NATIONAL GEOGRAPHIC KiDS

ULTIMATE BUG-OPEDIA

BY DARLYNE MURAWSKI & NANCY HONOVICH

THE MOST COMPLETE BUG REFERENCE EVER

MORE THAN 400 AMAZING COLOR PHOTOS THROUGHOUT THE BOOK!

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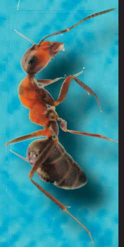

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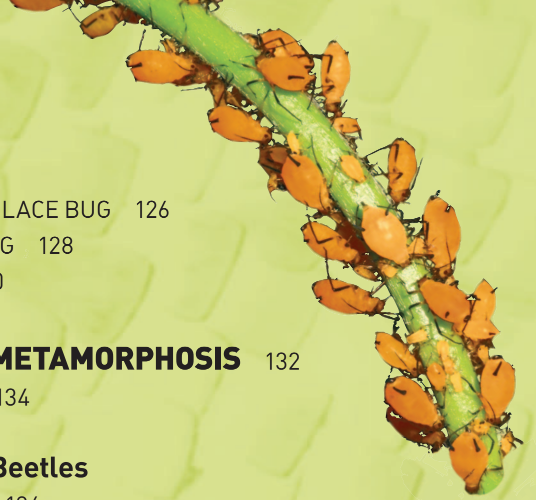
NATIONAL GEOGRAPHIC
WASHINGTON, D.C.

CONTENTS







INTRODUCTION

Insects are endlessly fascinating. They come in many sizes, shapes, and colors. They walk, fly, jump, swim, and burrow. They eat many things—and many things eat them. As they grow, they often transform themselves from one shape into a very different one. A few are harmful to us, but overall we need insects for many reasons—and, in fact, we need them for our own survival.

As an entomologist, my job is to study insects. I find something surprising about every insect that I encounter.

The *Ultimate Bugopedia* beautifully illustrates the diversity that scientists have discovered about insects and how they live. With more than 80 profiles of individual insects of different species and with many insect gallery spreads of even more insects within a group, along with hundreds of color photos throughout, this is a book that speaks to the life of insects. How do the bright colors of butterflies protect them from being eaten? Why do fireflies make their bodies flash? You'll find the answers to these questions and to just about anything else you want to know about insects in this book.

With *Bugopedia* as your guide and inspiration, you can go to your backyard, or almost anywhere, to study insects on your own. Observe insects carefully, and you can make your very own scientific discoveries about them.

When I was young, no single book encompassed the diversity of insect life like this one does. So you are lucky. With *Bugopedia* as your companion, I hope that you will discover the world of insects and become as fascinated with it as I am.

Bill Lamp, Ph.D.

Welcome to the *Ultimate Bugopedia*—a big source for information on the fascinating world of insects, with more than 400 photos. Insects are the most abundant and successful group of animals on earth—with more than a million known species and many more yet to be discovered. As a scientist and as a writer, I enjoyed working on this book, and I hope you will enjoy reading it.

When I was a child, I loved observing "bugs" and exploring nature outdoors. Those times provided endless small discoveries for me—like how bees visited different flowers in our garden at different times of day and how butterflies would try to stick their proboscises in the center of each flower on my brightly colored shirt!

My early enthusiasm for insects started me on a path toward pursuing my interests in a big way. As an adult, I've been fortunate to work as a biologist who studies butterflies and plants, and as a nature photographer who photographs them. In my travels around the world to places like Thailand, India, and the Amazon region of South America, I've encountered countless insects with amazing adaptations for survival. You can see a few of my photos of them on this page.

You may find yourself with a similar fascination for insects and their relatives. Some of the insects profiled in this book will be familiar to you, and others won't. The insects you'll see are from various parts of the world, and each has a story to tell. Enjoy exploring *Bugopedia*. You'll find another great thing about insects is that you never have to outgrow your interest in them. I haven't.

Darlyne Murawski, Ph.D.


HOW TO USE THIS BOOK

***Bugopedia* is filled with information about insects.**

Here you will find a guide to some of the pages in the different sections.

The first section, "Discovering Bugs," is an introduction to everything about these amazing animals. It will help you learn about and understand them, so that when you read the profiles of individual species, you'll already be in the know. The "Life Cycle of an Insect" is one topic explored in this section.


LIFE CYCLE OF AN INSECT

After hatching from its egg, a young insect grows until its skin, or exoskeleton, gets too tight. Then, it must shed its old skin, or molt. As it grows, an insect goes through a series of stages between molts.

Insects also go through some developmental changes as they mature. These changes are referred to as metamorphosis. There are two kinds of metamorphosis: simple and complete.

In species such as grasshoppers and true bugs, which undergo **simple metamorphosis,** there are three stages: the egg, nymph, and adult. The immature insect is called a nymph. Nymphs generally look like miniature versions of the adult, minus the wings. In species that develop wings, the nymphs have little wing buds visible on their backs.

In species such as butterflies and beetles, which go through **complete metamorphosis,** there are four stages: the egg, larva, pupa, and adult. The juvenile insect is called a larva. The larva looks very different from the adult insect. In order to transform into an adult, it must first go through an inactive stage, when it is called a pupa. During this stage, the larval tissues break down and adult tissues form—including the wings. When the time is right, a newly formed adult breaks out of the pupal skin and expands its wings. For protection, some insect larvae spin a silk cocoon before transforming into a pupa. The cocoon is a protective covering, like a blanket.

Life Cycle of a Monarch Butterfly: Complete Metamorphosis

1 Egg: After an egg is laid, a caterpillar develops inside. Upon hatching, the caterpillar begins feeding and growing. It molts a few times whenever its body gets too large for its exoskeleton.

2 Larva

3 Pupa: The caterpillar turns into a pupa. At first the pupa is green. But as the adult butterfly forms inside, its black, orange, and white colors become visible.

4 Adult: Eventually, the exoskeleton of the pupa cracks open and the adult butterfly slides out. It hangs onto its old exoskeleton until its wings have hardened and it is ready to fly.

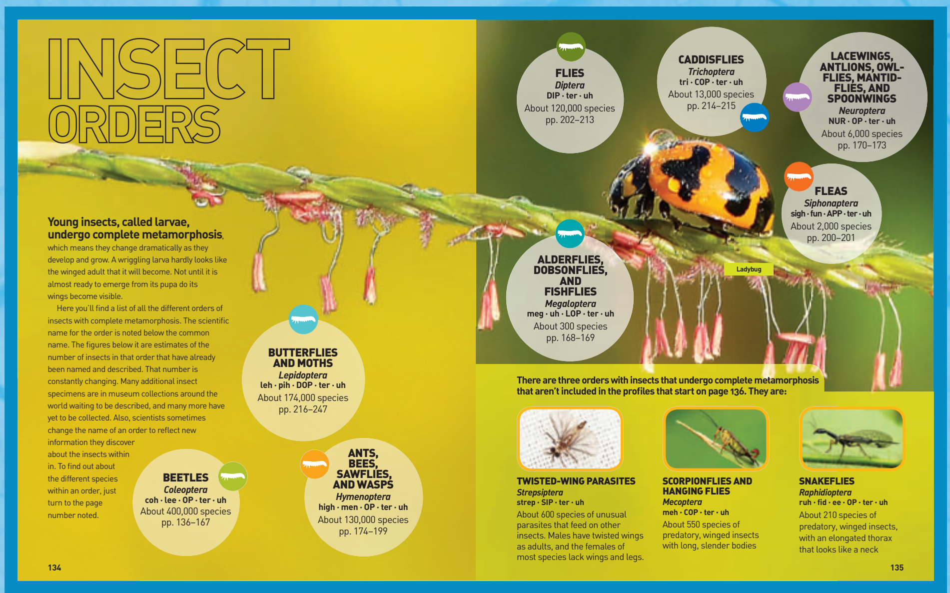
Life Cycle of a Grasshopper: Simple Metamorphosis

The two-striped grasshopper *(Melanoplus bivittatus)* typically lays its eggs in soil, where they will stay over winter. In the spring, when they hatch, tiny nymphs emerge and begin eating plants. As the nymphs grow, they molt a few times. At each stage of their development, their future wings grow. When the nymph molts for the last time, the emerging adult has fully developed wings and can fly.

