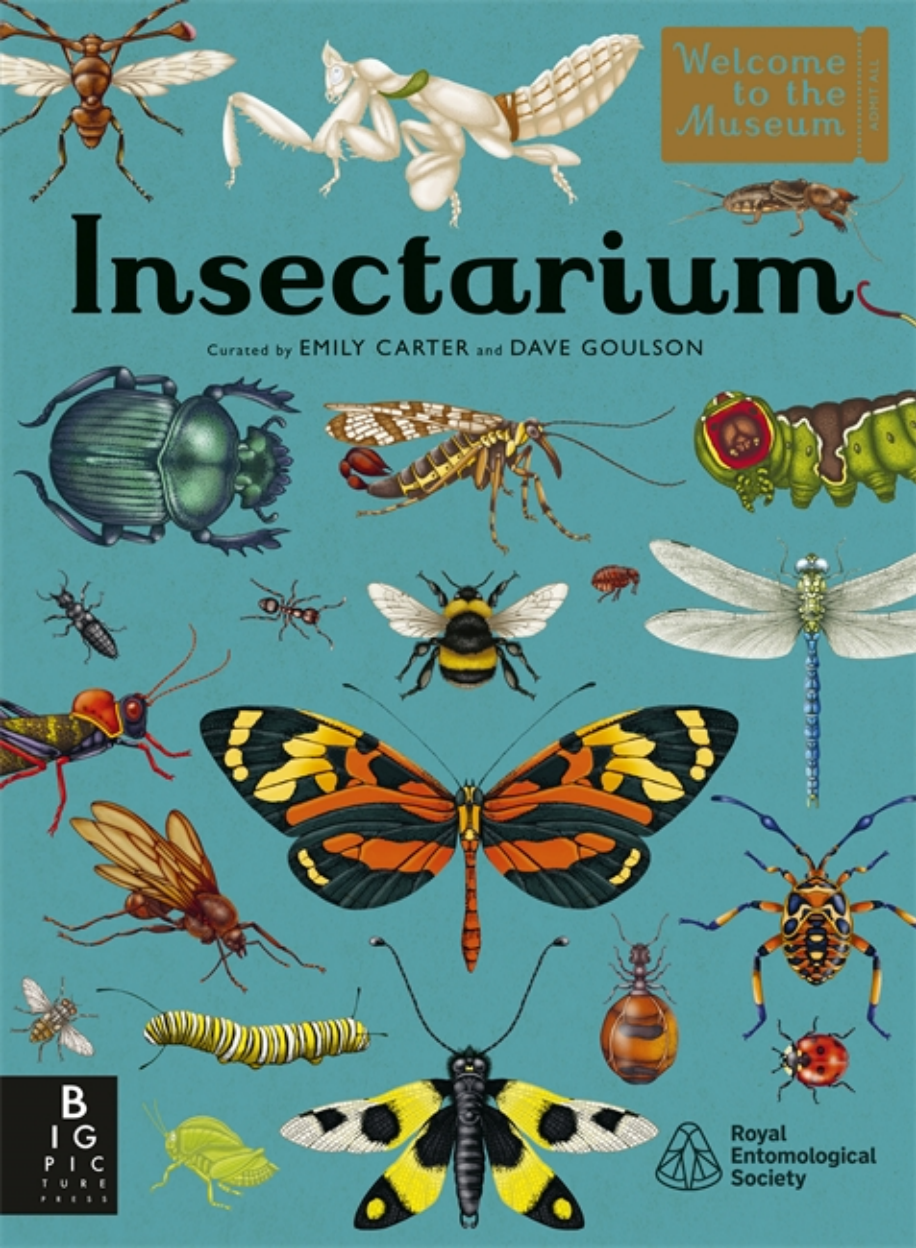


Insectarium

Curated by EMILY CARTER and DAVE GOULSON

BIG PICTURE PRESS

Royal Entomological Society

Entrance

Welcome to Insectarium

Between the pages of this book lurk the world's most beautiful, fascinating and peculiar insects. Amazingly diverse, insects have evolved into an incredible array of shapes and colours. More than a million species have been named so far, but, astonishingly, there might be another four million insect species awaiting our discovery.

Tour the galleries and learn how insects evolved in an ancient time, long before the dinosaurs. For most of the history of Earth, insects have been the dominant life form. They are found everywhere on land and in freshwater, from the Arctic to the hottest deserts, and from lakes to mountaintops. Discover the many vital ecological roles they fill, from pollinating wildflowers and crops to disposing of corpses and cowpats. Many people are not especially fond of insects but, love them or loathe them, we could not survive without them.

The insects in these pages live in different places all over the world. Some can only be found in tropical climates, while others live in meadows, woodlands or even in our parks and gardens at home. See how many you can find in your local patch. We often do not look down and take time to appreciate the wonderful diversity of these small creatures that live all around us, scurrying along the ground, burrowing in the soil, or buzzing through the air. Literally thousands of different types of insect can be found in a suburban garden, if you spend enough time looking. A small garden pond will attract pond skaters, backswimmers, water beetles and dragonflies that have changed little from those that swooped through our skies 300 million years ago. There is so much that we do not yet know about many insects; you too could make new discoveries. Enter *Insectorium*, and discover the secret world of the insects.

Butterflies

True flies

Scorpionflies

Fleas

Wasps

Ants

Bees

Beetles

Twisted-wing flies

Moths

Lacewings

Mantises

Grasshoppers

Earwigs

LARVAE AND
PUPAE EVOLVED

Lice

Booklice

True bugs

Termites

Stick insects

Dragonflies

Cockroaches

WING-FOLDING EVOLVED

Mayflies

Thrips

Bristletails

Silverfish

Proturans

WINGS EVOLVED

Dipterans

PRIMITIVE WINGLESS INSECTS

Most insects evolved a very long time ago, and we have few fossils of these early insects, so the exact shape of this tree is unknown.

Insect Evolution

Insects were amongst the first animals to live on land and arrived soon after the earliest primitive plants. By the Carboniferous period (350 million years ago) insects had evolved a waterproof skin so that they would not easily dry out on land. They multiplied and diverged into many forms, including numerous types of cockroach (Dictyoptera), grasshopper and cricket (Orthoptera), plus many others.

Insects were the first animals that evolved the ability to fly. During the Carboniferous period, primitive mayflies and dragonflies soared through forests of tree ferns. This period of Earth's history had higher atmospheric oxygen concentrations than today, allowing insects to grow larger, including dragonfly-like creatures with a wingspan of 70 centimetres. Insects had the skies to themselves for about 170 million years, until pterosaurs evolved. Being able to fly enabled insects to colonise new habitats, migrate to avoid cold winters, swiftly evade predators or swoop down on prey.

At the end of the Carboniferous, beetles (Coleoptera) appeared. These were the first insects to show complete metamorphosis – whereby the insect goes through an immature, larval stage that looks entirely unlike the adult (see page 68). This seems to be an effective strategy because the large majority of insects found today have this type of life cycle.

The final major event in insect evolution was a huge adaptive radiation, when lots of new species appear very quickly, coinciding with the first appearance of flowering plants (angiosperms) about 150 million years ago. Angiosperms started to produce colourful, scented flowers and attracted insect pollinators with the prospect of lots of nectar. This relationship seems to have enabled both angiosperms and insects to multiply. Our previously green planet burst into colour.

To this day, insects remain the most successful creatures on planet Earth. There are about 1.4 billion individual insects for every human. We are seriously outnumbered!

Insectarium

What is an Insect?

The earliest insects appeared on Earth about 480 million years ago. To put this in perspective, we humans have been around for barely one million years, and the first dinosaurs appeared 230 million years ago.

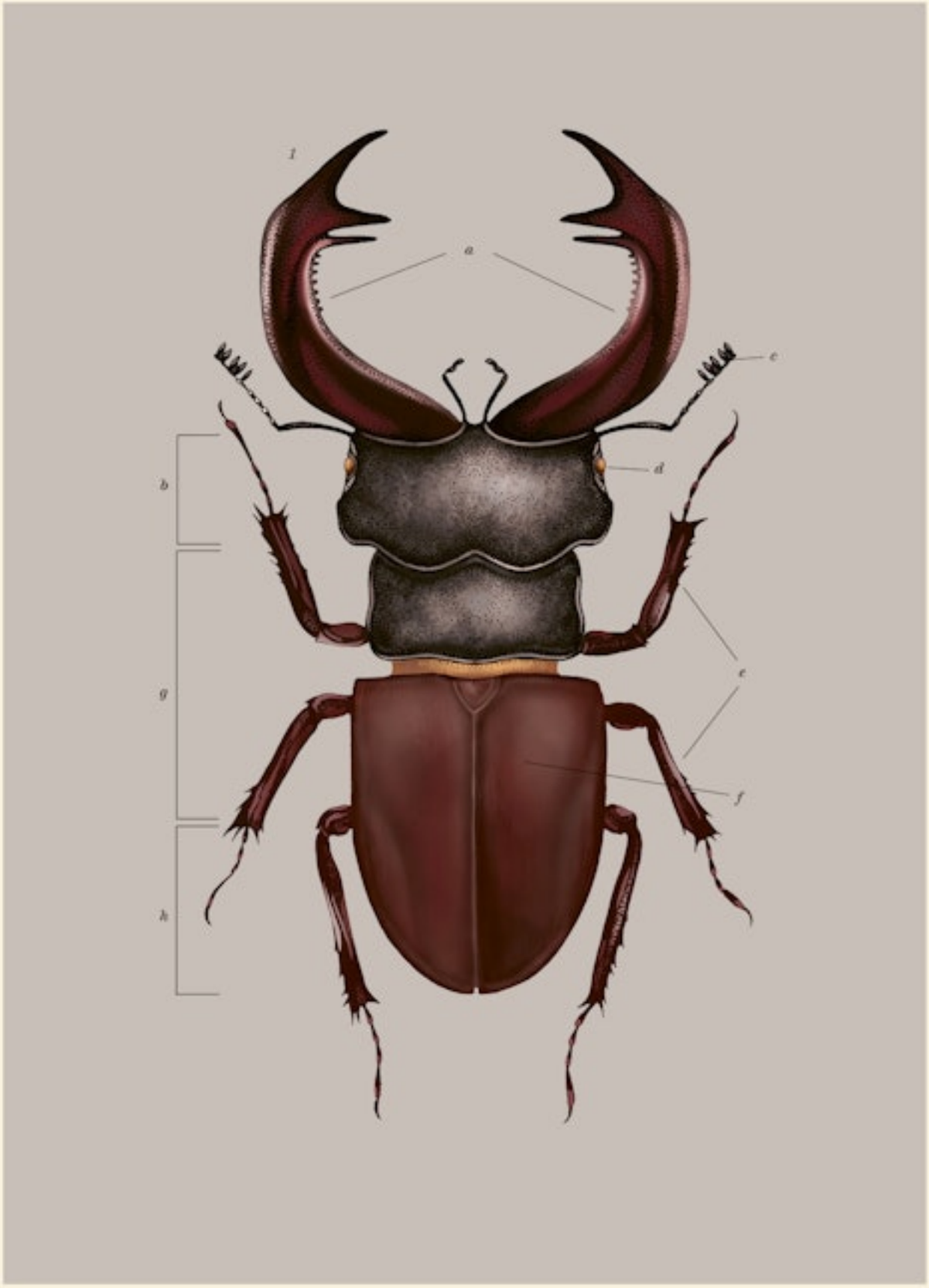
Insects are part of a larger group of creatures including millipedes, centipedes, spiders, scorpions, crabs and shrimps, collectively known as the arthropods. They all have an external skeleton: a more or less rigid 'shell' with muscles attached on the inside. To grow, arthropods have to repeatedly shed their skeleton, which is a delicate business and leaves them soft and vulnerable for a short time.

Insects are the only arthropods to have three pairs of legs. Their body is divided into three segments: the head, thorax and abdomen. The head has eyes, a mouth and a pair of sensory antennae that taste the air. The legs, and wings if present, are attached to the thorax, which is often filled with muscles to move them. The abdomen contains the gut and reproductive organs. Other arthropods, including arachnids, crustaceans, millipedes and centipedes, are not considered insects due to differences in leg count, antennae presence and body structures.

Nearly all insects start as eggs. Most undergo complete metamorphosis, which means they completely change their physical appearance, transforming from a larva to the adult insect by way of a pupal phase (see page 68). In more primitive insects, such as mantises, grasshoppers, true bugs and stick insects, the life cycle is similar to many other arthropods – the adult female lays eggs, which hatch into 'nymphs'. These nymphs look roughly similar to the adults, other than being much smaller and with tiny wing buds rather than wings. All arthropods must shed their exoskeleton (skin) to grow, so the nymphs proceed through, typically, five to seven stages until they reach adult size. This life cycle is known as 'incomplete metamorphosis'.

Key to plate

1: **Stag beetle (male)**
Lucanus cervus
Length: Up to 70mm
This stag beetle has the characteristic features of insects: three body segments, one pair of antennae, three pairs of legs and two pairs of wings, although the hind wings are kept hidden beneath the modified and hardened forewings.
a) jaws
In males, the huge jaws are used for fighting other males rather than for feeding. Females are easily distinguished as their jaws are relatively small.
b) head
This contains the brain, and has sensory organs attached.
c) antenna
Antennae detect chemicals in the air. They may be used to sniff out food or mates.
d) compound eye
Insect eyes are made up of hundreds of hexagonal facets. Some insects that need better vision, such as dragonflies, have much larger eyes.
e) legs
The feet are tipped with claws for gripping.
f) elytron
In beetles, the first pair of wings have evolved into a hardened case, under which the hind wings are folded.
g) thorax
This is largely filled with muscle to power the wings.
h) abdomen
This contains important organs like the digestive and reproductive systems.



For Finn, Jedd and Seth,
long may the insects fill your world. – D.G.

For my five-year-old self, who was fascinated by the intricacy and beauty of insects.
I hope this book inspires many future entomologists! – E.C.

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Welcome to the Museum

ENTER HERE

Insectarium

Illustrated by EMILY CARTER

Written by DAVE GOULSON

B P P

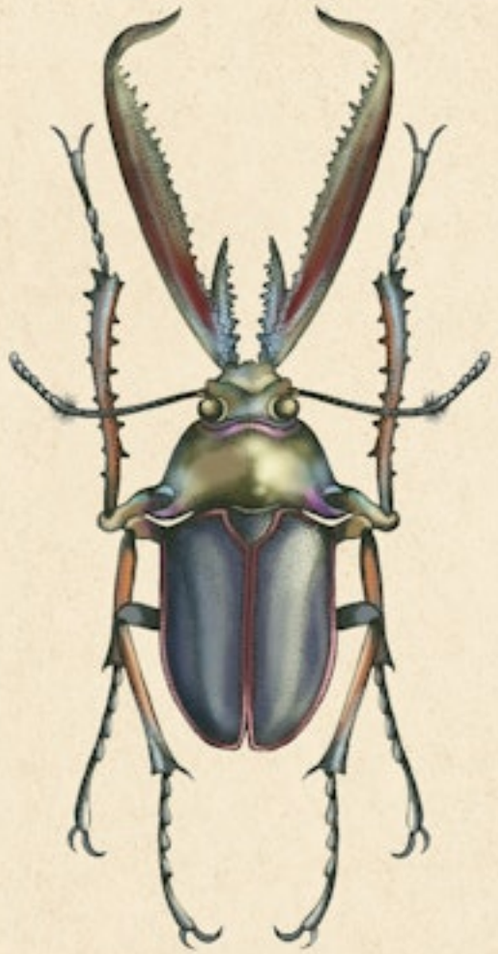
INSECTARIUM

Gallery 1

Ancient Insects

Dragonflies, Damselflies and Mayflies
Cockroaches and Termites
Mantises
Grasshoppers and Crickets
Stick Insects and Earwigs
Habitat: Ponds, Streams and Rivers

Preface



Insects are amazing. They make up a huge proportion of all life on Earth - about a half of all species are insects. Not only are insects beautiful to look at (and come in an astonishing variety of colours, shapes and sizes) but insects also play vital roles for us. They are a key part of the biodiversity around us.

Bees are important for our food – honey bees provide us with honey, and there are many other bees that pollinate our crops and orchards. Lots of other insects are valuable pollinators, including hoverflies, moths and wasps. Insects also provide us with a natural pest control service and are food for other animals, including birds and bats. But, of course, insects can also cause us problems, as pests of crops, and by bringing disease (some mosquitoes spread malaria, and fleas can carry bubonic plague).

There are increasing concerns about the loss of insects due to the loss of their habitats and the use of harmful pesticides. The entomologist E.O. Wilson ominously said, "If we were to wipe out insects alone on this planet, the rest of life and humanity with it would mostly disappear from the land. Within a few months."

In some countries, such as the UK, there are insect monitoring programmes. The monitoring of butterflies and moths in the UK has been going on for about 50 years, providing long-term information about which species are increasing and which are declining. Research on insects provides us with information to reverse declines. The large blue butterfly (*Phengaris arion*) went extinct in the UK in the 1970s, but was successfully re-introduced once its complex relationship with the red ant *Myrmica sabuleti* was understood.

The Royal Entomological Society has a vision to enrich the world with insect science. Founded in 1833, we are one of the world's oldest organisations devoted to insect science. We are a thriving community of Members and Fellows, and past Fellows include eminent scientists such as Charles Darwin, Alfred Russel Wallace and Miriam Rothschild.

Royal Entomological Society

Professor Jane K Hill, President of the Royal Entomological Society

Dragonflies, Damselflies and Mayflies

The ancestors of dragonflies were the first creatures on Earth to fly, around 380 million years ago. On hazy summer days it is not uncommon to see dragonflies and damselflies (Odonata) and their cousins the mayflies (Ephemeroptera) flitting across a pond or river, their wings catching the sunlight. Dragonflies zoom at high speed, damselflies flit furtively along the banks, while mayflies hover in swarms over the water. There are about 5,600 species of dragonfly and damselfly, and 3,100 species of mayfly.

Dragonflies are attractive, large and colourful insects, distinguishable by the way they hold their wings at right angles to their body when resting. Damselflies tend to be more slender and fold their wings behind their backs when resting. Both are active during the day and use their excellent eyesight to spot smaller flying insects which they catch with their legs, and often consume mid-air.

Dragonflies lay their eggs in water and the aquatic nymphs emerge as plain brown creatures. They are ambush predators, waiting motionless until their prey comes close. Then, using jaws mounted on a telescopic 'mask', their mouthparts shoot out to capture insects, tadpoles or even small fish. Development can take several years, but when fully grown the nymphs haul themselves out of the water, often using plant stems. The nymph sheds its aquatic exoskeleton, emerging into its impressive winged form. Discarded old, brown skins are a common sight around pond edges.

