# insect

arthropod class

*Alternate titles: Insecta*

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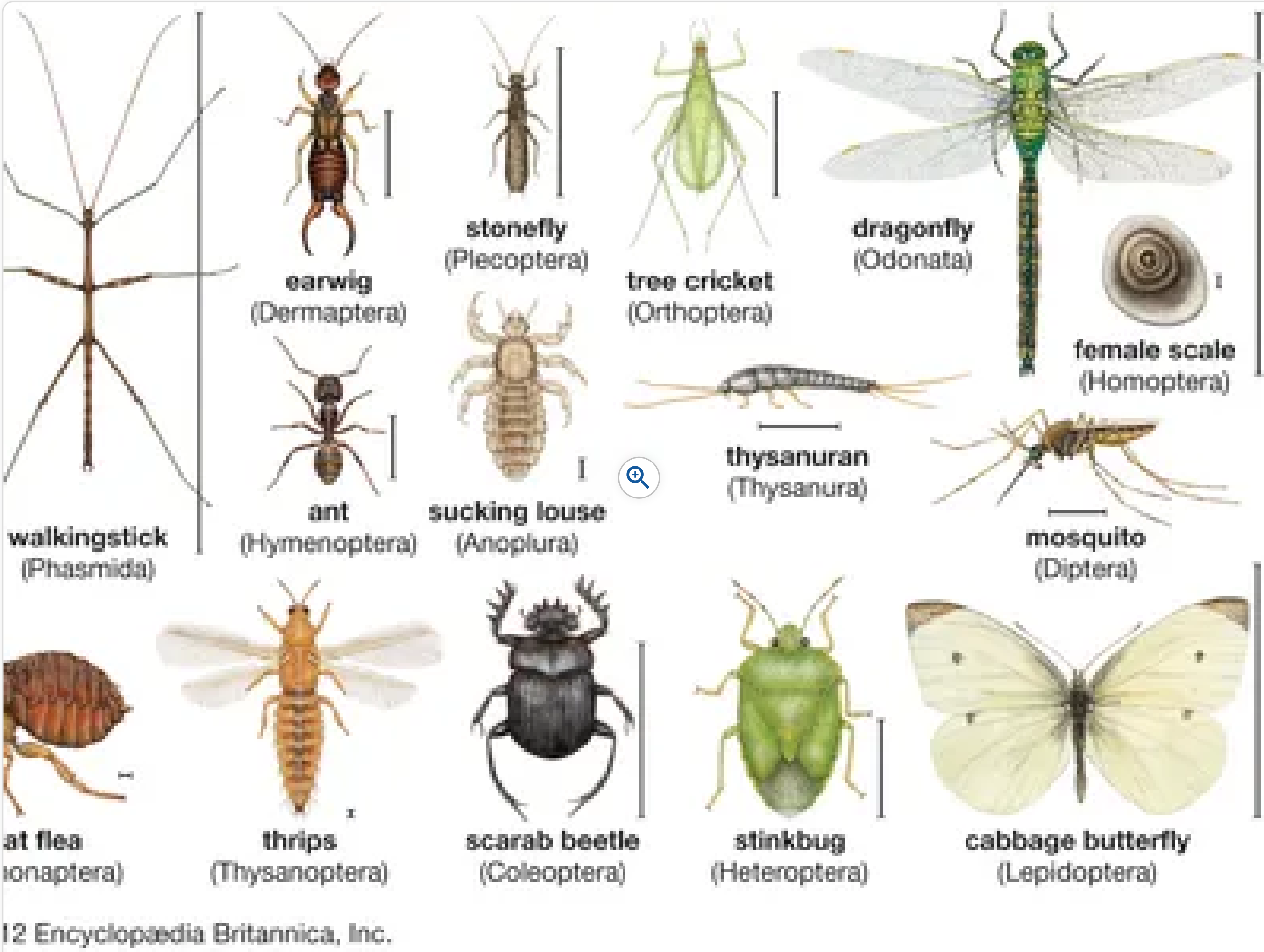


insect diversity

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paper wasp

**insect**, (class Insecta or Hexapoda), any member of the largest class of the phylum Arthropoda, which is itself the largest of the animal phyla. Insects have segmented bodies, jointed legs, and external skeletons (exoskeletons). Insects are distinguished from other arthropods by their body, which is divided into three major regions: (1) the head, which bears the mouthparts, eyes, and a pair of antennae, (2) the three-segmented thorax, which usually has three pairs of legs (hence "Hexapoda") in adults and usually one or two pairs of wings, and (3) the many-segmented abdomen, which contains the digestive, excretory, and reproductive organs.

European hornet

In a popular sense, "insect" usually refers to familiar pests or disease carriers, such as bedbugs, houseflies, clothes moths, Japanese beetles, aphids, mosquitoes, fleas, horseflies, and hornets, or to conspicuous groups, such as butterflies, moths, and beetles. Many insects, however, are beneficial from a human viewpoint; they pollinate plants, produce useful substances, control pest insects, act as scavengers, and serve as food for other animals (*see below* Importance). Furthermore, insects are valuable objects of study in elucidating many aspects of biology and ecology. Much of the scientific knowledge of genetics has been gained from fruit fly experiments and of population biology from flour beetle studies. Insects are often used in investigations of hormonal action, nerve and sense organ function, and many other physiological processes. Insects are also used as environmental quality indicators to assess water quality and soil contamination and are the basis of many studies of biodiversity.

## General features

**Eastern tailed blue butterfly**

In numbers of species and individuals and in adaptability and wide distribution, insects are perhaps the most eminently successful group of all animals. They dominate the present-day land fauna with about 1 million described species. This represents about three-fourths of all described animal species. Entomologists estimate the actual number of living insect species could be as high as 5 million to 10 million. The orders that contain the greatest numbers of species are Coleoptera (beetles), Lepidoptera (butterflies and moths), Hymenoptera (ants, bees, wasps), and Diptera (true flies).