1 Egg
2 Nymph
3 Adult

20 21

The second and third sections, the largest parts of the book, feature profiles of different insect species. They are organized by the type of metamorphosis that the insects undergo: simple or complete. The insects are then further arranged by their groups or orders. The pages at the right show insect orders for complete metamorphosis.


INSECT ORDERS

Young insects, called larvae, undergo complete metamorphosis, which means they change dramatically as they develop and grow. A wriggling larva hardly looks like the winged adult that it will become. Not until it is almost ready to emerge from its pupa do its wings become visible.

Here you'll find a list of all the different orders of insects with complete metamorphosis. The scientific name for the order is noted below the common name. The figures below it are estimates of the number of insects in that order that have already been named and described. That number is constantly changing. Many additional insect specimens are in museum collections around the world waiting to be described, and many more have yet to be collected. Also, scientists sometimes change the name of an order to reflect new information they discover about the insects within in. To find out about the different species within an order, just turn to the page number noted.

BEETLES *Coleoptera* coh · lee · OP · ter · uh About 400,000 species pp. 136–167

BUTTERFLIES AND MOTHS *Lepidoptera* leh · pih · DOP · ter · uh About 174,000 species pp. 216–247

ANTS, BEES, SAWFLIES, AND WASPS *Hymenoptera* high · men · OP · ter · uh About 130,000 species pp. 174–199

FLIES *Diptera* DIP · ter · uh About 120,000 species pp. 202–213

CADDISFLIES *Trichoptera* tri · COP · ter · uh About 13,000 species pp. 214–215

LACEWINGS, ANTLIONS, OWL-FLIES, MANTID-FLIES, AND SPOONWINGS *Neuroptera* NUR · OP · ter · uh About 6,000 species pp. 170–173

FLEAS *Siphonaptera* sigh · fun · APP · ter · uh About 2,000 species pp. 200–201

ALDERFLIES, DOBSONFLIES, AND FISHFLIES *Megaloptera* meg · uh · LOP · ter · uh About 300 species pp. 168–169

Ladybug

There are three orders with insects that undergo complete metamorphosis that aren't included in the profiles that start on page 136. They are:

TWISTED-WING PARASITES *Strepsiptera* strep · SIP · ter · uh About 600 species of unusual parasites that feed on other insects. Males have twisted wings as adults, and the females of most species lack wings and legs.

SCORPIONFLIES AND HANGING FLIES *Mecoptera* meh · COP · ter · uh About 550 species of predatory, winged insects with long, slender bodies

SNAKEFLIES *Raphidioptera* ruh · fid · ee · OP · ter · uh About 210 species of predatory, winged insects, with an elongated thorax that looks like a neck

134 135

There are eighty-three individual profiles of insect species in the book. Here is an example of one of them.


COLEOPTERA Beetles

GOLDEN TORTOISE BEETLE

FAMILY CHRYSOMELIDAE

Tortoise beetles look like they have an upside-down bowl over their backs, legs, and head. The bowl is actually their front wings and part of their thorax. It protects them so that predators, like ants, can't grab hold of them.

The golden tortoise beetle is named for its golden, jewel-like appearance on morning glory leaves, their preferred food. However, the bug isn't always golden. It can change its colors. The color change depends on the amount of fluids between layers inside their wings. The fluid is controlled by microscopic valves.

This color change once fooled scientists into believing that they were observing different species of beetles, not one. They even gave the beetle different names.

The larvae of the golden tortoise beetle have an effective way of defending themselves. They have a long, forklike extension at the end of their abdomen that holds large gobs of feces. When they hold this extension (called a fecal parasol) over their bodies, predators ignore them.

FACTS

OTHER COMMON NAME Sweet potato leaf beetle

SCIENTIFIC NAME *Charidotella sexpunctata* / Family: Chrysomelidae

WINGS Yes (their forewings are hardened wing covers and their hind wings are for flying)

FOOD Adult and Larva: morning glories

SIZE 0.20–0.28 inch (5–7 mm) long

HABITAT Found on morning glories

RANGE North America

138

139

Throughout the book, there are photo galleries—ten in all—that will show you even more species within a group than the ones individually profiled. The butterflies gallery below is one example.


BUTTERFLIES GALLERY

Butterflies have amazing wings made up of thousands of tiny scales. These scales can be brightly colored or dull, and even transparent. Some butterflies have shiny, metallic colors, like the morpho.

Butterflies use their wing colors and patterns in many ways. They can be used for camouflage, to absorb heat, and to find a mate. Some toxic butterflies also rely on their bright colors to warn predators that they taste foul. Potential enemies, like birds, learn to keep away. With about 20,000 butterfly species, these fluttering insects live just about anywhere in the world. They can be found in rain forests, mountaintops, deserts, cities, and even your own backyard. Do you have a favorite of the species shown here?

The peacock butterfly lives in Europe and parts of Asia. Its flashy eyespots may help deter predation. Adult butterflies hibernate over the winter.

A Malayan zebra butterfly drinks from moist, rocky soil. In Southeast Asia, these butterflies are often seen mud-puddling with other butterflies.

Cairns birdwing is Australia's largest native butterfly. It inhabits the rain forests of Queensland on the northeast coast.

A small skipper butterfly rests at attention on a flower stalk. Skippers have strong wing muscles for darting in flight.

A close-up of a butterfly's iridescent wing scales. The optically formed colors that you see depend on the angle at which you look at the wings.

This cattleheart butterfly from Jamaica is a type of swallowtail butterfly. Its fuzzy thorax is covered in tightly packed black and red hairs.

232

233

DISCOVERING BUGS

A sweet potato bug laying her eggs

A river jewelwing damselfly

Southern green stink bugs newly hatched from their eggs

Tree nymph butterfly

A scorpionfly on a leaf

A robber fly about to take off

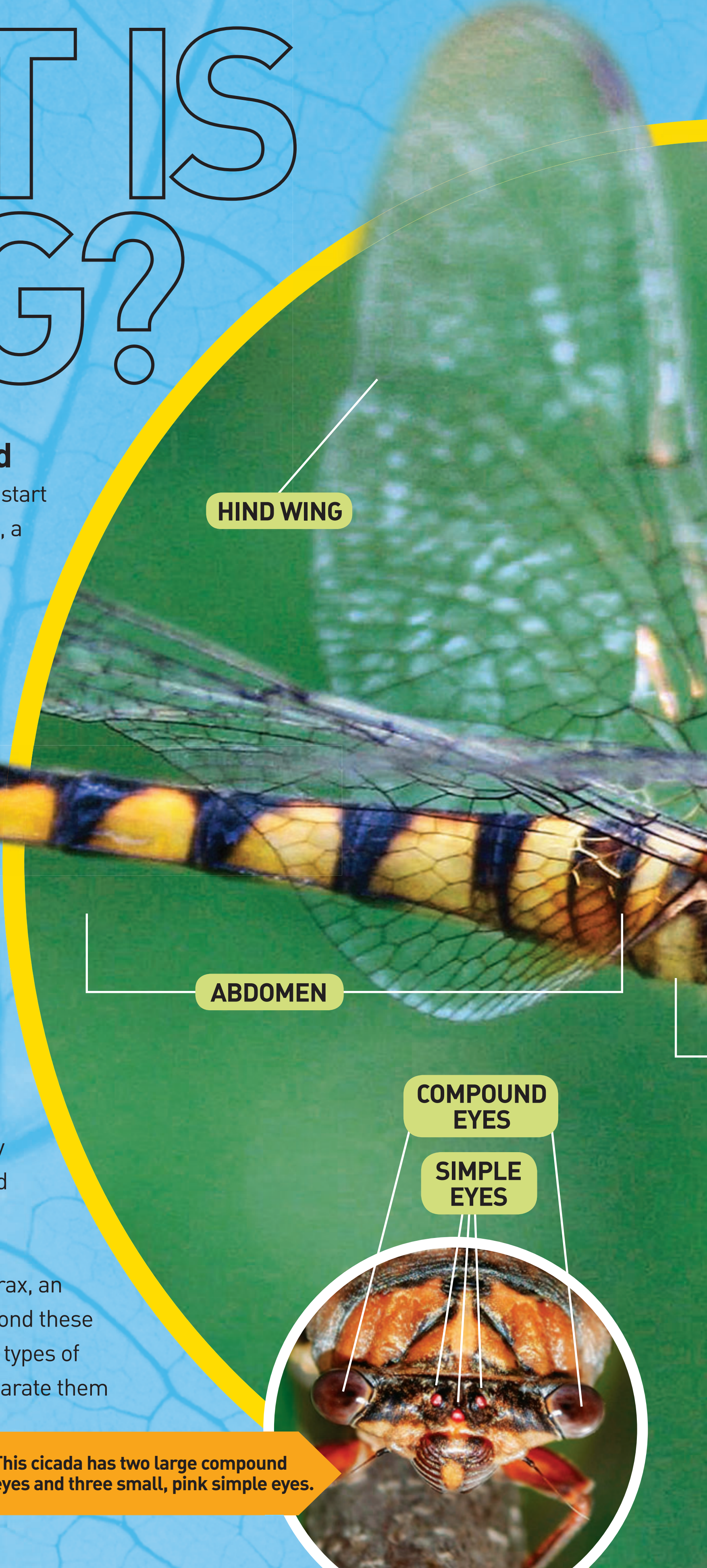
Ladybugs (ladybird beetles) on a vine tendril

