DK Eyewitness

INSECT

Eyewitness
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Chafer beetle
(Dicronorhina derbyana)
from Africa

Click beetle
(*Semiotus angulatus*) from
Central
America

Chafer beetle
(Jumnos ruckeri)
from northern
India

Fulgorid bug
(Pyrops delessertii)
from India

Stick insect
(Tirachoidea species*)*
from India

Shield bug
(Calliphara praslinea)
from Indonesia

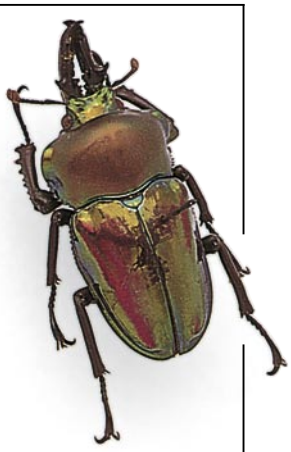
Lamellicorn beetle
(Chalcosoma atlas)
from Indonesia

Fungus weevil
(Mecocerus gazella)
from Southeast Asia

Blowfly *(Calliphora vomitoria)* found worldwide

Tawny mining bee *(Andrena fulva)* from Europe

Eyewitness INSECT



Stag beetle *(Phalacrognathus mulleri)* from northern Australia

Written by
LAURENCE MOUND

Bog bush cricket *(Metrioptera brachyptera)* from Europe

Leaf beetle *(Doryphorella 22-punctata)* from South America

Tortoise beetle *(Eugenysa regalis)* from South America

Longhorn beetle *(Callipogon senex)* from Central America

Shield bug *(Sphaerocoris annulus)* from Africa

Cuckoo wasp *(Stilbum splendidum)* from Australia

Rove beetle *(Emus hirtus)* from Great Britain

Shield bug *(Cantao ocellatus)* from Indonesia

Leaf beetle *(Doryphorella princeps)* from South America

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Butterfly *(Ancycluris formosissima)* from South America

Shield bug *(Poecilocoris latus)* from India

Bilberry bumblebee *(Bombus monticola)* from Europe

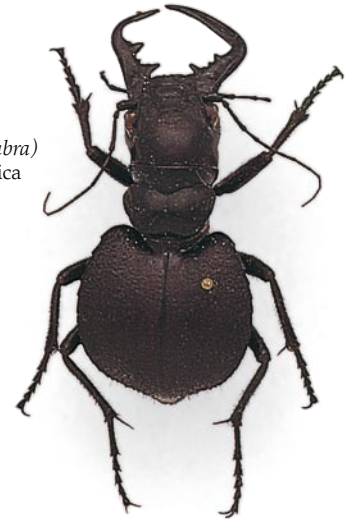
Dung beetle *(Phanaeus demon)* from Central America

Dung beetle *(Coprophanaeus lancifer)* from South America

Tree wasp *(Dolichovespula sylvestris)* from Europe

Longhorn beetle *(Sternotomis bohemanni)* from East Africa

Jewel beetle *(Chrysochroa chinensis)* from India



Tiger beetle *(Manticora scabra)* from East Africa

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Giant ant *(Dinoponera grandis)* from Brazil

Chafer beetle *(Agestrata luzonica)* from the Philippines

Dusky sallow moth *(Eremobia ochroleuca)* from Europe

Chafer *(Trichaulax macleayi)* from northern Australia

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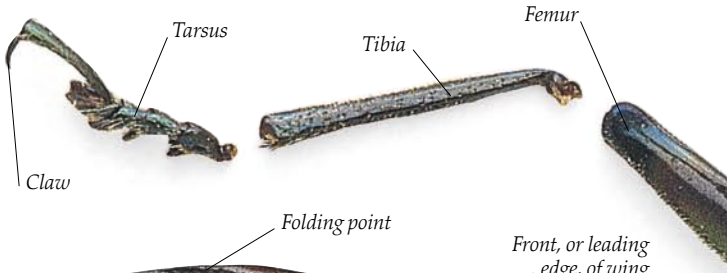
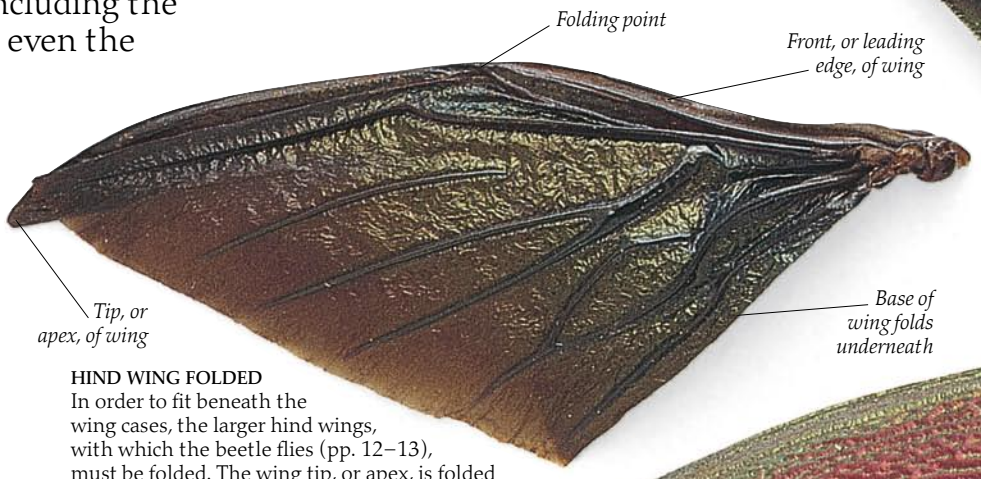
Contents

Lamellicorn larva
(Oryctes centaurus)
from New Guinea

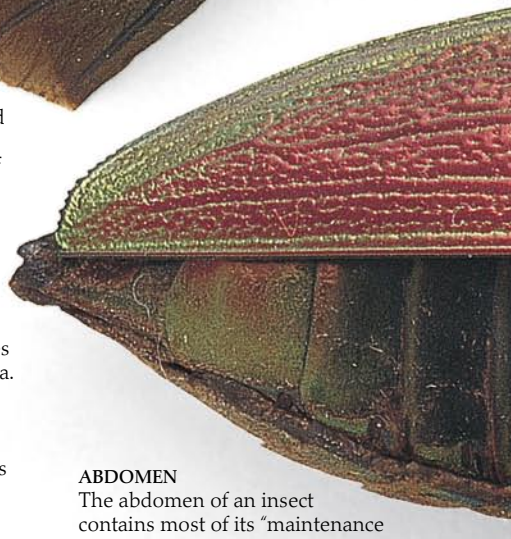
The parts of an insect

AN ADULT INSECT never grows any larger. It cannot, because it has a hard, external skeleton composed largely of a tough, horny substance called chitin. This "exoskeleton" covers all parts of the body, including the legs, feet, eyes, antennae, and even the internal breathing tubes, or tracheae. Young insects must molt, or shed all these surfaces, several times during their lives in order to grow to adult size. Beneath the old, hard skin, a new, soft skeleton forms. The insect takes in extra air to make itself larger and splits the old skin, which falls off. The young stages of many insects are grubs or caterpillars (pp. 24–25), which are very different from the adults; but these also molt, eventually producing a pupa or a chrysalis.



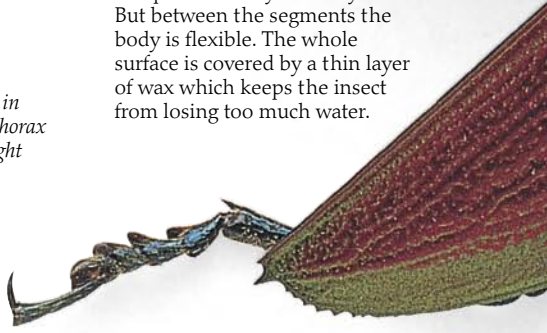


HIND WING FOLDED
In order to fit beneath the wing cases, the larger hind wings, with which the beetle flies (pp. 12–13), must be folded. The wing tip, or apex, is folded back at a special break known as the folding point in the front, or leading edge. The base of the wing is also folded underneath.

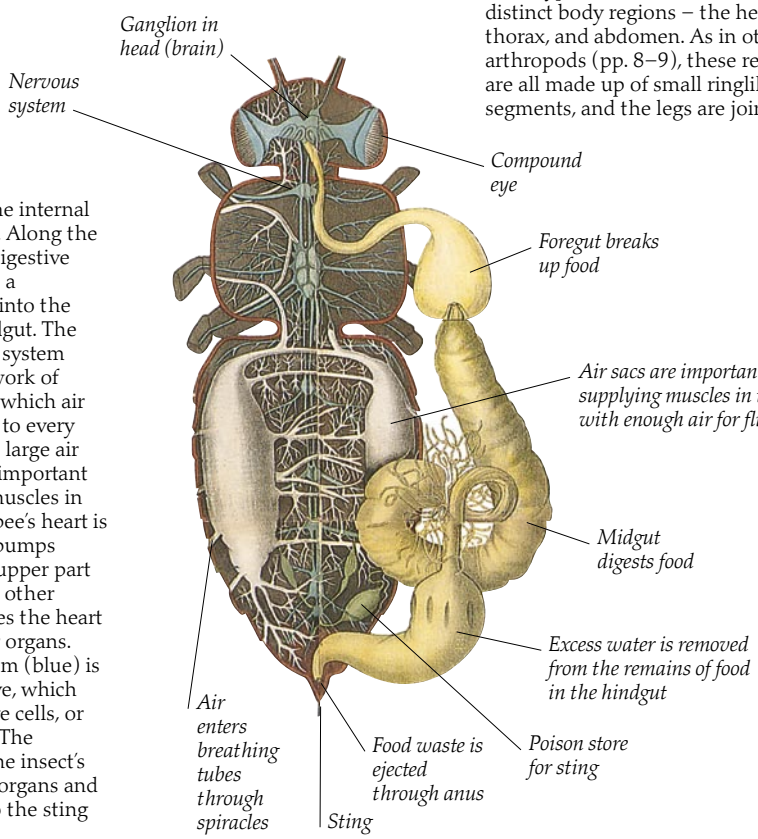


BEETLE BODY
This adult jewel beetle (*Euchroma gigantea*), shown here at three times life size, comes from South America. It is a typical insect with three distinct body regions – the head, thorax, and abdomen. As in other arthropods (pp. 8–9), these regions are all made up of small ringlike segments, and the legs are jointed.

ABDOMEN
The abdomen of an insect contains most of its "maintenance equipment" – the digestive system, heart, and sexual organs. Like the other parts of the body it is protected by the rigid exoskeleton, or cuticle, which is composed mainly of horny chitin. But between the segments the body is flexible. The whole surface is covered by a thin layer of wax which keeps the insect from losing too much water.



FRONT WING
In beetles (pp. 30–31) the front pair of wings is adapted as a pair of hard wing cases called elytra. These protect the body and are often brightly colored. When the beetle flies (pp. 12–13), the elytra are held forward.



INTERNAL ANATOMY
This illustration shows the internal anatomy of a worker bee. Along the center of its body is the digestive system (yellow), which is a continuous tube divided into the foregut, midgut, and hindgut. The breathing, or respiratory, system (white) consists of a network of branched tubes, through which air passes from the spiracles to every part of the body. The two large air sacs in the abdomen are important for supplying the flight muscles in the thorax with air. The bee's heart is a long, thin tube, which pumps blood along most of the upper part of the body. There are no other blood vessels. Blood leaves the heart to carry food to the other organs. The simple nervous system (blue) is formed by one main nerve, which has knots of massed nerve cells, or ganglia, along its length. The ganglion in the head is the insect's brain. The female sexual organs and store of poison leading to the sting are shown in green.

LEGS
Insects have three pairs of jointed legs (pp. 18–19), which are used for walking, running, or jumping – depending on the species. Each leg has four main parts: the coxa joins the leg to the thorax; the femur, or thigh, is the most muscular section of the leg; the tibia, or lower leg, often carries a number of spines for self-defense; and the tarsus, the equivalent of a human foot, consists of between one and five segments, also two claws between which there is sometimes a small pad for gripping smooth surfaces.

Tarsus has between one and five segments

Tibia

Femur

Coxa

Coxa

Second and third segments of the thorax each bear a pair of wings and a pair of legs

ARMOR PLATING
A tank is like a large beetle, with its hard outer skin protecting the important inner workings from being damaged by enemies.

Each foot bears two claws for climbing on rough surfaces

FEEDING IN INFORMATION
The head carries the feeding apparatus (pp. 20–21) as well as important sense organs such as the compound eyes (pp. 14–15), antennae (pp. 16–17), and the palps, or feelers, which are attached to the mouthparts and help give the insect information about the taste and smell of its food.

ANTENNAE
The antennae of insects (pp. 16–17) vary in size and shape from long and thin, as in crickets, to short and hairlike, as in some flies. Whatever their shape, the antennae bear many sensory structures that are able to detect air movements, vibrations, and smells.

Compound eye

COMPOUND EYES
Insect eyes (pp. 14–15) are called "compound" because each is made up of hundreds of tiny, simple eyes. These eyes enable an insect to detect movement around it in almost every direction at once.

First segment of thorax bears front pair of legs

Segmented antenna detects vibrations and smells

THORAX
The thorax is made up of three segments. The first bears the first pair of legs and is often clearly separated from the second and third segments, each of which has a pair of wings and a pair of legs. The second and third segments are closely joined to the abdomen.

Claw

Leading edge of hind wing

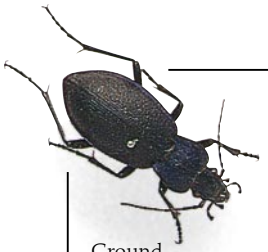
Wing case, or elytron

HIND WING OUTSTRETCHED
The wings have no muscles in them. As the wing cases are lifted, muscles inside the thorax pull on the leading edge of the hind wings and make them open automatically (pp. 12–13).

A spiracle can be closed to prevent the entry of air and control water loss

A BREATH OF FRESH AIR
Insects breathe air through a network of tubes (tracheae) that extend into the body from pairs of openings in the cuticle called spiracles. Some insects, like this caterpillar, have a pair of spiracles on each segment. More active insects often have fewer spiracles, as they can force air out of the tracheae.

What is an insect?

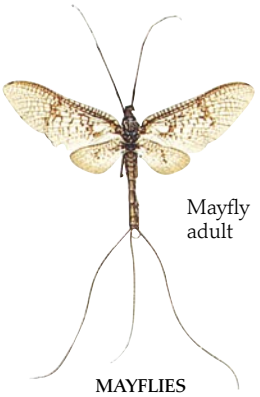


Ground beetle

Ladybird beetle

BEETLES
Beetles (pp. 30–31) belong to the order Coleoptera, meaning "sheath wings." The front pair of wings are hard, sheathlike coverings (elytra) that meet in the middle and protect the delicate hind wings and body.

INSECTS ARE THE MOST SUCCESSFUL creatures in the whole of the animal kingdom. They are remarkably adaptable and live everywhere on land, in the air, and in water. Thus insects can be found in scorching deserts and in hot springs, on snowy mountain peaks and in icy lakes. Their small size means they can fit into very small places and do not need much food to live. Insects are invertebrates, meaning that, unlike mammals, fish, reptiles, and birds, they have no backbone. Insects belong to the group of invertebrates called arthropods; that is, they have a hard, protective exoskeleton (pp. 6–7) and jointed legs. However, insects are different from other arthropods because they have only six legs. Most insects also have wings, which enable them to escape from danger and to search for food over a wide area. Today there are over a million known species of insect with many more waiting to be discovered. Each species is a member of a larger group, or order, made up of other insects with the same physical features.



Mayfly adult

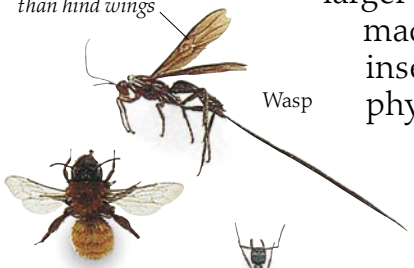
MAYFLIES
These insects belong to the order Ephemeroptera, referring to the short lives of the adults. Young mayflies live and feed underwater.

Fly

FLIES
Flies (pp. 32–33) belong to the order Diptera, meaning "two wings," so named because, unlike other insects, flies only have one pair of wings. The hind wings are modified into tiny balancing organs, called halteres (p. 12).

COCKROACHES
These flattened insects (p. 41) have hardened front wings that overlap each other. Young cockroaches look like smaller versions of the adults but without wings.

Front wings are larger than hind wings



Wasp

Bee

Ant

WASPS, ANTS, AND BEES
The name of the order that includes all wasps, bees, and ants (pp. 38–39) is Hymenoptera. This means "membrane wings" and refers to their two pairs of thin, veined wings. The males of this order are unusual because they develop from unfertilized eggs. Many females in this group are armed with a sting.

Dragonfly

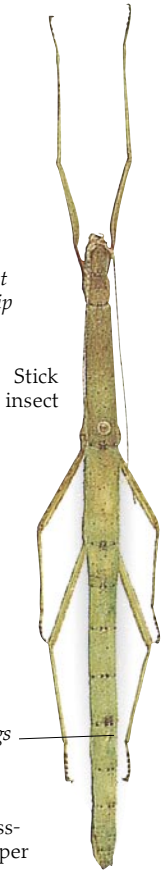
DRAGONFLIES AND DAMSELFLIES
These two insects (p. 41) are closely related and belong to the order Odonata. The name refers to their large, specially adapted jaws which they use to catch flies. The nymphs live underwater and only come to the surface when it is time for the adult to emerge (pp. 26–27).

Piercing, sucking mouthparts

Wings hard at base, soft at tip

Bug

BUGS
The name of the order of true bugs (pp. 36–37), Hemiptera, means "half wing" and refers to the front wings of many larger bugs, which are hard at the base but soft at the tip. Bugs have jointed piercing and sucking mouthparts.

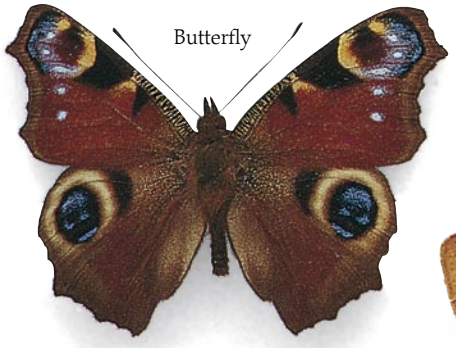


Stick insect

Folded wings

Earwig

EARWIGS
The order to which earwigs (p. 41) belong is Dermaptera, meaning "skin wings." This refers to the hind wings, which are kept curiously folded under very short front wings.



Butterfly

BUTTERFLIES AND MOTHS
These insects (pp. 34–35) belong to the order Lepidoptera, meaning "scale wings." This refers to the tiny scales (p. 13) that cover their bodies and wings and give them their beautiful rainbow-like colors.

Moth

Grass-hopper

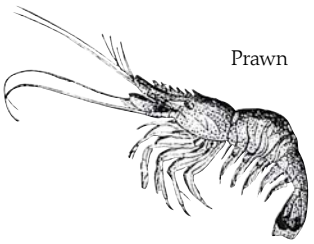
CRICKETS AND GRASSHOPPERS
These insects (p. 40) belong to the order Orthoptera, meaning "straight wings." They have strong hind legs, which they use for jumping and singing.

STICK INSECTS
When resting, these long and slender insects (p. 40) look just like the twigs and leaves that they eat (p. 45).

These are not insects

Many people confuse other arthropods with insects. Spiders and scorpions not only have four pairs of legs, rather than three as insects do, but their head and thorax (pp. 6–7) are fused together in a single structure. Unlike insects they have no wings, no antennae, and small, simple eyes instead of a pair of large compound eyes (pp. 14–15). Crabs and prawns, wood lice and centipedes, all have many more jointed legs than insects – millipedes even have two pairs on each segment. In contrast an earthworm, although composed of many segments, has no legs at all, and the body does not have a distinct head. The structure of slugs, snails, and starfish is very different and is not based on segments.

VERTEBRATES
This monkey is a vertebrate, meaning it has a backbone. Birds, fish, lizards (reptiles), frogs (amphibians), and mammals are all vertebrates. They breathe with lungs or gills, and have a central heart. None of them has six legs, and their bodies are not divided into segments.



SCORPIONS
Like all arachnids, including spiders and ticks, scorpions have four pairs of legs. This scorpion from North Africa catches its prey with its big pincers, which are really a specially adapted pair of limbs, called pedipalps.

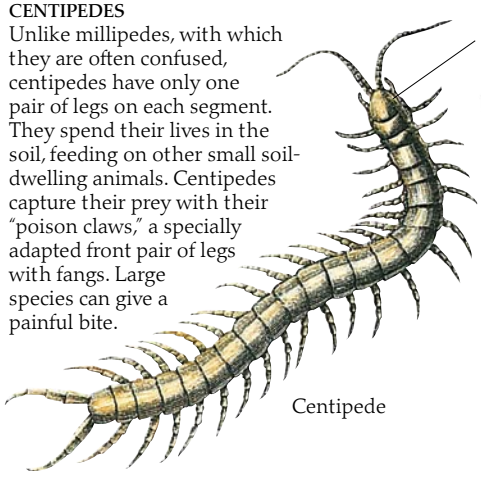
PRAWNS
These sea-dwelling creatures have an external skeleton and ten jointed legs – eight legs for walking and two for feeding and defense.

EARTHWORMS
All earthworms are made up of many ringlike segments. Unlike insects they have no legs and no hard parts and it is often difficult to tell which end the head is at. Giant earthworms may be more than 6 ft (2 m) long.

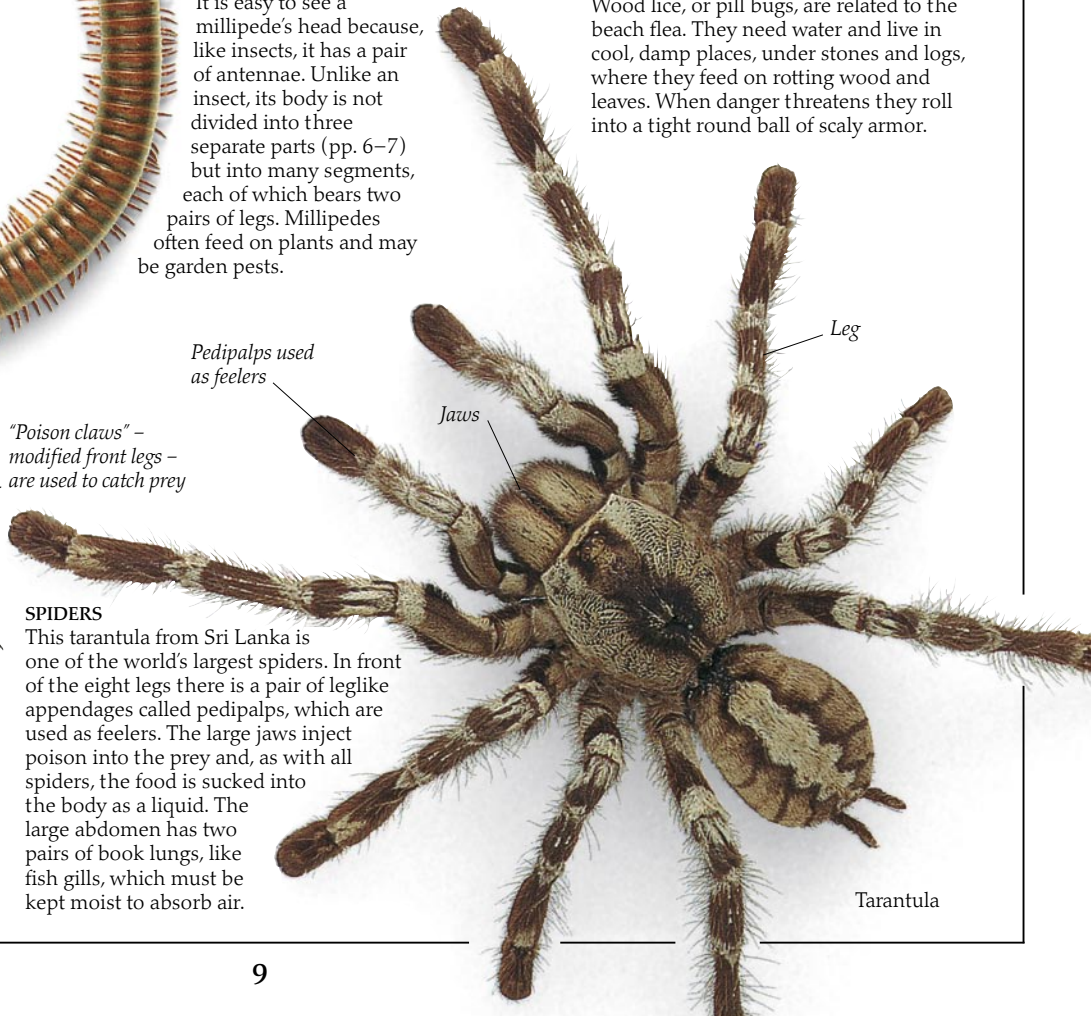
BEACH FLEAS
These strange creatures are similar to insects in appearance, but they have ten legs, rather than an insect's six. They live in damp sand on beaches all over the world. When disturbed, they use their front two pairs of legs to jump surprising distances.

WOOD LICE
Wood lice, or pill bugs, are related to the beach flea. They need water and live in cool, damp places, under stones and logs, where they feed on rotting wood and leaves. When danger threatens they roll into a tight round ball of scaly armor.

MILLIPEDES
It is easy to see a millipede's head because, like insects, it has a pair of antennae. Unlike an insect, its body is not divided into three separate parts (pp. 6–7) but into many segments, each of which bears two pairs of legs. Millipedes often feed on plants and may be garden pests.



CENTIPEDES
Unlike millipedes, with which they are often confused, centipedes have only one pair of legs on each segment. They spend their lives in the soil, feeding on other small soil-dwelling animals. Centipedes capture their prey with their "poison claws," a specially adapted front pair of legs with fangs. Large species can give a painful bite.

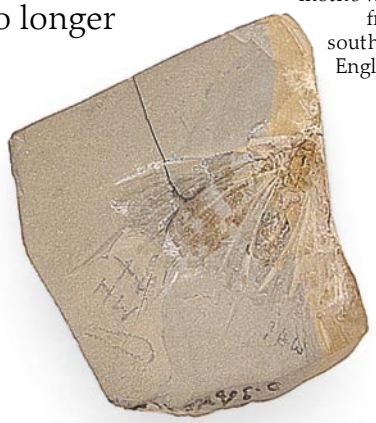


SPIDERS
This tarantula from Sri Lanka is one of the world's largest spiders. In front of the eight legs there is a pair of leglike appendages called pedipalps, which are used as feelers. The large jaws inject poison into the prey and, as with all spiders, the food is sucked into the body as a liquid. The large abdomen has two pairs of book lungs, like fish gills, which must be kept moist to absorb air.

The first insects

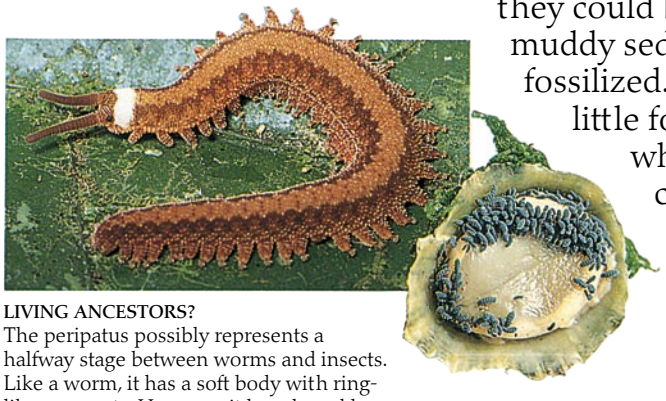
INSECT JEWELRY
Amber has been looked on as a precious stone for centuries. This piece of Baltic amber, cut and polished as a pendant, contains three very different types of flies.

THE FIRST WINGED INSECTS flew through the coal forests that covered the Earth over 300 million years ago. Early fossil remains show that a few of these insects, such as dragonflies and cockroaches (pp. 40–41), would have looked very similar to present-day species. But most of the oldest insect fossils represent groups that are no longer alive today. Some of these early insects were probably slowed down by large, unfolding wings, with spans of up to 30 in (76 cm), which prevented them from making a quick escape and made them sitting targets for hungry predators. Looking at fossils is our only means of understanding the evolution of insects, but because insects are usually small and delicate, most of them probably rotted away before they could become trapped in muddy sediments and fossilized. And so, with very little fossil evidence on which to base our conclusions, no one is yet sure how insects evolved.



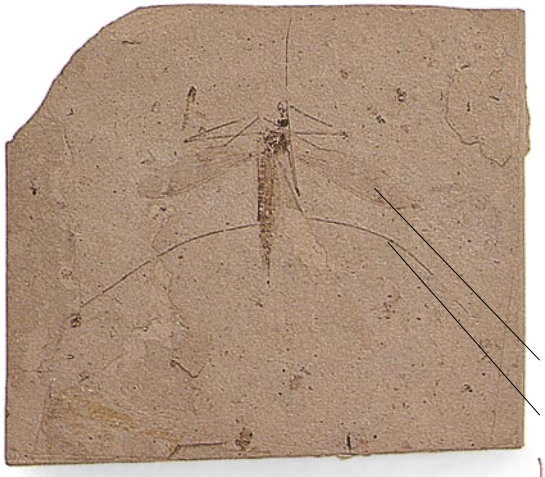
Limestone fossil of a moth's wing from southern England

SHOW YOUR COLORS
Pigments in the scales of this fossilized wing have altered the process of fossilization, so that parts of the pattern can still be seen millions of years later.

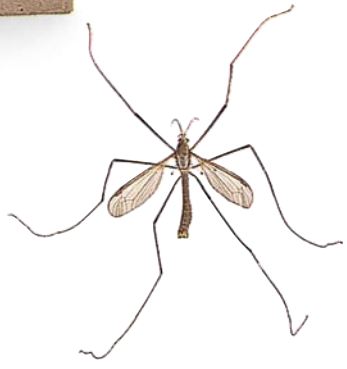


LIVING ANCESTORS?
The peripatus possibly represents a halfway stage between worms and insects. Like a worm, it has a soft body with ring-like segments. However, it has clawed legs like an insect and a similar circulatory and breathing system.

SPRINGTAILS
Springtails live in damp places all over the world. Many have a jumping organ under their tail – hence the name. This species, shown here on the underside of a limpet, lives on the shore. Once counted as a primitive insect, it is now classified separately.



EARLY CRANES
About 35 million years ago in what is now Colorado, this crane fly became trapped in muddy sediment at the bottom of a lake or a pond. The sediment was so fine that when it turned to stone, even details of the wings and legs were preserved. This fossilized specimen looks very similar to modern crane flies. The weak, drifting flight and the long, floppy legs were clearly important adaptations to life long before the American continent took its present shape.



How amber is formed

Amber is the fossil resin of pine trees that flourished on Earth over 40 million years ago. As the resin oozed from cracks and wounds in the tree trunks insects attracted by the sweet scent became trapped on its sticky surface. In time the resin, including the trapped insects, hardened and was buried in the soil. Millions of years later it was then washed into the sea. Copal looks similar to amber but is much younger.

Modern-day "sweat bee" (*Trigona* species)

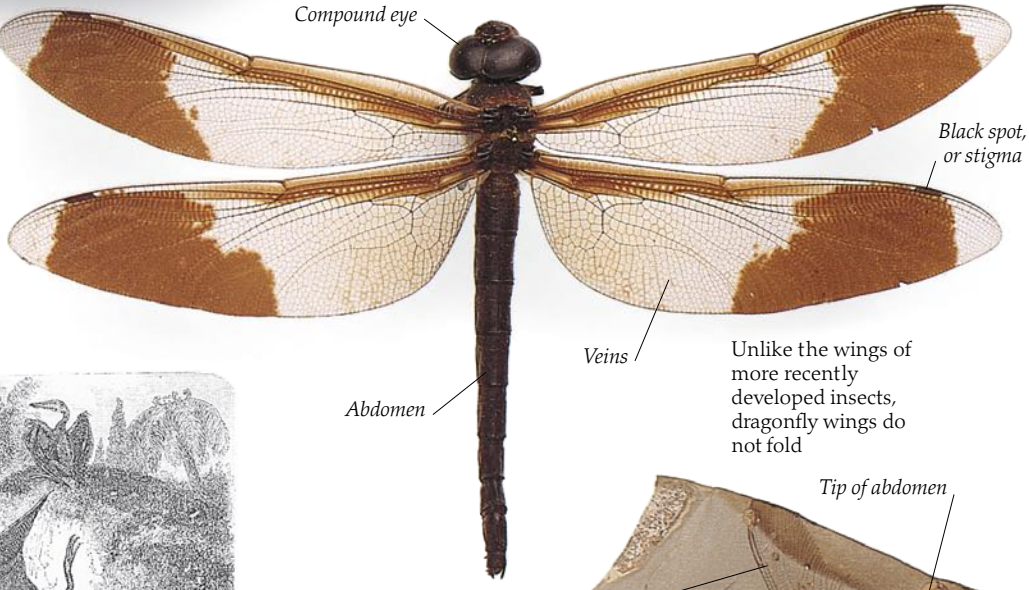
BEE IN COPAL
This piece of copal from Zanzibar (an island off the east coast of Africa) could be 1,000 or one million years old. It has been magnified to show the beautifully preserved "sweat bee" (*Trigona* species). The bee is similar to the present-day specimen shown above.

A STICKY END
Crawling and flying insects, attracted by the pine resin oozing from this tree trunk, are trapped forever. Scenes like this took place over 40 million years ago.

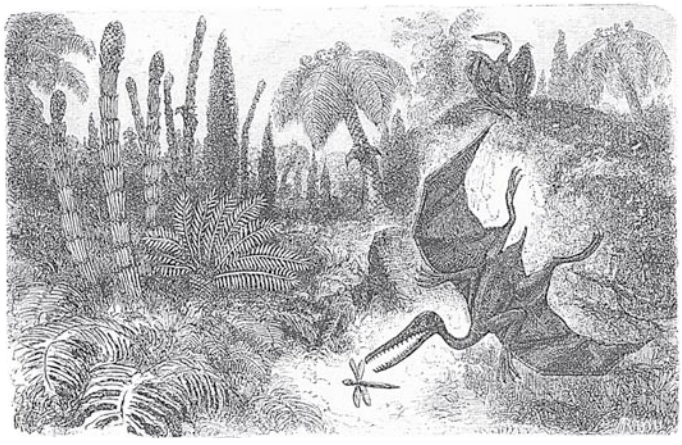
OLDEST DRAGONFLY
This fossilized folded wing is the oldest known dragonfly. It was found above a coal seam at Bolsover Colliery in Derbyshire, England, 2,300 ft (700 m) underground. The dragonfly flew 300 million years ago and had a total wingspan of 8 in (20 cm), considerably larger than the largest present-day species shown here.

FLOWERING PLANTS
The appearance of the first flowering plants about 100 million years ago signified a new source of food in the form of pollen and nectar. Insects thrived because of this new food, and the flowering plants thrived because of the variety of pollinating insects. The number of insects and plants increased together, a process known as coevolution (pp. 42–43).

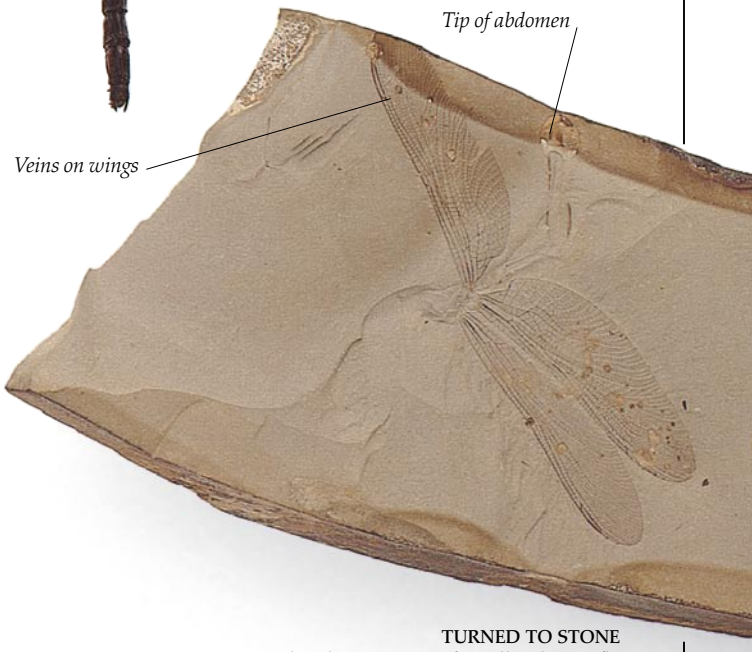
LARGEST DRAGONFLY
This dragonfly (*Tetracanthagyna plagiata*) from Borneo is a member of the largest dragonfly species still in existence today. The largest dragonfly ever known is a fossilized specimen from the U.S., with a wingspan of about 24 in (60 cm).



Unlike the wings of more recently developed insects, dragonfly wings do not fold



DRAGONFLY PREDATORS
The artist of this whimsical engraving clearly had more imagination than biological knowledge. Present-day dragonflies are fast and skilled fliers. Fossils prove their ancestors were similar and would not have made easy prey for a pterosaur.



DROWNED EARWIG
The lake deposits at Florissant, Colorado, are about 35 million years old. They contain many well-preserved insect fossils because of the fine sediment from which the rocks were formed. Many of these insects would not have lived in the lake – they simply fell in and were drowned.

Present-day earwig (*Labidura riparia*)

TURNED TO STONE
Fossilized specimens of smaller dragonfly species, such as this one from southern England, are relatively common. Even though this specimen appears to be missing a wing, it is possible to see all the veins quite clearly.

Wings and flight

CRUMPLED WINGS
The wings of an adult cicada are much larger than the body (p. 36). But a newly emerged adult has small, soft crumpled wings. Blood is pumped into veins in the wings making them expand rapidly. As the veins harden, the wings straighten ready for flight.

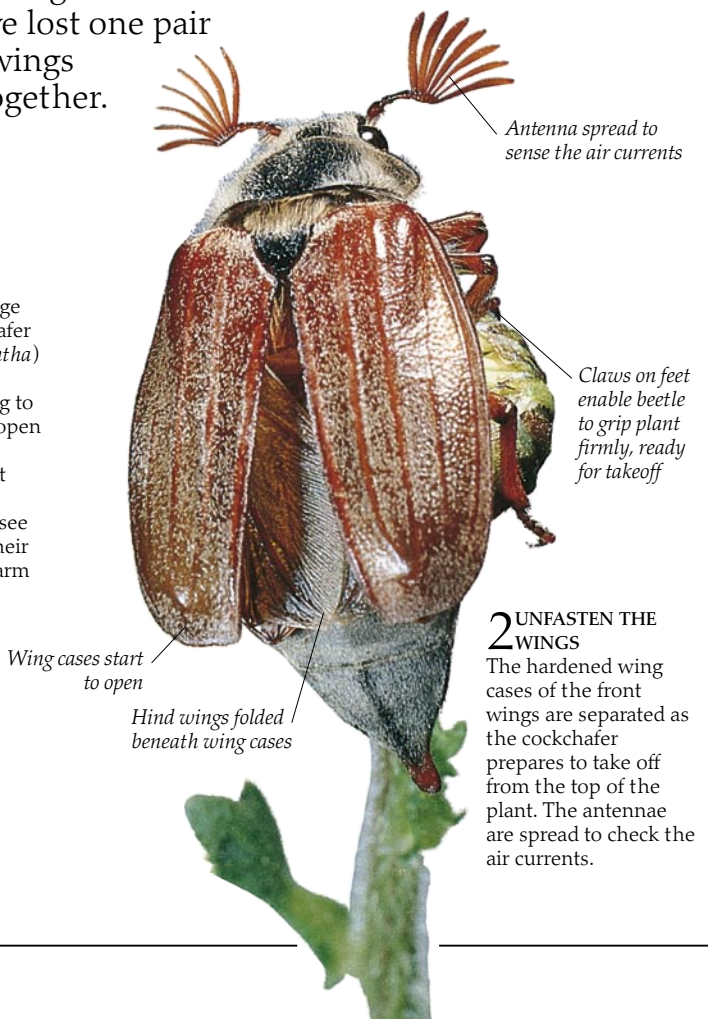
INSECTS WERE THE FIRST CREATURES TO FLY. Flight enabled them to escape more easily from predators, and to fly to new areas in search of better food. Later, wings became important for finding and attracting a mate – by being brightly colored or by producing a scent or making sounds. But the origin of wings is not understood. Some early wingless insects may initially have gained an advantage over others by gliding from trees using pairs of primitive flaps on several segments of their body. Gradually, because two pairs of flaps are more efficient in the air, wings evolved. The earliest known flying insects, like dragonflies today, had two pairs of independently flapping wings that did not fold. More recent insects, such as butterflies, wasps, and beetles, have developed various mechanisms for linking their front and hind wings to produce two, rather than four, flight surfaces that beat together. The true flies have lost one pair of wings altogether.

