs, larvae, and pupae.

Hunting expeditions sally forth daily from an army ant bivouac daily. Massive rivers of ants forge their way in a seemingly random path over the forest floor. Branching into smaller rivers and rivulets, the mass forms a tree-like configuration, which forces the fauna of the forest before it. The workers range in size; tiny workers kill fleeing ants and grasshoppers, while large workers attack frogs. The gigantic supermajors, 500 times heavier than the smallest workers, haul away debris from the path of the other workers and crush prey. Slightly smaller submajors slice prey into pieces small enough for parties of workers to carry back to the nest.

Army ants swarms have such a powerful effect on the forest that whole ecosystems have developed around them. Parasitic flies hover above a horde of Eciton burchelli, diving down now and then to try to lay an egg on a worker ant – the larva, if it hatched, would feed on the ant’s tissues. Opportunistic birds (such as antbirds), also follow the ants, feeding from the mass of panicked insects and other animals in front of the swarm. Ant butterflies follow the birds, feeding from guano.

143. An army ant column, marching.

144. A bivouac on the right, and an antbird on the left.

145. Ants forming a living bridge across on obstacle in their path.

TRAPJAW ANTS (146-147).

Trapjaw ants can spread apart their mandibles and lock them there in a primed trap position. When a spring-like mechanism in the mandibles is released, the trap closes in the fastest recorded animal action, taking less than a millisecond. Trap jaws are useful for catching prey, as well as for combating predators.

In the case of Odontomachus trapjaw ants, the mandibles may be spread apart 180 degrees (a straight line). Soft-bodied prey can be cut in two by the closure of an Odontomachus trap, and other insects may be stunned by the shock or lacerated by the serrated jaws. An ant may follow up its attack by stinging its victim with the tip of its abdomen. In fights between rival colonies of Odontomachus, workers orient their jaws down towards the ground, then trigger the closing mechanism and launch themselves more than a foot through the air and on top of their enemies. There is a video of the launching at berkeley.edu/news/media/releases/2006/08/21\_**ant**.shtml

Trapjaw ants in the genus Daceton stalk springtails (also called snow fleas). The ants rub soil on themselves to camouflage their scent, while also releasing springtail attractant chemicals. Freezing when its quarry moves, a Daceton worker can inch up to a springtail and snap its trap shut around the creature’s body. Few other animals can consistently capture springtails, whose escape mechanism of launching into the air is almost as rapid as the closure of trapjaw ant mandibles.

146. An *Odontomachus* trapjaw ant stalking prey.

147. The ant with the captured prey.

Pollination

There are numerous and diverse mechanisms by which plants accomplish pollination. While some plants disseminate their pollen by means of wind or water, many species provide animals with nectar, pollen, or other material in exchange for the motile force of transferring pollen from flower to flower. Animal-pollinated flowers possess both male organs (stamens with pollen) and female organs (carpels to capture pollen), since such an arrangement enables pollinators to be twice as efficient at pollination, both delivering and receiving pollen at each flower they visit.

148. A White-lined Sphinx Moth feeding from a flower with its long proboscis. These and other sphinx moths hover at flowers to feed, looking much like hummingbirds. The White-lined Sphinx is one of the diurnal species of sphinx moths.

Butterflies and moths are important pollinators of some plants. They seek nectar using sight and smell, and, hence, “butterfly” or “moth flowers,” flowers meant to attract butterflies or moths specifically, have strong (sweet) scents and bright colors. Flowers pollinated by butterflies or diurnal moths open during the day, while many pollinated by nocturnal moths open at night, and, so as to be as bright and visible as possible in darkness, are often pale or white.

Many butterfly and moth flowers have thin, tubular bases, in which they store nectar, keeping it out of the reach of insects without long proboscises. Particularly long tubes fit the particularly long proboscises of sphinx moths.

149. A sulphur butterfly (Orange Sulphur?) feeding from a flower.

150. A bee feeding. The 20,000 to 30,000 species of bees in the world form the largest group of animal pollinators. Many species increase foraging efficiency by visiting only one or a few species of enticing flowers, and many plants and bees have specialized together, bees aided by having good nectar sources designed specifically for them (not others) to reach, and plant species helped by consistent pollination of their flowers and not others. Flowers specialized for pollination by bees provide the bees with landing platforms (lower lips of foxglove flowers, for instance). Bees quickly learn to come to such flowers, aided by sweet scent, recognizable patterns that may particularly indicate the location of nectar, and bright colors in yellow, ultraviolet (invisible to humans), or blue; bees cannot see the color red. In plant species dependent on bees for pollination, nectar is placed at the tubular base of the flower, where it can be reached by the tubular mouthparts of bees, but cannot be taken by chewing mouthparts, like those of beetles.