WHAT IS A BUG?

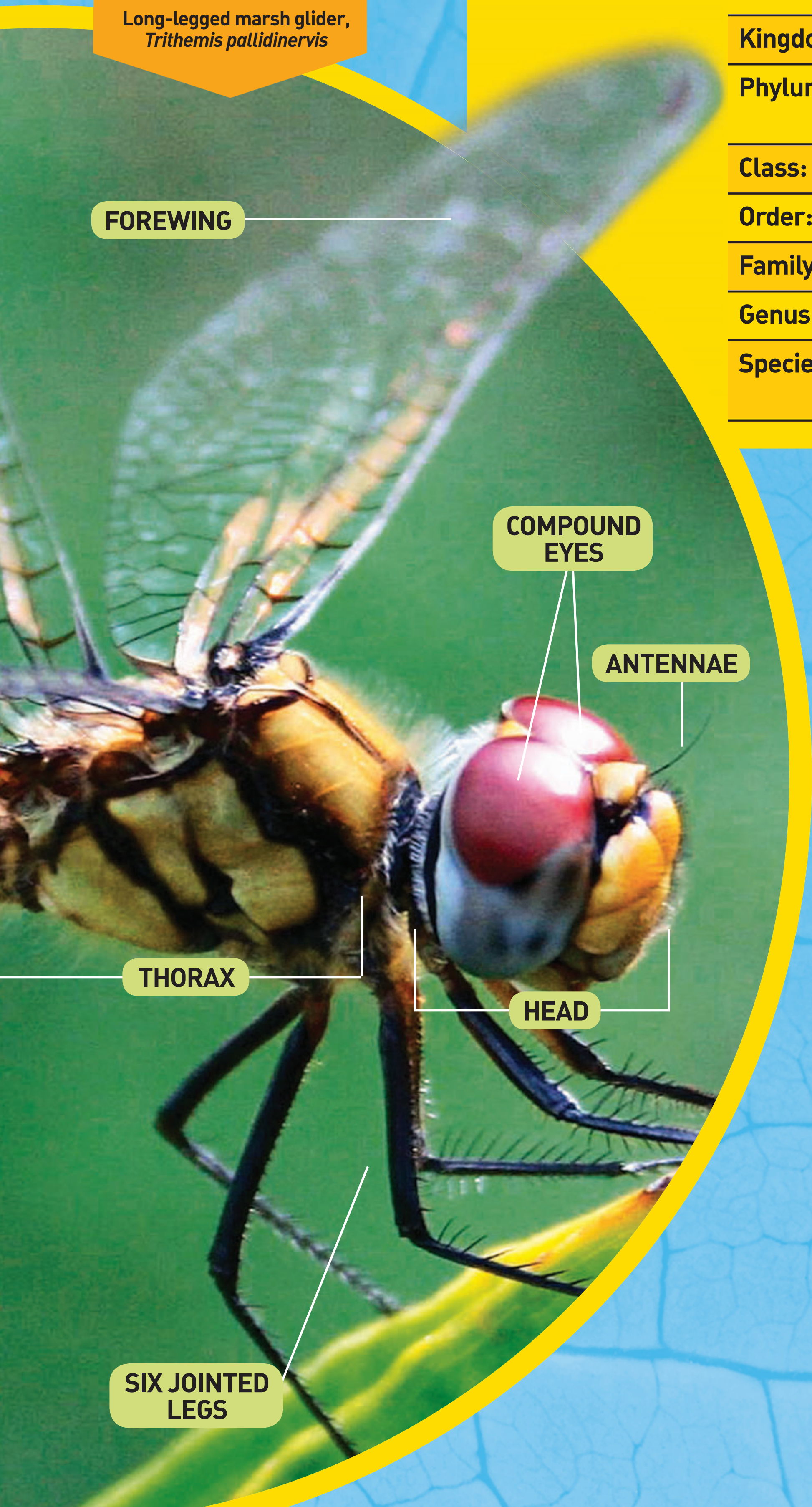
Look around you. It's not hard to find bugs. They crop up just about anywhere. But let's start off by thinking about what a bug actually is. To many, a bug is any small critter that looks vaguely like an insect, spider, or worm. To an entomologist, a scientist who studies insects, a bug refers to a specific group of insects called "true bugs." But generally, and in this book, the word "bug" is used to mean "insect." Not all of what we sometimes think of as bugs are insects, though: spiders and worms, for instance, aren't insects.

Insects have a hard external skeleton, called an exoskeleton. They have no spine, like we have. Along with other spineless animals, they are called invertebrates. Invertebrates also include spiders, worms, jellyfish, sponges, snails, crabs, and octopuses. Of all the invertebrates, insects are the only ones that evolved wings.

All insects have certain features in common. They have three main body sections: the head, thorax, and abdomen. On its head, an insect has eyes and two antennae. Insects have compound and simple eyes, although some have lost one or the other. On its thorax, an adult insect has six legs and two pairs of wings. Beyond these common features, insects have differences, such as types of mouthparts, wings, and shape of antennae, that separate them into various groups.



This cicada has two large compound eyes and three small, pink simple eyes.



Long-legged marsh glider, *Trithemis pallidinervis*

SCIENTIFIC CLASSIFICATION OF THE DRAGONFLY

Scientists divide animals into groups to help our understanding. Here's how the dragonfly gets grouped.

Kingdom:	Animalia (animals)
Phylum:	Arthropoda (jointed legs; or more precisely, "jointed foot")
Class:	Insecta (insects)
Order:	Odonata (dragonflies and damselflies)
Family:	Libellulidae
Genus:	*Trithemis*
Species:	*Trithemis pallidinervis* (long-legged marsh glider)

Insects breathe through pores in their bodies called spiracles. (See the white circles on the caterpillar above.) The spiracles lead to tubes inside the body (called tracheae). Insects don't have lungs, but like other animals, they breathe by taking in oxygen and letting out carbon dioxide. In some cases, their muscles expand and contract to control the intake of air.

INSECTS' CLOSEST RELATIVES

Insects are members of a larger group of animals we call arthropods. Their closest relatives are members of this group. Besides insects, other arthropods include arachnids (spiders, mites, and scorpions), crustaceans (crabs, lobsters, shrimp, and barnacles), myriapods (millipedes and centipedes), sea spiders, and horseshoe crabs. Of all the arthropods on earth, insects make up the vast majority of species.

