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These notes cover roughly what we talked about in class, as well as a good bit more. I have used red type to indicate species that are found in New England. Most of the species that are in our area I have seen in the vicinity of my house in southwest Vermont.

Most of the photos are not mine. Those that I did take I have marked with an X.

1. Cover slide (see slide 100).

Introduction:

2. This is a mason wasp (*Ancistrocerus adiabatus*) with a diagnostic smiley face on the thorax. The slide is meant to indicate the three segments of an insect's body: head, thorax, and abdomen. The legs and wings (if any) always are attached at the thorax. Insects have six legs (except for some legless forms, usually larvae) and up to two pairs of wings.

Birds evolved wings from one of their pairs of legs and as a result now have only one pair of legs left (they used to have two pairs when they were non-bird reptiles). Unlike birds, insects didn't have to give up any legs in getting wings – the wings are just extensions of the external skeleton (exoskeleton) of the insect's body.

3. The first stage of an insect's life is (generally) an egg. (Aphids often given birth to live young, but the aphid life cycle is awfully complicated and I won't discuss it here.) Shown here is the egg of a Monarch butterfly.

4. The next stage is (generally) a larva/nymph (like this Monarch caterpillar), which normally lacks wings and sexual organs.

In some insects (such as grasshoppers) this stage resembles the adult, except for the lack of wings – it is then called a "nymph" and there is no pupal stage; the nymph just sheds its skin and becomes an adult. This is called incomplete metamorphosis.

With other insects (such as butterflies, moths, flies, and beetles), the young insect looks totally unlike the adult – it is then called a "larva" and must go through a pupal stage before becoming an adult. This is called complete metamorphosis.

5. For insects (such as this Monarch) with complete metamorphosis, there is a pupal stage, during which the insect is relatively inert, does not feed, and reorganizes its body into the adult configuration.

6. The final stage is the life cycle is the adult.

7. Since insects live inside a rigid exoskeleton, they must, if they are growing, periodically shed their old exoskeleton and make a new larger one. A shed

exoskeleton is called a "molt." This ladybug larva is molting. It may eat the molt after it is done, so as not to waste the energy.

Some major groups of insects:

LEPIDOPTERA (Butterflies and moths)

8. Atlantis Fritillary (butterfly) using its straw-like proboscis to drink nectar from a red clover flower. The proboscis is the feeding apparatus for all (adult) moths and butterflies, and is only capable of extracting liquid food.

9. Tiger swallowtail sp. nectaring.

10 X. Some sort of Nymphalid butterfly that I found in Costa Rica.

11. A Dorcas Copper. Related species found in our area are the Bronze Copper and American Copper.

12. A Banded Hairsteak being eaten by a Goldenrod Spider. This spider, a variety of crab spider, has the ability to change color between yellow and white to help it blend in with the flowers where it lies in wait.

13 X. A variety of Ithomiine butterfly from Costa Rica. I found it resting for the night on the tip of a tendril.

14. A Yehl Skipper drinking up nutrients from some bird poop. Butterflies and moths don't feed just from flowers. Many also drink up nutrients from rotten fruit, tree sap, or moist poop. In our area during the summer, one can often find groups of bright yellow Clouded Sulphur butterflies clustered on a dirt road to obtain salt from the mud. There is even a moth in Asia that drinks the tears of Water Buffalo and other large animals. A related species, the Vampire Moth, has a sharp proboscis that it uses to pierce the skin of animals and drink their blood. This exciting moth is, however, found only in Malaysia and thereabouts.

Skipper butterflies, like the Yehl Skipper shown here, are (in general) tiny orange butterflies that fly at hyperspeed, whizzing around so fast that you can barely see them. They normally drink from flowers, rather than poop. There are several dozen species of skipper in New England (though the Yehl Skipper itself is found only in the Southeast).

15. An Indonesian Owl Moth. It is quite large, with a wingspan of up to 8 inches. Moths vastly outnumber butterflies (in the US, about 10 to 1), and butterflies might be considered a subset of moths. While people often consider moths to be small and drab, most actually have beautiful, intricate markings, and many are large and brightly colored (the biggest moths are larger than the biggest butterflies).

16. An Emperor Moth (a kind of silkmoth). It was suggested in class that the moth might be from a Spanish-speaking country, given the URL on the photo. In fact, it is found in northern Eurasia. (I think the URL was derived from Czech.)