## Appearance and habits

African goliath beetle

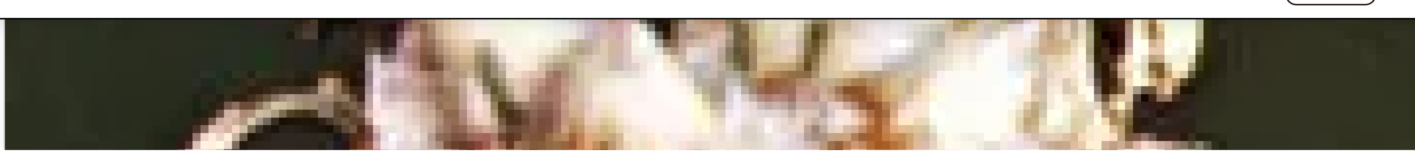
The majority of insects are small, usually less than 6 mm (0.2 inch) long, although the range in size is wide. Some of the feather-winged beetles and parasitic wasps are almost microscopic, while some tropical forms such as the hercules beetles, African goliath beetles, certain Australian stick insects, and the wingspan of the hercules moth can be as large as 27 cm (10.6 inches).

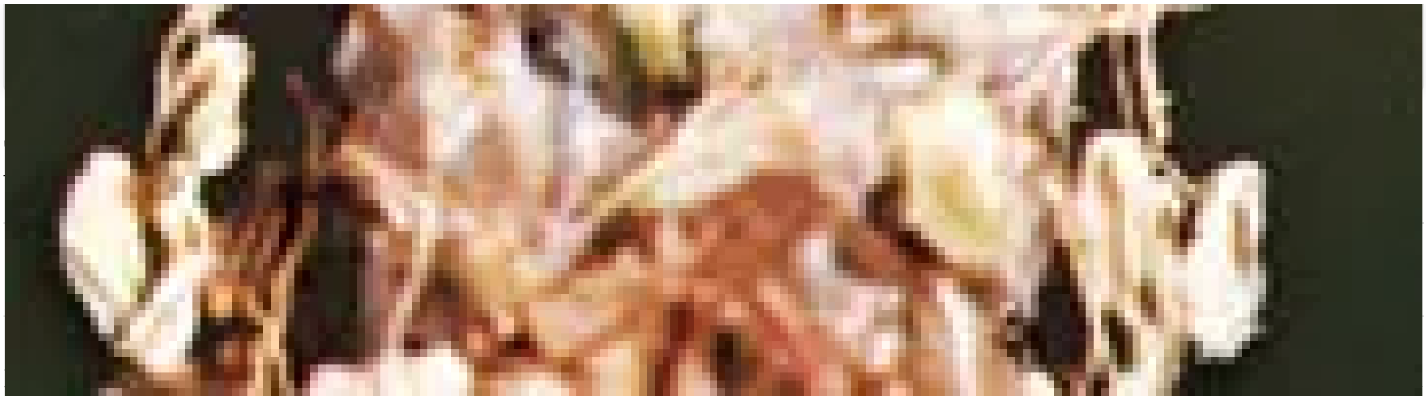


mayfly

In many species the difference in body structure between the sexes is pronounced, and knowledge of one sex may give few clues to the appearance of the other sex. In some, such as the twisted-wing insects (Strepsiptera), the female is a mere inactive bag of eggs, and the winged male is one of the most active insects known. Modes of reproduction are quite diverse, and reproductive capacity is generally high. Some insects, such as the mayflies, feed only in the immature or larval stage and go without food during an extremely short adult life. Among social insects, queen termites may live for up to 50 years, whereas some adult mayflies live less than two hours.







by absorption, to dragonflies that pursue victims in the air, tiger beetles that outrun prey on land, and predaceous water beetles that outswim prey in water.

In some cases the adult insects make elaborate preparations for the young, in others the mother alone defends or feeds her young, and in still others the young are supported by complex insect societies. Some colonies of social insects, such as tropical termites and ants, may reach populations of millions of inhabitants.

### Distribution and abundance

carpenter ant

Scientists familiar with insects realize the difficulty in attempting to estimate individual numbers of insects beyond areas of a few acres or a few square miles in extent. Figures soon become so large as to be incomprehensible. The large populations and great variety of insects are related to their small size, high rates of reproduction, and abundance of suitable food supplies. Insects abound in the tropics, both in numbers of different kinds and in numbers of individuals.

ladybug

If the insects (including the young and adults of all forms) are counted on a square yard (0.84 square metre) of rich moist surface soil, 500 are found easily and 2,000 are not unusual in soil samples in the north temperate zone. This amounts to roughly 4 million insects on one moist acre (0.41 hectare). In such an area only an occasional butterfly, bumblebee, or large beetle, supergiants among insects, probably would be noticed. Only a few thousand species, those that attack people's crops, herds, and products and those that carry disease, interfere with human life seriously enough to require control measures.

Insects are adapted to every land and freshwater habitat where food is available, from deserts to jungles, from glacial fields and cold mountain streams to stagnant, lowland ponds and hot springs. Many live in brackish water up to $^{1}/_{10}$ the salinity of seawater, a few live on the surface of seawater, and some fly larvae can live in pools of crude petroleum, where they eat other insects that fall in.

## Importance

### Role in nature

codling moth larva

Insects play many important roles in nature. They aid bacteria, fungi, and other organisms in the decomposition of organic matter and in soil formation. The decay of carrion, for example, brought about mainly by bacteria, is accelerated by the maggots of flesh flies and blowflies. The activities of these larvae, which distribute and consume bacteria, are followed by those of moths and beetles, which break down hair and feathers. Insects and flowers have evolved together. Many plants depend on insects for pollination. Some insects are predators of others.

### Commercial significance

Certain insects provide sources of commercially important products such as honey, silk, wax, dyes, or pigments, all of which can be of direct benefit to humans. Because they feed on many types of organic matter, insects can cause considerable agricultural damage. Insect pests devour crops of food or timber, either in the field or in storage, and convey infective microorganisms to crops, farm animals, and humans. The technology for combatting such pests constitutes the applied sciences of agricultural and forest entomology, stored product entomology, medical and veterinary entomology, and urban entomology.

### Insects as a source of raw materials

For primitive peoples who gathered food, insects were a significant food source. Grasshopper plagues, termite swarms, large palm weevil grubs, and other insects are still sources of protein in some countries. The dry scaly excreta of coccids (Homoptera) on tamarisk or larch trees is the source of manna in the Sinai Desert. Coccids were once the source of the crimson dye kermes. The cochineal, or carmine, from *Dactylopius* scale insects found on Mexican cacti, was used for dying cloth by the Aztecs and is used today as a dye in foods, cosmetics, drugs, and textiles. Several insect waxes are used commercially, especially beeswax and lac wax. The resinous product of the lac insect *Kerria lacca* (Homoptera), which is cultured for this purpose, is the source of commercial shellac.