Compared to dragonflies, mayflies are rather feeble fliers. Their nymphs are also aquatic and tend to graze on algae. The adults are famously very short-lived, lasting from just a few hours to a few days. Incredibly they do not feed; indeed, they do not even have a mouth. Their sole job is to mate, disperse and lay eggs. Because of the short lifespan of the adult, many thousands of mayflies tend to emerge at once, usually on a day in late spring or summer. They can form huge shimmering swarms which rise and fall above the water. The males race to mate with females as soon as they emerge.

Key to plate

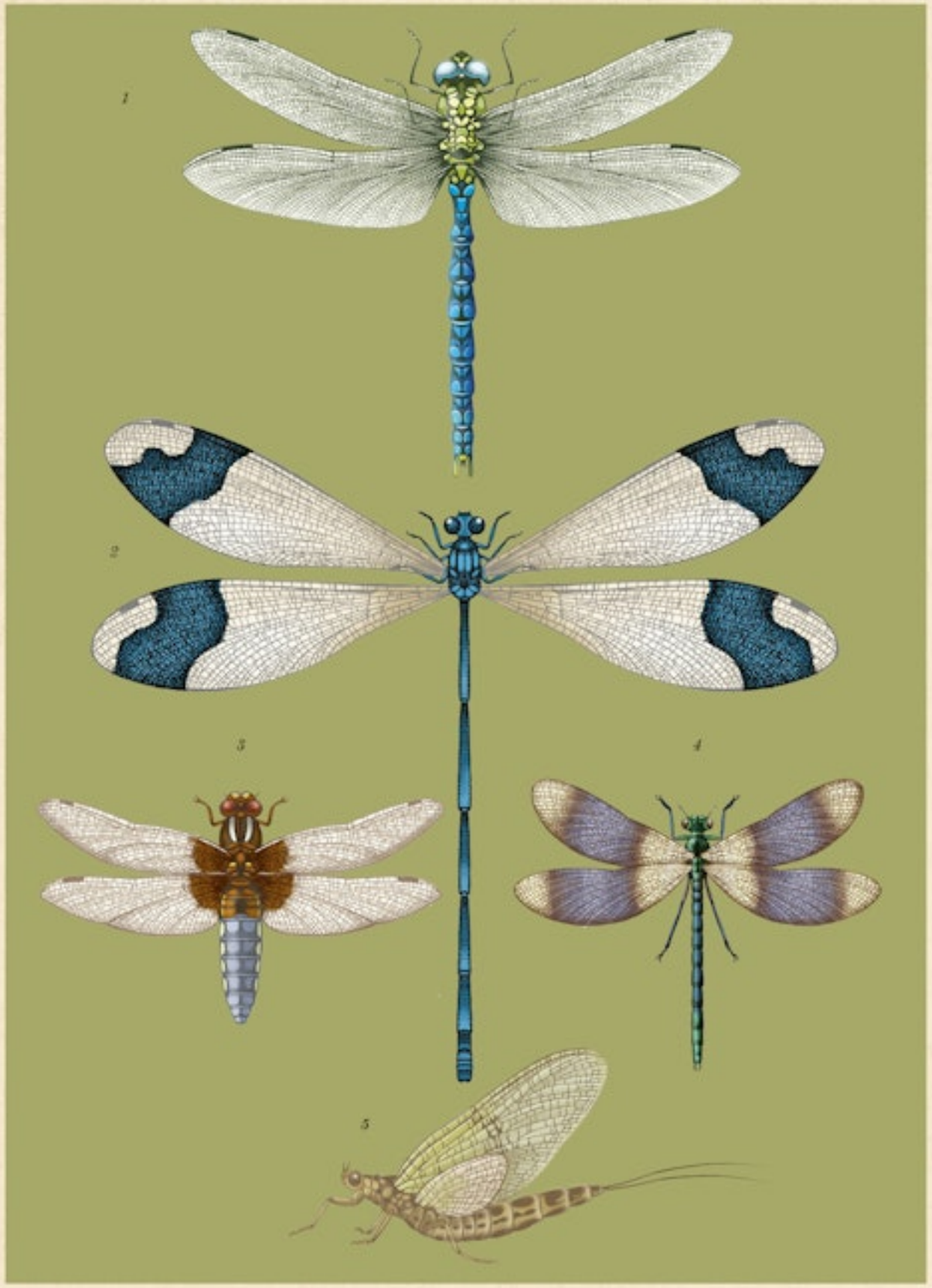
1: **Emperor dragonfly**
Anax imperator
Wingspan: Up to 110mm
This dragonfly tends to fly quite high and fast, and spends most of its time hunting for larger insects such as butterflies and damselflies.

2: **Helicopter damselfly**
Megaloprepus coerulatus
Wingspan: Up to 190mm
The largest of the damselflies, this insect specialises in plucking orb-web spiders, or their prey, from webs.

3: **Broad-bodied chaser (male)**
Libellula depressa
Wingspan: Up to 70mm
This broad dragonfly has 'sexual dimorphism' which means the sexes look quite different. The males are pale blue and the females are brown and yellow.

4: **Beautiful demoiselle (male)**
Calopteryx virgo
Wingspan: Up to 70mm
This damselfly is so named because of its iridescent colouration. The male has a metallic blue-green body and dark wings while the female has a green body and brown wings.

5: **Green drake mayfly**
Ephemera danica
Wingspan: Up to 80mm
One of the larger mayfly species, the green drake mayfly larvae is a filter feeder, sieving fine organic particles from the water.
Mayflies are very sensitive to water pollution, and are often used as an indicator of water quality.



Cockroaches and Termites

There are about 8,500 known species of Dictyoptera worldwide, mostly large, weak-flying insects which lay batches of eggs in protective cases called an oothecae. The group is made up of cockroaches, termites and mantises.

Cockroaches are a tough and adaptable bunch; it is often suggested that they will long outlast us humans. Despite generally being considered unwelcome household pests, the large majority of cockroach species are harmless creatures that live in the wild. They are particularly common in forests where they feed mainly on dead and decaying plant material, helping to recycle the nutrients.

Some cockroaches are sociable creatures preferring to live in groups. Some have even evolved into ant-like termites. Termites are known as eusocial insects (along with ants, bees and wasps), meaning that they live in colonies in which reproduction is carried out by a few specialist individuals (queens) and most individuals are workers which never have their own offspring. Incredibly, termite queens can lay up to 7,000 eggs in a single day, and can live for 50 years or more, making them the longest-lived insect that we know of. They are also likely to hold the record for the most offspring, perhaps laying more than 100 million eggs in their lifetime, although no-one has ever counted. A single colony may have several million workers at any one time.

Termites are remarkable creatures in many ways, not least because they have a special stomach filled with symbiotic microbes that help them to digest the dead leaves and wood they eat. This means they play an important role in recycling nutrients in the soil. However, just as cows release methane (a powerful greenhouse gas) as they ferment plant material in their stomach, so do termites. They are estimated to produce about 10 per cent of all atmospheric methane.

Key to plate

1a: **Magnetic termite**
Amitermes meridionalis
Length: Up to 6mm
Found in Northern Australia, this termite species is tiny and almost blind.

1b: **Magnetic termite mound**
Termite nests are made of mud, wood or their own faeces. The mounds can be over 10 metres tall and are built with air ducts that act like air-conditioning systems. The magnetic termite builds flattened, gravestone-like mounds up to 4 metres tall that are always aligned north-south, so that only a narrow edge is facing the sun during the hottest part of the day.

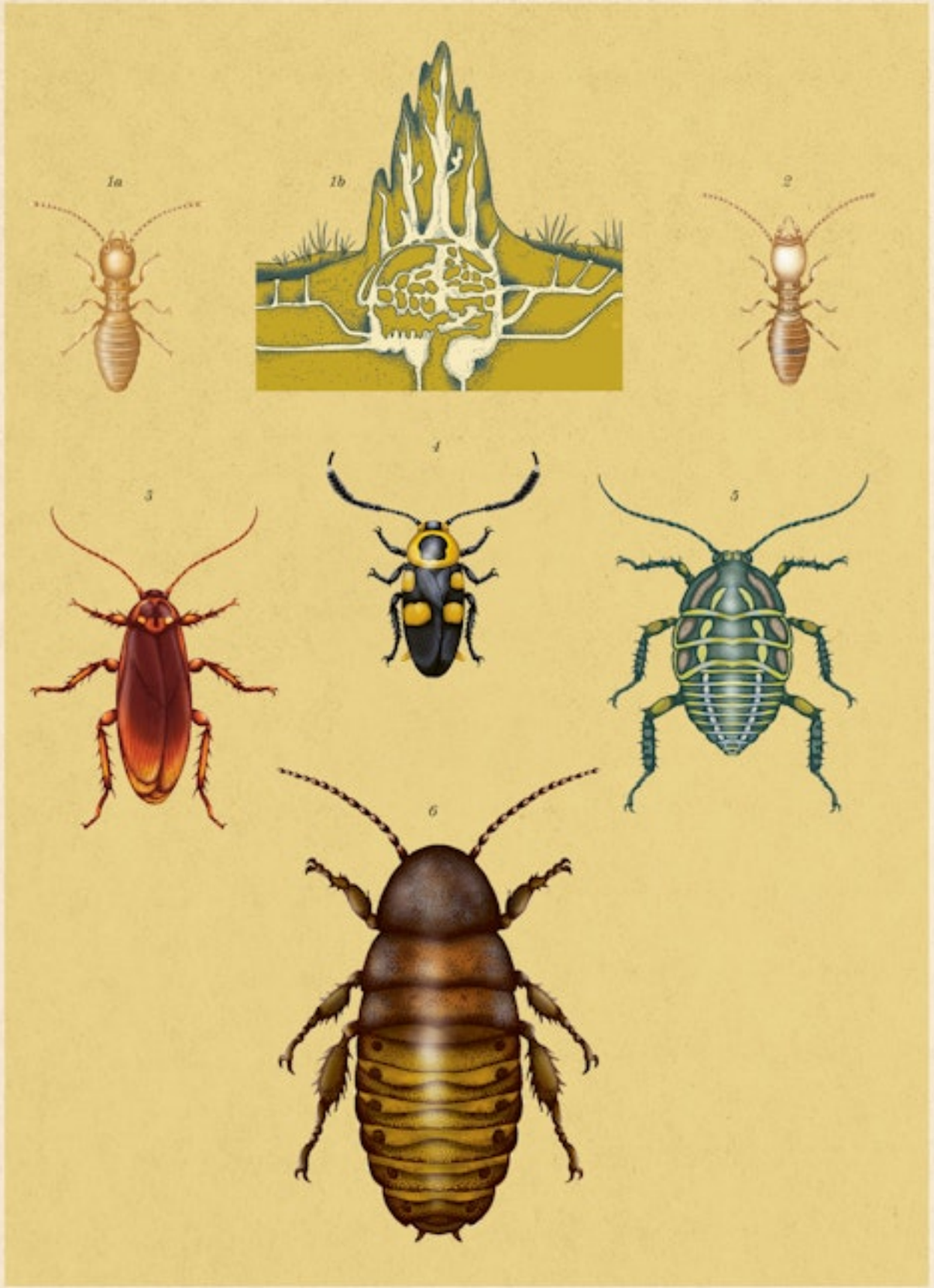
2: **Suicide bomber termite**
Neocapritermes taracua
Length: Up to 8mm
Termites have many natural predators, including ants. Most termite species have a soldier caste – individuals with large jaws who defend the nest. In this species, old workers develop bluish sacs inside their body containing poison. When attacked these termites burst open, killing themselves in the process but releasing a toxic goo that can also kill many of their enemies.

3: **American cockroach**
Periplaneta americana
Length: Up to 40mm
This classic roach is often found infesting buildings. Despite the name, this species originated in Africa, but with the accidental help of humans has spread to all the warmer parts of the world.

4: **Thyrsocera spectabilis**
Length: Up to 25mm
A colourful cockroach found in the rainforests of South East Asia. As with many insects living in tropical climates, very little is known about its biology.

5: **Mardi Gras cockroach**
Polyzosteria mitchelli
Length: Up to 50mm
The striking blue and yellow colours of this Australian cockroach act as a warning that it will squirt out a foul-smelling liquid if attacked.

6: **Madagascar hissing cockroach**
Gromphadorhina portentosa
Length: Up to 75mm
These slow-moving insects live in groups inside rotting logs in their native Madagascar. When alarmed, they create a hissing noise by expelling air through the small breathing holes along their sides.



Mantises

Mantises are the more glamorous wing of the Dictyoptera insect order, found most commonly in the tropics. Their stunning camouflage ranges from beautiful flowers to trembling leaves. That beautiful exterior is deceiving, however, as they are fascinating ambush predators. They catch their prey – mainly other insects – with their strong front legs which are equipped with rows of sharp spines. Gruesomely, their prey is consumed alive. While waiting for prey, mantises sit in a characteristic position with their front legs folded, giving rise to their common name of praying mantis. Mantises have large eyes situated on either side of their triangular head. Their flexible neck allows them to track the movement of approaching prey while moving only their head.

Courtship is a dangerous business for mantises as the male is much smaller and weaker than the female. Males of many species perform an elaborate swaying dance by way of courtship, but even so, if the female is hungry, she may prefer to eat him rather than mate with him. Sometimes she does both.

After mating, the female lays a batch of eggs which she covers with a quick-setting foam to create a tough protective case, known as an ootheca. The tiny young mantises that eventually emerge appear very delicate but are ferociously cannibalistic.

Key to plate

1: **Ghost mantis**
Phyllocrania paradoxa
Length: Up to 50mm
This African mantis bears an uncanny resemblance to a dried, twisted leaf, complete with what appear to be leaf veins. So as long as it remains motionless, this species is almost impossible to spot.

2: **Orchid mantis**
Hymenopus coronatus
Length: Up to 75mm
This beautiful pink and white mantis mimics the petals of a flower. This helps the mantis avoid predation by birds, and, at the same time, attracts flower-visiting insects such as butterflies and bees which the mantis consumes.

3: **Spiny flower mantis**
Pseudocreobotra wahlbergi
Length: Up to 40mm
This small African mantis resembles an elaborate creamy flower when motionless. If the camouflage fails and the insect finds itself under attack from a predator, it can flash large eyespots on its wings which gives the impression that it is a much larger creature.

Grasshoppers and Crickets

The soothing sounds of grasshoppers and crickets are often synonymous with warm summer days and nights. Incredibly, the Orthoptera group of insects, which also includes locusts, katydids and weta, may have been the first creatures to sing on Earth, some 350 million years ago. Each of the 24,000 species that make up this group has a distinctive song to ensure they only attract females of their own species.

Many of this group sing to attract a mate, with grasshoppers rubbing their hind legs against their forewings to create their song, while crickets rub their forewings together. Grasshoppers tend to be active and sing in the day, while crickets are usually nocturnal. Since they move around at night, most crickets have very long antennae so that they can feel their way.

Aside from singing, another of the most notable attributes of this group is their enlarged hind legs for jumping. Grasshoppers can jump 80 centimetres or more, the equivalent of a human leaping the length of a football field. Their forewings are narrow, protecting larger and more delicate hindwings that fold out for flight. Most are not particularly accomplished fliers, usually hopping to take off and soon crashing clumsily to the ground. However, a few, such as locusts, can form enormous swarms which fly for hundreds of kilometres.

Key to plate

1: **House cricket**
Acheta domesticus
Length: Up to 21mm
In its native Asia, house crickets are kept as pets for their cheerful song and also to bring good luck. Highly nutritious, they are often bred in large quantities for human food, and eaten dry-roasted. This species is also reared for reptile food.

2: **Wetapunga**
Deinacrida heteracantha
Body length: Up to 100mm
Amongst the heaviest insects in the world (it weighs up to 70 grams – the weight of a small apple), this is one of eleven weta species found in New Zealand. The population of these gentle, slow-moving herbivores has declined sharply, mainly due to predation by introduced rats and cats.

3: **Stone grasshopper**
Trachypetrella andersoni
Length: Up to 55mm
Grasshoppers are the favourite food of many birds, and so have evolved remarkable camouflage. This large, round grasshopper avoids being eaten thanks to its uncanny resemblance to a stone. It blends in perfectly in the stony arid regions of southwest Africa where it lives.

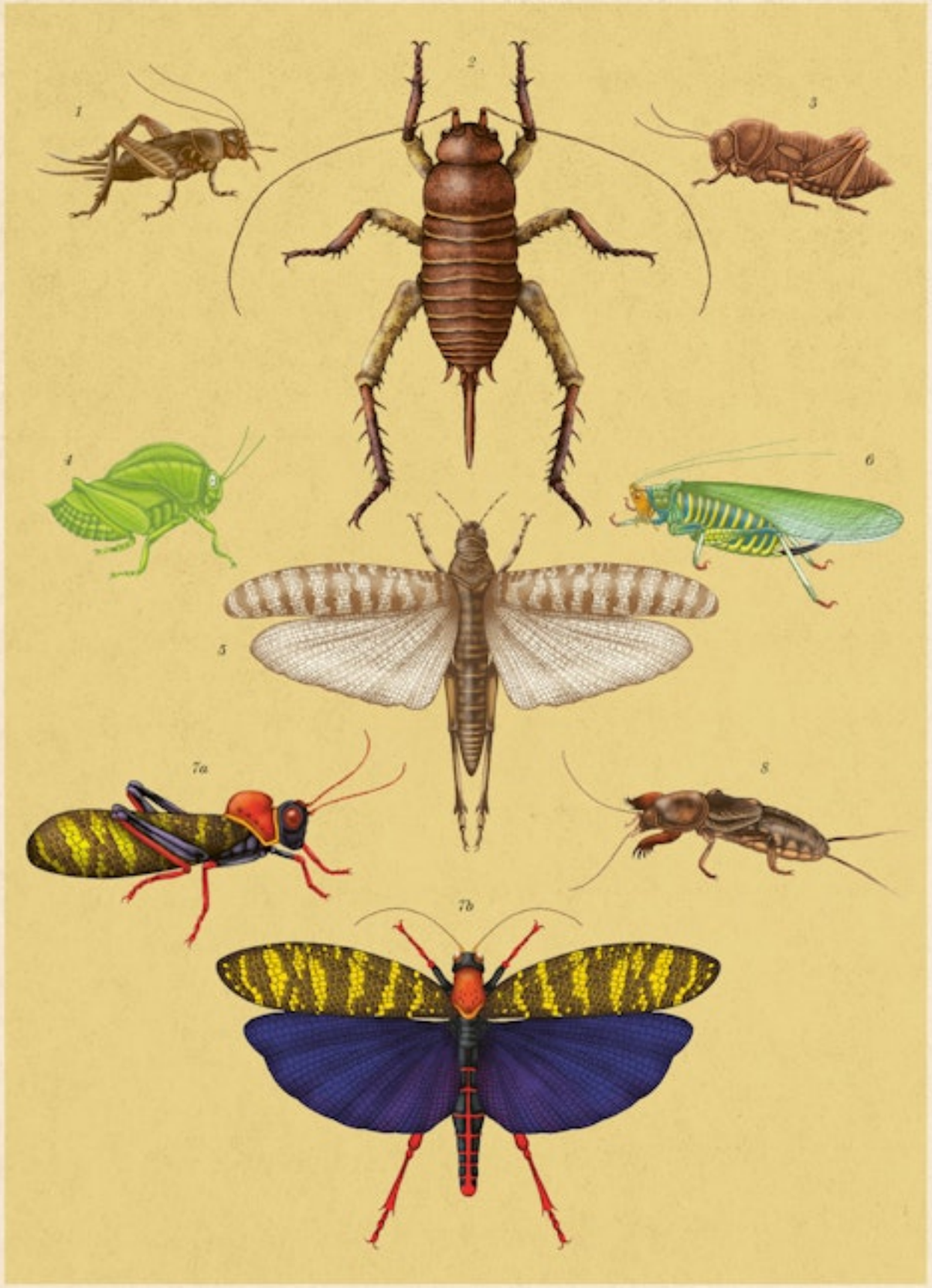
4: **Hooded grasshopper**
Teratodes monticollis
Length: Up to 40mm
The extended front section of the thorax of these insects gives them a remarkable resemblance to a leaf.

