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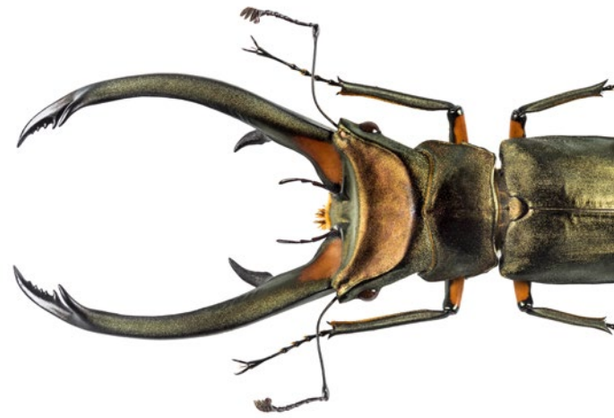


CONTENTS

INTRODUCTION

We live in "The Age of Beetles." Coleopterists, scientists who study beetles, estimate that there are approximately 400,000 species known to science. That's more than ten times the number of all vertebrate species (fish, amphibians, reptiles, mammals, and birds) combined.

If the sheer number of species were a criterion for success, beetles would certainly be considered among most successful organisms on Earth. Their staggering diversity is attributed to the fact that they have crawled, burrowed, flown, swam, and chewed their way around the planet for millions of years. Recent studies suggest that beetles likely originated as early as the Late Carboniferous period (322–306 million years ago, or MYA).

The success of beetles is likely due to an ancient body plan that simultaneously allowed them to fly as well as to hide in narrow spaces. These morphological adaptations, in combination with their behavioral, physiological, and developmental attributes all wrought by a long evolutionary history, have contributed to their extraordinary diversification.

THE ECONOMIC IMPORTANCE OF BEETLES

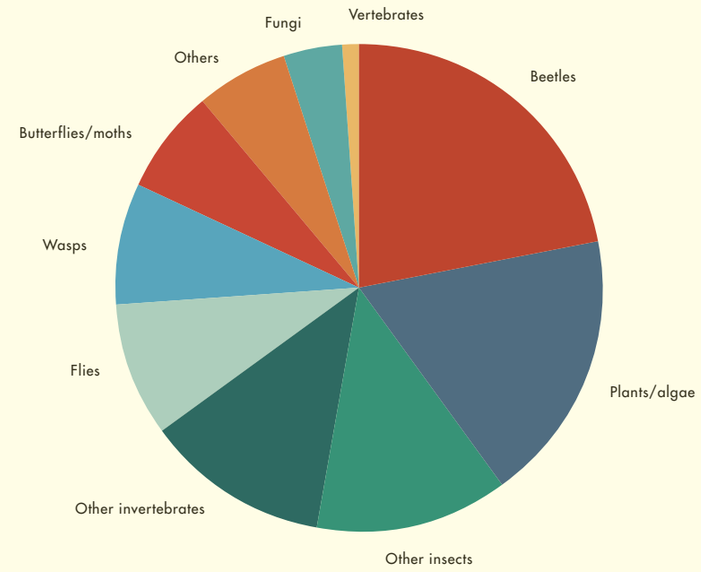
Most beetles are of little or no direct economic importance, but a few species may cause tremendous damage or are considered to be incredibly beneficial. Some species are considered pests because they exploit plant and animal materials improperly stored in our pantries, warehouses, and museum collections. Still others attack our gardens, damage our crops, or destroy our forests. On the positive side, some species are important as biological control agents of agricultural pests, while others are sources of inspiration for the development of new technologies and materials. All beetles, pestiferous and otherwise, also embody an incredible amount of genomic data that potentially provides new insights into the origins of all life on Earth.

← Beetles, such as this *Chrysochroa saundersii* (Buprestidae) from Thailand, represent one the most successful groups of animals on Earth. Their success is in part due to possessing physical features that enabled them to adapt to a myriad of mostly terrestrial habitats over the course of evolutionary time.