**silkworm cocoon**

Two of the most important domesticated insects are the silkworm (Lepidoptera) and the honeybee (Hymenoptera). Some coarse silks are produced from the cocoons of large wild silkworm species. Most commercial silks, however, come from the silkworm *Bombyx mori*. This insect is unknown in the wild state and exists only in culture. It was domesticated in China thousands of years ago, and selective breeding, notably in China and Japan, has produced many specialized strains. The honeybee is a close relative of existing wild bees. In the Middle Ages, honey was Europe's most important sweetener, and both beeswax and honey are still articles of commerce. However, the major importance of honeybees lies in their pollination of fruit trees and other crops.

## Insect damage to commercial products

When insects that break down dead trees invade structural timbers in buildings, they become pests. This is true of insects such as dermestid beetles and various tineid moths that ecologically are latecomers to carcasses and are capable of breaking down the keratin in hair and feathers. When these insects invade skins, furs, and wool garments or carpets, they can become problems for humans.

In many hot, dry climates, as in North Africa or the plains of India, ripened grain in the fields is invaded by certain beetles and moths. When the grain is harvested, these insects thrive in the grain stores. They can be carried throughout the world in commerce and have become universal pests of stored grain, dried fruit, tobacco, and other products. Quarantine and disinfestation methods are used to control importation of such insects from grain-exporting countries.

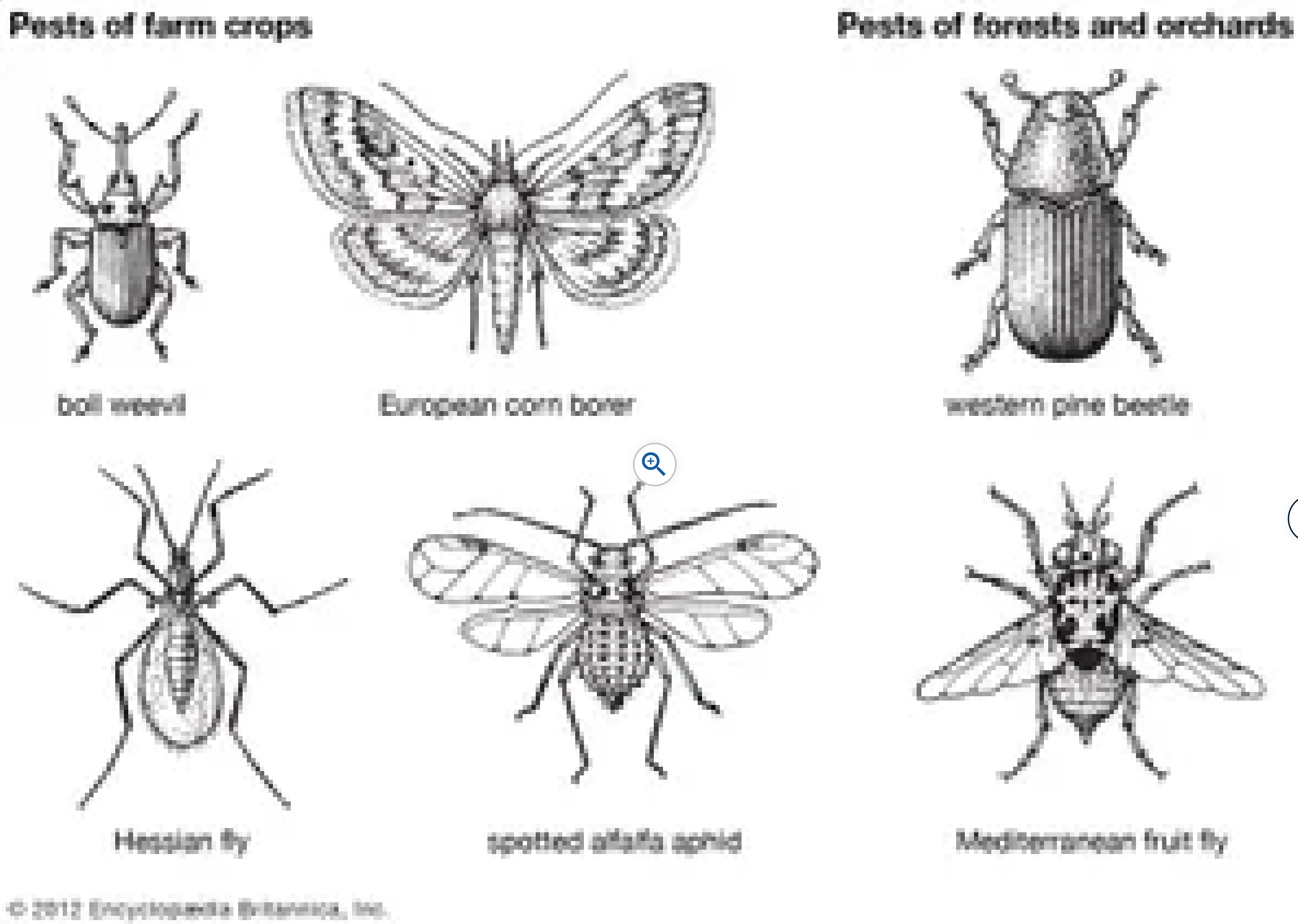


## Agricultural significance

## Ecological factors

**spotted cucumber beetle**

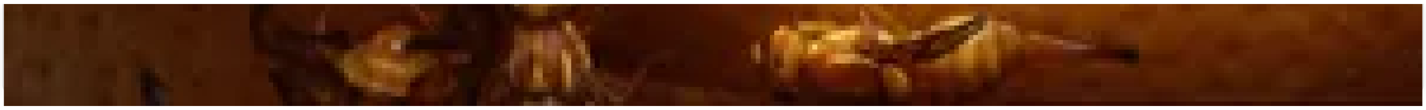
Many insects are plant feeders, and, when the plants are of agricultural importance, humans are often forced to compete with these insects. Populations of insects are limited by such factors as unfavourable weather, predators and parasites, and viral, bacterial, and fungal diseases, as well as many other factors that operate to make insect populations stable. Agricultural methods that encourage the planting of ever larger areas to single crops, which provides virtually unlimited food resources, has removed some of these regulating factors and allowed the rate of population growth of insects that attack those crops to increase. This increases the probability of great infestations of certain insect pests. Many natural forests, which form similar giant monocultures, always seem to have been subject to periodic outbreaks of destructive insects.