5: **Desert locust**
Schistocerca gregaria
Length: Up to 90mm
This large grasshopper is known for its swarms during which millions of individuals destroy crops, causing famine. When populations are low the locusts are green, camouflaged and sedentary. After heavy rains, when conditions are favourable for rapid population growth, they switch to a colourful yellow and black phase and become highly mobile.

6: **Rainbow katydid**
Vestria sp.
Length: Up to 70mm
This is a supremely colourful cricket from South America. Its bright colours warn that, if attacked by a predator, it will release toxic chemicals.

7a and 7b: ***Monochidium lunum***
Length: Up to 110mm
This attractive grasshopper species from South America uses black- and yellow-striped forewings and bright red legs to advertise that it is poisonous to eat. It then reveals violet hindwings when it takes off.

8: **European mole cricket**
Gryllotalpa gryllotalpa
Length: 70mm
This creature displays a striking likeness to a mole, an example of convergent evolution – whereby unrelated creatures evolve similarities due to a common lifestyle. Mole crickets are omnivores, eating roots, tubers and insects as they burrow. The churring song of males is amplified by a special underground chamber and can be heard at up to 300 metres.



Stick Insects and Earwigs

Stick insects (Phasmida) are the ultimate masters of disguise. They have evolved to shed or reduce their wings to seamlessly blend in with the twigs and leaves they mimic. These elusive creatures often call the tropics home. Some have grown to astonishing proportions, and are recognised as the longest known insects. Usually sedentary, these herbivores move slowly and sway as they walk, giving the impression of a twig waving gently in the wind.

It is not just the adults who perform this remarkable art of mimicry because the eggs of many species mimic plant seeds. As they grow, the young nymphs have an impressive ability to regrow lost limbs. Some species exist in populations that are predominantly or entirely female, breeding 'parthenogenetically'. This means the females produce offspring without mating.

Earwigs are related to stick insects but are perhaps a less-loved group of insects. They are often falsely thought to have a penchant for entering human ears! Earwigs are omnivores, sometimes feeding on ornamental flowers, fruit blossom and bruised fruits, which is the reason they are often regarded as pests. However, in their role as natural enemies of crop pests such as aphids, they do a lot of good. This is particularly true in orchards where they consume many small insects during their nocturnal trips into the tree canopy. Earwigs are capable of flight (although most species rarely do so) and fold their large hindwings elaborately to fit under tiny leathery forewings. An earwig's characteristic tail pincers are used for defence and in mating.

Key to plate

1: **Indian stick insect**
Carausius morosus
Length: Up to 100mm
This species is entirely female. They sit with their legs folded against their sides to maximise their resemblance to a stick. If attacked, their defence is to play dead.

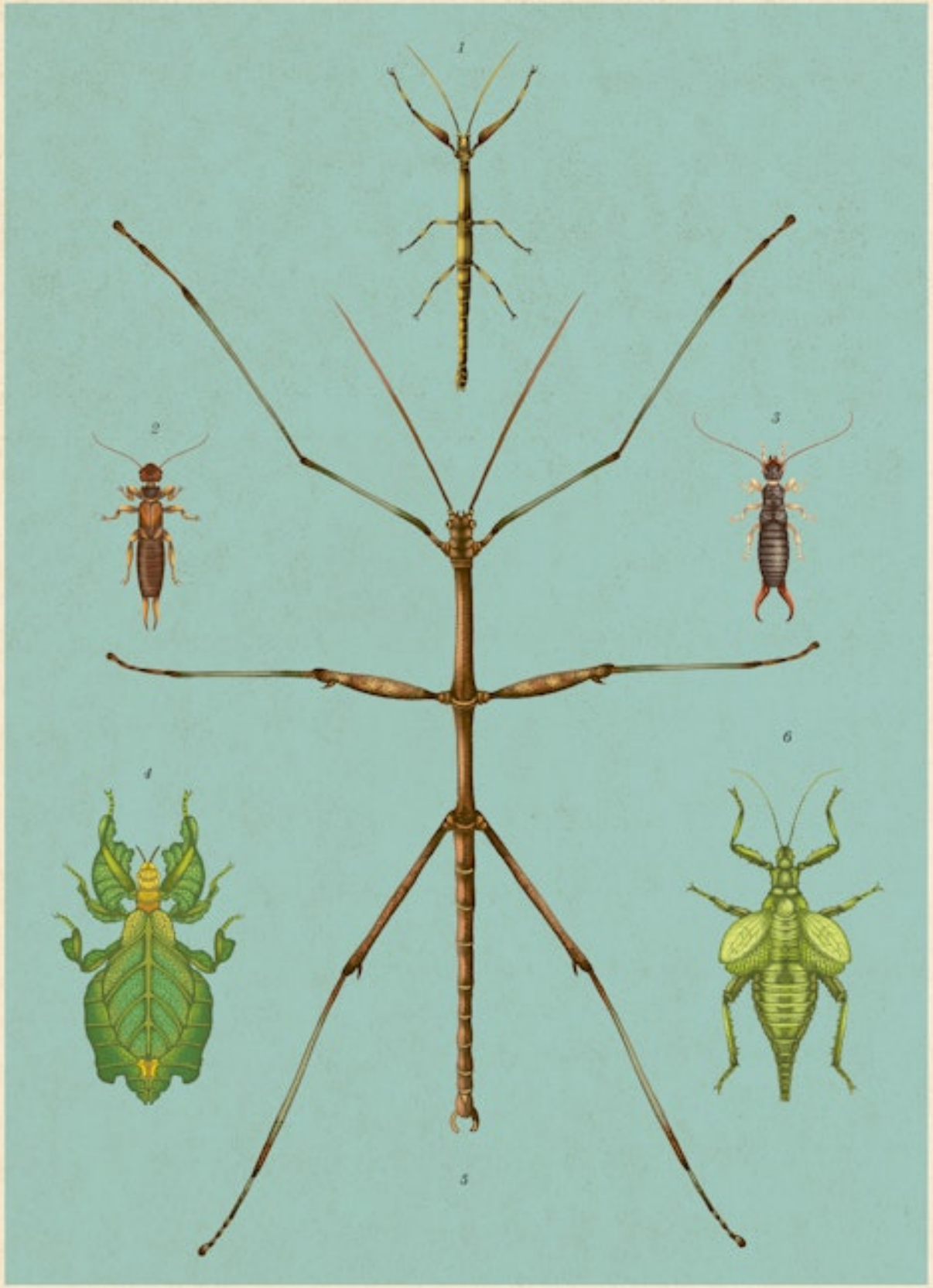
2: **Common earwig**
Forficula dentata
Length: Up to 15mm
Very common throughout much of its native Europe and western Asia, female common earwigs build nests underground and lay eggs in autumn that they guard over the winter months until the larvae hatch in early spring.

3: **Maritime earwig**
Anisolabis maritima
Length: Up to 30mm
These insects are usually found under rocks, driftwood and seaweed close to the sea. Originally from Asia, this earwig has since hitchhiked its way around the world.

4: **Giant Malaysian leaf insect**
Pulchriphyllium giganteum
Length: Up to 105mm
These creatures are impressive mimics of leaves, even having brown scalloping along their body margins that looks like leaf damage. Males are extremely rare.

5: **Giant Chinese stick insect**
Phryganistria chinensis
Length: Up to 400mm
The longest known insect, this species was only discovered in 2016 when one was found crossing a road in southwest China.

6: **Jungle nymph**
Heteropteryx dilatata
Length: Up to 170mm
These large and sturdy stick insects from Malaysia, Thailand and Singapore are contenders for the heaviest known insect – females measure up to 170 millimetres and weigh up to 65 grams. The males are slender and can fly, though weakly. Both have sharp barbs on their legs which they use in defence.



Habitat: Ponds, Streams and Rivers

So long as they are unpolluted, freshwater habitats are often extraordinarily rich in insect life. Colourful dragonflies and damselflies soar above the water surface, seeking mates, prey, or somewhere to lay their eggs. Swarms of mayflies flutter weakly above the water, their wings silver in the sunlight. In the shade beneath overhanging trees drift clouds of tiny black dance flies. One of the reasons that there are so many insects in ponds is because insects can fly, so are able to quickly find and colonise ephemeral ponds – ponds that only exist for a short amount of time. These ponds also usually lack predators such as fish.

Across the water surface, pond skaters skip, water measurers plod sedately and groups of whirligig beetles indulge in frenzied gyration. And beneath the water lie many more insects: dragonfly nymphs, water beetles, backswimmers, water scorpions, caddisfly and hoverfly larvae, to name just a few.

Drawn by this richness of insects, birds such as dippers, swallows and waders come to freshwater to feed. The insect life in rivers and lakes also supports fish such as trout and salmon, and amphibians such as frogs, toads and newts.

Key to plate

1: **Pond skater**
Gerris lacustris
Length: Up to 10mm
These insects skim across the surface of the water in ponds and streams, using water-repellent feet to stay afloat. They are predators, drawn to the ripples created by insects that have fallen into the water.

2: **Great silver water beetle**
Hydrophilus piceus
Length: Up to 50mm
These shiny pond-dwelling beetles can live up to three years. The adults are omnivores, while the grubs, which can reach up to 70 millimetres in length, are specialist predators of pond snails.

3: **Giant water bug**
Lethocerus americanus
Length: Up to 90mm
These fearsome true bugs are capable of eating small snakes, turtles, fish and frogs. While their bite is very painful, it is not serious to humans.

4: **Tiger hoverfly**
Helophilus pendulus
Length: Up to 12mm
This hoverfly species breeds in small ponds and puddles and is found across Europe. The aquatic larvae have elongated tails which they use as snorkels to breath, earning them the name rat-tailed maggots.

5: **Caddisfly**
Limnephilus flavicornis
Length: Up to 15mm
Caddisflies are related to moths. The larvae are aquatic, and live within protective cases that they construct from pieces of leaf, twigs or grains of gravel and sand, all stuck together with silk.

6: **Globe skimmer**
Pantala flavescens
Wingspan: Up to 80mm
This dragonfly undergoes the longest known insect migration from India across the Indian Ocean to Uganda, then south to South Africa and back to India. The dragonflies appear to be following the monsoon rains and cover about 18,000 kilometres in total in three or more generations.

7: **Roseate skimmer**
Orthemis ferruginea
Wingspan: Up to 65mm
This gorgeous dragonfly appears either pink or purple, depending on the light. It is found from the United States southwards to Brazil, breeding mainly in small ponds and ditches.

INSECTARIUM

Gallery 2

True Bugs and Relatives

True Bugs
Pharaoh Cicada
Thrips, Lice, Booklice and Barklice
Habitat: Temperate Forests

True Bugs

The word 'bug' is often applied to any small creature but should properly only be used for members of this insect group. Hemiptera are a diverse group of true bugs that first appeared in the Carboniferous period, about 310 million years ago. There are over 90,000 species, including aphids, whitefly, bed bugs, wheel bugs, cicadas, froghoppers and shield bugs. Many are aquatic as adults, such as pond skaters, backswimmers and water scorpions. They all feed using sharp, piercing, sucking mouthparts, which can be used to suck the sweet sap of plants or to suck the body fluid from animal prey.

Some true bugs are serious crop pests. Aphids are particularly hard to keep in check as they can breed parthenogenetically (without mating). Females give birth to live female offspring which already have their own offspring developing inside them. The offspring can then give birth themlseves within just a few days. Aphids weaken crop plants by sucking their sap, but more importantly they can transmit viral diseases amongst crops in a similar way to mosquitoes spreading malaria between humans.

Many true bugs have symbiotic relationships with ants, who often milk them for sugary secretions in exchange for protection from predators. Some ants carry aphids down into special chambers underground to keep them safe at night, provide them with food, and bring them back up again in the morning.

Key to plate

1a: **Giant mesquite bug (nymph)**
Thasus acutangulus
Length: Up to 25mm
These nymphs sport a polka-dot pattern of red, blue, yellow and black. They are gregarious, and cluster together in huddles for protection.

1b: **Giant mesquite bug (adult)**
Thasus acutangulus
Length: Up to 40mm
Adult insects abandon bright colours and become a dull black. They are found across Mexico and Central America, feeding on shrubs and trees.

2. **Green shield bug**
Palomena prasina
Length: Up to 13mm
The young of this common European shield bug use an aggregation pheromone to help them stay together in clusters.

3a: **Thorn bug (front)**
3b: **Thorn bug (side)**
Umbonia crassicornis
Length: Up to 12mm
This leafhopper has evolved to resemble a sharp thorn. Gathered on the stems of the shrub they feed on means the plant looks thorny, not at all appetising to an insect-eating bird.

4: **Candy-striped leafhopper**
Graphocephala coccinea
Length: Up to 8mm
The vibrant colours of this little leafhopper warn that it is not palatable. It is found in meadows and scrubland from Canada to Panama.

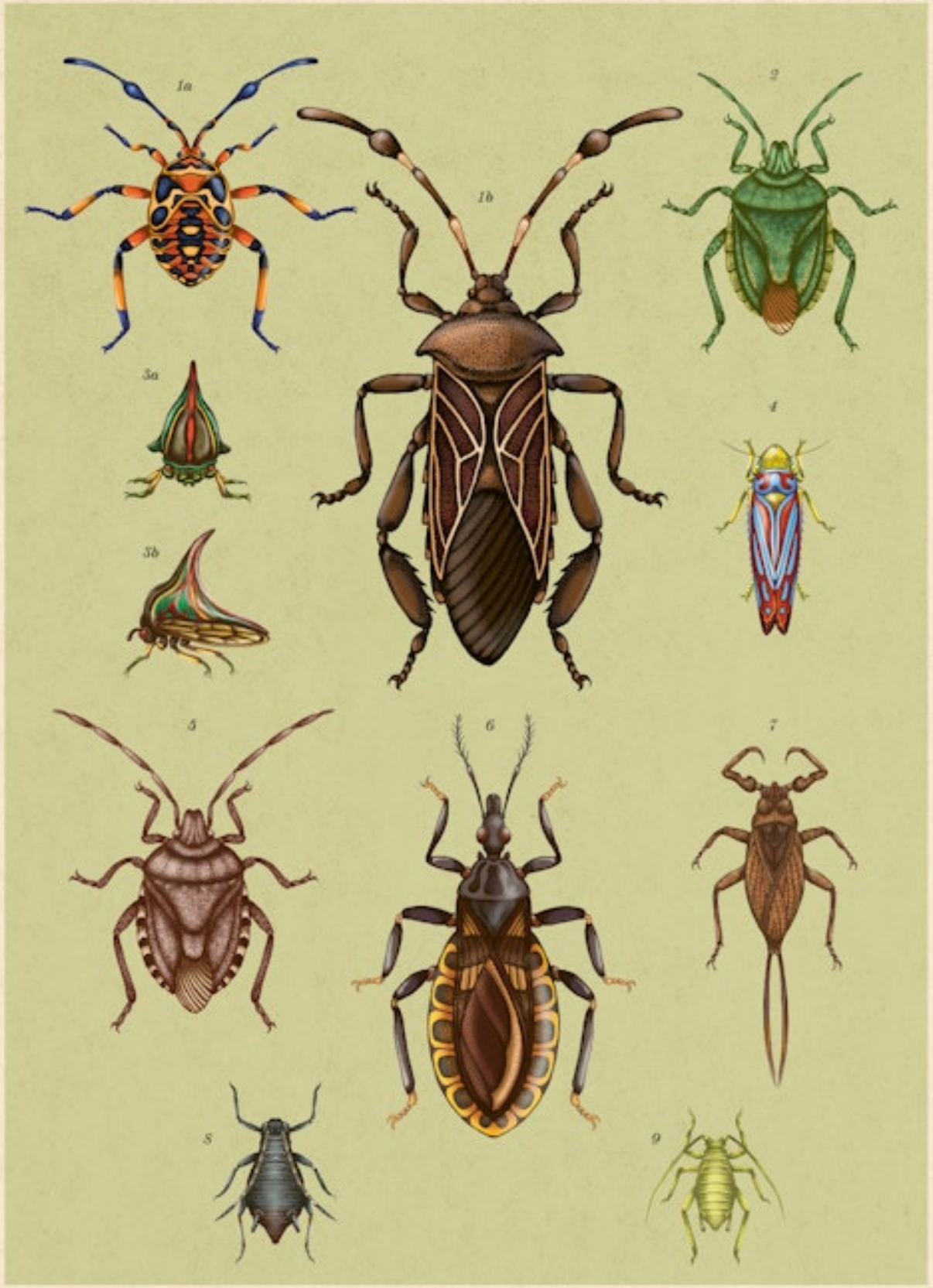
5: **Brown marmorated stink bug**
Halyomorpha halys
Length: Up to 17mm
This plain brown bug originated in China but was accidentally transported to the United States in 1998 and has since become a huge pest of fruit and nut crops, particularly apples.