151. A hummingbird feeding. Flowers, such as columbine (though this flower is not columbine), that are pollinated by hummingbirds or other birds provide large quantities of nectar (in some cases so much that the flowers drip with nectar) to meet their pollinators’ high energy requirements. Such well-stocked flowers, however, could not properly be pollinated by small insects, which, requiring only moderate amounts of nectar, would not have the need to move from flower to flower to find sufficient food.

Bird-pollinated flowers, therefore, to deter small insects, are often odorless (since many insects are attracted by smell to flowers, while birds are not); are often red (very noticeable to birds but invisible to insects such as bees); and often have elongated tubes, which, like the tubes of butterfly and moth flowers, serve to exclude insects with short mouthparts from taking nectar. (Tubes do not always work, however; bees such as the carpenter bee species *Xylocopa tabaniformis orpifex*, which have mouthparts too short to delve into tubular flowers, may pierce the bases of such flowers and pilfer nectar intended for other pollinators.)

Columbine flowers hang upside-down so that only hummingbirds can feed from them. Bees, for instance, which can’t hover, would need a flat landing platform to feed, and columbine denies them this.

152-153. “Sesquipedalian” is a magnificent word. The derivation is from Latin "sesqui" meaning 1.5 and "ped" meaning foot, so it literally translates as "a foot and a half long.” In English, the word means (of a word) really long or (of a piece of writing) characterized by really long words. I love this word, partly because it describes itself; other words that do that are "terse," "short," "drab," “mellifluous,” and "attenuated."

It turns out that there is a Madagascan orchid that is called Angraecum sesquipedale; this orchid’s flower has a very long “spur” (thin tube hanging downwards from the flower) – up to 14 inches long. Darwin, after observing the orchid in 1862, explained the length of that part of the flower by conjecturing the existence of a moth with a proboscis long enough to reach the nectar at the base of the spur. This moth would benefit from the weird structure of the flower, since few other pollinators would be able to compete for the orchid’s nectar. The orchid would also benefit from the arrangement, since the moth would extensively pollinate its flowers. Darwin hypothesized that this unknown pollinator would be a sphinx moth – one of the large, hummingbird-like moths that hover above flowers to feed on their nectar.

Some forty years later, a Madagascan entomologist confirmed Darwin’s conjectures when he discovered the sole pollinator of A. sesquipedale - a sphinx moth with a 10-inch proboscis, now named Morgan’s Sphinx (Xanthopan morgani). Darwin’s “I told you so” is manifested in the subspecies name of “praedicta.”

Slide 152 shows the orchid A. sesquipedale (the long green things hanging down from the flowers are the nectar-filled spurs). Slide 153 is a painting of Xanthopan morgani praedicta feeding from the orchid (photos of this act are really rare since the sphinx moth is scarce, only feeds at night, and the orchids are in the high canopy).

154. Why is fruit red?

Seed dispersal is a problem for many plants. Trees, for instance, are liable to shade out and kill their own seedlings if the seeds are not somehow transported away from the parent plant.

Wind is sometimes used for transportation. Milkweed seeds are equipped with fine hairs to catch the wind. Maple seeds have “wings” for the same purpose. (Note: these wings are also angled, giving a spinning motion to the seeds, slowing them down and, thereby, giving more time for the wind to blow the seeds away from the tree.) Entire tumbleweed plants are blown by the wind, scattering seeds as they go.

Other seeds, such as coconuts, are dispersed by water. The hard husk of a coconut enables it to float for long periods on the surface of the sea.

Animal power is also harnessed for seed dispersal. The velcro-like hooks on burdock catch in the fur of animals, who unknowingly transport the seeds to new places. Cherries, raspberries, bananas, and other fleshy fruits are eaten by animals. The seeds pass through the digestive systems unharmed and exit far from their parent plants. To this end, such fruits are sour and hidden among the leaves by green pigments until the seeds mature, when the fruits turn bright colors to attract the attention of animals. Red is particularly favored, as, to invertebrates, who might eat the flesh without transporting the seed, the color is indistinguishable from the green of the leaves, while, to the larger and, therefore, more useful vertebrates, it acts as a beacon to draw attention.