Arthropods have jointed legs. They also have a segmented body and a hard external skeleton, or exoskeleton. The inside of an arthropod is a cavity full of fluids. These internal fluids are similar to our blood.

Red crab from Mandarmani, India. Its head and thorax are fused together and covered by a hard shell called a carapace. The crab's eyes are on stalks that help it see in all directions.

Argiope spider in its web. Spiders—along with scorpions, ticks, and mites—differ from insects in the number of body parts and legs they have.

Horseshoe crabs from Thailand. These arthropods are not true crabs but are related to extinct sea scorpions. The hinged shell covers the crab's body, including its legs.

This scorpion has powerful claws for grasping and a venomous stinger on the tip of its long, segmented abdomen.

FOSSIL BUGS

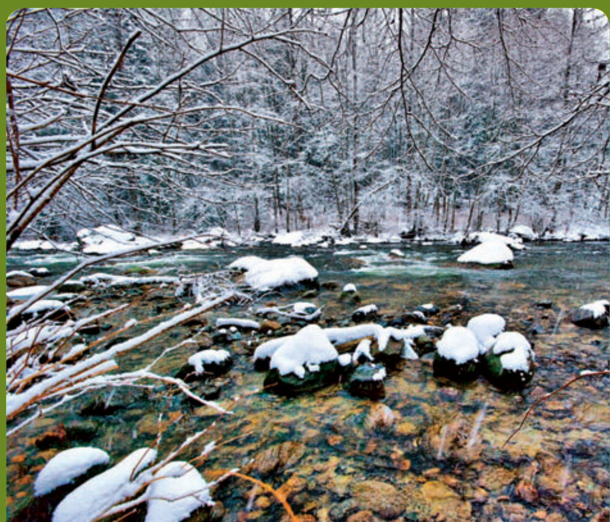
A beetle fossilized in Baltic amber from about 50 million years ago

Throughout their history, when insects died, some of them left behind impressions or imprints of themselves, which became fossilized.

According to these fossil records, the first winged insects were the mayflies, grasshoppers, and cockroaches. They appeared about 350 million years ago. That's about 120 million years before the appearance of the earliest dinosaurs!

Then, over a period of time that began 145 million years ago, the first flowering plants appeared. As flowering plants evolved, an explosion of diverse forms of insects followed—many of which were pollinators (like bees) and plant-eaters (like butterfly and moth larvae).

Ancient insects became fossilized if they met certain conditions. Some fell into sticky tree resin that over the years turned into a transparent, golden, stone-like substance called amber. Insects that fossilized in amber reveal lots of detail. Other insects were buried in materials like clay and sand that over millions of years turned into sedimentary rock. Inside the rock, the insect's flattened body made an imprint (or impression). Certain fossils can reveal more than just an impression. They can also hold the blackened (carbonized) remains of the insect. Other fossils are mineralized replacements of the original insect, meaning that the space once held the insect's body was filled in over time with minerals.



Where Insects Go in Winter

Depending on the species, they may migrate to warmer locations, find shelter from the cold, or hibernate until warmer weather. Many insects have a type of antifreeze in their body that keeps ice crystals from forming. They may hibernate at any point in their life cycle.

A well-preserved prehistoric grasshopper in amber. Size of insect: 0.5 inch (13 mm).

This is the oldest known full-bodied fossil of an ancient insect, which resembles a dragonfly. It is estimated to be 312 million years old and was found in Massachusetts. When the insect was alive, it left its imprint in mud.

INSECT DIVERSITY

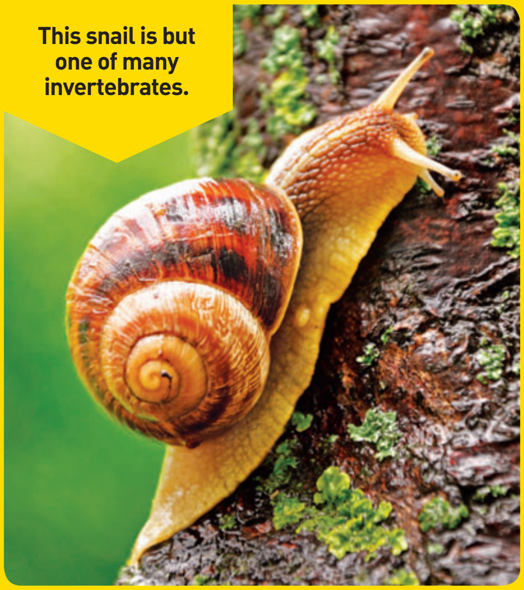
About one million species of insects have been described and named. Sometimes it takes years after discovery to describe and name a new species. It's hard to say exactly how many insects there are worldwide because new species are being described all the time, so the number is always increasing. But that's not all. There are many more species that have yet to be discovered.

Scientists have only been able to come up with rough estimates of the total number of insect species in the world. And those estimates range from 3 to 100 million species, with many agreeing on an estimate of at least 30 million. This means there are plenty of new insects for future generations of scientists—like you—to discover and study!

Insects and other invertebrates make up an impressive 95 percent of all animal species. And vertebrates, the animals people are most familiar with (including mammals, birds, reptiles, amphibians, and fish), make up only about 5 percent of all animals.

Insect diversity is highest in the tropical areas of the world, especially in the treetops of the rain forest. In tropical rain forests, a large portion of the insects are beetles. In the coldest climates, insect diversity is the lowest. Some insect groups found in the coldest climates include icebugs, dagger flies, and balloon flies.

Some insects are found over a large area that covers different continents, while others have smaller distributions. Often, non-migratory insects that live in isolated places like on islands and mountaintops are not found anywhere else.



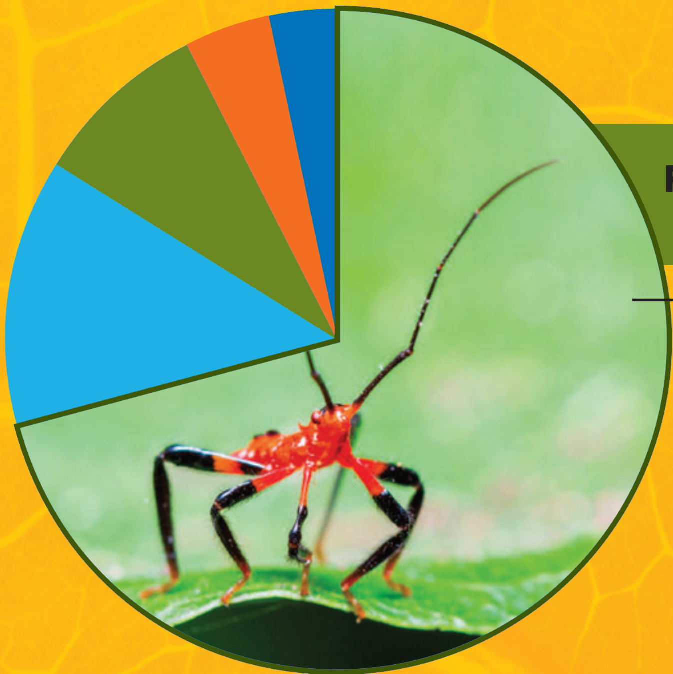
This snail is but one of many invertebrates.

Mammals, like this tiger, make up less than one percent of all animals.

DIVERSITY OF THE ANIMAL KINGDOM

INVERTEBRATES 95.6%
MAMMALS 0.4%
AMPHIBIANS 0.5%
REPTILES 0.6%
BIRDS 0.7%
FISH 2.2%

PERCENTAGE OF INVERTEBRATES BY GROUP



INSECTS 71.1%
MOLLUSKS 8.5%
CRUSTACEANS 4.3%
SPIDERS 3.1%
OTHER INVERTEBRATES 13.0%

PERCENTAGE OF INSECTS BY ORDER

BEETLES 40.0%
TRUE BUGS 8.2%
SMALLER INSECT ORDERS 9.4%
FLIES 12.0%
ANTS, BEES, WASPS, SAWFLIES 13.0%
BUTTERFLIES & MOTHS 17.4%

LIFE CYCLE OF AN INSECT

After hatching from its egg, a young insect grows until its skin, or exoskeleton, gets too tight. Then, it must shed its old skin, or molt. As it grows, an insect goes through a series of stages between molts.