17 X. A Luna Moth (wingspan of about 4 inches), which is the most common type of large silkmoth in our area (I have attracted as many as 7 to my light during a single night). Like other silkmoths, Luna Moths should be looked for in June. Setting up a light at a window is the best way to attract silkmoths since they do not feed as adults, subsisting entirely on food stored from the caterpillar stage. (Most other moths do, however, feed as adults.)

Luna moths are featured in the advertisements of the sleep medication Lunesta.

18. A Columbia Silkmoth, found in northern New England and Canada. You may notice on its thorax a large amount of what looks like fur. The fur is actually made of the same stuff as the colored scales on the wings, just the scales have been modified to be very long. The fur (which is technically called “pile” to distinguish it from the hair of mammals) helps keep the moth warm.

19 X. Its close relative the Cecropia Moth. This one (which came to my light) is perched on my shirt. It is the largest silkmoth in our area and is moderately common.

20 X. A Polyphemus Silkmoth, another large silkmoth in our area. This one is on my hand. The large eyespots on the hindwings are intended to startle predators.

21 X. An American Swordgrass Moth, one of the Cucullinae, a group of moths that fly during the middle of winter. They are well-insulated (look at how furry the thorax is) thus can keep their muscles going even when the air is just above freezing point. When they are not flying, the moths roll up in the leaf litter and becoming cold, torpid lumps. This one is well-camouflaged as a piece of twig or dead leaf.

Winter moths such as this one can be reasonably common in our area, but they don’t generally come to lights, since, when they are flying, they are generally looking for food – i.e. sap that is leaking from trees. I will be putting up a handout including how to make sugary bait to attract such moths.

22 X. A Chocolate Prominent, a pretty moth common around June in our area.

23 X. An amazing moth called the Lettered Habrosyne, which is uncommon in our area. It flies in the summer.

24 X. The beautiful Parthenice Tiger Moth. There are many sorts of tiger moth, most of which are diurnal and brilliantly colored. This one is relatively uncommon, but the Virgin Tiger Moth, which looks almost identical to it, is reasonably common. During the day, it can be found in meadows, and at night it comes to lights.

25 X. Some sort of tiger moth from Costa Rica. The adult moth has evidently just emerged from pupation. The white thing beside the moth is the cocoon, inside which the moth pupated. Many (though by no means all) moths make such a silken cocoon around their pupal case (note that the cocoon does not *replace* the pupa, merely surrounds it). The cocoon protects against predators and is often distasteful and hard to get into.

In this photo, the slit in the cocoon is where the moth got out of it. Some moths, when emerging from their pupae as adults, have to secrete an enzyme to dissolve the cocoon and allow them to break out, since the silk of the cocoon is so strong. I don't know whether this is one of those moths.

26 X. This is one of the large group of moths called "geometers" (also called inchworms because of the peculiar way in which the caterpillars walk). You can tell geometer moths as adults by the combination of the following two characteristics: (1) They normally have slender bodies without much fur, and (2) when at rest, they hold their wings spread out and flat against whatever they are on. We have hundreds of species of beautiful geometers in our area, though this particular one, which is in the genus *Phrygionis*, is from Costa Rica.

27 X. This is another geometer. It is one of many species of "emeralds," a group of small, gem-like geometers that are mostly green. This species is again from Costa Rica, but many other species of emerald are common in our area.

28. This is a Common Gluphisia moth. As caterpillars they feed on aspen leaves, which are apparently very low in salt. That means that as adults they must somehow acquire salt. The male does this by drinking huge quantities of water from mud, extracting the salt, and ejecting the leftover water in forceful jets from his rear end. The salt he has garnered he then presents to a female, who passes some of it on to her eggs.

29. This is a colorful day-flying moth called the Faithful Beauty. Unfortunately it is found only as far north as Florida.

30 X. This is a Lettered Sphinx, which holds its body in a very interesting position. With the up-curled abdomen and thin, jagged wings, it does a great job of mimicking a dead leaf. Like other sphinx moths, this species has a shape like a fighter jet – very narrow wings and a large thorax. The thorax is big because it is filled with huge flight muscles, which the moth uses to beat its wings really fast, enabling it to fly with the speed and whirr of a hummingbird. The huge flight muscles also produce lots of heat, which the moth uses to regulate its temperature (active sphinx moths are effectively "warm-blooded").

31. The larvae of butterfly and moths are called caterpillars. They generally feed on the leaves or flowers of plants, though some feed on other materials such as dead

leaves, beeswax, or even the shells of dead tortoises! This is the brightly colored caterpillar of the Black Swallowtail butterfly. It feeds on fennel and related plants.

