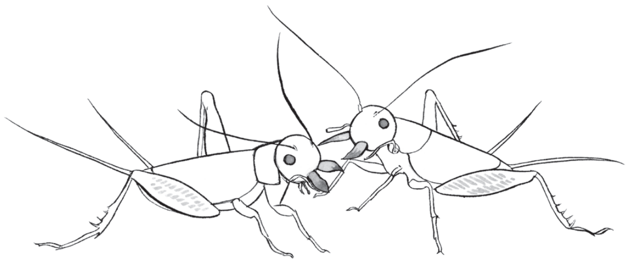


Prizefighters in the cricket world can be created without a pedigree. While larger individuals tend to dominate, reaching their peak about twelve days into adulthood, other factors can enhance performance. Research shows that males that have just mated are more aggressive, as are individuals housed in isolation for a period of time. Males that have secured a fortress like a burrow or crevice are likewise antagonistic to other males. These nuances are not lost on owners of fighting crickets, and great care and ceremony is given to the sport, with investments in housing and feeding.

Darning Needles

Dragonflies are steeped in myth and superstition, which has led to many regional names for them based on such folklore. Among these epithets is "darning needle." Indeed, the common name for the family Aeshnidae is "darners," perhaps owing to the long, slender, somewhat tapering shape of the abdomen of these elegant aerialists.

The name carries a sinister reputation for the poor insect, especially when "devil" is attached, as in "devil's darning needle." According to folklore, dragonflies will sew up various body parts, such as lips, ears, nostrils, or eyelids. This fate mostly awaited naughty or untruthful children, but the New England version claims anyone falling asleep within reach of a dragonfly might have their fingers or toes stitched together.

As if that isn't frightening enough, other myths have dragonflies associating with serpents, referring to them as "snake doctor," "snake feeder," or "snake servant." Dragonflies supposedly alerted snakes to approaching threats, or helped them find food. Folks were thus discouraged from causing harm to dragonflies, lest a snake seek revenge.

Other aliases for dragonflies include "devil's riding horse," "horse-stinger," and "bullstang." From European cultural history comes "adder's needle," "adder's servant," "adderspear," and "ox-viper." Dragonflies cannot sting, but anyone who has seen a female darner ovipositing in a log, aquatic vegetation, or mud can understand how the act could be misinterpreted, and used to full advantage to scold impressionable youngsters into behaving themselves.

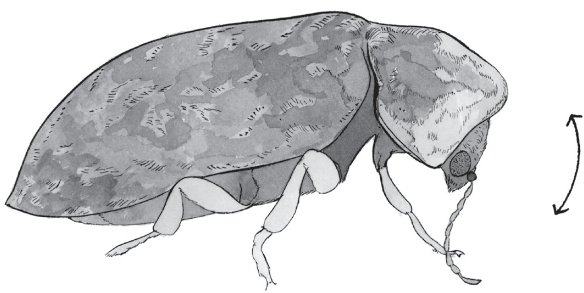
Leave it to Eastern culture to redeem the evil ascriptions of Western culture. Dragonflies are celebrated in Japanese culture as the embodiment of strength, courage, and happiness. They are also given spiritual significance as representatives of spirits visiting homes.

Deathwatch Beetles

The original head-banger might be the deathwatch beetle, *Xestobium rufovillosum*, of the family Ptinidae. The insect lives in tunnels it bores in wood, and adult males and females find each other by slamming their faces on the floors of their tunnels, then orienting to the direction of the replies. This is seismic communication, as they do not hear the sounds, but perceive the vibrations instead. It is audible to us, though, prompting dire superstitions that the tick-ticking of the beetles was an omen of death in old houses infested by the insects.

The male beetle initiates dialogue by tapping four to eleven times in rapid succession. Females apparently tap only in response to males. Males may travel long distances, only to find they overshot their female target, or made some other mistake in orienting to her. Not all females are receptive to mating at all times, either, so may not respond. It is the beetle equivalent of Tinder: it works often enough to keep the population going.

In nature, deathwatch beetles bore into dead or dying trees, and they may infest lumber at any stage between logging and milling, or even later. Once established,



Deathwatch beetle
Xestobium rufovillosum

beetle populations can sustain themselves for many generations. They prefer old wood, and wood infested with fungi appears to be most coveted.