Insects also go through some developmental changes as they mature. These changes are referred to as metamorphosis. There are two kinds of metamorphosis: simple and complete.

In species such as grasshoppers and true bugs, which undergo **simple metamorphosis,** there are three stages: the egg, nymph, and adult. The immature insect is called a nymph. Nymphs generally look like miniature versions of the adult, minus the wings. In species that develop wings, the nymphs have little wing buds visible on their backs.

In species such as butterflies and beetles, which go through **complete metamorphosis,** there are four stages: the egg, larva, pupa, and adult. The juvenile insect is called a larva. The larva looks very different from the adult insect. In order to transform into an adult, it must first go through an inactive stage, when it is called a pupa. During this stage, the larval tissues break down and adult tissues form—including the wings. When the time is right, a newly formed adult breaks out of the pupal skin and expands its wings. For protection, some insect larvae spin a silk cocoon before transforming into a pupa. The cocoon is a protective covering, like a blanket.

Life Cycle of a Grasshopper: Simple Metamorphosis

The two-striped grasshopper *(Melanoplus bivittatus)* typically lays its eggs in soil, where they will stay over winter. In the spring, when they hatch, tiny nymphs emerge and begin eating plants. As the nymphs grow, they molt a few times. At each stage of their development, their future wings grow. When the nymph molts for the last time, the emerging adult has fully developed wings and can fly.

Life Cycle of a Monarch Butterfly: Complete Metamorphosis

1 Egg

After an egg is laid, a caterpillar develops inside. Upon hatching, the caterpillar begins feeding and growing. It molts a few times whenever its body gets too large for its exoskeleton.

2 Larva

3 Pupa

The caterpillar turns into a pupa. At first the pupa is green. But as the adult butterfly forms inside, its black, orange, and white colors become visible.

4 Adult

Eventually, the exoskeleton of the pupa cracks open and the adult butterfly slides out. It hangs onto its old exoskeleton until its wings have hardened and it is ready to fly.

1 Egg

2 Nymph

3 Adult

COURTSHIP, MATING, AND EGG-LAYING

Finding a suitable mate is a challenge for insects. In addition to visual cues like color patterns, airborne chemicals called pheromones help insects locate possible mates. Courtship can involve dancing, gift giving, serenading, touching, and blinking their lights to entice a partner to mate. Many insects also use sound or surface vibrations.

The mating process involves contact between a male and female in order to fertilize the eggs. Hoverflies, butterflies, and other winged insects sometimes even mate in flight.

After laying eggs, most insects don't hang around to care for their young. That doesn't mean they don't try to improve their offsprings' chances of survival, though. Insects may prepare nests in advance or carefully select just the right host plant for laying their eggs.

Species in which one or both of the parents care for their young include social insects like ants, wasps, and termites. (See "Social Insects" on pp. 40–41.)

The male dance fly courts the female by offering her a nuptial gift. She eats the gift while mating.

To find a mate, a male *Creatonotos gangis* moth turns its greenish scent organ inside out from the end of its abdomen. It secretes a pheromone that attracts females of its species.

After courtship, a pair of tiny hairstreak butterflies mate on a leaf, after which the female will seek host plants to lay her fertilized eggs.

A group of ants carrying their pupae (in cocoons). Ants look out for their young, transporting them to safe places with favorable temperature and humidity.

INSECT EGGS AND EGG CASES

Female insects tend to lay many eggs—up to thousands over their lifetime. By laying so many eggs, they improve the chances that a few of their young will survive. Insect eggs come in many different shapes, colors, and sizes, depending on the species. The eggs might be bundled in silk cases, or set in jelly-like (gelatinous) masses. Some eggs have long stalks, and some are glued to tree branches. The females of most types of insects lay eggs, but aphids, some moths and flies, and a few cockroach species give birth to live young, meaning the eggs hatch before the babies are born.

A leopard lacewing butterfly laying her eggs on a vine tendril

A large cluster of eggs of the cabbage butterfly

A stink bug in the process of laying her eggs

Many young mantises stream out of the bottom of a large egg case made by their mother.

Some lacewings lay their eggs on the end of a stalk, which may then attach to a plant, wood, or even a windowsill.

PUPAE

The pupa is the resting stage between larva and adult in insects that undergo complete metamorphosis. Pupae may appear quiet on the outside, but on the inside, their larval body is breaking down and their new body as a winged adult is forming. The seemingly helpless pupae have some special ways of protecting themselves. A few are able to wriggle if touched or even walk around. Some pupae can make sounds or vibrate to scare predators. Some secrete toxic chemicals to avoid being eaten. Others, especially certain butterfly pupae, are defended by ants. (See the alcon blue butterfly, p. 222.) The pupae of bees, wasps, and ants remain in their hives or nests and are protected by adults of their species. Other insects spend their time as pupae underground, on trees and branches, or underwater.

Two black swallowtail caterpillars transforming into pupae. The one above is almost finished shedding its larval skin. Both are supported by silk strands connecting them to the branch.

A tomato hornworm caterpillar under attack by parasitoid wasps. After feeding on the caterpillar, the wasp larvae spin white silk cocoons and turn into pupae inside it.

A monarch butterfly emerges from its pupal exoskeleton. Once out, the butterfly will hang from the exoskeleton as its wings expand.

Two adult worker ants carrying an ant pupa

A mosquito pupa floating near the surface of the water. It leaves the water as an adult.

BUG SENSES

Bugs have the same senses of sight, taste, smell, hearing, and touch that we do, but they work in a very different way from our own senses. Imagine if we could taste with our feet and hear with ears on our legs, or see in front of and behind us at the same time.

TASTE

Insects taste mainly with their mouthparts and their feet. Some insects, such as bees, also have taste receptors on their antennae. And female wasps and crickets can determine by taste where to lay their eggs, using the egg-laying organ (ovipositor) on the end of their abdomen.

Gulf Fritillary butterfly

Fly

SIGHT

Insects see with simple or compound eyes—many have both types, and a few have no eyes at all. Simple eyes can't focus on images, but merely distinguish between light and dark. Many larvae and termites have simple eyes. Compound eyes, with their faceted lenses, can see objects in color and detail. Insects with large compound eyes can see in all directions. A honeybee's compound eyes are able to see a wider range of colors than most insects because they have three color pigment receptors, like us, rather than the two that most insects have.

Bedbug

TOUCH

An insect's sense of touch comes from the small hairs on its body that have a nerve at their base. Insects can feel if these hairs touch another object or if there are changes in air movement around them.

HEARING

Many insects don't have the ability to hear. Of those that do, their ears can be on various parts of the body—usually the thorax or abdomen, but sometimes on their front legs. Crickets, grasshoppers, katydids, and cicadas are among the insects that can hear. Certain moths have ears. Hearing allows these moths time to drop to the ground and play dead when bats approach them at night.

A grasshopper's hind leg, showing its hearing organ (the white area)

Male luna moth

SMELL

The antennae act as an insect's nose. They are covered in smell-gathering receptors that make them sensitive to odor molecules in the air. Besides being used for smell, antennae put insects in touch with the environment in other ways. For example, antennae can also detect humidity. Mosquitoes use their antennae to detect sound, and to assess air speed as they fly.

ANTENNAE

Insect antennae come in many forms.

The antennae are made up of a row of segments. Each segment is jointed, so the antennae bend, and each segment can have its own shape. The segments can be simple and straight—like those of mayflies, cockroaches, and caddisflies. The antennae can be clubbed on the ends, as in butterflies. They can be rounded or plate-like, as in many beetles. And they can be feathery, like those of many moths and flies. In ants and weevils, the antennae are bent in the middle.

The male cecropia moth has large feathery antennae. It is in the same silk moth family as the luna moth on p. 29. Females have thinner antennae than males.