32. This is the amazing caterpillar of the Cecropia moth (see slide 19). The bright nodules all over the caterpillar are presumably there to warn predators to avoid it – those spines have irritating chemicals. In general, spiny or furry caterpillars have some sort of chemical defense in the hairs. The chemicals are not normally particularly irritating to humans, but some people are allergic and it is generally advisable not to touch or pet such caterpillars.

33. The furry caterpillar of the common Hickory Tussock Moth. The most frequently seen caterpillars are often hairy, since these caterpillars have chemical defenses and therefore advertise their presence with bright colors (while the large number of chemical-free caterpillars are usually well-camouflaged). The word caterpillar in fact derives from the French for "hairy cat."

34. This is a Crowned Slug caterpillar. Slug caterpillars are small slug-like blobs with almost invisible legs. Many are beautifully colored.

ODONATA (Dragonflies and damselflies)

35. Two mating Halloween Pennant dragonflies, so named for the bright orange-and-black markings on their wings.

36. A Common Green Darner, which is probably the most common large dragonfly in our area, often seen cruising over ponds. It is one of the fastest insects in the world, able to fly at 53 mph (compared with the fastest insect, an Australian dragonfly, that can fly at 60 mph). Dragonflies are aerial hunters, using speed, their amazingly controlled flight (each pair of wings is controlled separately), and huge eyes to track and catch smaller insects flying by.

37. An Ebony Jewelwing damselfly, commonly found flapping slowly beside woodland streams and rivers. Damselflies are the slimmer, more delicate relatives of the dragonflies. They tend to hold their wings folded over the back, rather than out horizontally like dragonflies.

38. A Slender Bluet, one of many species of small neon blue damselflies. These "bluets," as they are called, are extremely common in marshes and wet meadows, and around ponds. As with most other dragonflies and damselflies, look for them in summer.

39. A large uncommon damselfly called the American Rubyspot.

40. The nymphs of damselflies and dragonflies are aquatic and look rather different from the adults. They are predatory and have a sort of expandable mouth that they

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can shoot out to catch prey. This one has captured a small fish.

HYMENOPTERA (Wasps, bees, and ants)

41. This is the mason wasp shown in slide 2. (Remember the smiley face on the thorax! :-))

42. A Great Golden Digger Wasp feeding on some milkweed flowers.

43. A Tricolored Bumblebee, one of the most common bumblebees in our area. It is very fuzzy (which helps it keep warm on cold mornings) and is brightly colored to warn predators of its sting.

44. A variety of cuckoo wasp. I don't know which species it is, but wasps like this one are common in our area. They are tiny jewel-like insects, and, like many of the smaller wasps, are solitary (rather than living in large nests).

45. A nest of Bald-faced Hornets, a very common large wasp in our area.

46. This is a very large solitary wasp called the Cicada Killer.

47. This is a cicada, what the wasp is after. (Male cicadas are those insects that make a deafening zithering noise at noon on hot summer days.)

48. This is the wasp and cicada together. The wasp hasn't actually killed the cicada, but has paralyzed it with a special poison. It is trying to get the cicada into a burrow it has built, but the cicada is heavier than the Cicada Killer, and so the wasp can't fly with its burden. It has to climb up trees/posts/people and glide down in order to move the cicada over to its burrow. Once the cicada is in the burrow, the Cicada Killer lays a single egg on it and closes the burrow. The larva of the wasp, when it hatches, will feed from the cicada's body, which is kept fresh because it is still alive, just paralyzed! The larva is careful to eat the nonessential organs first so the cicada stays alive as long as possible.

49. This is a kind of fairy fly, the smallest of all insect groups (though called "flies" they are actually a subgroup of the wasps). Some are only 0.2 millimeters long (about 1/100 of an inch). The image here was taken by a microscope. The ridiculous wings of the fairy fly are perfectly sufficient for the insect to "fly" since something that small gets carried by the breeze with ease. Fairy flies are parasites, laying their eggs inside the eggs of other insects!

COLEOPTERA (Beetles)

There are more species of beetle than any other group of insects – some 400,000 species are known, making up about 25% of all known species of organism (including plants, bacteria, etc.)!

50. A Dogbane Beetle, so called because it feeds on plants in the dogbane family.

51. A ladybug laying eggs. This particular species is an introduced species called the Multicolored Asian Lady Beetle, whose population has exploded across the US. It is this species that commonly crowds into houses in an attempt to find some shelter in which to spend the winter.