insect pests of farm crops, forests, and orchards

In some agricultural monocultures, nonnative insect pests have been accidentally introduced along with a crop but without also bringing along its full range of natural enemies. This has occurred in the United States with the oystershell scale (*Lepidosaphes ulmi*) of apple and other fruit trees, the cottony-cushion scale (*Icerya purchasi*) of citrus, the European corn borer (*Pyrausta nubilalis*; also called *Ostrinia nubilalis*), and others. The Colorado potato beetle (*Leptinotarsa decemlineata*), which caused appalling destruction to the cultivated potato in the United States beginning about 1840, was a native insect of semidesert country. The beetle, which fed on the buffalo burr plant, adapted itself to a newly introduced and abundant diet of potatoes and thus escaped from all previous controlling factors. Similar situations often have been controlled by determining the major predators or parasites of an alien insect pest in its country of origin and introducing them as control agents. A classic example is the cottony-cushion scale, which threatened the California citrus industry in 1886. A predatory ladybird beetle, the vedalia beetle (*Rodolia cardinalis*), was introduced from Australia, and within a year or two the scale insect had virtually disappeared. The success was repeated in every country where the scale insect had become established without its predators. In eastern Canada in the early 1940s the European spruce sawfly (*Gilpinia hercyniae*), which had caused immense damage, was completely controlled by the spontaneous appearance of a viral disease, perhaps unknowingly introduced from Europe. This event led to increased interest in using insect diseases as potential means of managing pest populations.

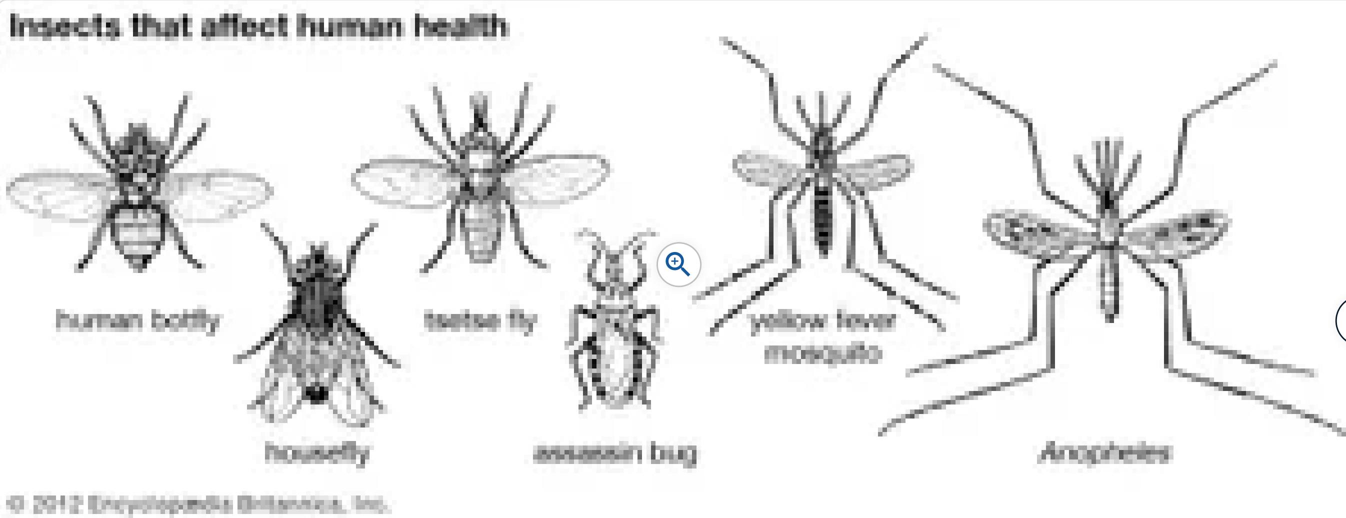
### Damage to growing crops



Insects are responsible for two major kinds of damage to growing crops. First is direct injury done to the plant by the feeding insect, which eats leaves or burrows in stems, fruit, or roots. There are hundreds of pest species of this type, both in larvae and adults, among orthopterans, homopterans, heteropterans, coleopterans, lepidopterans, and dipterans. The second type is indirect damage in which the insect itself does little or no harm but transmits a bacterial, viral, or fungal infection into a crop. Examples include the viral diseases of sugar beets and potatoes, carried from plant to plant by aphids.

Although most insects grow and multiply in the crop they damage, certain grasshoppers are well-known exceptions. They can exist in a relatively harmless solitary phase for a number of years, during which time their numbers may increase. They then enter a gregarious phase, forming gigantic migratory swarms, which are transported by winds or flight for hundreds or thousands of miles. These swarms may completely destroy crops in an invaded region. The desert locust (*Schistocerca gregaria*) and migratory locust (*Locusta migratoria*) are two examples of this type of life cycle.

### Medical significance




**insects that affect human health**

Insect damage to humans and livestock also may be direct or indirect. Direct human injury by insect stings and bites is of relatively minor importance, although swarms of biting flies and mosquitoes often make life almost intolerable, as do biting midges (sand flies) and salt-marsh mosquitoes. Persistent irritation by biting flies can cause deterioration in the health of cattle. Some blowflies, in addition to depositing their eggs in carcasses, also invade the tissue of living animals including humans, a condition known as myiasis. An example of an insect that causes this condition is the screwworm fly (*Cochliomyia*) of the southern United States and Central America. In many parts of the world, various blowflies infest the fleece and skin of sheep. This infestation, called sheep-strike, causes severe economic damage.

