Arthropods

Insects, spiders and other arthropods form the great majority of animal species on Earth. The number of described species of arthropods worldwide is almost 900,000 (out of just over a million animal species), and there are thought to be 5 million to 50 million yet to be described! Arthropods are integral to many ecosystem functions, such as pollination by bees, butterflies, flies and beetles. breakdown and recycling of organic matter by spiders, mites, and insect larvae, and predation on herbivorous insects by bugs, beetles, dragonflies, wasps and flies. Insects also are a key food item for many birds, mammals, reptiles, and amphibians (Wilson 1987).

An ongoing study at Quail Ridge and other nearby localities highlights the ecological role of arthropods. Bees are important pollinators not only of wildland flowers that produce habitat and food for other wildlife, but also of commercial crops. Recently there has been concern about declines in populations of the European honeybee and other important crop pollinators. But a survey of farms and natural habitats along the western edge of the Central Valley shows that wildlands, such as Quail Ridge, support a rich diversity of native bees that provide pollination to bee-dependent crops such as tomatoes and melons on nearby farms (Kremen et al. 2002).

Despite the importance of arthropods, we do not have a full list of the species for Quail Ridge or for virtually anywhere else on Earth. Many groups of species have not yet been fully classified, and even most nature reserves have not been thoroughly surveyed. However, Professor Lynn Kimsey and her Entomology 107 class made a good start in 1997, 1999, and 2001 by compiling a list of the insect families they collected at Quail Ridge (Appendix 3). With 132 families, it falls short of the 221 recorded at Stebbins Cold Canyon, probably because there are fewer streamside habitats at Quail Ridge, but also because there has not been as much collecting yet.

How many arthropod species might there be at Quail Ridge? We can get an estimate by considering the survey of butterflies and moths (order Lepidoptera) conducted at Quail Ridge by Greg Kareofelas and Bill Patterson. In over ten years of netting the day-flying species and capturing the nocturnal ones by blacklighting (where moths and other night-flying insects come to rest on a white sheet hung next to an ultraviolet light), these dedicated lepidopterists found just over 500 species (Appendix 4). Since Lepidoptera typically comprise about 15% of all insect species in a locality or region (Borror et al., 1989), we can predict there to be about 3,300 insect species at Quail Ridge. Add another 400 mites, spiders, and other arthropods, and we get a total of nearly 4,000 arthropod species – nearly 80 times the number of mammal species thought to occur at the Reserve.

In this chapter we will briefly describe the major kinds of arthropods likely to be found at Quail Ridge, emphasizing insects since they are the largest and best-studied group. We conclude with some suggestions on how to go and see interesting insects at the Reserve.

ARTHROPODS

What are Arthropods?

Arthropods are invertebrate animals with a hard chitinous exoskeleton, jointed appendages, and a body that is composed of segments. These segments are themselves grouped into major body regions (tagmata), for example the head, thorax, and abdomen of insects. All arthropods undergo periodic molting to grow out of the confines of their rigid exoskeleton. There are four major groups of arthropods:

Spiders, mites, and relatives (chelicerates) have two tagmata, usually 4 pairs of legs, and no antennae.

Sow bugs, pill bugs, and their aquatic relatives (crustaceans) have many legs and two pairs of antennae.

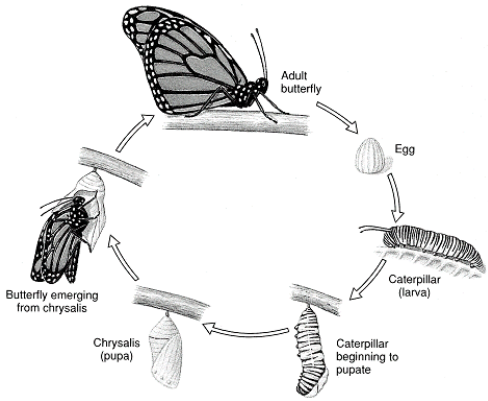
Centipedes and millipedes (myriapods) have two tagmata, many legs, and one pair of antennae.