52. Beetles, like many other insects, have two pairs of wings, but in their case the front pair are hardened into protective wing cases called "elytra" (singular, "elytron"). When a beetle is not flying, the elytra are folded over the membranous hindwings and are all that you can see. When the beetle flies, it opens the elytra and holds them out stiffly while beating the hindwings to generate thrust.

53. This large green beetle is called the Glorious Beetle.

54. This is the Round-headed Apple Tree Borer, the larva of which feeds on the wood of apple trees.

55. This is a dung beetle. These beetles seek out dung (poop) of large animals like deer or elephants and roll balls of dung into burrows the beetles build. Eggs are laid on the dung, and the beetle larvae feed on it. While Africa has particularly large dung beetles, there are species found in New England as well.

56. This is a kind of pleasing fungus beetle, so-called, presumably, because they feed on fungus and are often brightly colored.

57. A variety of brightly colored beetles feeding at rotten fruit somewhere in East Africa.

58. A kind of Eyed Click Beetle (also called Eyed Elater). The eye spots on the thorax, which are nowhere near the beetle's real eyes, are to scare away a potential predator. Like other click beetles, this species has a little clicky thing at the tip of its abdomen. If overturned, the beetle snaps the clicky thing and thereby flings itself upward into the air – it repeats the clicking until it lands right way up.

59. A kind of Long-necked Ground Beetle.

60. A Golden Buprestid beetle.

61. A kind of beetle called the Fiery Searcher, which climbs up trees to eat caterpillars. It was introduced to the United States in an attempt to combat the invasive Gypsy Moth (a caterpillar of which this individual is eating). However, the beetles also eat many native species of caterpillar and have therefore perhaps proved more of a problem than a cure.

62. A kind of checkered beetle.

63. Two *Zygogramma* beetles. They are related to the *Calligrapha* beetles, so-called because of the fine markings like writing that adorn their elytra.

64. A kind of diving beetle. This aquatic beetle uses its front legs to catch prey, while another pair of legs is modified into paddles for swimming.

65. A species of whirligig beetle. These shiny black beetles, found in groups, dash about in circles on the surfaces of lakes looking like bits of moving hematite.

66. Side-view of the head of a whirligig beetle. You will notice two eyes on this side, one pointing up and one pointing down. The beetles in fact have four eyes, two for looking above the water and two for below. The antenna of the beetle is placed so as to rest on the surface as the beetle swims, and an organ at the base of each antenna detects the movements of the water and senses, by the ripples, what potential prey or predators are nearby.

HEMIPTERA (True bugs)

67. Many true bugs have parental care. This brightly colored nymph (it is probably toxic) is holding onto a larger and more drably patterned parent.

68. True bugs are told by the peculiar mode of feeding – they have a stiff strawlike mouthpart called a rostrum, which they fold beneath the head when they aren't using it. The rostrum is the red thing beneath the head of this wheel bug.

Having a straw to eat with, true bugs must feed from something liquid. Some of them drink up plant juices. Others, like this wheel bug, stick their rostrum into other insects, inject enzymes that dissolve the other insect's body, and then suck up the nutritious soup with the rostrum.

69. This blood-sucking conenose drinks the blood of mammals such as squirrels. I've never seen one in this area, and it doesn't normally feed from humans…!

70. This ambush bug lies in wait in the tops of flowers, particularly goldenrod. Camouflaged and motionless, it seizes unwary bees and other insects that land.

71. Not all true bugs are predators. This leafhopper (genus *Graphocephala*), one of several brightly striped species in our area, is a tiny insect that feeds on plant juices. Species of green leafhoppers are very common in lawns and make up most of the tiny insects that flee the approach of a lawnmower. They can hop and fly, and their exoskeleton repels water, which prevents them drowning in tiny water droplets, which would otherwise be a very real danger for creatures that small.

72. This Broad-headed Sharpshooter, like other sharpshooters, are large leafhoppers named for their long, straight jumps.

73. This Buffalo Treehopper, related to the leafhoppers, also feeds from plant juices. It can hop well and evades detection by camouflaging itself in green and also by appearing thorny and unappetizing. It spends its time on stems and, if you try to catch it, has the endearing habit of always dodging around to the side of the stem opposite to the side you are on.

74 X. This planthopper (family Derbidae) is one of the species of true bug that hold their wings out like the wings of a moth. (This individual is the only such bug I have seen – I was very excited when I found this in Costa Rica.)

75. Aphids are soft-bodied true bugs that often live in large masses, drinking the sweet sap from plants. These are Milkweed Aphids.