6: **Kissing bug**
Triatoma infestans
Length: Up to 30mm
Encountered by Charles Darwin on his visit to South America, these blood-sucking insects live in crevices in human dwellings and emerge at night to feed on blood. They often bite around the mouth, giving rise to their name. Kissing bugs transmit a parasite, which can cause Chagas disease.

7: **Water scorpion**
Nepa cinerea
Length: Up to 22mm
This odd aquatic insect is not a scorpion; the long tail is actually a breathing tube. It uses its powerful front legs to grab and hold prey, which include small fish, tadpoles and insects.

8: **Black bean aphid**
Aphis fabae
Length: Up to 4mm
This insect is commonly farmed by the black garden ant, *Lasius niger*. The ant chases away aphid predators such as ladybirds in exchange for sugary honeydew excreted from the aphids.

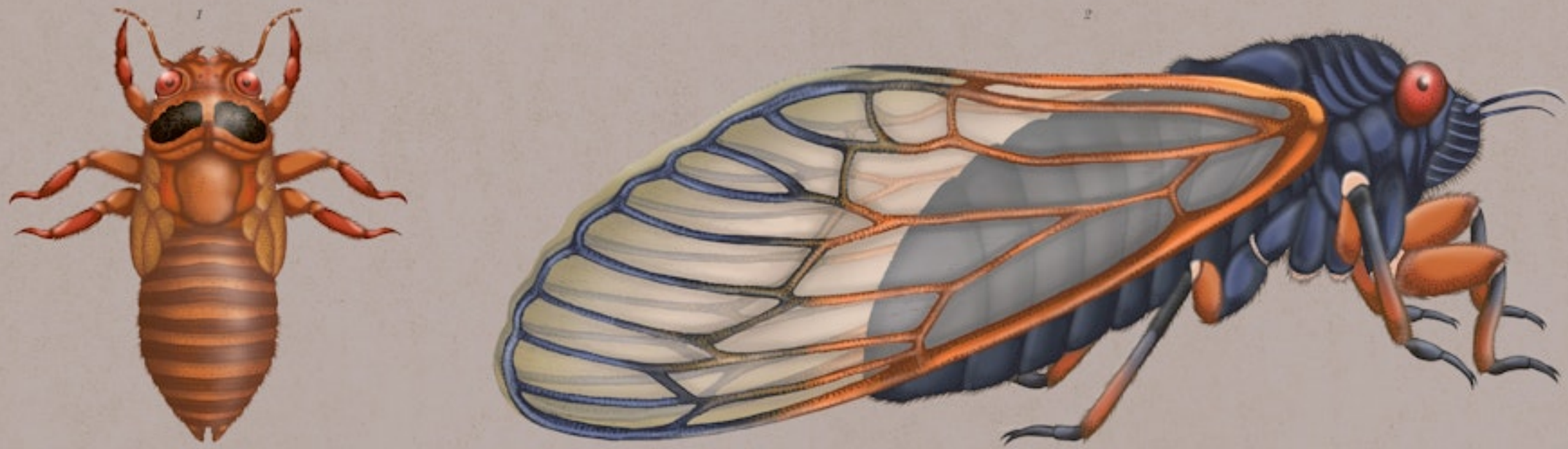
9: **Peach-potato aphid**
Myzus persicae
Length: Up to 3mm
These tiny insects breed fast and can travel long distances by both flying and using the wind to reach new crops. This species attacks many fruit and vegetable crops, and transmits plant viruses such as cucumber mosaic virus.



Pharaoh Cicada

Beneath the Earth's surface, cicada nymphs lead a mysterious existence. Using their mouthparts to pierce tree roots, they quietly feed on the sap. The nymphs grow slowly and it takes a remarkable 17 years before they begin to burrow upwards, finally emerging as adults. When the moment arrives, they surface in droves, at densities up to three million per hectare. Their mission is to moult into their adult form, attract a mate with their zithering song (the loudest made by any insect) and produce the next generation before dying just a few weeks later.

For those few weeks, the forests will be filled with the songs of millions of cicadas reaching a deafening 100 decibels. The noise makes life unbearable for human residents in the parts of eastern North America where this species can be found. After mating, the females make small incisions into the tree branches and release hundreds of eggs inside, which will eventually hatch, fall to the ground and burrow beneath the soil, ready to begin the cycle again.



Though nobody is sure of the exact reasons for this extraordinary life cycle, it is thought it helps pharaoh cicadas evade predators such as birds, which are unable to eat more than a tiny proportion of the vast horde of insects before they disappear again for another 17 years.

Key to plate

Pharaoh cicada
Magicicada septendecim

1: **Nymph**
Length: Up to 2.5mm
The nymphs live underground at depths of 30 centimetres or more. They shed their thick skins several times over the course of their development into adults. When it is time to emerge, they climb to a suitable place on nearby vegetation to complete the final stage of their transformation. Here they shed their skins and then spend approximately six days hidden under the leaves, waiting for their exoskeleton to harden.

2: **Adult**
Length: Up to 24mm
Adults are distinguished by their black bodies, striking red eyes and wing veins, with a black 'W' near the tips of the forewings. Most adults emerge around May and June, living only for a few weeks.

Thrips, Lice, Booklice and Barklice

These obscure groups of insects are much maligned, despite their tiny sizes. Their biting and feeding habits, ability to damage crops and, in some cases, to transmit diseases such as typhus, mean they are often considered irritants or pests. However, of the thousands of species of thrips, lice, booklice and barklice, many are harmless to humans and other animals, and play important ecological roles in their natural habitats. For example, thrips are important pollinators, while booklice and barklice help to recycle dead leaves.

Thrips are tiny, rarely exceeding one millimetre in length. Sometimes known as thunderbugs, they only really gain the attention of us humans if they get into our eyes on summer days, causing irritation. Thrips have narrow, feathery wings and are very weak fliers. They can however drift on the wind over long distances, doing so particularly on warm summer afternoons. Of the 6,000 thrips species that make up the Thysanoptera order, most are herbivores, using their sucking mouthparts to feed on plant sap.

Lice (Phthiraptera) are the only insects that live as external parasites on their hosts for their entire lives. Found on birds and mammals, some lice are exclusively blood-suckers, while others graze on blood, hair, skin and feathers. Flat, flightless, and more-or-less blind, these creatures have strong claws on their legs to cling on to their host, before gluing their eggs to hairs or feathers.

Booklice and barklice (both from the group Psocodea) are generally small insects that live on trees, grazing on algae, fungi and lichens. However, a few species live in houses, feeding on flour, glue and damp paper, and are considered to be pests. About 5,000 species are known, but there are likely to be many that remain undiscovered as this is a little-studied group.

Key to plate

1: **Body louse**
Pediculus humanus humanus
Length: Up to 3mm
Very closely related to the head louse, the body louse prefers to lay its eggs in clothing and can spread pathogens that cause serious diseases such as typhus. The two species separated about 100,000 years ago, suggesting that humans have worn clothing for at least that long.

2: **Head louse**
Pediculus humanus capitis
Length: Up to 3mm
A contender for the least popular insect, this species is found only on the scalps of humans, attaching its eggs to hair. Although this insect causes irritation, it does no serious harm.

3: ***Liposcelis bostrychophila***
Length: Up to 1mm
This tiny wingless brown booklouse is one of the more serious pests in this group, commonly infesting stored grain and flour. It seems able to survive in completely dry food by absorbing water from the atmosphere. Males are rare or absent in most populations, and females are able to reproduce parthenogenetically (see page 18).

4: **Privet thrips**
Dendrothrips ornatus
Length: Up to 1mm
This thrips feeds on the foliage of privet and lilac. It is regarded as a minor horticultural pest as it causes the leaves to become silvery.

5: **Barklouse**
Graphopsocus cruciatus
Length: Up to 2mm
An Asian and European species, this barklouse is found on various trees, where it probably grazes on lichens and fungi.

6: **Onion thrips**
Thrips tabaci
Length: Up to 1mm
A pest of onion, potato, cotton and tobacco, this insect damages the leaves through feeding and also spreads pathogens that cause crop diseases such as tomato spotted wilt virus.

Habitat: Temperate Forests

Woodlands once covered much of the temperate Northern Hemisphere, a band of green stretching almost unbroken from Western Europe across Russia and China to Korea and Japan, with more vast expanses of forest once covering large portions of North America. There are also smaller areas of temperate forests in southern Australia and southern South America. Unlike tropical rainforests, life in temperate forests is strongly seasonal, with activity shutting down in winter and many trees losing their leaves. Lots of woodland insects time their seasonal activity to coincide with the availability of fresh new shoots in spring, which provide food for aphids, shield bugs, cicadas, bush crickets, caterpillars and more. Woodland birds such as blue tits and chickadees time their nesting so that they can feed their chicks on this spring glut of insects.

The complex architecture of trees offers food and shelter for a huge diversity of insects, which may suck the sap, chew the roots, nibble the leaves, mine within the leaf blades, form galls or feast on the flowers and seeds. Columns of ants often wind up the trunk, spreading out in the canopy to milk honeydew from the aphids. A single mature tree can support hundreds of different species of insect. Even when they are dying or long dead, trees support wood-boring beetles and wasps, and the holes these insects make provide homes for solitary bees, with all of these insects providing food for hungry woodpeckers and sapsuckers.

Key to plate

1: **Speckled bush-cricket**
Leptophyes punctatissima
Length: Up to 20mm
These chubby little crickets are common in woodlands, hedges and gardens across Europe. They are nocturnal, feeling their way with their very long antennae. The males make a gentle chirp at night to attract a mate.

2: **Wheel bug**
Arilus cristatus
Length: Up to 40mm
This fearsome predator of North American woodlands feeds on other insects, which it grabs with its front legs and then stabs with its elongate, sharp mouthparts, injecting enzymes to dissolve the contents before sucking out the fluids.

3: **Wasp beetle**
Clytus arietis
Length: Up to 16mm
This European beetle has evolved to mimic wasps to deter potential predators. While the adult feeds on flowers, the larvae feed on dead wood, slowly chewing tunnels in the darkness. This and other wood boring beetles perform the vital role of helping to break down dead trees, releasing the trapped nutrients.

4: **Buff-tip moth**
Phalera bucephala
Wingspan: Up to 60mm
When resting during the day this moth beautifully resembles a broken birch twig, the silvery wings having the same colour as birch bark, and the head and wing tips looking like snapped twig ends. Found throughout Asia and Europe.

5: **Hawthorn shield bug**
Acanthosoma haemorrhoidale
Length: Up to 17mm
Common in woodlands, this shield bug likes to feed on the berries of hawthorn. Shield bugs are known as stink bugs in the United States because they release a foul-smelling liquid if under attack.

6: **Purple emperor butterfly**
Apatura iris
Wingspan: Up to 80mm
A beautiful, fast-flying butterfly, the purple emperor spends most of its time perching near the top of tall trees, but can be lured to the ground to drink juice from a decaying rat, a trick long used by butterfly collectors. The caterpillar resembles a hairy green slug.

7: **Giant woodwasp**
Urocerus gigas
Length: Up to 45mm
This formidable insect is in fact harmless to humans. The female has a long ovipositor – egg-laying tube – which she uses to inject her eggs into pine trees. The larvae burrow through the timber and can take several years to mature.

INSECTARIUM

Gallery 3

True Flies and Relatives

True Flies
Bumblebee Hoverfly
Scorpionflies and Fleas
Habitat: Soil

True Flies

True flies first appeared in the Triassic period, 240 million years ago – about the same time that dinosaurs first evolved. They became one of the most successful insect groups, largely because of their supreme mastery of flight. Some are even able to fly upside-down and backwards. Their name is the subject of confusion. Many insects have 'fly' in their name – such as dragonfly, caddisfly and butterfly – because they are able to fly, but they are not, technically, flies in the scientific sense of the word. True flies are a group of insects that use only one pair of wings to fly: the hindwings having evolved into tiny drumstick-like organs called 'halteres' that help them to balance in flight.

True flies generally have mouthparts designed for piercing and sucking and may use them to draw blood (tsetse flies, mosquitoes, horseflies), or to lap at liquid foodstuffs such as nectar (bee-flies, hoverflies). About 150,000 species of true fly have been described, but there are estimated to be perhaps one million species of fly in total.

This is the first insect group we have encountered that shows complete metamorphosis. Adults lay eggs that hatch into usually legless, pale larvae often known as maggots. Many maggots feed on bacteria, in dead and decaying animals, cow pats, soil or in freshwater, and many live as parasitoids inside other insects.

Flies are of great importance to humans, in both positive and negative ways. Some, such as mosquitoes, blackfly and sandflies, transmit pathogens that cause diseases in humans and livestock. Mosquitoes are in fact the deadliest creatures on our planet due to the number of people they indirectly kill through disease. Certain flies, including fruit flies and the onion fly, damage crops. But flies also play essential roles as pollinators, food sources for birds and bats, and in recycling dung and decomposing matter.

Key to plate

1a: **House fly**
Musca domestica
Length: Up to 7mm
Thriving on human waste, house fly maggots eat all types of rotting organic matter. As a result, the housefly has become one of the most widespread organisms on Earth. By feeding on both human food and putrefying matter, the adults can spread diseases such as typhoid and cholera.

1b: **House fly egg**
1c: **House fly larva**
1d: **House fly pupa**
When fully grown, the larvae enter a pupal phase, from which emerges the adult insect.

2: **Antarctic midge**
Belgica antarctica
Length: Up to 6mm
This small wingless midge is the only insect that lives in Antarctica, and despite its size, it is also the largest full-time land-based animal in Antarctica. Anti-freeze in its blood enables it to survive down to –15°C. It then avoids more extreme temperatures by burrowing beneath the snow.

3: **Marmalade hoverfly**
Episyrphus balteatus
Length: Up to 11mm
Many hoverflies have evolved to mimic wasps as a way to deter predators. They are vital pollinators whose larvae primarily consume aphids.

4: **Crane fly**
Tipula paludosa
Length: Up to 30mm
These large, long-legged flies often enter houses at night, attracted by the light.

5: **Tsetse fly**
Glossina morsitans
Length: Up to 8mm
Tsetse flies are found across tropical Africa. They feed on the blood of large mammals, including humans and cattle, and transmit parasites that cause sleeping sickness.

6: **Bee-fly**
Bombylius major
Length: Up to 12mm
These endearing bumblebee mimics use their long, rigid proboscis to drink nectar from flowers.

7: **Malaysian stalk-eyed fly**
Teleopsis dalmanni
Length: Up to 10mm
An extraordinary example of 'sexual selection', the female stalk-eyed flies prefer to mate with the males whose eyes are furthest apart, and so over millions of years the eyes have become located on long stalks.

8: **Yellow fever mosquito (female)**
Aedes aegypti
Length: Up to 6mm
This mosquito is capable of transmitting viruses such as yellow fever and dengue fever. Only the female feeds on blood.

Bumblebee Hoverfly

Despite its uncanny resemblance to a bumblebee, this large, furry fly has no sting of its own. Instead, it gains protection from predators by tricking its observers, including humans! It is a fantastic example of Batesian mimicry, whereby a harmless creature gains protection by evolving to closely resemble an animal that has a sting or is poisonous or unpleasant to eat. Named after British naturalist Henry Walter Bates (1825–1892), who first identified it in South American butterflies, Batesian mimicry is also demonstrated by temperate hoverflies that closely resemble wasps.

The bumblebee hoverfly comes in two very distinct colour forms: one black with a red tail resembling the red-tailed bumblebee (*Bombus lapidarius*) and one which has yellow and black stripes with a white tail resembling the white-tailed bumblebee (*Bombus lucorum*).

The female fly relies on her uncanny resemblance to bumblebees to stealthily infiltrate their nests and deposit her eggs. Once they've hatched inside the hive, the maggots assume the role of nest scavengers, hoovering up scraps of food and faeces which fall to the bottom of the nest. They neither disrupt nor harm their bumblebee hosts. In fact, they may benefit the hive with their constant cleaning up.

The bumblebee hoverfly is found in much of the temperate Northern Hemisphere and its ability to thrive in a range of environments makes it a common sight in these regions. It is often seen drinking nectar from flowers in gardens.

Key to plate

1a: **Bumblebee hoverfly, white-tailed variety**
1b: **Red-tailed variety**
Volucella bombylans
Length: Up to 16mm
These bumblebee mimics can be distinguished from the real thing by their relatively tiny antennae and by having only one pair of wings, where real bumblebees have two pairs.

2: **White-tailed bumblebee**
Bombus lucorum
Length: Up to 18mm (worker)
This European bumblebee is found in a range of habitats, particularly scrub, woodland edges and gardens. It often nests under garden sheds, patios and other human-made structures.

3: **Red-tailed bumblebee**
Bombus lapidarius
Length: Up to 18mm (worker)
This is a common bumblebee species, and usually the most abundant species in flower-rich grassland habitats. Nests are usually formed in existing cavities beneath the ground.

Scorpionflies and Fleas

Scorpionflies are peculiar creatures, with long, beak-like faces. Many male species have tails that curl up like scorpion stingers, but we needn't worry; they are not dangerous. These tails are special claspers used to hold on to the female scorpionflies during mating.

Scorpionflies feed opportunistically on dead insects, nectar, rotting fruit, plant sap and other organic matter. Some of them are quite daring, even stealing deceased insects from spider webs. Astonishingly, there have even been documented instances of them scavenging on human corpses. In some scorpionfly species, the male attracts females by offering a dead insect as a 'nuptial gift' – a present in exchange for mating. If no dead insect is available, they will offer a blob of brown, dried saliva instead. Understandably, females much prefer a dead insect.

Fleas boast their own extraordinary feeding habits – they are external parasites on mammals and birds, feeding on the blood of their host. Their ancestors were probably scorpionflies, and presumably they lost their wings as they were of little use when living in the fur of a host. They are very thin insects, enabling them to scuttle through dense fur or feathers, and have tiny but powerful claws which they use to cling on. Despite being small, they have the capacity to cause catastrophe through the spread of disease. Most famously, bubonic plague was spread from black rats to humans by fleas, and successive outbreaks of plague killed millions of people before the advent of antibiotics. It is estimated about one third of the entire human population of Europe died of the plague between 1346 and 1353.