Insects (hexapods) have three tagmata, three pairs of legs, one pair of antennae, and usually one or two pairs of wings.

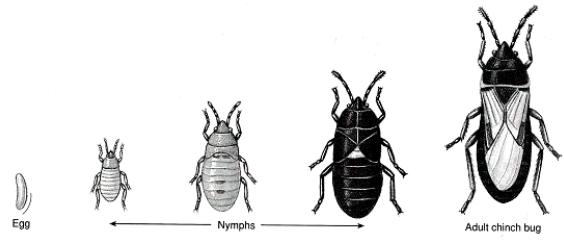
There are also other less conspicuous invertebrates at Quail Ridge, such as earthworms (annelids) and snails and slugs (molluscs). See *The Natural History of Stebbins Cold Canyon Reserve* (Greene and Huntzinger 2001) for more about these non-arthropod invertebrates.

More About Insects

Insects are easily the most diverse and abundant group of arthropods. They are the only invertebrates to evolve wings, which perhaps helps explain why they are so successful. Also, most insects have complex metamorphosis that allows their immature and adult life stages to occupy different habitats and use different resources. The most advanced insects, including beetles, wasps, butterflies, and flies, have a "holometabolous" life cycle with four stages (egg, larva, pupa, and adult). During the pupal stage a remarkable transformation occurs as the maggot or grub-like larva becomes a winged adult. Other insects have a "hemimetabolous" life cycle with three life stages (egg, nymph, and adult); the nymphal stage may have several substages (instars), each one a larger version of the one before.



Example of holometabolous development, with four life stages (egg, larva, pupa, adult), as seen in endopterygote insects.



Example of hemimetabolous development, with three life stages (egg, nymph, adult), as occurs in exopterygote insects.

Insects in strongly seasonal environments may produce one or several generations every year, but typically become dormant during the unfavorable season. In California's Mediterranean climate, winter and spring are the time of feeding, growth, and mating for most species, followed by dormancy in summer and fall. Depending on the species, the dormant stage may be the egg, larva, pupa, or adult. A few species, such as the tortoise-shell butterfly (*Nymphalis californica*), undergo spectacular migrations to take advantage of spring conditions at higher elevations after summer has begun at lower elevations.

A good reference for learning basic insect identification is the *Peterson Field Guide to Insects* (Borror and White 1970); try the pictorial key to orders on the front and back endpapers. Other useful field guides include *California Insects* (Powell and Hogue 1979); *National Audubon Society Field to Guide to North American Insects and Spiders* (Milne and Milne 1998); *Peterson Field Guide to Western Butterflies* (Tilden and Smith 1986); *Sierra Nevada Natural History* (Storer and Usinger 1963); and *The Natural History of Stebbins Cold Canyon Reserve* (Greene and Huntzinger 2001). More technical keys to insect families can be found in *An Introduction to the Study of Insects* (Borror et al. 1989).

Common Orders of Insects

Bees, ants, wasps, and sawflies (Order Hymenoptera) have two pairs of membranous wings and chewing mouthparts; some have tongue-like mouthparts for drinking nectar. All except sawflies have a distinct "waist" between their second and third tagmata. Females have a well-developed ovipositor, which is sometimes developed into a venom-bearing stinger. All ants and some bees and wasps are social insects, living in long-lived colonies with a reproductive queen (or queens) and a large number of non-reproductive workers. Other bees and wasps are solitary. Many wasps are parasitoids, meaning they lay their eggs on or inside another insect, and their larvae feed inside and devour the host. Bees feed on nectar and pollen as adults.

Butterflies and moths (Lepidoptera) have four wings covered with colored scales that rub off easily, and mouthparts that form a tube (proboscis) for drinking nectar or sap. Butterflies hold their wings vertically at rest, while moths either hold their wings roof-like, curled around the body, or flat. Also, butterflies have threadlike antennae with a knob at the end, while moths have various other shapes of antennae (whiplike, featherlike, or comblike). While the adults sip nectar to provide energy for flying and mating, the real work of feeding and growth is done by the larvae (called caterpillars), which are powerful eating machines. Each species of moth or butterfly is usually specialized to feed in the larval stage on one or more plant species. The pupa is called

a chrysalis in butterflies, and it is attached by a silken belt to a plant. Moth pupae are often hidden in a silken cocoon.