76. The nymphs of periodic cicadas live in the ground for many years (13 or 17), feeding on the sap of tree roots. They then all emerge at the same time and transform into winged adults such as this one, which zither in the treetops, mate, and die within a summer. The synchronization helps mating and also swamps predators, who are faced with far more cicadas than they can possibly eat.

Since adult cicadas zither (by scraping their wings) in the treetops at the hottest part of the summer day, those that live in the southwest get very hot. To cool off, they sweat – emitting water from pores, which evaporates and cools them.

77. A rather different problem of hot weather and water faces this beetle. (I don't really know why I thought that I should put this slide here, but it is a fun story.) Anyway, this beetle (genus *Stenocara*) lives in really dry deserts in Namibia. Six times a month, fog sweeps over the desert at dawn, and that is about all the water there is. But the beetle has a way of collecting it. The beetle stands on a dune and faces the fog. Tiny nodules on the beetle's elytra (those hard, modified forewings) foster the condensation of water. Grooves in the elytra channel the condensed water, and it runs into the beetle's mouth. The water-gathering apparatus is so efficient that the US Army is currently trying to copy it as a way of getting water in arid areas.

DIPTERA (Flies)

78. Craneflies are large flies with really long legs. Like almost all flies, they are harmless, and in fact craneflies eat mosquitoes. This Phantom Cranefly spreads its black-and-white legs as it flies, with the air pockets in the legs providing increased buoyancy. It is somewhat ghostly to watch, since, as it glides smoothly through the air, its black-and-white pattern causes it to appear and disappear depending on the background.

79. These fruit flies are mating. Like many other flies, they have amazing eyes.

80. More amazing eyes. This fly is found in our area, though I have forgotten its name.

81. A kind of picture-winged fly. The male struts up and down like a peacock to attract females.

82. A stalk-eyed fly from Southeast Asia. The red things at the end of the stalks are the eyes – the fly inflates the eye stalks immediately upon emerging from the pupa. Only the males have stalked eyes, and they are for attracting females – in fact, the males compete for mates by wrestling with their eye stalks!

83. Two mating Gold-backed Snipe Flies, one of my favorite local flies.

84. A fly in the genus *Sericomyia*, mimicking a bee or wasp.

ORTHOPTERA (Grasshoppers, Crickets, Katydids)

85. A Carolina Locust, a very large grasshopper that is very common here in dry gravelly areas. When disturbed, it jumps up and flies away with a startling crack noise.

86. A Treetop Bush Katydid, an elegant insect that chirrups from the tops of trees.

87. The Spring Field Cricket, one of the common species of cricket in our area.

NEUROPTERA (Lacewings, antlions, and more)

88. This Green Lacewing is a voracious predator of aphids. It is very common in meadows and gardens.

89. Lacewings lay their eggs on stalks to defend them from ants. If an ant walks across the leaf, it will hopefully not notice the eggs suspended above its head.

MANTODEA (Mantises)

90. This Chinese Mantis, an introduced species, is now common in America.

Fulgoridae (Lanternflies and others)
These are actually a subgroup of the true bugs, but I put them here because I forgot that, and because they are so weird.

91 X. I found this lanternfly in Costa Rica.

92. Here is another species of lanternfly from somewhere.

93. And another. The class decided that this should be called an Elecock (from "elephant" and "peacock").

Defenses against predators:

94 X. This White Underwing moth (with a wingspan of 3 inches) is patterned so as to blend in with the bark of the Paper Birch (a tree that is common in the northern forests in which the moth lives). I put this individual on a Paper Birch to show the camouflage.

95. One of these leaves is not a leaf, but an Indian Leaf Butterfly with its wings closed. At the bottom of this page is written which leaf is the butterfly.[1] Notice how the butterfly copies the veins, mildewed spots, and rough outline of the leaf.

96. The same butterfly with wings open.

97. A kind of leaf insect, a relative of the stick insects, which is camouflaged to look like a leaf.

98. A kind of katydid called the Greater Anglewing, camouflaged as a leaf. It is very common in our area and makes an excellent pet, subsisting well upon leaves in summer and upon cheerios and berries in winter.

99. A kind of dead-leaf-mimicking mantis, hidden among the leaf litter.

100. Another mantis, from Southeast Asia, mimicking a purple orchid! The mantis lies in wait among the flowers of the orchid and catches insects that come to the flowers.

101. I have sadly forgotten the name of this tropical moth, but the camouflage is amazing.

102. The caterpillar of the Viceroy butterfly, which mimics a bit of bird poop that no predator would want to eat. The adult butterfly is shown in slide 125.