Fleas are a little-studied group of insects, with over 2,500 known species. It is estimated that this number could increase by 50 per cent with many more species awaiting discovery. A flea's maggot-like larvae do not live on the host, but instead are found in nests or bedding, where they feed on a variety of organic matter but particularly enjoy the faeces of adult fleas. A female flea can lay 5,000 eggs in her lifetime, so infestations can increase rapidly.

Key to plate

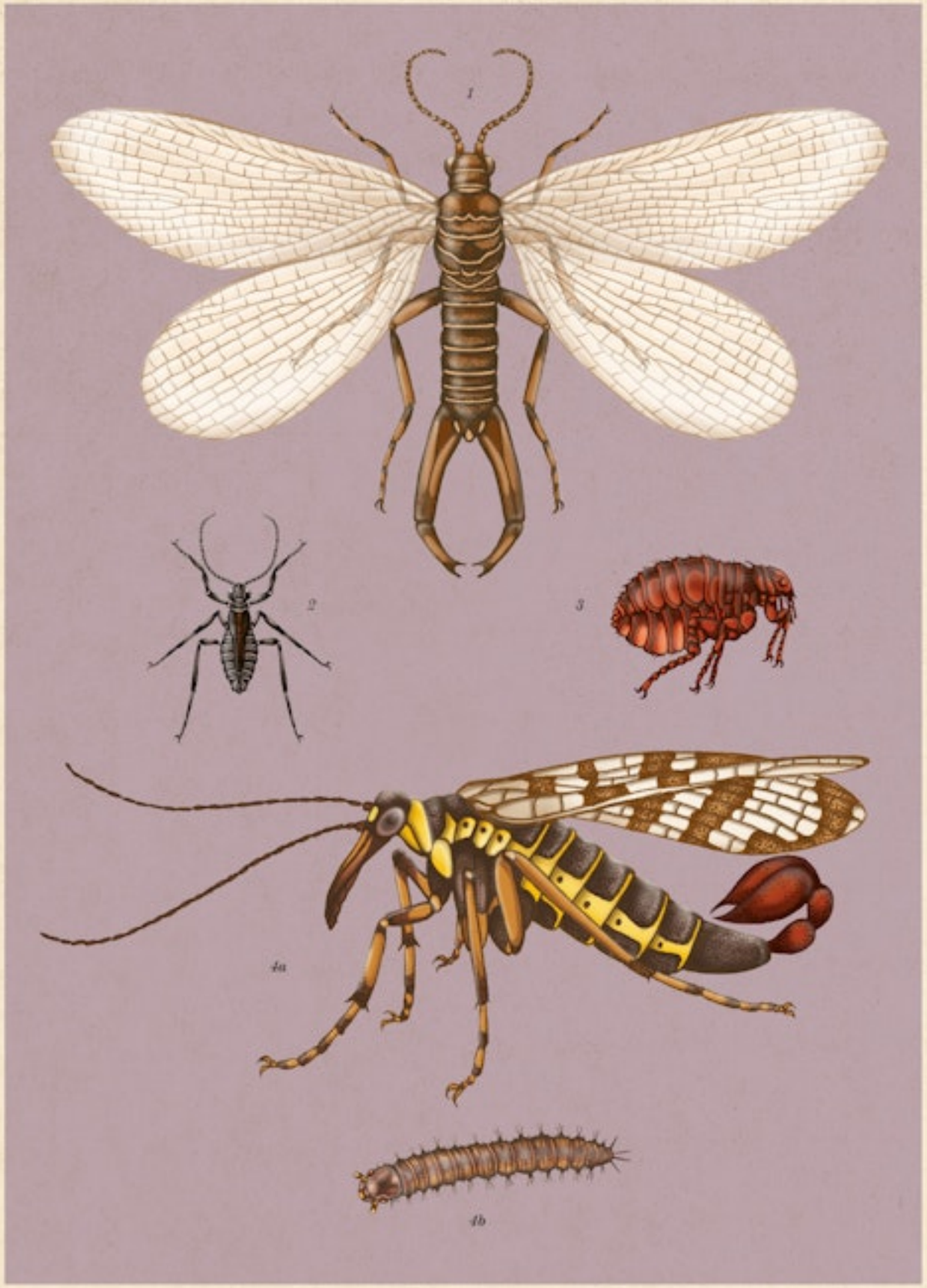
1: **Earwigfly**
Merope tuber
Length: Up to 10mm
Neither an earwig nor a fly, the earwigfly is an obscure relative of the scorpionfly found in North America. Little is known about this nocturnal insect, and the larvae have never been seen.

2: **Snow flea**
Boreus hyemalis
Length: Up to 5mm
Snow fleas are obscure and little-studied flightless relatives of scorpionflies found on heaths and moors in the winter months. These dark brown insects can be seen hopping on snow, hence their name. They manage to be active in the depths of winter by using snow as insulation, and trapping energy from the sun to raise their body temperature.

3: **Rabbit flea**
Spilopsyllus cuniculi
Length: Up to 1mm
This tiny insect primarily lives on rabbits and plays a role in the spread of myxomatosis, a viral disease that naturally occurs in various American rabbit species. The disease was deliberately introduced to Europe and Australia to control rabbit populations, which can be considered pests. European rabbits are much more susceptible to the disease.

4a: **European scorpionfly**
Panorpa communis
Length: Up to 30mm
A fairly common species, European scorpionflies often turn up in gardens where they can frequently be found sunning themselves on a warm leaf.

4b: **European scorpionfly larva**
Length: Up to 20mm
The larvae are caterpillar-like, bristly grey creatures that live on the soil surface and consume a range of plant material and dead insects.



Habitat: Soil

We may mistakenly think of 'dirt' as dull and unimportant, but healthy soils teem with life, including fungi, bacteria, worms, lots of small insects and a few larger ones. We are only just beginning to understand how complicated soils are, and how vital they are as stores of carbon. Soils are the essential medium in which almost all plants and crops grow. Insects play a vital role in soil health by chewing up larger pieces of organic matter to break down and therefore release nutrients. They also pull dung down into the soil, increasing organic carbon content, while their tunnels help with aeration and drainage.

Healthy soils contain a complex food web of interacting species so are an entire ecosystem in themselves. Plant roots exchange nutrients with fungal webs and with communities of billions of soil bacteria. Many flies, beetles and moths have soil-dwelling larvae, which wriggle through the soil feeding on organic matter and plant roots or preying upon other small soil creatures. The legless maggots of dung flies, dance flies and midges graze on soil microbes. Soil may seem like a safe, dark place for insect larvae to hide from predators, but many birds have evolved long bills that enable them to probe into soil in search of insects and worms. Centipedes, spiders and rove beetles squeeze through soil crevices to prey upon smaller insects while hedgehogs and badgers dig for them near the surface and moles burrow under the ground searching for their prey.

Key to plate

1a: **Crane fly**
1b: **Crane fly larvae**
Tipula paludosa
Length: Up to 30mm
The larvae are known as leatherjackets, and live in soil where they feed on grass roots. The larvae are a favourite food for birds such as starlings, while the adults are an important part of the diet of some larger bats.

2: **Jerusalem cricket**
Ammopelmotus fuscus
Length: Up to 35mm
These powerful insects burrow through the soil in search of their preferred food: decaying plant roots and tubers. If disturbed, they emit a foul smell and can give a painful bite. Despite the name, they are found in western United States and Mexico.

3: **Western harvester ant**
Pogonomyrmex occidentalis
Length: Up to 10mm (worker)
Many ants have a profound impact on soil structure, with their network of tunnels providing aeration and allowing rain to permeate deep into the ground. This species from the central United States builds large mounds of sand and gravel above their nests, which contain up to 20,000 workers and can be five metres deep.

4a: **Cockchafer**
4b: **Cockchafer larva**
Melolontha melolontha
Length: Up to 40mm
These large beetles fly clumsily and loudly at dusk in May and June, often crashing into lights. Their fat, white larvae, known as grubs, live underground, munching on plant roots and sometimes damaging crops.

5: **St Mark's fly**
Bibio marci
Length: Up to 14mm (worker)
This common European fly spends almost all the year as a soil-dwelling maggot, grazing on roots and dead vegetation. The adults emerge, often in large numbers, on or around the 25th April – St Mark's Day – and live for just a few days.

6: **Giant burrowing cockroach**
Macropanesthia rhinoceros
Length: Up to 80mm
The world's heaviest cockroach, weighing up to 35 grams, this species is found burrowing in forest soils of tropical Australia.

7: **Eastern eyed click beetle**
Alaus oculatus
Length: Up to 40mm
The larvae of the eyed click beetle take between two and five years to develop, remaining underground and grazing on leaf litter. If adults find themselves upside-down, they can flip themselves over with an audible click.

INSECTARIUM

Gallery 4

Lacewings and Relatives

Lacewings and Relatives
Spotted-Winged Antlion
Habitat: Deserts

Lacewings and Relatives

This little-known insect group – Neuroptera – is made up of an unusual-looking selection of around 6,000 species, including lacewings, antlions, owlflies, snakeflies and the fierce-looking dobson flies. Their name is derived from the Greek *neuron* (nerve) and *pteron* (wing), describing the delicate, nerve-like network of veins on their thin, translucent wings. The wings of owlflies and antlions are often intricately patterned and quite beautiful. As adults, they mostly prey on smaller insects, although a few feed on pollen and nectar from flowers.

During courtship, lacewings 'tremulate', which means they produce low-frequency vibrations that transmit through the ground. Males and females perform a duet, each taking turns to tremulate before they are ready to mate. Lacewings also have the unusual ability to lay their eggs at the end of long silk stalks, suspending them in the air. This makes them hard to reach, and the silk is so fine it is hardly noticed by any passing predators, such as ants.

After a few days, the larvae hatch, and the newly born lacewings need to fend for themselves. The larvae of Neuroptera tend to be ferocious predators, usually of other small pest insects, such as aphids (see page 24) and thrips (see page 28), making them allies of farmers, gardeners and ecosystems. They have large, sickle-shaped jaws with which they stab their prey. The jaws are hollow and are used to suck out the body fluids. Bizarrely, some green lacewing larvae stick the husks of their dead prey onto their back as a form of camouflage or disguise.

Key to plate

1: **Green lacewing**
Chrysopa perla
Length: Up to 12mm
The delicate, greenish-blue green lacewing adults feed on nectar, pollen and honeydew. The sickle-jawed larvae are voracious predators of aphids and other small insects.

2: **Alderfly**
Sialis lutaria
Length: Up to 20mm
The alderfly adults are found in spring and summer near streams and ponds in Europe. They live for just a few days. The larvae are aquatic predators, feeding on small insects, crustaceans and worms.

3: **Snakefly**
Phaeostigma notata
Length: Up to 15mm
Often described as living fossils, snakeflies have changed little since the Jurassic period. They have a flexible head and thorax, which creates the snake-like appearance. Both adults and larvae eat small insects such as aphids.

4: **Owlfly**
Libelloides coccajus
Wingspan: Up to 55mm
Aside from their long, clubbed antennae, owlflies strongly resemble dragonflies in both appearance and behaviour. Large and colourful insects, they use their powerful wings and large eyes to chase and catch insects mid-air. They are also known as 'butterfly lions', as they often eat butterflies.

Spotted-Winged Antlion

It is the fearless larvae of these creatures that earn them their name. Distinctive conical pits in the sandy ground are often the only signs that they are present. These pits are traps. At the base of each, lurking just beneath the surface, is a stocky, powerful insect with huge, spined jaws that curve inwards. The pit is made by the larva sweeping sand onto its flattened head with a leg, and then flicking the sand away with a sharp upward jerk. This is repeated while slowly shuffling in an inward spiral pattern, until eventually the larva is sitting at the bottom of a steep-sided pit. The larva then covers itself with sand and waits patiently for unsuspecting ants or other small insects to slide into the pit. Once the antlion detects movement, it frantically flicks sand at the prey, causing miniature sand avalanches which drive the unfortunate insect to the bottom of the cone. Here, it is seized by the antlion's huge jaws and dragged beneath the sand. The antlion injects a cocktail of venom and enzymes with its bite, and then sucks out the innards of its prey.

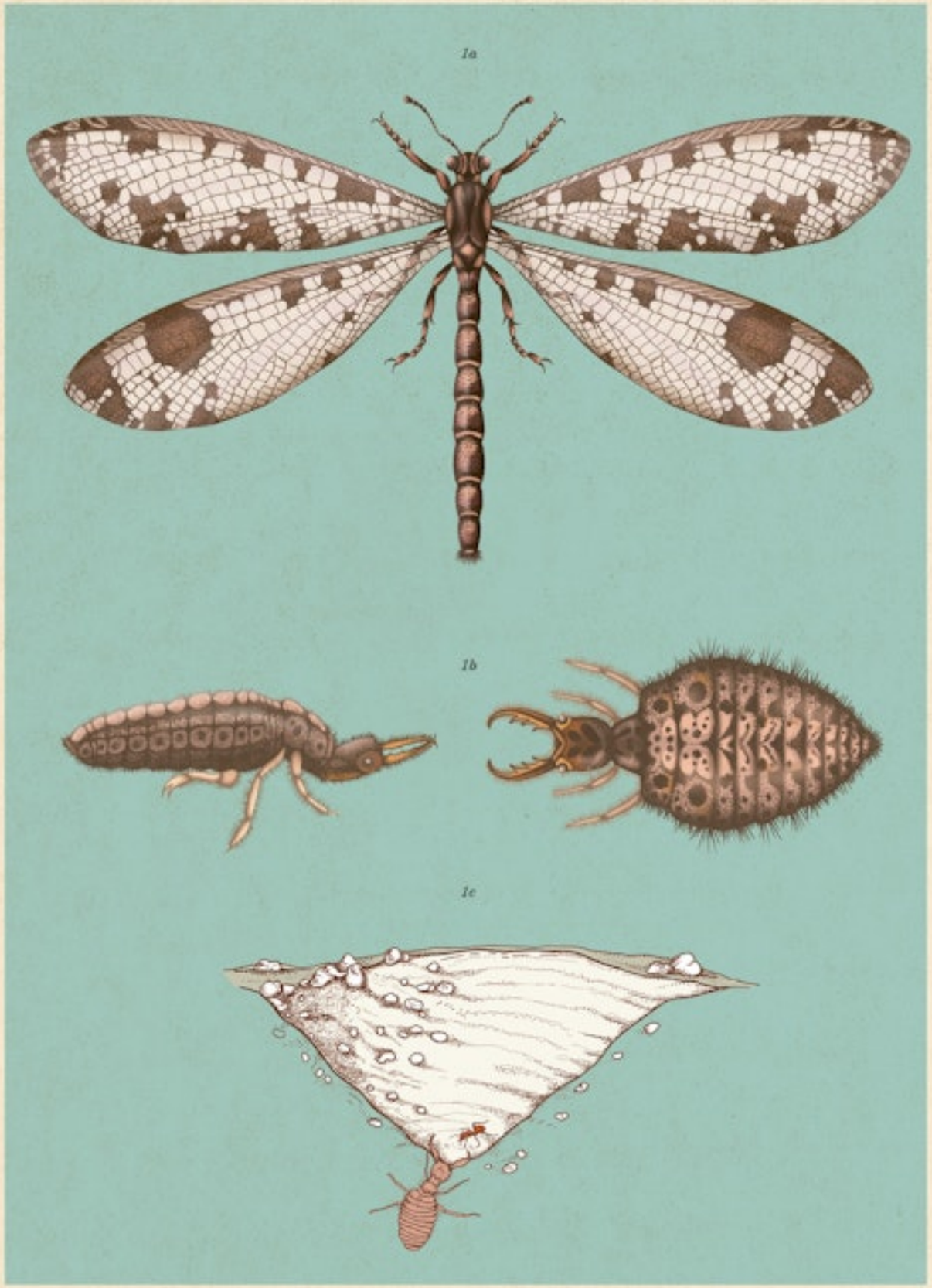
The adult antlion looks quite different to its larvae. On first glance, the adult could be mistaken for a damselfly, with its long, slender body and shimmering veined wings. However, unlike damselflies, antlions are feeble fliers. About 2,000 species of antlion are known, found throughout the warmer parts of the globe. As adults they feed on nectar and pollen, or small insects, depending on the species.

Key to plate

1a: **Spotted-winged antlion (adult)**
Dendroleon obsoletus
Wingspan: Up to 70mm
This particular species of antlion is found in North America.

1b: **Spotted-winged antlion larva**
Length: Up to 14mm
Unusually, antlion larvae have no anus, and so have to wait until they eventually emerge from their pupa to defecate.

1c: **Spotted-winged antlion pit**
Diameter: Up to 80mm
The pits are found in sandy soil, usually in a sheltered site beneath trees where wind and rain are less likely to destroy them.



Habitat: Deserts

We imagine that deserts are lifeless, empty places, but they actually harbour great diversity of life, especially in terms of insects. Insects evolved a waterproof cuticle early on in their colonisation of land some 480 million years ago. This feature means they are resistant to desiccation, which means they don't dry out. Nonetheless, most insects cannot survive in the full desert sun for long, so many hide underground or in caves during the hotter parts of the day, and some, such as the threadwing antlion, emerge only at night. The Saharan silver ant is clothed in hairs that reflect the sun, helping to keep it cool. Magnetic termites build their nest mounds like gravestones, aligned along a north-south axis so that they catch the morning and evening sun but only have a narrow edge facing the sun at midday. Some insects aestivate, which means they remain dormant for the summer months, then emerge in the slightly cooler weather of autumn. Highly mobile insects, such as the painted lady butterfly, spend their winters in the desert but migrate to cooler climes during summer.

Food is scarce in deserts, but most arid regions have specially adapted plants that can cope with the harsh conditions, such as cacti and succulents that store water in fleshy stems and leaves. Many desert plants protect their scarce resources by flooding their tissues with poison to deter herbivores, but specialised insects such as caterpillars and grasshoppers have overcome these defences either by evolving tolerance to the poison or by breaking it down. Some even store the poison in their body so that they become poisonous themselves. Cacti and other desert plants must flower to produce seeds, and their flowers provide sweet nectar and pollen which feed desert bees, butterflies, moths, flies and beetles. These in turn provide food for antlions, mantises and spiders.

Key to plate

1: **Egyptian spoonwing**
Nemoptera aegyptioca
Wingspan: Up to 40mm
These elegant, day-flying insects are found in the deserts of Israel and Egypt, often visiting flowers for pollen. Little is known about their life cycle, but it is thought that the larvae may live within ant nests and feed upon the ants.