Flies, midges, mosquitoes, and gnats (Diptera) have one pair of membranous wings, while the second pair is reduced into knobs called halteres. The mouthparts are designed for lapping, sucking, or piercing. The larvae (called maggots) are soft, wingless, and legless, and most live in soil or decaying material. Some flies, like some wasps, are parasitoids whose larvae feed and develop inside the bodies of other living insects.

Beetles (Coleoptera) are identified by their modified forewings (elytra) which form a protective and often colorful shell. Most beetles have chewing mouthparts with well-developed mandibles. Beetles may be aquatic or terrestrial, and may be predators, scavengers, or rarely parasites. Beetle larvae, called grubs, may be predators or herbivores. Some feed on wood inside live or dead trees.

Bugs, hoppers, cicadas, aphids, and scales (Hemiptera) have a pair of forewings that fold over the back, covering their short membranous hindwings. The forewings cross each other or are held roof-like over the back, distinguishing bugs from beetles, whose forewings meet in a straight line down the back. Hemipterans have beaklike mouthparts. Many species suck plant juices, while others feed on small insects and even small vertebrates. Most are terrestrial but a few are aquatic with oar-like legs. Many have glands that extrude strong odors to repel predators and enemies. The nymphs are wingless and usually resemble miniature adults.

Grasshoppers, crickets, and katydids (Orthoptera) are heavy-bodied insects with hind legs that often are enlarged for jumping. Their leathery forewings protect membranous hind wings. They may be herbivores or predators. They use characteristic sounds, made by rubbing wings or legs against the body, to attract mates and establish territories.

Mantids (Mantodea) are long thin hard-bodied insects with a flexible neck and a triangular head with strong jaws. They sit perched with their forelegs raised while waiting to catch prey, hence the name “praying mantis.”

Dragonflies and damselflies (Odonata) are large slender insects with long membranous wings, large compound eyes, long legs, and sharp biting mouthparts. Both the adults and the aquatic nymphs (naiads) hunt and capture insect prey. They typically are found near water, but adults can range many miles. Dragonflies perch with wings held horizontal and perpendicular to the body, while damselflies hold their wings more parallel to the body.

Mayflies (Ephemeroptera) have large triangular wings and long slender tails. Adults live only a few days, emerging in swarms to perform aerial mating dances above lakes, rivers, or streams. They live for one to several years as aquatic nymphs (naiads), with gills and two tail-like filaments, feeding on small aquatic plants and animals.

Walking sticks (Phasmatodea) are long slender plant-feeding insects. They have chewing mouthparts and feed on a variety of plants, including toyons and oaks in California. A primitive walking stick, *Timema*, occurs in the inner coastal range of California. *Timema* adults and nymphs are wingless and green to brown. Adults only reach about one inch in length.

Other terrestrial insect orders known or likely to occur at Quail Ridge include cockroaches (Blattaria), earwigs (Dermaptera), termites (Isoptera), thrips (Thysanoptera), snakeflies (Rhaphidioptera), silverfish and bristletails (Thysanura), fleas (Siphonaptera), booklice and barklice (Psocoptera), net-veined insects (Neuroptera), scorpionflies (Mecoptera), and webspinners (Embioptera). Aquatic insects that may occur in the Berryessa Reservoir, and perhaps in the Reserve's stock ponds, are alderflies and dobsonflies (Megaloptera), stoneflies (Plecoptera), and caddis flies (Trichoptera).