Beetle diversity

This pie chart shows the estimated proportions of various groups of organisms on Earth today based on their numbers of species. At a number of about 400,000 species, beetles represent nearly one-quarter of all described species of plants, animals, and fungi.

- 22% Beetles
- 18% Plants/algae
- 13% Other insects
- 12% Other invertebrates
- 9% Flies
- 8% Wasps
- 7% Butterflies/moths
- 6% Others
- 4% Fungi
- 1% Vertebrates



WHAT'S IN A NAME?

The Greek philosopher Aristotle (384–322 BCE) divided animals into two groups—those with red blood (vertebrates) and those without blood (invertebrates). His bloodless animals included insects, arachnids, and a few other non-marine arthropods. In recognition of the characteristically articulated bodies of insects, he selected for them the Greek name *entomos*.

Aristotle further subdivided the entomos on the basis of whether they had chewing or sucking mouthparts. Among the chewing insects, those with thickened forewings were assembled into a group called Coleoptera, a name that combined the ancient Greek words *koleos*, or sheath, and *pteron*, or wing. Later, the Swedish naturalist Carl Linnaeus (1707–1778) incorporated the Coleoptera in his tenth edition of the *Systemae Naturae*, published in 1758, a work considered to be the official starting point for zoological taxonomy.

Dressed for success

Like all insects and other arthropods (crustaceans, arachnids, millipedes, centipedes, and kin), beetles are encased within a hardened external skeleton, or exoskeleton, that is further divided into segments. These segments are joined together by more or less flexible hinges that allow them considerable mobility.

The beetle exoskeleton functions as both skin and skeleton and comes in an astounding array of colors and patterns. The largest and heaviest beetles in the world, all scarabs, include the African Goliath beetles (*Goliathus*), the Central and South American elephant beetles (*Megasoma*), and the Atlas beetles (*Chalcosoma*) of Southeast Asia. The aptly named titan beetle, *Titanus giganteus* (Cerambycidae), also among the world's largest beetles, measures in at a whopping 12–20 cm ($4^{23}/_{32}$–$7^{7}/_{8}$ in) length! Despite the enormous size of *Titanus*, almost nothing is known about them, other than that the adults are sometimes attracted to lights. Conversely, the featherwing beetle *Scydosella musawasensis* (Ptinidae) from Central and South America measures only 0.325 mm ($1/64$ in) and could comfortably complete its entire life cycle within the titan beetle's head with plenty of room to spare! Not only is *Scydosella* the world's smallest beetle, it is also the world's smallest free-living (nonparasitic) insect.

← *Lamprima adolphinae* is a stag beetle found on the island of New Guinea. The male shown here uses its oversized mandibles to cut plants to obtain sap as food and defend sapping shoots from other males.

↑ With tough and durable exoskeletons that are also light and segmented, beetles are afforded great protection and flexibility as they crawl, fly, swim, and dig.

→ The South American titan beetle, *Titanus giganteus*, is one of the largest beetles in the world. In spite of its size, virtually nothing is known about its biology.

Where to find beetles

Beetles have successfully colonized nearly every part of the planet, save for its oceans, barren high mountain peaks, and the perpetually frozen polar ice caps. The myriad of microhabitats found in woodlands, forests, grasslands, deserts, and tundra support unique assemblages of beetle species.

The best places to find beetles are moist habitats that are free of pesticides and have a diversity of native plants. Some places to look for beetles in backyards, gardens, parks, and beyond are:

ON LIVING PLANTS, SHRUBS, AND TREES

Flowering forbs, vines, shrubs, and trees are particularly attractive to beetles in the families Buprestidae, Cantharidae, Cerambycidae, Meloidae, Mordellidae, Nitidulidae, and Scarabaeidae. Inspect fruits, seedpods, male cones, galls, needles, leaves, and roots for species living on their surfaces or tunnelling inside their tissues. Sap flows also attract beetles.