Mosquito wing

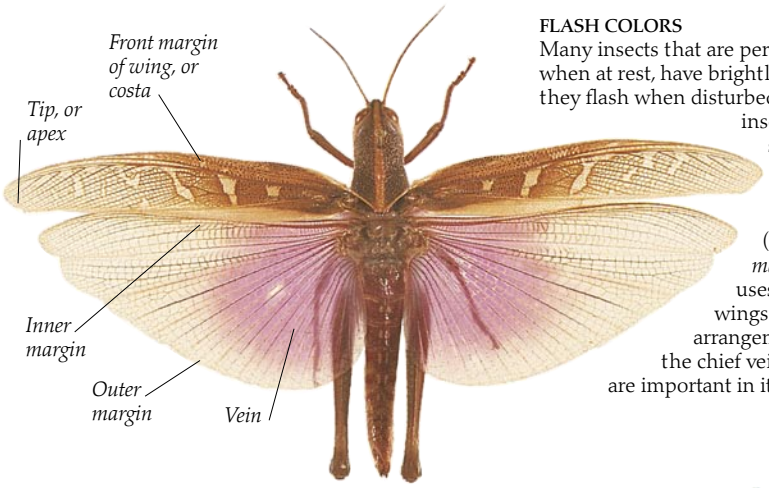
FRINGED WINGS
Small insects have great difficulty flying. The fringe of scales on this magnified mosquito wing probably act like the flaps, or airfoils, on an airplane wing, and help reduce the "drag." Very small insects often have narrow wings with even longer fringes.

CRICKET SONGS
Male crickets produce songs with their specially adapted front wings. The base of the left front wing (above left) has a rigid file that is scraped against a special drumlike area, or mirror, on the right front wing (above right). This mirror amplifies the sound to attract female crickets many yards away.

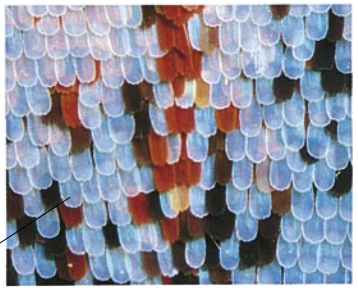
1 BEFORE TAKEOFF
Like any airplane, a large insect such as this cockchafer beetle (*Melolontha melolontha*) must warm up its engines before flying. Before taking to the air, beetles will often open and shut their wing cases several times to check that they are in good working order. It is not unusual to see moths rapidly vibrating their wings before takeoff to warm up their flight muscles.



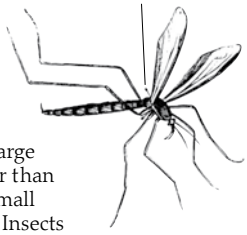
2 UNFASTEN THE WINGS
The hardened wing cases of the front wings are separated as the cockchafer prepares to take off from the top of the plant. The antennae are spread to check the air currents.



FLASH COLORS
Many insects that are perfectly camouflaged when at rest, have brightly colored wings that they flash when disturbed. As soon as the insect settles again it seems to disappear, thus confusing a would-be predator. This grasshopper (*Ornithacris pictula magnifica*) probably uses its beautiful lilac wings for this purpose. The arrangement and number of the chief veins in an insect's wing are important in its identification.

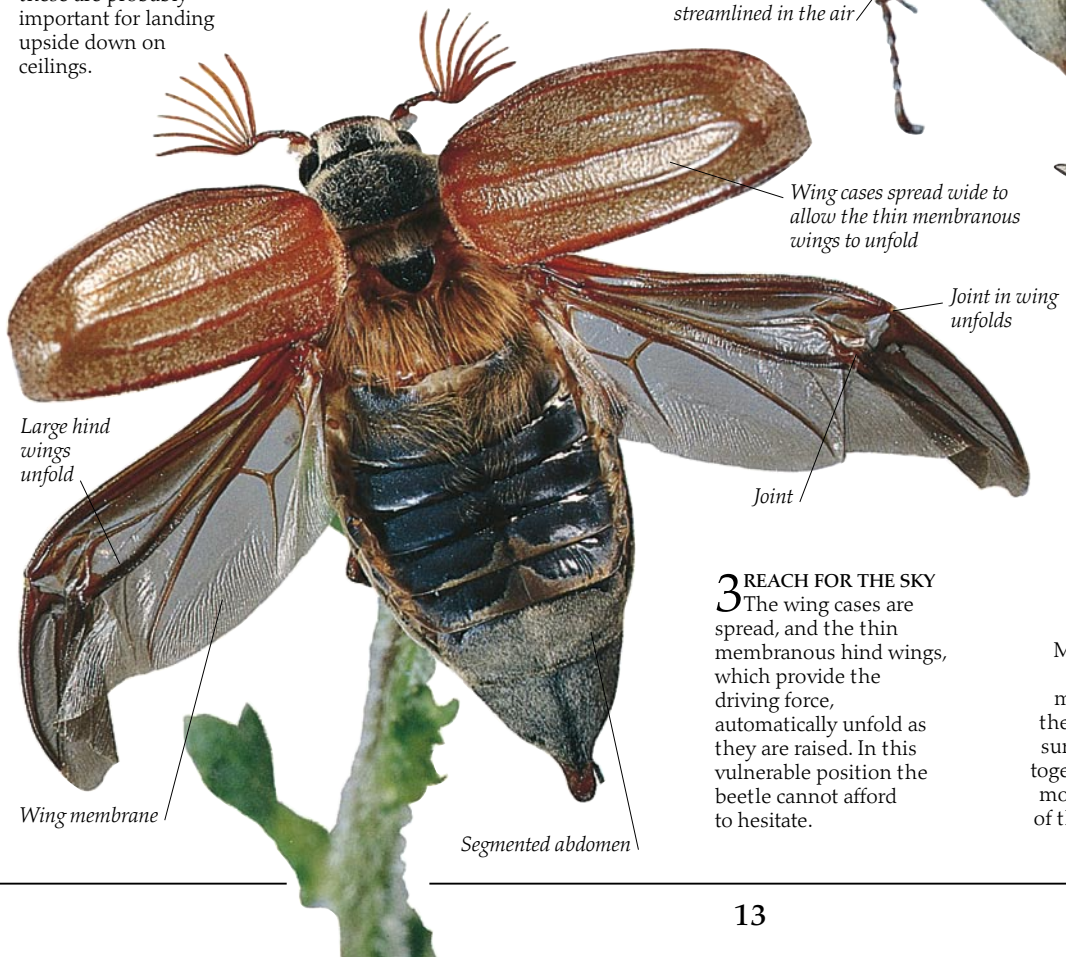


COLOR SCALES
The overlapping scales on butterfly wings are really flattened, ridged hairs. These often form beautiful patterns. In some species the scales may be further modified to contain special scents.

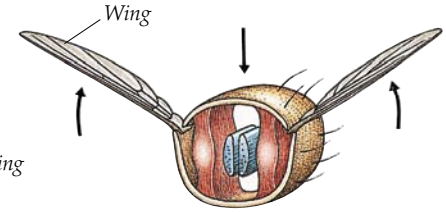


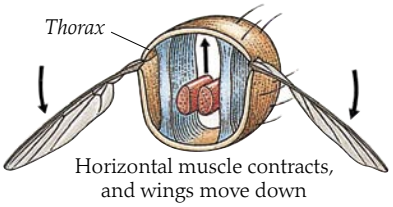
BALANCING
Designing a large glider is easier than designing a small fighter plane. Insects have similar design problems – they must be able to fly in gusty winds close to moving leaves and branches. Flies have overcome such problems by reducing one pair of wings to special knoblike balancing organs, called halteres; these are probably important for landing upside down on ceilings.

4 WE HAVE LIFT-OFF
With a spring from the legs, the cockchafer throws itself into the air. The hind wings provide the driving force, but the curve of the rigid front wings almost certainly provides aerodynamic lift as the speed increases.



3 REACH FOR THE SKY
The wing cases are spread, and the thin membranous hind wings, which provide the driving force, automatically unfold as they are raised. In this vulnerable position the beetle cannot afford to hesitate.



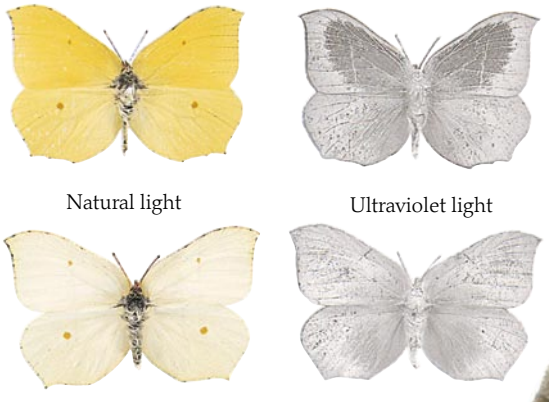


MOVING THE WINGS
Most of the power for flapping the wings is provided by large horizontal and vertical muscles housed in the thorax (pp. 6–7). As these contract alternately, the upper and lower surfaces of the thorax are rapidly pulled closer together, then driven apart, causing the wings to move up and down. Other muscles at the base of the wings adjust the angle of each stroke and thus determine the direction of flight.

LIGHT ATTRACTION
At night, bright lights attract many insects. It seems that night-flying insects navigate by keeping the natural light of the moon at a constant angle to their eyes. An artificial light is treated in the same way; the insects fly toward the light in a straight line but when they reach it they circle around it continuously.

Through an insect's eyes

IT IS VERY DIFFICULT to explain what is meant by color to someone who has never been able to see. But it is far more difficult to understand what color, or even sight, means to an insect. Insects have acute senses that humans do not share. Many insects can smell particular odors over great distances. Others can detect vibrations and hear sounds that are inaudible to people. But we cannot know what sort of image insects have of the world through their eyes. We know that a large bee sitting on a post can see a person move several yards away – but does it just see a moving shape, or can it perceive that the moving object is a human and not a horse? We know some bugs can see, or are particularly attracted to, ultraviolet light and the color yellow, but are not attracted to blue or red. But do they see colors, or shades of black and white? Different insects have evolved solutions to different problems. Dragonflies can catch mosquitos in flight at dusk, when it is too dark for these small flies to be seen by humans; but does the dragonfly see them, or does it respond to their sound and movement? The subject of insect senses is full of such questions.



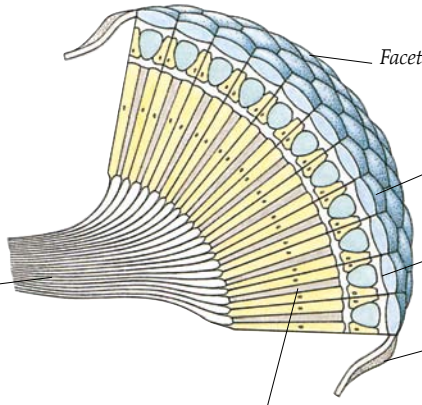
Natural light

Ultraviolet light

BEAUTY LIES IN THE EYES OF THE BEHOLDER
The eyes of many insects register things that humans cannot see. These two brimstone butterflies have been photographed in natural light (left) and in ultraviolet light (right). Insects possibly do not see a yellow butterfly with four orange spots, but a gray insect with two large dark gray areas. Many insect-pollinated flowers rely on ultraviolet vision to attract pollinating bees (pp. 42–43); the position of the nectar within the flower is indicated by lines called honey guides, which are visible only in ultraviolet light.

A WASPISH FACE
The head of a typical insect has a pair of large compound eyes as well as three simple eyes on top. The compound eyes of this wasp (*Vespula vulgaris*) extend low down on the cheeks toward the jaws but are not developed on the part of the face across which the antennae usually lie. The segmented antennae are important not just to detect odors but also to measure the size and shape of each new cell in the nest as it is built (pp. 50–51). The powerful jaws are the hands and tools of a wasp and are used to cut up food, to dig with, and to lay down new nest material. The brilliant yellow and black pattern warns other animals that this insect has a dangerous sting.

INSIDE AN INSECT'S EYE
Each compound eye is made up of hundreds of facets, often fitting together hexagonally. Each facet consists of the lens at the surface with a second conical lens inside. These focus the light down a central structure, the rhabdome, which is sensitive to light and is connected directly to the optic nerve and brain.

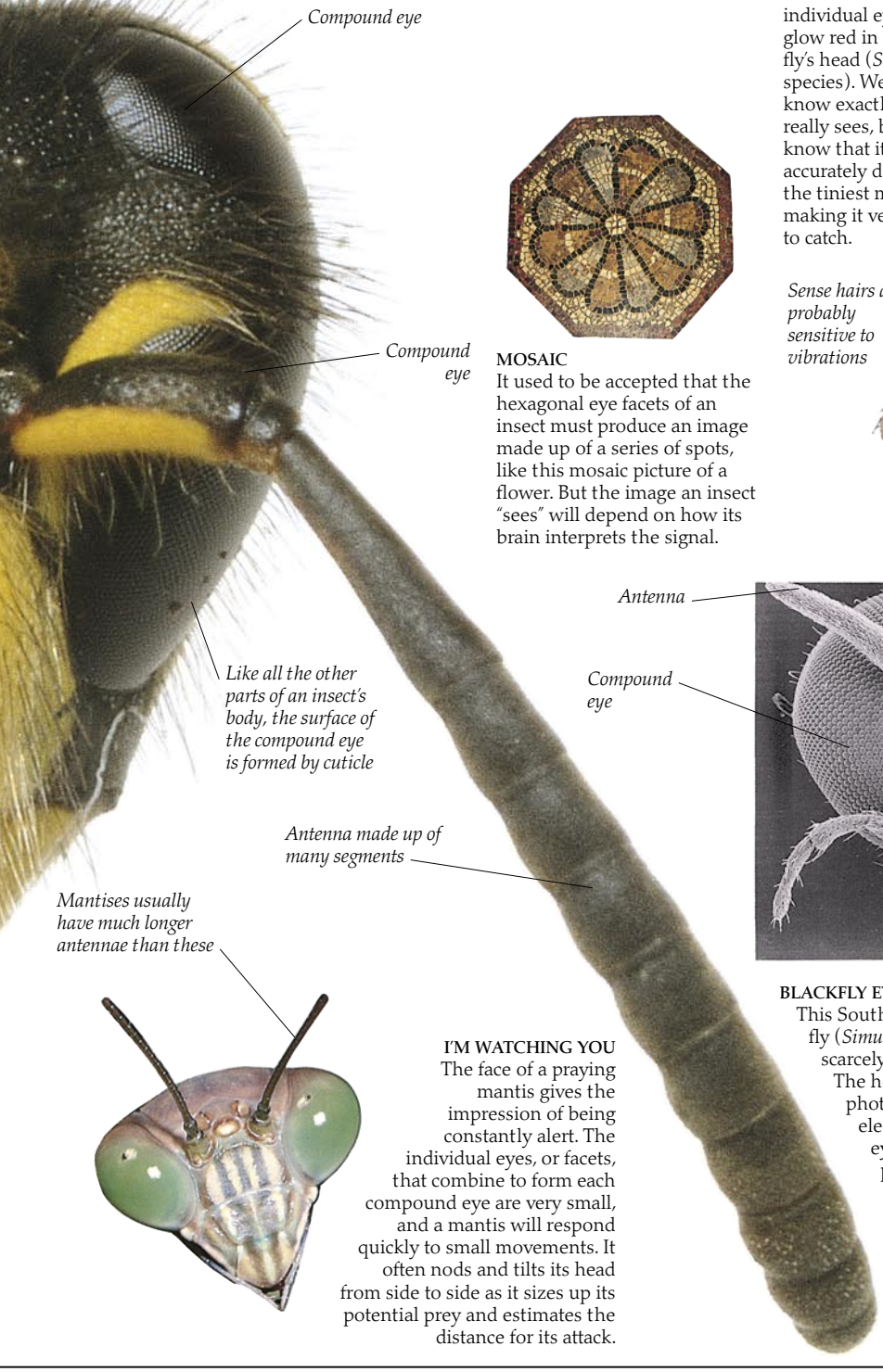


Optic nerve fibers along which information is passed to the brain

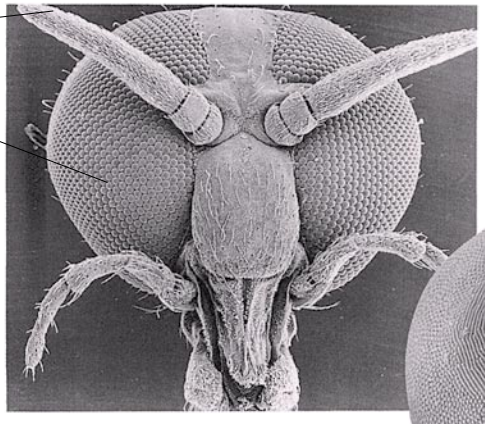
FLESH FLY
The hundreds of individual eye facets glow red in this flesh fly's head (*Sarcophaga* species). We do not know exactly what it really sees, but we do know that it can accurately detect even the tiniest movements, making it very difficult to catch.

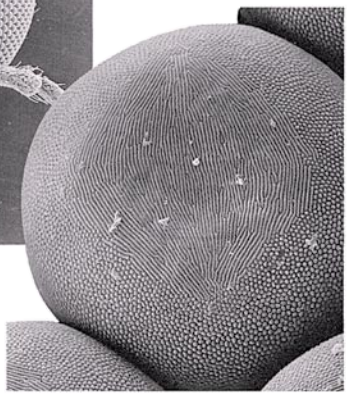
Sense hairs are probably sensitive to vibrations

Between the claws of a fly's foot is a sucker-like pad (p. 18) that enables the fly to walk upside down on smooth surfaces



MOSAIC
It used to be accepted that the hexagonal eye facets of an insect must produce an image made up of a series of spots, like this mosaic picture of a flower. But the image an insect "sees" will depend on how its brain interprets the signal.



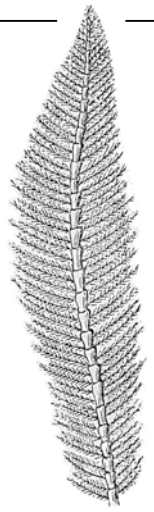


BLACKFLY EYES
This South American bloodsucking fly (*Simulium bipunctatum*) is tiny, scarcely 0.08 in (2 mm) long. The head (above) has been photographed with an electron microscope to show the large, many-faceted compound eyes extending around the bases of the antennae. The photograph on the right shows just one of the individual eyes, or facets, of the blackfly eye, magnified 4,000 times. The surface of each facet is finely sculptured, quite different from the diagram shown above. What does the blackfly "see" through its hundreds of tiny eyes, each one covered in tiny ridges and peglike tubercles?

Mantises usually have much longer antennae than these

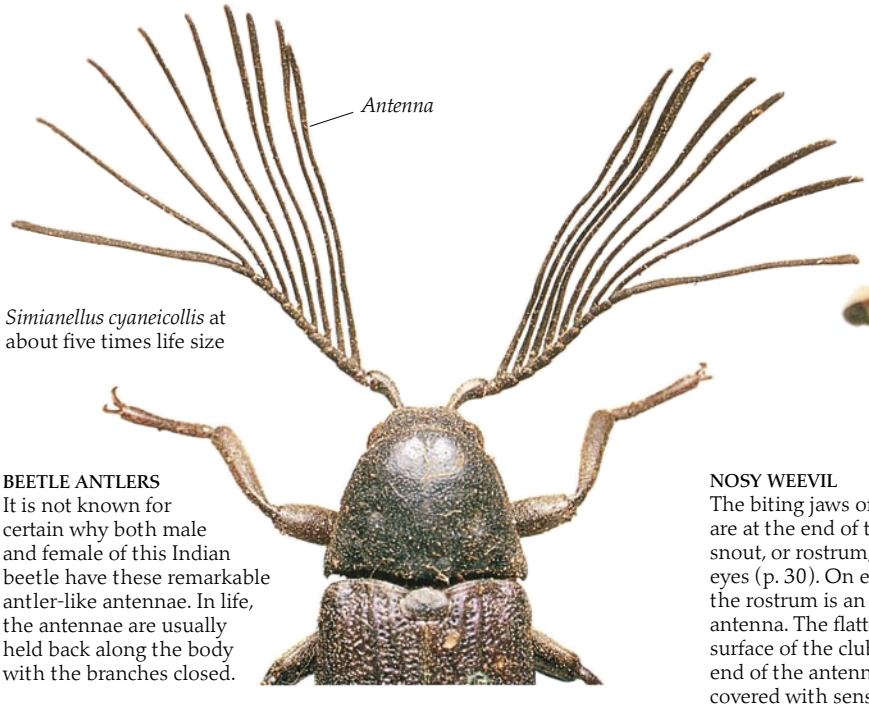
I'M WATCHING YOU
The face of a praying mantis gives the impression of being constantly alert. The individual eyes, or facets, that combine to form each compound eye are very small, and a mantis will respond quickly to small movements. It often nods and tilts its head from side to side as it sizes up its potential prey and estimates the distance for its attack.

Touch, smell, and hearing



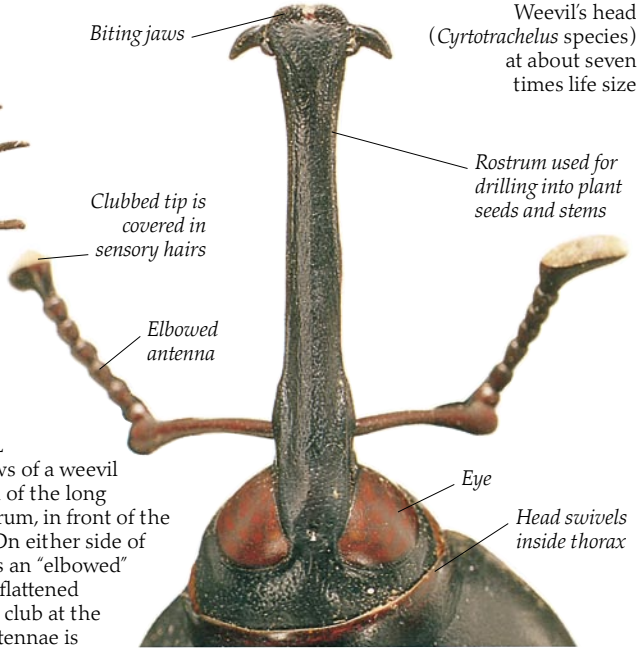
FEATHERY FEELERS
This feather-like structure is the highly sensitive antenna of a male moth. The central rod has many side, or lateral, branches, each of which is covered in tiny sensory hairs.

FOR MANY INSECTS the world is probably a pattern of smells and tastes. Most insects have eyes, but sight is not as important to them as it is to humans in understanding the world around them. Ants lay down a chemical trail and constantly touch each other to pass on their nest odor. Alarm chemicals are produced by many insects, so that the other members of a colony quickly respond. Female moths produce chemicals capable of attracting males from great distances. Dung beetles can locate fresh dung within 60 seconds of its being produced. Some insects, such as bark beetles, produce chemicals that attract members of the same species; this causes them to group together on a suitable tree. Other species, such as the common apple maggot, produce chemicals to prevent a second female from laying eggs on a fruit that is already occupied. This insect world of smells and tastes also includes vibrations and sounds undetected by humans. Such vibrations may be detected by insects through well-formed "ears" as on the front legs of crickets and on the abdomen of grasshoppers and cicadas, or they may be picked up through the legs and antennae.



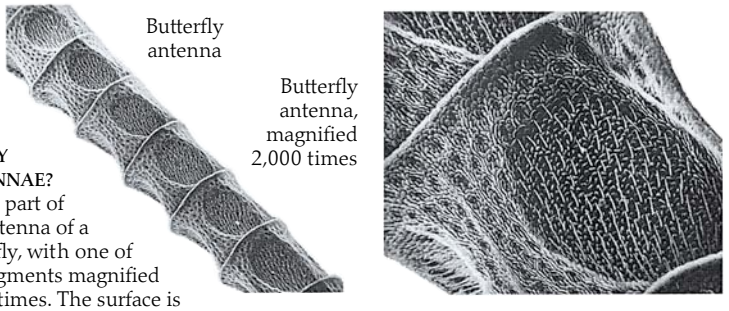
Simianellus cyaneicollis at about five times life size

BEETLE ANTLERS
It is not known for certain why both male and female of this Indian beetle have these remarkable antler-like antennae. In life, the antennae are usually held back along the body with the branches closed.



NOSY WEEVIL
The biting jaws of a weevil are at the end of the long snout, or rostrum, in front of the eyes (p. 30). On either side of the rostrum is an "elbowed" antenna. The flattened surface of the club at the end of the antennae is covered with sensory hairs, which the weevil uses to explore the surface it is feeding on or into which it is drilling with its rostrum.

MAGNIFIED HAIRS
The hairs on an insect's body are often not just simple and "hairlike," which becomes apparent when they are magnified 1,000 times. These hairs, from around the mouth of a carpet beetle larva, each have their own "ball and socket" joint at the base and ridged sides. Each hair is probably sensitive to vibrations.

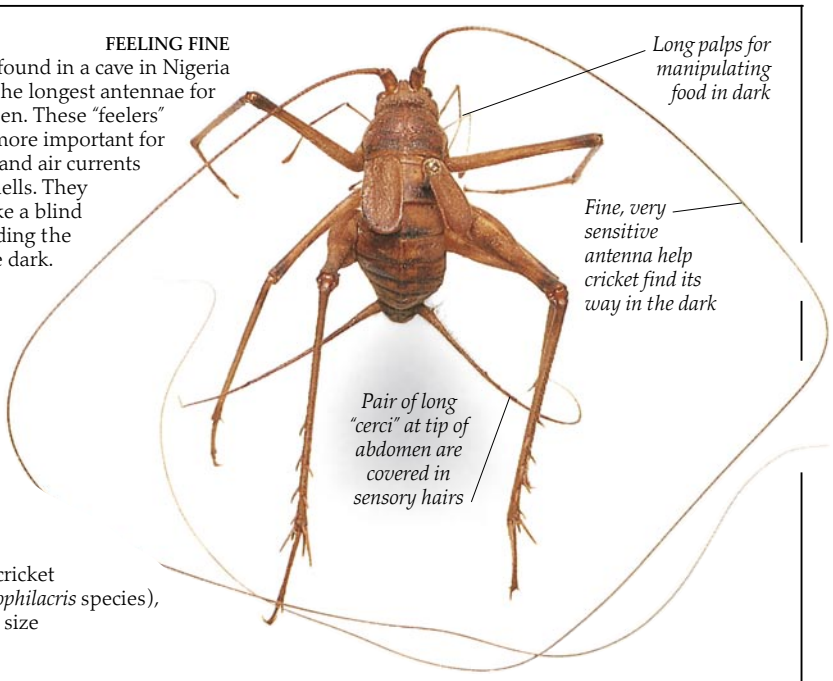


SIMPLY ANTENNAE?
This is part of the antenna of a butterfly, with one of the segments magnified 2,000 times. The surface is covered with intricate patterns of tiny sensitive pegs, or tubercles, and there are thin areas of cuticle (pp. 6–7) with tiny scent-sensitive hairs.

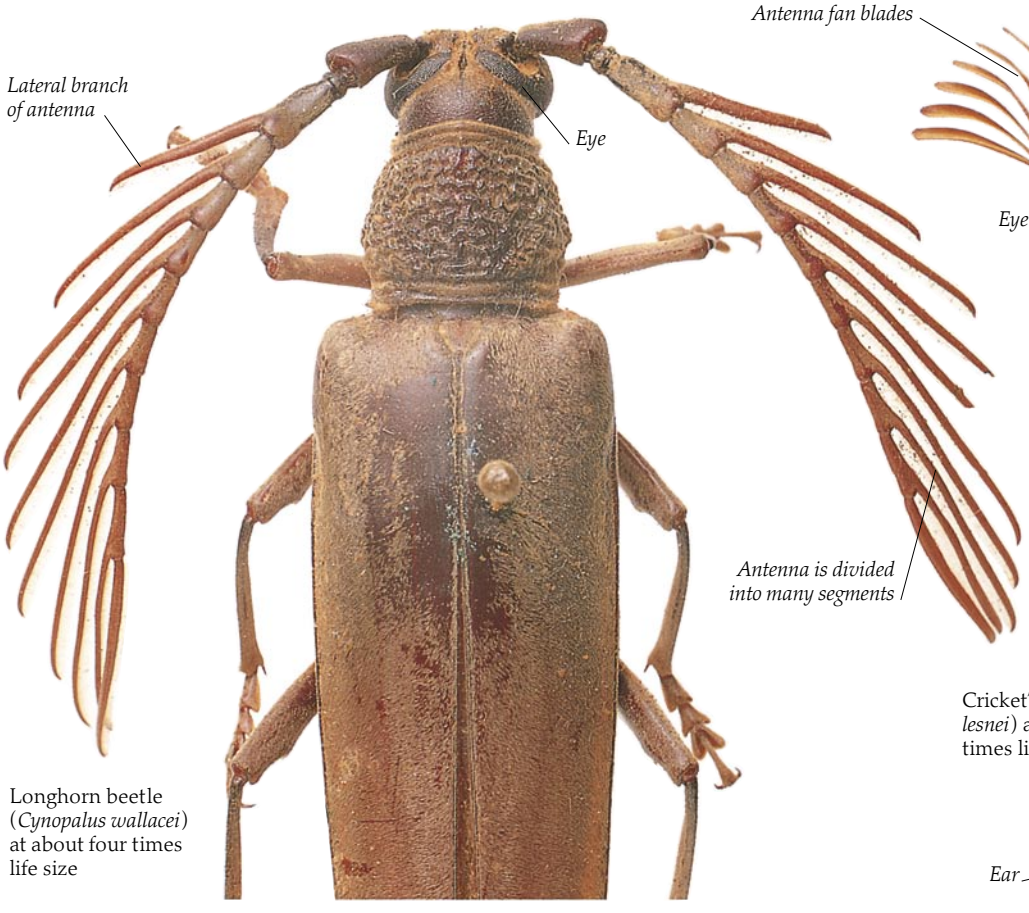
Underside of wing showing perfume brushes

PERFUME BRUSHES
This male South American forest butterfly (*Antirrhea philoctetes*) has a curious whorl of long hairs on the lower side of the front wing. These hairs brush against a patch of specialized "scent scales" on the upper side of the hind wing. The socket at the base of each hair is shaped like the figure 8, so that the hair can stand up – as in a brush – or lie flat. The brush picks up the scent scales and scatters the scent to attract females.

FEELING FINE
This cricket was found in a cave in Nigeria (West Africa). It has the longest antennae for its body size ever seen. These "feelers" are probably more important for detecting vibrations and air currents than for detecting smells. They may also be used like a blind person's cane for finding the way in the dark.

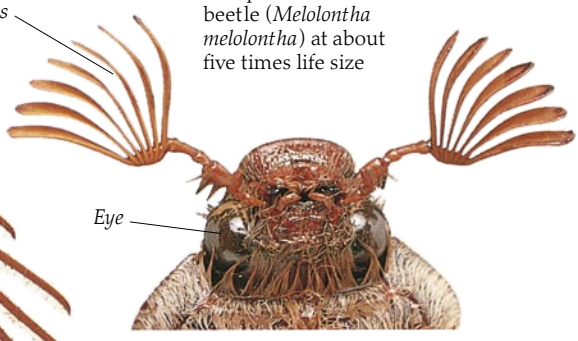


Cave cricket (*Phaeophilacris* species), actual size



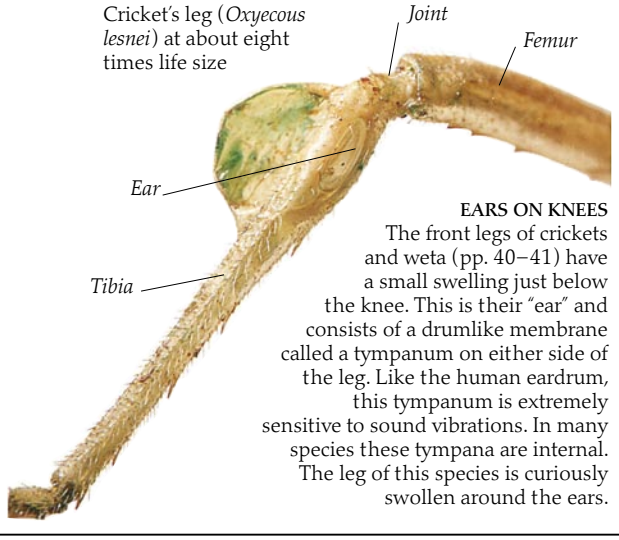
Longhorn beetle (*Cynopalus wallacei*) at about four times life size

LONGHORN ANTLERS
Longhorn beetles are so-called because of their long antennae (p. 31). The antennae of most species are simple and unbranched, or have a few small side branches. But this male longhorn from Malaysia (Southeast Asia) is remarkable for having long side branches, each of which is covered in tiny sense hairs, making the antennae doubly sensitive.



European chafer beetle (*Melolontha melolontha*) at about five times life size

CHAFER FANS
All scarab beetles (pp. 30–31) have fan-shaped antennae like this chafer. When the beetle is walking around, the fan blades are usually closed, but when the beetle starts to fly (pp. 12–13), they are fanned out to detect the direction of the wind and any smells it may be carrying.



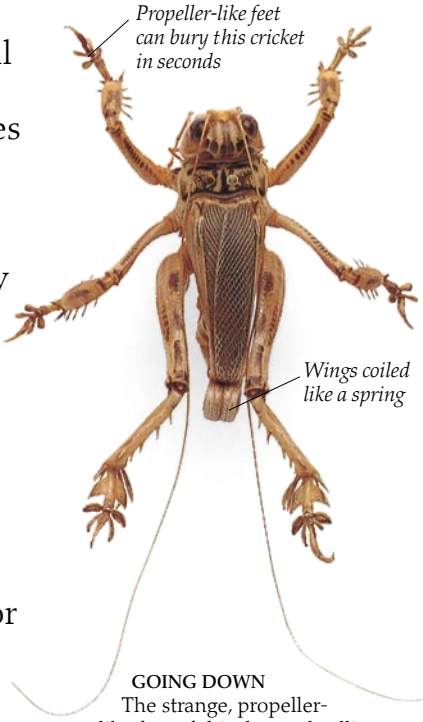
Cricket's leg (*Oxyecous lesnei*) at about eight times life size

EARS ON KNEES
The front legs of crickets and weta (pp. 40–41) have a small swelling just below the knee. This is their "ear" and consists of a drumlike membrane called a tympanum on either side of the leg. Like the human eardrum, this tympanum is extremely sensitive to sound vibrations. In many species these tympana are internal. The leg of this species is curiously swollen around the ears.

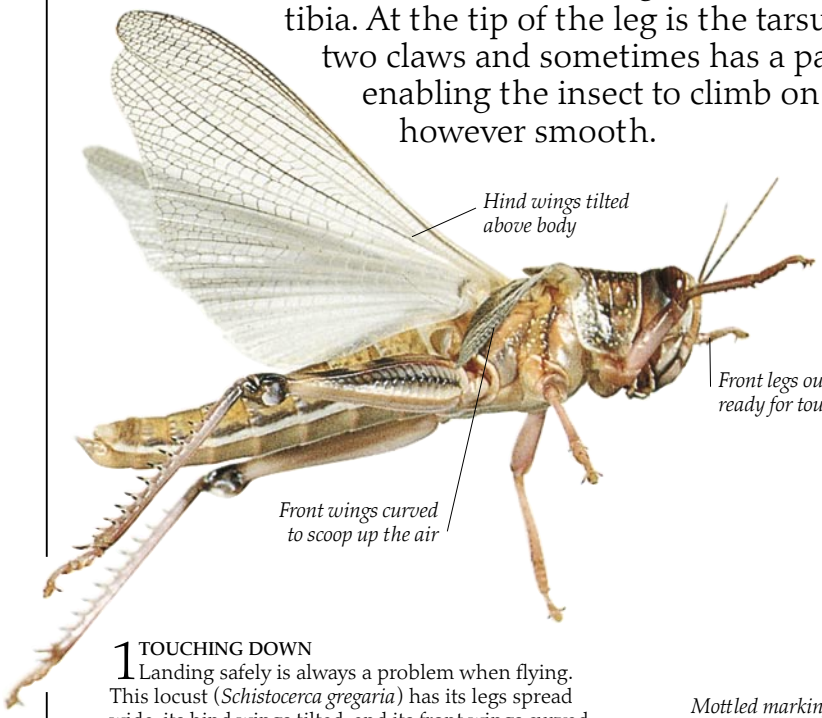
Legwork

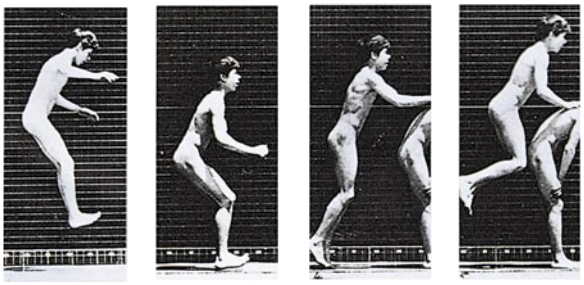
CLEANING LEGS
Flies are covered in hairs, which must be cleaned and groomed regularly if the insect is to fly effectively. The feet of houseflies have special pads between the claws that work like plastic wrap, enabling the insect to walk upside down on smooth surfaces.

LEGS ARE IMPORTANT to most creatures for walking, running, and jumping, as well as for generally keeping the body off the ground. Insects have found even more uses for their legs. Bees (pp. 58–59) have little brushes and baskets on their legs for collecting and storing pollen (pp. 42–43). Grasshoppers can "sing" with their legs by rubbing a small file on their hind legs against their front wings. Crickets have ears on their knees, and many insects' legs are modified for fighting or for holding on to the opposite sex when mating. Some water insects (pp. 48–49) have flattened legs with long hairs that work like paddles or oars; others have long, delicate, stilt-like legs for walking on the surface without sinking. All insects have six jointed legs, and each leg has four main parts. At the top is the coxa, which joins the leg to the thorax; then comes the thigh, or femur; and the lower leg, or tibia. At the tip of the leg is the tarsus, which usually has two claws and sometimes has a pad in between, enabling the insect to climb on almost any surface, however smooth.



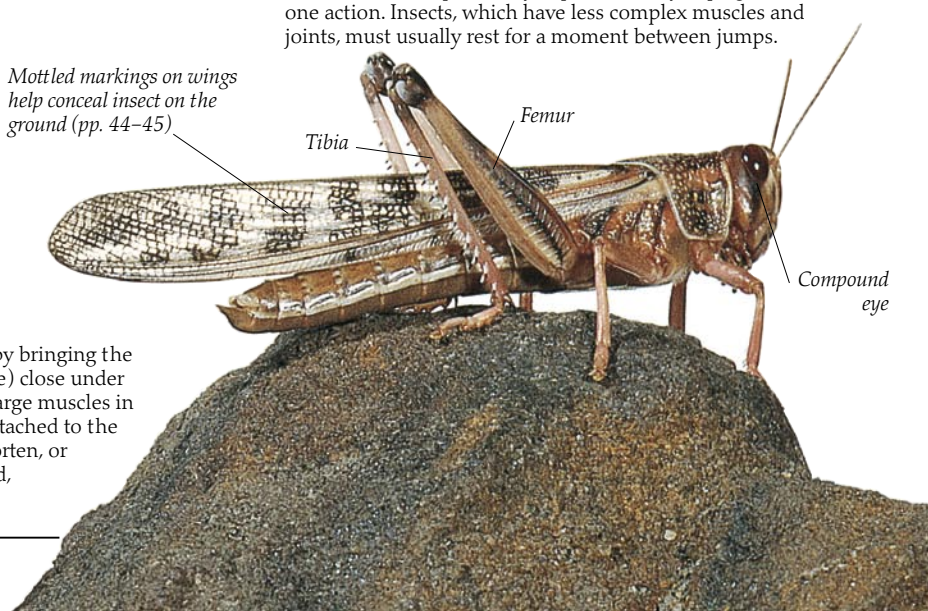
GOING DOWN
The strange, propeller-like feet of this desert-dwelling cricket (*Schizodactylus monstrosus*) enable it to dig a hole in sand directly beneath itself and disappear in a matter of seconds – straight down. The ends of the wings are coiled like a spring, which keeps the wings out of the way.





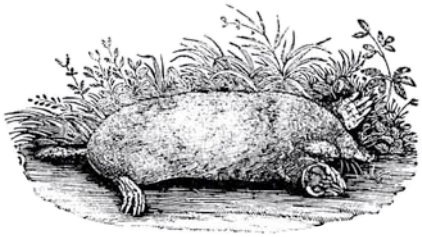
BOUNCING BOYS
This famous sequence by Muybridge (1830-1903) shows how vertebrates (p. 9) can jump, land, and jump again in one action. Insects, which have less complex muscles and joints, must usually rest for a moment between jumps.

1 TOUCHING DOWN
Landing safely is always a problem when flying. This locust (*Schistocerca gregaria*) has its legs spread wide, its hind wings tilted, and its front wings curved to catch the maximum amount of air. The wing shape of birds and airplanes is adjusted in the same way when landing, to enable them to slow down and drop gently to the ground. Locusts are particular species of grasshopper that occasionally change their behavior and form migrating swarms of thousands of millions of insects (p. 61).