103. A group of treehoppers mimicking thorns. I think that the plant that they are on does not actually have any real thorns.

104. This is actually a caterpillar – and just one caterpillar! It is called a Monkey Slug (the adult moth is called a Hag Moth). Those projections on the sides of the caterpillar are not legs, but extensions of the body. The whole caterpillar is set up to look like the shed skin of a tarantula! Strangely, it is found far further north than

[1] The bottom left leaf.

tarantulas (including in New England), but presumably even here predators would be wary of eating such an unappetizing lump.

105. 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.

106 X. The adult Double-toothed Prominent moth. This one is from my house.

107 X. 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).

108 X. Close-up of the moth hiding.

109 X. The same moth, but with wings open, showing the bright red-and-black hindwings. Underwing moths like this one generally have brightly colored hindwings – red, orange, or yellow. 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.

At least two dozen species of underwing moths are found in our area. Owing to their bright colors and large size, they can be quite exciting moths to find. They fly in late summer, and are especially attracted to sugary bait, but also come to lights sometimes, as this one did.

110. Many grasshoppers have an anti-predator tactic similar to that of underwings. 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.

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

112. And a Plains Yellow-winged Grasshopper with yellow hindwings. This species is not in our area, but other species of yellow-winged grasshoppers are.

113. Another species with bright red hindwings.

114. 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.)

115. Eye spots can replace bright colors in startling a predator. When this Io Moth (one of the smaller silkmoths in our area) opens its wings, it looks like the face of a big scary animal. Hopefully, a predator will run away.

116 X. 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.)

117 X. 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.

118. The same species from various angles.

119. This is a Scarlet-bodied Wasp Moth. 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.

120. This is the Bella Moth. 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.

121. 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.

122. 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.

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

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

125. 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.

126 X. 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.

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

128. 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.)

129. This is a syrphid fly (*Spilomyia longicornis*). 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.

130. Here is an Eastern Yellowjacket for comparison.

131. This is a Bald-faced Hornet.

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

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

134. 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.

135. This is a caterpillar, not a snake! It is holding on with the tip of its abdomen (there are some appendages [not legs] that it is using for that) and dangling upside down, so that we see its underside. The head of the caterpillar is the nose of the "snake," and the legs of the caterpillar (all six are visible) are on the top of the

snake's head. The eyes of the snake are just bulges on the side of the caterpillar – they are not the caterpillar's eyes (which are tiny). This caterpillar is from the tropics.

136. This is a local snake-mimic caterpillar, the tiger swallowtail caterpillar. The huge eyespots are again 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.

137. This is the adult tiger swallowtail butterfly. (This particular butterfly is a Canadian Tiger Swallowtail, and it is very, very common here.)

138. 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).

139. 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.

140. These are Milkweed Aphids. 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.

141. 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. The bright, iridescent gold is typical of tortoise beetles.

142. 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 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.

143. 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).]

144. 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).]

145. The beetle walking.

146. 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.

Ants:

147. These are some green tree ants from Australia.

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

149. 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.

150. A queen ant digging a new nest.

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

152. 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.

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

154. 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.

155. 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 (156-158)

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.

156. An army ant column, marching.

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

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

TRAPJAW ANTS (159-160).

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.

159. An *Odontomachus* trapjaw ant stalking prey.

160. The ant with the captured prey.

Flowers and fruit:

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.

161. 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.

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

163. 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.

164. 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.

165-166. "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 165 shows the orchid *A. sesquipedale* (the long green things hanging down from the flowers are the nectar-filled spurs). Slide 166 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).

167. 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 Cedar Waxwing eating some red hawthorn berries. The waxwing 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.

168-170. 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 168 shows an orchid flower mimicking a female bee. Slide 169 shows a Warty Hammer Orchid, and slide 170 shows a wasp trying to mate with the orchid.

More stuff about insects:
171-175. 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.

171 shows a firefly glowing. 172 shows a firefly larva; firefly larvae are armored, can glow, and often feed on snails. 173 shows a *Photinus*. 174 shows a *Photuris*. In 175, a *Photuris* is eating a *Photinus*.

176. 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.

177. 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.

178. 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 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 albicans* 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 introduced Winter Moth.

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 (see slide 32)!

179. 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…

180. 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.

181 and 182. 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 182).

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

183 and 184. 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 184 – 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…

185. 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!

186. The Columbia Silkmoth again – see slide 18.

THE END!