Here is a mouse eating some red fruit. The mouse may eat the seeds of the fruit whole and excrete them unharmed elsewhere, whereas a beetle, say, that ate the fruit would likely gnaw some of the flesh and perhaps bite into the tasty seed and eat part of it, destroying it in the process. Insects don’t eat seeds whole.

155-157. Pollination by orchids and bunchberry.

Orchids in the genus *Ophrys*, instead of luring pollinators with nectar, have flowers that mimic the females of certain species of bees, wasps, and flies. Real males of mimicked species, after emerging into adulthood before the real females, discover newly blooming *Ophrys*, with which they try to mate. The flowers deposit pollen on the insects, and as the insects try to mate with various individual flowers, the pollen is transferred.

The Warty Hammer Orchid flower doesn’t look much like an orchid – or indeed a flower. It consists mainly of a warty-looking, brown lump (modified petal) attached to a hinged stalk. The lump produces a scent that attracts male Thynnine wasps, which fly around searching for females (which are flightless) to carry off and mate with. When a male wasp finds a Warty Hammer Orchid, it believes the warty part to be a female, lands on it, and tries to fly off with it. The hinged stalk instead causes the flying wasp to pivot around and smack into a mass of glue. The wasp then struggles to get out of the flower, and, in doing so, an amount of pollen adheres to the glue on its body. If the wasp is subsequently deceived by another Warty Hammer flower, the pollen will transferred.

Certain tropical orchids have a mutualistic relationship with bees (i.e., a relationship helping both bees and orchids instead of just the orchids). Male orchid bees scrape chemicals from patches on the flowers of the orchids, and store the chemicals in special leg glands. As each bee collects chemicals, the orchid it is visiting fixes a packet of pollen to a particular place on the bee. The packet is picked up when the bee visits another orchid of the same species. Orchid bees can be found flying with pollen packets of different species of orchid affixed at different and specific parts of head, thorax, or abdomen. It is believed that the bees modify the chemicals they acquire from flowers for use as pheromones to attract females.

Bunchberry, an 8-inch-high plant, is found on the floor of cool evergreen forests in Canada and the northern U.S. Above a whorl of light green leaves, four wide white bracts like petals radiate from a cluster of minuscule flowers (22 on average). Each of the tiny flowers begins as a compact bud, with four real petals fused at their tips, holding back the pressure generated by four hinged anthers, bent like springs within the flower. When an insect touches the long trigger on one of the petals, the flower explodes. The petals burst open, and the anthers, initially bent towards each other, snap up and apart, flinging a mass of pollen upwards at 4 meters per second, with an acceleration 800 times that of a space shuttle liftoff. The whole process (which has been investigated by a Williams College team led by Professor Joan Edwards) takes less time than the movement of a bullet down a rifle barrel, making it the fastest recorded plant action.

The result of this dramatic flowering is that the insect that bumped against the flower now has pollen spread all over it, thereby impeding the insect from eating the pollen (as pollinators are prone to do). Small insects (which often stay put on a flower and therefore don’t make good pollinators) do not trigger the release, and the flowers also ripen sequentially, so that a single pollinator will not use up the whole supply of pollen by triggering all the flowers at the same time.

This behavior is somewhat similar to that of certain orchids (genus Catasetum). The male flowers fire packets of pollen at visiting bees, to which the pollen adheres by means of a glue. The bees don’t like this much, so after being treated in this manner by a male orchid, each bee is more likely to visit female orchids instead of the vicious male ones (according to biologist John Alcock). That is just what most benefits the male orchids, since they get their pollen transferred exclusively to females.

Slide 155 shows an orchid flower mimicking a female bee. Slide 156 shows a Warty Hammer Orchid, and slide 157 shows a wasp trying to mate with the orchid.

158-162. Fireflies.

Fireflies produce light by means of an enzyme called luciferase (the name means “the light-bearing enzyme”). (Genetic engineers have inserted the gene coding for luciferase into other creatures and have thereby produced potatoes and mice that glow green.)

Male fireflies blink their lights to attract females. The females respond with their own set of blinks. Each sort of firefly has its own distinctive pattern of courtship flashes - it would never do to have one species of firefly try to mate with another species. The female of one firefly in the genus Photuris takes advantage of this arrangement. She mimics the flash pattern of a male firefly in the genus Photinus. When a Photinus comes to mate, the trickster Photuris eats it.

The reason why it does this is because Photinus have some nice toxic chemicals in them called lucibufagins that make them unpalatable to predators. A female Photuris acquires these toxins from a Photinus she eats and then passes the chemicals on to her eggs, thereby making them safer from predators.