Old structures are thus prone to prolonged infestation by deathwatch beetles. In the absence of any human noise, the sound of lovelorn males can be all the louder. The eerie tapping gave rise to the belief that someone in the household would soon die. This might not be far-fetched if the timbers are so structurally undermined by generations of beetles that the building is in imminent danger of collapse.

See also Tok-Tokkies.

Delusory Parasitosis

The belief that "bugs" are infesting one's body, burrowing under the skin and causing unbearable irritation, is surprisingly common. It carries a stigma that the victim is to blame, and that they willfully draw an irrational conclusion. Delusional parasitosis is the clinical term for this malady, shortened to "delusory parasitosis."

Typically, four attributes indicate this condition. First, the person presents "evidence" of lint, dust, and other detritus, usually in a plastic baggie, box, or stuck to clear adhesive tape. The recipient of this material, be they entomologist or physician, is told that there are bugs in the sample. Invariably, there are not. The second indicator is an exhaustive narrative describing the offending creatures, and speculation as to their origin. The third warning sign is refusal to accept any alternative explanation for their symptoms. Lastly, the person may have inflicted damage to their skin in an effort to rid themselves of the sensations and "bugs."

There could be a host of other causes for their skin irritation. It could be connected to their behavior, prior circumstances, other illnesses, or drugs. Delusory parasitosis commonly afflicts methamphetamine addicts, for example. Someone who has had a previous infestation of cockroaches, lice, bed bugs, or other pests can be more prone to delusory parasitosis. Other medical conditions, and side effects of some prescription drugs, can produce similar symptoms.

In the absence of an obvious arthropod-related cause, the entomologist is left with no choice but to recommend evaluation by a physician and/or psychologist to eliminate other potential causes. Providing empathy while retaining professional protocol is not easy, but that should be the goal.

Diapause

In insects, "hibernation" is a misnomer. The correct term is diapause, which can be seasonal like vertebrate hibernation, but not necessarily so. Diapause is a temporary cessation of growth and development, and suppression of metabolic processes, which may be provoked by any number of conditions, including food scarcity.

In most insects, diapause is facultative, meaning it is sparked by environmental cues that initiate changes in bodily chemistry. Obligatory diapause is known for a few insects, in which case it occurs regardless of environmental stimulus, and *must* occur in order for growth and development to proceed normally. Most facultative diapause is triggered by changes in daylength, the usual precursor to extreme cold or heat. A period of chilling is usually required before an insect can exit from diapause, in regions with distinct seasons.

Many moths undergo diapause as caterpillars. Diapause of insect larvae in general is controlled by hormones, or their absence in the case of steroids that regulate molting. Larvae may resume feeding once their diapause is over; in other cases, they have been in diapause as a prepupa, and pupation is the next activity. The solution to food scarcity in some dermestid beetles, like *Trogoderma glabrum*, is not to enter diapause, but to molt regressively into a smaller larva, repeatedly if need be, and resume a normal course when favorable conditions return.

Adult diapause is expressed as a halt in reproduction, and sexual organs do not produce eggs or sperm during that interval. Migratory populations of the Monarch butterfly enter diapause upon reaching their wintering grounds. They subsist on fat reserves accumulated during the journey. Other insects, especially true bugs, beetles, wasps, and flies, also enter diapause as adults. Their wing muscles may shrink so there is less metabolic demand on their fat reserves.

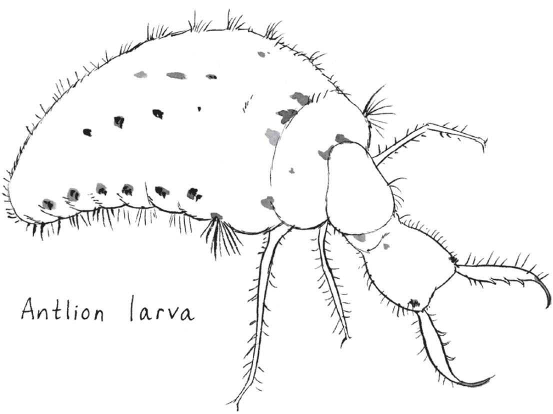
See also Chrysalis; Cocoon; Juvenile Hormone; Metamorphosis.