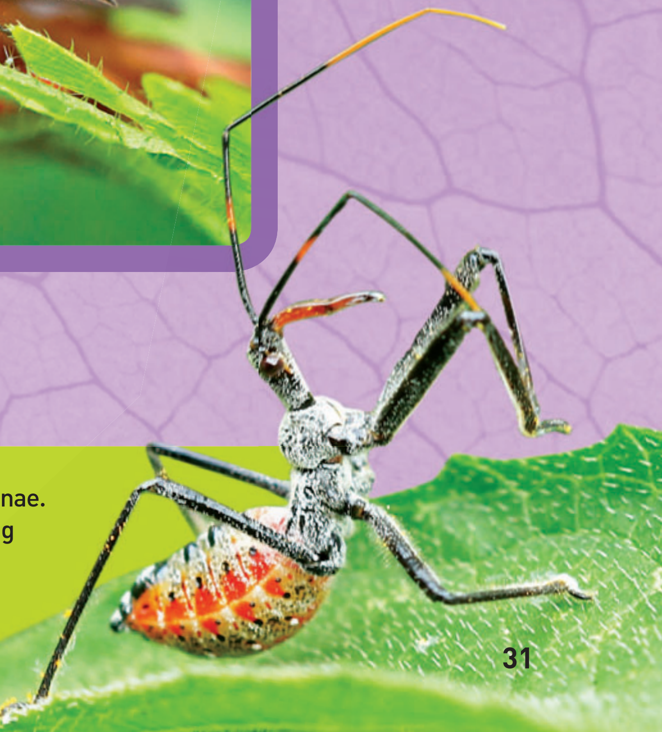
A female mosquito with thin, feathery antennae. She uses them to find blood meals. The males have bushier antennae for finding females.

A Red Admiral butterfly. Butterfly antennae are knobbed on the tips. They can detect the smells of nectar and pheromones.

An Asian longhorn beetle with very long antennae typical of its family: Cerambycidae.

Male ten-lined June beetles have huge antlerlike antennae that help them locate females.

Only the male glowworm beetle has ornate, comblike antennae. The females are larger than the males and look like larvae.



A wheel bug nymph cleaning its antennae. The wheel bug is a type of assassin bug that preys on pest insects (see p. 120).

HOW BUGS "TALK"

People communicate both verbally and nonverbally with other people. We talk, make noises, make faces, gesture, touch, and use scents. Insects do similar things. They communicate with sounds, visual signals, touching, and also by using their sense of smell. They communicate in order to find mates, escape predators, mimic other insects, warn of danger, threaten others, and give directions to food sources or other resources.

Insects make sounds by rubbing their body parts together (called stridulating), and by hissing, tapping, and vibrating their wings or special sound-producing membranes. They communicate visually with color patterns, body movement, and light flashes. Several types of insects, such as fireflies and glowworms, have light-emitting organs that glow in the dark.

Touching is an especially important form of communication for insects that can't hear and don't see well. For example, when ants and termites run in a line, they use their antennae to tap the hind legs of the individual in front of them, as if to say "I'm still behind you."

Insects communicate by smell using chemical odors called pheromones. They emit these odors, or messages, into the air. In addition to the pheromones that attract mates, insects use other odors in making food trails and for sounding the alarm to members of their species when danger is near.

A male African monarch communicates his interest to a potential mate. The male has two brushlike organs that it pushes out at the end of its abdomen. The "brushes" disperse pheromones in the air.

Fireflies "talk" to each other with light signals (above). The pattern of blinking can signal different things, such as an interest in finding a mate or in defending a territory.

Ants communicate with each other through visual signals, sounds, touch, and pheromones. The two ants at left, with their powerful jaws, are threatening to attack each other.

FOOD AND FEEDING

Many insects—especially those with complete metamorphosis—change what they eat when they grow up. For example, the caterpillars of butterflies and moths typically chew leaves, but as adults they drink nectar or other liquids.

An insect's mouthparts correspond with its diet. For instance, the proboscis of a butterfly or moth is long and hollow for reaching into flowers to drink nectar. The proboscis coils up when the meal is over. The group of insects called true bugs have a combined proboscis and hardened beak to pierce plants and drink their sap. Both mosquitoes and aphids can pierce and suck—the mosquito to feed on animal blood and the aphid to feed on plant fluids. Insects that chew their food feed with a pair of mandibles that can cut, tear, and crush. Meat-eating insects tend to have knife-like mandibles, whereas plant-eating insects have flatter, wider ones. Some mandibles are modified for fighting and hunting.

A praying mantis holds a grasshopper with a vice-like grip while feeding on it.

Host plants are the source of food for many larval and adult insects. Some insects can survive on only one species of host plant. For this reason, these species are called specialists. Other insects can eat various plants and are considered generalists. The larvae of a few generalists, like the gypsy moth, will eat just about any kind of leaf. Large groups of them can remove the leaves from a patch of forest.

10 COOL BUG MOUTHS

Fly maggot

Dragonfly

Katydid

Wasp

Beetle

Assassin bug

Mosquito

Butterfly

Stag beetle

Grasshopper

WHERE BUGS LIVE

Insects are found just about anywhere on Earth—from the polar regions to rain forests, from treetops to underground, as well as underwater, in houses, on animals, and on and inside of plants. One group of insects called sea skaters is even found on the surface of the ocean. Over time, insects have adapted to every available habitat where they can find resources. Special adaptations allow them to survive in places with extreme conditions, such as the freezing-cold Arctic, and the dry Namib desert, which gets only a half inch (13 mm) of rain per year. With the exception of the water striders, there are no insects in the open ocean.

Many insects require more than one habitat over their life spans. For example, some insects may live underground or underwater as larvae or nymphs, and aboveground as adults.

Mosquitoes are found in moist environments and their larvae live in standing water. Adult females need occasional blood meals.

These termites march with nest-mates in search of new sources of dead wood in the forest.

Whirligig beetles twirl around on the surface of flowing streams. They can swim, dive, and fly.

Caterpillars can often be found on the undersurface of leaves, where they're less visible to passing birds.

Flies are attracted to warm and moist places like animal dung (feces), where they lay their eggs.

Leaf miners are the larvae of several types of insects that feed on an inner layer of leaf tissue, making visible trails as they move along.

Two spotted cucumber beetles on a flower. They sometimes feed on pollen when they're not eating the green parts of plants.

Wasps often build their nests in protective locations, like under the eaves of houses.

INSECTS IN NATURE

Insects form an important link in the food chain. They provide food for birds, lizards, mammals, fish, amphibians, spiders, and other insects. If insects were to disappear off the face of the earth, there would be a chain reaction, and many other animals and plants that depend on them would become extinct. We rely on insects to pollinate crops, make honey, make silk, and clean up the environment. Scientists use insects like *Drosophila* flies (fruit flies) for research. Gardeners use predatory insects to get rid of plant-eating pests. And in some parts of the world, people eat protein-rich insects as part of their diet.

Small as they are, insects play major roles in the environment, and whether they are herbivores, predators, parasites, or parasitoids determines what part they play. They are herbivores if they feed on plants; predators if they kill small animals for food; parasites if they get their nutrients from living on or inside another animal without killing it; and parasitoids if they live as parasites but eventually kill their host.

Insects may engage in a "mutualistic" partnership with other organisms such as plants. This means that both the plant and the insect benefit from each other. A classic example of mutualism is pollination. The plant gets fertilized, and the insect typically gets rewarded with nectar, pollen, or resin. About 85 percent of flowering plants depend on insects for pollination—and that includes many of our crop plants such as apples and broccoli.

Some insects have a special role in cleaning up the environment. They may chew up the wood of fallen trees, recycle animal dung, and even break down dead animal bodies. They perform tasks that people don't want to do, and by burrowing and burying, they do wonders to improve the soil.

A brown anole lizard with a cicada in its mouth. The lizard's entire diet consists of insects.

After attacking a honeybee, these African driver ants are carrying it back to their nest, along a clothesline.

A bumblebee drinks nectar and gets covered in pollen.