**mosquito: malaria vector**

Many major human diseases are produced by microorganisms conveyed by insects, which serve as vectors of pathogens. Malaria is caused by the protozoan *Plasmodium*, which spends part of its developmental cycle in *Anopheles* mosquitoes. Epidemic relapsing fever, caused by spirochetes, is transmitted by the louse *Pediculus*. Leishmaniasis, caused by the protozoan *Leishmania*, is carried by the sand fly *Phlebotomus*. Sleeping sickness in humans and a group of cattle diseases that are widespread in Africa and known as nagana are caused by protozoan trypanosomes transmitted by the bites of tsetse flies (*Glossina*). Under nonsanitary conditions the common housefly *Musca* can play an incidental role in the spread of human intestinal infections (e.g., typhoid, bacillary and amebic dysentery) by contamination of food. The tularemia bacillus can be spread by deerfly bites, the bubonic plague bacillus by fleas, and the epidemic typhus rickettsia by the louse *Pediculus*. Various mosquitoes spread viral diseases (e.g., several encephalitis diseases; dengue and yellow fever in humans and other animals).

***Aedes aegypti* mosquito**

The relationships among the various organisms are complex. Malaria, for example, has a different epidemiology in almost every country in which it occurs, with different *Anopheles* species responsible for its spread. These same complexities affect the spread of sleeping sickness. Some relationships are indirect. Plague, a disease of rodents transmitted by flea bites, is dangerous to humans only when heavy mortality among domestic rats forces their infected fleas to attack people, thereby causing an outbreak of plague. Typhus, tularemia, encephalitis, and yellow fever also are maintained in animal reservoirs and spread occasionally to humans.

### Control of insect damage

The historical objective of the entomologist was primarily to develop and introduce modifications into the environment in such ways that diseases will not be spread by insects and crops will not be damaged by them. This objective has been achieved in numerous cases. For example, in many cities flies no longer play a major role in spreading intestinal infections, and land drainage, improved housing, and insecticide use have eliminated malaria in many parts of the world.

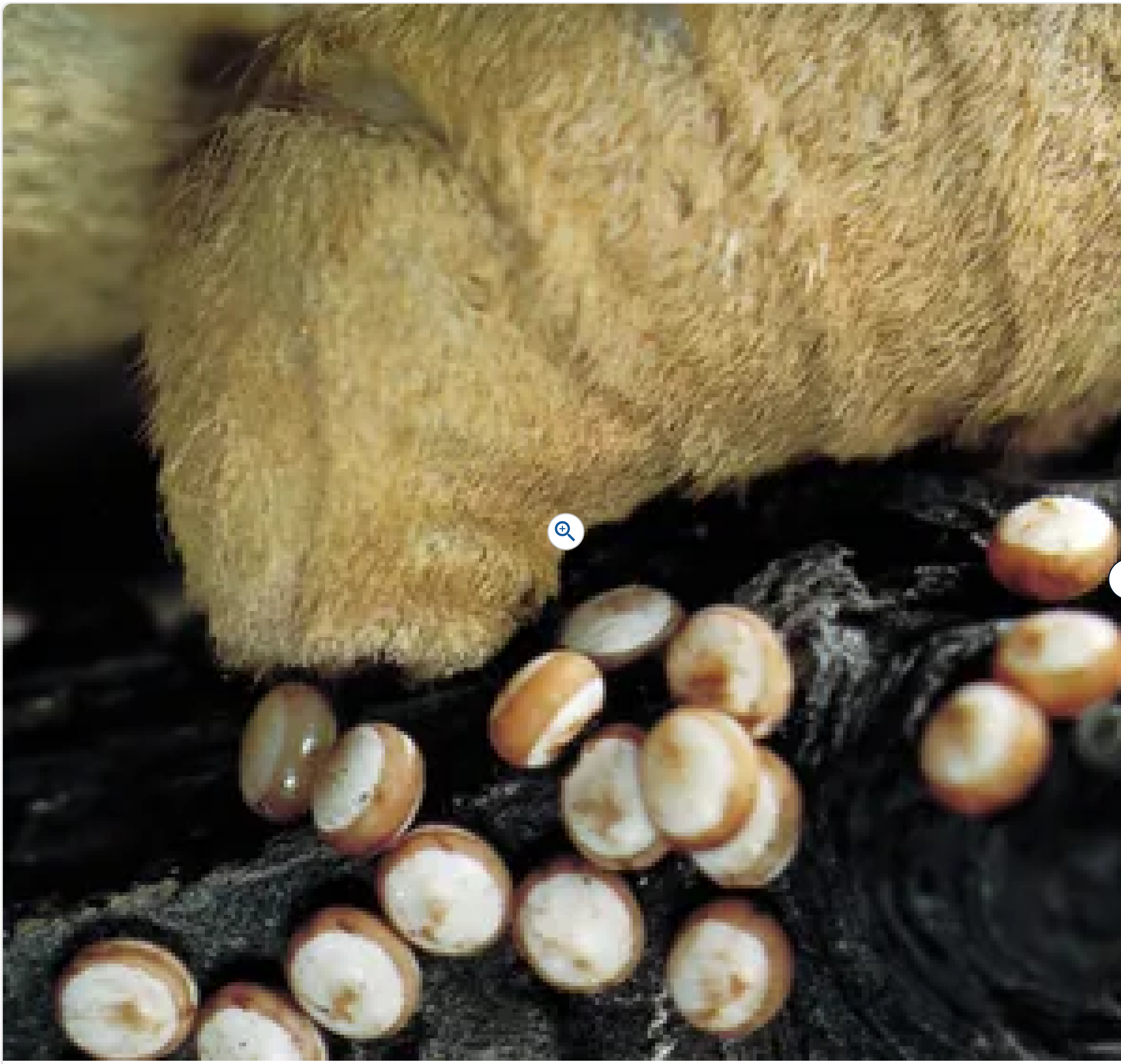
Massive outbreaks of the Colorado potato beetle in the 1860s led to the first large-scale use of insecticides in agriculture. These highly poisonous chemicals (e.g., Paris green, lead arsenate, concentrated nicotine) were used in large quantities. The continued search for effective synthetic compounds led in the early 1940s to the production of DDT, a remarkable compound that is highly toxic to most insects, nontoxic to humans in small quantities (although cumulative effects may be severe), and long-lasting in effect. Widely used in agriculture for many years, DDT was not the perfect insecticide. It often killed parasites as effectively as the pests themselves, creating ecological imbalances that permitted new pests to develop large populations. Furthermore, resistant strains of pests appeared. The environmental longevity of many early insecticides was also found to cause significant ecological problems. Similar difficulties were encountered with many successors to DDT, such as Dieldrin and Endrin.