IN DECAYING SNAGS, LOGS, AND STUMPS

Adults and larvae live under bark or tunnel into the wood of dead or dying trees. Always replace the bark after searching for beetles. Freshly cut or recently burned wood attracts jewel (Buprestidae), longhorn (Cerambycidae), and bark and ambrosia (Curculionidae) beetles, in addition to other wood-boring species.

AMONG FUNGI, MOSSES, AND LICHENS

Species in several beetle families feed on only fungi or non-vascular plants. Using a pocket loupe, check puffballs, mushrooms, and shelf fungi for these mycophagous beetles, as well as for predatory rove (Staphylinidae) and hister (Histeridae) beetles.

← Nearly all stag beetles (Lucanidae) are associated with decaying logs and spend several years as larvae developing in or under fungal-ridden wood.

→ Soldier beetles (Cantharidae) are often found feeding on flowers where they feed on pollen and nectar. Their velvety larvae are usually nocturnal and develop under bark or in damp soil beneath rocks and logs. They prey upon earthworms, slugs, caterpillars, and other soft-bodied invertebrates.

↑ Some beetles and their larvae, such as these scarab grubs, are typically found beneath rocks and logs. In these situations, scarab grubs usually feed on plant roots.

→ Predatory beetles and their larvae often search for prey in leaf litter or accumulations of decaying plant materials. This fleet-footed ground beetle larva in the genus *Galerita* uses its sharp, slender mandibles to seize insect prey.

→→ Many aquatic beetles, such as this streamlined predaceous diving beetle in the genus *Dytiscus*, have specially adapted legs that function like oars to help propel them through the water.

UNDER ROCKS, LOGS, AND OTHER DEBRIS

Ground (Carabidae) and darkling (Tenebrionidae) beetles are just two beetle families with species that habitually take shelter under objects on the ground, especially in grassy areas and habitats along the edges of ponds, lakes, streams, rivers, and other wetlands. Ensure you return these objects to their original positions to preserve the habitats.

IN LEAF LITTER AND COMPOST

Accumulations of leaves and needles under trees and shrubs, as well as compost heaps and other piles of rotting vegetation harbor many kinds of predatory, mycophagous, and detritivorous beetles. Carefully raking this material will reveal these species.

IN PONDS AND STREAMS

Predaceous diving beetles (Dytiscidae) prefer open, gravelly bottoms or hiding beneath submerged objects, while water scavenger (Hydrophilidae), crawling water (Haliplidae), riffle (Elmidae), and long-toed water (Dryopidae) beetles are found swimming near emergent plants, crawling on mats of algae, or clinging under rocks and logs. Whirligig beetles (Gyrinidae) live singly or in groups on the surfaces of various standing waters.

ALONG SHORELINES AND BEACHES

Ground (Carabidae), tiger (Cicindelidae), rove (Staphylinidae), and variegated mud-loving (Heteroceridae) beetles are commonly found on sandy or muddy shorelines. Some rove beetles

↑ The golden-spotted tiger beetle, *Cicindela (Cosmodela) aurulenta*, and its subspecies, are denizens of sandy habitats throughout the Indo-Malayan region, especially along sandy shorelines and riverbars.

↗ Various rove beetles (Staphylinidae) search under mats of rotting seaweed, carcasses, or fresh piles of ungulate dung for eggs, larvae, and other small insects. The rove beetle *Ontholestes murinus* from western Europe is commonly found on dead animals.

→ The red-breasted carrion beetle, *Oiceoptoma thoracicum*, inhabits woodlands throughout Eurasia and lays its eggs near the carcasses of birds and small mammals. In spite of its common name, the adults and larvae feed primarily on the larvae of other carrion-visiting insects.

(Staphylinidae), antlike beetles (Anthicidae), and weevils (Curculionidae) live under decomposing piles of seaweed and seagrass. Sand-loving beetles burrow at the bases of grasses and other plants growing on coastal dunes, appearing on the surface only briefly during cool weather.