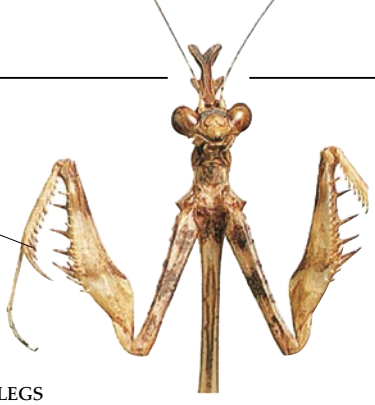


2 PREPARING TO JUMP
The locust gets ready to jump again by bringing the long, slender parts of its hind legs (tibiae) close under the body near its center of gravity. The large muscles in the thicker part of the leg (femur) are attached to the tip of the tibia. When these muscles shorten, or contract, the leg is suddenly straightened, throwing the insect into the air.

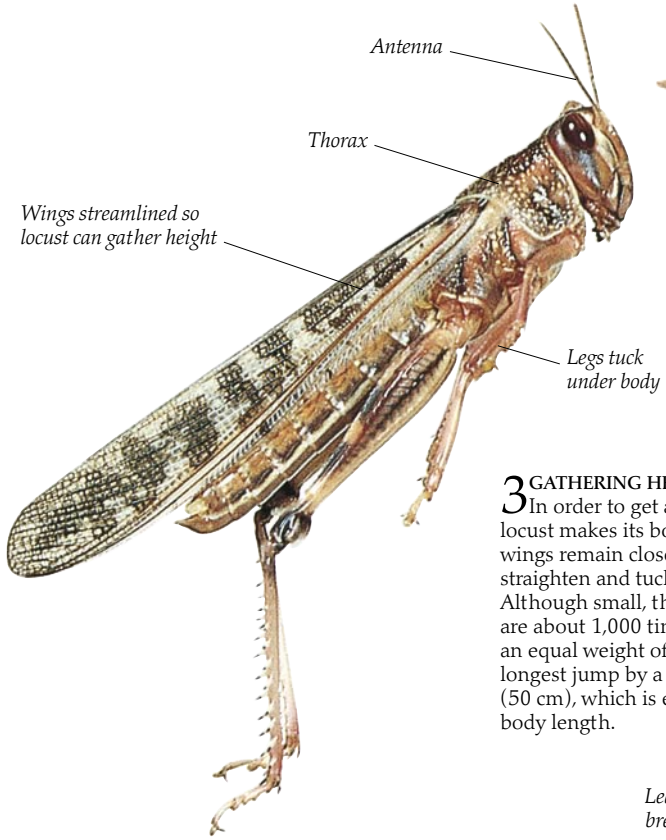
MINI MOLES
Mole crickets (*Gryllotalpa gryllotalpa*), like moles, have unusually strong and flattened front legs which serve as shovels for burrowing into the soil. As they tunnel underground, they eat roots, which they cut through with specially adapted mouthparts that work like a pair of scissors. When very active, they may become pests in grassy lawns.



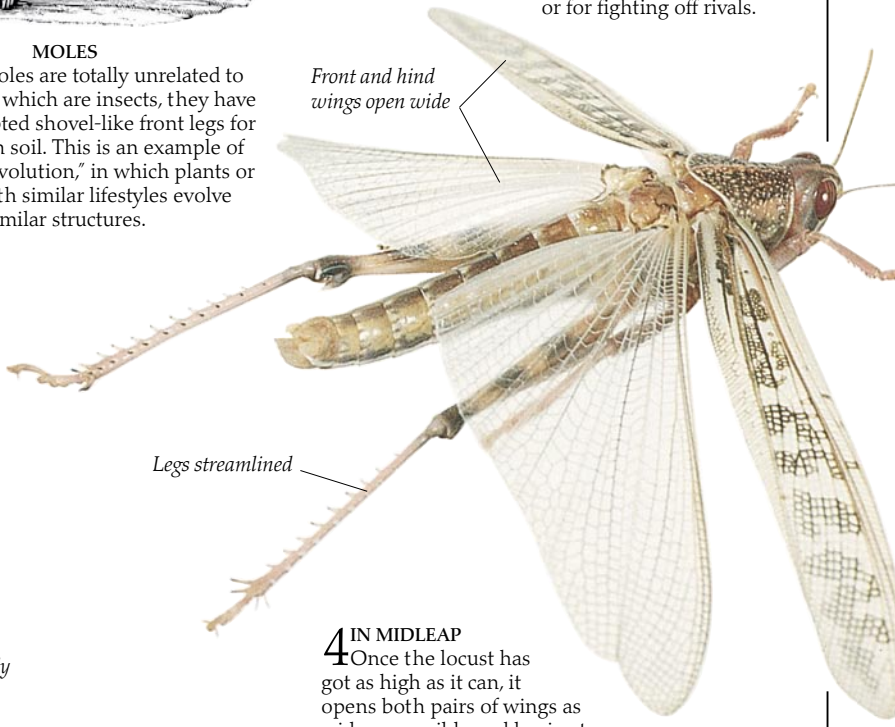
MOLES
Although moles are totally unrelated to mole crickets, which are insects, they have similarly adapted shovel-like front legs for burrowing in soil. This is an example of "convergent evolution," in which plants or animals with similar lifestyles evolve similar structures.



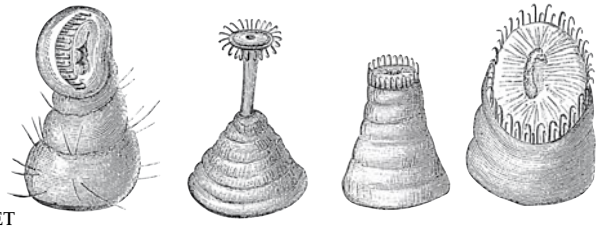
GRASPING LEGS
Many insects have grasping, or raptorial, legs. Sometimes, as with this mantid (*Sibylla pretiosa*), the legs are used to grab and hold prey while it is being eaten. But often such legs are more important for holding on to the opposite sex during mating, or for fighting off rivals.



3 GATHERING HEIGHT
In order to get as high as possible, the locust makes its body streamlined. The wings remain closed, and the legs straighten and tuck under the body. Although small, the leg muscles of locusts are about 1,000 times more powerful than an equal weight of human muscle. The longest jump by a locust is about 20 in (50 cm), which is equal to ten times its body length.

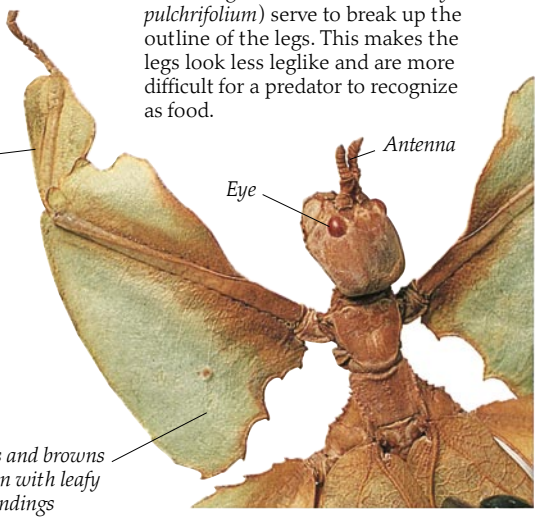


4 IN MIDLEAP
Once the locust has got as high as it can, it opens both pairs of wings as wide as possible and begins to flap them rapidly, to propel it even farther forward. The hind legs are still streamlined, but the front legs are stretched out as the locust prepares to land again.

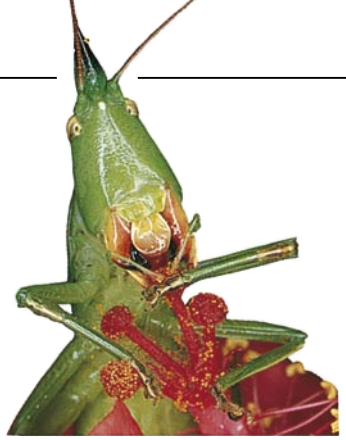


PSEUDOFEET
The "legs" on the abdomen of caterpillars are not real legs. They are muscular extensions of the body wall, called prolegs, each with a circle of hairs at the tip. The prolegs are important for locomotion, and the three pairs of real legs on the thorax are used to hold the food.

HIDING BEHIND YOUR OWN LEGS
The color and shape of the extensions on the legs of this leaf insect (*Phyllium pulchrifolium*) serve to break up the outline of the legs. This makes the legs look less leglike and are more difficult for a predator to recognize as food.



Mouthparts and feeding



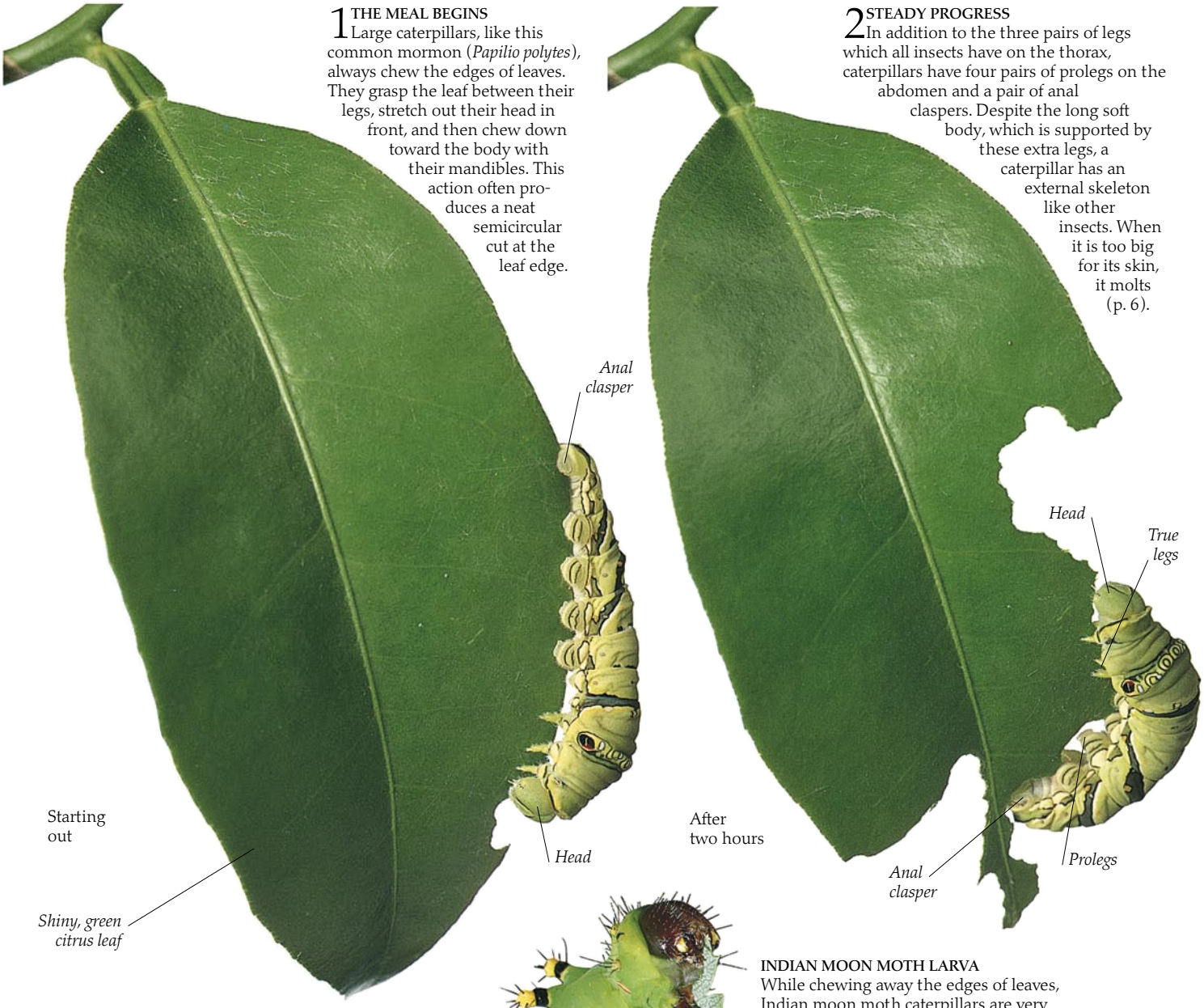
BUSH CRICKET
This bush cricket is feeding on part of a flower. It is holding the plant with its front legs while the large and powerful sawlike mandibles chew it up. Crickets also eat other insects – even their own young.

THE ANCESTORS OF INSECTS had three pairs of jaws on their head. In modern insects the first pair, the mandibles, remain well developed in all chewing species. The second pair, the maxillae, are smaller and modified to help push or suck food into the mouth. And the third pair are joined together to form the lower lip, or labium. But in many insects these three pairs of jaws are modified according to diet into piercing needles, long, sucking tubes, and absorbent sponges.

FLEA BITES
This old engraving is not accurate, but it shows that fleas have a strong sucking tube surrounded by two pairs of palps, or sensory organs.

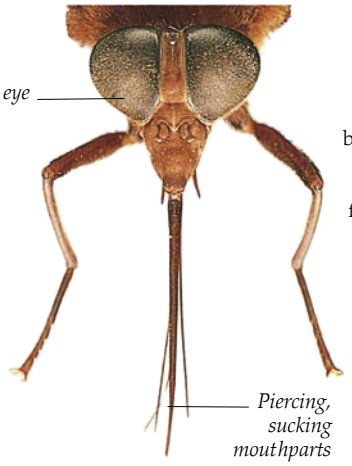
1 THE MEAL BEGINS
Large caterpillars, like this common mormon (*Papilio polytes*), always chew the edges of leaves. They grasp the leaf between their legs, stretch out their head in front, and then chew down toward the body with their mandibles. This action often produces a neat semicircular cut at the leaf edge.

2 STEADY PROGRESS
In addition to the three pairs of legs which all insects have on the thorax, caterpillars have four pairs of prolegs on the abdomen and a pair of anal claspers. Despite the long soft body, which is supported by these extra legs, a caterpillar has an external skeleton like other insects. When it is too big for its skin, it molts (p. 6).



INDIAN MOON MOTH LARVA
While chewing away the edges of leaves, Indian moon moth caterpillars are very exposed to predators. When touched, a caterpillar is liable to wriggle vigorously, and the pairs of spiny tubercles on its back will deter some birds from eating it.

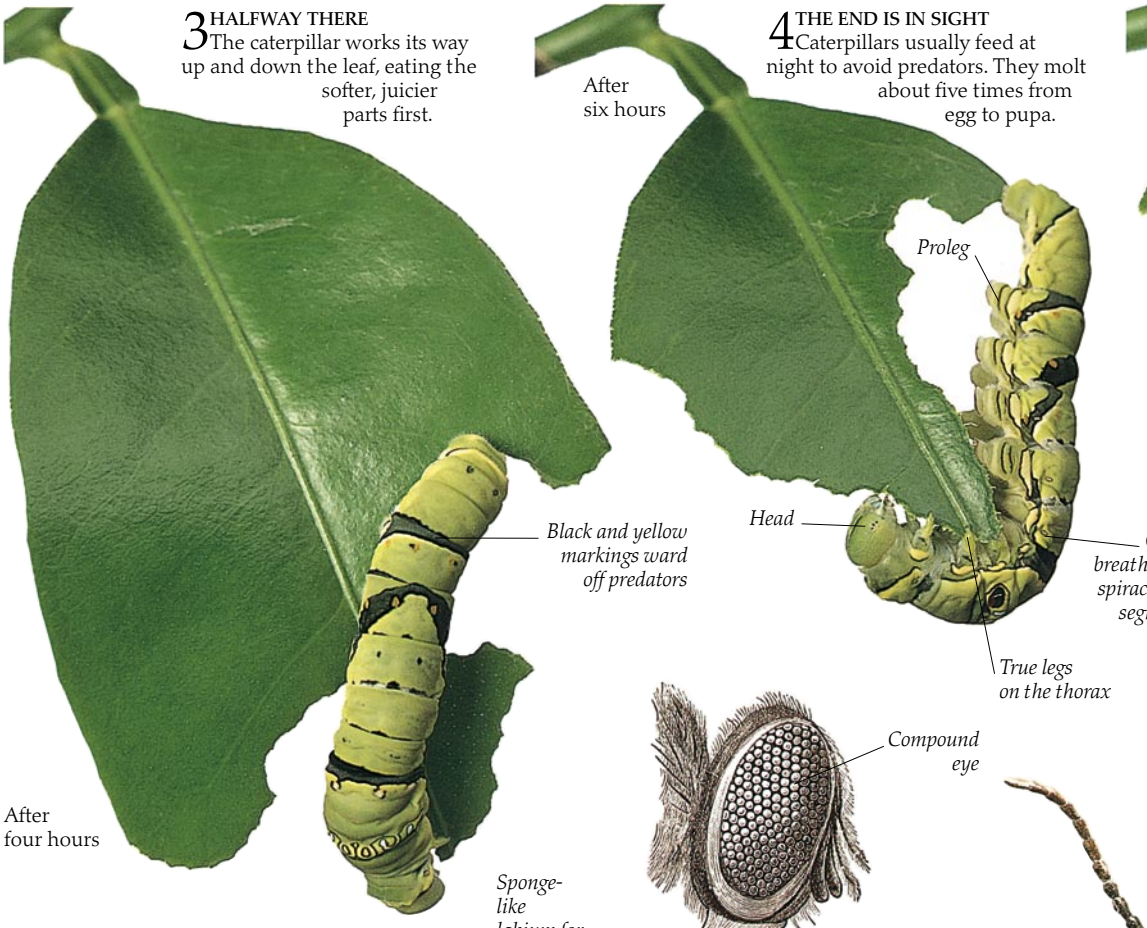
ANTS AND APHIDS
Small plant-sucking bugs, such as aphids, are often looked after by ants, who may even build a small shelter over the bugs to keep off rain and other insects. The ants feed on honeydew, a sugary substance excreted by the aphids that would otherwise build up, grow a sooty mold, and kill the aphid colony. One way of controlling aphid populations on trees is to keep the ants from climbing up and protecting them.



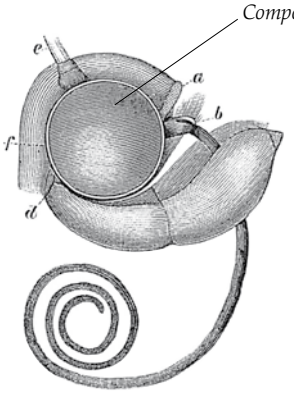
BLOODSUCKING FLY
This tabanid fly (*Fidena castanea*) has long sharp mouthparts, like very fine needles, for piercing the skin. The rest of the mouthparts form a tube for sucking up blood. This insect can feed on humans, but probably usually feeds on the blood of monkeys. These flies are not delicate feeders like mosquitos and produce a very painful, open wound.

3 HALFWAY THERE
The caterpillar works its way up and down the leaf, eating the softer, juicier parts first.

4 THE END IS IN SIGHT
Caterpillars usually feed at night to avoid predators. They molt about five times from egg to pupa.

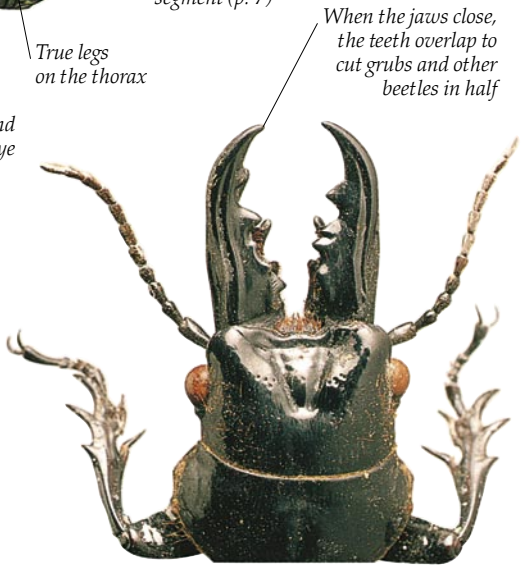


5 DINNER IS OVER
After eight hours the leaf has gone, and the caterpillar is ready to look for the next one. A few more leaves like that and it will be ready for its final molt to produce the pupa from which the adult moth will emerge (pp. 24–25).



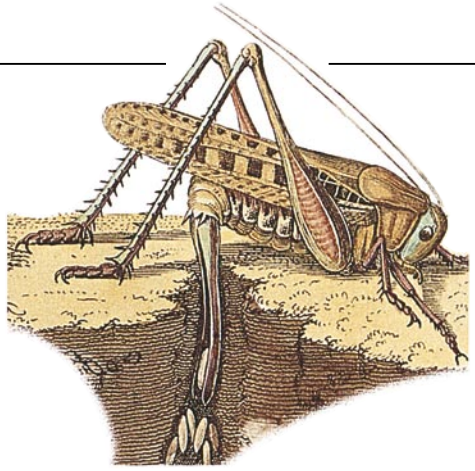
BUTTERFLY HEAD
This engraving shows how the feeding tube, or proboscis, of moths and butterflies coils up under the head. Unlike caterpillars, adult butterflies have no mandibles. The feeding tube is made from the pair of maxillae, which have become very long and pressed against each other.

FLY HEAD
In houseflies and blowflies, the mandibles and maxillae are not developed. The spongelike structure used by these flies to pick up liquids is formed from the labium, which in other insects is simply the lower lip of the mouth.



ALL CUT UP
The teeth on the powerful jaws of this East African ground beetle (*Ochryopus gigas*) overlap when the jaws are closed. This scissor-like action enables the beetle to attack and cut up grubs and even large beetles in the soil and in rotting wood.

Battling beetles



DIGGING DEEP
Grasshoppers lay their eggs in groups around the roots of grasses. In contrast, locusts and also this bush cricket (*Decticus albifrons*) drill into the soil with a long straight ovipositor and lay their eggs underground. They then fill in the hole and rake over the surface to conceal it from parasites.

In warm weather, if its host plant is healthy, an aphid can produce 50 offspring in a week, each of which will be mature one week later. At this rate of breeding the world could be knee-deep in aphids within a few weeks – but this does not happen. The number of plants necessary to feed large insect populations is limited, and this lack of resources together with hungry predators limits the number of insects. Despite this, a large swarm of locusts will include many thousands of millions of individuals. Some insects, such as those that feed on dead wood, compete for food and breeding sites. In many such insects, the males may have large horns or big jaws to fight off rival males and lay claim to a dead branch on which to mate and breed.

Femur

Tibia

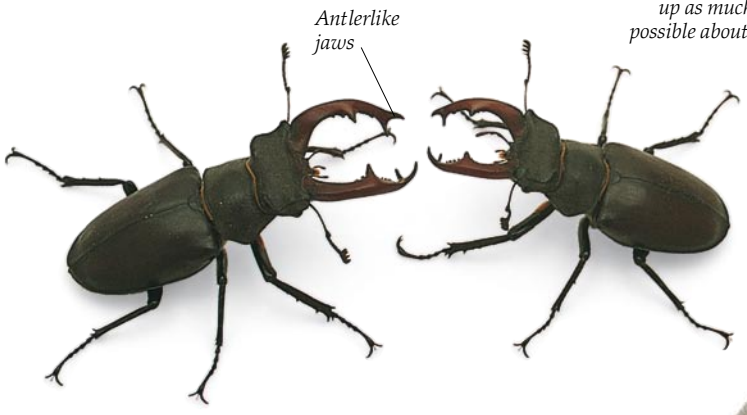
Tarsus

Let's see who's boss around here!

Antlerlike jaws

Antenna outstretched to pick up as much information as possible about the other beetle

Thorax



1 EYEING UP THE OPPOSITION
Stag beetles, like these two from Europe (*Lucanus cervus*), get their name from the large branched "horns" of the male. These are really greatly enlarged jaws that are used for fighting, much like the antlers of a real stag. A male defends his territory, usually at dusk, by adopting a threatening position.

Hard, black, protective wing case

Female cockroach with egg purse

Antenna

Ootheca, or egg purse

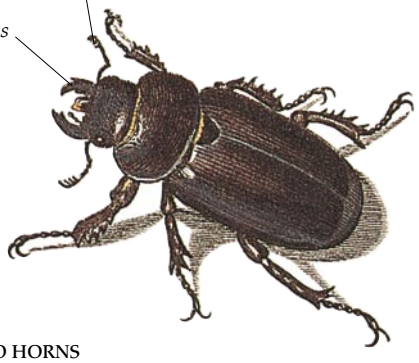
Spiny legs to deter predators

EGGS IN ONE BASKET
Cockroaches lay their eggs in groups, like grasshoppers. But whereas the egg pods of grasshoppers are made of soil particles, a female cockroach produces a hard, purselike structure called an ootheca, with two rows of eggs standing neatly upright inside.

POWER STRUGGLE
Fighting between two males is very common in many animal species as a way of proving male dominance and defending territory. Ritualized fighting, in which no one is really hurt, is one way of reducing aggressive male instincts.

Antenna

Very small horns



Female stag beetle

NO HORNS
Unlike most male stag beetles, the females do not have large fighting jaws. This is because the females play different roles from the males and are not concerned with defending feeding and breeding sites. Such a marked difference between male and female is known as sexual dimorphism. Curiously, very small male stag beetles also do not have large fighting jaws. It seems small, non-fighting males are successful at times when there is not enough food to produce large males.

Claws

Segmented tarsus

Hard wing case, or elytron, protects more delicate hind wings and abdomen underneath

Jaws encircle rival beetle

Eye

Antenna

The fight in full swing

Palp for sensing food

Hard, antlerlike jaws

2 THE FIGHT
When threats prove insufficient, the defending male will grapple with its rival and each beetle will attempt to lift the other off its feet by grasping it around the middle with its horns. Once this is done, it is a simple matter to drop the rival off the branch or log onto the ground.

Vanquished beetle lands upside down

Front right leg missing

3 VANQUISHED
If the defeated beetle lands on its back, it may be unable to get to its feet before being eaten by ants, particularly if, like this one, it has been injured. Sometimes the teeth on the encircling jaws of the winner may punch a hole in the rival's armor and it will die.

Tarsus

Tibia

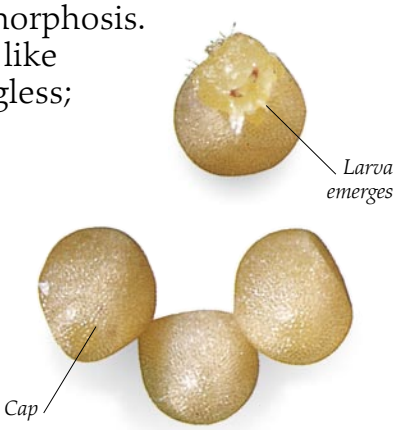
Claws on tarsus help beetle take a firm grip on the branch it is defending

Complete metamorphosis

METAMORPHOSIS MEANS "change of body form and appearance." The most advanced insects have a complex life cycle involving "complete" metamorphosis. The eggs hatch to produce larvae (caterpillars, grubs, or maggots) that are quite unlike adult insects in both form and appearance. The larvae grow and molt several times (pp. 6–7), finally producing a pupa (chrysalis). Inside the pupa the whole body is reorganized, and a winged adult is produced. This type of life cycle enables the larvae to specialize in feeding, and the adults to specialize in breeding and looking for new sites. Wasps, bees, ants, flies, beetles, butterflies and moths, caddis flies, fleas, lacewings, and scorpion flies all undergo complete metamorphosis. But not all insects obey the rules: the adults of some species of beetle look like larvae; some female mountain moths are wingless; and some flies have no adults because each larva can produce many more larvae inside its body.

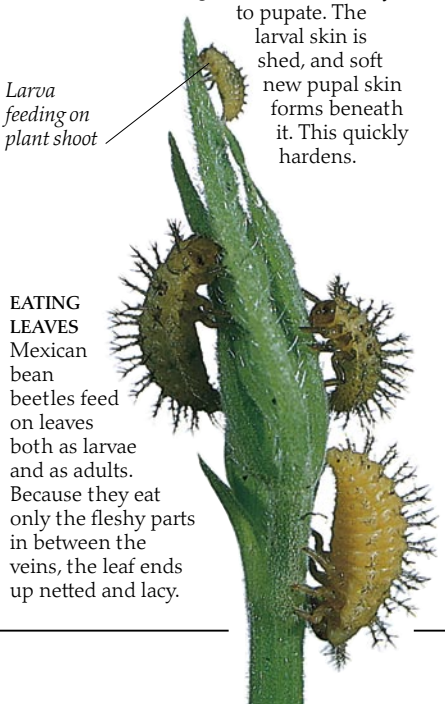
MATING
Mexican bean beetles (*Epilachna varivestis*) are a species of plant-feeding ladybird beetle. The adult males and females look very similar and mate frequently.

EGGS
Female Mexican bean beetles lay their eggs in groups of about 50 on the underside of leaves where they are well protected. Each egg stands on end and takes about a week to hatch.

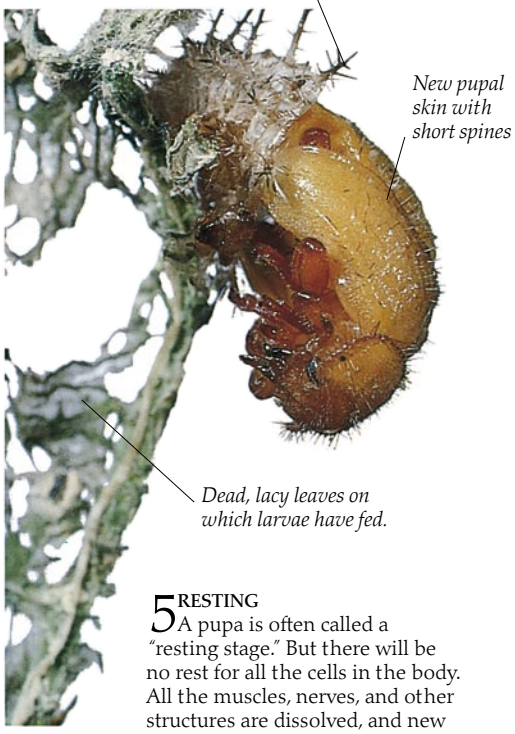


1 EGG HATCHES
Even eggs have to breathe. Around the top of each egg is a ring of pores which allow air to reach the developing larva inside. About a week after the egg has been laid, the cap at the top is broken or chewed off, and the larva emerges.

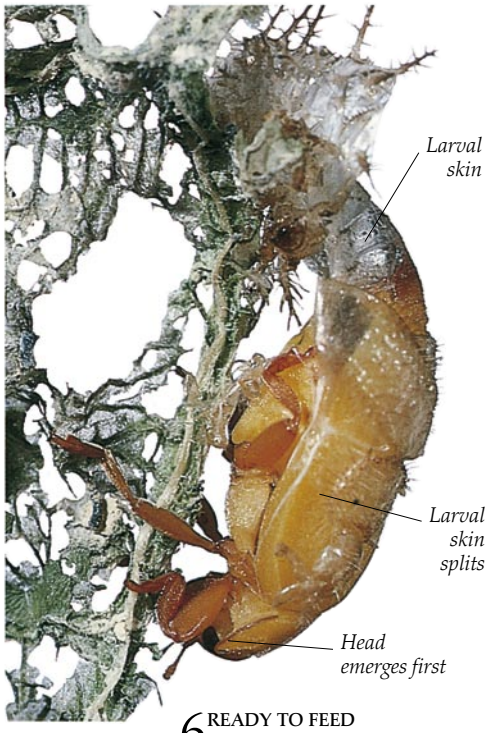
4 ABOUT TO CHANGE
When the larva has eaten enough food, it attaches itself to the underside of a damaged, netted leaf, ready to pupate. The larval skin is shed, and soft new pupal skin forms beneath it. This quickly hardens.



EATING LEAVES
Mexican bean beetles feed on leaves both as larvae and as adults. Because they eat only the fleshy parts in between the veins, the leaf ends up netted and lacy.



5 RESTING
A pupa is often called a "resting stage." But there will be no rest for all the cells in the body. All the muscles, nerves, and other structures are dissolved, and new limbs, with new muscles and nerves, are formed. In this picture, the smooth yellow of the adult beetle's wing cases and the first segment of the thorax can be seen through the thin, spiny skin of the pupa.



6 READY TO FEED
The thin, spiny pupal skin splits along the underside, and the smooth young adult slowly draws itself free, head first. It takes the young beetle about one hour from the splitting of the pupal skin to free itself fully.

Eggs

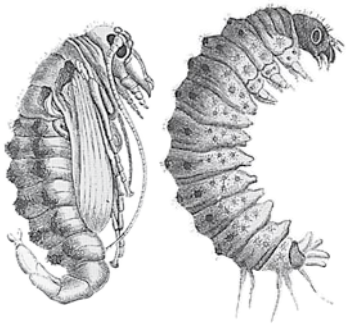
Young larva

Mature larva

Male pupa

Female pupa

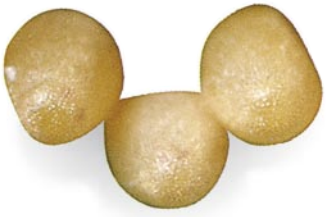
STAG BEETLE DEVELOPMENT
The larvae of stag beetles and other scarab beetles always adopt a C-shaped posture. The male pupa with its large jaws is easy to tell apart from the female pupa.



SCORPION FLIES
Like ant lions (p. 41), scorpion flies also have a complete metamorphosis. This drawing shows a larva, and a pupa with well-developed wing buds.

A MAN TRANSFORMED
This painting by Barbara Lofthouse depicts a scene from Kafka's *Metamorphosis*, in which a man is transformed into an insect.

Red spots are associated with simple eyes



2 LARVA EMERGES
As the soft-spined larva crawls out of its egg, three red pigment spots can be seen on either side of the head. Larvae do not have compound eyes, like adults, and these spots are associated with simple eyes.

3 A FIRST MEAL
In many insect species, as soon as a young larva is free from its egg, it turns around and eats the shell, which is thought to contain valuable nutrients. The soft spines on the surface of the larva quickly harden.

PROTECTION FROM PARASITES
The spines on the surface of the larvae are branched, with hard, pointed tips. Spines like this are found on the larvae of all plant-feeding ladybirds, but not on any of the more common predatory species. The spines make the larvae unpleasant to birds and may prevent parasites from laying eggs.

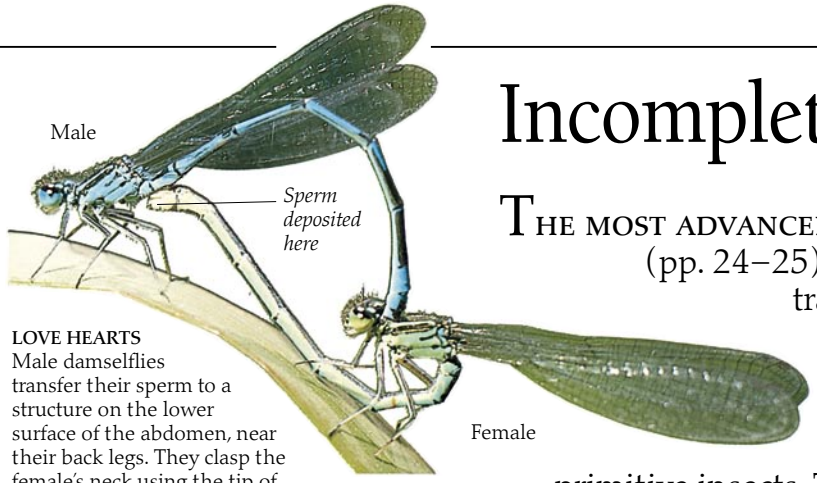
7 NO SPOTS
Immediately after emerging, the young beetle is yellow and has no spots, although the wing cases quickly harden. Before the beetle can fly, there then follows a crucial stage lasting two to three hours, where the young beetle holds its wing cases up and expands the wings below to allow them to dry.

Old larval skin remains attached to leaf

Young adult

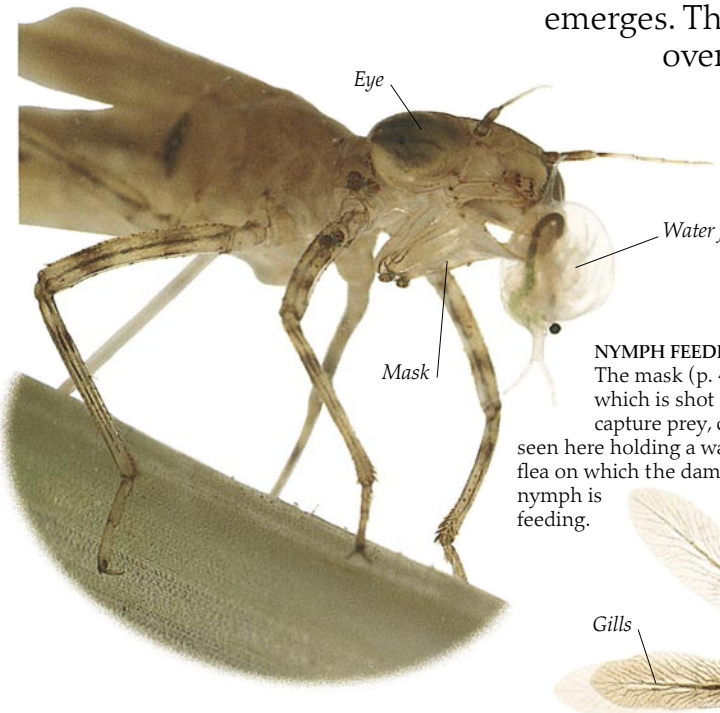
8 ONE MORE PEST
After about 24 hours the adult spots will appear on the wing cases, but the copper color takes seven to ten days to develop fully. About 100 years ago this species spread slowly northward from Mexico on plots of phaseolus beans. Then in 1918 it was accidentally imported to the eastern United States and spread rapidly toward Canada. Today it is a serious pest of bean crops in North and Central America, but it cannot live in central areas because of the harsher winters.

Incomplete metamorphosis

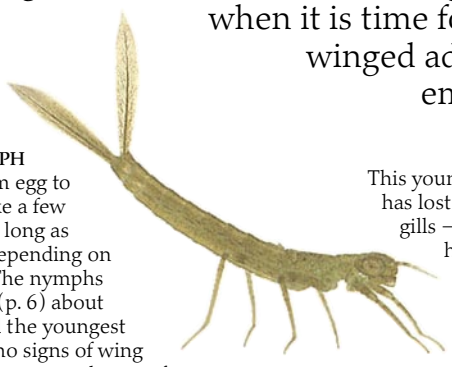


LOVE HEARTS
Male damselflies transfer their sperm to a structure on the lower surface of the abdomen, near their back legs. They clasp the female's neck using the tip of their abdomen, and the female then raises her own abdomen to collect the sperm. They may fly together in this tandem position for some time, often forming a heart shape with the male's head down at the tip and the female's head at the top of the heart.

The most advanced insects undergo complete metamorphosis (pp. 24–25), in which the body form is relatively quickly transformed from larva to adult during a pupal stage. But a gradual transformation through a series of stages, in which the nymphs look progressively more like adults, must have been the life cycle of the original primitive insects. This "incomplete" metamorphosis is found in grasshoppers, cockroaches, termites, mayflies, dragonflies, and true bugs. Very young nymphs show no signs of wings, but older nymphs have shorter or longer "buds" on the thorax, inside which the adult wings are developing. At each molt (pp. 6–7) these wing buds get longer, until finally a nymph molts and an adult emerges. The nymphs of some insects, like the damselfly shown over the next four pages, live underwater, surfacing only when it is time for the winged adult to emerge.

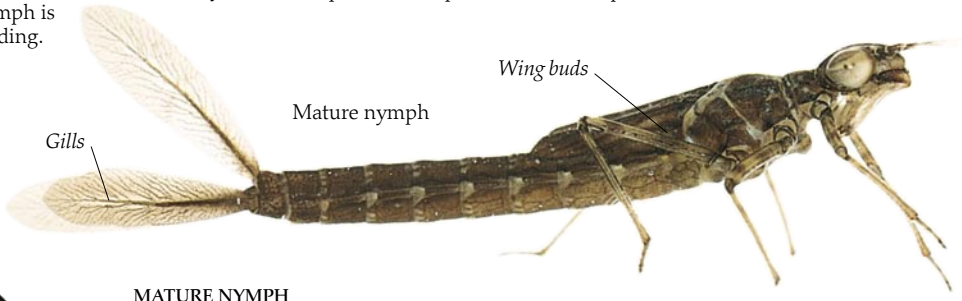


NYMPH FEEDING
The mask (p. 49), which is shot out to capture prey, can be seen here holding a water flea on which the damselfly nymph is feeding.



YOUNG NYMPH
The time from egg to adult may take a few months or as long as three years depending on the species. The nymphs usually molt (p. 6) about 12 times, and the youngest stages show no signs of wing buds. The young nymphs are often transparent to help them hide from predators.

This young nymph has lost one of its gills – it should have three



MATURE NYMPH
When fully grown, a nymph is often colored in a way that enables it to hide both from its prey and from predatory fish. The wing buds can be seen extending from the thorax over the first three segments of the abdomen.