Doodlebugs

Before the internet, and the distraction of cell phones, children had to work to find amusement, and it usually took them outdoors. One favorite pastime seems to have been pestering the larvae of antlions, members of the family Myrmeleontidae, and related to lacewings.

Look in dusty or sandy soil at the base of trees, under bridges, rock overhangs, and other spots sheltered from rain and you will likely find several small, funnel-like pits. These are produced by "doodlebugs," the whimsical name we have assigned to these deadly predators of ants and other insects. Tickle the walls or floor of the pit and you may get a rise out of the occupant buried at the bottom. Traditionally, a child would chant a verse like "Doodle-bug, doodle-bug, are you at home?" while prodding the pit. From the Caribbean to Asia, Australia, and South Africa, variations on this theme abound.

"Doodlebug" stems from the meandering scrolls left by an antlion larva seeking a new site for its pit. The plump, stubby insect walks backwards in a circle, spiraling inwards, in order to construct a pit. It flings sand beyond the perimeter, using its head as a shovel. Not all antlions dig pits. Most species bury themselves in the sand and wait in ambush with open jaws.



Antlions pupate in silken cocoons at the bottom of their pits. They more than make up for the pudgy appearance of their youth, emerging as slender adults with two pairs of long, delicate wings. Watch for them at your porch light at night, or fluttering feebly through tall grass in fields. Meanwhile, check out *The Antlion Pit* website for online enchantment.

***Drosophila* "Fruit Flies"**

If there is one insect responsible for the most scientific advances, it could well be the pomace flies in the genus *Drosophila* in the family Drosophilidae. Often referred to as "vinegar flies" or "fruit flies," the latter name correctly applies to members of the family Tephritidae.

These are the "gnats" (again a misnomer) that flit through your kitchen and alight on overripe bananas, the wine glass, and anything else with an odor of fermentation. The flies' attraction to, and tolerance for, all things alcoholic stems from the need to find appropriate food resources for their maggot offspring. The larvae thrive best on the yeasts that colonize decaying organic matter. The life cycle is very short, completed in ten days at 25° Celsius, and can quickly yield high populations of adult flies.

It is this rapid turnover of generations that has made *Drosophila* one of the most popular laboratory organisms, especially for genetic research. That, and the supersized chromosomes found in their salivary glands. It was pomace flies that aided Dr. Thomas Hunt Morgan in his research on heredity and helped win him the Nobel Prize in Physiology or Medicine in 1933. Since then, of the more than 2,000 known *Drosophila* species, *D. melanogaster* has continued to be the go-to lab fly. Publication of its genome sequence took place in the year 2000.

The flies will no doubt continue yielding new revelations in the fields of cell biology, developmental biology, neurobiology and behavior, population genetics, and evolutionary biology. What does that mean for you? Well, we *Homo sapiens* do share 60% of our DNA with *Drosophila melanogaster*, and 75% of the genes known to cause human diseases can be found in fruit flies.

Ecosystem Services

Humans have a tendency to justify everything in purely economic terms. What cannot be appraised in dollars and cents is all too often not valued at all. It is easy to calculate what insect pests cost us in damages, but the accounting of the benefits of insects is infinitely more difficult.

John Losey and Mace Vaughan, in a 2006 article in *BioScience*, selected pollination by native insects, pest control by predators and parasitoids, disposal of fecal material and decomposing plants and animal carcasses, and food for fish and wildlife as four major ecosystem services provided by insects. They estimated the economic value of these to be at least $57 billion annually in the United States alone. This estimate does not include pollination of crops by non-native honey bees, honey and other products from insects, nor seed dispersal by ants, maintenance of forest health through pruning of trees, and other tasks performed by insects that do not directly impact humanity. The authors also excluded species introduced and/or reared for the exclusive purpose of pest control in agricultural ecosystems.

This landmark paper finally elevated insects to their rightful place as economic engines, not economic disasters. It also served as a call for mitigation and restoration of natural habitats lost to agriculture and urbanization. Promoting biodiversity even on the fringes of plots and subdivisions increases the potential impact of beneficial insects in those adjacent human ecosystems. We could all use less expenditure for chemical pest control, and more fruits and vegetables resulting from pollination.