UNDER CARRION AND DUNG

Carrion and burying beetles (Staphylinidae) typically arrive first at a carcass, followed by skin beetles (Dermestidae) and ham beetles (Cleridae) that prefer to scavenge dried tissues. Keratin-feeding hide beetles (Trogidae) gnaw on the remaining bits of feathers, fur, and hooves. The most conspicuous dung beetles are in the families Geotrupidae and Scarabaeidae. Predatory rove and hister beetles frequent both carrion and dung.

AT LIGHTS

Nocturnal beetles and other insects are thought to use the stars, moon, and other distant sources of natural light for navigation. Nearby artificial sources of light confuse these insects and they must continually adjust their flight path in ever tighter spirals that direct them to a light source. Once at the light, these confused nocturnal insects go into daylight mode and rest. Porch lights, storefronts, and other well-lit establishments, especially in less developed areas, are particularly attractive to nocturnal beetles. Lights with a strong ultraviolet component, such as bluish mercury vapor lights, are particularly attractive to them.

Cultural influences of beetles, past and present

The dazzling forms, colors, and behaviors of beetles have generated mythologies and inspired artisans, craftspeople, authors, and various purveyors of popular culture for centuries. Their likenesses have appeared in rock art and on vases, porcelain statuary, precious stones, paintings, sculptures, jewelry, coins, and illustrated manuscripts. Their durable bodies have long been used around the world as jewelry and to adorn various objects.

↙ The ancient Egyptians revered the sacred scarab (*Scarabaeus sacer*) as a symbol of renewal and rebirth. Their inclusion in hieroglyphs were meant as offers of protection and to convey positive ideas of growth, effectiveness, existence, and manifestation.

→ Albrecht Dürer (1471–1528) was a German painter and engraver. His well-known watercolor of a stag beetle was rendered in 1505. A beetle as the focal point of a piece of art was unprecedented during the early Renaissance because they and other insects were considered among the lowest of creatures.

→→ This larger-than-life bronze sculpture *Dung Beetles* (1999) by Wendy Taylor was commissioned by the Zoological Society of London and placed at London Zoo in Regent's Park.

The ancient Egyptians were fascinated by dung-rolling scarabs and interpreted the beetles' activities to represent their own world in miniature. Images of sacred scarabs appeared everywhere in ancient Egypt. Early hieroglyphs depict the god Khepri as a scarab holding up the sun. The likenesses of scarabs were also used in jewelry and on official seals. The sun god Ra was symbolized as a great scarab that moved the sun, like a dung ball, across the sky. Carvings of scarabs often bore religious inscriptions or simple wishes for good luck, health, and life. Heart scarabs were placed on or near the chests of mummies and bore inscriptions admonishing the heart not to bear witness against its owner on judgement day.

Some scholars have suggested that the ancient Egyptians knew of the scarab's metamorphic process. The emergence of the adult beetle from mummy-like pupa within the buried dung ball was likened to rebirth, possibly inspiring human mummification within underground chambers as a means of achieving immortality.

Our fascination with scarabs continues today. They are depicted as comic book superheroes or fictional swarms of flesh-eating beetles at the movies. In 1999, The Zoological Society of London commissioned the larger-than-life bronze *Dung Beetles,* sculpted by Wendy Taylor, and placed it outside the B.U.G.S. (Biodiversity Underpinning Global Survival) exhibit at the UK's London Zoo in Regent's Park.

The head, horns, mandibles, and legs of various large beetles have long been used to fashion headdresses, necklaces, and earrings. The metallic elytra of jewel beetles (Buprestidae) are a favorite medium for making jewelry. Living beetles are sometimes used as ornaments, too. In the Caribbean, the historical uses of bioluminescent click beetles in the genus *Pyrophorus* (Elateridae), also known as headlight beetles, fire-beetles, or cucujos, are the stuff of legend. Among other practices, these beetles were placed in gauze sacks and affixed to clothing or hair as continuously lit ornaments at evening gatherings.