We are probably used to North American species of fireflies, the males of which blink independently (or seemingly so). But certain fireflies in Southeast Asia light up in synchrony. Whole dazzling riverbanks of trees, as far as one can see, pulse together, thanks to the thousands or millions of male fireflies in the treetops keeping in perfect time with one another. No one knows definitively why they do this, though presumably it gives some mating advantage to each participating male.

158 shows a firefly glowing. 159 shows a firefly larva; firefly larvae are armored, can glow, and often feed on snails. 160 shows a Photinus. 161 shows a Photuris. In 162, a Photuris is eating a Photinus.

163. This is a termite mound. Such mounds can rise to a height of 30 feet and contain millions of termites. Some termite nests are so well-populated that they need ventilation shafts, similar to those in human apartment buildings, to bring oxygen inside. The shafts run to the top of the nest, where the movement of wind over the nest sucks out used air from inside and replaces it with fresh air.

One species of African termite builds a huge aboveground nest with built-in air-conditioning and air-circulation. The way it works is this: The termites’ bodies, as well as the fungus the termites grow, warm the air in the lower part of the nest, where the termites and fungus both live. Since hot air rises, the air at the lower part of the nest goes up to the top of the nest - passing through a series of increasingly small pipes just inside the wall of the nest, where some of this inner air’s heat is lost to the outer air. The pipes then release the cooler air back into the bottom of the nest to continue the cycle.

164. These are magnetic termites from Australia. The nests are tall and narrow with the thin ends pointing to the north and south (the termites judge the directions based upon the Earth’s magnetic field). The nest absorbs the sun’s rays in the morning and evening, at which times the sun strikes the large sides of the nest. However, the nest does not absorb the sun’s rays in the hottest part of day as the sun then strikes the thin top, which has very little surface area. Thus the termites keep their nest at a moderate temperature through the whole day.

165. This is a mole cricket. Mole crickets are nocturnal, ground-dwelling crickets an inch or two long. The burrow of a male mole cricket has two openings, each with a carefully constructed mouth flared like that of a trumpet. Between and below the entrances lies (among other tunnels and openings in the cricket’s burrow system) a spherical chamber in which the male sits and calls to females (much as many other grasshoppers and crickets stridulate to attract mates). The cricket would reach a larger audience if its call were louder, so it would presumably benefit from megaphones. These are provided by the megaphone-shaped entrances to the burrow; on a quiet night, a mole cricket can be heard nearly half a mile away.

Parasitism

Many insects have larvae that develop on or in a host animal by feeding from the animal. These are called parasitoids, and are often wasps or flies. The adult parasitoid lays an egg on or in or near an insect of the host species, and the larval parasitoid, when it hatches, feeds on the host. Generally, a parasitoid will have a very narrow range of host species that it will parasitize – sometimes only a single species of host will do.

Given how particular the requirements are, finding an individual of the host species can be problem for an adult parasitoid. Clues lead many parasitoids in a correct direction. Some species follow chemical pheromones that their hosts use as mating signals. Others track chemicals emitted defensively by plants attacked by herbivorous hosts. The braconid wasp *Cotesia marginiventris*, for instance, is attracted to the terpenoids emitted by corn seedlings attacked by its host *Spodoptera* sp. caterpillars (armyworms).

The closely related *Cotesia melanoscela* examines areas where caterpillars of its host, the Gypsy Moth, have laid strands of silk (this wasp is one of 13 species that parasitize the Gypsy Moth in specific stages of its development). The parasitoid tachinid fly *Cyzenis albincans* is attracted to sugars released by munched oak leaves, and distributes its eggs over leaves, where they may be eaten by the caterpillars of its host, the winter-flying moth *Operophtera brumata*.

Some plants, indeed, particularly attract parasitoids when they are under attack by caterpillars. Such a plant, when munched on by a caterpillar, identifies the species of caterpillar by means of the chemicals in its saliva, and then sends out a chemical help signal that calls in parasitoid wasps. The particular species of wasp that is called in depends upon the species of caterpillar that the plant needs to be defended from.

Some parasitoid species leave chemical “occupied” markers behind upon hosts where they have planted eggs. Other parasitoids of the same or different species notice these markers and do not parasitize marked host individuals, within which competition would likely kill their own larvae.