2: **Saharan silver ant**
Cataglyphis bombycina
Length: Up to 10mm
These silver ants resemble tiny but fast-moving robots. This is the world's fastest ant, scampering across the hot desert sand at speeds of up to 3.1 kilometres per hour – equivalent to a human running at 700 kilometres per hour. They have to be fast to avoid cooking before they get back into their nest.

3: **Head-stander beetle**
Onymacris unguicularis
Length: Up to 8mm
Found in a region of the Namib Desert which has frequent fogs, this beetle collects water droplets on its body and then stands on its head to allow the water to run down to its mouth so that it can drink.

4a: **Threadwing antlion**
4b: **Threadwing antlion larva**
Dielocroce hebraea
Wingspan: Up to 35mm
While the adult threadwing is a very delicate, fairy-like, nocturnal insect, the peculiarly long-necked larvae are brutal assassins. They lurk in the dust of desert caves and pounce upon small insects that pass by.

5: **Lubber grasshopper**
Taeniopoda eques
Length: Up to 70mm
This vivid grasshopper advertises that it is poisonous to eat through its bright colours. It is found in the deserts of southern United States and Mexico.

6: **Cochineal (female)**
Dactylopius coccus
Length: Up to 5mm
This creature is a scale insect, related to aphids and shield bugs (the order Hemiptera). The fat, wingless females feed on prickly pear cacti and rarely move at all, while the much smaller male insects can fly. The insects can be crushed up to produce a bright red dye, long used to colour fabrics such as the red coats of British soldiers, and today used as a food colouring.

7a and 7b: **Painted lady**
Vanessa cardui
Wingspan: Up to 70mm
One of the most widespread butterflies in the world, these European butterflies migrate south to the Sahara and beyond for the winter, flying north as far as Iceland in the spring.

INSECTARIUM

Gallery 5

Beetles and Relatives

Beetles
Common Eastern Firefly
Ladybirds
Twisted Wing Flies
Habitat: Tropical Rainforests

Beetles

Beetles dominate the insect world. With approximately 350,000 known species, they constitute nearly one quarter of known organisms. Biologist John Burdon Sanderson Haldane (1892–1964) was once asked what his studies of evolution had taught him about the mind of God. He replied, "He must have an inordinate fondness for beetles."

Despite their diversity, beetles share a distinctive glossy appearance. This is due to the modification of their forewings into a pair of hardened elytra which form a protective shell that covers much of their body. The hindwings, which are used for flying, are carefully folded under the elytra when not in use.

Beetles undergo complete metamorphosis (see page 68). Their larvae often resemble soft, grub-like creatures. Most remain hidden away in the soil, dense vegetation or within plant stems and tree trunks, so are less recognisable to us humans. Both larval and adult beetles have chewing mouthparts and feed upon a huge range of living or dead animals, plants or fungal material, depending on the species. Dung beetles help to recycle the nutrients in cow pats and other dung, while carrion beetles bury and eat dead animals, including small birds and mice.

The very first beetles, which appeared about 295 million years ago, are thought to have been wood-borers, and many still do this. Wood-boring beetles perform an important role in decomposing dead trees, releasing trapped nutrients so that new trees can grow. Some domestic species, such as the furniture beetle and death watch beetle, are pests and slowly consume the timber in houses.

Some beetles are herbivores, feeding on leaves, petals, seeds, or pollen and nectar as adults. Many more, such as tiger, rove and ground beetles, are voracious predators, controlling crop pests such as aphids, caterpillars and slugs.

Key to plate

1: **Jewel beetle**
Chrysochroa fulgidissima
Length: Up to 40mm
Native to Japan, Korea and eastern China, the grubs bore through tree trunks, eating the wood.

2: **Darwin's beetle (male)**
Chiasognathus grantii
Length: Up to 90mm
Charles Darwin first saw this beetle when visiting Chile during his voyage on HMS *Beagle*. A type of stag beetle, the males often have enlarged jaws which they use in battles.

3: **Chinese tiger beetle**
Cicindela chinensis
Length: Up to 21mm
This fierce predatory beetle is found throughout much of Asia. It is spectacularly colourful, with the pattern varying depending on the region.

4: **Giraffe weevil**
Trachelophorus giraffa
Length: Up to 25mm
These are found only on giraffe beetle trees in the few remaining rainforests of Madagascar. Each male guards a female, and pushes rivals off the foliage where the females lay their eggs.

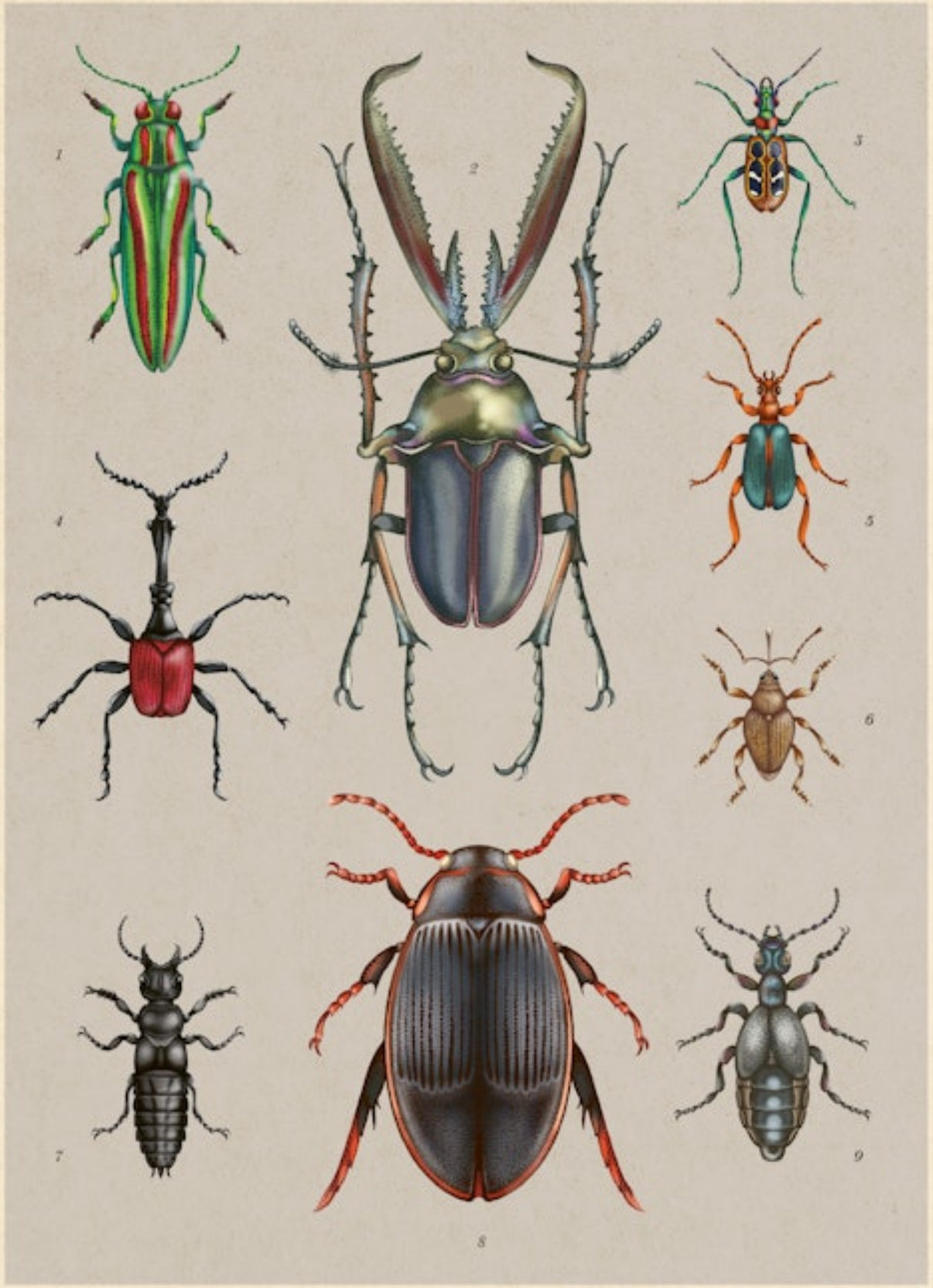
5: **Bombardier beetle**
Brachinus sclopeta
Length: Up to 7mm
When attacked, this beetle can blast its assailant with near-boiling acid created in a controlled explosion inside its bottom. The blast produces an audible 'pop' and can kill smaller predators.

6: **Acorn weevil**
Curculio glandium
Length: Up to 6mm
The acorn weevil lays its eggs inside acorns, where the larvae develop.

7: **Devil's coach horse**
Staphylinus olens
Length: Up to 28mm
This fierce insect has hardened, short forewings – a characteristic of rove beetles, the family to which it belongs. When threatened, they curve their abdomen in a scorpion-like manner, but it is a bluff for they have no sting.

8: **Great diving beetle**
Dytiscus marginalis
Length: Up to 60mm
A predator of ponds and streams, the great diving beetle feeds on insects, tadpoles and small fish, which it grabs with its powerful forelegs. The hind legs are adapted into oars which it uses to row through the water.

9: **Black oil beetle**
Meloe proscarabaeus
Length: Up to 32mm
If alarmed, this oil beetle releases a foul-smelling oily black liquid from its joints.



Common Eastern Firefly

In the tranquil darkness of a North American forest, a magical, yet entirely natural, performance takes place. Clouds of fireflies, enchanting insects often known as glow-worms, emerge to illuminate the night. Yet despite their common names, fireflies are neither flies nor worms; they are beetles. Across our planet over 2,000 species of fireflies grace the evening skies with their bioluminescent artistry. In some species, thousands of individuals synchronise their flashes, causing entire forests to pulse with a lightshow.

Fireflies use a chemical reaction in their abdomens to generate a yellow or greenish light. The organ that produces this light is called the 'lantern', and inside the substance luciferin is mixed with oxygen, releasing energy in the form of light. These flashes are how these little insects communicate, find mates and even warn predators that they are not a tasty meal. In some species the female gently glows to attract males, while in others the males fly about, flashing their bottom and creating streaks of light in the dark. Where several firefly species occur together, each species uses a precise sequence of flashes, a little like Morse code, to avoid confusion.

The common eastern firefly, *Photinus pyralis*, is the most prevalent firefly species in North America. It faces a unique challenge in its quest for a mate. The males of this species must exercise caution, as lurking in the darkness are female fireflies belonging to a different genus, *Photuris*. By mimicking the flashes of female *Photinus*, these crafty females lure the unsuspecting males, only to make them an unfortunate meal. As well as providing a tasty snack, the male *Photinus* fireflies contain a toxin, lucibufagin, which the female *Photuris* store in their bodies to help them to repel predators such as spiders.

Key to plate

1: **Common eastern firefly**
Photinus pyralis
Length: Up to 12mm
Fireflies are predators, many specialising in feeding upon snails. When seeking a mate, the male hovers close to the ground, then flies in a J-shape while flashing the light in its bottom, creating a characteristically shaped streak of light in the dark. If a female is interested, she points her bottom at him and creates a flash of light of her own. A short duet of flashes ensues until he locates her.

Ladybirds

Perhaps the most familiar, easily recognised and endearing of beetles, ladybirds feature in nursery rhymes and folklore around the world. In most cultures ladybirds are a sign of good luck. One popular European myth is that a ladybird that crawls on a woman will then fly off to land on her true love.

Over 6,000 species of ladybird have been identified so far, and they are found on all continents except Antarctica. Many ladybirds feed on aphids and other small insect pests, both as adults and as larvae. They are therefore seen as friends of gardeners and farmers. For this reason some ladybird species have been deliberately released far from their natural range, and some are bred in factories to be released in crop fields.

Unlike most beetle larvae, ladybird larvae are active in the daytime. While often seen, they are not easily recognised as ladybirds because they look so different to the adults. Their boldness is possible because both larvae and adults are poisonous if eaten, containing toxins called alkaloids. Their bright colours advertise this so that birds do not eat them by mistake, something known as aposematic colouration. If they are attacked, many ladybirds resort to the odd tactic of releasing a bitter-tasting body fluid from their knees.

Although ladybirds are poisonous to most predators, many will happily eat each other, cheerfully cannibalising eggs or larvae of their own or other species if the opportunity arises.

Key to plate

1: **Seven-spot ladybird**
Coccinella septempunctata
Length: Up to 10mm
Found throughout Europe and Asia, this ladybird has also been introduced to America and Australia. It is often found in gardens and is mass-reared for use as a biocontrol agent.

2: **Mexican bean beetle**
Epilachna varivestis
Length: Up to 7mm
This North American ladybird is unusual in that it prefers to feed on plants rather than insects, and can be a pest of bean crops such as green beans and soya beans.

3: **Eyed ladybird**
Anatis ocellata
Length: Up to 9mm
A large and handsome European ladybird found mainly in pine forests.

4: **Harlequin ladybird**
Harmonia axyridis
Length: Up to 8mm
An unusual ladybird, the harlequin can be found in a near-infinite range of red and black patterns. They are from Asia but have been deliberately spread to Europe, America and Africa for aphid control, where they have become an invasive pest, often eating native ladybirds.

5: **22-spot ladybird**
Psyllobora vigintiduopunctata
Length: Up to 5mm
A small but lovely ladybird from Europe, it is unusual in that it feeds mainly on mildew rather than insects.

6: **Striped ladybird**
Micraspis frenata
Length: Up to 4mm
A native of grassland and scrub in Eastern Australia.

7: **Steelblue ladybird**
Halmus chalybeus
Length: Up to 4mm
A glorious metallic-blue ladybird from the gum tree forests of Australia, the steelblue ladybird is encouraged in citrus orchards where it helps to control small insect pests.

8: **Pink-spotted ladybird**
Coleomegilla maculata
Length: Up to 6mm
Commonly found in arable crops and orchards in its native North America, the pink-spotted ladybird eats not just aphids but also the eggs of moth pests, so it is favoured by farmers.

9: **Yellow-shouldered ladybird**
Apolinus lividigaster
Length: Up to 4mm
This species is found in Australia and New Zealand, commonly turning up in gardens and parks. The larvae are small and hairy.

Twisted Wing Flies

There are a great many peculiar insects, but twisted wing flies must surely be amongst the oddest and perhaps most elusive. Despite there being around 600 species, very few people have ever seen one, although they are found all over the world. This is because twisted wing flies spend almost their entire lives as parasites inside larger insects such as bees, wasps, ants, cockroaches or grasshoppers, depending on the species. The female never leaves her host, and once fully grown she may almost entirely fill the unfortunate insect. The host somehow remains alive and even able to fly!

Even as an adult, the twisted wing fly female has no eyes, legs or wings, resembling more of a maggot than a fly, but this seemingly helpless creature pushes her blind head out between the segments of her host's abdomen and releases a pheromone to attract a mate. The male twisted wing fly does emerge from his host as a small, delicate, free-flying insect with a single pair of dark, triangular, twisted wings. He does not feed and lives for just a few hours, during which time he must race to find a female using the pheromones she releases to track her down. He mates with the female while she is still inside her host, and then promptly dies from the exertion.

Finally, in a scene that would not feel out of place in a horror movie, the female produces a thousand or more tiny offspring, each less than a quarter of a millimetre long. The larvae hatch inside their mother and begin to consume her from the inside, before crawling out of her head and leaving the host's exhausted body and their dead mother behind. Once in the open, the tiny larvae are very active, for they cannot survive long and must quickly locate and burrow into a fresh host, to start the cycle once more.

Key to plate

1a: **Yellow-legged mining bee**
Andrena flavipes
Length: Up to 9mm
This ground-nesting bee is fairly common in much of Europe. Although a solitary species, each female making her own burrow, they often nest in large aggregations on south-facing slopes.

1b: **Female *Stylops melittae* protuding from yellow-legged mining bee**

2: **Stylops melittae (female)**
Length: Up to 7mm
The adult female resembles a maggot, with no functioning eyes, antennae or legs. She does have jaws, however, which she uses to chew a hole in the cuticle of her host through which to poke her head.

3: **Stylops melittae (male)**
Length: Up to 4mm
This twisted wing fly species specialises in attacking solitary mining bees. The young parasitic larvae climb onto flowers and then latch on to a visiting bee. Once inside the host's nest, they burrow into a bee larva and develop within it while allowing the bee to develop to adulthood. Infected bees can be recognised as the head of the parasite usually protrudes slightly from between the segments of the host's abdomen.

Habitat: Tropical Rainforests

Tropical rainforests occur in areas near the equator that are warm all year round and have high levels of rainfall. These conditions allow the growth of enormous buttressed trees covered with orchids, bromeliads and ferns. Rainforests are Earth's oldest living ecosystems. Some have existed for more than 100 million years, which means an incredible diversity of life forms has evolved. Although they cover just six per cent of the Earth's surface, they contain more than half of all known species of animal and plant, including some of the largest and most spectacular insects, such as giant stick insects, birdwing butterflies and atlas moths. Beetles reach the peak of their diversity in tropical forests, and include gorgeous metallic jewel beetles; giant lumbering Hercules, Goliath and Acteon beetles; longhorn beetles with outsized antennae; and lots of smaller species that nibble leaves, chew wood or burrow in the rainforest soils.

There are countless species of rainforest insect that have yet to be described by science. In particular, numerous creatures live high in the forest canopy which makes them inaccessible to scientists. Who knows what amazing beasts await discovery. Sadly, our rainforests are rapidly disappearing, due to logging, land clearance for agriculture and climate change. One of the most important tasks for humans in the 21st century is to protect as much of this vital habitat as possible.

Key to plate

1: **Hercules beetle (male)**
Dynastes hercules
Length: Up to 190mm
This giant is the longest known beetle. It occurs in rainforests from Mexico southwards to Bolivia, and on some Caribbean islands. The larvae feed on dead wood, while the adults graze on rotting fruits that fall to the forest floor. Only the males have long horns, which are used to flip over rival males in combat.

2: **African giant swallowtail**
Papilio antimachus
Wingspan: Up to 230mm
Africa's largest butterfly, this magnificent insect is found in tropical forests of West Africa. Males come down from the tree canopy to drink from muddy puddles. The caterpillars have not yet been discovered.

3: **Thorny devil stick insect**
Eurycantha calcarata
Length: Up to 140mm
These heavily armoured insects are nocturnal, spending the day hiding amongst leaf litter or in hollow logs, and climbing up to feed on leaves in the canopy at night.

4: **Acteon beetle**
Megasoma acteon
Length: Up to 130mm
This giant of a beetle is the heaviest known insect when in its larval stage, with one specimen weighing 228 grams – about the same as a large hamster. Found in tropical South America, it is one of many species of scarab beetle, a group which also includes dung beetles and the Hercules beetle.