Parasites feed on many insects. Some are fairly harmless like the tiny mites covering this beetle.

These tiny caterpillars are eating a willow leaf. Once the leaf is eaten, the group will move on to other leaves. The larvae of many insects have entirely different diets from the adults of their species.

SOCIAL INSECTS

Some insects are solitary and others naturally group together, like a cluster of ladybugs or certain caterpillars, when they feed in a row on the edge of a leaf. But truly social (or eusocial) insects have a system with special tasks for each member. Social insects include all ants, all termites, and many bees and wasps.

Social insects have certain features in common. They live together in a nest. They tend their young. They have overlapping generations—meaning that new insects are constantly being produced in a colony—and they have a division of labor, or caste system, in which members carry out specific tasks. Their castes include "reproductives," which are the queens and drones. The task of queens and drones, besides reproducing, is to select a location for a colony and to begin preparing the new nest. Other caste members, including workers and soldiers, don't reproduce. Workers are responsible for cleaning the nest; caring for eggs, larvae, pupae, and the queen; and collecting food. Soldiers defend the colony from predators.

Workers of a paper wasp colony build the hive and tend the young. If the queen wasp happens to die, one of the workers will replace her.

Look at the difference in shape and relative size of these three leafcutter ants. They belong to the same species—*Atta cephalotes*. The largest is a queen, whose sole responsibility is to reproduce, and the other two are workers: a major and a minor.

The nymphs of true bugs often group together as a large family. They are social in one sense, but not eusocial like insects with a caste system.

Worker ants from one colony of weaver ants are working together to bridge a gap between two leaves. Once the bridge is established, other ants can cross over it.

COLORS AND PATTERNS

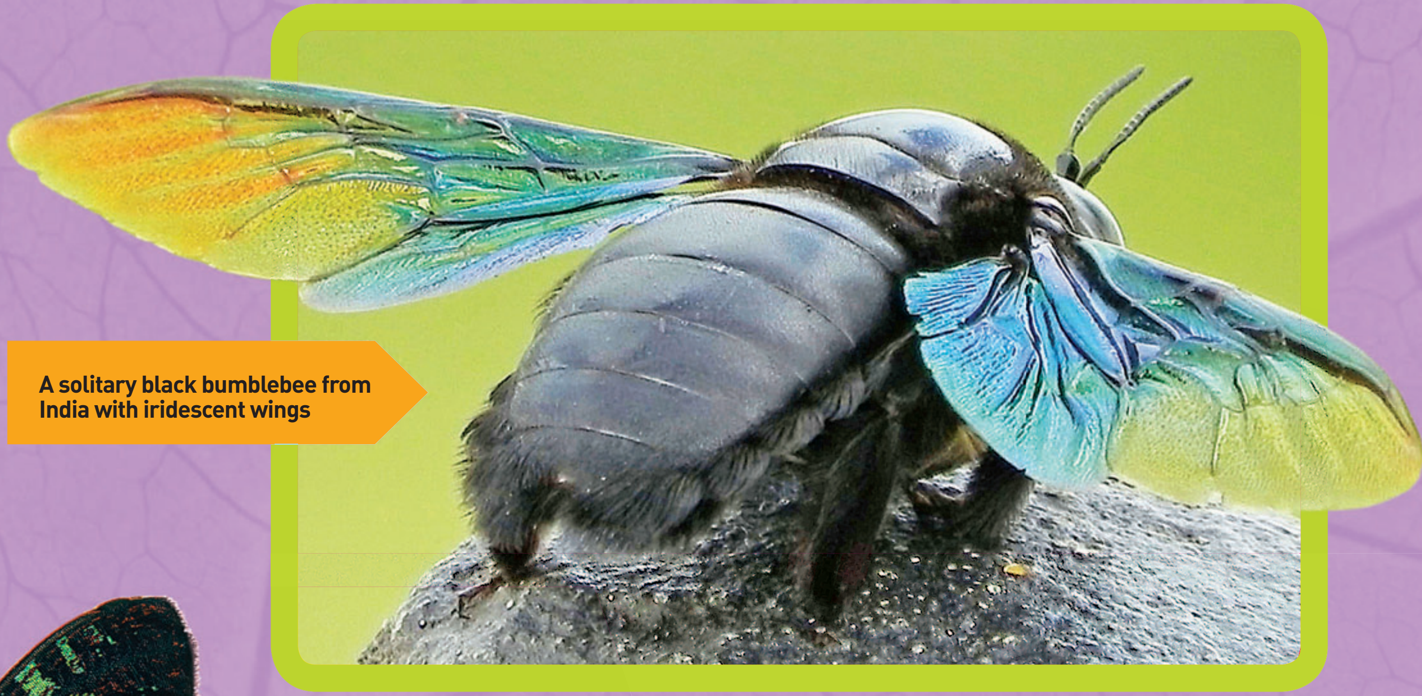
The incredible colors and designs on insects like beetles and butterflies help them to recognize each other, to impress mates, and to avoid predators. The colors and patterns are mostly determined by an insect's genes.

There are two types of colors in insects. One comes from pigments (or dyes) that are in their exoskeleton or below its surface. For example, bloodworms (the larvae of a type of insect called a midge) are red because of the color of their body fluids. The other type of color is formed optically, by the reflection of light off the surface of the insect's body. The three-dimensional texture is responsible for the colors we see. Optical colors can look metallic or iridescent—shifting as you see them from different angles.

The scales covering the wings and bodies of butterflies and moths can have either type of color and often have both. The striking, iridescent wings of blue Morpho butterflies and Madagascan sunset moths are examples of optical colors. Flies, dragonflies, and other clear-winged insects have optical color patterns that they display by holding their wings at certain angles.

This bloodworm is a midge larva with a transparent exoskeleton. Hemoglobin, found mostly in vertebrates, is a red protein that gives the larva its bright red color.

The Madagascan sunset moth has iridescent green on the forewings and various iridescent colors on the hind wings.



A solitary black bumblebee from India with iridescent wings

Close-up of iridescent blue scales from a butterfly's wing. The fine texture on each scale produces the color we see.

An iridescent green damselfly with transparent, blue-green wings

DEFENSES

Being near the bottom of the food chain, insects are surrounded by predators— mammals, birds, reptiles, amphibians, fish, and various arthropods. As a result, they have evolved an incredible array of defenses in order to survive. Take chemical defenses, for one. Many insects have poisonous or bad-tasting chemicals in their bodies. Some, like bees and wasps, can sting. Others spit or shoot acid at their foes, or they release foul-smelling chemicals.

Mimicry is also a widespread defense. Butterflies often mimic each other's color patterns for protection. There are insects that look like spiders, and spiders that look like insects. Some insects have false faces with real-looking eyes (see pp. 46–47). And there are insects that use camouflage to hide in plain sight by resembling leaves, sticks, or other things in their environment. Additional adaptations that protect insects include spines, horns, sharp mandibles, and a thick exoskeleton.

Running, jumping, wriggling, flying away, and hiding are other ways insects avoid being eaten. If insects can't find hideouts, some will make their own by rolling leaves or creating other forms of shelter. Some insects confront their enemies by fighting them. In a pinch, others even shed appendages—the monkey slug caterpillar, for example, sheds its false legs—in order to escape.

Most impressive is how many insects use a variety of defenses. If one doesn't work, perhaps another will!

The end of a wasp to avoid! The stinger is hollow and can inject its venom repeatedly. The painful sting has the effect of keeping potential enemies at bay.

A bombardier beetle sprays a boiling-hot chemical when it feels threatened. It has excellent aim, and it can cause intense pain.

A female clouded sulphur butterfly blends in with the leaves that surround it. Many insects rely on camouflage to be invisible to predators.

This saddleback caterpillar stings anything that comes too close to its hollow, venom-filled spines.