The best-known example of a beetle used as living jewelry is *Zopherus chilensis* (Zopheridae), a species that ranges from southern Mexico to Venezuela. Popularly known as the ma'kech in Yucatán, Mexico, these incredibly tough beetles are decorated then affixed to a small chain and worn as a living broach.

Beetles as pests

Plant-feeding beetles are essential for breaking down and recycling nutrients bound up in plant materials. They also keep plant populations in check via consumption of reproductive and vegetative structures. However, when these insects direct their activities to ornamental and landscape plants, agricultural crops, forests managed for timber, or wood products, the economic impacts can be significant.

↙ In their native country Japanese beetles (*Popillia japonica*) are considered minor pests. Since their discovery in New Jersey in 1916, this species has become a serious horticultural and agricultural pest in many parts of eastern United States.

→ Bark beetles, such as this *Hylastes* species, are essential in forests and woodlands because they help to break down dead wood. However, outbreaks of these beetles during extended periods of drought in forests managed for timber may result in substantial economic losses as a result of tree mortality.

Catastrophic monetary losses resulting from lost production, damaged goods, trees killed, and destruction of water- and viewsheds are compounded by the cost of pest control.

Deathwatch (Ptinidae) and bostrichid (Bostrichidae) beetles, which normally tunnel into dry wood, may severely damage wood carvings, furniture, flooring, and paneling. Bark and ambrosia beetles (Curculionidae) regularly attack and kill trees in forests and along city streets, usually focusing their efforts on recently dead, injured, or felled trees, or on trees stressed by drought or overwatering. Others attack the roots and branches of fruit and nut trees in orchards. The tunneling activities of these and other wood-boring beetles disrupt a tree's ability to transport water and nutrients and introduce fungal infections.

INVASIVE SPECIES

Nonindigeous beetles, also referred to as non-native or adventive beetles, are species inadvertently or purposely introduced to habitats well outside their native range. In the absence of their predators, pathogens, and parasites that help to keep their populations in check in their native lands, these species may become pests and are thus considered invasive species. Three of the most notorious invasive beetle pests in North America are indigenous to eastern Asia.

In Japan, Japanese beetles, *Popillia japonica* (Scarabaeidae), are considered minor pests, but in eastern North America they are serious horticultural and agricultural pests. The adults feed on the flowers, fruits, and foliage of more than 300 species of ornamental and landscape plants, garden crops, and commercially grown fruits and vegetables. The grubs consume the roots of turfgrass and other plants, often causing severe damage. First discovered in a New Jersey nursery in 1916, they were likely accidentally introduced several years earlier as grubs in root stock of irises imported from Japan.

Japanese beetle grubs are easily transported with roots and soil, while the flying adults hitchhike on airplanes, trains, and automobiles, thus posing a serious threat to agriculture in western North America.

→ The emerald ash borer (EAB), *Agrilus planipennis* (Buprestidae), has killed hundreds of millions of ash trees in North America. The destruction of these valuable trees costs property owners, municipalities, nurseries, and forest product industries millions of dollars. Regulatory agencies, such as the United States Department of Agricultures have imposed quarantines to prevent firewood and other potentially infested ash products from spreading EAB to new areas.

↘ The North American Colorado potato beetle, *Leptinotarsa decimlineata* (Chrysomelidae), has become a pest throughout western Europe. It is likely that it was first introduced there via American military bases established there during World War I.

They are regularly intercepted in the West and several small, isolated infestations have been or are in the process of being eradicated. Japanese beetles were first discovered in Europe in 1970 on Terceira Island in the Azores of Portugal and subsequent populations were located in Italy (2014) and adjacent Switzerland (2017), where they have adapted well to climatic conditions well beyond those found in Japan. Agricultural officials have reason to be concerned about the continual spread of this beetle in other temperate regions of the world as the climate changes.