In the course of developing effective insecticides, the primary emphases have been to reduce their potential to cause human health problems and their impact on the environment. Biological methods of pest management have become increasingly important as the use of undesirable insecticides decreases. Biological methods include introducing pest strains that carry lethal genes, flooding an area with sterile males (as was successfully done for the control of the screwworm fly), or developing new kinds of insecticide based on modifications of insects' growth hormones. The sugar industry in Hawaii and the California citrus industry rely on biological control methods. Although these methods are not consistently effective, they are considered to be less harmful to the environment than are some chemicals.

## Natural history

### Life cycle

#### Egg



**polyphemus moth**

Most insects begin their lives as fertilized eggs. The chorion, or eggshell, is commonly pierced by respiratory openings that lead to an air-filled meshwork inside the shell. For some insects (e.g., cockroaches and mantids) a batch of eggs is cemented together to form an egg packet or ootheca. Insects may pass unfavourable seasons in the egg stage. Eggs of the springtail *Sminthurus* (Collembola) and of some grasshoppers (Orthoptera) pass summer droughts in a dry shrivelled state and resume development when moistened. Most eggs, however, retain their water although they may pass the winter in a state of arrested development, or diapause, usually at some early stage in embryonic development. However, dried eggs of *Aedes* mosquitoes enter a state of dormancy after development is complete and quickly hatch when placed in water.

The hatching of young larvae is achieved in several ways. Some, such as caterpillars, bite their way out of the egg. Many, such as the flea, have hatching spines with which they cut a slit in the shell. Some insect eggs have a preformed “escape cap” that the larva pops from the shell by increasing the pressure inside the egg. Depending on the species, this may be accomplished either by swallowing air and then constricting muscles in the body to exert pressure on the cap or by having an expandable region on the head (many Diptera have a ptilinum) that can be extended by hydraulic (blood) pressure. After hatching, the larva continues to distend itself in this way, although the ptilinum collapses back into the body, until the cuticle hardens.

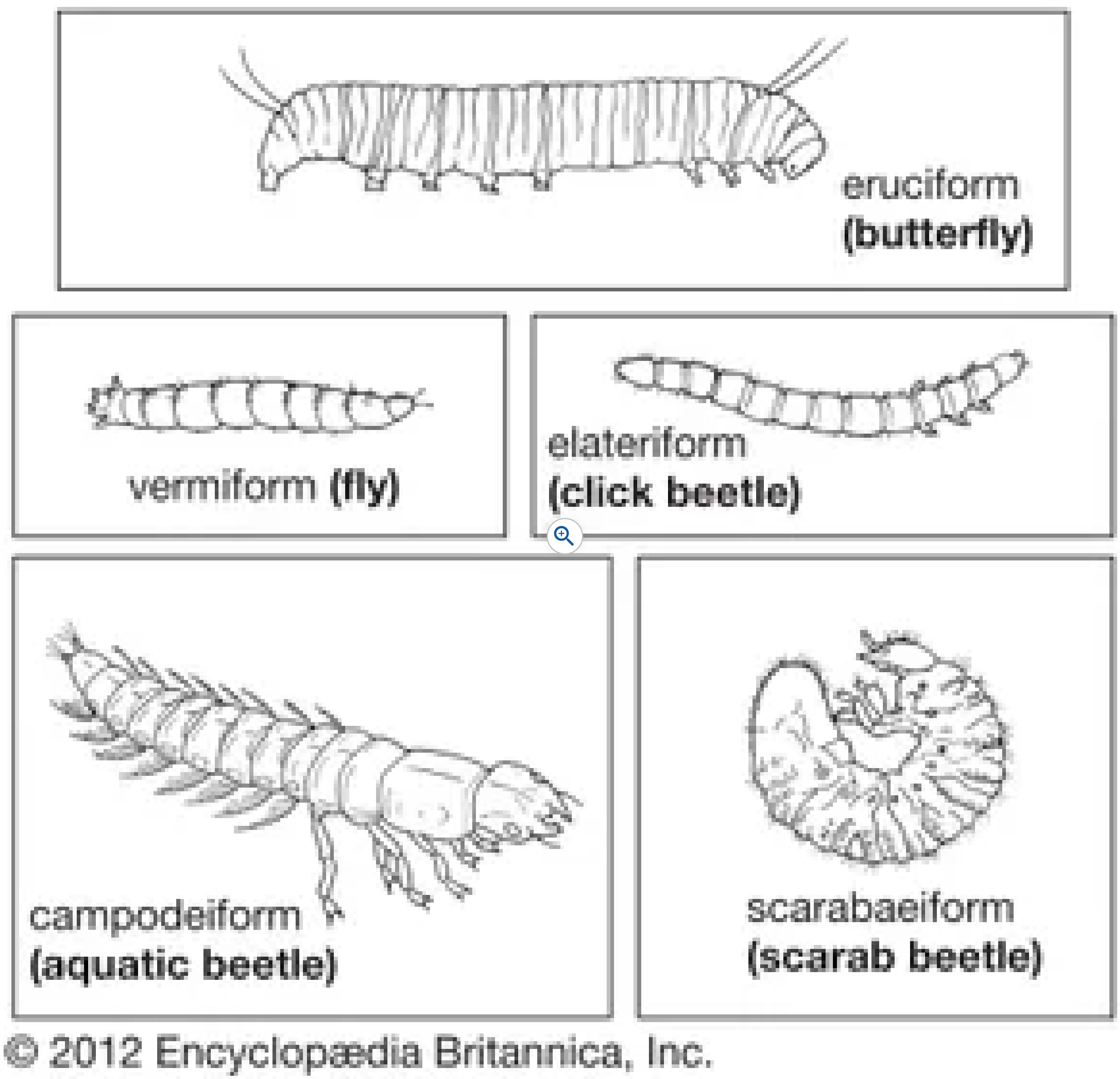
Once formed, the insect cuticle cannot grow. Growth can occur only by a series of molts (ecdyses) during which new and larger cuticles form and old cuticles are shed. Molting makes possible large changes in body form.

