What Is an Insect?

Insects occur everywhere except in the high polar regions and below the surface of the oceans. A few species have even adapted to life on the Antarctic shelf margins; on cold, subarctic islands; in intertidal zones; and on the surface of the open ocean. Insects live in great abundance at every ecological horizon on land and in freshwater—in soil, where many feed on decaying organic matter and fungi or on plant roots; on ancient, low-growing plants such as mosses and ferns; on or in the trunks of shrubs and trees; and on or in foliage, flowers, or seeds of flowering plants. At each of these horizons, there is a complex of insects, each living in its own way, as a scavenger, primary consumer of plant material, predator, or parasite of other insects or other animals, and so on. Among both plant feeders and parasites, there are some generalist feeders and some that show great specialization for particular hosts.

Growth and Reproduction

In most insects, males and females are produced in about equal numbers, mating occurs, and females deposit eggs on or near the food used by the young. There are many modifications of this basic pattern—males may be produced only at certain seasons, as in social insects; generations of females may be produced without mating (parthenogenesis) while environmental conditions are favorable, as in aphids; or sexual forms are lost altogether, a phenomenon known in certain weevils, moths, and other insects. In typical forms, the sexes locate one another extremely effectively, and most females are mated almost as soon as they emerge. Commonly, the attraction of mates is accomplished using a volatile chemical or scent (pheromone) broadcast in the air, usually by the female. In some insects, such as butterflies and fireflies, visual perception of the mate is necessary; in others, like crickets and cicadas, calls or other sounds are perceived by one or both mates.

Adult insects do not grow. Growth occurs through a series of stages (instars) in juveniles; at the end of each, the shell or skin is shed (molted), and the new, temporarily pliable stage of the insect enlarges. After the final juvenile instar, molting produces the adult stage. In the simplest life cycle (hemimetabolous), such as that of roaches and grasshoppers, the eggs hatch into tiny nymphs resembling the adults except that they are smaller and lack wings and reproductive organs. Most insects have a more complex life cycle, normally with four stages (holometabolous—a complete change or metamorphosis): adults lay eggs that hatch into caterpillars, maggots, or various other forms of larvae that feed and grow through a series of molts. A largely nonmotile pupa is produced at the

last larval molt. A cocoon of silk may or may not be formed by the larva when it is ready to form the pupa, varying with the kind of insect. Finally, transformation to the adult occurs within the pupa, the shell of which is broken by the emergence of the adult.

An intermediate kind of change or metamorphosis occurs in certain aquatic insects, such as mayflies. The young stages, called nymphs or naiads, are quite different from the adults that do not live in water, and the transformation includes an active but nonfeeding subadult stage (subimago). In an evolutionary sense, the adaptation to complete metamorphosis was perhaps the single greatest achievement by insects. It enabled them to exploit a vast range of habitats by allowing adults and larvae to occupy and specialize in different niches. Complete metamorphosis allowed more versatile development of a resting stage, in which all growth and development can be stopped (diapause). This resting stage enables insects to synchronize activities to favorable seasons and to enhance survival during unfavorable times, such as the long dry season in California, by remaining dormant. Diapause may occur in the egg, larva, pupa, or adult, varying with the species. Many insects can even wait two or more years to complete the life cycle if seasonal conditions are highly unfavorable or uncertain, as in desert habitats.

Breathing and Circulation

Insects and related animals, such as sowbugs, spiders, and lobsters (Arthropods), have an exterior shell or skeleton within which the blood (hemolymph) freely circulates (open circulation). In insects the blood is moved primarily by the action of a tubular heart located in the upper part of the body cavity, opening just behind the brain. Blood is pumped forward to the head area, from which it circulates to the organs and into the appendages before reentering the posterior end of the heart.

In the majority of insects, air is taken in through holes in the body wall (spiracles). These are located along the sides of the body, usually one pair to each segment or fewer where segments have merged. Tubes (tracheae) lead from the spiracles throughout the body cavity. These branch through the organs and appendages, branching into finer and finer tubes (tracheoles). Oxygen passes from the tracheoles directly into the body, and carbon dioxide diffuses in the reverse direction. Most respiration is via passive diffusion, but limited, active pumping of air is known for some insects.