A native of China and Korea, the Asian longhorn beetle, *Anoplophora glabripennis* (Cerambycidae), is established in several places in eastern North America, including New Jersey, southern Ontario, northeastern Illinois, Ohio, and South Carolina. The repeated tunneling activities of the larvae weaken and kill otherwise healthy urban and forest hardwood trees, thus threatening millions of street and park trees and the region's maple syrup industry. Although adults were first reported in New York in 1996, the larvae were probably introduced ten years earlier in untreated wood used to crate heavy equipment. Eradication efforts involve cutting down, chipping, and burning thousands of trees. Since 2001, Asian longhorn beetles have become established in at least eleven European countries. In recent years, they have also increased their range in China as a result of the widespread planting of poplar hybrids that are especially susceptible to beetle attack.

The emerald ash borer, *Agrilus planipennis* (Buprestidae), is native to northeastern Asia, where it seldom causes any significant damage to native trees. In North America, the species was first discovered in Detroit, Michigan, and Windsor, Ontario, during the summer of 2002, but the beetles likely arrived in wood packing materials imported from eastern Asia in the early 1990s. They are now established throughout much of the Northeast and upper Midwest, killing millions of ash trees, which are important street trees and provide wood for making furniture, tool handles, and baseball bats. Efforts to control the spread of the emerald ash borer include quarantines that ban the movement of firewood. Several species of parasitoid wasps and entomopathogenic fungi are also showing promise as biological controls.

Many of North America's pest beetles are either Asian or European in origin. But the exchange of potential pests from one region to another is a two-way street; a few North American beetles have become pests on other continents, too. One such example is the Colorado potato beetle, *Leptinotarsa decimlineata* (Chrysomelidae), a species indigenous to the American Southwest and adjacent Mexico, where it feeds on native plants in the nightshade family. As agriculture developed in the United States, so did the widespread planting of potatoes, a nightshade crop that originated in South America. By the mid-1850s, potato beetles had developed a taste for potato crops and became widespread across southern Canada and most of continental United States.

By the 1870s, American agricultural officials were warning their European counterparts of the threat these beetles posed to their potato crops, but to no avail. Numerous outbreaks of potato beetles were reported in Europe during the latter part of the nineteenth century. They became established near American military bases in France during World War I and spread rapidly through much of Europe during and immediately after World War II. Unable to effectively control the pest, the communist government of East Germany (German Democratic Republic) launched a propaganda program in 1950 accusing the United States of dropping these insects, dubbed *Amikäfer*, or Yankee beetles, out of low-flying planes to sabotage their potato crops.

Beneficial beetles

Biological control involves the use of a pest's natural enemies (predators, parasitoids, herbivores, and pathogens) as control methods, rather than solely relying on pesticides that may adversely affect animal and plant life.

The birth of modern biocontrol began with efforts in California to combat the cottony cushion scale, *Icerya purchasi* (Monophlebidae), an Australian insect that was wreaking havoc with the state's fledgling citrus industry. Entomologists were dispatched to Australia to locate the cottony cushion scale's natural enemies. Shipments of several species of Australian lady beetles (Coccinellidae) were sent to California, where they were released to combat the citrus pest. The vedalia beetle, *Rodolia cardinalis* (Coccinellidae), was credited for saving California's citrus industry and its use as a control method was hailed at the time as a miracle of science. To this day, the vedalia beetle continues to help keep the cottony cushion scale in check.

After World War II, the growth and success of the synthetic pesticide industry overshadowed the use of biocontrol agents. With the publication of Rachel Carson's *Silent Spring* in 1962, which decried the use of pesticides, there was renewed interest in biocontrol. This resulted in the import of many other coccinellid species, but the benefits of these introductions have been mixed. For example, the multicolored Asian lady beetle, *Harmonia axyridis* (Coccinellidae), is often viewed as more of a nuisance in the United States, rather than as a beneficial species. The implication that this and other introduced lady beetle species have contributed to the decline of some native lady beetle populations in North America requires further study.

TACKLING TAMARISK

The application of beetles as biological control agents in wildlands is known as conservation biocontrol. For example, tamarisk or saltcedar (*Tamarix*) trees were introduced from Asia and became widespread in the western United States over the past 200 years. During the early 1900s, the rapid expansion of tamarisk in both natural and artificial riparian habitats was associated with the decline of cottonwood-willow woodlands, mesquite bosque, and other native plant complexes west of the Mississippi River.