### Types of metamorphosis

**exoskeleton; molting insect**

In the most primitive wingless insects (apterygotes) such as the silverfish *Lepisma saccharina*, there is almost no change in form throughout growth to the adult. These are known as ametabolous insects. Among insects such as grasshoppers (Orthoptera), true bugs (Heteroptera), and homopterans (e.g., aphids, scale insects), the general form is constant until the final molt, when the larva undergoes substantial changes in body form to become a winged adult with fully developed genitalia. These insects, called hemimetabolous, are said to undergo incomplete metamorphosis. The higher orders of insects, including Lepidoptera (butterflies and moths), Coleoptera (beetles), Hymenoptera (ants, wasps, and bees), Diptera (true flies), and several others, are called holometabolous because larvae are totally unlike adults. These larvae undergo a series of molts with little change in form before they enter into complete metamorphosis, which includes molting first into pupae and then into fully winged adults.

**Types of larvae**



**insect larvae**

Larvae, which vary considerably in shape, are classified in five forms: eruciform (caterpillar-like), scarabaeiform (grublike), campodeiform (elongated, flattened, and active), elateriform (wireworm-like), and vermiform (maggot-like). The three types of pupae are: obtect, with appendages more or less glued to the body; exarate, with the appendages free and not glued to the body; and coarctate, which is essentially exarate but remaining covered by the cast skins (exuviae) of the next to the last larval instar (name given to the form of an insect between molts).

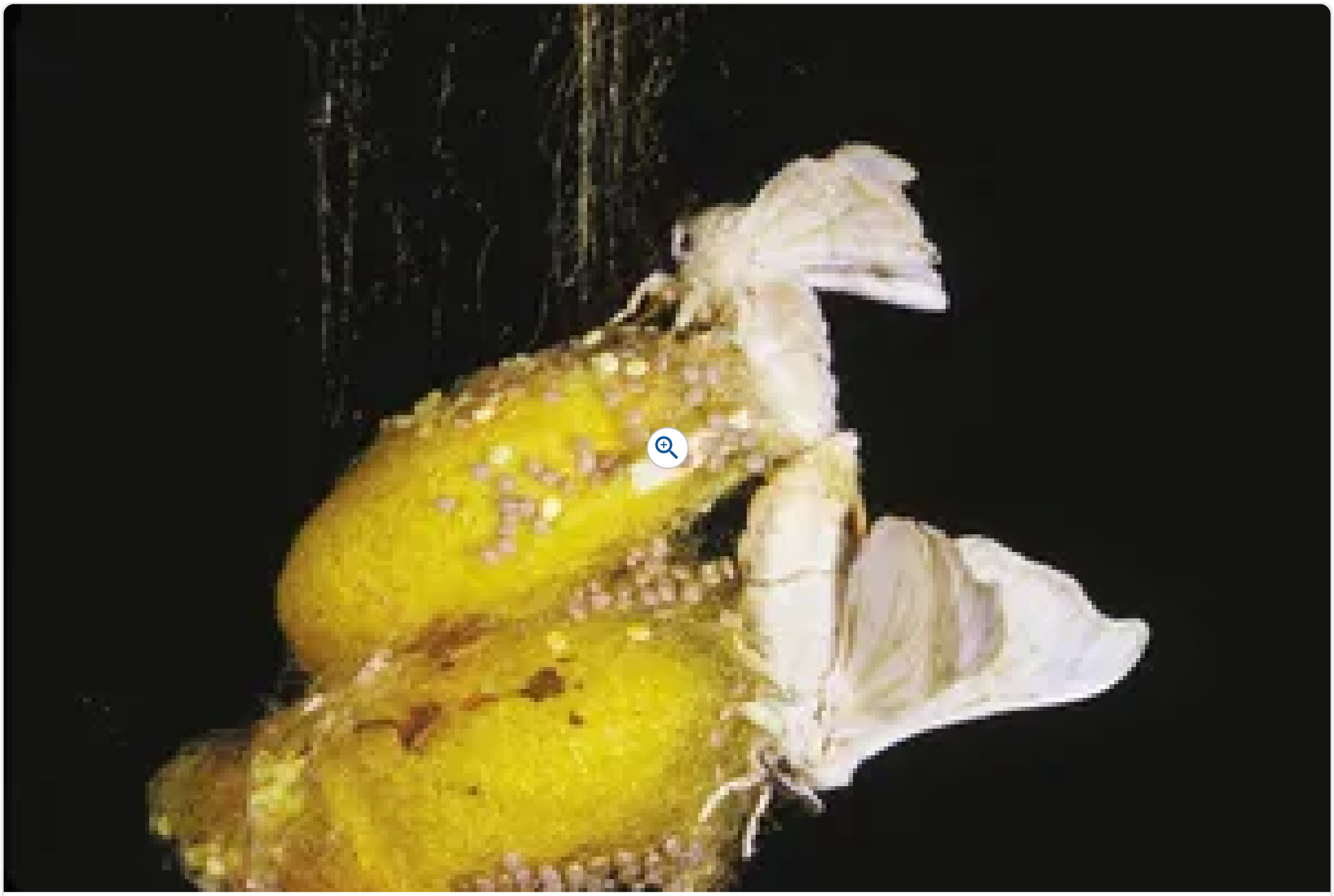
### Role of hormones

Both molting and metamorphosis are controlled by hormones. Molting is initiated when sensory receptors in the body wall detect that the internal soft tissues have filled the old exoskeleton and trigger production of a hormone from neurosecretory cells in the brain. This hormone acts upon the prothoracic gland, an endocrine gland in the prothorax, which in turn secretes the molting hormone, a steroid known as ecdysone. Molting hormone then acts on the epidermis, stimulating growth and cuticle formation. Metamorphosis likewise is controlled by a hormone. Throughout the young larval stages a small gland behind the brain, called the corpus allatum, secretes juvenile hormone (also known as neotenin). As long as this hormone is present in the blood the molting epidermal cells lay down a larval cuticle. In the last larval stage, juvenile hormone is no longer produced, and the insect undergoes metamorphosis into an adult. Among holometabolous insects the pupa develops in the presence of a very small amount of juvenile hormone.

Although a state of arrested development may occur during any stage, diapause occurs most commonly in pupae. In temperate latitudes many insects overwinter in the pupal stage (e.g., cocoons). The immediate cause of diapause, failure to secrete the growth and molting hormones, usually is induced by a decrease in daylength as summer wanes.