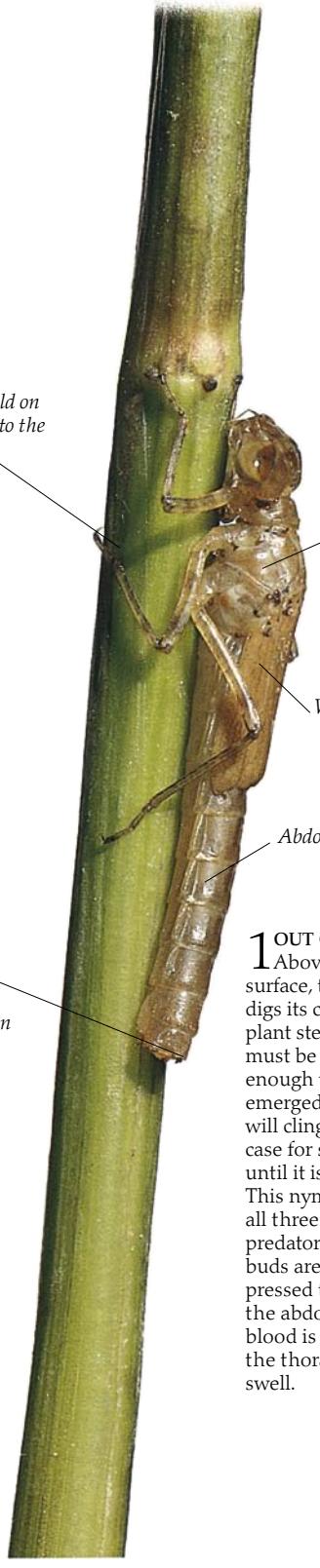
EARWIGS
Female earwigs are known to show a primitive type of social behavior. They sometimes dig a small hole in which to lay their eggs and then remain with the eggs and protect them. If the eggs are deliberately scattered, the female earwig will gather them up again. Even when the young nymphs emerge, the female remains with them until they are ready to go off and fend for themselves.

BREATHING UNDER WATER
Dragonfly and damselfly nymphs absorb oxygen and get rid of carbon dioxide in the same way that fish do – by means of gills. But, unlike a fish, the gills of a damselfly nymph are not on the head, but in the form of three fan-shaped structures on the tail. Just how necessary these are for breathing is not quite certain because they are often bitten off by predators, although they do grow back again. Perhaps the gills have an important decoy function in diverting the attack of a predator away from the head of a nymph.

The adult emerges

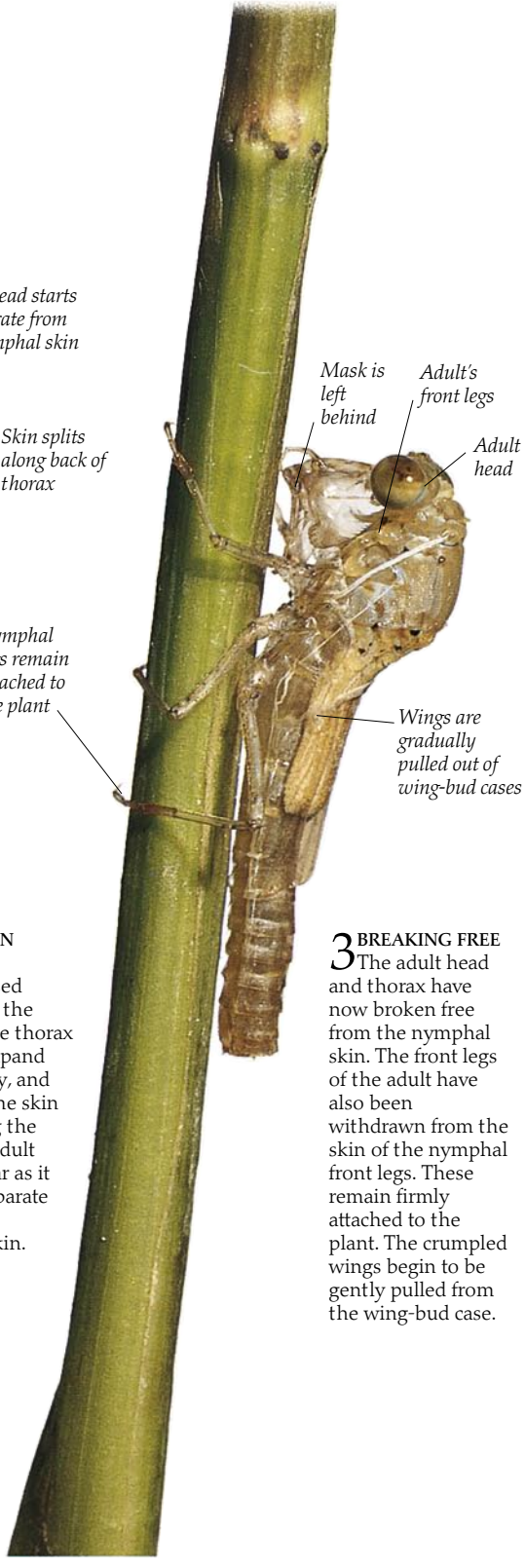
Although the damselfly nymph lives under water, and the adult is able to fly, the structure of the adult can clearly be seen in the mature nymph. The flight muscles and deep thorax are there, but the body and wings must become longer, and the nymphal mask must be shed from the head. These changes have all been prepared within the nymph underwater. Once it has crawled up into the air, it must change to an adult and fly quickly, usually in about two hours, or it will be eaten by some other animal.

The mature nymph crawls up a stem out of the water, where the adult will emerge



1 OUT OF WATER
Above the water surface, the nymph digs its claws into the plant stem. Its grip must be strong enough to support the emerged adult, which will cling to the empty case for several hours until it is ready to fly. This nymph has lost all three gills to a predator. The wing buds are no longer pressed tightly against the abdomen, and blood is pumped into the thorax to make it swell.

2 THE SKIN SPLITS
The increased pressure of the blood in the thorax makes it expand very quickly, and suddenly the skin splits along the back. The adult head is clear as it starts to separate from the nymphal skin.



3 BREAKING FREE
The adult head and thorax have now broken free from the nymphal skin. The front legs of the adult have also been withdrawn from the skin of the nymphal front legs. These remain firmly attached to the plant. The crumpled wings begin to be gently pulled from the wing-bud case.

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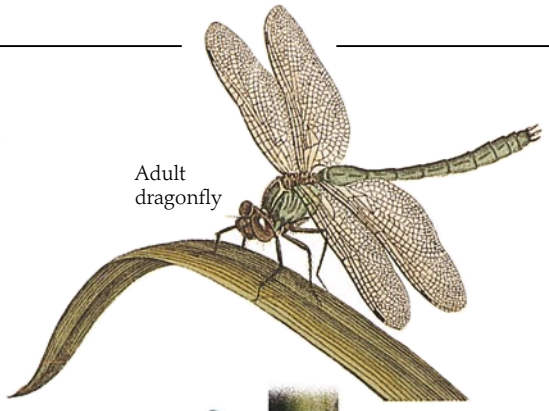
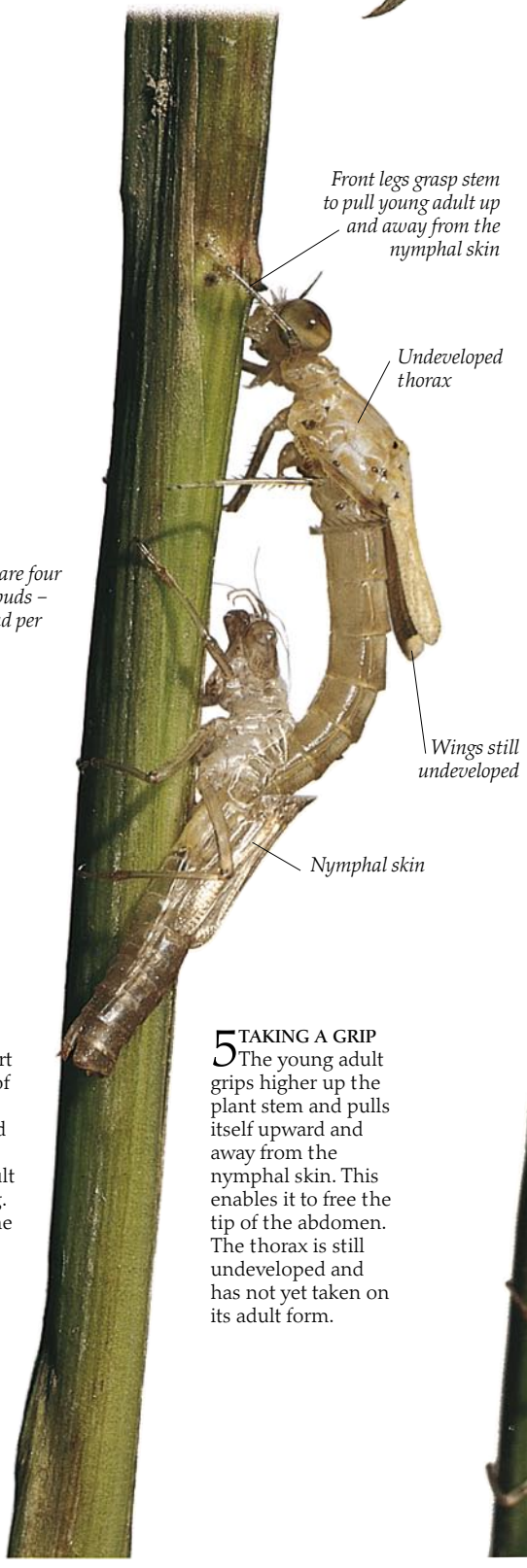
Dragonfly nymphs



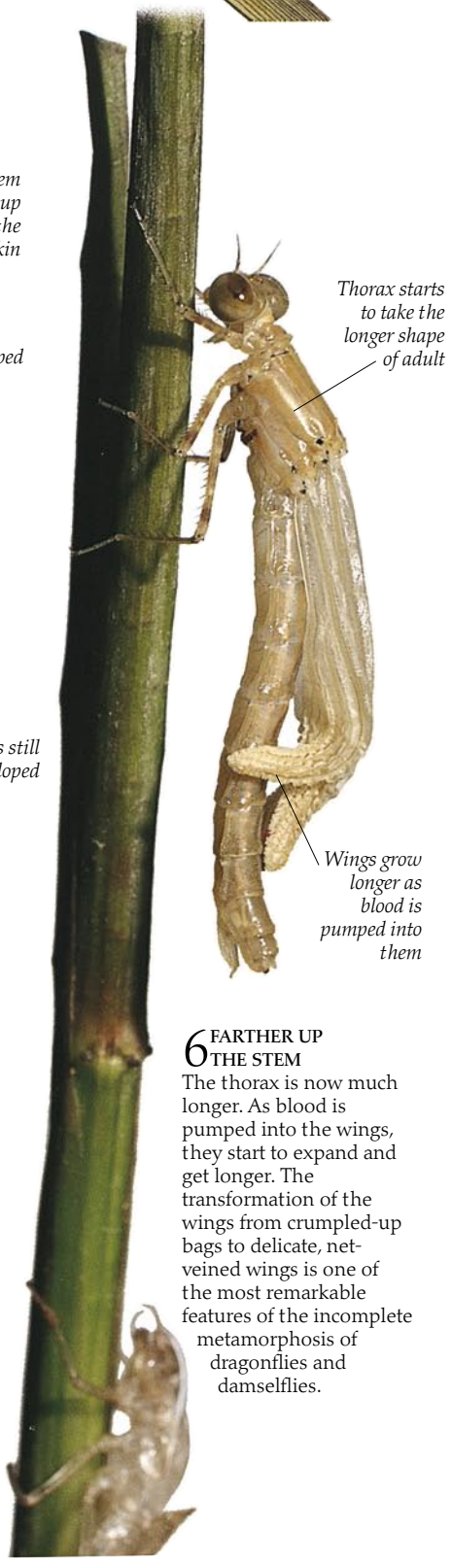
Adult dragonfly

DRAGONFLIES
The life cycle of dragonflies is similar to that of damselflies but longer; dragonflies are larger and may take two to three years from egg to adult. The nymphs do not have fan-shaped gills on their tails. Instead they have complicated gills inside the tip of the abdomen. Water is pumped in and out over these gills, and nymphs use this pumping action to move around by jet propulsion. Adult dragonflies rest with their wings spread wide horizontally and are usually much more active fliers than the gentle damselflies.

4 ALMOST THERE
Most of the upper part of the body is now free of the nymphal skin. The eyes seem to be hard and functional, but the front legs of the emerging adult are still soft and bending. The four wing buds – one per adult wing – are still very small and compact.



5 TAKING A GRIP
The young adult grips higher up the plant stem and pulls itself upward and away from the nymphal skin. This enables it to free the tip of the abdomen. The thorax is still undeveloped and has not yet taken on its adult form.

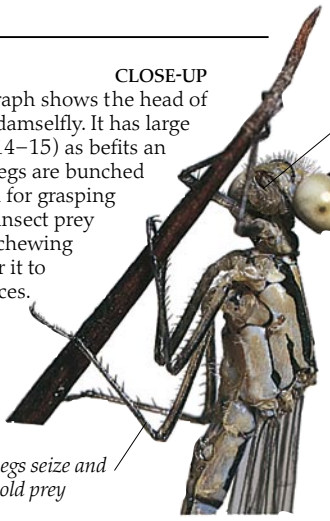


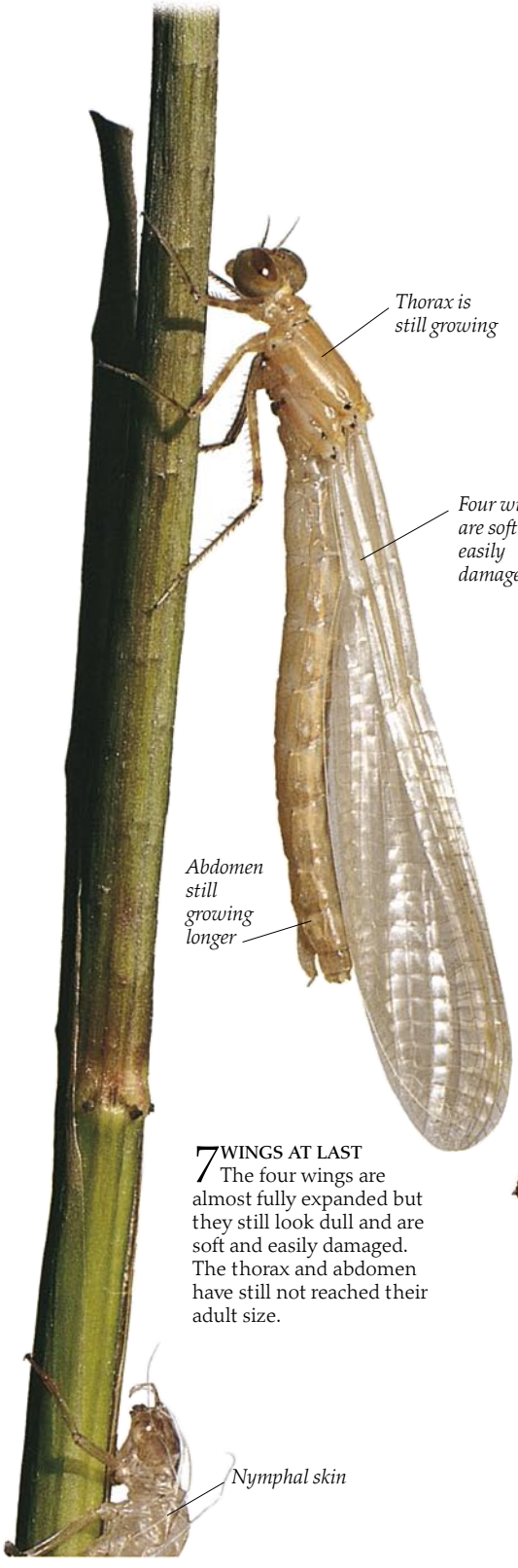
6 FARTHER UP THE STEM
The thorax is now much longer. As blood is pumped into the wings, they start to expand and get longer. The transformation of the wings from crumpled-up bags to delicate, net-veined wings is one of the most remarkable features of the incomplete metamorphosis of dragonflies and damselflies.

Continued from previous page

DAMSELFLIES
These delicate-looking insects are found near water. They have four similarly shaped, net-veined wings, which they hold flattened together above their body when at rest. The damselfly photographed for the emergence sequence over these pages is a female of the species *Coenagrion puella*. Male and female damselflies are frequently quite different in color. In this species the females are black on the back and brilliant green along the sides; the males are blue on the back.

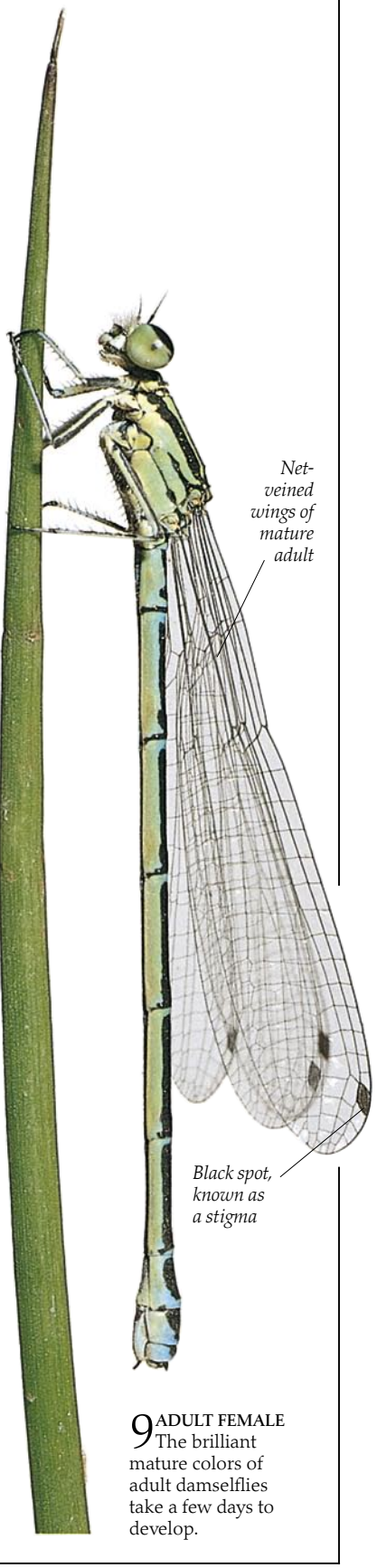
CLOSE-UP
This close-up photograph shows the head of an adult male damselfly. It has large compound eyes (pp. 14–15) as befits an active hunter. The legs are bunched behind the mouth for grasping and holding the insect prey while the powerful chewing mouthparts tear it to pieces.





7 WINGS AT LAST
The four wings are almost fully expanded but they still look dull and are soft and easily damaged. The thorax and abdomen have still not reached their adult size.

8 READY TO FLY
When the abdomen reaches its full length, a drop of liquid exudes from the tip. This is a female. She is now ready to fly weakly, although the wings are still rather milky in appearance. It is just two hours since she crawled out of the water as a curious nymph. The colors remain yellowish for many hours, and it will be several days before she gets her typical black and green color pattern.

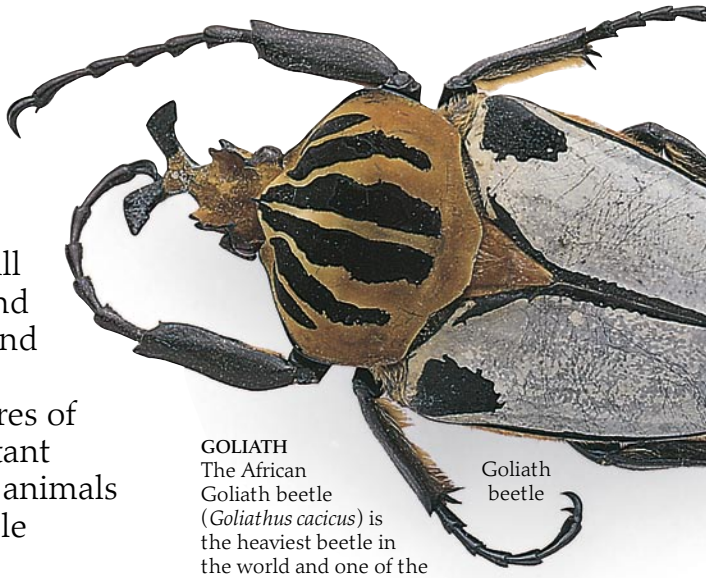


9 ADULT FEMALE
The brilliant mature colors of adult damselflies take a few days to develop.

Beetles

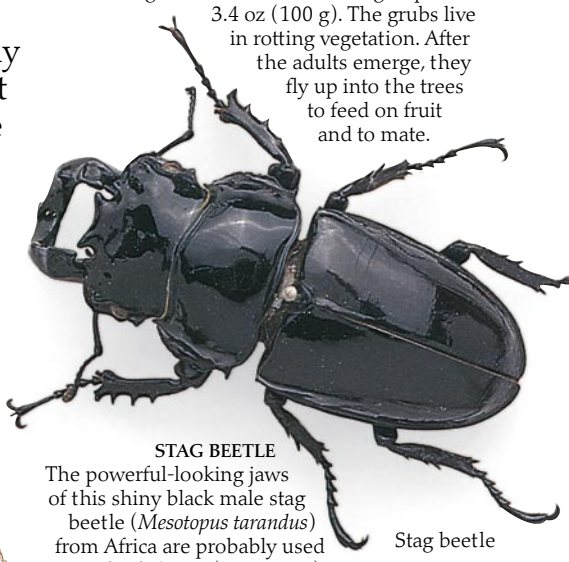
SACRED SCARAB
The ancient Egyptians believed that the scarab rolling her ball of dung symbolized the sun god Ra rolling the sun and renewing life.

THERE ARE AT LEAST 300,000 different kinds of beetle, living everywhere from snowy mountaintops to scorching deserts and muddy ponds (pp. 48–49). Beetles eat all kinds of plants and animals, dead or alive, and are eaten in vast numbers by birds, lizards, and small mammals. Although they may be pests, attacking crops and devouring stores of human food, beetles also play an important role in nature by eating dead plants and animals and returning them to the soil as valuable nutrients. All beetles undergo complete metamorphosis (pp. 24–25). Their eggs hatch into grubs, some of which feed and grow for several years before pupating and becoming adults. Adult beetles are the most heavily armored of all insects. They have hardened front wings that meet in the middle to cover and protect the more delicate hind wings, which they use for flying (pp. 12–13). Beetles come in all sizes, from tiny fungus beetles smaller than a pinhead, to the giant Goliath, up to 6 in (15 cm) long.



Goliath beetle

GOLIATH
The African Goliath beetle (*Goliathus cacicus*) is the heaviest beetle in the world and one of the largest flying insects. The adults may be as long as 6 in (15 cm) and weigh up to 3.4 oz (100 g). The grubs live in rotting vegetation. After the adults emerge, they fly up into the trees to feed on fruit and to mate.



Stag beetle

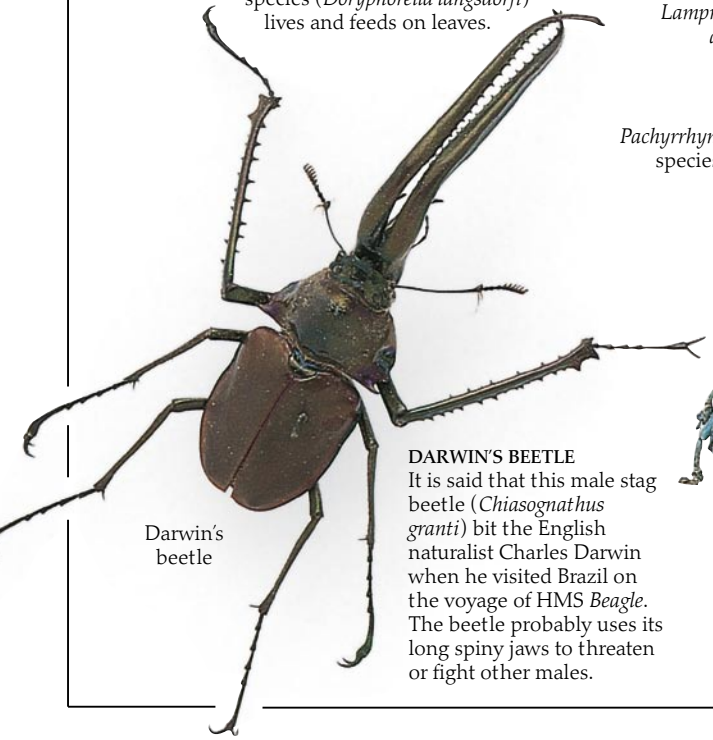
STAG BEETLE
The powerful-looking jaws of this shiny black male stag beetle (*Mesotopus tarandus*) from Africa are probably used for fighting (pp. 22–23).

Malayan frog beetle (male)

Doryphorella langsdorfi

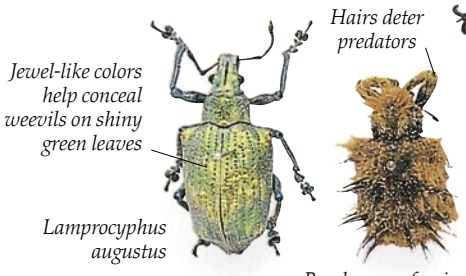
Froglike hind legs

LEAF LIFE
Leaf beetles, like the two shown above, are often brightly colored. The Malayan frog beetle (*Sagra buqueti*) uses its large hind legs to clasp the female during mating. The South American species (*Doryphorella langsdorfi*) lives and feeds on leaves.



Darwin's beetle

DARWIN'S BEETLE
It is said that this male stag beetle (*Chiasognathus granti*) bit the English naturalist Charles Darwin when he visited Brazil on the voyage of HMS *Beagle*. The beetle probably uses its long spiny jaws to threaten or fight other males.

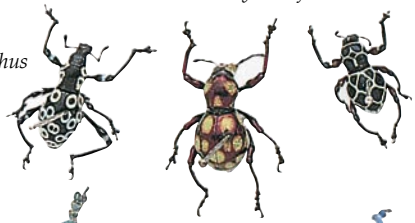


Jewel-like colors help conceal weevils on shiny green leaves

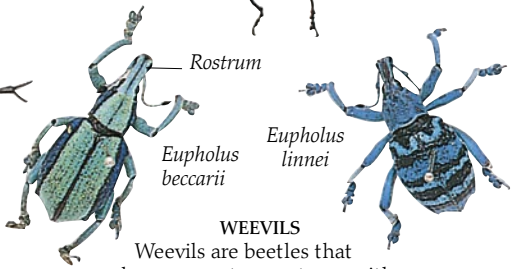
Hairs deter predators

Lamprocyphus augustus

Brachycerus fascicularis



Pachyrrhynchus species

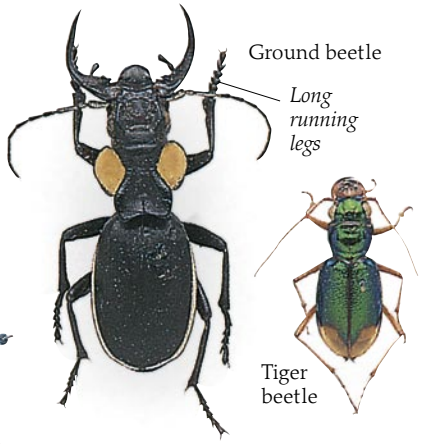


Rostrum

Eupholus beccarii

Eupholus linnei

WEEVILS
Weevils are beetles that have a snout, or rostrum, with small biting jaws at the tip. Most weevils are plant feeders. Some are brilliantly colored and patterned, and others are hairy, possibly to deter predators. The middle three, from the Philippines, possibly mimic spiders (p. 46).



Ground beetle

Long running legs

Tiger beetle

KILLER BEETLES
Ground beetles and the closely related tiger beetles usually hunt and kill smaller insects for food. This large African species (*Anthia thoracica*) does not fly but scurries along the ground after its prey. The green tiger beetle (*Megacephala australis*) from Australia runs and flies in sunny places.

LONG-HORNED LONGHORNS
Adult longhorn beetles are recognized by their long antennae. The grubs of all species feed on dead wood. This giant longhorn from Fiji is probably extinct, because of a shortage of dead trees to feed the huge grubs. The yellow species is a pest of cola trees in Africa; females strip a ring of bark off the base of a twig so it dies and can be eaten by the grubs. No one really knows the purpose of the "bottle brushes" on the legs and antennae of the little Brazilian longhorn – perhaps they are waved to attract a mate.

HAIRY JEWELS!
Most jewel beetles are bright and shiny, like jewels – but not all. This strange, hairy species (*Julodis klugi*) from Africa probably gathers pollen on its back, so predators cannot see it when it is sitting on a flower.

OF EVERY HUE
Not all beetles are black – many are as colorful as birds and flowers. White, blue, and gold are unusual, but metallic greens and reds are common.

SEED MIMIC
This ground-living tenebrionid beetle (*Helaeus subserratus*) from Western Australia hides from predators by looking like a seed.

DUNG ROLLERS
Helped by her mate, this green scarab beetle is rolling her ball of buffalo dung to a burrow she has dug nearby. Here she will knead it before laying an egg in the center.

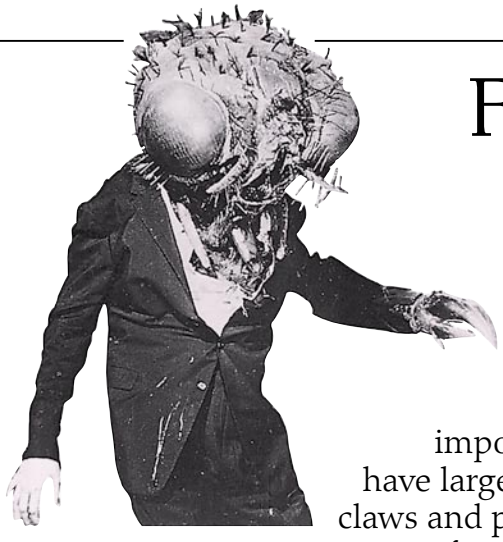
VIOLIN BEETLE
This beetle (*Mormolyce phyllodes*) is flat because it lives between the layers of bracket fungi on Indonesian trees.

LIGHT WORK
Glowworms are not worms, but beetles. The wingless females of some species can flash their tails to attract a mate.

LYCID BEETLE
This female beetle, (*Demosis* species) is called a "trilobite larva", because it looks like the now extinct sea-dwelling trilobites.

STICKING HIS NECK OUT
Only the male Madagascan giraffe beetle (*Tachelophorus giraffa*) has a long neck. In contrast, the front of the head of both the male and the female of this large Malaysian brentid (*Eutrachelus temmincki*) looks as though it has been stretched.

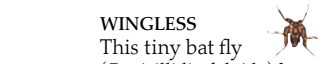
Flies



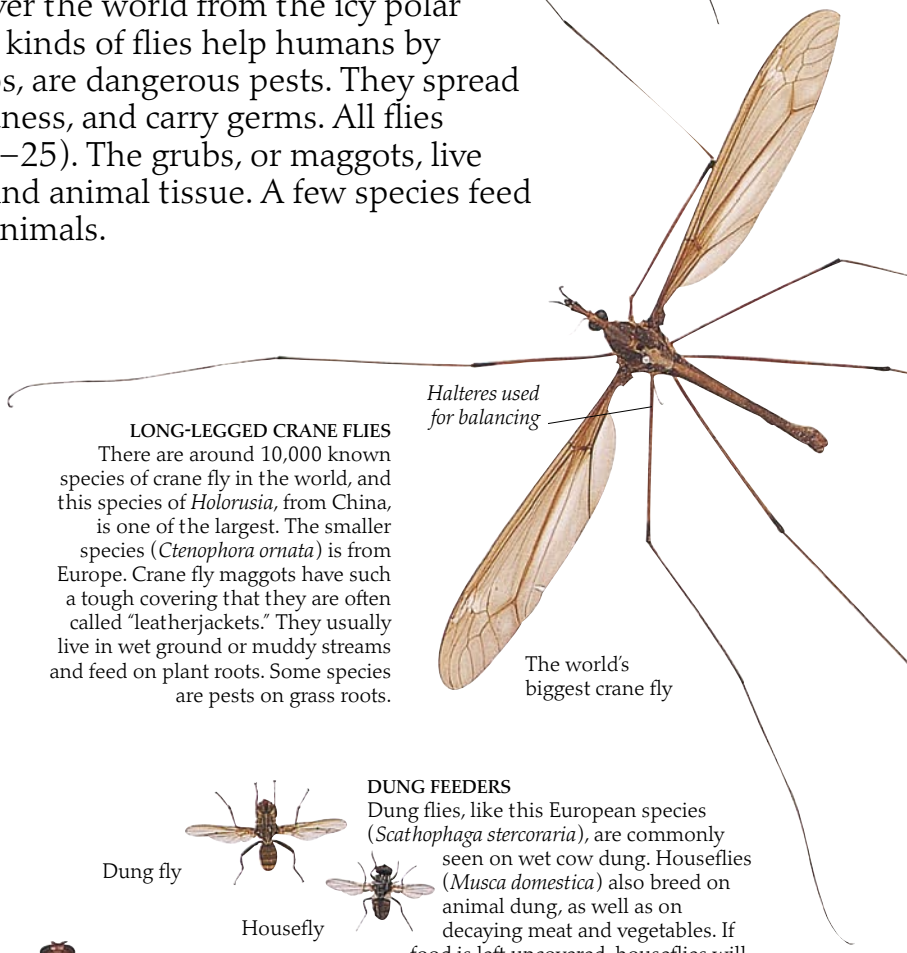
NO FLIES ON ME!
This character in the film *Return of the Fly* is gradually turning into a fly.

A FLY IS AN INSECT WITH TWO WINGS. Many other insects are called flies, like butterflies and dragonflies, but they have four wings and are not true flies. Instead of hind wings, flies have a pair of small drumstick-like structures called halteres, which are important for balancing in flight. Flies have large compound eyes (pp. 14–15) and claws and pads on the feet so they can walk on any surface. They can perform amazing acrobatics in the air, walking on the ceiling, flying backward, and hovering on the spot. True flies are found all over the world from the icy polar regions to the equatorial rain forest. Some kinds of flies help humans by pollinating crops, but many, like mosquitos, are dangerous pests. They spread diseases, such as malaria and sleeping sickness, and carry germs. All flies undergo complete metamorphosis (pp. 24–25). The grubs, or maggots, live mainly in water or in moist, rotting plant and animal tissue. A few species feed only on living plants or animals.

WINGLESS
This tiny bat fly (*Penicillidia fulvida*) has no wings at all. It lives in the fur of bats and feeds on blood. The female gives birth to a fully grown grub that falls to the ground and pupates (pp. 24–25).



European crane fly

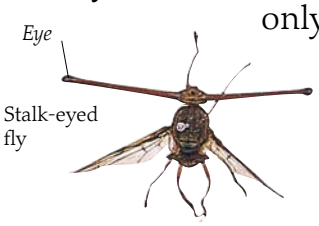


Halteres used for balancing

LONG-LEGGED CRANE FLIES
There are around 10,000 known species of crane fly in the world, and this species of *Holorusia*, from China, is one of the largest. The smaller species (*Ctenophora ornata*) is from Europe. Crane fly maggots have such a tough covering that they are often called "leatherjackets." They usually live in wet ground or muddy streams and feed on plant roots. Some species are pests on grass roots.

The world's biggest crane fly

Eye



Stalk-eyed fly

AN EYE FOR AN EYE
The stalked eyes of this male fly (*Achias rothschildi*) from New Guinea are used to threaten other males with shorter eye stalks. The fly with the longest eye stalks wins.

Soldier fly

Celyphus hyacinthus

BEETLE MIMIC
This small fly (*Celyphus hyacinthus*) from Malaysia looks remarkably like a beetle.

GREEN SKIN
The green color of this South American soldier fly (*Hedriodiscus pulcher*) is caused by an unusual green pigment in the cuticle (p. 6) rather than by iridescence (a trick of the light).

FATTEST FLY
The grubs of this South American fly (*Pantophthalmus bellardii*) bore into living wood. Little is known about the habits of these large adults, and it may be that they do not even feed.

NO EYE STALKS
This African fly (*Clitodoca fenestralis*) is related to the stalk-eyed fly from New Guinea shown above, but nothing is known about its life-style. The patterned wings and red head may be important in courtship.

Dung fly

Housefly

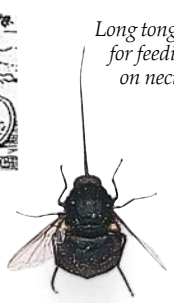
DUNG FEEDERS
Dung flies, like this European species (*Scathophaga stercoraria*), are commonly seen on wet cow dung. Houseflies (*Musca domestica*) also breed on animal dung, as well as on decaying meat and vegetables. If food is left uncovered, houseflies will soon begin feeding, and in this way they spread many diseases.

Human warble fly

Bluebottle

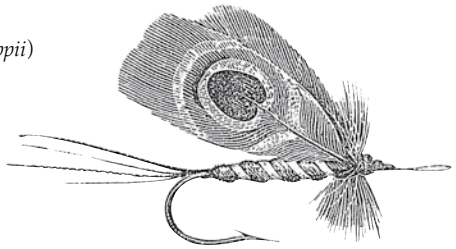
FLESH EATERS
The female of this human warble fly (*Dermatobia hominis*) lays her eggs on a mosquito. When the mosquito feeds on a human, the eggs hatch and the fly larva begins to bore under the human's skin, where it lives and feeds for about six weeks. Like the housefly, bluebottles (*Cynomya mortuorum*) are common pests, breeding in rotting meat and dead bodies, and spreading disease.

OUT OF THE STRONG CAME FORTH SWEETNESS
According to the Old Testament, Samson saw a swarm of bees in the dead and rotting body of a lion. In fact, the insects he saw were almost certainly not bees, but yellow and black drone flies. These flies look like bees, but their larvae live and pupate in putrid water. This probably fooled ancient writers into believing that bees lived in the bodies of dead animals.

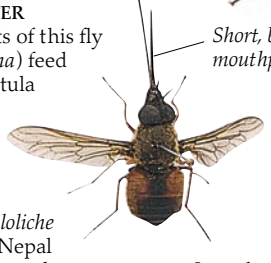


SPIDER EATER
The maggots of this fly (*Lasia corvina*) feed in live tarantula spiders.

FLAT FLOWER-FEEDER
This fly (*Trichophthalma philippii*) from Argentina sips nectar. The maggots feed in live scarab beetle grubs.



FLY-FISHING
People who fish disguise their hooks with fantastic "flies" like this, made from feathers and twine. Floating on the surface, the mock fly fools fish into thinking it is a drowning insect.

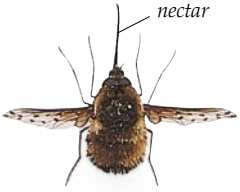


A VARIED DIET
This horsefly (*Philoliche longirostris*) from Nepal has short, biting mouthparts to feed on blood, and a long tongue to sip nectar.

TACHINID FLIES
There are many thousands of species of tachinid fly in the world. The maggots are always parasitic; that is, they feed on other insects while they are still alive. For this reason they are often important in controlling pests. The yellowish species (*Paradejeeria rutiloides*) is from America, where it attacks moth caterpillars. The brilliant green species (*Formosia moneta*) from New Guinea feeds on scarab beetle larvae.

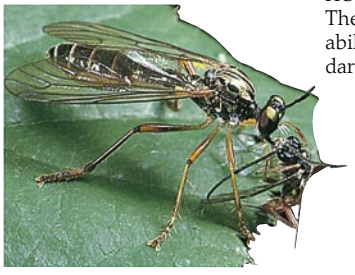
MEAT-EATING MAGGOTS
This African bee fly (*Ligyra venus*) feeds on nectar, but its maggots eat developing grubs in wasps' nests.

A SLIM PROFILE
Like the true bees, this slender-bodied bee fly (a species of *Systropus*) from Java sips nectar. Its larvae feed on live moth caterpillars.

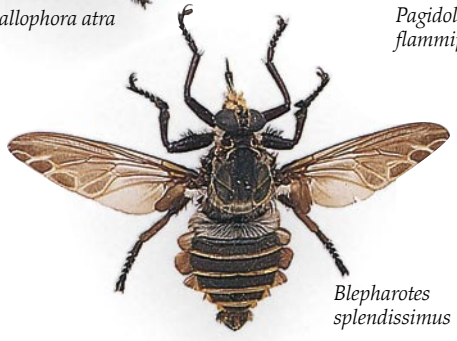


BEE-EATING BEE FLIES
This European bee fly (*Bombylius discolor*) is easily mistaken for a bumblebee feeding on nectar. Its maggots feed on grubs in the nests of solitary bees.

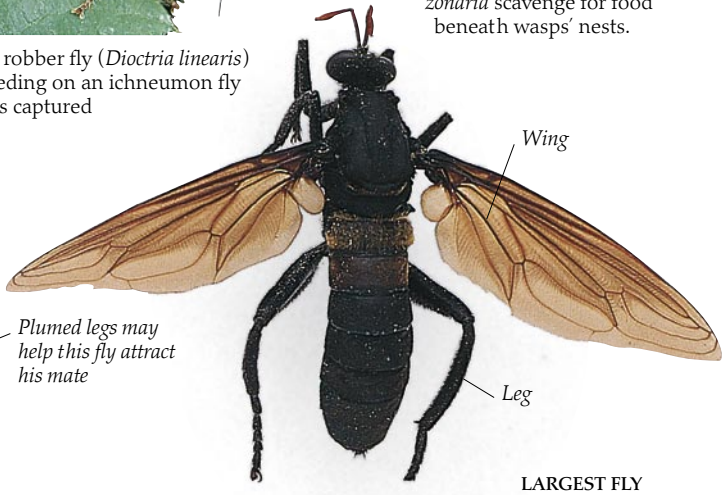
HOVER FLIES
The name of these flies refers to their amazing ability to hang in the air almost motionless, then dart away, almost too quick to be seen. Many of the species are striped yellow and black and look like wasps or bees. The maggots of the smaller species (*Syrphus torvus*) are popular with gardeners in Europe because they feed on aphids and keep numbers down. The maggots of *Volucella zonaria* scavenge for food beneath wasps' nests.