More recently, scholars have expanded beyond these support and regulatory services to include recognition of insects in provisioning services (food, silk, dyes, shellac, and other material resources), medicine, and cultural services such as recreation, tourism, and spiritual values.

See also Cochineal; Entomophagy; Lac Insect; Medicinal Maggots; Pollinators; Seed Dispersal; Sericulture.

Endangered Insects

The poster animal for endangered species conservation is never going to be an insect, but that does not mean that there are no bugs on the brink of extinction. The overwhelming threats to insects are the same as they are for vertebrate wildlife: habitat destruction and climate change. Pesticide use is an ongoing problem. Competition from invasive foreign species is of increasing concern.

The most critically imperiled insect species are those that occupy limited, unique habitats such as caves, bogs and other wetlands, isolated sand dune systems, ever-shrinking prairies, steadily warming alpine areas, and islands. There are many species endemic to such locations, found nowhere else on the planet, and by adaptation unable to exist anywhere else. Protection and preservation of those localized ecosystems is of paramount importance in securing the safety of the insects and other organisms that live there. Fail at this and all other efforts will be futile.

Captive breeding programs have been a strategy for saving many vertebrates, with the goal of returning a portion of the offspring to the wild. This strategy is being applied to a few insects, too. In the United States, several butterflies, including the Karner Blue, and beetles, including the American Burying Beetle and Salt Creek Tiger Beetle, are reared for release. Internationally, zoos create species survival plans for threatened animals of all kinds.

Salt Creek tiger beetle
Cicindela nevadica lincolniana

While extinction is a natural phenomenon, the *rate* of species extinctions is increasing almost exponentially as a result of human activities. Less than 1% of all known insect species have even been evaluated for potential listing as endangered or threatened at the national or international level.

See also Insect Apocalypse; Weta; Xerces Society.

Entomology

The study of insects is frequently confused with etymology, the study of words. Born largely out of innate curiosity, entomology has expanded and evolved to meet one crisis after another.

The Greek philosopher Aristotle began giving order and meaning to the physical world, but it was not until the Renaissance that René Antoine Ferchault de Réaumur of France (1683–1757) began studying the anatomy, function, metamorphosis, and other biological aspects of insects.

The 1800s saw an age of exploration and colonialism, with all specimens retained by colonizers. To this day we have scarcely extended reparations for the hoarding of collections. The travels of Darwin, Alfred Wallace, and others did, however, inspire important principles such as natural selection. Concurrently, the Industrial Revolution caused a dramatic increase in the scale of agriculture. Entomology turned its attention to pest control, and by the early 1900s some biological controls were being utilized to combat pests.

World War II forced entomologists to confront emergencies like typhus, a louse-borne disease. Triumph was achieved through development of insecticides like

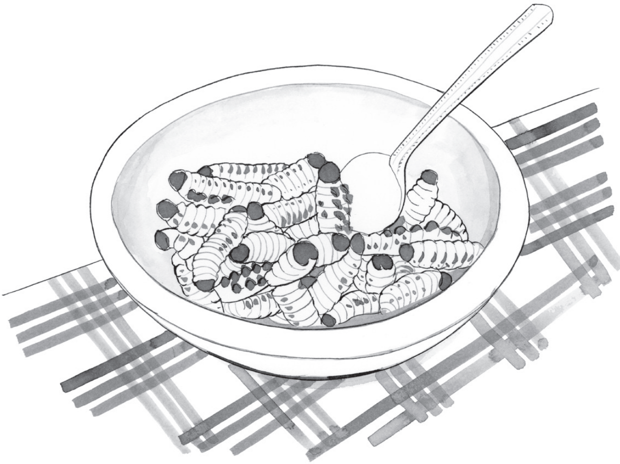
DDT. After the war, chemical controls were applied to agricultural and urban pests. Victory was short-lived. Insects developed resistance to many insecticides, while vertebrates suffered. These shortcomings were brought into public view by Rachel Carson in *Silent Spring*, and by entomologist Robert van den Bosch in *The Pesticide Conspiracy*. The revelations led in part to creation of the U.S. Environmental Protection Agency in 1970.