← Adults and larvae of the predatory vedalia beetle (*Rodolia cardinalis*) prey on the pestiferous cottony cushion scale (*Icerya purchasi*), a small sap-sucking insect covered in cotton-like wax. The importation of these beetles from Australia in the 1880s not only saved California's citrus industry, it also marked the beginning of modern biocontrol.

↑ The introduction of the splendid tamarisk weevil (*Coniatus splendidulus*) has proven to be quite successful at reducing tamarisk trees that have long been choking riparian habitats throughout western United States.

↓→ Colonies of adult and larval museum beetles assist museum curators with cleaning animal skeletons. Small, nimble, and ravenous, they are able to remove the last bits of flesh from skeletons destined for use in research, displays, and educational programs.

The dominance of tamarisk has not only displaced native plant communities; it also provides poor habitat for wildlife and is thought to reduce local water sources and increase soil salinity.

In order to help reclaim these tamarisk-choked riparian habitats, entomologists investigated hundreds of herbivorous insects that feed only on tamarisk. This effort led to the selection of several beetle species, including the splendid tamarisk weevil, *Coniatus splendidulus* (Curculionidae), and the northern tamarisk beetle, *Diorhabda carinulata* (Chrysomelidae). The northern tamarisk beetle was very successful at reducing the tamarisk canopy, but this conservation biocontrol program quickly became controversial. Efforts to restore these habitats with native cottonwoods and willows lagged far behind, raising concerns that the nests of the federally endangered southwestern willow flycatchers would be exposed to increased temperatures and predation. Such conflicts highlight the need of government and private agencies to work together to develop and implement broad, science-based monitoring protocols that assess multiple key parameters, including soil and water dynamics, wildlife habitat use, and habitat restoration.

FLESH-EATING BEETLES

The hordes of flesh-eating scarabs depicted in the 1999 film *The Mummy* were pure Hollywood magic and completely computer generated. Long before the appearance of these fictional film beetles, museums have utilized the services of real flesh-eating beetles to help them clean skeletons for study as well as for exhibits. Colonies of skin or museum beetles in the genus *Dermestes* (Dermestidae) are maintained in secure, climate-controlled spaces so that they don't escape and harm reference collections. When feeding the beetles, fresh carcasses are first flensed, then butchered to remove as much muscle as possible. The remains are set out on racks to dry since *Dermestes* prefer to gnaw on tissue with a hard, jerky-like consistency. A small bird or rodent placed in a container of hungry museum beetles will be thoroughly cleaned overnight, while larger animals may take a few days or weeks. The larvae of museum beetles do most of the work and their use is significantly more efficient and less messy than other methods for cleaning skeletons. Working in these stench-filled spaces is not for the faint-of-heart!

DUNG BEETLES TO THE RESCUE

Adapted primarily for handling the small, fibrous pellets produced by marsupials, Australia's indigenous dung beetle fauna largely ignored the large, juicy feces deposited by cattle. Freshly deposited cow pads became breeding sites for the pestiferous bush fly. As the dung dried up into cow chips, the productivity of pasturelands decreased; rank herbage unpalatable to cattle would sprout around old dung, reducing the overall amount of forage available in the pasture.

To combat pestiferous flies and the loss of palatable forage, the Australian Dung Beetle Project was launched in 1966 by entomologist George Bornemissza. The project's mission was to identify select dung beetle species living in comparable climates around the world for import into Australia. Dung beetles inhabiting South Africa were ideal candidates because they were adapted to subtropical climates similar to those in Australia. Strict quarantine measures were put into place to avoid the introduction of parasites and other cattle pests into Australia. The first large-scale releases took place in 1967 and by 1985 more than forty species of dung beetles had been released. Today, more than twenty species have become established in Australia.