Some aquatic insects breathe in the usual manner, by periodically coming to the surface to collect a bubble of air. In many aquatic forms, however, breathing occurs through the general body surface, special organs, or gills. Therefore, some of these forms can spend their whole lives beneath the surface of the water. Insect gills are thin-walled out-

growths located along the sides of the thorax, abdominal segments, at the tail end, or on some combination of these body regions. Oxygen diffuses directly from the water through the gill walls, which are well supplied with tracheae and tracheoles. Tracheal gills are present in immature stages of mayflies, dragonflies, damselflies, stoneflies, caddisflies, alderflies, and many aquatic two-winged flies.

Feeding

Insects use many methods to feed. The kind of mouthparts and the mode of feeding are generally correlated with major groups or orders of insects. Thus grasshoppers and related insects have jaws or mandibles adapted for biting and chewing, as do beetles, wasps, bees, and most other insects. By powerful musculature, the horizontally opposing mandibles are capable of biting through solid food substances, which may be as tough as hardwood. In other insects, such as aphids, leafhoppers, true bugs, and some flies, the mouthparts are formed into a tubular beak that is stabbed into the food and juices are sucked up using pumping action. Butterflies and moths have the mouthparts modified into a long, coiled tube that is inserted into food sources such as nectar in flowers, and this is taken up by a pumping action. In some insects, enzymes are ejected from salivary glands to liquefy food, such as dried honeydew, before it is sucked up. In other cases, as in mosquitoes and fleas, salivary fluid is injected that prevents coagulation of vertebrate blood that is then ingested. Many kinds of flies are adapted to feed on blood, and they have piercing and sucking mouthparts, while other flies take up their food via a proboscis with a sponge-like tip.

Most insects are harmless to humans from a medical or health standpoint. However, lice, fleas, bedbugs, and a few other true bugs as well as mosquitoes and certain other flies are familiar for their bites. Some bugs and flies, normally predaceous on other insects, can inflict a painful bite if prompted, but none of these injects venom comparable to that of a black widow spider. But certain diseases are transmitted by insects, especially in tropical regions, commonly by biting and blood-feeding insects. In California these diseases include plague, transmitted by fleas from rodents; encephalitis and West Nile virus infecting birds, transmitted by mosquitoes; and malaria, carried by mosquitoes. None of these is epidemic today in California, although some cases of West Nile virus, encephalitis, and plague are recorded each year. Other mosquito-borne diseases not known in California presently, such as Chikungunya or Zika virus, have entered the United States and in time may be found in the state.

Stinging

Few insects are capable of stinging, but often the term "sting" is misused to describe insect bites. The true stinging apparatus is a modified ovipositor in female ants, wasps, and bees. No other insects sting, but many nonstinging insects mimic those that do and thereby gain protection from potential predators that are fooled. In contrast to insect bites, the sting is accompanied by the injection of toxins, a mixture of complex proteins and enzymes that act on the tissues of the victim, and in humans and other mammals this often causes the release of histamines. In humans, depending on individual sensitivity, the effects may be severe. Many kinds of wasps and bees are capable of stinging if provoked, but the behavior has its most damaging effect in social species: ants, yellowjackets, bumble bees, and the Honey Bee. When provoked, the workers rush out in great numbers to attack intruders, activated by alarm chemicals given off by their sisters. Some ants both sting and bite. In the Honey Bee worker the sting stylet is equipped with barbs so that it fixes in place and the entire sting apparatus pulls out of the bee, which kills her. Worker bees are expendable for the protection of the colony as a whole.

Distribution and Diversity of the California Insect Fauna

California's size, long span of latitude, and diverse topographic features set the stage for tremendous biological diversity. The second largest of the 48 contiguous states, comprising an area about equal to the New England states, Pennsylvania, and New York combined, California by size alone would be expected to have large numbers of plant and animal species. In addition, several geographic and climatic zones are created by topography, dominated by two mountain systems. These ranges parallel the coast and serve to modify the ocean's influence. Elevations extend from above 4,400 m in the Cascade Range and the Sierra Nevada to below sea level in the Imperial and Death Valleys. Average annual rainfall varies from more than 270 cm in Del Norte County to less than 5 cm in parts of the deserts. In most of the state, nearly all the precipitation falls between October and May. Coastal areas often have 365 frost-free days per year, while there are fewer than 100 at high elevations. Fog is also an important climatic influence, particularly along the coast, where it is regular during the summer months, and ground fog may be an important winter influence in the interior valleys.