5: **Lantern bug**
Fulgora laternaria
Length: Up to 90mm
It was thought for many years that the enlarged head of this strange insect was luminescent, giving rise to the common name, but this is not true. It is also known as the peanut bug because of the resemblance to a peanut shell.

6: **Harlequin beetle**
Acrocinus longimanus
Length: Up to 75mm
The harlequin beetle belongs to a large group known as the longhorn beetles after their very long antennae. Longhorn larvae bore into the stems of plants or the trunks of trees. Male harlequin beetles have greatly elongated forelegs, which they use to wrestle each other over females.

7a: **Pink katydid (female)**
7b: **Pink katydid (male)**
Eulophophyllum kabulotum
Body length: Up to 30mm
Many katydids, also known as bush crickets, mimic green leaves, as do males of the pink katydid. In contrast, the females are reddish-pink with bright yellow 'veins', perfectly copying the young pink leaves of the rainforest trees on which they live. This species was only discovered in 2016 on Mount Kinabalu on the island of Borneo.

INSECTARIUM

Gallery 6

Moths and Butterflies

Moths

Butterflies

Complete Metamorphosis

Monarch Butterfly

Habitat: Meadows

Moths

Most human cultures separate butterflies from moths, having different words for them and different attitudes to them. Yet, in scientific terms, there are no meaningful scientific differences between the two insect groups. Together, the two groups form the Lepidoptera, with moths comprising the large majority: 147,000 of the 165,000 known species. While there are no hard rules to separate butterflies from moths, butterflies tend to fly in the day, while the majority of moths are nocturnal. Most butterflies have clubbed antennae and sit with their wings folded vertically above their backs, while moths usually have feathery or thin filamentous antennae, and sit with their wings held horizontally when resting. However, there are exceptions to all these rules, and butterflies are best seen as a colourful branch of the moth family tree.

Moths first evolved about 190 million years ago during the Jurassic period, with butterflies branching off much later, about 56 million years ago. Moths are ecologically important as pollinators of night-scented flowers such as honeysuckle and tobacco. They are a favourite food of many larger bat species, while their juicy caterpillars are a vital food source for many birds and small mammals. One of our most prized fabrics – silk – is woven from the pupae of silk moths.

Some male moths have an extraordinary ability to sniff out a female up to eight kilometres away. They use their feathery antennae to sift the air for just a few molecules of the scent she is releasing, then follow the scent upwind.

Key to plate

1: **Garden tiger moth**
Arctia caja
Wingspan: 60mm
The bright colours of this moth warn potential predators that it is poisonous. Once a common species that often turned up in gardens, sadly this moth is now quite rare.

2: **Emperor gum moth**
Opodiphthera eucalypti
Wingspan: 150mm
The caterpillars of this Australian moth feed on the leaves of eucalyptus trees. Like many silk moths, the adults do not feed and live for just a few days.

3: **Spanish moon moth**
Graellsia isabellae
Wingspan: 150mm
This is a stunning and very rare silk moth found in Spain and France, restricted to high altitudes in the Alps and Pyrenees.

Butterflies

Perhaps one of the most familiar, colourful and easily recognised of all the insect groups is the butterfly. There are about 17,500 known species of butterfly found throughout the world. In many cultures, including Ancient Greece, butterflies were thought to be incarnations of the souls of the dead. The Greek word for butterfly is *psyche*, also meaning soul or spirit, while the Aztecs believed that butterflies were reincarnations of great warriors who had died in battle. The Navajo thought butterflies could carry messages to the Great Spirit. The origins of these beliefs are unknown, but presumably relate to the beauty and delicacy of these creatures.

The Latin name of the group to which butterflies belong, Lepidoptera, means 'scaly wing'. This name refers to the many thousands of tiny, coloured scales arranged like the tiles of a roof that give butterflies their often beautiful and elaborate wing patterns. Sometimes the bright colours help to attract a mate, while in other butterflies, red and black or yellow and black patterns advertise that they are poisonous to eat. An additional characteristic feature of this group is that the adults have a coiled proboscis, which they unfurl to drink nectar.

Sadly, many butterflies are particularly vulnerable to climate change. Some are weak fliers and therefore find it difficult to travel to cooler latitudes as the climate warms. These fragile creatures are also easily damaged by storms and heavy rain, both of which are becoming more frequent. Mild winters disturb hibernation and can disrupt the timing of butterfly life cycles that need to be synchronised with the plants on which they feed.

Key to plate

1: **Hypothyris sp.**
Wingspan: Up to 50mm
One of a group of similar, brightly coloured butterflies that fly lazily through the tropical forests of South America. Predators do not bother them as they have a strong smell and are poisonous.

2: **Scarce swallowtail**
Iphiclides podalirius
Wingspan: Up to 90mm
A handsome angular butterfly, which despite its name is fairly common across much of Europe and east to China. The caterpillars feed on sloe bushes and sometimes on orchard fruit trees.

3: **Giant blue morpho**
Morpho didius
Wingspan: Up to 150mm
Found in Peru, this butterfly is a strong contender for the title of most beautiful insect. The wings of the males are a spectacular iridescent blue, flashing in the sunlight as the butterflies soar through the rainforest.

Complete Metamorphosis

Butterflies, moths, beetles, bees, wasps and true flies all undergo a miraculous process called complete metamorphosis. The larvae hatch from eggs as flightless, soft-bodied creatures that look nothing like their parents. The larvae feed and grow, and then eventually turn into a non-feeding pupa, inside which the tissues of the larva break down and completely reorganise themselves. Eventually the adult insect emerges.

In butterflies and moths, the larvae are known as caterpillars. Caterpillars typically have three pairs of 'true' legs at the front, and then usually five pairs of 'prolegs', with which they cling tightly to their foodplant. They are eating machines with sturdy jaws for munching up leaves. They feed almost constantly and grow fast. To avoid becoming a tasty snack many are beautifully camouflaged, while some are brightly coloured or clothed in dense hairs. Some are gregarious, living in large groups. Almost all are herbivores.

Caterpillars of some butterflies have mutually beneficial arrangements with ants, whereby the caterpillar produces sugar- and protein-rich secretions from glands on their back which are eagerly gathered by ants. In exchange, the ants keep a watchful eye on the caterpillars, guarding them against predators or parasites.

After moulting several times as they grow, caterpillars eventually pupate, sometimes within a protective cocoon which they spin from silk. Upon emerging from the pupa, the adult must swiftly pump blood into its tiny, soft wings to expand them before they dry and harden. The adults don't live long, their role being to find a mate and lay eggs. In some species the adults migrate long distances – up to thousands of kilometres – to escape winter.

Key to plate

1: **Monarch butterfly caterpillar (stages from caterpillar to butterfly)**
Danaus plexippus
Length: Up to 45mm
A familiar but declining North American butterfly, the caterpillars feed on milkweed.

2: **Pale tussock moth caterpillar**
Dasychira pudibunda
Length: Up to 40mm
These fluffy caterpillars are common in much of Europe, feeding on the leaves of oak, birch and other trees.

3: **Saddleback moth caterpillar**
Acharia stimulea
Length: Up to 30mm
Common in eastern North America and Mexico, the hairs of this caterpillar cause a nasty rash if touched.

4: **Puss moth caterpillar**
Cerura vinula
Length: Up to 50mm
When under attack, this caterpillar extrudes red, whip-like tails and an unpleasant odour as a defense.

5: **Flannel moth caterpillar**
Megalopyge opercularis
Length: Up to 25mm
These cute caterpillars, found in North America, have poisonous spines that can cause severe rashes, blisters and nausea.

6: **Jewel moth caterpillar**
Acraga coa
Length: Up to 20mm
The caterpillars of this species are transparent, except for the small brightly coloured protuberances. This camouflage disguises the caterpillars to look like water droplets or jelly.

7: **Japanese owl moth caterpillar**
Brahmaea wallichii
Length: Up to 90mm
These bizarre caterpillars may be found on privet bushes in Japan.

8: **Death's-head hawkmoth caterpillar**
Acherontia atropos
Length: Up to 130mm
These huge and colourful caterpillars are surprisingly hard to spot when feeding on the leaves of potato plants, one of their preferred foods.

9: **Lobster moth caterpillar**
Stauropus fagi
Length: Up to 30mm
This peculiar caterpillar is sometimes said to mimic a spider, although this is not entirely convincing.

Monarch Butterfly

Being able to fly gives insects many advantages, not least the ability to travel long distances to escape unfavourable seasons, such as freezing winters or hot, dry summers. Some insects undergo amazing migrations – tiny and delicate creatures are somehow able to cross oceans and mountain ranges. For example, recent scientific research using radar suggests that somewhere in the region of 3.5 trillion individual insects, including many different moths, aphids, beetles and flies, migrate into the UK each spring. Most of the smaller kinds travel at high altitude, using wind currents to speed their progress, but some larger insects, such as dragonflies and some butterflies, are powerful fliers and so can migrate without the help of the wind.

Perhaps the most famous insect migration is that of the monarch butterfly, *Danaus plexippus*. An iconic, large and beautiful butterfly from North America, the monarch migrates south to hibernate. It gathers in dense clusters in a small area consisting of just a few hectares in the forests of central Mexico. The pine trees appear to be clothed in orange leaves, an illusion created by the many millions of butterflies hanging from the trees. In spring, the butterflies fly northwards, passing through three or four generations and moving as far north as Canada. In autumn, the great-grand offspring of those that set off in spring retrace the steps of their ancestors, flying over 3,000 kilometres to return to precisely the same place in Mexico. How they locate exactly where to return to is unknown.

Sadly, monarch numbers have fallen by about 80 per cent in the last 25 years. This is largely driven by modern farming methods; the caterpillars of the monarch will eat only milkweed, a plant that used to be common in farmland but has been decimated by high levels of herbicide use. In 2022, the monarch was formally recognised as endangered by the International Union for the Conservation of Nature.

Key to plate

1: **Monarch butterfly**
Danaus plexippus
Wingspan: Up to 100mm
Monarch butterflies from all over North America gather together in their millions to hibernate for the winter in just a few hectares of cool mountain forests in central Mexico.

Habitat: Meadows

Meadows and grasslands are amongst the richest habitats for insects in temperate zones. They were probably created originally by the grazing of large mammals – wild cows, horse, bison and even elephants in the past – which would have browsed and knocked over saplings and trees, providing open space. More recently, similar grasslands were maintained by extensive farming practices, such as hay meadow management and livestock grazing.

Because of the lack of shade provided by trees, grasslands are open, sunny habitats, often supporting a high diversity of flowering plants; for example, chalk meadows in Europe may have up to 40 different plant species per square metre. This provides a great diversity of leaves for herbivorous insects such as grasshoppers, leaf beetles and caterpillars to eat, and also creates a diversity of flowers, catering for the needs of a multitude of pollinating insects such as butterflies, flies and bees.

These beautiful meadows are under threat from modern intensive farming practices. Many have been ploughed and reseeded with grass monocultures or replaced with arable crops; both habitats have minimal plant diversity and provide very few opportunities for insects. In England, 97 per cent of our flower-rich meadows were lost in the 20th century. However, many conservation projects are now underway to protect and restore the meadows that remain, and to create new ones by sowing wildflower seed mixes.

Key to plate

1: **Great yellow bumblebee**
Bombus distinguendus
Length: Up to 22mm (worker)
This handsome furry bee favours meadows in cooler parts of Europe, where it uses its very long tongue to feed on the nectar of deep flowers such as red clover, foxgloves and tufted vetch. The great yellow bumblebee has disappeared from much of its former range as the flower-rich grasslands have been lost.

2: **Meadow froghopper**
Philaenus spumarius
Length: Up to 6mm
Froghoppers, also known as spittlebugs, are unrivalled in their jumping abilities, able to accelerate at four metres per second and travelling 100 times their body length. Froghoppers are most often noticed for the 'spittle' on plants in spring, a frothy secretion produced by the nymph to protect itself.

3: **Adonis blue (male)**
Polyommatus bellargus
Wingspan: Up to 32mm
Males of this small butterfly are a dazzling sky blue, while the females are usually chocolate brown. They are found on sunny, south-facing downlands on chalky soils where the foodplant, horseshoe vetch, grows.

4: **Wart-biter cricket**
Decticus verrucivorus
Length: Up to 36mm
This handsome insect is found on chalk downlands. Its name comes from its historical use in Scandinavian countries to bite off warts. Unusually, the eggs of this cricket usually pass through two winters before the larvae hatch.

5a: **Cinnabar moth**
5b: **Cinnabar moth caterpillar**
Tyria jacobaeae
Wingspan: Up to 40mm
The yellow-and-black stripy caterpillars feed on ragwort (*Senecio jacobaea*), the leaves of which contain toxic alkaloids. The caterpillars store the poison in their tissues and pass it to the adult stage. The adults use crimson and black colours to warn birds that they are toxic. Native to Europe and Asia, they have been introduced elsewhere to control ragwort.

6: **Regal fritillary**
Speyeria idalia
Wingspan: Up to 100mm
This handsome butterfly is found in the native tallgrass prairie of North America. Ninety-nine per cent of this habitat has been lost, ploughed up for arable crops, so the butterfly is much less common than it used to be.

INSECTARIUM

Gallery 7

Wasps, Ants and Bees

Wasps

Wasps, bees and ants all belong to a highly successful group of insects known as the Hymenoptera, with 150,000 known species. The Hymenoptera contains most of the 'eusocial' insects – those that live in large nests with the majority of individuals being workers with just one, or a few, queens.

The earliest known wasps appeared about 200 million years ago in the Jurassic period and today more than 100,000 species of wasp have been identified. When most people think of a 'wasp' the common yellow and black social species (known as yellowjackets in North America) comes to mind – the type that tend to cause a nuisance at picnics. These are not typical wasps however. The large majority of known species of wasp are 'parasitoid' wasps: solitary insects that as larvae live on or in hosts (usually other insects). These wasps invariably kill their host, bursting from its corpse in a manner that almost certainly inspired the movie *Alien* (1979). Most parasitoids are small and easily overlooked, and so it is highly likely that huge numbers of species are yet to be discovered.

Most of the social wasps, such as yellowjackets, build nests from chewed up and regurgitated wood pulp. They create a light and strong papier mâché that is fashioned into an insulating papery ball containing sheets of hexagonal honeycomb-like cells. In social wasps, the egg-laying tube of the female has evolved into a sting, used particularly if the nest is under attack. The nests are typically short-lived, founded by a queen in early spring and dying out with the onset of autumn.

Wasps are much maligned, yet they serve many important functions as biocontrol agents and important pollinators.

Key to plate

1: **European beewolf**
Philanthus triangulum
Length: Up to 14mm
A handsome wasp, the beewolf specialises in feeding on honey bees, which are paralysed and stored in burrows underground for the offspring to consume. Many females may nest near one another in dense aggregations in sandy soil.

2: **Giant Asian hornet**
Vespa mandarinia
Length: Up to 45mm
Sometimes known as the murder hornet, this is the largest hornet species and has a potent sting. It is from Asia, but recently colonised northwest North America. It is a fierce predator, commonly attacking and destroying honey bee colonies.

3: **Common wasp**
Vespula vulgaris
Length: Up to 13mm
Nests are founded by a queen in spring and built of paper. They can grow to house several thousand workers by late summer. These wasps are important predators of crop pests.

4: **Emerald cockroach wasp**
Ampulex compressa
Length: Up to 22mm
This colourful insect has a sinister lifestyle. They are parasitoids of large cockroaches, stinging their prey in a particular part of its brain so that the cockroach loses the ability to run away, but is otherwise unharmed. The wasp then leads its victim by one of its antennae, like a dog on a lead, back to its lair where it lays an egg on the roach. The cockroach then stands helpless for days while it is consumed alive by the wasp's offspring.

5: **Tarantula hawk wasp**
Pepsis grossa
Length: Up to 50mm
These splendid blue-black insects have distinctive rusty orange wings. They prey on tarantulas which they paralyse, drag back to their nest and lay a single egg upon. The grub then burrows into the spider and eats it alive. Said to have one of the most painful stings of any insect, the tarantula hawk wasp is also one of the largest wasp species.

6: **Red velvet ant (female)**
Dasymutilla occidentalis
Length: Up to 19mm
The wingless females resemble furry ants. Their bright colours warn of a powerful sting. Velvet ants are parasitoids; eggs of this species are laid on the brood of various solitary wasps.

7: **Giant scoliid wasp**
Megascolia procer
Length: Up to 77mm
Perhaps the largest wasp species, the giant scoliid is a parasitoid of atlas beetle grubs, paralysing an unfortunate grub with a sting, laying an egg on it and then burying it for the emerging wasp grub to consume at its leisure.

Ants

Ants are arguably the most successful group of insects, found almost everywhere except Antarctica, and comprising 15–25 per cent of the total animal biomass in many ecosystems. It has been estimated that there are more than two million ants for every human on the planet. Ants first evolved about 150 million years ago, and today about 14,000 species of ant are known.

All species of ant are eusocial and live in colonies that may vary in size from a few dozen individuals to several million. This phenomenon has drawn the fascination of people, who often liken their industrious and organised societies to our own.

Aside from their ability to work together, one of the keys to their success is that many ants have evolved 'mutualisms' – mutually beneficial arrangements – with other organisms. For example, many ants farm aphids, protecting them from predators in exchange for sugary honeydew (see page 24). Others protect the caterpillars of blue and hairstreak butterflies in exchange for sugar- and protein-rich secretions. Acacia ants live within the swollen thorns of bullshorn acacia, which in addition to providing a home also offers sugary secretions and protein-filled nodules for the ants to eat. In exchange, acacia ants fiercely defend the tree against grazing herbivores such as cattle.

Like the wasps from which they evolved, most ants are predators. This means they can play a major role in pest control. Since at least 400 CE, farmers in China have been placing nests of tree-dwelling weaver ants in their citrus orchards to eat pests. Ants are often regarded as 'keystone species' because of the profound effect they have on ecosystems.

Key to plate

1: **Bullet ant (worker)**
Paraponera clavata
Length: Up to 30mm
These huge ants are famed for having one of the most painful stings of any insect, which has been likened to being shot – hence the common name. This species lives in the tropical forests of South and Central America. Nests are small, with just a few hundred workers which forage high in the tree canopy.

2: **Bulldog ant (worker)**
Myrmecia pyriformis
Length: Up to 26mm
These large Australian ants have a very painful sting and have caused multiple human deaths. They defend nests aggressively, chasing, biting and stinging any intruder. They are unusual amongst ants for being able to jump several centimetres high.