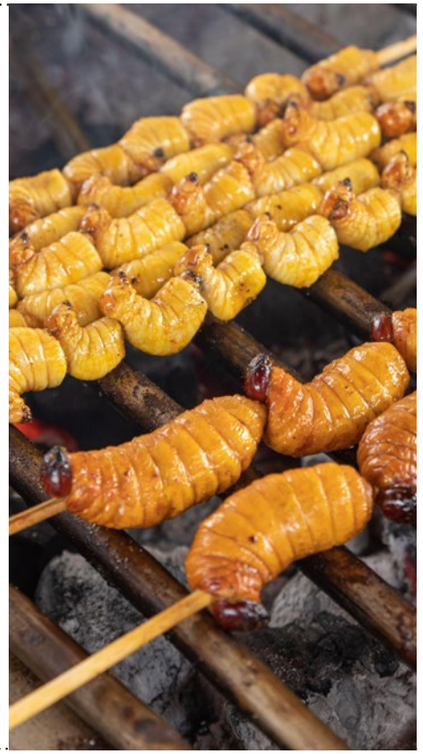
The Australian Dung Beetle Project ended in 1986, but interest in their use continues. The Dung Beetle Ecosystem Engineers are working to expand the range of dung beetles in Australia. African dung beetles have also been introduced into New Zealand and throughout the New World, where they compete with native species already adapted to placental mammal dung.

DELECTABLE BEETLES

Entomophagy, or the consumption of insects, has been practiced by humans around the world for centuries. They are an important source of carbohydrates, fats, proteins, minerals, and vitamins. Although uncommon or taboo in Western cultures, eating insects is widespread in cultures outside of North America and Europe.

With the rising costs associated with producing animal-based protein, coupled with ever-increasing interest in sustainable farming, the appeal of using beetles and other insects as food has never been greater. More than 300 species of beetles or their larvae are eaten around the world. Yellow mealworms, *Tenebrio molitor* (Tenebrionidae), various species of rhinoceros beetles (Scarabaeidae), and palm weevil larvae (Curculionidae) are among the most highly prized of consumable beetles and are seasoned with salt and various spices, then baked, fried, roasted, or toasted. Shown here are the skewered larvae of *Rhynchophorus phoenicus* at a traditional food market in Ecuador.

In an attempt to make eating beetles more palatable in North America and Europe, dried mealworms are ground into protein-rich flour for use in baking. Mealworm flour has more than twice as much protein as beef, requires a fraction of the water to produce, and contributes virtually no greenhouse gases.



Beetles matter

The mind-boggling diversity of beetles is testament to their evolutionary success and, combined with their ubiquity, makes them the perfect ambassadors for environmental awareness. A keener appreciation of beetles strengthens our connection to the natural world, so it just makes good sense to get to know them better.

Over the millennia, beetles have continually adapted to life's various hazards, all while dealing with a changing climate. As a result, their bodies, behaviors, and defensive secretions have enormous scientific, medical, technological, and nutritional potential. Additionally, the study of beetles not only offers insights into addressing human challenges, but can also help us to answer questions that we haven't yet thought to ask. In short, we need beetles not only for the ecological services they provide, but also for the aesthetic, scientific, and technological pursuits they inspire.

The richly illustrated chapters that follow reveal the fascinating lives of beetles. Each chapter includes nine select species profiles that highlight the chapter's theme. As you read this book, the seemingly alien world of beetles becomes familiar; the familiar becomes cherished.

↑ The diversity of forms and colors of beetles is astounding, as evidenced by this gorgeous metallic and hirsute jewel beetle, *Julodis viridipes*, which inhabits the southern Cape region of South Africa.

← Blister beetles, such as *Hycleus lugens* from Tanzania, produce cantharidin. This blistering defensive compound has long been extracted from select blister beetles for use in both folk and traditional medicine. The topical use of cantharidin is widespread for the treatment of various skin disorders, including warts caused by the human papilloma and molluscum contagiosum viruses.

INDEX

INDEX