This robber fly (*Dioctria linearis*) is feeding on an ichneumon fly it has captured



ROBBER FLIES
The members of this large family get their name from their habit of perching on suitable lookout points and attacking other insects flying past. They can be pests around beehives, killing bees as they fly home. The large black species (*Mallophora atra*) from South America probably mimics carpenter bees (p. 38). The remarkable male with plumed legs (*Pegesimallus teratodes*) is from Africa. It is thought that he waves his legs to try and attract a mate.

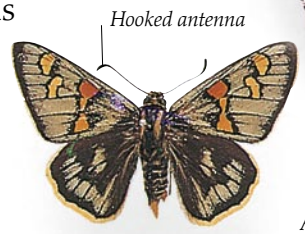


LARGEST FLY
This South American mydas fly (*Mydas heros*) is probably the largest in the world. The maggots live in ants' nests, feeding on beetles - which are themselves scavenging on the rubbish left by the ants.

Butterflies and moths

A BEE OR NOT A BEE
This harmless European hawk moth (*Hemaris tityus*) is easily mistaken for a stinging bee.

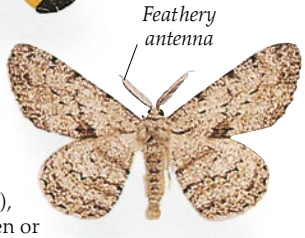
BUTTERFLIES AND MOTHS together form a single group of around 200,000 known species. It is sometimes difficult to tell a butterfly from a moth, but, generally, butterflies are brightly colored and fly during the day (or, rarely, early evening), whereas the more subtly colored moths are usually night-fliers. The antennae of most butterflies are clubbed, rather than straight or feathery, like moths' antennae, and butterflies rest with their wings folded upright over their backs, while moths hold them flat and roof-like over the body Adult butterflies and moths feed on liquids, which they suck up through a long, coiled "proboscis." Their wings and body are covered in tiny scales, which are really flattened and ridged hairs. All species undergo complete metamorphosis (pp. 24–25), and the larvae, or caterpillars, are as varied in color and shape as the adults.



BUTTERFLY OR MOTH?
The skippers are like both butterflies and moths. Their antennae are thickened and hooked, rather than clubbed like those of true butterflies. Adults are usually brown – in contrast to these two brightly colored species from Peru.

NYMPHALID BUTTERFLY
The deep, intense blue of this nymphalid (*Asterope sapphira*) is caused by the way the light strikes the tiny scales that cover the wings.

GEOMETRID MOTHS
The caterpillars of geometrids are called inchworms. The adults of many species, like this night-flying great oak beauty from Europe (*Boarmia roboraria*), are camouflaged pale green or light brown. The bright colors of *Milionia weliskei* from Southeast Asia suggest that it is day-flying and not very tasty for birds.



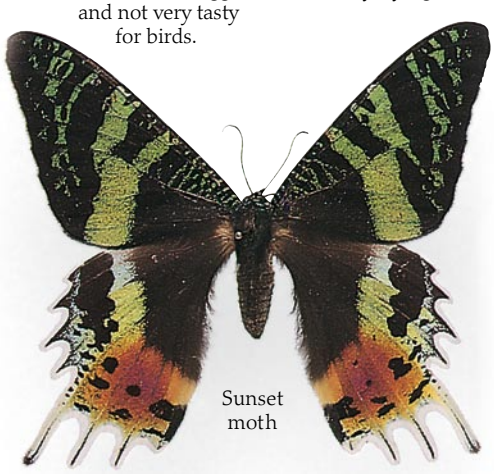
DON'T EAT ME!
In insects a combination of red, yellow, and black is often an indication that an insect is poisonous. This day-flying zygaenid moth (*Campylotes desgodinsi*) from Southeast Asia is probably avoided by birds because of its colors.

SPECIAL LEGS
Some butterflies use their front pair of legs for cleaning their eyes, rather than for walking.

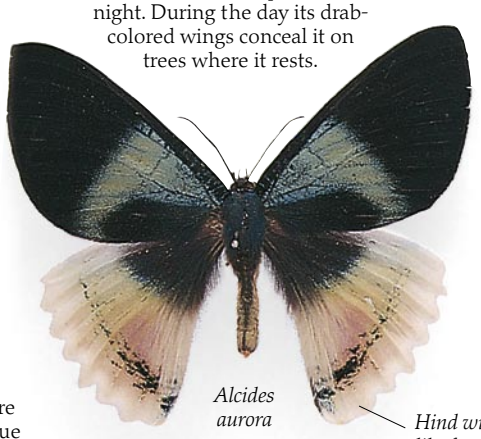
OLD LADY MOTH
This old lady moth (*Mormo maura*) from Europe flies at night. During the day its drab-colored wings conceal it on trees where it rests.

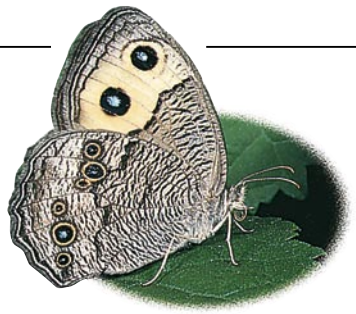
END OF A TAIL
The eyespots on the wings of this African moon moth (*Argema mimosae*) probably divert predators away from the delicate body. Similarly, the long tails will break off if the moth is attacked. In the light the green color quickly fades. Zulus are said to have used the silvery cocoons of this African species as ankle decorations.

Long tails will break off if caught



URANIID MOTHS
The uraniid moths are found only in the tropics, where they are often confused with butterflies. Many, like the Madagascan sunset moth (*Chrysiridia ripheus*), are day-flying, and several have been known to migrate long distances. The brilliant iridescent colors on the wings are produced by scales that catch the light as it flies. The blue and white species (*Alcides aurora*) comes from New Guinea and has fanlike hind wings.





BUTTERFLY WINGS
Butterflies rest with their wings folded together above their back.

Underside

Upper side

COME IN, NUMBER 89!
These two South American 89 butterflies (*Diaethria marchalii*) are identical – the left one shows the underside of the right one. A bird chasing the bright, blue spots on the wings will lose sight of them as soon as the butterfly settles and folds its wings.

Scent scales

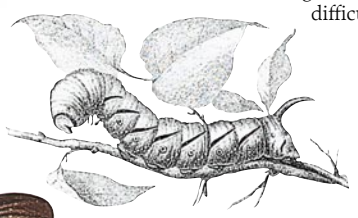
PERFUME FOR THE LADY
This colorful South American butterfly (*Agrias claudina sardanapalus*) feeds on rotting fruit. The males have bright yellow scent scales on the inside of the hind wings, which help to attract the females.

PUPAE
When a caterpillar has eaten enough, it turns into a pupa. As soon as this splits open, the adult emerges.

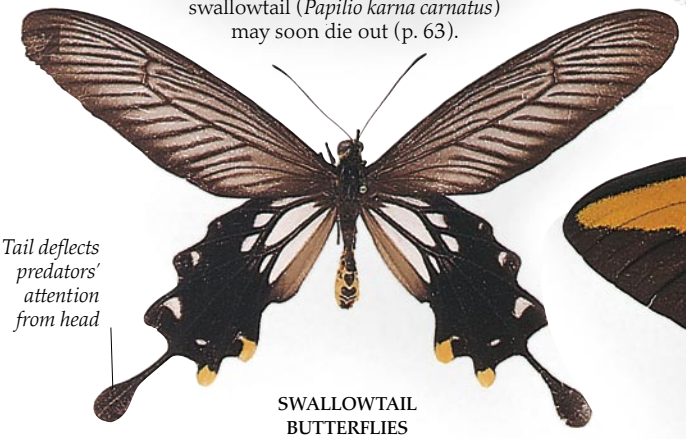
UNDER THREAT
The destruction of forests in Indonesia means this glass swallowtail (*Papilio karna carnatus*) may soon die out (p. 63).

Very few scales make wings clear

A SEE-THROUGH CHARACTER
Some butterflies and moths, like this South American species (*Cithaerias esmeralda*), have see-through wings, making them difficult targets for predators.



CATERPILLARS
The eggs of butterflies and moths hatch into caterpillars.



Tail deflects predators' attention from head

SWALLOWTAIL BUTTERFLIES
The swallowtails, some of the most beautiful butterflies in the world, get their name from their peculiarly extended hind wings, which often look like the forked tail of a swallow. Because of its unusually clubbed hind wings, this common clubtail butterfly (*Pachliopta coon coon*) flies rather haphazardly and is often difficult to catch.

Male bird-wing butterfly

Abdomen

Metallic fleck

METALMARKS
These butterflies often have metallic flecks on their wings. The six tails of this species (*Helicopis cupido*) help confuse predators.

BETTER RED THAN DEAD
The deep red of this red glider butterfly (*Cymothoe coccinata*) is probably difficult to see in the colorful West African tropical forest where it lives. The underside is brown like a dead leaf.

BIRD-WING BUTTERFLIES
The name of this species, *Ornithoptera croesus*, refers to the golden colors of the male. The female is one of the largest butterflies in the world and spends most of her life high in the trees. The future of many bird-wing species is threatened because the forest in which they live is gradually being cut down (p. 63).

Female bird-wing butterfly

Bugs

WHO NEEDS MEN!
Many aphids, like the one shown above, bear live young and can reproduce by "parthenogenesis" – without males.

THE WORD "BUG" is used loosely to describe any crawling insect. But bugs are a special group of insects with a long, jointed feeding tube specially adapted to piercing and sucking. Bugs include water boatmen and water striders (pp. 48–49), which suck the juices from other insects in ponds; plant-sucking aphids, scale insects, exotic seed bugs, and lantern flies; and bloodsucking bedbugs and assassin bugs, some of which spread dangerous diseases in humans. The front wings of many bugs are hard and horny at the base with thin, overlapping tips that cover and protect the delicate, membranous hind wings. Many plant-sucking bugs have entirely membranous front wings. All bugs undergo incomplete metamorphosis (pp. 26–29), and the little bugs look very similar to their parents, except that they are smaller and have no wings.

HISSING ASSASSIN
Assassin bugs, like this species (*Rhinocoris alluaudi*), can produce hissing sounds by rasping their curved feeding tube, or rostrum, against a filelike structure under the body.

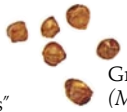
Locris adult

IT'S FROTHY, MAN
The froth "cuckoo spit" is produced by young plant-feeding froghoppers to protect them from drying out and possibly from being eaten.

SPITTING WITH RAIN *above left*
This adult African froghopper (*Locris* species) produces so much froth in the big trees where it lives that the froth falls to the ground like rain.

LEAFHOPPERS
This leafhopper (*Graphocephala fennahi*) feeds on rhododendron leaves. Other leafhopper species, usually green in color, damage the leaves of many plants including roses and cotton plants.

GROUND PEARLS
Many bugs are wingless and barely look like insects. These "ground pearls" are the hard skins of a group of bugs that feed on plant roots.



Ground pearls (*Margarodes formicarum*)

Bedbugs (enlarged)

Bedbug (natural size)

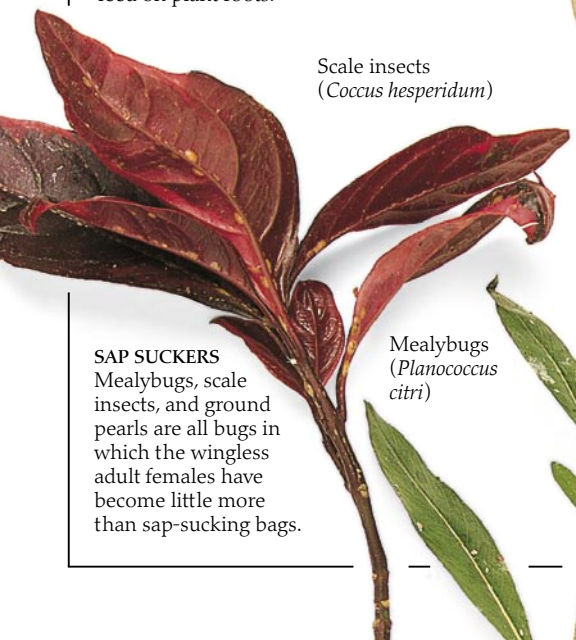
NIGHTTIME PESTS
The bedbug (*Cimex lectularis*) belongs to a small family of bloodsucking bugs, most of which live in the roosts and nests of bats and birds. They all feed on blood, and can survive without food for several months. They reproduce fastest in warm conditions, such as houses with warm bedrooms.

Thasus acutangulus

Ceratocoris horni

Hemikyptha marginata

UNUSUAL PLANT FEEDERS
The reason for the strange shapes and variety of sizes of many plant-feeding bugs often remains a complete mystery. Some have unusual legs, like the spiny-legged bug on the left (*Thasus acutangulus*), and others have strange shapes (*Hemikyptha marginata*) or horns (*Ceratocoris horni*).



Scale insects (*Coccus hesperidum*)

Mealybugs (*Planococcus citri*)

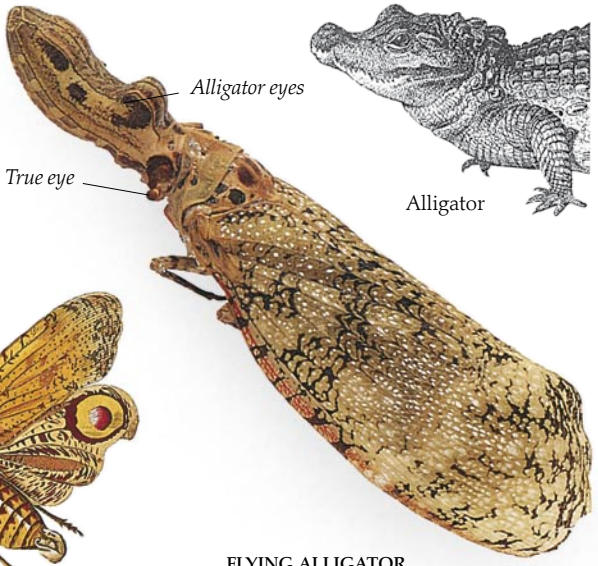
SAP SUCKERS
Mealybugs, scale insects, and ground pearls are all bugs in which the wingless adult females have become little more than sap-sucking bags.

SERENADING CICADAS
Cicadas, like this Indian species (*Angamiana aetherea*), have been famous throughout history for the songs the males use to attract females. The nymphs (pp. 26–27) live underground, sucking sap from plant roots. In North America one species takes 17 years to become adult. Whole populations of adults emerge at the same time, crawl up trees, and sing for a few weeks.

Assassin bug (*Centraspis* species)

Assassin bug (*Gardena melanarthrum*)

DEADLY ASSASSINS
Assassin bugs are predators. This species (*Gardena melanarthrum*) is believed to use its long, slender legs to pick food off spiders' webs. The stoutly built species *Centraspis* probably attacks more mobile prey such as millipedes. One group of assassin bugs, the triatoma, includes species that carry Chagas' disease in South America.

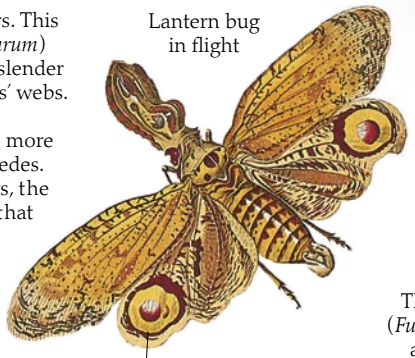


Alligator eyes

True eye

Alligator

Lantern bug in flight



Eyespots probably deter predators

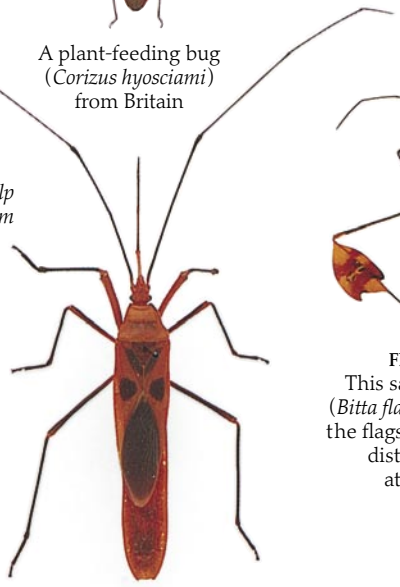
FLYING ALLIGATOR
The front of the head of this lantern bug (*Fulgora servillei*) is expanded and looks like an alligator head, complete with teeth, nostrils, and eyes. The true eyes and antennae are low down at the back of the head. The bug lives in trees and is hard to see when sitting on branches. Despite rumors, the "lantern" at the front of the head does not light up at night.

Assassin bug (*Platymeris biguttata*) feeding on a cockroach

Broad legs help bug swim

Wings overlap

A plant-feeding bug (*Corizus hyosciami*) from Britain



Flags on hind legs are probably waved gently, so a predator will attack these, rather than the body

FLYING THE FLAG
This sap-feeding coreid bug (*Bitta flavolineata*) gently waves the flags on its legs, probably to distract predators from attacking the body.

Shield hides wings

Runibia decorata

Calliphara excellens

Adult shield bug (*Pycanum rubens*)

Young shield bugs look like tiny adults

Chrysocoris sellatus

TASTY WATER BUGS
Giant waterbugs (*Lethocerus grandis*), or toe biters, are common throughout the tropics. They live underwater and catch snails and even small frogs and fish for food. They are specially imported into California to give a particular flavor to some Chinese food.

TUBULAR FEEDING
In life a bug's feeding tube usually points backward under the body, but in this pinned specimen (*Lohita grandis*) it is pointing forward, making it easier to see. This bug feeds on seeds of cotton and hibiscus.

SHIELDING HER YOUNG
Shield bugs vary in color, shape, and size. In some species the female shields her eggs and young by sitting over or with them. Many species are brightly colored such as the two on the right of this group of four, in which the wings are hidden beneath a huge shield that covers the hind part of the body.

FLASH COLORS
Many fulgorid bugs have brightly colored hind wings and curious heads, like this Central American species (*Phrictus quinquepartitus*) and the lantern bug shown above. The color is probably flashed to startle predators (p. 47).

CHANGE OF DIET
Fragile derbid bugs like this mothlike species (*Derbe longitudinalis*) have a curious lifestyle; the young bugs feed on fungus but the adults can be plant pests.

The patterns and shapes of shield bugs resemble tribal shields, like this one used by the Masai in Africa

Wasps, bees, and ants

WASPS, BEES, ANTS, and their relatives comprise one of the largest groups of insects in the world. Today there are about 200,000 known species, but many more are constantly being discovered. Apart from the sawflies, all wasps, bees, and ants are easy to recognize by the narrow "waist." At the end of the abdomen of many female wasps and bees, the egg-laying apparatus, or ovipositor, is modified as a painful sting for use in self-defense (pp. 46–47). Several species of wasps, bees, and ants are "social" insects, meaning that many of them live together looking after their brood communally in a nest they build themselves (pp. 52–55). Since the earliest times, humans have kept bees for honey (pp. 58–59) and been fascinated by the complex societies of ants (pp. 56–57), but comparatively little is known of wasps, despite their importance to us. Many wasps spend their lives killing the grubs and caterpillars of insects that damage and destroy crops. Together with bees they are also important pollinators, ensuring that our fruit and vegetable crops flourish.

Male

TREE WASPS
In summer tree wasp workers (*Dolichovespula sylvestris*) help farmers by killing caterpillars to feed their grubs. In autumn, when there are no more grubs to feed, they become household pests searching for sugary foods.

Queen

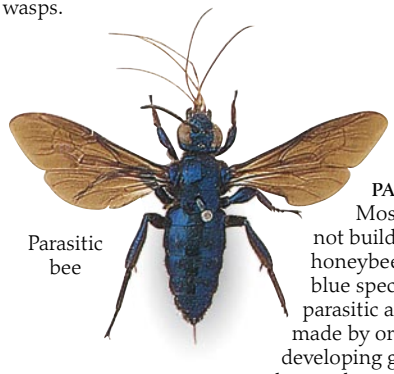
Worker

Sting injects poison into victim causing a painful wound

STING
This is a highly magnified photograph of a sting – a modification of the egg-laying apparatus of many bees and wasps.

Hornet

HORNETS
The hornet (*Vespa crabro*) is the largest wasp in Europe, with a very painful sting. Like the tree wasps the queen overwinters and begins her nest in spring. Her first eggs hatch into female workers, which take over the tasks of expanding the nest and providing food for the grubs and for the queen herself, who goes into full-time egg production. Males are produced later along with the next season's queens.

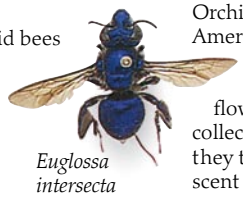


Parasitic bee

PARASITIC BEE
Most bees are not social and do not build large nests like the honeybee (pp. 58–59). This large blue species (*Aglae caerulea*) is parasitic and lays its eggs in the cells made by orchid bees (below); the developing grub then eats the orchid bee grub as well as its food store.

Euglossa assarophora

Orchid bees



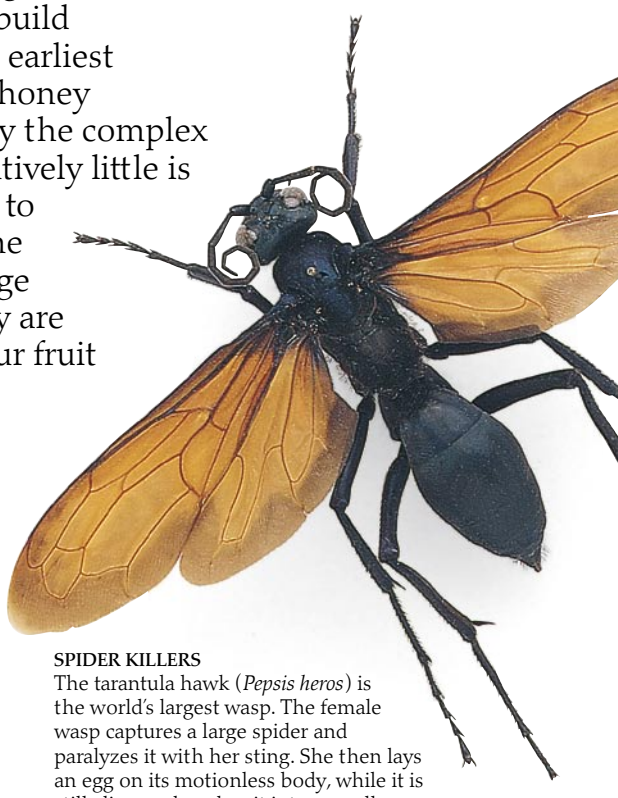
Euglossa intersecta

PERFUME MAKERS
Orchid bees from South America are so-called because the males visit orchid flowers, where they collect a substance that they then convert into a scent to attract females.

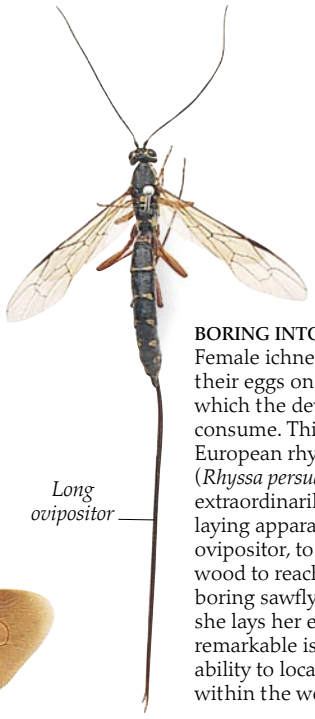
BIGGEST BEE
This Asian carpenter bee (*Xylocopa laticeps*) is the largest bee in the world. It makes nests in the tunnels it digs in rotting wood. The males often defend their territories by buzzing around intruders.

BUMBLEBEES
Like the honeybees, bumblebees are social insects and live in groups. They are found all in temperate areas all over the north. This mountain bumblebee (*Bombus monticola*) nests in a burrow in the ground, often close to bilberry bushes.

WASP WAIST
In the late 19th century tiny "wasp waists" were the height of female fashion.

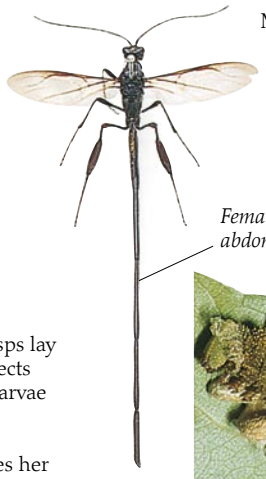


SPIDER KILLERS
The tarantula hawk (*Pepsis heros*) is the world's largest wasp. The female wasp captures a large spider and paralyzes it with her sting. She then lays an egg on its motionless body, while it is still alive, and pushes it into a small burrow. When the egg hatches, the developing grub has a ready supply of fresh spider meat on which to feed.



Long ovipositor

BORING INTO TREES
Female ichneumon wasps lay their eggs on other insects which the developing larvae consume. This female European rhyssa wasp (*Rhyssa persuasoria*) uses her extraordinarily long egg-laying apparatus, or ovipositor, to drill through wood to reach a live, wood-boring sawfly grub, on which she lays her egg. Particularly remarkable is this wasp's ability to locate the grub within the wood.



Male

Female has long abdomen for laying eggs

CONSUMED FROM WITHIN
A new generation of parasitic wasps will soon emerge from the cocoons on this hawk moth caterpillar.

LONG ABDOMEN *left*
This female American wasp (*Pelecinus polyturator*) has a long, thin abdomen to reach into rotting wood and lay her eggs on beetle grubs. The male looks quite different.

Cocoons of Apanteles *wasp*

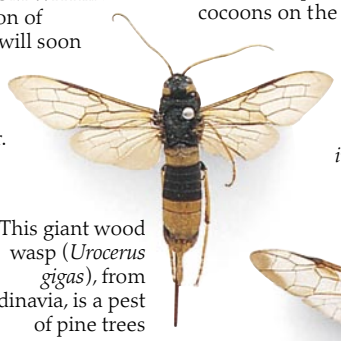
PARASITIC WASPS
Many braconid wasps can develop inside a single caterpillar. The African species (*Apanteles gratiosus*) lays its eggs on hairy caterpillars. After the tiny grubs have eaten the inside of the caterpillar, they form cocoons on the surface.

Amblyteles wasp

Chrysalis

FUSSY FEEDERS
Many wasp species are quite specific about where they lay their eggs and where their grubs will feed. This European ichneumon wasp (*Amblyteles armatorius*) will only develop inside the chrysalis of one particular species of moth.

BUTTERFLY HUNTER
This handsome wasp (*Editha magnifica*) from South America attacks butterflies as they sit in groups on the ground. The wasp stings the butterflies one at a time, bites off their wings, and stores the bodies in a burrow in which it lays its eggs. The developing grubs feed on the butterflies' bodies until they are large enough to pupate.



This giant wood wasp (*Urocerus gigas*), from Scandinavia, is a pest of pine trees

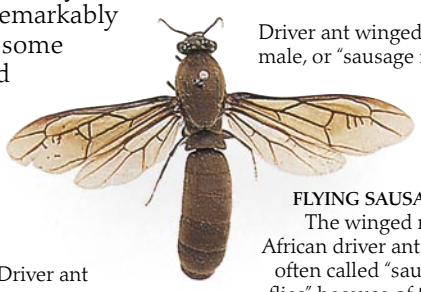
The larvae of this African wasp (*Chalinus imperialis*) feed on beetle grubs in wood

The grub of this species (*Cimbex femoratus*), from Europe, feeds on birch leaves

SAWFLIES
The sawflies differ from other wasps in not having a typical "wasp waist." They owe their name to the sawlike blades of the egg-laying apparatus, or ovipositor, which the females use to insert eggs into plant tissues. The grubs, which often look like moth caterpillars, feed on plants, sometimes forming galls or boring into stems. Unlike most other insect groups, sawflies are much less common in the tropics than in temperate parts of the world.

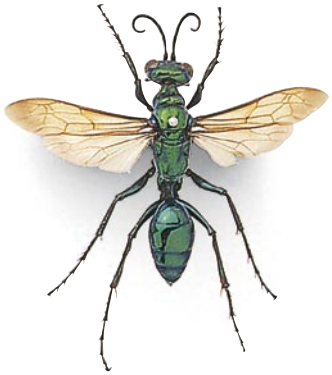
Ants

Ants live in colonies in which there may be as many as 100,000 individuals (pp. 56–57). They have remarkably strong jaws and can give a painful nip. When some species bite, they are able to squirt formic acid from the end of their abdomen into the wound – making it doubly painful.



Driver ant winged male, or "sausage fly"

FLYING SAUSAGES
The winged male African driver ants are often called "sausage flies" because of their long, fat sausage-like bodies.



HUNTING WASPS
This brilliant wasp (*Chlorion lobatum*) from India and Borneo catches and stings crickets in their burrows or on the soil surface. The wasp egg hatches, and the grub feeds on the cricket's body.

Dinoponera grandis

LARGEST ANT
Dinoponera ants from South America have the largest known workers. These live in small colonies but, unlike many ants, they are solitary hunters.

Driver ant workers

Driver ant queen

DRIVER ANTS
These African driver ants (*Dorylus nigricans*) form large colonies but they do not have permanent nests. They set up temporary camps, or bivouacs, while the queen lays eggs; then they move on, carrying with them the developing grubs. Periodically the ants fan out and eat everything in their path.

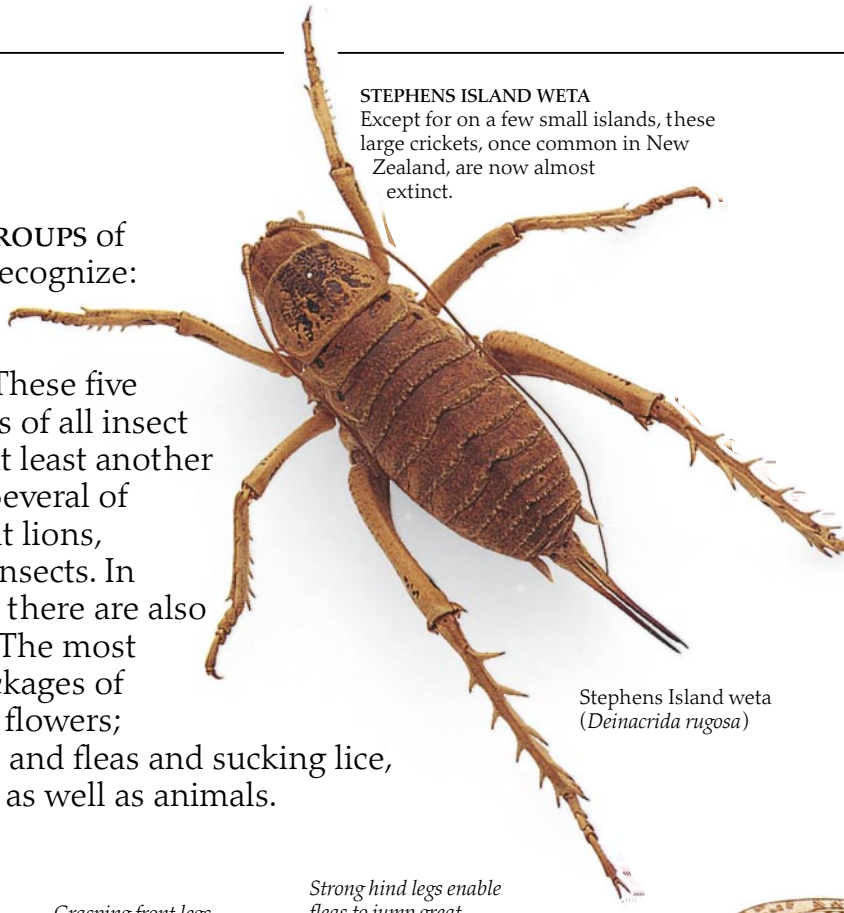
Ants communicate by touch and smell

Other insects

JIMINY CRICKET
Walt Disney's Jiminy Cricket must be the only four-legged cricket in the world!

THERE ARE FIVE MAIN GROUPS of insects which we can all recognize: beetles, bugs, flies, wasps (including ants and bees), and butterflies and moths. These five include about three quarters of all insect species. However, there are at least another 15 similar but smaller groups. Several of these are shown here: cockroaches, earwigs, ant lions, dragonflies, mantises, grasshoppers, and stick insects. In addition to these groups of large insects there are also several groups of much smaller species. The most common are book lice, which live in packages of dried food; thrips, which can damage flowers; chewing lice, which live on birds; and fleas and sucking lice, which irritate people as well as animals.

STEPHENS ISLAND WETA
Except for on a few small islands, these large crickets, once common in New Zealand, are now almost extinct.



Stephens Island weta (*Deinacrida rugosa*)

Slender, jointed leg

LIVING STICKS
Stick insects may be green or brown and are usually long and thin with slender legs and antennae. During the day they avoid attack by predators by hanging almost motionless in shrubs and trees where they look like just another twig (p. 45). At night they move around more and feed on leaves. The males of many species have wings; the females are often wingless.

Wing

Eurycantha calcarata from Papua New Guinea

Antenna

Anchiole maculata from New Guinea

Spines on legs protect against attack

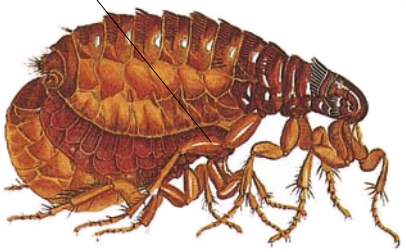
Grasping front legs make the insect look as though it is praying

Praying mantis (*Sibylla pretiosa*) from Africa

PRAYING FOR FOOD
Praying mantises are often slender, like stick insects. Many species are camouflaged in bright greens or dull browns (p. 45). They feed on other insects, which they grasp in their specially adapted front legs.

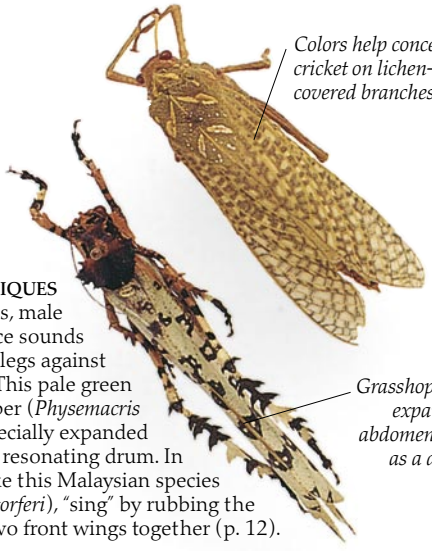
Strong hind legs enable fleas to jump great distances

Fleas



FLEAS
Adult fleas are bloodsuckers, each kind of flea preferring the blood of one kind of animal or bird. An animal flea will attack a human only if it is very hungry. The tiny white flea larvae do not feed on blood, but live on decaying material in nests and carpets. The adults can often survive without food for a long time, but as soon as a possible meal passes by, they quickly jump aboard.

Colors help conceal cricket on lichen-covered branches



Grasshopper's expanded abdomen acts as a drum

SINGING TECHNIQUES
To attract females, male grasshoppers produce sounds by rubbing their hind legs against the hard front wings. This pale green African grasshopper (*Physemacris variolosa*) has a specially expanded abdomen to act as a resonating drum. In contrast crickets, like this Malaysian species (*Trachyzulpha fruhstorferi*), "sing" by rubbing the two front wings together (p. 12).

In life, most damselflies hold their wings together over their body when they are resting, unlike dragonflies which rest with their wings open

Biggest damselfly

DRAGONFLIES
This Indonesian species (*Nannophya pygmaea*) is the smallest dragonfly known.

DAMSELFLIES
Most damselflies are small, delicate insects, often with brightly colored bodies. This Costa Rican species (*Megaloprepus coerulatus*) is the largest damselfly in the world. Its nymphs (pp. 26–27) live in the water that collects in rotting tree holes. Dragonfly and damselfly nymphs always live in water, where they feed on other insects.

Streamer-like hind wings trail behind and draw predator's attention away from the vulnerable parts of the body

THREAD LACEWINGS
This lacewing (*Nemoptera sinuata*) is related to the ant lion. The young live in the dust of cave mouths and rocky overhangs in the Mediterranean.

Palpares libelluloides

Jaws

Ant lion larva

ANT LIONS
Ant lions are the larvae of a delicate four-winged insect, similar to a damselfly. They dig funnel-shaped pits in loose sand and lie in wait at the bottom with only their large jaws sticking out. When an ant tumbles into the pit the ant lion seizes it and sucks it to death. The adults of this Mediterranean species (*Palpares libelluloides*) are unusual because they fly during the day.

An ant lion in its pit

HEAD LOUSE
This monster is a human head louse, magnified many times. Lice feed on dead skin and grip the hair with specially adapted claws.

Human head louse

FRINGED LARVAE
The adults of this brightly colored western Mediterranean species (*Libelloides coccajus*) are strong fliers. The flat, fringed larvae are similar to ant lions but do not make pits.

Megaloblatta longipennis is the largest flying cockroach

COCKROACHES
These ancient insects live just about everywhere and eat almost anything. Some species can become pests in the home where their flattened bodies enable them to hide in narrow crevices, making them difficult to get rid of.

Many kinds of cockroach, like this shiny green species (*Polyzosteria viridissima*), from Australia, do not develop wings

EARWIGS IN YOUR EAR
This earwig (*Titanolabis colossea*) from Australia is the largest in the world. People once wrongly believed that earwigs entered people's ears and killed them. Earwigs eat living and dead plants and animals and have short, dark front wings, under which the longer, see-through hind wings are folded.

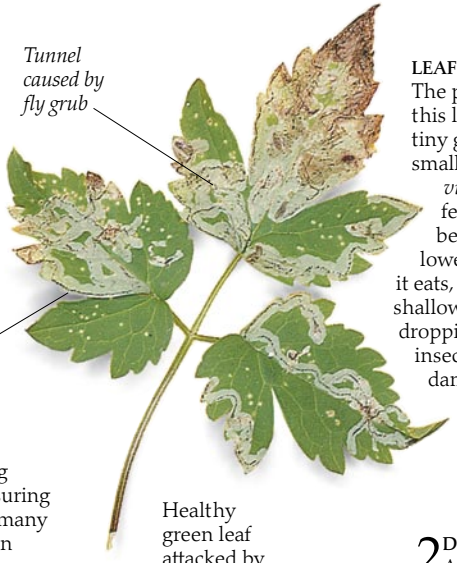
Biggest earwig

Living with plants

FLOWERS
Many flowers rely on insects for pollination.

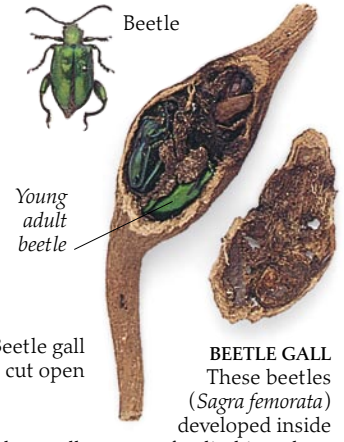
In the coal forests that covered the Earth over 300 million years ago, there were very few kinds of insects. Dragonflies flew around the swampy areas (pp. 48–49), but butterflies, bugs, and beetles had scarcely evolved. Nor had the flowering plants and trees that are now so common throughout the world. The evolution of flowers and the increased variety of plants produced new opportunities that encouraged the evolution of many new species of insect. Some of these insects evolved as pollinators, others specialized in feeding on the rich food in buds and seeds; yet others fed on the many different types of leaves and fruit that gradually became available. The increase in the numbers of plant and insect species seems to have gone hand in hand. Equally important was the evolution of all the insects that live on dead plants and so restore nutrients to the soil – not to mention the wide range of predatory insects that feed on the plant eaters.

NAIL GALLS
In Australia, eucalyptus trees often produce galls when they are fed on by a group of unusual mealybugs (p. 36). This gall is short and round with four very long horns on top. When mature, the wingless female inside is fertilized by a winged male through a tiny hole between the horns. Males develop in nail-like galls that often grow on a female gall.



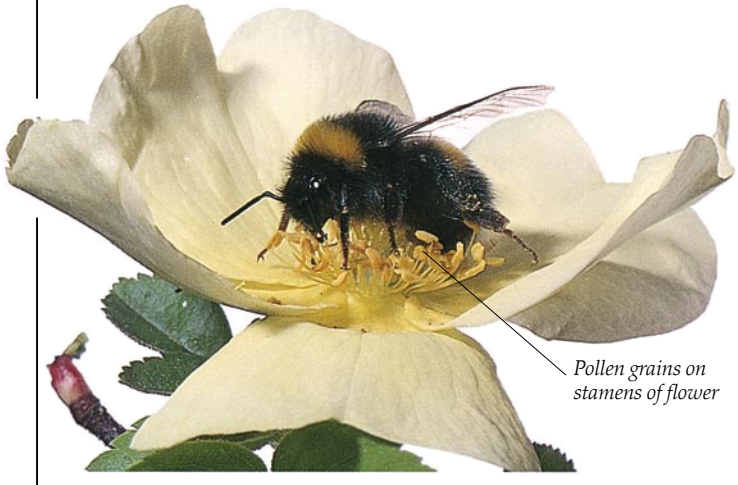
LEAF MINERS
The pale, twisting trails on this leaf are caused by the tiny grubs of a species of small fly (*Phytomyza vitalbiae*). Each grub feeds on the living tissue between the upper and lower surface of the leaf. As it eats, it tunnels out its own shallow mine, leaving a trail of droppings behind it. These insects cause noticeable damage to green leaves and can eventually kill a healthy plant.