3: **Fire ant (worker)**
Solenopsis invicta
Length: Up to 6mm
A native of South America, the fire ant has invaded many countries including the United States and Australia. Their name derives from their very painful sting which creates a burning sensation. During floods, fire ants create living rafts by linking their bodies together, and so can float to safety.

4: **Honeypot ant (worker)**
Camponotus inflatus
Length: Up to 5mm
These Australian ants live in arid areas where food can be scarce. To survive these times, some of the workers become living food stores, ingesting so much food that their abdomen becomes hugely distended, resembling a golden grape. The Indigenous people of Australia value these ants as food, eating them raw and whole.

5: **Pharaoh ant**
Monomorium pharaonis
Length: Up to 2mm
A tiny, near-transparent ant, this species commonly lives in buildings and is considered a major pest. Concealed in cargo, it has spread to every continent.

Leafcutter Ant

The leafcutter ants of South America (genus *Atta*) form perhaps the largest and most complex societies on Earth, after humans. As many as eight million individuals may live in a single colony. Each worker has a specific role, and they have bodies to suit each role. Nimble, small workers tend to the brood in the nest and look after the queen while medium-sized workers forage for leaves. Large workers, with greatly enlarged heads and fearsome jaws, protect the nest from anteaters and other large predators. Parasitic flies will try to lay their eggs in crevices in the forager ants' heads, so some of the tiny workers hitchhike on the foragers, and protect them from the flies.

Like most animals, ants cannot digest cellulose, the main constituent of plant material. Yet the foragers collect thousands of leaves per day, carrying them back to the giant underground nest along trails that meander across the rainforest floor. The leaves are carried back to underground chambers that hold a fungal garden, a type of fungus that is tended meticulously by the workers. The fungus can digest cellulose, and in return for being fed chewed-up leaf pulp, it produces small bundles of nutritious bodies known as staphylae, which the ants eat. The unique species of fungi found in ant nests are found nowhere else; they cannot survive without the ants, and the ants would soon starve without them. Incredibly, the ants are so in tune with the fungus, they switch between gathering leaves from different tree species according to its nutritional needs. This is a fantastic example of symbiosis and, remarkably, the entire process takes place without any one individual being in charge.

Key to plate

The caste system in *Atta cephalotes* leafcutting ants.

1: **Queen**
Length: 30mm
The queen creates the nest and lays eggs.

2: **Male**
Length: 25mm
Their sole job is to mate with a young queen.

3: **Media**
Length: Up to 16mm
These ants collect leaves for the nest.

4: **Soldier**
Length: Up to 23mm
These have powerful jaws to defend the nest from predators.

5: **Minim**
Length: Up to 6mm
Minim mainly tend to the fungal garden and the queen.

Bees

Bees evolved from wasps about 120 million years ago, during the age of the dinosaurs. They are essentially vegetarian wasps and are the only insects we know of that feed exclusively on pollen and nectar throughout their lives. To gather enough food to feed their offspring, the adult bees must visit many thousands of flowers. They are therefore hugely important pollinators of both crops and wild plants. There are about 25,000 known species of bee.

Contrary to many people's perception of bees, most of them are solitary. Female bees make small nests – often a burrow in the ground – and stock them with pollen mixed with nectar. Here, they will lay one or more eggs. Only a few bee species, including honey bees, bumblebees and stingless bees, have evolved an eusocial lifestyle. These bees live in a colony consisting of a queen and many daughter workers.

Bees are remarkably intelligent insects, capable of incredible feats of navigation, and quickly learning which flowers provide the most rewards. One particularly marvellous adaptation is their in-built magnetic compass, which they use to aid navigation. This compass senses Earth's magnetic field and essentially helps bees to map out the local area and head in the direction of the most nectar-rich blossoms.

Bees are also capable of communication. Perhaps the most well-known example is the waggle dance of honey bees. This involves a worker bee conveying to her nestmates the direction and distance to a patch of flowers she has discovered by performing a dance in the darkness of the nest.

Key to plate

1: **Wallace's giant bee**
Megachile pluto
Length: Up to 38mm
The world's largest bee was discovered by the famous biologist Alfred Russel Wallace (1823–1913) in 1858, but was then thought to be extinct until rediscovered in tiny numbers in the 1980s. It nests within tree-dwelling termite nests on a handful of Indonesian islands.

2: **Blue-banded bee**
Amegilla cingulata
Length: Up to 12mm
A stocky and colourful Australian solitary bee, nesting in holes it digs in clay banks or the soft mortar of old houses. It is capable of 'buzz pollination', the rapid vibration of flowers to shake loose the pollen.

3: **Panzer's nomad bee**
Nomada panzeri
Length: Up to 8mm
This wasp-like bee is a cuckoo of solitary mining bees, sneaking in to lay an egg in the nest of its host. The young cuckoo grub has sickle-shaped jaws with which it kills the host's offspring.

4: **Hairy-footed flower bee (female)**
Anthophora plumipes
Length: Up to 12mm
This is a fast-flying solitary bee species, one of the first to emerge in early spring. The males have very hairy middle feet, which they use to stroke the face of the female during mating.

5: **Blue carpenter bee**
Xylocopa caerulea
Length: Up to 24mm
A handsome, large solitary bee, the blue carpenter bee gets its name from its habit of burrowing into timber to nest. It is found in India and China.

6: **Stingless bee**
Melipona beecheii
Length: Up to 10mm
This is a social bee from Central and South America, living in colonies of several thousand workers with a single queen. As the name suggests, this species has lost its sting. They have been cultured since Mayan times for their honey.

7: **Orchid bee**
Euglossa imperialis
Length: Up to 16mm
Orchid bees are a family of beautiful, metallic bees found in tropical America, resembling flying jewels. The males visit orchid flowers to gather scents which they store in their porous, swollen hind legs, and use to attract a mate. These bees are the main pollinators of many orchid species.

8: **Hill cuckoo bumblebee (female)**
Bombus rupestris
Length: Up to 19mm
Some bumblebee species such as this one have abandoned the job of building their own nests, but instead act as cuckoos. The female hill cuckoo bee seeks out an established nest of the red-tailed bumblebee (*Bombus lapidarius*, see page 36), kills the queen and enslaves the workers which then have little choice but to rear the offspring of the invader.

Habitat: Gardens

Many people are surprised to discover that there can be literally thousands of species of insect living right under their noses in suburban gardens. The record is held by a small urban garden in Leicester, England, which was surveyed with remarkable dedication for 35 years by its owner Jenny Owen; her final species list comprised 1,997 species of insect (and 766 other animals and plants).

Seen from the air, urban areas are a patchwork of habitats, including neat lawns, flower beds, mature trees, shrubberies, ponds, parks, abandoned plots and a huge diversity of plants. This provides lots of 'niches' for diverse insects – a variety of different places to shelter, nest and eat. For example, consider a bumblebee nest in a suburban garden. With a flight range of 1.5 kilometres or more, workers from the nest can visit thousands of gardens, and so are usually likely to be able to find suitable flowers somewhere.

Of course, not all is rosy for insects living in urban spaces. Concrete, bricks and tarmac offer little in the way of opportunity, while insects may encounter traffic fumes, pesticides, plastics and industrial pollutants. There are things we can all do to help our local insects, however. Overly manicured gardens, for example, are not insect-friendly. Mow less, and as the grass grows, flowers often appear, and grasshoppers and crickets may move in. Many plants, such as dandelions in the UK and milkweeds in the United States, are demonised as weeds, and are often dug up or sprayed with weedkiller. Most weeds are native plants however, and they are often very valuable to wildlife. Try thinking of these plants as wildflowers rather than weeds and let them flourish. You could also try building a bee hotel, or simply pile sticks and logs in a quiet corner and leave them. As they slowly decay, they will become home to an entire community of insects, spiders, centipedes and more.

Key to plate

1: **Red mason bee**
Osmia bicornis
Length: Up to 14mm
These small solitary bees nest in hollow plant stems, or dig into clay banks or soft mortar of old walls. They commonly occupy 'bee hotels'. Red mason bees emerge in spring, and are excellent pollinators of apples.

2: **Black garden ant (worker)**
Lasius niger
Length: Up to 5mm
Very common in European gardens, this ant is found under almost every patio slab or large stone. On a few warm days each summer, many nests will synchronously release swarms of winged queens and tiny winged males.

3: **Elephant hawk-moth**
Deilephila elpenor
Wingspan: Up to 65mm
A common moth species in much of Europe and Asia, the caterpillars possess large eye spots behind their head. When threatened they expand this section of their body, enlarging the eye spots, creating a passable impression of a snake.

4: **Common eastern bumblebee (worker)**
Bombus impatiens
Length: Up to 16mm
The most common bumblebee in the eastern United States, this species will happily nest in gardens, opportunistically nesting in underground cavities such as rodent burrows. This species is bred commercially to pollinate glasshouse crops such as tomatoes.

5: **Eastern yellowjacket (worker)**
Vespula maculifrons
Length: Up to 13mm
This is a familiar insect in much of North America, helpful in controlling pests such as aphids and caterpillars in vegetable plots and urban farms. This social wasp often builds its substantial papier mâché nests in attics and sheds.

6: **Red admiral**
Vanessa atalanta
Wingspan: Up to 75mm
A fast-flying butterfly, found throughout much of the Northern Hemisphere, the red admiral is often seen in gardens feeding on rotting fruits towards the end of summer.

7: **Ruby-tailed wasp**
Chrysis ignita
Length: Up to 10mm
Gloriously beautiful insects, ruby-tailed wasps are often seen in gardens, usually creeping about furtively near bee hotels. This species is a parasitoid of potter wasps, which themselves often nest in bee hotels.

The Need for Insects

The famous American entomologist E.O. Wilson (1929–2021) once said, "Without insects, the environment would collapse into chaos". He said this because insects play vital roles in almost every biological process on land and in freshwater. They provide food for most bird species, bats, amphibians, reptiles and freshwater fish. Predatory insects such as ladybirds, earwigs, lacewings and hoverflies help to keep crop pest numbers down, reducing the need for pesticides. Pollinating insects ensure that our crops give good harvests, and that wildflowers set seed. About 80 per cent of all plant species depend on insects to pollinate them, while 75 per cent of the crop varieties we humans grow also need to be pollinated by insects to provide a full harvest. Without insects, crop yields of apples, strawberries, cherries, blueberries, squashes, tomatoes, runner beans and many more would be greatly reduced. Even coffee and chocolate depend upon insect pollinators. All this means we could not grow enough food to feed our rising human population without pollinators.

Insects are also great recyclers. Many insects feed off dead organic material, recycling the nutrients and releasing them for other organisms to eat. Dung beetles and dung flies, for example, help to recycle animal faeces such as cow pats, beetle and wasp larvae tunnel in dead tree trunks, while blow-flies and carrion beetles help to swiftly dispose of animal corpses. Some insects disperse seeds, helping plants to reproduce, while others tunnel in soil, helping to aerate it. Silk moths provide us with silk, and bees provide us with honey and wax.

Insects are everywhere, burrowing, nibbling, pollinating, eating and being eaten. We need them; without these unsung heroes, our ecosystems would grind to a halt, and we humans would not survive.

Key to plate

1: **Ground beetle**
Abax parallelepipedus
Length: Up to 22mm
Ground beetles dash about on the soil surface at night, enthusiastically consuming slugs. They provide a valuable pest control service.

2: **Silk moth**
Bombyx mori
Wingspan: 50mm
This moth has been domesticated in China for at least 5,000 years, and in captivity has lost the ability to fly. When fully grown, each caterpillar (known as a silkworm), spins a cocoon from a single silken thread that can be up to 900 metres long. These threads are unravelled and used to weave silk.

3: **African dung beetle**
Kheper nigroaeneus
Length: Up to 40mm
This copper beetle rolls neat spheres of fresh dung and pushes them along backwards using its hind legs. The female lays a single egg on each ball of dung and mating pairs work together, burying it for their offspring to consume.

4: **Buff-tailed bumblebee**
Bombus terrestris
Length: Up to 18mm
This species is reared commercially for pollinating glasshouse tomatoes. Tomato flowers need vibrating to release the pollen, which bumblebees do by buzzing their flight muscles while biting the flower.

5: **Squash bee**
Peponapis pruinosa
Length: Up to 14mm
One of the many thousands of solitary bee species, squash bee females nest in burrows in the ground. They visit only flowers of squashes and pumpkins, and are excellent pollinators of these crops.

6: **Yellow dung fly**
Scathophaga stercoraria
Length: Up to 11mm
These fluffy yellow flies are particularly fond of sitting on cow pats. The larvae live within and eat the dung.

7: **Ceratopogonid midge**
Forcipomyia sp.
Length: Up to 3mm
These tiny flies are responsible for pollination of the cacao tree, so without them we would not have chocolate. Other ceratopogonid midge species, however, are less welcome as they can spread pathogens.

8: **Morgan's sphinx moth**
Xanthopan morganii
Wingspan: Up to 160mm
The Madagascan orchid *Angraecum sesquipedale* has nectar hidden in spurs 30cm deep. Charles Darwin predicted that there must be a moth with a tongue long enough to reach it, and this is it!

Saving Our Insects

Sadly, the majority of insect species for which we have long-term data are in decline. For example, in the United States the number of monarch butterflies has declined by 80 per cent in 30 years. It is estimated that up to 500,000 insect species have gone extinct since the industrial era began, with many more likely to follow if we do not act.

Insect declines are due to many factors. Insect habitats are often destroyed to be used for cattle pasture or for growing crops, while industrialised farming involves using numerous pesticides, many of them designed to kill insects. Climate change and the associated extreme weather events – fires, droughts, floods – are also beginning to have an effect, and light pollution disorients nocturnal insects. Another factor is that invasive species, such as rats in New Zealand or cane toads in Australia, eat many native insects.

Fortunately, most insects have not yet gone extinct, and their populations can recover swiftly if they are given suitable habitats. Because insects live everywhere, we can all do something to help. Make your garden a haven for insects (see page 84) and avoid using pesticides. Buy organic, local, seasonal food if you can, to encourage pesticide-free, sustainable farming.

Imagine green, vibrant towns and cities brimming with insect life, with more native trees, green walls and roofs, and wildflowers blooming in every garden, park and cemetery. Road verges and roundabouts filled with wildflowers could help to connect towns together, creating national networks of insect-friendly habitats. We can all help to achieve this in lots of small ways. If everyone does their bit, it would add up to a big win for nature, and would go a long way to ensuring a healthy future for insects and for ourselves.

Key to plate

1: **Rocky Mountain locust**
Melanoplus spretus
Length: Up to 28mm
In 1875, this grasshopper may have been the most abundant creature on Earth, when a swarm estimated to contain 12.5 trillion insects spread over the United States. Just 27 years later, in 1902, the last one was seen alive. It is thought that the core breeding grounds in river valleys were ploughed by farmers. Frozen individuals that became entombed in snow high in the Rocky Mountains can still be found thawing in the melting glaciers.

2: **St Helena giant earwig**
Labidura herculeana
Length: Up to 84mm
Little is known of this earwig, the largest known species, which was found on the remote Atlantic island of St Helena, where it lived in burrows in seabird colonies and gumwood forests. Last seen in 1967, it was probably wiped out by a combination of habitat loss to construction projects, and because rats, mantises and centipedes were introduced to the island.

3: **Large blue butterfly**
Phengaris arion
Wingspan: Up to 44mm
This rare butterfly is found in flower-rich meadows across Europe and east to China. The eggs are laid on wild thyme, but the young caterpillars drop to the ground and produce chemicals mimicking the scent of the grub of the ant *Myrmica sabuleti*. If a passing ant finds it, she will carry the grub back to her nest. The hungry caterpillar then proceeds to feast on the real ant grubs.

4: **Violet click beetle**
Limoniscus violaceus
Length: Up to 12mm
Many insects evolved to live in and feed on rotting wood, a habitat that has become scarce because dead trees are usually tidied away by us humans. The violet click beetle lives in the rotting heartwood of ash and beech trees. It is considered endangered in Europe, and in the UK it is now only found at three sites.

5: **Giant golden bumblebee**
Bombus dahlbomii
Length: Up to 21mm
Once common in the Andes of Chile and Argentina, this huge bumblebee is now close to extinction. It declined rapidly following the introduction in 1998 of European buff-tailed bumblebees, which carry European bee diseases.

INSECTARIUM

Library

Index

Curators

Dave Goulson is Professor of Biology at University of Sussex, specialising in bee ecology. He has published more than 400 scientific articles on the ecology and conservation of bumblebees and other insects, plus seven books, including *The Sunday Times* bestsellers *A Sting in the Tale* (2013), *The Garden Jungle* (2019) and *Silent Earth* (2021). Goulson founded the Bumblebee Conservation Trust in 2006, a charity which has grown to 12,000 members. In 2015, he was included in *BBC Wildlife* magazine's list of the top 50 most influential people in conservation. He is an ambassador for the UK Wildlife Trusts.

Emily Carter is an award-winning British designer based in London, specialising in hand-illustrated silk accessories and interiors. The collections are inspired by a lifelong interest in the natural world, where each design tells its own unique and individual story. She has received numerous awards and recognition for her work, including Forbes 30 Under 30 and Drapers 30 Under 30. Her products are stocked internationally, including in stores such as Liberty and Selfridges in London.

To Learn More

Amateur Entomologists' Society
A club for amateur insect enthusiasts of all ages.
www.amentsoc.org

Buglife
A membership-based conservation charity in the UK, devoted to saving insects and other invertebrates.
www.buglife.org.uk

Bumblebee Conservation Trust
A membership-based UK charity devoted to conserving bumblebees and other wild bees.
www.bumblebeeconservation.org

Butterfly Conservation
A membership-based UK charity devoted to conserving butterflies and moths.
butterfly-conservation.org

Dave Goulson on YouTube
Information on how best to conserve insects in your garden.
@davegoulson6831

Entomological Society of America
Aimed mainly at professional entomologists, with more than 7,000 members.
entsoc.org

London Zoo
Run by the Zoological Society of London, the zoo has an impressive display of tropical insects and other invertebrates.
www.londonzoo.org

Natural History Museum, London
Displays of insects, plus a collection of over a million insect specimens held behind the scenes for research and study.
www.nhm.ac.uk

Royal Entomological Society
A society which aims to promote the study of insects and public understanding of their importance.
www.royensoc.co.uk

Xerces Society for Invertebrate Conservation
A North American membership-based charity working to save insects and other invertebrates.
www.xerces.org