Hyperparasitoids parasitize primary parasitoids. Alloxysta victrix, for instance, one species of hyperparasitoid, inserts an egg into the body of a parasitoid which is, in turn, inside the body of an aphid. There are even hyperhyperparasitoids, which parasitize the hyperparasitoids. Thus, one can have a larva inside a larva inside a larva inside a caterpillar of the Cecropia Moth!

166. Caterpillars are particularly prone to being parasitized. This slide shows a wasp crawling around on a sphinx moth caterpillar preparatory to (or perhaps after) laying an egg on/in it. The egg will hatch into a wasp larva that will eat the caterpillar from the inside out even as the caterpillar continues to eat and feed. Keeping the caterpillar alive keeps the meat fresh for the parasitoid larva…

167. This is what can happen to a parasitized caterpillar. The white things hanging off of this sphinx moth caterpillar are the cocoons of wasp larvae that fed on the caterpillar.

168. This is a Pigeon Horntail, a relative of the wasps. Its larva lives inside tree trunks and eats the wood. Now wood is quite hard – and therefore hard to eat. It would be better for the larva if something softened the wood inside the tree so it could eat it more easily. Fungus is quite good at decomposing and softening wood. Wouldn’t it be nice for the horntail larva if it could put some fungus in the wood it’s eating?

So the adult female Pigeon Horntail, when she is laying an egg in a tree trunk, besides laying an egg, also deposits some fungal spores that she carries around in a pouch in her abdomen. This softens the wood up nicely even before the horntail larva hatches from its egg.

But how does the adult horntail lay an egg in a tree trunk? Tree trunks are, after all, quite hard. Well, that is the reason for the huge spiky thing on the end of the horntail’s abdomen. That is called an ovipositor. Lots of insects have them (though most aren’t nearly this formidable). They are tubes through which eggs can be laid. This one is strong and pointy enough to pierce wood (see Slide 169).

So, a horntail larva can develop inside an impenetrable tree trunk eating specially softened wood, safe from danger – right?

170. Where there is a nice sort of food in nature, such as a nutritious horntail larva, be assured that some insect has found out how to get access to it. This is a giant ichneumon of the species Megarhyssa macrurus. Ichneumons in general are parasitoids. This one is specially adapted to parasitizing horntail larvae.

How to get an egg through the tree trunk and into the horntail larva? That is what the huge ovipositor is for (it’s longer than the ichneumon’s body). It gets inserted into the tree and into the horntail larva and then an egg is laid through it.

But wait – how can something as thin as a thread pierce solid wood? Nobody really knows. Somehow, the ichneumon manages it – the ovipositor goes in (see Slide 171 – the ovipositor has separated into different tubes and each of the tubes has been looped up and then forced down through the wood underneath the ichneumon’s body). Many ichneumons (I don’t know whether this species is one of them) have metal tips on their ovipositors that make them better drills. The metal is zinc or manganese, and it is actually in the ionized form, so I guess that one might more accurately say that these ichneumons are using drills tipped with rock, rather than drills tipped with metal.

Another wonder is that the ichneumon knows exactly where the horntail larvae are in a tree trunk and where to insert its ovipositor into the wood…

172. This is a bug zapper. Bug zappers kill something on the order of 100 billion insects each year in the U.S., but they don’t work. Not only do they kill mostly moths and other insects that they aren’t intended to kill, they are ineffective, perhaps actively counterproductive, at eliminating mosquitoes. (I personally don’t want to kill mosquitoes, just as I don’t want to kill moths, but I understand that many people do.)

While moths and various non-biting flies are attracted to the ultraviolet light that bug zappers produce, mosquitoes are only mildly attracted to it. In one study (University of Delaware), out of 13,789 insects killed by bug zappers, of which only 0.22 percent (a total of 31) were biting insects. On the other hand, there were about 2000 “beneficial” insects that eat insect “pests.” Some of those are predators of mosquitoes.

In addition to being ineffective, bug zappers do other bad things. They kill insects by electrocuting them and thereby exploding them. The result is that viruses and bacteria that were in an insect get shot out all over the place in an aerosol form, together with a lot of insect particles that are really bad for people who have asthma or other respiratory problems.

Also, for the occasional mosquito that is attracted to a bug zapper (the UV light is a mild attractant), if a human is outside near the bug zapper, the mosquito may abandon the light in favor of the very strong attractants carbon dioxide and water vapor that the human is exhaling. So the bug zapper, insofar as it brings mosquitoes in (which it doesn’t really), may be bringing them in just so that they can bite you.

Don’t use bug zappers!