Students pursuing entomology today have a wealth of career choices. Forensic entomology has re-emerged as a vital component of criminal science. Medical and veterinary entomologists address issues of public health. Forest entomologists manage native and invasive pests, as well as broaden our understanding of insect ecosystem services. Insect conservation is expanding to meet the challenges of decreasing insect abundance and diversity.

Entomophagy

The practice of eating insects has a long history that is experiencing something of a resurgence in our modern age. In Western cultures, the "ick factor" now struggles to reconcile with recognition of the nutritional value of insects.

There is little question that insects are an excellent source of protein, fat, and key minerals and vitamins. Many insects are exploited as food in parts of Africa, Asia, Australia, and Latin America. Consumption of insects has its roots in the traditions of indigenous peoples but has become a commercial enterprise in some places. The giant water bug *Lethocerus indicus* is so coveted that it commands high prices; this is especially



Mopane worms (fried)
Gonimbrasia belina larva

true in Thailand and Laos, where glands of the male insect are the prime ingredient of spicy *mangda* sauces. Other insects popular as food include "witchetty grubs," huge, root-boring larvae of the cossid moth *Endoxyla leucomochla* in Australia, and "mopane worms," caterpillars of the giant silkmoth *Gonimbrasia belina*, found abundantly in southern Africa. Grubs of palm weevils, *Rhynchophorus phoenicis*, are a traditional food in Angola, and other species in the genus are harvested in tropical Africa, Asia, and Latin America. Most of these insects are palatable because they eat plants and lack toxins used in self-defense.

Even in cultures accustomed to consuming insects, entomophagy accounts for only 5%–10% of the annual animal protein in the human diet. The mentality of Western civilization seems to be that eating insects is a behavior we have overcome, having advanced beyond our hunter-gatherer ancestry to farming and livestock ranching. Entomophagy thus remains, sadly, a novelty reserved for dares and reality television.

Epomis spp. Ground Beetles

Entice something to eat you so *you* can eat *it*. That is the mind-bending strategy of beetle larvae in the genus *Epomis*. Amphibians, especially frogs and toads, are primary vertebrate predators of insects, particularly soft and juicy larvae that do not require chewing. Incredibly, these beetle larvae turn the tables.

Epomis is an Old World genus of ground beetles (Carabidae) with thirty known species, most occurring in Africa. Entomologist Gil Wizen has studied them in the lab, and in the field in Israel, if only to make certain his eyes have not been deceiving him. Both the adult insects and the larval stages appear to be obligate, specialized predators of young frogs and toads. *Epomis* synchronizes its metamorphosis with that of its amphibian prey, such that beetle larvae and "froglets" and "toadlets" are present at the same time.

The beetle larva waits on the edge of a temporary pond or rain-pool and lures a prowling toad or frog. The larva waves its antennae alternately and moves its jaws in the same manner. The motion stimulates the amphibian to approach and attempt to nail the poor insect with its tongue. Faster than a speeding bullet, the larva dodges the mouth-missile and launches its own attack, latching onto the frog's mouth or throat. The double-hooked mandibles hold fast and the beetle larva begins drawing body fluids from its prey immediately. It eventually consumes it entirely.

Adult *Epomis* simply approach a small frog or toad and seize it in their jaws, holding on with all six legs to avoid being flung off. The beetle commences chewing and kills and eats most of its prey. The beetle is a beautiful metallic insect, but perhaps appearances can't overcome its macabre lifestyle.

EPT

The acronym for three orders of aquatic insects that are used by environmental researchers and consultants in diagnosing water quality, mostly in rivers and streams.

E Ephemeroptera, the mayflies. Known for their ephemeral life as adults, the aquatic naiads can take years to mature. Most are "collector-gatherers" feeding on fine particles on the streambed, or "scrapers" that eat algae coating the surface of stones. Some actively swim, while others are "clingers" to objects on the bottom. Adults emerge from the last naiad stage.

P Plecoptera, the stoneflies. As aquatic naiads, they are typically "shredders" that tear chunks of plant matter, or predators on other aquatic invertebrates. Most species cling to the surface of stones. Adults of the largest species are the "salmonflies" familiar to anglers. They emerge from the last instar of the naiad stage.