Healthy green leaf attacked by leaf miners



BEETLE GALL
These beetles (*Sagra femorata*) developed inside the swollen stem of a climbing plant. The swelling started when an adult female beetle laid her eggs in the stem. As the beetle grubs grew, so did the swelling, until the grubs were ready to metamorphose (pp. 23-24) into adults.

1 A CLEAN BUMBLEBEE
Bees are essential to plants for carrying pollen from one flower to another, so ensuring that seeds are produced. For this reason, many flowers are brightly colored and scented in order to attract bees and other pollinating insects. The bumblebee, attracted by the sweet scent of the dog rose, lands to feed on pollen and sugary nectar.



2 DUSTED WITH GOLDEN POLLEN
As the bee sucks the nectar from the center of the dog rose using its long tongue, its hairy coat picks up grains of pollen from the stamens.

YEW TREE GALLS
The tiny flies known as gall midges feed on many types of plant. On yew trees they cause the buds to stop growing and produce a ball of many small leaves. Each gall contains a single fly grub (*Taxomyia taxi*), and the small leaves turn brown as the fly matures.

Normal yew shoot

Yew gall

Yew gall

MARBLES ON OAK TREES
Oak marble galls are often common on oak trees in Europe. They are produced by the parthenogenetic females of a small gall wasp (*Andricus kollari*). The complete life-cycle, involving males and females, is still not fully understood.

Oak marble gall

CHERRIES ON OAK TREES
When a small gall wasp (*Cynips quercusfolii*) lays an egg in the vein of an oak leaf, a cherry gall is formed. Each gall grows around the developing grub, supplying it with food and protection.

Young gall is white

PISTACHIO GALLS
These tubular galls are produced by pistachio trees around colonies of a particular aphid (*Baizongia pistaciae*) in the Mediterranean region. Like many other aphids, this species has two separate life-cycles, each on different plants.

Pistachio gall

Leaf

ROSE GALLS
Rose galls, or bedeguars (meaning "wind rose"), are caused when a tiny gall wasp (*Diplolepis rosae*) lays her eggs on rosebuds in spring. Each gall contains many wasp grubs in separate chambers.

WIND ROSES
Hundreds of years ago in Persia, where modern roses came from, people believed that these pinkish, mosslike galls came on the wind and called them "wind roses."

Currant gall cut in half

Gall

Grub inside gall

Cherry galls on oak leaf

Young grub

Mature grub

CHERRY GALL
Only female gall wasps (*Cynips quercusfolii*) are produced in cherry galls. In winter these females lay eggs on oak tree buds, and in spring the grubs from these eggs give rise to males and females. These mate, and the females lay eggs on oak tree leaves to produce cherry galls again.

Silk strands

SAFE AND SOUND
Some caterpillars roll up a leaf, fix it with silk, then pupate safely hidden inside.

OAK CURRANTS
Female gall wasps (*Neuroterus quercusbaccarum*) lay eggs on oak tree catkins in spring, to produce a currant gall around each single wasp grub. These quickly develop to produce adult males and females. In summer, after mating, the females lay eggs on oak leaves. The oak tree produces a small, flat, reddish cushion called a spangle gall around each developing egg. The spangle gall falls to the ground, and in spring females emerge from this to lay eggs that develop parthenogenetically (p. 36).

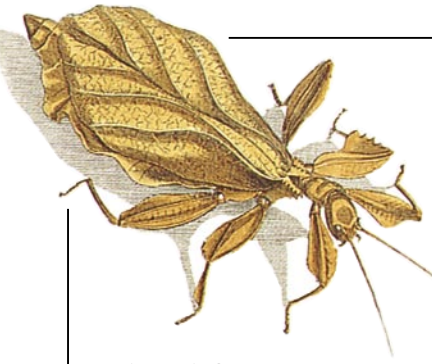
3 FILL YOUR BASKETS
As the bumblebee collects more and more pollen grains, it combs them from its body, packs them into the hairy pollen baskets on its hind legs, and then flies off to its nest. In domesticated honeybees (pp. 58–59), this pollen and nectar is stored in the hive as honey.

Pollen packed into tiny baskets on hind legs

OAK APPLES
Oak apple galls are produced when a wingless female gall wasp (*Biorhiza pallida*) lays her eggs on an oak leaf bud. The group of small gall wasp grubs that develop by parthenogenesis (p. 36) give rise to winged males and females, in separate galls; these mate and the females lay eggs on the roots of the trees. Females produced on the roots are wingless and have to climb all the way up the oak trees to lay their eggs on the buds and so produce next year's oak apples.

Oak apple

Hide-and-seek



LEAF ME ALONE!
Some stick insects protect themselves against predators by looking like leaves. The wings are leaflike, and the legs have flattened plates along them to break up their outline.

INSECTS ARE EATEN by many other animals. Without them, bats would not be able to live, and half the species of birds in the world would probably starve. Frogs, lizards, and alligators include insects in their diet, as do shrews, foxes, and monkeys. Many insects themselves hunt and kill other insects for food, and in some parts of the world even people eat insects. With this range of predators it is not surprising that many insect species have developed unusual colors, patterns, and shapes as ways of pretending they are something they are not. Some insects have oddly patterned or mottled wings to match the color of the bark on which they live. Other insects, like the leaf and stick insects, are so well disguised as leaves and twigs that they are ignored by would-be predators. Birds and lizards see such a protectively colored insect not as an insect but as the leaf it is imitating and leave it alone.

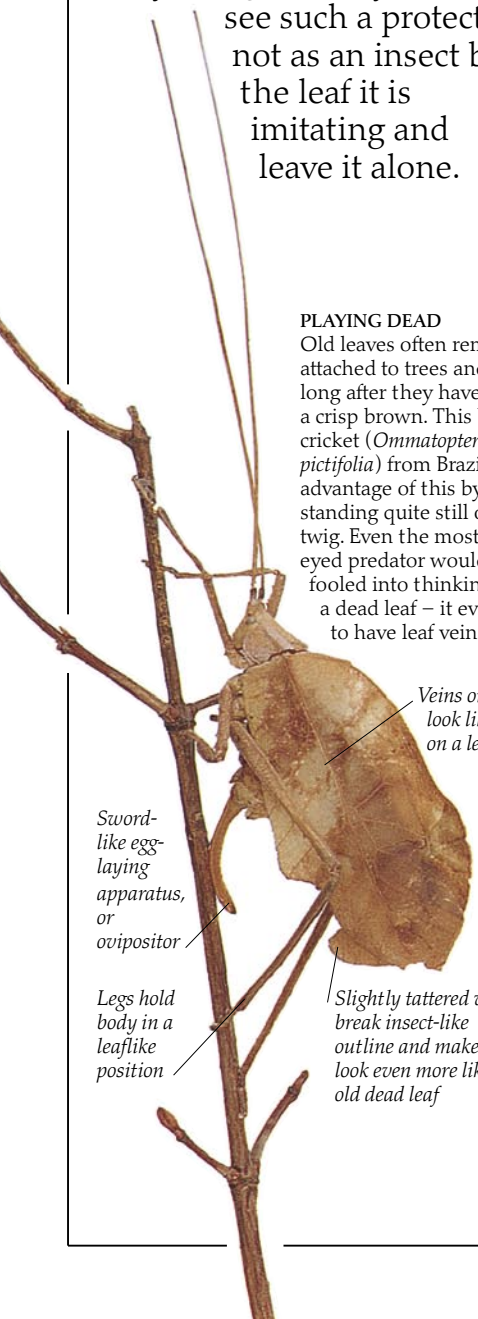
Flatid bug on bark

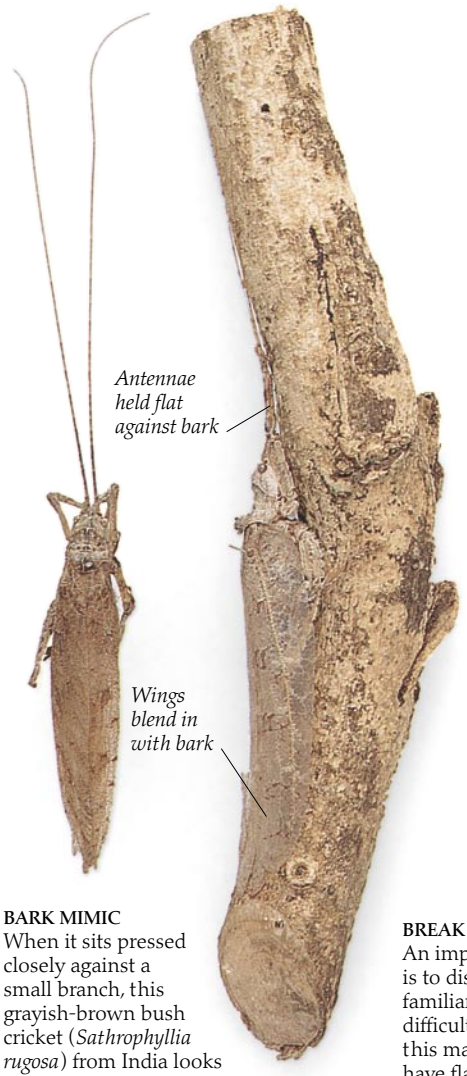
Flatid bug

BARK BUGS
Although there are many hundreds of species of flatid bug in the tropics, surprisingly little is known about the lifestyle of any of them. This Central American species (*Flatoides dealbatus*) apparently sits on the bark of trees, where its light brown coloring makes it difficult to see. Some species are see-through, or translucent, and others have mottled brown and gray patches to conceal them on lichen-covered trees where they rest.

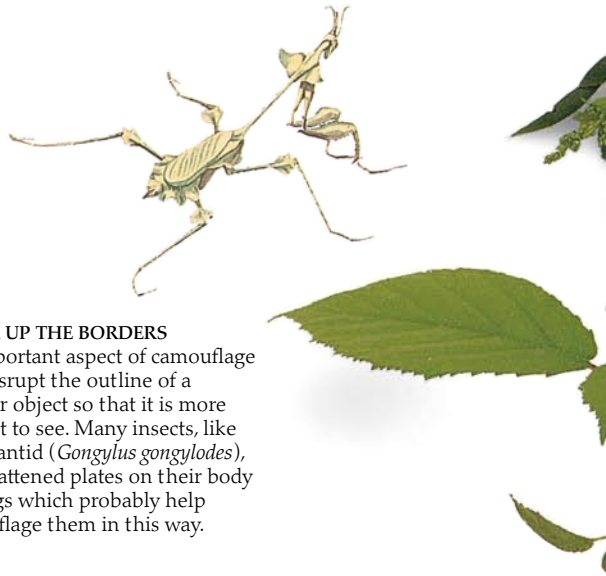
CLICK BEETLE ON BARK
The whitish patches on the body of this click beetle (*Alaus* species) help it blend in with the patch of lichen on the bark of the tree where it was photographed in Nigeria (West Africa).

PLAYING DEAD
Old leaves often remain attached to trees and bushes long after they have dried to a crisp brown. This bush cricket (*Ommatoptera pictifolia*) from Brazil takes advantage of this by standing quite still on a twig. Even the most bright-eyed predator would be fooled into thinking it was a dead leaf – it even seems to have leaf veins.





BARK MIMIC
When it sits pressed closely against a small branch, this grayish-brown bush cricket (*Sathrophyllia rugosa*) from India looks just like a piece of bark. The wings of the insect merge with the roughness of the bark, and the cricket completely vanishes.



BREAK UP THE BORDERS
An important aspect of camouflage is to disrupt the outline of a familiar object so that it is more difficult to see. Many insects, like this mantid (*Gongylus gongylodes*), have flattened plates on their body and legs which probably help camouflage them in this way.

Lichen is a kind of plant that grows on tree trunks and on twigs

Mottled gray and white patches break outline of insect

Beetle

Beetle

Beetle

Beetle

LICHEN LONGHORNS
Longhorn beetles often mimic their surroundings or other insects (p. 46). This Madagascan species (*Lithinus nigrocristatus*) is remarkable for its ability to hide on lichen-covered twigs. It is almost impossible to see the four beetles hidden above.

Lichen

Bark

Moth's folded wings are the same color as the lichen on the bark

Merveille du jour moth out of camouflage

MERVEILLE DU JOUR MOTH
Many night-flying moths that spend their days resting on bark are well camouflaged against birds and lizards. Like the lichen longhorns, this merveille du jour moth (*Dichonia aprilina*) disappears from view in its natural habitat of lichen-covered trees. Out of camouflage it is much easier to spot.

CAMOUFLAGED STICKS
Live stick insects can be easy to overlook because when sitting quite still on leaves and twigs they are almost invisible. Occasionally some stick and leaf insects will gently sway from side to side, so all a predator sees is just another leaf or twig caught by the breeze. Even the eggs produced by female stick insects are similar in appearance to plant seeds.

Winged male of Macleay's specter (Extatosoma tiaratum) *from Australia*

Spiny green nymph (Eurycantha calcarata) *(p. 40) from Papua New Guinea*

Adult female green Indian stick insect (Carausius morosus)

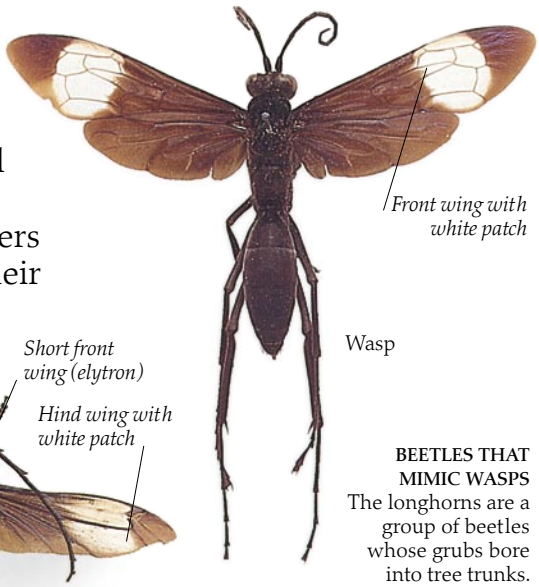
Short-winged female of Macleay's specter (Extatosoma tiaratum)

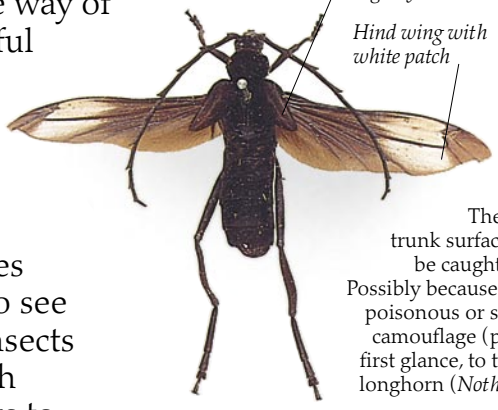
Green, sticklike legs

Adult female pink-winged stick insect (Sipyloidea sipylus) *from Indonesia*

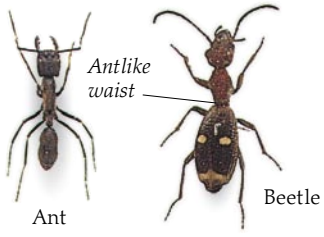
How to avoid being eaten

AVOIDING BEING EATEN by other animals is the key to survival for many insect species. Some insects do this by camouflage, blending in perfectly with their surroundings (pp. 44–45). Others have developed different ways of protecting themselves from their many enemies. After a nasty experience, hungry predators soon learn to leave poisonous or unpleasant-tasting insects alone, and will keep well out of the way of anything they know can give them a painful sting or bite. Some quite harmless insects take advantage of this by looking and behaving like poisonous or stinging creatures so that predators will mistake them for the real thing and will not even attempt to eat them. In some cases this mimicry is so good that it is difficult to see which insect is mimicking which. Other insects protect themselves in different ways – with clearly visible spines; bright, flashing colors to shock and surprise; strong, biting jaws; and powerful, kicking legs.



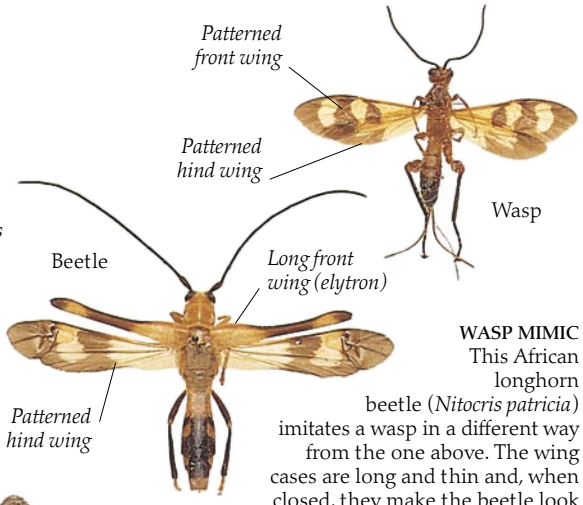


BEETLES THAT MIMIC WASPS
The longhorns are a group of beetles whose grubs bore into tree trunks. The adults mate and lay their eggs on the trunk surface. At such times they are very likely to be caught and eaten by predators, such as birds. Possibly because of this, many longhorn beetles mimic poisonous or stinging insects, or develop remarkable camouflage (pp. 44–45). It is almost impossible, at a first glance, to tell the difference between this Borneo longhorn (*Nothopeus fasciatapennis*) and the wasp it is mimicking (*Hemipepsis speculifer*).

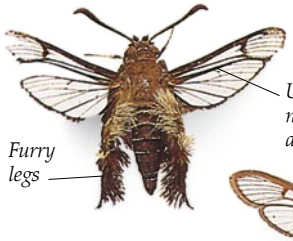


ANT MIMIC
Many small insects benefit from looking like and running around like ants. This harmless African ground beetle (*Eccoptoptera cupricollis*) avoids being attacked by predators by looking remarkably like a velvet ant, which has a powerful, painful sting.

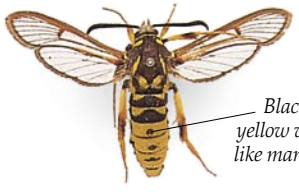
SPIDER MIMIC
Some insects mimic spiders. This curious New Guinea weevil (*Arachnopus gazella*) runs around on the bark of trees looking just like a small spider. Unlike a real spider (p. 9), it has six rather than eight legs.



WASP MIMIC
This African longhorn beetle (*Nitocris patricia*) imitates a wasp in a different way from the one above. The wing cases are long and thin and, when closed, they make the beetle look like it has a "wasp waist." The wasp it mimics (*Paracollyria* species) attacks beetle grubs in plant stems. The wasp and the longhorn probably fly together and rest on the same tree trunks.



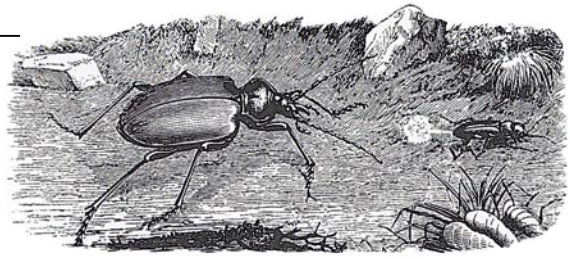
BEE-WARE!
One group of moths, the aegerids, often look like wasps, but when this species (*Melittia gloriosa*) holds its furry legs against its abdomen it looks like a large hairy bee. Predators leave it alone for fear of being stung.



HORNET MIMIC
Many insects, such as the flower-feeding hoverflies (p. 33), look like wasps. But this aegerid moth (*Sesia apiformis*) is a most remarkable mimic of the common hornet, or yellow-jacket (p. 38), recognized by predators for its painful sting.

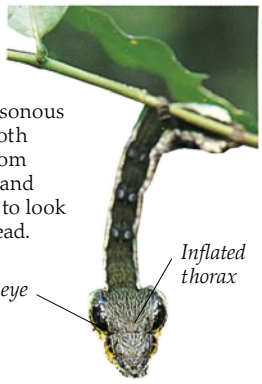
WARNING EYES
Various insects, like this fulgorid bug (*Fulgora laternaria*), have curious eyelike patterns on their hind wings. These are usually concealed when the bug is at rest. But when disturbed, the large "eyes" are flashed, giving the insect an opportunity to escape from its surprised predator. The bird possibly mistakes them for the eyes of one of its own enemies, such as a cat or a bird.

Eyespots look like the large staring eyes of a bird, like this eagle owl

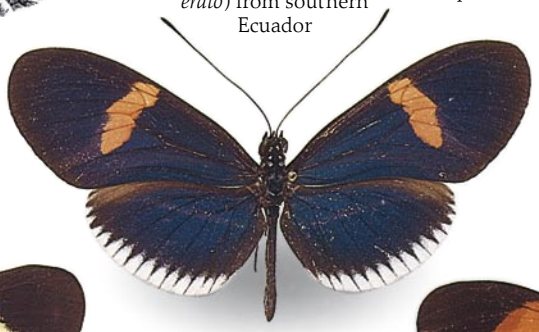


CHEMICAL GUN
When a bombardier beetle (*Brachinus crepitans*) is disturbed, it can mix two harmless chemicals at the tip of its abdomen to produce a sudden explosion that frightens away predators.

SNAKE IN THE GRASS
Rather than mimicking insects, some caterpillars have unusually large heads to trick predators into thinking they are small but very poisonous snakes. When alarmed, this hawkmoth caterpillar (*Leucorhampha ornatus*) from Brazil rears its head and inflates its thorax to look like a snake's head.



Small postman butterfly (*Heliconius erato*) from southern Ecuador



Small postman butterfly (*Heliconius erato*) from western Brazil

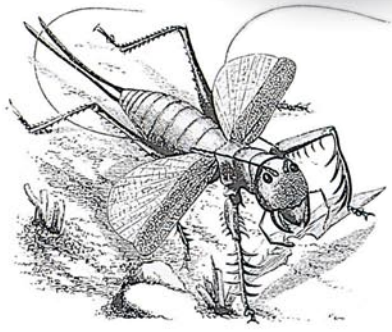
RINGS OF MIMICS
Some groups of butterflies, such as the heliconiids, feed, particularly as larvae, on rather poisonous plants. As a result the adult butterflies often taste unpleasant and are avoided by insect-eating birds. Different species may take advantage of this by mimicking each other's color patterns. These species may also vary in color from place to place. These six butterflies represent two species from three different parts of South America.

Small postman butterfly (*Heliconius erato*) from southern Brazil

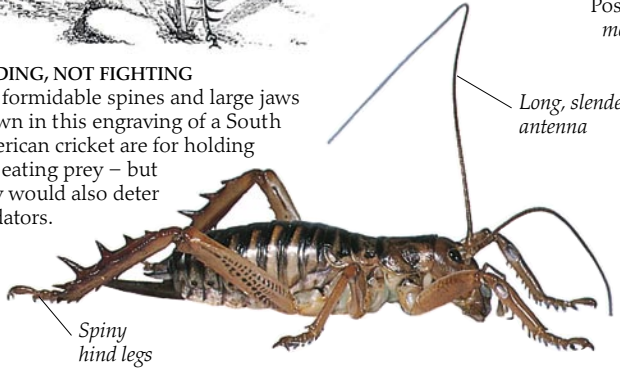
Postman butterfly (*Heliconius melpomene*) from western Brazil

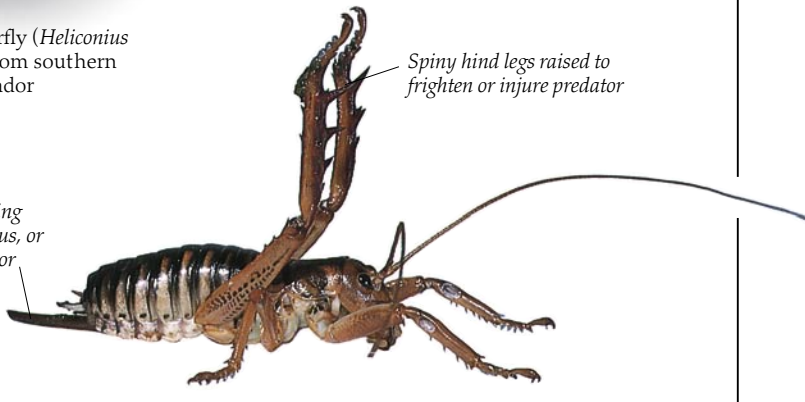
Postman butterfly (*Heliconius melpomene*) from southern Ecuador

Postman butterfly (*Heliconius melpomene*) from southern Brazil



FEEDING, NOT FIGHTING
The formidable spines and large jaws shown in this engraving of a South American cricket are for holding and eating prey – but they would also deter predators.





1 WARNING WETA
Because the wildlife in New Zealand developed without any mammals, one group of large crickets called weta (p. 40) filled the role of the ground-living predators, eating a diet similar to that of shrews. These enormous insects are now almost extinct except on small islands, since humans introduced rats into their habitat.

2 STICK 'EM UP!
When disturbed, this species (*Hemideina thoracica*) raises its hind legs into a threatening posture. The spines on the legs can cause a nasty wound when the insect kicks.

A watery life

Insects evolved on land. This is clear from their breathing system (pp. 6–7), which takes in air from the atmosphere. Water insects have therefore had to adapt and must either swim to the surface for air, or develop ways of extracting air from the water, like fish. Some insects, such as dragonflies and many true flies, take advantage of the food supplies in water for their feeding and growing phase – the larva or nymph – and become winged and independent of water in the adult phase. Other insects have adapted wholly to water and spend their entire life cycle there. The adults leave the water only when they need to fly to new areas.

Mayfly adult

SKATING
Pond skaters (*Gerris lacustris*) skim over the surface, feeding on drowning insects.

Prey is held in four front legs
Oarlike hind legs
Sucking mouthparts
Eye

SURFACE HUNTERS
Water boatmen (*Notonecta glauca*) are predatory bugs that swim upside down just beneath the surface, attacking and eating other insects that have fallen in. Water boatmen come to the surface to breathe. They push the tip of their abdomen above the surface, and store air under their wings, from where it can gradually be taken in through the spiracles (p. 7).

Silvery film of air around body
Hairs help bug swim
Pincer-like legs

SWIMMING SAUCERS
Saucer bugs (*Ilyocoris cimicoides*) have strong front legs for grasping their prey and can give a painful "bite" if handled.

Strong pincer-like front legs

SAUCER BUG
The silvery underside of a saucer bug is caused by a film of air, or plastron, trapped beneath tiny hairs. Oxygen diffuses directly into the plastron from the water.

GIANT WATER BUG
This giant water bug, shown smaller than life size, was drawn by Maria Merian (1700) in Surinam.

Air is stored beneath the wings
Fringes on legs propel beetle through water
Gills extract oxygen from water
Strong, grasping front legs
Segmented antenna
Sucker-like pads used in mating

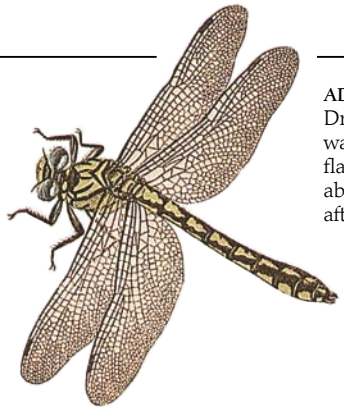
DIVING BEETLES
The great diving beetles (*Dytiscus marginalis*) are fierce predators of small fish and insects. They store air under their wings, like water boatmen, and occasionally fly from one pond to another.

PREDATORY DAMSEL
Damselfly nymphs (p. 26) breathe by means of three external gills at the tip of the abdomen.

CADDIS FLY LARVAE
The larvae of many caddis flies (*Limnephilus* species) spin a tube of silk onto which they stick small stones, sand, or pieces of plant to act as camouflage and protection.

Pieces of plant
Caddis fly larvae
Sticks and stones

WATER BEETLE PUPA
The larva of the great diving beetle crawls out of the pond and burrows into damp soil, where it pupates (pp. 24–25). After emerging, the young adult stays in the pupal cell for a few hours while the wing cases harden.



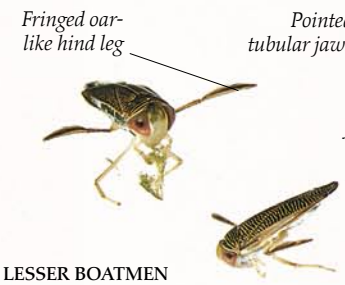
ADULT DRAGONFLY
Dragonflies are well worth watching. With their bright colors flashing in the sun, they hover above water, ready to dart away after the insects on which they feed.

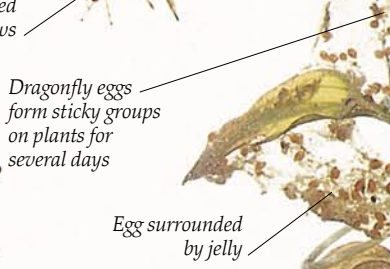
DRAGONFLIES EMERGING
When they are big enough, the wingless dragonfly nymphs crawl up stems and out of the water (pp. 26–29). They then split their nymphal skin to emerge as majestic winged adults (p. 41).

WATER SIPHONS
Mosquito larvae (*Culex* species) have no legs but can swim by wriggling sharply. They breathe by coming up to the surface and drawing in air through a special siphon at the tip of the abdomen.

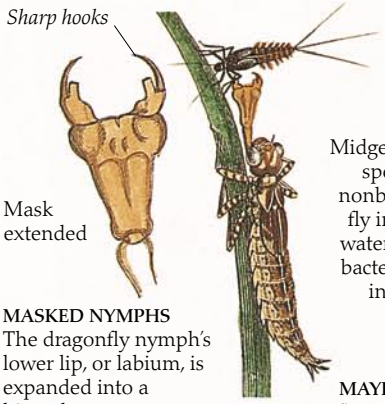
A MEASURED PACE
The water measurer (*Hydrometra stagnorum*) is a long-legged, slow-moving predatory bug. It walks on the surface of the water and feeds on dead and dying insects.

WATER BEETLE LARVA
The larva of the great diving beetle has pointed tubular jaws through which digestive juices are pumped into its prey. The digested body contents are later sucked back into the larva. It breathes by drawing air into the large breathing tubes at the tail.



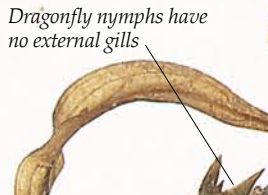


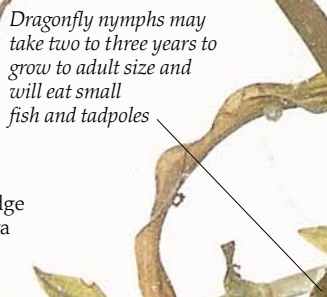
LESSER BOATMEN
Lesser water boatmen (*Sigara striata*) are often found in polluted water. They are predatory bugs, but will also feed on decaying plants and animals.

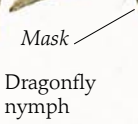


MASKED NYMPHS
The dragonfly nymph's lower lip, or labium, is expanded into a hinged structure called a mask, which has hooks at the tip. The mask shoots out to grasp prey and draw it back to the real jaws (p. 26).

MILLIONS OF MIDGES
Midges (*Chironomus* species) are tiny, nonbiting flies that fly in swarms near water. The larvae feed on bacteria and are important in the disposal of human waste in sewage plants.







MAYFLY NYMPH
Mayfly nymphs eat plants and breathe through feathery gills along the sides of the abdomen.

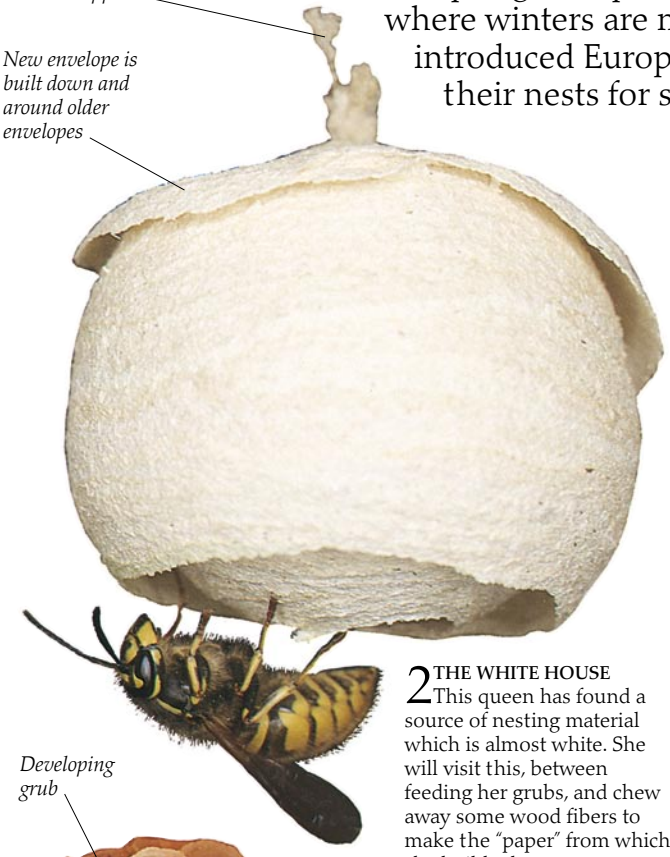
Building a nest

THE START
The common wasp queen (*Vespula vulgaris*) starts a nest by building a short stalk with a cap, covering a comb of four or five cells. She lays one egg at the bottom of each cell.

THE NESTS built by the common wasp (*Vespula vulgaris*) are always begun by a single queen working on her own. She builds a series of papery envelopes from chewed-up wood fibers and lays her eggs inside. She must safely rear her first batch of eggs through to adults. These then become the first workers who expand the nest and forage for food, so that the queen can remain within the nest laying more eggs. New nests are always built again each spring, except in parts of New Zealand where winters are mild enough for introduced European wasps to maintain their nests for several years.

Stalk attached to support

New envelope is built down and around older envelopes



1 INSULATING LAYERS
The queen builds a series of envelopes around her small comb. These layers insulate the developing larvae from cold winds. The nests of the common wasp are always built with the entrance at the bottom, unlike some tropical wasps' nests (pp. 52–54).

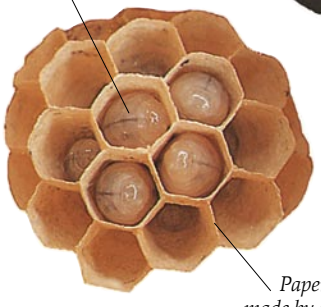
The queen lays one egg at the bottom of each paper cell

CARING FOR THE EGGS
When the eggs hatch, the queen must collect caterpillars as food for the developing grubs. She must also collect more material to extend the walls of the nest.

3 KEEPING GUARD
The nest entrance is now just a small hole. This is easier to defend from other insects, including other queens who might try to take over the nest. Keeping the hole small also makes it easier to control the temperature and humidity around the developing grubs.

2 THE WHITE HOUSE
This queen has found a source of nesting material which is almost white. She will visit this, between feeding her grubs, and chew away some wood fibers to make the "paper" from which she builds the nest.

Developing grub



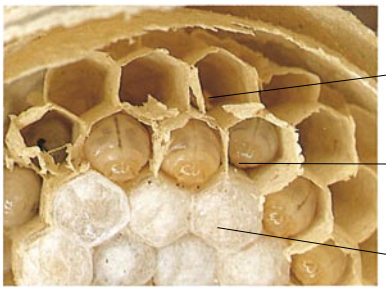
Paper cells made by queen

LARVAE
On their rich diet of chewed insects and caterpillars, the grubs are growing fast, each in its own cell. The time from egg to adult varies with the temperature and the amount of food available, but it is usually about five weeks.

BUILDING WALLS
As the queen builds the nest she uses her antennae to measure the size of the envelopes and the cells.

White paper envelopes are made from fibers of wood which the queen chews and mixes with saliva to make a sort of "paper"

Entrance to nest is small to protect the larvae inside, and to help control the temperature and humidity



GRUBS WITH CAPS ON
When the larvae are fully grown, just before they pupate, they spin their own silken cap to close their cell. A few days later the first set of workers emerges and the nest can start to grow.

4 THE NEST CHANGES COLOR
The first workers produced in a nest are often very small. They immediately start to collect wood fibers from many different sources, and so the "paper" they make is often multicolored and striped. Wasps can often be seen on fence posts, scraping the surface in a series of parallel lines. Inside the nest the old paper envelopes are chewed away to make room for larger combs of cells.

Darker speckles on walls may be the result of some of the workers having fed on poisonous, treated wood

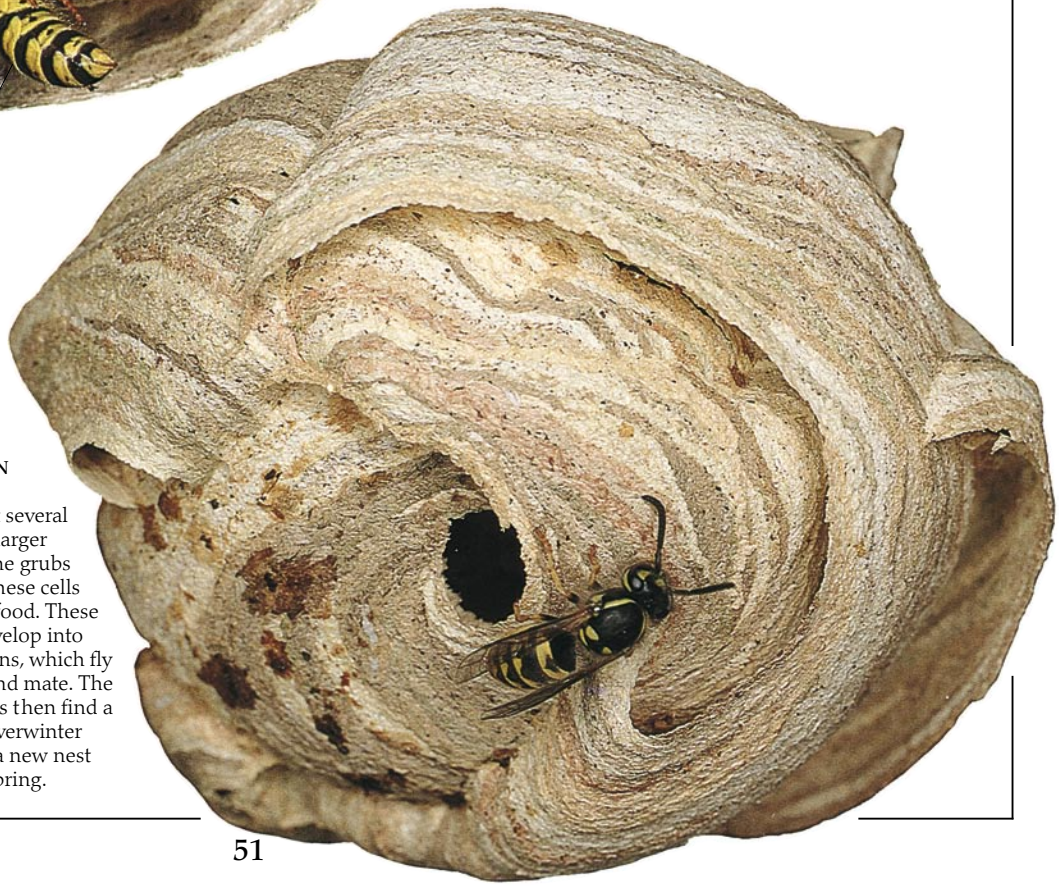
The workers scrape fibers from many different types of wood, making the paper multicolored

5 HOW MANY WASPS?
A large nest of common wasps may measure as much as 18 in (45 cm) in diameter and may contain more than 500 adults in summer. Between spring and autumn it will produce several thousand individuals, most of whom die from exhaustion. Fresh eggs are laid in the cells of each comb as soon as they become vacant.

CROSS-SECTION
This old engraving, although stylized, shows how the envelopes surround the comb of cells in a young nest. Older nests will have four or five horizontal combs.

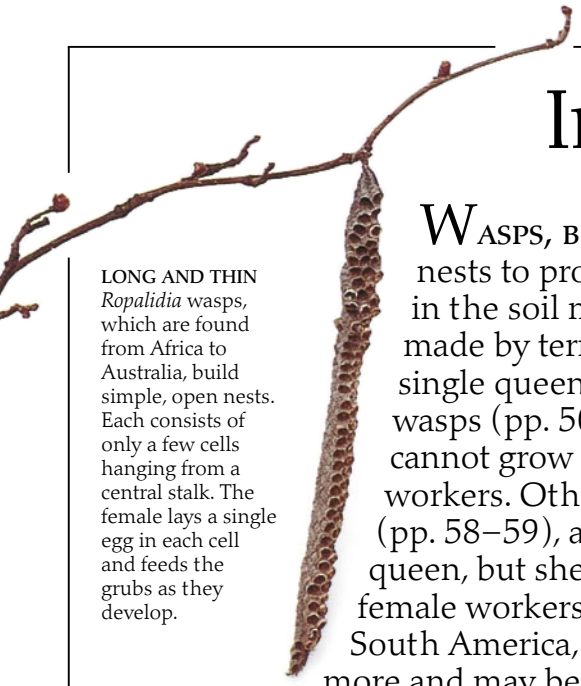
UNDERGROUND NESTS
The common wasp often builds nests underground. As the nest grows the workers have to dig soil and stones away to provide more room. Sometimes small piles of stones can be found near the entrance to the nest.