SEEING INSECTS AT QUAIL RIDGE

A number of interesting insects can be observed at Quail Ridge, mostly in the spring. Some of the more conspicuous include:

Butterflies: Among the most colorful and easily seen insects at Quail Ridge are the pipevine swallowtail butterfly (*Battus philenor*), whose larvae feed on pipevine (*Aristolochia californica*), the chalcedon checkerspot butterfly (*Euphydryas chalcedona*), whose caterpillars are common on bush monkeyflower (*Mimulus aurantiacus*), and the California sister butterfly (*Adelpha bredowii*), whose larvae feed on oaks (*Quercus* spp.). Early in spring you can see the brightly colored, spiky (but not hairy) caterpillars on their host plants. Later in spring the even-more-brilliant adults can be observed nectaring at buckeye trees (*Aesculus californica*) and other plants. The mass emergence of adult pipevine swallowtails in April is a truly spectacular sight.

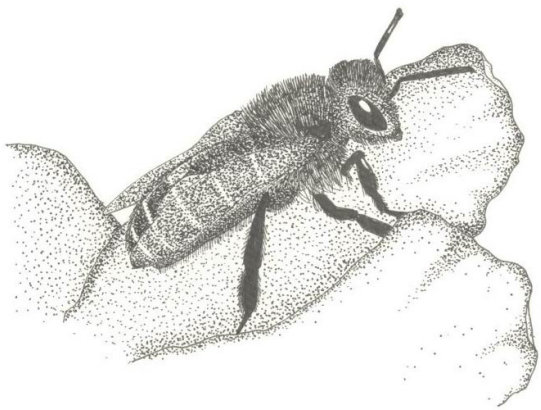
Butterflies are the one group of insects you can easily identify to species using a field guide, such as *A Field Guide to Western Butterflies* (Opler and Wright 1999) or *Butterflies of North America* (Brock and Kaufman 2003). Additionally, the Quail Ridge butterfly list is essentially complete (Appendix 5). Bill Patterson and Greg Kareofelas's observations of the 66 butterfly species at the Reserve, including what plants the caterpillars feed on and what time of year the adults are active, comprise this infomative list.

Mission Blue (*Icaricia Icarioides*) on perennial *Lupinus* sp.

ARTHROPODS

Moths: The list of moths collected by Greg Kareofelas and Bill Patterson at Quail Ridge (Appendix 4) continues to grow every year. Most of the species are inconspicuous both as caterpillars and adults, but caterpillars of several species are sometimes seen in large numbers devouring the foliage of oaks in spring. During outbreak years for the Pacific tent caterpillar (*Malacosoma constrictum*, Lasiocampidae), you may see hundreds of reddish-brown, hairy caterpillars eating oak leaves or crawling on the ground beneath trees. The fruit-tree leaf-roller (*Archips argyrospilus columbiana*, Tortricidae) also sometimes has huge outbreaks on the blue oaks at Quail Ridge. Other oak defoliators that are common in the region, but have not been seen often at Quail Ridge, are the California oakmoth (*Phryganidia californica*, Dioptidae), which has hairless large-headed caterpillars, and the western tussock moth (*Orgyia vetusta*, Lymantriidae), whose caterpillars have a row of white "hairbrushes" down their backs.

Bees: There are at least 40 species of bees at Quail Ridge (see the list of species collected by Robbin Thorp and Claire Kremen – Appendix 6). Most are natives except for the familiar European honey bee, *Apis mellifera*, a generalist flower visitor, and a medium-sized leafcutting bee, *Megachile apicalis*, from the Mediterranean area, a specialist on the invasive weed yellow starthistle (*Centaurea solstitialis*). Most of our native bees are solitary ground-nesting species, except for the large, fuzzy, colorful bumblebees, *Bombus* spp., which live in colonies.