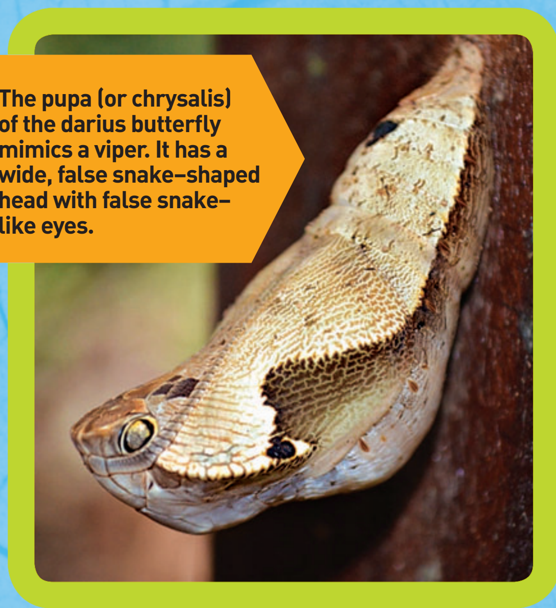
A green katydid resembles a leaf in color and pattern.

FALSE FACES

A polyphemus moth in a defensive posture, its hind wings exposing a pair of fake eyes

Birds are major predators of insects. But while hunting they can be spooked by anything resembling snakes or other bird-eating predators. If they don't react quickly, they might be eaten themselves! Insects have evolved ways to take advantage of this fear in birds and other animals that hunt using their sense of sight. Some insects have false faces with fake eyes, and some have eyespots that create the appearance of a spooky face staring back at you. Birds are easily startled by such false faces or eyes, giving the insect another chance to survive. Some false faces, however, may not be adaptations, but chance patterns that we mistakenly interpret as faces.

A spicebush swallowtail caterpillar. Its real head is tucked underneath the black line that looks like a mouth. The false eyes, complete with eyeshine, seem real.



The pupa (or chrysalis) of the darius butterfly mimics a viper. It has a wide, false snake-shaped head with false snake-like eyes.

The comical face on the back of this shield bug may not be a real adaptation to frighten predators, but its coloration may warn that it's toxic.

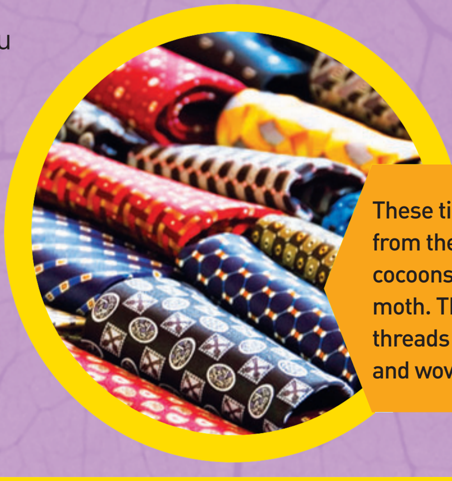
The io moth normally has its hind wings covered while it rests. If a bird approaches, it lifts its forewings to expose giant fake eyes.

The Oleander hawkmoth caterpillar has a pair of false eyes in a fold on its back. When disturbed (right), it tucks its head down and flashes its huge false eyes. When at rest (below), its false eyes are half closed.

THE SILK MAKERS

Spiders spin silk threads for webs. But did you know that at some point in their lives, many insects make silk threads too? The silk is a liquid inside the silk glands of insects and spiders, but when it is secreted from the glands and exposed to air, it dries into silk strands. Both insects and spiders use silk threads for many purposes, such as for making cocoons, traps, safe havens, drag lines, coverings for their eggs, and support structures, as well as for molting, wrapping prey, and ballooning (using the wind to blow them to another location).

Silk is a natural fiber composed of proteins. It is exceptionally strong and elastic. The larvae of most butterflies and moths and various other insects secrete silk from spinnerets below the mouth. But, insects called webspinners secrete silk from glands in their front legs. They work together to make their homes of silken tunnels and sheets on tree trunks, rocks, and leaf litter.



These ties are made from the unwound cocoons of the silk moth. The silk threads are dyed and woven into fabric.

Two silkworm caterpillars making their cocoons

10 COOL INSECT SILK MAKERS

Moth larvae

Webspinner nymphs

Some wasp and bee larvae

Raspy crickets

Fungus gnat larvae

Weaver ant larvae

Caddisfly larvae

Lacewings (egg stalks)

Black fly larvae

Butterfly larvae

MIGRATION

A number of animals—many birds, some whales, African elephants, caribou—migrate, and so do insects. Insects that migrate include Australia's Bogong moths, and many species of dragonflies, beetles, and butterflies, such as the well-known monarch. As with other animals, reasons that insects migrate include escaping drought or cold and finding food.

One of life's big mysteries has been exactly how animals migrate. When monarchs migrate, they use the sun as a compass. But the sun changes position in the sky over the day. Despite this, monarchs are able to keep flying in a particular direction. Scientists have been trying to learn how this happens. They have discovered a molecular process in the butterfly's antennae that compensates for the sun's shifting position.

Scientists also think that monarchs might use a magnetic compass that informs them where to go. Monarchs have a mineral in their bodies called magnetite. This mineral is the most magnetic on earth. It's found not just in monarchs, but also in some other insects such as bees, dragonflies, termites, and grasshoppers, as well as in migrating birds. It appears to play a role in insect migration, and scientists are actively researching this possibility.

Migration routes shown are some of the longer examples for the particular species.

INSECTS AS PESTS

Less than one percent of insects are considered serious pests, yet their effect is impossible to ignore. Insect pests damage crops, eat wooden structures, sting, bite, ruin lawns and gardens, and make loud noises.

Lice, bedbugs, fleas, some flies, and some mosquitoes are pests—taking blood meals and leaving irritating rashes and bites. And some mosquitoes can endanger human health by carrying diseases like malaria. Malaria is a serious parasitic disease that affects about 300 million people around the world. About one million people die from it each year.

Ticks, related to spiders, also bite and can transmit microorganisms that cause human disease (such as Lyme disease and Rocky Mountain spotted fever). Chiggers, also related to spiders, can transmit illness, and they cause serious itching and leave red welts.

Locusts are grasshoppers that form huge swarms. "Plagues" of locusts can darken the sky as they fly into an area, and then eat everything in sight before moving on. The desert locust has such a reputation in drier parts of Africa.

Pest management has become a huge industry in which professional entomologists try to control the numbers of certain insect species. One means of controlling insect pests without pesticides is through biological pest control. Living organisms like predators and parasites are employed to do the job. Entomologists also help to protect species that are not pests.

Body lice are one type of insect pest that especially affects people with limited access to bathing or clean clothes. The lice cause intense itching and might also transmit diseases such as typhus.

Termites caused this damage to a wooden pillar in the corner of a porch. Termites can also be beneficial. Their diet of wood enables them to break down fallen trees and branches.

Locusts travel in swarms, dropping into an area in huge numbers. They eat all plants in sight—including crops—before moving on to other areas. Only certain species of grasshoppers are capable of becoming locusts. The change happens when grasshopper populations become very dense.

THE THREAT OF INSECT EXTINCTION

As human populations expand, people use more and more natural resources, and in the process, they alter the natural environment. Most of the earth's land surface, about 83 percent, has been altered by humans. As a consequence of our activities, certain animals, including insects, have become extinct—which means they will never be seen again. And many other animals are in danger of extinction right now. Scientists estimate that many insects are disappearing even before they are discovered and named!

The aim of conservation is to preserve and protect animals and plants, their natural environments, and the ecosystems they live in. And where natural areas have been damaged, people are making efforts to restore them to their previously healthy condition.

When we help animals, plants, and the environment, we help ourselves too!

As Harvard biologist E. O. Wilson once wrote, "So important are insects and other land-dwelling arthropods, that if all were to disappear, humanity probably could not last more than a few months."

The erosion and loss of insects' natural habitats alters the balance of nature. One problem facing us is how to manage land in order to maintain biodiversity and a healthy ecosystem.

10 CHALLENGES INSECTS FACE


Water pollution


Deforestation


Air pollution


Industrial waste (in water)


Climate change (flooding)


Building construction


Industrial waste (on land)


Climate change (drought)


Habitat degradation


Overuse of pesticides

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