6 THE NEXT GENERATION
In summer, the wasps construct several cells which are larger than normal. The grubs developing in these cells are given extra food. These larger grubs develop into males and queens, which fly from the nest and mate. The fertilized queens then find a quiet place to overwinter before starting a new nest the following spring.



Insect architects

Wasps, bees, ants, and termites build a wide range of nests to protect their young. The simplest nest is a burrow in the soil made by a solitary wasp. The most complex is made by termites and contains millions of workers and a single queen. Some nests, like the ones built by common wasps (pp. 50–51), are started by a single queen and cannot grow until her first eggs hatch into adult workers. Others, like the honeybees' nest (pp. 58–59), are also started by a single queen, but she is aided by a swarm of female workers from an older nest. In South America, wasps' nests vary even more and may be started by single females, groups of cooperating females, or by swarms of females, sometimes with several queens.



LONG AND THIN
Ropalidia wasps, which are found from Africa to Australia, build simple, open nests. Each consists of only a few cells hanging from a central stalk. The female lays a single egg in each cell and feeds the grubs as they develop.

OPEN HOUSE
These open nests are built in warm countries by *Polistes* wasps. Other wasps sometimes occupy the exposed combs, and drive the original builders away.

JOB SHARING
African *Belanogaster* wasps build exposed combs with long cells. Each nest is started by one female who is joined later by several others. Unlike many wasps these females do not have specific roles, though one female may lay most of the eggs.

LEAFY NEST
This common South American wasp species (*Protopolybia sedula)* builds a nest of up to ten vertical combs between the leaves of a plant. A large nest may contain up to 10,000 wasps.

MUD VASE
Oriental *Stenogaster* wasps produce attractive, vaselike nests of mud or mud and plant fibers. Each nest is made by a solitary female. She feeds her two or three grubs as they grow, then seals them up to pupate.

CLAY NEST
Unlike most large nests, which are made of plant fibers to keep them light, the nest of *Polybia singularis* is built largely of mud. Because each nest is so heavy, it must be hung from a stout branch.

PAPER CONES
Nests built by the South American wasp *Chartergus globiventris* are collected frequently but have rarely been studied in their natural state. The cylindrical nests hang from a branch and always have a small entry hole at the bottom. They vary in size from about 2 in (5 cm) long and 1.2 in (3 cm) wide to 3 ft (100 cm) long and 6 in (15 cm) wide. The largest nests contain many thousands of wasps with several egg-laying queens. The size of the nest is thought to depend on the size of the swarm that begins building it, but much still remains to be discovered about these wasps.

Branch supporting nest

Entrance hole

Papier-mâché walls made of plant fibers, which the adult wasps collect and chew into a paste

Hole at the center of each level allows wasps to move from floor to floor

Nest is made of chewed plant fibers

Papery spines

Entrance hole

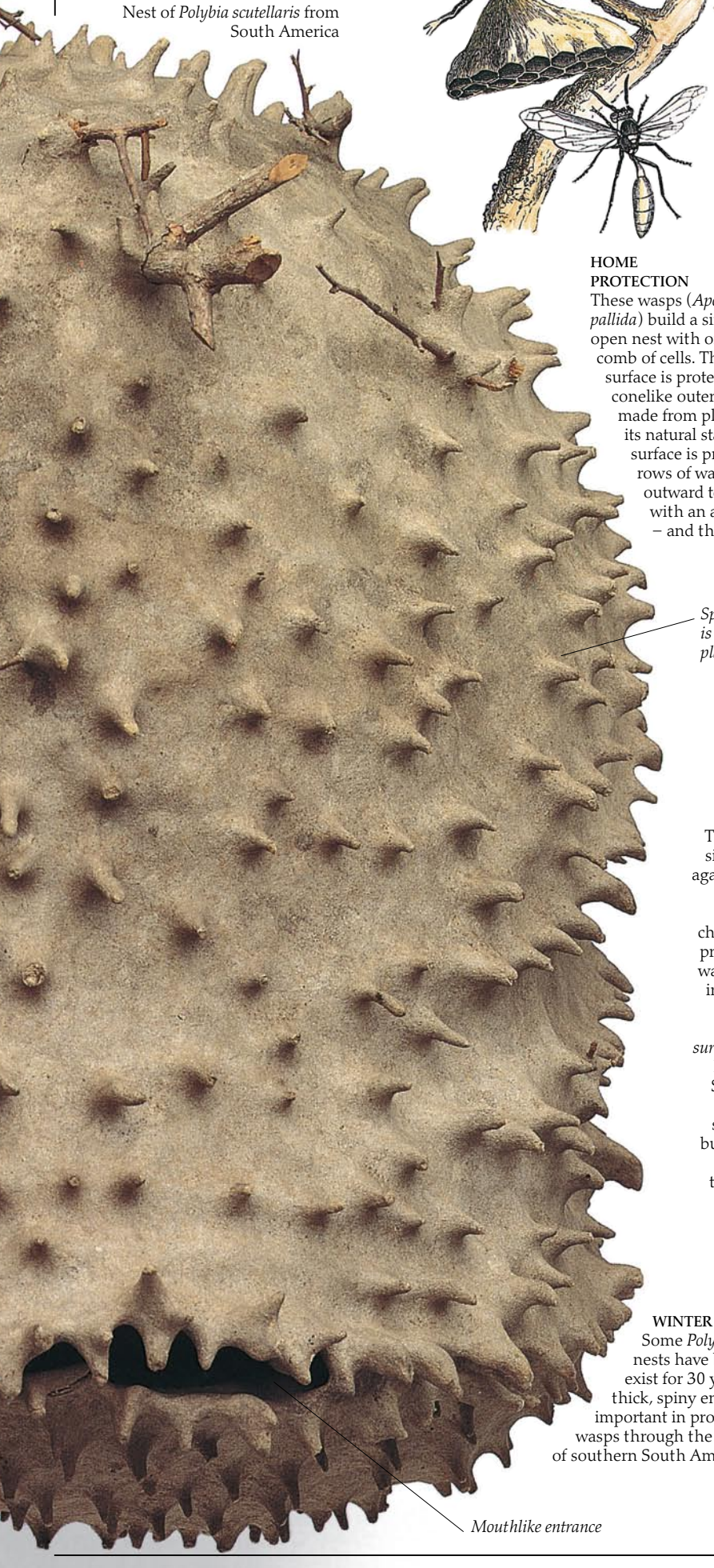
CROSS-SECTION OF A CARTON NEST
This nest is similar to the one above, but it has been cut in half to show the inside. Each nest is built from plant fibers, which the adult wasps collect and chew into a paste like papier-mâché. They build several layers of combs for rearing their young, with a hole at the center of each layer, so they can easily move from floor to floor. The new combs are probably added at the bottom and then covered by a new envelope.

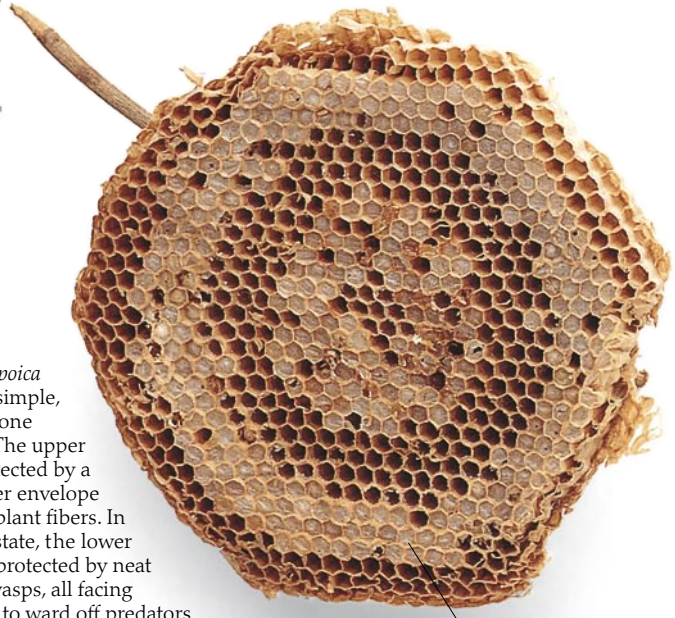
SPINY NEST
Polybia scutellaris is a common wasp in Argentina and southern Brazil, where nests are sometimes built under the eaves of houses. Each nest is made of chewed plant fibers, and the outer envelope is covered with hard papery spines.

TREE HOUSES
This engraving shows another spiky nest. The entrance is different from the *Polybia scutellaris* nest above, suggesting that it may have been built by a different species.

Continued on next page

Nest of *Polybia scutellaris* from South America





HOME PROTECTION
These wasps (*Apoica pallida*) build a simple, open nest with one comb of cells. The upper surface is protected by a conelike outer envelope made from plant fibers. In its natural state, the lower surface is protected by neat rows of wasps, all facing outward to ward off predators with an array of eyes and antennae – and the ever-ready stings.

Brood cells containing developing grubs

Spiny outer casing is made of chewed plant fibers

Entrance to nest

DRUMMERS' HOME
This simple nest with a single comb is built flat against a tree branch and enclosed in a ridged envelope made from chewed plant fibers. It is produced by a swarm of wasps that is thought to include several queens. These metallic blue wasps (*Synoeca surinama*) are among the largest social wasps in South America, with a powerful and painful sting. They fly quietly, but when annoyed they drum on the inside of their nest, producing a warning sound.

WINTER PROTECTION
Some *Polybia scutellaris* nests have been known to exist for 30 years, and the thick, spiny envelope may be important in protecting the wasps through the cooler winters of southern South America.

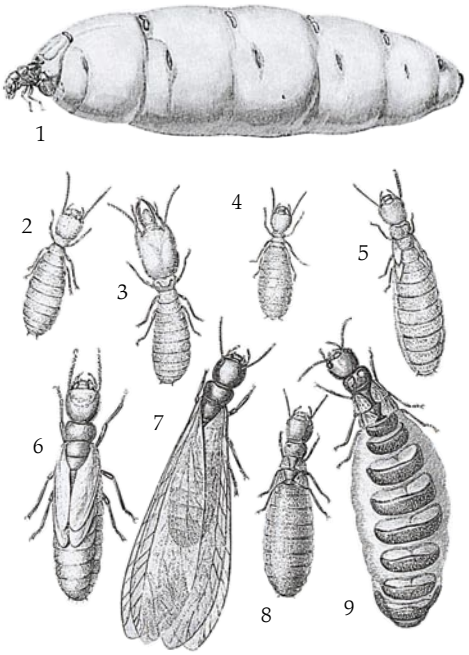
Mouthlike entrance

Continued from previous page

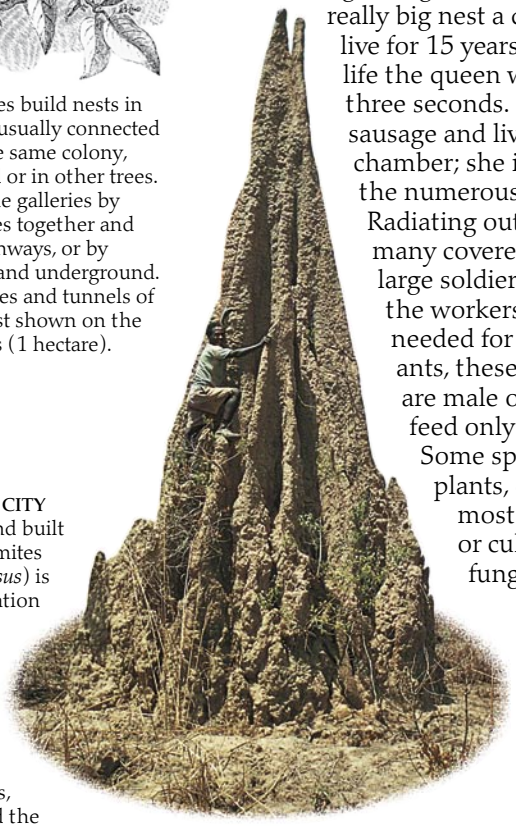
Termites

The biggest and most complex of insect societies are built by termites. The nests of some species, such as the West African *Macrotermes bellicosus* (below), may house up to five million – many more termites than the entire human population of New Zealand – and are extraordinarily complex buildings, with full air conditioning. Nests usually have a single queen, who lays all the eggs, and a single king, who fertilizes them all. In a really big nest a queen and king may live for 15 years, and for much of her life the queen will lay one egg every three seconds. She looks like a small sausage and lives in a special chamber; she is fed continuously by the numerous workers of her nest. Radiating out from the nest are many covered trails, guarded by large soldier termites, along which the workers bring all the food needed for the colony. Unlike ants, these soldiers and workers are male or female, and they all feed only on plant material. Some species attack young plants, others eat seeds, but most eat rotting wood or cultivate special fungus gardens.

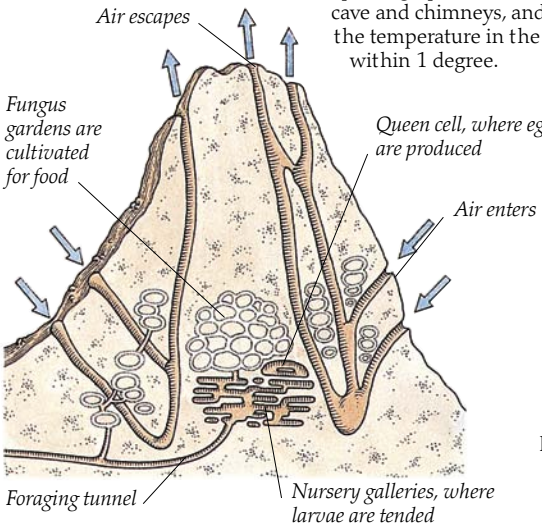
TREE TERMITES
Many termite species build nests in trees; the nests are usually connected to other parts of the same colony, either underground or in other trees. Termites connect the galleries by sticking soil particles together and roofing in their highways, or by tunneling in wood and underground. The foraging galleries and tunnels of the *Macrotermes* nest shown on the right cover 2.5 acres (1 hectare).



TERMITE CASTES
1) Fully grown *Macrotermes* queen; the head and thorax are dwarfed by the enormous abdomen; 2) worker; 3) soldier; 4) young nymph; 5) short-winged nymph; 6) long-winged nymph; 7) male; 8) young female; 9) egg-laying female (note wings cut off after mating flight).

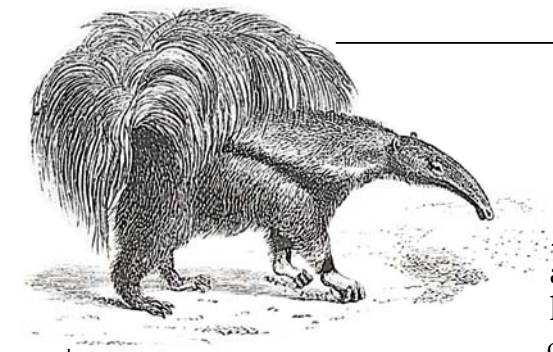


AIR-CONDITIONED CITY
This towering mound built by West African termites (*Macrotermes bellicosus*) is really a giant ventilation chimney through which hot air from the nest can escape. Beneath the tower is a cave about 9 ft (3 m) in diameter housing the nursery galleries, the queen's cell, and the fungus gardens. Below the main cave are cavities 32 ft (10 m) or more deep, from which the termites obtain water. At the top of the main cave is a hole, which the termites can make bigger or smaller by adding or removing soil particles. This varies the speed of warm, moist air passing up and out through the cave and chimneys, and controls the temperature in the nest to within 1 degree.



INSIDE A TERMITES' NEST
The *Macrotermes subhyalinus* nest differs from that of its relative *M. bellicosus*, but the principle of keeping a constant temperature within remains the same.

MYSTERIOUS UMBRELLAS
The study of insects often raises more questions than answers. These umbrella nests of African *Cubitermes* are well known. They are about 18 in (45 cm) high. But what is their function? A nest starts hidden underground. Then one or more columns may suddenly be built, and up to five caps may be added to each one. No queen cell is built by these termites.



ANTEATERS
Anteaters feed on ants and have powerful claws to break open nests and termite mounds and a long snout to reach inside.

Social ants

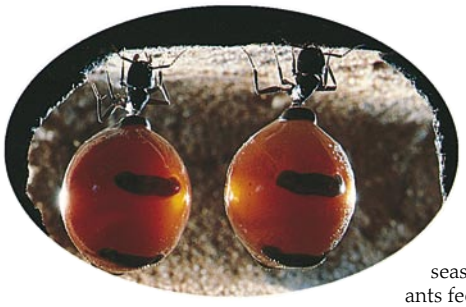
ANTS ARE SOCIAL INSECTS, closely related to wasps and bees (pp. 38-39). Most ant species live and work together in big colonies, often building complex nests in which to rear their young. Each nest is begun by a single queen who lays all the eggs. There is no king; soon after she emerges from her pupa in the old nest, the young winged queen mates once with a winged male and stores the sperm to use throughout her life. She then bites off her wings and starts a new nest. The nest is built by wingless, sterile female workers, which forage for food and tend the developing eggs and grubs. Ant species vary greatly. There are solitary and parasitic species; ants that rear workers from other nests as slaves; and "cuckoo" queens that enter nests and persuade the workers to kill their queen so they can raise her brood.

WEIGHTLIFTERS
Tiny ants can lift objects that weigh more than they do. When a nest is disturbed, the ants rush about to defend and rebuild it; but their first priority is to move the brood to a place of safety deeper in the nest. The large white objects in this photograph are not eggs, but pupae, each with an almost mature adult inside.

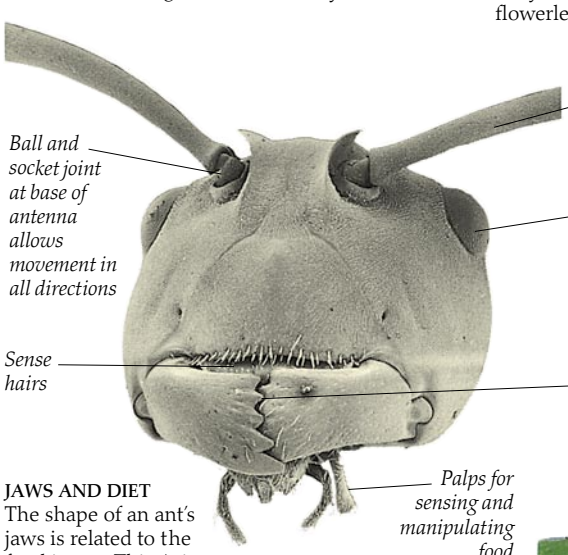
WOOD ANTS
In forests wood ants are important insect predators and a large colony will collect many thousands of insects in one day. A large nest may contain 100,000 ants with several queens and can last for many years. In 1880 in Aachen, West Germany, the European wood ant became the first insect to be protected by a conservation law.

Parasol ants

The "parasols" of this trail of tropical American leaf-cutting ants (*Atta cephalotes*), are pieces of leaves and flowers, which each ant cuts out and carries back to the nest. In the nest they are cut into smaller pieces and used to grow a kind of fungus on which the ants feed. The nest is usually underground, and has special air conditioning to insure that the temperature and humidity remain almost constant. A large nest may be several yards across and will house a number of fungus gardens and separate brood chambers. A colony of parasol ants consumes a vast quantity of leaves. In their natural habitat, where they are part of the balance of nature, this causes no problem. But on plantations, where they are competing with humans for food, they can become a serious pest.



HONEYPOT ANTS
In semidesert areas all over the world different species of ant have independently evolved the same remarkable way of staying alive in the dry season. During the rains, the ants feed some of their workers with water and nectar. These workers store the extra food in their crop, and the front part of their abdomen swells. They cannot move around but hang upside down in the nest as living larders, for use by the rest of the colony during the long, flowerless dry season.



JAWS AND DIET
The shape of an ant's jaws is related to the food it eats. This Asian tree-living ant has simple jaws with a few teeth for feeding on soft insects and honeydew (p. 21). Most ants are predators with long, slender, pointed jaws; but some species have become plant-feeders. Harvester ants have broad-tipped crushing jaws without teeth for feeding on grass seeds.

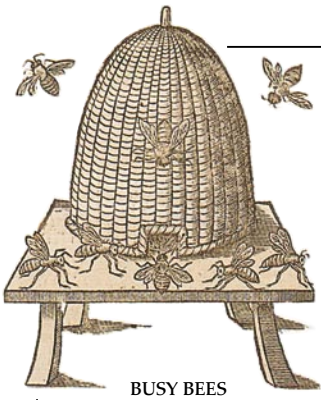
Two ants cut out a large piece of leaf with their powerful cutting jaws

STITCHED UP
Some ants in tropical areas from Africa to Australia build nests in trees by "sewing" together groups of large leaves. A row of worker ants pulls two leaves together. When the edges are close, more workers, each holding a live ant larva in their jaws, sew the leaves together using strands of silk produced by the larva's salivary glands. The finished nest (right) is a ball of leaves. If the nest is disturbed, the thousands of weaver ants give a noisy warning by tapping on the leaves from within. When these ants bite, they squirt formic acid into the wound, making it doubly painful.

A LEAFY TRAIL
The trails of small green leaves are often very clear during the day where they cross footpaths on the route back to the nest. Outward-bound workers can be seen stopping and encouraging their laden colleagues. Sometimes a "parasol" is dropped; then several ants rush forward and hoist it into the air to be carried home by one of them.

FAIR-WEATHER WORKERS
Parasol ants do not collect leaves when it is raining, and if a heavy shower occurs while they are out cutting, the leaves are usually dropped outside the nest. Perhaps wet leaves would upset the delicate balance inside the fungus gardens and endanger the colony's food supply.

Honeybees and hives



BUSY BEES
Straw "bee skeps," like this one drawn 400 years ago, changed little for thousands of years. Inside, the bees built their own combs on a supporting stick.

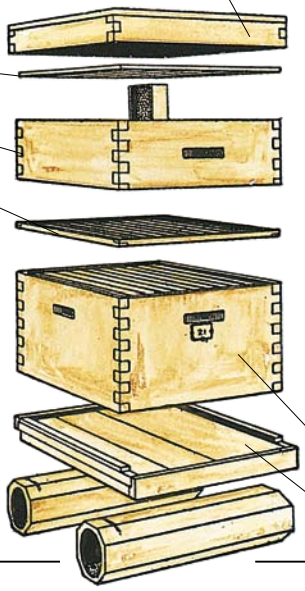
PEOPLE HAVE COLLECTED HONEY from the nests of bees for many centuries. The oldest record is a cave painting in Spain, nearly 9,000 years old, which shows a figure apparently taking honey from a nest on a cliff – a practice still followed today in some parts of the world. Egyptian tomb decorations indicate that humans were keeping bees, not just robbing wild nests, 2,500 years ago, and methods changed little until recently. Only during the last hundred years have efforts been made to breed docile bees that produce a lot of honey. In a modern domestic hive, there are three types of honeybee (*Apis mellifera*): one queen, a fertile, mated female who lays all the eggs – sometimes over 1,000 a day; a few hundred males called drones, whose only function is to fertilize new queens; and up to 60,000 sterile female workers, who do all the work in the hive.

SWARMING
A bee colony produces a few new queens each year. Just before the first queen emerges from her pupa, the old queen and about half the workers fly away as a swarm. Swarming bees are often docile, and this engraving shows a swarm being gathered into a straw skep. The first new queen to emerge in the old nest normally kills her rivals so she can reign supreme.

LOWER FRAME FROM HIVE
On the lower frames of a hive honey and pollen are stored in the upper cells, and the brood is reared in the lower cells, as shown here. When a bee finds a source of nectar, it flies back to the hive and performs a curious "dance" on the comb. This tells other bees how close the food is and where it lies in relation to the position of the sun. Bees foraging in open country make a "beeline" between the hive and the food source that is as busy as a highway.

Large drone cells

Cell walls are made of wax, which the workers produce in flakes from glands between the joints of their abdomens



Outside cover

Inside cover

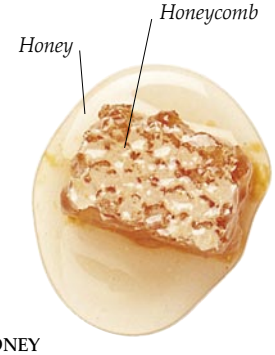
Shallow super

Queen excluder – a grid with slots too narrow to let the queen through into the upper combs

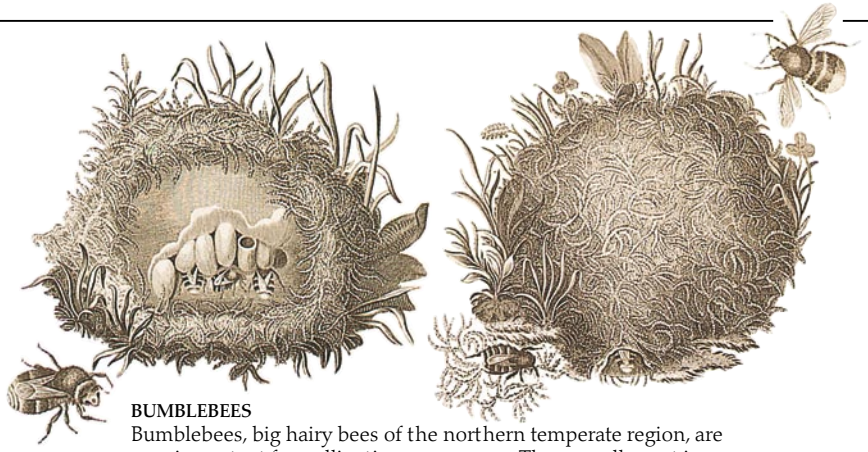
Brood chamber

Bottom board with hive entrance

MODERN HIVES
The modern Langstroth hive was invented in 1851 in Philadelphia. The bees are provided with combs in removable frames; a lower set for the brood chamber, and an upper set ("shallow super") for storing nectar and pollen. The queen is prevented from laying eggs in the upper combs by the "queen excluder."



HONEY
Combs from a hive, with the cells full of honey, are often sold as a delicacy.



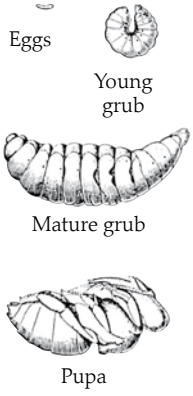
BUMBLEBEES
Bumblebees, big hairy bees of the northern temperate region, are very important for pollinating some crops. They usually nest in the burrows of small mammals and construct a few irregularly shaped cells.

BEE BONNET
Swarming bees can be very docile. This swarm has been encouraged to sit on a man's head. He probably first placed the queen on his head in a small cage, so that the workers would gather around her.

White wax-capped cells contain honey for feeding developing grubs – and the beekeeper

Yellow-capped cells at top of comb contain pollen stores

Young C-shaped grubs at bottom of wax cells



LIFE STAGES
Bees undergo complete metamorphosis (pp. 24–25). As the eggs develop into grubs and then pupae, they are fed and looked after by young workers. Older workers look for food outside the hive.

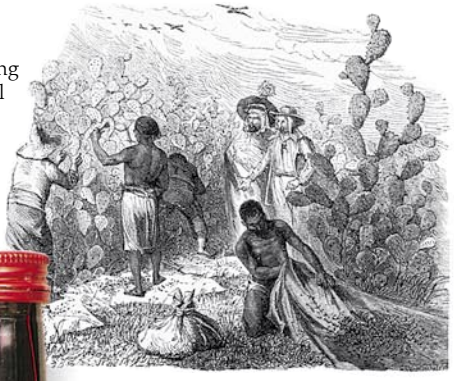
Older workers bring back pollen to hive, where it is stored in cells to feed the developing grubs

The yellow silk-capped cells in the lower half of the frame contain pupae

Newly hatched grubs are fed first on royal jelly, a special saliva produced by the workers, then on honey

Helpful and harmful

Insects are essential to the well-being of the living world. Bees, flies, and butterflies help pollinate our crops and so insure that fruit and seeds are produced. Wasps and ladybirds destroy the caterpillars and aphids that attack our plants. Beetles and flies clean up animal dung and the rotting bodies of dead plants and animals, recycling the nutrients for use by new generations of plants. Many animals rely on insects for food, and in many parts of the world people traditionally eat fat, juicy caterpillars and grubs. Bees provide us with honey and beeswax; moth caterpillars produce silk; and food coloring is made from the crushed bodies of certain bugs. But people often notice insects only when they become a nuisance or a threat. Many insects transmit diseases to people, animals, and plants and every year they are responsible for the destruction of between 10 and 15 percent of the world's food.



Harvesting cochineal insects

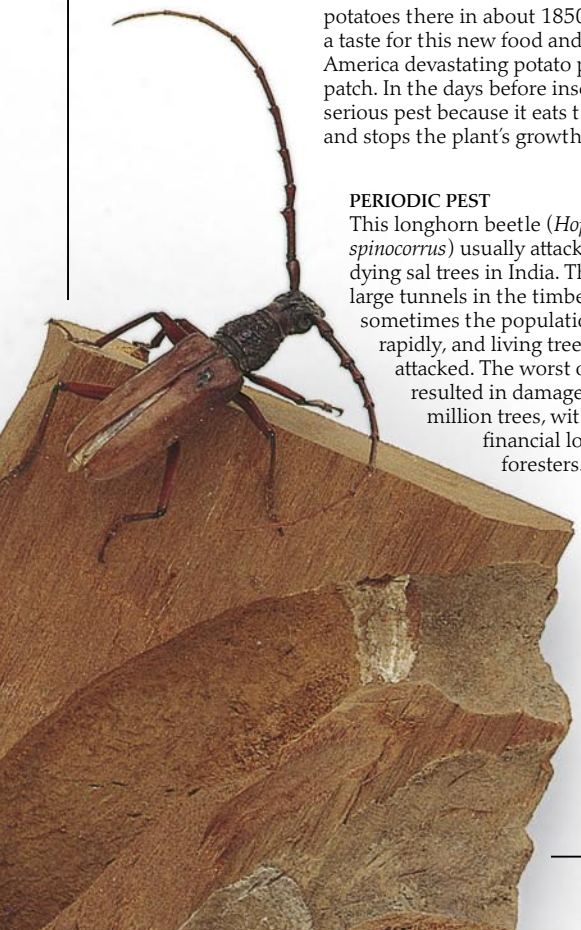
Cochineal coloring

DYES AND MANNA
Cochineal is a red food coloring extracted from the crushed bodies of scale insects (*Dactylopius coccus*). Originally from Mexico, these tiny bugs (p. 36) and the opuntia cacti on which they feed are now cultivated in other hot, dry countries. The biblical manna that fed the children of Israel was probably derived from similar bugs on tamarisk trees.

Colorado beetles kill potato plants by eating the leaves and buds

COLORADO BEETLE
The Colorado beetle (*Leptinotarsa decemlineata*) used to feed harmlessly on leaves in the Rocky Mountains. But when settlers introduced potatoes there in about 1850, the beetle developed a taste for this new food and swept eastward across America devastating potato patch after potato patch. In the days before insecticides it was a serious pest because it eats the leaves and buds, and stops the plant's growth.

POISON DARTS
The pupae of this African leaf beetle (*Polyclada bohemani*) contain a remarkably powerful poison. South African bushmen used to use this poison on their arrows when hunting.



PERIODIC PEST
This longhorn beetle (*Hoplocerambyx spinocorrus*) usually attacks dead and dying sal trees in India. The grubs drill large tunnels in the timber. But sometimes the population increases rapidly, and living trees are attacked. The worst outbreak resulted in damage to one million trees, with serious financial loss to the foresters.

CIGARETTE BEETLES
Smoking is harmful to your health. But cigarette beetle grubs (*Lasioderma serricorne*) do not read the health warnings (the adults do not feed at all). Sixty years ago, one way to get the beetles out of a horsehair-stuffed settee was to soak the furniture in gasoline. This too is harmful to your health, particularly if you are smoking at the time.

Death watch beetles can reduce structural timbers to little more than a skeleton

DEATH WATCH
Death watch beetles (*Xestobium rufovillosum*) can be serious pests of timber in houses. In spring, the noise of the adults tapping the front of their heads against the wood as a mating call has been linked superstitiously with approaching death. But the most likely disaster it heralds is the house falling down.

Locusts
(*Schistocerca gregaria*)

Nymph

Nymph

Adult locusts have wings, but the nymphs are wingless

Adult

GROUPS OF GRASSHOPPERS
Most of the time locusts are ordinary, solitary grasshoppers. But sometimes they become gregarious (gather in groups), their body structure and behavior changes, and they form swarms.

LOCUSTS SWARMING
When a locust swarm breeds uncontrolled for a few months, the number of individuals can rise to hundreds or even thousands of millions. Such a plague will eat all the available plants in an area, leaving the human population destitute.

HOME WRECKERS
Termites will sometimes eat away the wooden structure of a house from within the timbers, leaving just the thin painted surface undamaged. This door lintel from St. Helena was once 11 in (28 cm) square.

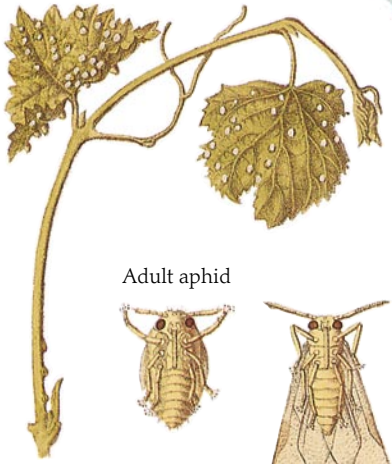
UNWELCOME GUESTS
Two entomologists recall visiting Alexandria, Egypt, in 1920 and spending one night catching bedbugs rather than sleeping. By morning they had 70 pins with 10 bugs on each.

Granary weevils

Red-rust flour beetles

BEETLE PARADISE
The red-rust flour beetle (*Tribolium castaneum*) is a common pest in packages of flour and in grain stores. The larvae of grain weevils (*Sitophilus granarius*) live inside the kernels of stored cereals and make them useless for flour production.

Leaf galls on American vine



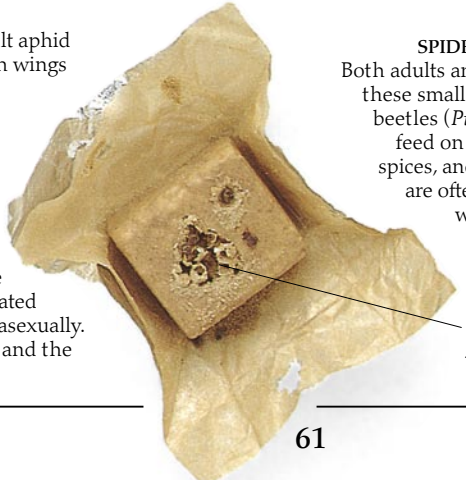
Adult aphid

Adult aphid with wings

GRAPEVINE PEST
The grape phylloxera (*Viteus vitifoliae*) is an aphid pest (p. 36) of grapevines. It reached Europe from America in 1860, and within 25 years it destroyed 2.5 million acres (1 million hectares) of vines through the galls it produced on the roots. It has a complicated life-history and reproduces both sexually and asexually. In America vines may have galls on the leaves and the roots, but in Europe only root galls are found.

DISEASE SPREADERS
Mosquitos are bloodsucking flies, with biting, sucking mouthparts (pp. 20-21) that inject humans with diseases, such as yellow fever and malaria. They only need to feed on the contaminated blood of one person for the disease to be passed on to others.

SPIDER BEETLES
Both adults and larvae of these small spider-like beetles (*Ptinus tectus*) feed on dried food, spices, and grain and are often found in warehouses.



Spider beetles feeding on a dried stock cube

Termites only eat the softer parts of the wood – the hard parts are left

Looking at insects

INSECT INTEREST
In the 19th century, interest in natural history became fashionable, and private collections of insects, plants, and minerals were common. This engraving is of an elaborate glass tank called a vivarium, in which the life histories of living insects could be observed.

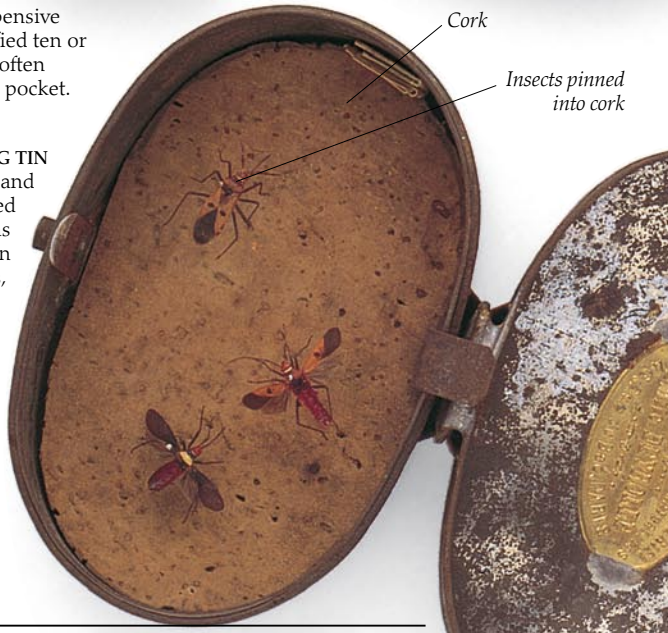
More than three centuries of studying and collecting insects have made it possible to recognize most of the insect species in Europe. But it is still impossible to guess how many different species live in parts of North America and less well-explored tropical countries. Today, insect collecting should be concerned with examining the ways in which insects help maintain the balance of nature. How important are they for pollinating flowers and trees? Which insects are needed to decompose wood and dead leaves and produce nutrients for new plants? How many insects are needed to feed other animals? But looking at insects can also be fun. At its simplest, all it requires is patience and good eyesight – possibly helped by a magnifying glass and a camera. Just observing how these fascinating creatures live is an important way of learning how the natural world works.

JEAN FABRE (1823-1915)
The French naturalist Jean Henri Fabre wrote many popular books about the lives of insects.

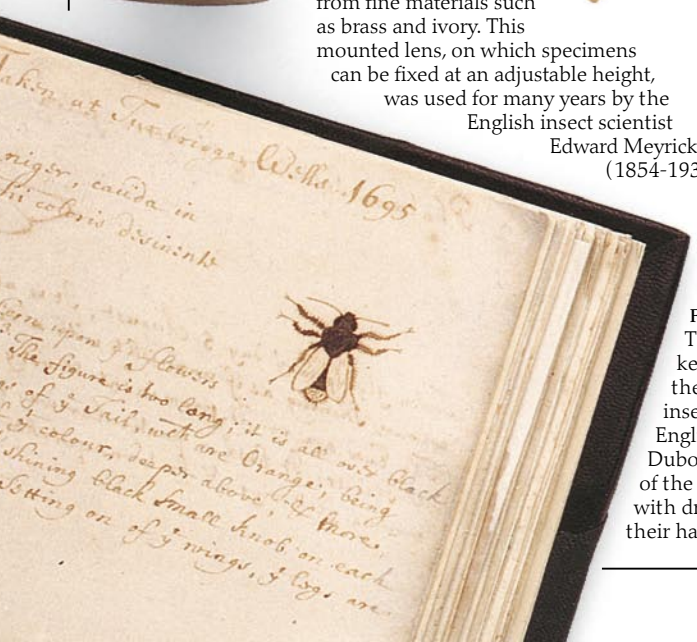
CHLOROFORM BOTTLE
One method of killing freshly caught specimens was to shake a few drops of chloroform from the pointed nozzle of a brass container such as this.

IVORY HANDLES
Before the invention of plastic, small pieces of apparatus were made from fine materials such as brass and ivory. This mounted lens, on which specimens can be fixed at an adjustable height, was used for many years by the English insect scientist Edward Meyrick (1854-1938).

HAND LENS
Magnifying glasses were once common, from large low-powered lenses to small, expensive ones which magnified ten or even 25 times and often folded up to fit in a pocket.



COLLECTING TIN
Insect collectors and entomologists pinned the fragile specimens they caught outdoors in special cork-lined tins, like this one, which was made in France.



FIELD DIARY
The most devoted students kept detailed notebooks of their observations on live insects. The diaries of the English entomologist Charles Dubois (1656-1740) include notes of the insects he saw, sometimes with drawings and comments on their habits and appearance.

Scissor-like handles

SCISSOR NET
To catch an insect, the two flat sheets of muslin of this old-fashioned scissor net could be snapped shut.