In addition to changes in form during development, many insects exhibit polymorphism as adults. For example, the worker and reproductive castes in ants and bees may be different, termites have a soldier caste as well as reproductives and persistent larvae, adult aphids (Homoptera) may be winged or wingless, and some butterflies show striking seasonal or sexual dimorphism. The general interpretation of all such differences is that, although the capacity to develop different forms is present in the genes of every member of a given species, particular lines of development are evoked by environmental stimuli. Hormones, including perhaps juvenile hormone, may be agents for the control of such changes.

### Reproduction



**silkworm moths**

The life of the adult insect is geared primarily to reproduction. Since reproduction is sexual in almost all insects, mating must be followed by impregnation of the female and fertilization of eggs. Usually the male seeks out the female. In butterflies in which vision is important, the colour of the female in flight can attract a male of the same species. In mayflies (Ephemeroptera) and certain midges (Diptera), males dance in swarms to provide a visual attraction for females. In certain beetles (e.g., fireflies and glowworms) parts of the fat body in the female have become modified to form a luminous organ that attracts the male. Male crickets and grasshoppers attract females by their chirping songs, and the male mosquito is lured by the sound emitted by the female in flight. The most important element in mating, however, is odour. Most female insects secrete odorous substances called pheromones that serve as specific attractants and excitants for males. The male likewise may produce scents that excite the female. Certain scales (androconia) on the wings of many male butterflies function in this way. Assembling scents, active in small quantities, are well known in female spongy moths and silkworms as male attractants. The queen substance in the honeybee serves the same purpose.

Mating and egg production require appropriate temperatures and adequate nutrition. The need for protein is particularly important, and in insects such as Lepidoptera (butterflies and moths), which take only sugar and water in the adult stage, necessary protein is derived from larval reserves. Temperature and nutrition often influence hormone secretion. Juvenile hormone or hormones from the neurosecretory cells commonly are needed for egg production. In the absence of these hormones reproduction is arrested, and the insect enters a reproductive diapause. This phenomenon occurs in potato beetles of genus *Leptinotarsa* during the winter.

A few insects (e.g., the stick insect *Carausius*) rarely produce males, and the eggs develop without fertilization in a process known as parthenogenesis. During summer months in temperate latitudes, aphids occur only as parthenogenetic females in which embryos develop within the mother (viviparity). In certain gall midges (Diptera) oocytes start developing parthenogenetically in the ovaries of the larvae, and the young larvae escape by destroying the body of their mother in a process called paedogenesis.

## Sensory perception and reception

### Touch

Insects have an elaborate system of sense organs. Tactile hairs, concentrated on the antennae, palps, legs, and tarsi, cover the entire body surface. The hairs serve to inform the insect about its surroundings and its body position (a phenomenon known as proprioception). For example, contact between the hairs on the feet and the ground inhibits movement and may lead to a state of rest in some insects. Modified mechanical sense organs in the cuticle called campaniform organs detect bending strains in the integument. Such organs exist in the wings and enable the insect to control flight movements. Campaniform organs, well developed in small clublike halteres (the modified hind wings of dipterans), serve as strain gauges and enable the fly to control its equilibrium in flight.

### Sound

Exceedingly sensitive organs called sensilla are concentrated in organs of hearing. These can be found on the bushy antennae of the male mosquito or tympanal organs in the front legs of crickets or in abdominal pits of grasshoppers and many moths. In moths these sensitive organs can perceive the high-pitched sounds emitted by bats as they hunt by echolocation. Insects complement organs of sound reception with sound-producing organs, which usually are (as in crickets) wing membranes that vibrate in response to movement of a stiff rod across a row of stout teeth. Sometimes (as in cicadas) a timbal (membrane) in the wall of the thorax is set in vibration by a rapidly contracting muscle attached to it.

### Chemicals

Chemical perceptions by the thin-walled sensilla may be comparable to the human sense of taste or smell. Many insect chemoreceptors are specialized according to specific behaviour patterns. For example, although approximately equivalent to humans in the perception of flower odours and sugar sweetness, honeybees are exceedingly sensitive to the queen substance, which is scentless to humans. And male silkworm moths are excited by infinitesimal traces of the female sex pheromone, even in the presence of odours that are intensely strong to humans.

### Sight

Although the insect eye provides less clarity than the human eye, insects can form adequate visual impressions of their surroundings. Insects have good colour vision, with colour perception extending (as in ants and bees) into the ultraviolet, although it often fails to extend into the deep red. Many flowers have patterns of ultraviolet reflection invisible to the human eye but visible to the insect eye.

## Behaviour

### Instincts

The insect orients itself by responding to the stimuli it receives. Formerly, insect behaviour was described as a series of movements in response to stimuli. That hypothesis has been supplanted by one that holds that the insect has a central nervous system with built-in patterns of behaviour or instincts that can be triggered by environmental stimuli. These responses are modified by the insect’s internal state, which has been affected by preceding stimuli. Patterns of behaviour range from comparatively simple reflex responses (e.g., the avoidance of adverse stimuli, the grasping of a rough surface on contact with the claws) to elaborate behavioral sequences (e.g., searching for mates, courtship, mating, and locating egg laying sites; hunting, capturing, and eating prey). The highest developments of behaviour, found in social insects such as the ants, bees, and termites, are based on the instinct principle.

An interesting example of a behavioral pattern is that found in the leaf-cutter bee *Megachile*. The female bee first locates a site for her nest in rotten wood and shapes the nest into a long tunnel. She then seeks out a preferred shrub from which pieces of leaves are gathered to build a cell. She first cuts a disc for a cell cap and then a series of oval pieces for the walls. After preparing the nest, she provisions it with a mixture of pollen and honey, lays an egg, and then closes the cell with more cut leaves. The leaf-cutter bee repeats this sequence until the nest is filled. Each act can be performed only in this set sequence. The insect does not stop to repair any damage to the nest but proceeds undeterred to the next step in her behavioral pattern.

Honeybee behaviours are more flexible than those of the leaf-cutter bee. Behavioral sequences of individuals are predictable, but the choice of acts or duties within the hive can be influenced by the needs of the colony. Honeybees exhibit capacity for learning (e.g., interpreting the waggle dance, learning flower colours), which is important in any insect that has to find its nest. Although these behaviours are necessary for both colony and food source location, learning capacity plays a relatively small part in the overall pattern of honeybee behaviour.

Experimental studies of details of behaviour have provided significant information about the properties of the sense organs. These studies also have provided information on the ability of insects to learn from their experience in the environment.