T Trichoptera, the caddisflies. They go through complete metamorphosis. Larval lifestyles are diverse.

Some spin nets or purselike bags, or tubes, and are "filterers," or predators, straining swift currents for very small particles of decomposing organic matter, or tiny aquatic invertebrates. Many species build cases around themselves, using specific types of vegetation or fragments thereof, or pebbles, or sand grains. These casemakers can be scrapers, collector-gatherers, or even predators. Some occur on the streambed or lake bottom, others climb aquatic vegetation and debris. Adults resemble moths.

All three orders are more sensitive to pollutants than other macroinvertebrates, and relatively easy to identify. In addition to chemical sensitivity, they may have limited tolerance to acidity, turbidity, and warmer water temperatures. The EPT index provides a measure of species richness that in turn reflects the overall health of the aquatic habitat from which samples were taken. The less diversity, the more likely pollutants are exerting harmful effects.

See also Ecosystem Services; Exuviae.

Exploding Ants

Even the insect world has its suicide bombers. Certain carpenter ants in the "*C. saundersi* complex" of the genus *Colobopsis* (*C. cylindrica*, *C. saundersi*, *C. explodens*, *C. badia*, *C. corallina*, and probably others) of southeast Asia practice autothysis.

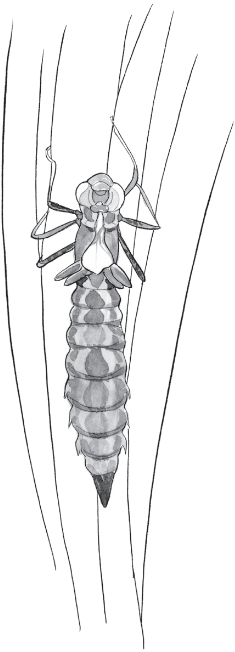
That is, they commit suicide during individual confrontations and battles with other ants, especially weaver ants. Powerful contractions of muscles in the abdomen force the contents of their mandibular gland reservoirs to expel tacky and irritating compounds so violently that the abdomen explodes. It also tears the mandibular gland itself, spraying the goo in all directions from the front of the head. The substance is white, cream, or yellow, and aromatic, with a spicy quality reminiscent of curry. It is quite the cocktail, full of phenols and terpenoids in particular.

This defense is a last resort, of course. *Colobopsis*, known informally as "janitor ants," nest primarily in hollow twigs and stems. The major workers have blocky heads and flattened faces they use to plug the small round entrance holes. Entry by colony members is by the ant equivalent of a keypad, the proper "code" of antenna strokes to the guard's face eliciting an open door as the sentry backs inside.

The term autothysis was coined in a 1974 publication by Ulrich and Eleonore Maschwitz. This kamikaze-like phenomenon is not restricted to ants, either. The termites *Neocapritermes taracua*, found in French Guiana, accumulate stores of copper-containing proteins throughout their lives. Older worker termites volunteer as living bombs should the colony be attacked. Saliva from the labial gland reacts with the crystals upon autothysis, yielding a toxin deadly to other termites. Termites in six other genera self-detonate to block tunnels in their nests, preventing enemies (usually marauding ants) from making further inroads.

Exuviae

When an insect molts, the discarded exoskeleton it leaves behind is called an exuviae. The word is both singular and plural. These ghostly objects often perplex non-entomologists.



Exuvia of a dragonfly

Two circumstances amplify the mystery of exuviae. They often appear in large numbers in a localized area. Secondly, the immature insects depicted by the exuviae bear little or no resemblance to the adults. This lack of resemblance is especially true of insects that live as nymphs in the soil, or naiads in water, hidden from view until they emerge as winged adults. Molting usually takes place at night, so association between the adult and immature is rarely made.

Aquatic insects like dragonflies, stoneflies, and mayflies leave exuviae clinging to rocks or emergent vegetation. Entomologists can often deduce the species, even the sex, from those vestiges. Mayflies molt twice once they leave the water. The first results in a subimago, a pre-adult that anglers call a "dun." This subimago molts again into a full-fledged adult, the fly-fisherman's "spinner."