Square tips for holding pins

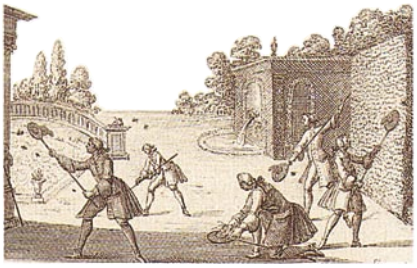
Fine points for tiny insects

Opticians' forceps

Finely woven cotton muslin prevents the captured insect from escaping

Metal needle holder

Tweezers



COLLECTORS
This group of gentlemen in 18th-century court dress and wigs was illustrated by R. A.F. de Réaumur in about 1740. Their nets are curiously hat-shaped.

Old pin box

Very fine pins for small insects

INSECT PINS
Insect pins differ in size, as do insects. Very small insects are usually stuck onto pieces of cardboard, or mounted on microscope slides for study.

Long, stout pins used for larger insects

LABELS
The scientific value of an insect usually depends on how much information is given on the label accompanying it, such as where and when it was collected, and what it was feeding on. These labels must be small but clearly printed, as on these tiny leafhoppers.

Labels

Microscope slide

TOOLS
Opticians' forceps with fine points are useful for picking up tiny specimens. In contrast, tweezers with square tips are used for holding pins. Needles of differing sizes can be mounted into metal handles, so that single legs or antennae can be positioned.

SMALL INSECTS
Many insect species are less than 0.04 in (1 mm) long – too small to be pinned. They are usually collected into alcohol, stored in small glass vials, and studied under a microscope on glass slides, in watch glasses, or in small glass dishes.

Glass dish containing alcohol

Base of box is lined with white plastic foam

MODERN PLASTIC COLLECTION BOX
The advantage of plastic is that it is not as heavy as metal, and collections can be seen without removing the lid. This is a typical collection of small moths attracted to a light trap at night.

MODERN TRAPS
The Malaise trap catches large numbers of flying insects. When they fly into the central wall, most crawl upward into the bottle at the top – although some drop to the ground and crawl away.

Extinction

In recent years, radical changes in land use have reduced forests and other natural habitats all over the world. As a result many insect species are vanishing – some of them becoming extinct before they have ever been discovered. The St. Helena earwig is a very large insect that used to live only on the island of St. Helena in the middle of the South Atlantic Ocean. It has not been seen alive for many years and is probably now extinct.

Extinct St. Helena earwig

Did you know?

AMAZING FACTS

A cockroach can live for up to three months without its head.

The bombadier beetle defends itself by firing boiling hot liquid from its abdomen. The gas is formed by a chemical reaction and irritates the eyes of the enemy, acting as a smokescreen while the beetle scuttles off to safety.

The color a head louse will be as an adult can be determined by the color of the person's hair in which it lives.

The tallest known insect nest is one built by a colony of African termites. It measured 42 ft (12.8 m) high.

One of the most deadly species of insect on Earth is the desert locust, or *Schistocerca gregaria*. The danger lies not in a direct threat posed to humans but in the havoc wreaked on agriculture when a plague of locusts attacks a crop. The desert locust appears after heavy monsoon rains and devours every single plant in an area, often causing famine among local humans and animals.

A swarm of desert locusts may contain up to 40 billion members. It can travel 400 sq miles (1,036 sq km) and eat 40,000 tons of plants a day, enough to feed a city with a population of 400,000 people for a year.

A man walks safely through a locust swarm

Killer bees, or Africanized honeybees

Queen termites have been known to lay an egg a second—that adds up to an incredible 30 million eggs a year. This rate of reproduction is only possible because the queen termite grows to such a size that her whole body is filled with ovaries.

Sorting silkworm cocoons to make silk

Killer bees, one of the most deadly insects on Earth, are not a naturally occurring species. The bees were first bred in Brazil in 1956 when the African honeybee was crossed with local bees in an attempt to increase their honey yield. However, the experiment went wrong when the new breed turned out to be aggressive with a tendency to attack both humans and animals. Although killer bees do not have more venom than domestic bees, and are no bigger in size, they are ten times more likely to attack.

Hawk moths can fly at speeds of 33.3 mph (53.6 km/h).

The silkworm (*Bombyx mori*) is the caterpillar of a moth whose cocoon is used to make silk. The silk is a single, continuous thread made from protein and secreted by two glands at either side of the caterpillar's head. Each cocoon contains one silk thread that can range from 984–2,952 ft (300–900 m) in length! To harvest, the silkworm is allowed to spin its cocoon and is then placed in boiling water to kill the pupa and help unravel the thread.

The insect with the most acute sense of smell is the Indian moon moth, which can detect the pheromones of a mate from a distance of 6.8 miles (11 km).

Young desert locust

QUESTIONS AND ANSWERS

Q How many species of insect are there overall?

A There are at least one million different species of insects in total, more than all the other animal and plant species put together. Insects form around 80 percent of all animal life on Earth and, of this, ants and termites each make up ten percent. In insect classification, beetles are the most diverse group, with 125 different families and 300,000 individual species. It is estimated that there are one billion insects for every human being.

Q Which insect can withstand the hottest temperatures?

A The adults and the larvae of the *Scatella thermarum* are found in hot springs in Iceland and can live in temperatures as hot as 48° C (118° F), which is too hot for most people to put their hands into.

Q What is the best way to repel insects?

A Natural insect repellents that can be worn on the skin include oil mixtures containing cedar, tea tree, lavender, or vanilla. Some people believe that eating garlic may keep insects at bay—especially blood-hungry pests such as mosquitoes. This is because garlic emits an odor when absorbed into the blood, which many insects find unpleasant.

Garlic can keep insects at bay

Q What is an insect's favorite food?

A Although many insects have very precise diets, some are not fussy and will eat almost anything lying around, including wood, shoe polish, and paper!

Q Can insects be eaten?

A Many peoples of the world include insects as part of a nutritious diet. One example is the annual moth feast held by the Aboriginal peoples in the Bogong mountains of New South Wales, Australia. Moths are collected from rock crevices and then cooked in hot sand. After the heads have been removed, the moths' bodies are ground into a paste and baked as cakes. The moths provide valuable fat content to the diet of the Aborigines. Other popular insect meals around the world include fried grasshoppers, roasted crickets, and larvae paste or pulp.

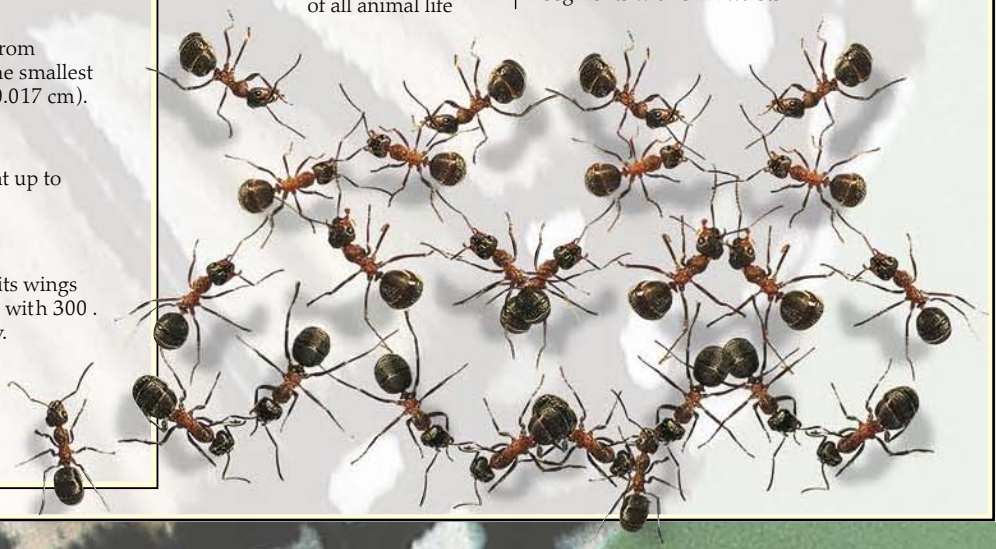
Q Do insects have brains?

A Yes. An ant brain, for example, has about 250,000 brain cells. A human brain has 10,000 million cells, so a colony of 40,000 ants has collectively the same size brain power as a human being.

Q What is the biggest ant colony ever known?

A A supercolony of *Formica yessensis* on the coast of Japan is reported to have been home to more than one million queens and 306 million worker ants living in 45,000 interlinked nests underground.

Ants form ten percent of all animal life



Q Which insect has the longest body?

A One species of walking stick insects, *Pharnacia kirbyi*, has the longest body of all insects. Females can reach up to 14 in (36 cm) long.

Q Which is the loudest insect?

A The African cicada *Brevisana brevis* produces a sound pressure at a level of 106.7 decibels over a distance of 19.5 in (50 cm). This is the loudest insect call on record. Insect songs form a vital part of communication, defence, and reproduction.

Q What is the biggest insect that has ever lived?

A The largest insect we know about was an ancient dragonfly called a *Meganeura*. This predatory flying insect lived about 250 million years ago and had a wingspan of about 2 ft (0.6 m).

Stick insect

Q Which insect has the longest life cycle?

A Periodical cicadas, *Magicicada septendecim*, have a natural life cycle of around 17 years. However, the larvae of some wood-boring beetles can live for up to 45 years. The ordinary housefly has the shortest lifespan of all, lasting only 17 days.

Q How can you tell the difference between ants and termites?

A Although termites can appear similar to ants, there are several ways to tell them apart. Termites have straight antennae, and no waistline. Ants are usually larger, have elbowed antennae, and three body segments with slim waists.

Record Breakers

Highest jumper

• Proportional to its body size, a tiny flea can jump the highest of any insect, equivalent to a human being jumping 24.6 ft (7.5 m) into the air.

Tiniest insect

• The tiny parasite *Megaphragma caribea* from Guadeloupe in the Caribbean is one of the smallest insects known, measuring just 0.006 in (0.017 cm).

Fastest flier

• Dragonflies can speed through the air at up to 20.5 mph (33 km/h).

Most wingbeats

• In scientific tests, a tiny midge can flap its wings up to 50,000 times per minute, compared with 300 . times per minute for the average butterfly.

Heaviest insect

• The Acteon beetle (*Megasoma acteon*) can weigh in at 2.4 oz (70 grams).

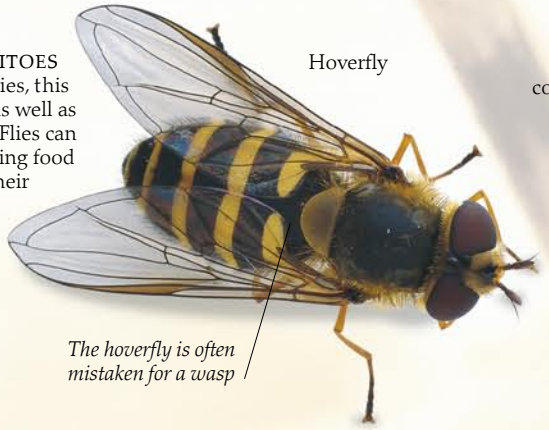
Insect classification

There are more than one million species of known insect in the world and some experts estimate that there may be as many as 10 million. Here are the main insect groups.

Flies, gnats, and mosquitoes

Including around 90,000 species, this group contains the household fly as well as bloodsuckers such as mosquitoes. Flies can transmit diseases by contaminating food with organisms picked up on their hairy legs and mouthparts.

Hoverfly



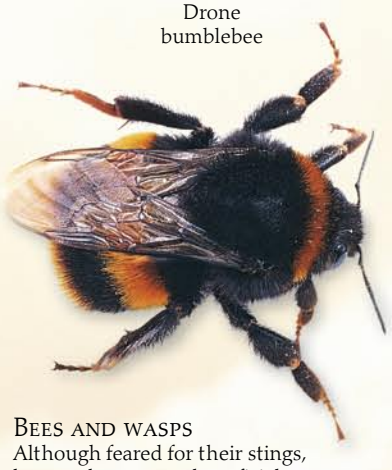
The hoverfly is often mistaken for a wasp

Flying cockroach

Cockroaches

Cockroaches include around 5,500 different species and have been present on Earth for more than 400 million years. Cockroaches are very sturdy insects and can run at speeds of nearly 2 mph (3 km/h). They are nocturnal and are sometimes kept as pets.

Drone bumblebee



Bees and wasps

Although feared for their stings, bees and wasps are beneficial insects since they are key to flower pollination and feed on many smaller insects that are harmful to crops. Bees and wasps are social creatures that often live and work in communities.

Bugs

This group includes greenflies, shield bugs, cicadas, and pond skaters. Shield bugs, numbering around 6,500 species worldwide, are often called "stink bugs" because they can produce a horrible smell by emitting a fluid from their glands.

Shield bug

Crab louse

Lice

These wingless parasites infest humans and animals, laying eggs in hair-covered parts of the body and feeding on skin and blood. There are three types of human louse: the head louse, the body louse, and the crab louse.

Stick insect

Stick insects

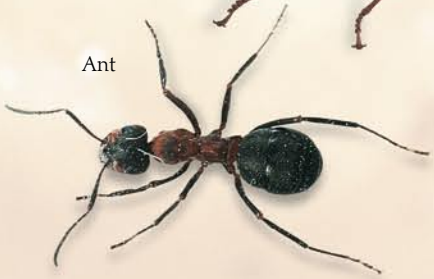
Containing around 2,500 species, these insects are mostly found in the tropics. Stick insects may or may not have wings and are often bred as pets. These insects often blend in perfectly with foliage.

Stag beetle

Beetles

The largest single group in insect classification, beetles number around 350,000 species. Beetles include animals as diverse as the wingless glow worm, woodworm (beetle larvae that eat furniture), and the gardener's friend, the aphid-munching ladybug.

Ant



Ants

Ants are among the most numerous of the insect species and are estimated to comprise 10 percent of all animal life on Earth. These social insects live and work in massive colonies underground.

Swallowtail butterfly

Eyespots may divert predators away from delicate body

Butterflies and moths

Numbering more than 300,000 species in all, this group can be found all over the world. However, many species of butterfly are becoming extinct due to pollution and deforestation.

Stone fly

Stone flies

So called because they are often seen resting on stones, these aquatic insects number around 2,000 named species. They are a favorite food of fish such as trout, and fishermen often use artificial fly baits modeledon stone flies to attract a catch.

Praying mantises

There are about 1,700 varieties of praying mantis. Most species live in warm climates and will attack bees, beetles, and butterflies and occasionally even small mice and birds. The female mantis often cannot fly due to the number of eggs in her abdomen. She may eat the male after mating.

Praying mantis

Mantis females are among the largest insects

Scorpionfly

Flea

Fleas

Feeding off animals, a flea's diet consists of blood. The average flea can consume up to 15 times its own body weight in blood daily. This insect spends 95 percent of its life as an egg, larva, or pupa and only five percent as an adult. Adult fleas cannot survive or lay eggs without regular blood meals.

Scorpionflies

This small group includes only 400 species, most of which measure around 1 in (2 cm) in length and can be found worldwide. They derive their name from the male tail, which is turned upward like a scorpion's, although it is harmless and carries no sting.

Silverfish

Bristletails

There are about 600 species of bristletails, and as a group they are found worldwide. The silverfish shown above grows to about half an inch (1 cm) in length. These insects do not have any wings and are found scavenging for food in a domestic household.

Grasshopper

Thrips

Thrips love to feed on flowers

Dragonflies

Dragonflies are so called because of their fierce jaws, although they actually use their legs to catch their prey. This insect is ancient and was in existence long before the dinosaurs. The dragonfly's big eyes give them excellent vision.

Dragonfly

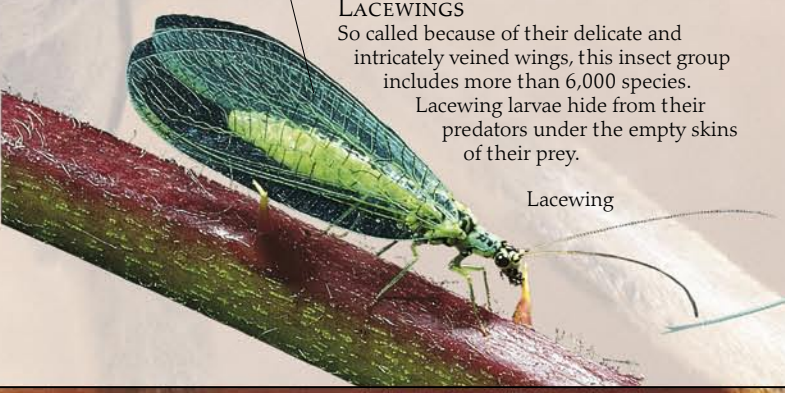
Grasshoppers and crickets

This group contains 17,000 species and also includes the troublesome desert locust. Crickets have long antennae, or feelers, and many species are called "katydids" in North America.

Thrips

These tiny insects measure just 0.1 in (0.25 cm) in length and number around 3,000 species. They live among crops and can cause real damage to harvests. They fly in swarms in sultry weather and are often called "thunderbugs."

Lacewings feed on other insects

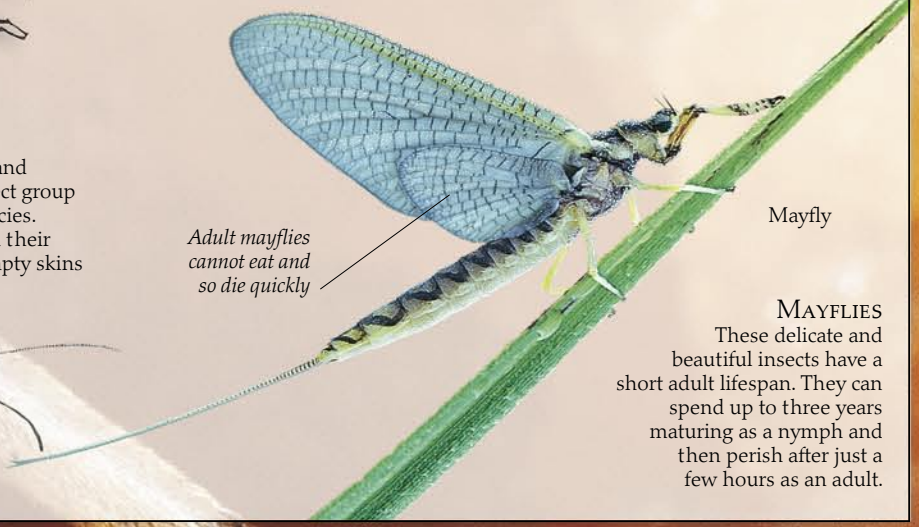


Lacewing

Lacewings

So called because of their delicate and intricately veined wings, this insect group includes more than 6,000 species. Lacewing larvae hide from their predators under the empty skins of their prey.

Adult mayflies cannot eat and so die quickly



Mayfly

Mayflies

These delicate and beautiful insects have a short adult lifespan. They can spend up to three years maturing as a nymph and then perish after just a few hours as an adult.

Find out more

NATURAL HISTORY MUSEUM
One of the best places to learn more about the insect world is at a natural history museum, such as the American Museum of Natural History, shown above. Here you can find exhibitions dedicated to ancient and modern insects, carefully collected and preserved by entomologists—scientists who study insects—down through the years.

To get more insight into the world of creepy crawlies without getting too up-close and personal, check out your nearest natural history museum. Here you can examine preserved insect specimens kept safely at bay behind glass! However, some of the best expeditions can start right at home. Insects are all around us, from the microscopic creatures in your carpet and sofa to the household flies buzzing around the kitchen table. A venture into the yard or your local park can prove equally rewarding in terms of what you may dig up.

USEFUL WEB SITES

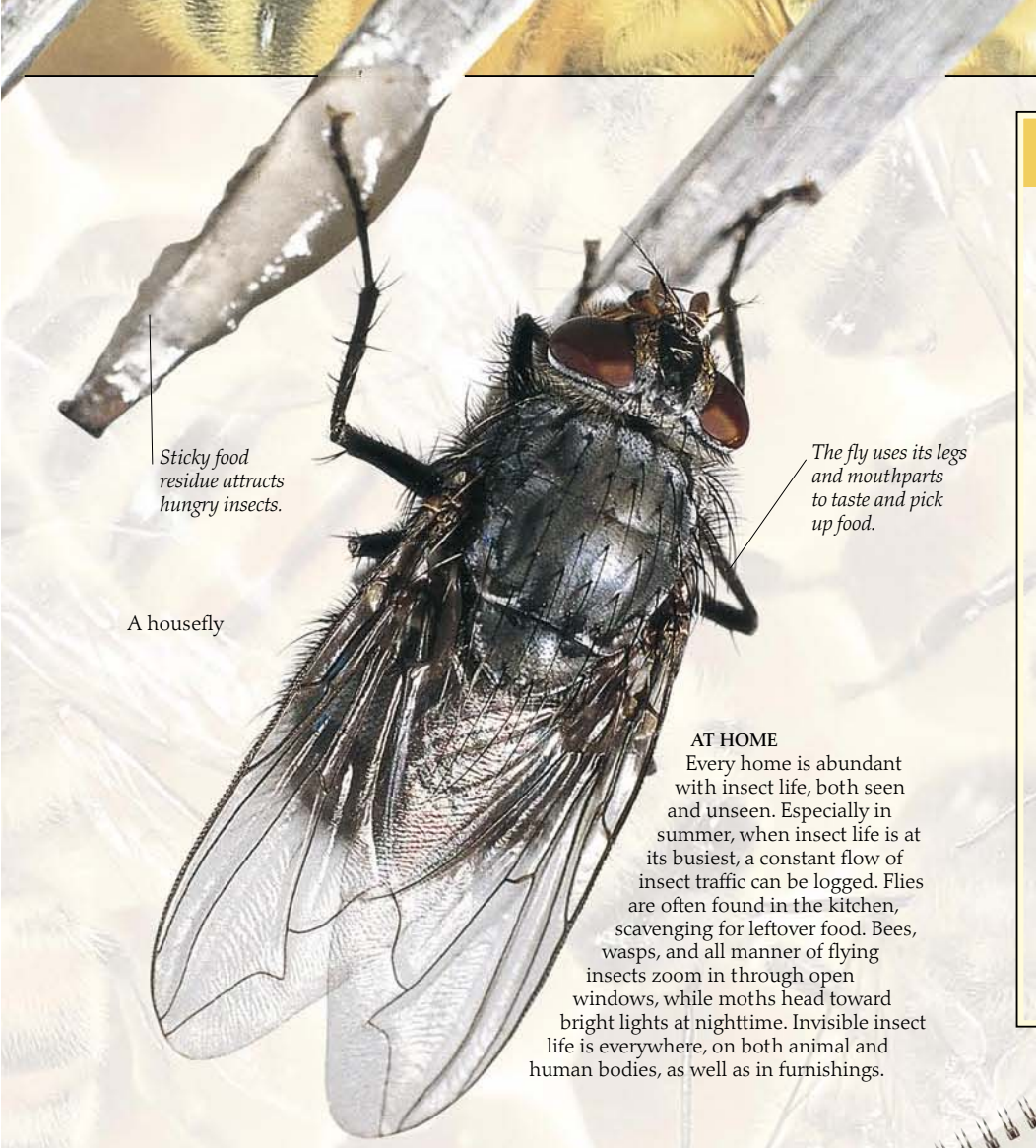
- Bug Bios: Illustrated database of very cool bugs: **www.insects.org**
- National Geographic articles on many types of insect: **news.nationalgeographic.com/news/animals.html**
- Gateway to the world of insects including experiments, information, and photographs: **www.insectworld.com**
- Photographs and descriptions of lots of creepy-crawlies: **www.enature.com/guides/select_Insects_and_Spiders.asp**

A natural history exhibition

NATURAL HISTORY EXHIBITIONS
When you visit a natural history museum, there will usually be a section devoted to entomology, the study of insects. Here you can view preserved specimens of many exotic species from around the globe without ever having to leave your own country! Look out for other exhibitions outside the entomology department that may be organized thematically by environment or historical period. These may also have interesting information about insects.

Stones, wood, and dead leaves often hide busy insect colonies.

IN THE COUNTRY
With around one million species known to science, the countryside is always teeming with a vast array of insect life. Upturn any piece of wood and you will find busy colonies beavering away. If you quietly observe flower clusters during summer, you will see insects in search of nectar.



A housefly

AT HOME

Every home is abundant with insect life, both seen and unseen. Especially in summer, when insect life is at its busiest, a constant flow of insect traffic can be logged. Flies are often found in the kitchen, scavenging for leftover food. Bees, wasps, and all manner of flying insects zoom in through open windows, while moths head toward bright lights at nighttime. Invisible insect life is everywhere, on both animal and human bodies, as well as in furnishings.

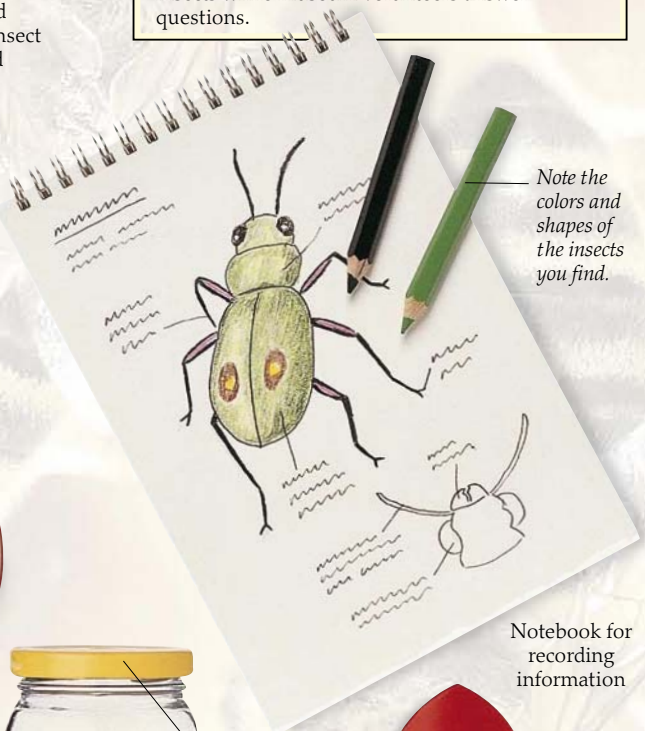
Places to visit

AMERICAN MUSEUM OF NATURAL HISTORY, New York, New York
The insect collection at the American Museum of Natural History is among the largest in the world with 17 million specimens representing 300,000 species. Open one of the museum's many insect drawers to see amazing examples, such as the enormous African goliath beetle.

THE INSECT ZOO AT THE CHILDREN'S ZOO, San Francisco, California
On weekends, insects are brought out from behind their glassed enclosure for the Insects in Action demonstration. Weekdays, see a microcosmic world of giant walkingsticks, millipedes, scorpions, spiders, and more.

THE BUTTERFLY PAVILLION, Westminster, Colorado
Stroll though the tropical conservatory surrounded by more than 1,200 free-flying butterflies. Watch metamorphosis in action as adult butterflies emerge from chrysalids. In the insect center, watch, touch, or look at a rose-haired tarantula from Chile or a Madagascar Hissing Cockroach.

THE O. ORKIN INSECT ZOO AT THE NATIONAL MUSEUM OF NATURAL HISTORY, SMITHSONIAN, Washington, D.C.
The Insect Zoo is a special exhibit hall where visitors can observe live insects and other arthropods. Visitors get to touch and hold live insects while museum volunteers answer questions.



Notebook for recording information

Nets gently capture flying insects for inspection.

Butterfly net

Tiny insects can be seen in detail under a magnifying glass.

Magnifying glass

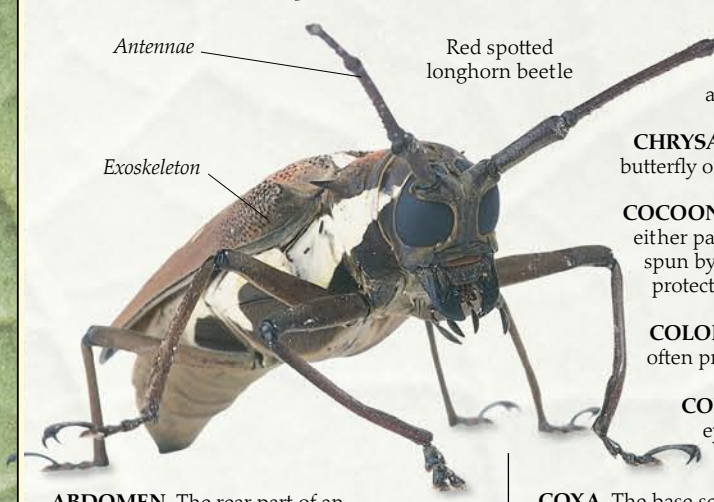
Jar

Trowel for turning over soil

DISCOVERY KIT

Armed with a few simple tools, you can study and record the abundant insect life outdoors. A soft butterfly net allows you to temporarily catch flying insects, which can briefly be placed in a jar while you record information in a notebook. A garden trowel can be used to dig up soil and view insects underground.

Glossary



Red spotted longhorn beetle

ABDOMEN The rear part of an insect's body.

ANTENNAE The sensory organs on each side of the head, also called feelers or horns, and with many possible functions including navigation, taste, "sight," and hearing.

APPENDAGE Any limb or other organ, such as antennae, that is joined to an insect's body by a joint.

ARTHROPOD An invertebrate with a jointed body case, such as an insect or a spider. Insects and spiders are often confused with each other, but the usual characteristsics of an insect are that is has three separate body parts, three pairs of legs, and antennae.

AQUATIC Living or growing in water.

BENEFICIAL INSECTS Any insect that has a lifestyle that is beneficial to humans. Pollinators, recyclers, and insects that preserve the balance of nature by feeding on other insects are all examples of beneficial insects.

CAMOUFLAGE When an insect adopts the color or texture of its surrounding environment to conceal itself from predators or prey.

CATERPILLAR The larva of a moth, butterfly, or saw fly.

CERCI The paired appendages or features, often very long, that spring from the tip of the abdomen in many insects.

CHITIN The tough material that makes up an insect's exoskeleton.

CHRYSALIS The pupa of a butterfly or moth.

COCOON A covering composed either partly or wholly of silk and spun by many larvae as a protection for the pupae.

COLONY A local population, often produced by a single queen.

COMPOUND EYE An eye made up of many separate compartments.

COXA The base segment of a leg by which the leg is attached to the rest of the body.

DIMORPHISM A difference in size, form, or color between individuals of the same species, denoting two distinct types.

ENVELOPE A protective covering made by some wasps for their nests. In common wasps, the envelope is constructed from chewed wood fibers mixed with saliva.

EXOSKELETON The hard outer case that surrounds an insect's body. It is made of curved plates and tubes that fit together at joints.

GRUB A thick-bodied larva with thoracic legs and a well-developed head. A grub is sluglike in appearance.

HIND Relating to the back part, such as hind legs or hind wings.

INVERTEBRATE An animal without a backbone.

LARVA An immature insect that looks different from its parents and often eats different food. When a larva is mature, it undergoes complete metamorphosis.

Centipede, an arthropod but not an insect

LATERAL Concerning the sides of the body, such as lateral eyes, positioned on the side of the head.

MAGGOT A larva without legs and without a well-developed head.

MANDIBLES The first pair of jaws in insects. These are toothlike in chewing insects, pointed in sucking insects, and form the upper jaw of biting insects.

MAXILLA The second pair of jaws that some insects possess.

MESOTHORAX The second or middle part of the thorax, which bears the middle legs and the front wings.

METAMORPHOSIS The series of changes that an insect undergoes between its early life and adulthood. Insects that undergo incomplete metamorphosis change gradually as they grow up. Ones that undergo complete metamorphosis change abruptly, during a resting stage called a pupa. In both cases, growth normally stops once the adult stage is reached.

METATHORAX The third segment of the thorax, or chest region, which bears the hind legs and the second pair of wings. Sometimes it appears as part of the abdomen.

MOLTING In insects, the process of shedding the exoskeleton.

MOTTLED A surface with blotchy color variation or difference.

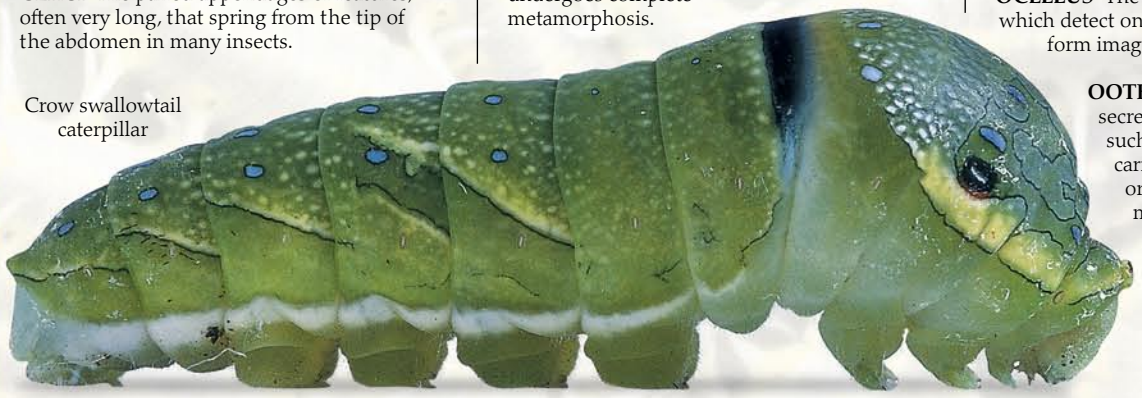
NECTAR The sugary liquid secreted by many flowers and on which some insects feed.

NYMPH The name given to the young stages of those insects that undergo incomplete metamorphosis. The nymph is usually quite similar to the adult except that its wings are not fully developed. It normally feeds on the same kind of food as the adult.

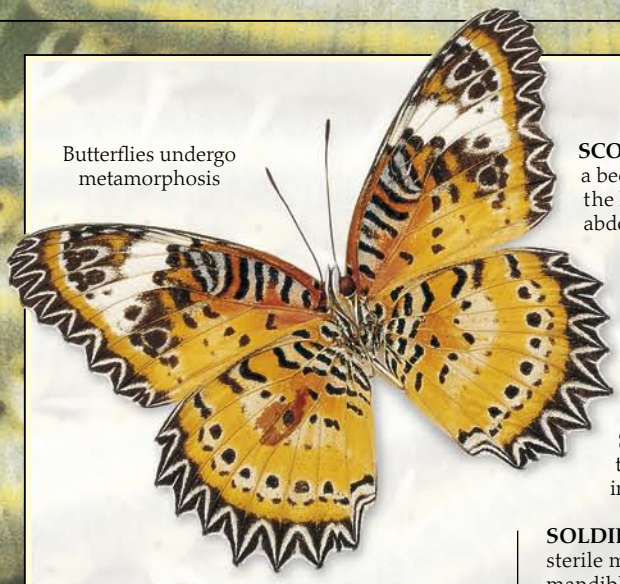
OCELLUS The lateral simple eyes in larvae, which detect only light and dark but cannot form images.

OOTHECA An egg case formed by secretions from the genital glands, such as the purselike structure carried around by cockroaches or the spongy mass in which mantids lay their eggs.

OVIPOSITOR The tubular egg-laying apparatus of a female insect. It is concealed in many insects.



Crow swallowtail caterpillar



Butterflies undergo metamorphosis

PALP A segmented leglike structure. Palps have a sensory function and play a role in tasting food.

PARTHENOGENESIS Egg development without fertilization.

PARASITE An organism that spends part or all of its life in close association with another species, taking food from it but giving nothing in return. Ectoparasites live on the outside of their hosts, while endoparasites live inside the host's body. A louse is an ectoparasite.

POLLEN Fertilizing powder or grains produced by a flower and often carried from plant to plant by traveling insects attracted to the flowers by bright colors and nectar.

PREDATOR An insect that preys on or hunts another animal to kill it for food.

PROBOSCIS Any extended mouth structure, usually applied to the mouth of flies, the beak of bugs, the tongue of butterflies and moths, and sometimes the mouth of long-tongued bees.

PROLEG An insect larva's abdominal leg, distinguished from a thoracic or "true" leg. Can specifically refer to the fleshy, stumpy legs on the hind region of a caterpillar.

PROTHORAX The first part of the thorax.

PUPA The resting inactive stage of complete metamorphosis, between larva and adult.

QUEEN CELL The special cell in which a queen honey bee develops from the egg to the adult stage.

RAPTORIAL Predatory, or relating to predatory life. Can refer to bodily features adapted for seizing and grasping prey, such as the front legs of a mantis.

ROSTRUM A snout or beaklike feature; applied especially to a piercing mouthpart.

SCAVENGER An insect that searches for food among human waste or feeds on dead plants or animals.

SCOPA The pollen-collecting apparatus of a bee, whether it be the pollen basket on the leg or a brush of hairs on the abdomen.

SEGMENT One of the rings or divisions of the body, or one of the sections of a jointed limb.

SERRATED A sharply toothed surface, much like a saw.

SOCIAL Insects such as ants or bees that live in organized communities of individuals.

SOLDIER In termites and ants, soldiers are sterile males or females with large heads and mandibles, or jaws. Their role is to protect and guard the colony from intruders and predators.

TARSUS The foot or jointed appendage at the end of the leg.

TIBIA The fourth joint of an insect's leg.

THORAX The second or intermediate part of the body, corresponding roughly to the chest region in humans. The thorax bears the "true" legs and wings and is made up of three separate regions: the prothorax, the mesothorax, and the metathorax.

TRACHEAE Tubes in the body of an insect that transport oxygen around.

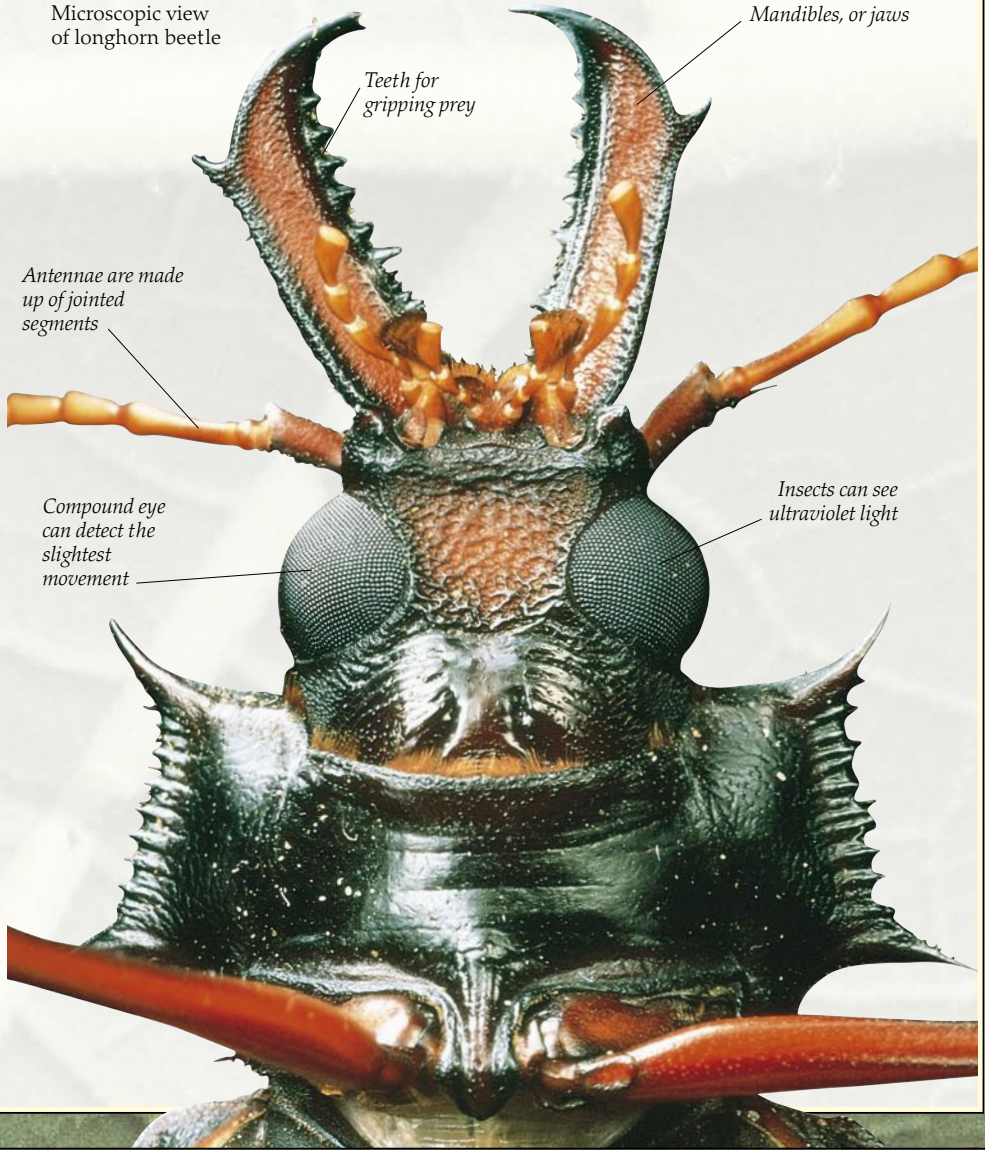
TRUE FLIES Those flies that have only one pair of wings. The remnants of a second pair of wings function as stabilizers or airspeed detectors during flight.

TYMPANUM The vibratory membrane in various parts of an insect's body that serves as an eardrum.

ULTRAVIOLET Beyond the violet end of the light spectrum, ultraviolet is invisible to most mammals, but visible to most insects.

WORKER A member of an insect colony that is sterile (cannot breed) and whose duties include finding food.

Microscopic view of longhorn beetle



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