Honey bee (*Apis mellifera*)

In early spring, large bees may be heard buzzing loudly around manzanita (*Arctostaphylos manzanita*) shrubs in flower. The large fuzzy gray *Habropoda depressa*, and queens of the yellow-and-black striped *Bombus melanopygus*, are among those you may see quickly sipping nectar from the bell-shaped white flowers. On buttercup (*Ranunculus californicus*) flowers, you can see males and females of the solitary ground-nesting *Andrena caerulea*, which specializes on buttercup pollen to feed its young. They are slender and dark metallic bluish-green, and about half as long as the diameter of the flower. Males are smaller and more slender than females and have white hairs on their faces. Females gather pollen into special brushes on their hind legs that appear to get larger and more yellow as they accumulate pollen. On redbud (*Cercis occidentalis*), you can observe honeybees, bumblebees, and a variety of native solitary bees. The solitary bees include the blue orchard bee, *Osmia lignaria propinqua*, a honeybee-sized metallic blue species that is available commercially for pollination of orchard and other crops. Smaller bees belonging to the sweat bee family (e.g. *Halictus, Evylaeus, Dialictus*) glean pollen from redbud flowers that have been opened by larger bees.

Ants: There are probably about 40 species of ants at Quail Ridge. Easily seen species include: the seed harvester *Messor andrei*, a large black ant whose nest entrances are typically decorated with large piles of seed chaff; the velvety tree ant *Liometopum occidentale*, an orange and gray species that forms large foraging lines on the trunks of oak trees; and the carpenter ant *Camponotus semitestaceus*, a very large red and black species that makes conspicuous crater-shaped nest entrances on the ground.

Other notable species are the army ant, *Neivamyrmex nigrescens,* a nocturnal marauder that attacks other ant colonies, and *Pseudomyrmex apache*, a bright-orange species that lives and forages on manzanita shrubs. Both of these species are among the northernmost representatives of tropical groups. Manzanita (*Arctostaphylos manzanita*) is a key plant species for *Pseudomyrmex* and other arboreal ants because older plants have abundant cavity-riddled dead wood that provides nest sites for ants, adjacent to live wood that provides moisture.

Gall wasps: Galls are modifications of plant growth induced by other organisms. The oak species at Quail Ridge provide many fine examples of twig and leaf galls caused by wasps of the family Cynipidae. The galls of each wasp species are distinctively different. The most familiar one is the oak apple gall, a large smooth gall found on valley oaks (*Quercus lobata*), caused by the tiny cynipid wasp *Andricus quercuscalifornicus*. The cynipid wasp *Antron douglasii* induces two types of galls on valley oaks and blue oaks (*Q. douglasii*): pink spiny turbans in summer, and white berry-like ones in early spring. Other galls range from simple woody swellings to exotic shapes like artichokes or sea urchins. Moreover, each kind of gall supports a small community of parasites and other dwellers, usually other kinds of wasps, that are specialized to live in the gall of a particular cynipid species. See the *Fremontia* articles by Russo (1990) and Schick (2002) for more about the fascinating ecology of Californian oak galls. A good comprehensive reference is Russo's (1979) *Plant Galls of the California Region*.

Aquatic insects: The man-made stockponds on Quail Ridge contain complex communities of native aquatic insects. These include many beetles (e.g. Dytiscidae, Hydrophillidae), dragonflies and damselflies (e.g. Coenagrionidae, Libellulidae, Aeshnidae), Mayflies, true bugs (e.g. Bellostomatidae, Corixidae, Gerridae, Notonectidae), and others. One of the most impressive of the pond residents is the 7 cm long giant water bug, *Lethocerus americanus*. Herpetologist Mike Benard has seen this voracious bug eat the tadpoles and adults of the Pacific treefrog, *Hyla regilla*, a rare example of an invertebrate preying on (as opposed to parasitizing) a vertebrate (see page 30)! Look in the stock ponds to see what other aquatic insects you can find.

There are also several streams on the Reserve. These are largely ephemeral, but contain many interesting groups of insects. In the winter through early summer, large numbers of water striders (Gerridae) fill the many pools of the stream. Also in the stream are aeshnid dragonfly nymphs, which possibly prey on the newt larvae that share the pools with them. Other notable residents of the streams are dobsonflies (Corydalidae), large Dipteran larvae, and club-tailed dragonflies (Gomphidae).