A newly minted adult insect is called a teneral. Generally, it means the adult is still soft, with pigments not fully expressed. The term is used differently for dragonflies and damselflies, whereby the young adult insect, even when hardened and a capable flier, possesses coloring different from a mature adult.

Examine an exuviae closely and you may see stringy white filaments protruding from the hollow inside. These are remnants of the major tracheal pathways, representing invaginations of the cuticle that form those breathing passages.

Keen-eyed predators like birds notice clues like leaf damage and insect waste, so most caterpillars consume their exuviae after molting to hide their presence. Other insects detach their shed "skin" and let it fall or be blown by the wind, eliminating all traces of their continued existence on the plant.

See also Metamorphosis.

Fabre, Jean-Henri (1823–1915)

Frenchman Jean-Henri Casimir Fabre is celebrated as the "father of entomology," but it was his ability to captivate nonscientists with his narratives of the life histories of insects that is most remembered and revered.

Fabre was in many ways the archetypical entomologist in his solitude, indefatigable curiosity, sharp and patient observational skills, and innovative thought processes. His career path was never straightforward nor ascending, and he struggled with financial poverty throughout his life. Disdain for the confining rules of academic, social, and political life defined him, and limited his ability to excel via "normal" avenues. His biggest break came courtesy of his friendship with Victor Duruy, Minister of Public Instruction under Napoleon III. In 1870, Duruy invited Fabre, by then 47 years old, to present a lecture series in Avignon, the audience composed in part of secondary school girls. The opportunity to engage young, impressionable minds changed the direction of Fabre's career and led him to advocate openly for teaching science to young women.

Fabre's writings are his most enduring legacy, especially his ten-part *Souvenirs entomologiques* (1879–1909). The texts included prose and poetry related to insects and plants, as well as topics of instinct and heredity, even veering into ethics and anthropological theories. More popular works each detailed the lives of glow-worms, mason bees, flies, hunting wasps, and other arthropods.

One might assume Fabre traveled often, and far, but his entire adult life was centered within a twenty-mile radius of Avignon, Carpentras, and Orange in the south of France. Fabre's life is a testament to the power of a sense of place, and devotion to passionate observation and lifelong learning. To see the world through his eyes, watch the documentary *Microcosmos* (1996), a fitting tribute to him.

See also Pine Processionary Caterpillars.

Fairyflies

Would you believe that certain wasps lay claim to the title of world's smallest insect? The "fairyflies" of the family Mymaridae are stripped-down DNA delivery vessels, the smallest, it is claimed, able to fly through the eye of a needle.

Mymarids are all parasitoids of the eggs of other insects. That is, they are parasites that ultimately kill their hosts. They get to their hosts quickly, before embryogenesis has progressed to any great degree, and their oviposition into the host egg usually halts further development. The mymarid larva apparently lacks

a tracheal system and spiracles, the typical breathing system for insects. It progresses through its own metamorphosis entirely within the host egg.

As delicate as they appear, fairyflies are remarkably durable. Some species have the wings greatly reduced (brachypterous), or lacking completely (apterous). A few are aquatic, using paddle-like wings to row through water. Those species are parasitoids of eggs of aquatic insects such as diving beetles, so they must submerge to locate their hosts. They can carry out mating and host-seeking without leaving the water but may climb emergent vegetation to break the surface film and fly to another pond.

On dry land, fairyflies typically seek insect eggs in concealed situations to avoid competition from other egg parasitoids, namely wasps in the family Trichogrammatidae. Consequently, mymarids search plant tissues in which host eggs can be embedded, or look in flower bracts or between bud scales, or in the soil.

These tiny wasps are among our most helpful allies in the war on pest insects. *Anaphes nitens* is employed to control the weevil *Gonipterus scutellatus*, a pest of ornamental eucalyptus trees in South Africa, New Zealand, South America, and Europe. Various species of *Anagrus* are utilized as biocontrol agents for various leafhopper pests, or are being actively evaluated as such.

See also Biocontrol; Integrated Pest Management.

Fig Wasps

Figs (*Ficus* spp.) do not produce fruit in the truest sense. What we call a fig fruit is a syconium. As keystone species, figs are at the center of many food webs, and their pollination hinges on a mutualistic relationship with certain wasps.

Flowers are located inside the syconium, accessible only to female wasps of the family Agaonidae through the ostiole, a tiny hole at the apex of the fig. It is a tight squeeze even for wasps that average less than 2 millimeters. Once inside, each female wasp goes about laying a single egg in the ovary of each flower. The styles of the florets vary in length, so sometimes she cannot reach the ovary. She still accomplishes pollination in the attempt. A larva hatches from the egg and feeds inside a gall that develops in the floret. At the completion of metamorphosis, which takes three to twenty weeks depending on the fig species, an adult wasp emerges.

Females are wasplike, but adult males resemble predatory beetle larvae. Some individuals possess formidable jaws they use to battle other males for the right to mate with females. After mating, the male bores a passage through the fig wall to allow the female's escape. Before her exit, she harvests pollen from male flowers, or passively accumulates it on her way out. She finds another fig by following an aromatic odor trail broadcast by the fig.

There are many exceptions to the preceding. About half of fig species have male and female syconia on separate trees. The wasps successfully complete their life cycle in the male figs, where all florets allow for successful oviposition. To the female wasps, female figs look and smell identical to the male figs, but inside, *none* of the female florets allow successful oviposition. The female wasps that fall for this trap succeed in pollination but fail to reproduce.

See also Ecosystem Services; Pollinators.

Fire Bugs

A surprising number of pyrophilous (fire-loving) insects flock to forest fires and other smoldering situations. Beetles, flies, some moths, and a few true bugs, collectively representing at least twenty-five families, are known to be attracted to fire.

Beetles have developed the most sophisticated sensory systems for locating conflagrations. The Black Fire Beetle, *Melanophila acuminata*, in the family Buprestidae, is the most studied. The beetle has two pit organs on the underside of its thorax. Inside each pit are 50–100 sensilla that each detect infrared radiation in a range corresponding to the 435°–1150° Centigrade temperature at which forest fires burn. Remarkably, the single dendrite in each sensillum converts the radiation input into a micromechanical stimulus that is then measured by a mechanoreceptor. The beetle essentially reads the radiation intensity as a vibration.

Meanwhile, the antennae of *M. acuminata* are tuned to the volatile chemicals in smoke. This is the longer-distance fire detection system, whereas the heat receptors are effective at impressive distances by themselves, at least 1–5 kilometers. Since buprestids usually attack freshly killed or severely weakened trees, arriving before the competition is of paramount importance. Buprestid larvae, called flathead borers, typically tunnel under bark and/or through the wood itself.

Merimna atrata, a buprestid found in Australia, possesses two pairs of infrared receptors on the underside of the abdomen, but they are unable to detect thermal radiation at great distances. Instead, the receptors help the beetle avoid scorching its feet upon landing, detecting "hot spots" not otherwise perceptible.

Some flat bark bugs in the genus *Aradus* detect forest fires using about a dozen infrared receptors similar to *Melanophila*, distributed across the underside of the front of the thorax. These insects feed on fungi that grow on burned wood.

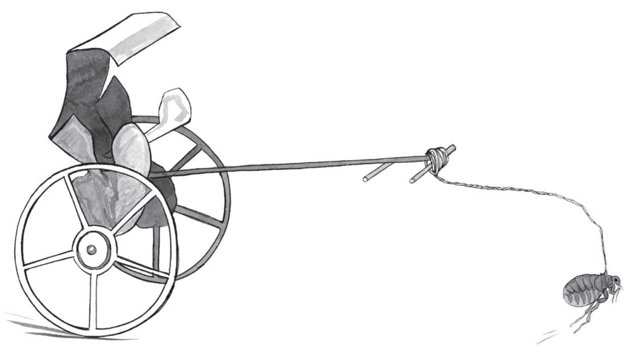
Flea Circus

How unlikely is it that fleas, one of the worst insect enemies of mankind, should be candidates for our amusement? It is a testament to the entrepreneurial spirit of our species that we can find entertainment in such a ridiculous source.

The origin of flea circuses is murky, but they may have existed in Europe as early as the sixteenth century, according to secondhand information from English writer Thomas Muffet. They perhaps reached their zenith when Signor Bertolotto's "Extraordinary Exhibition of the Industrious Fleas" catapulted the flea circus into the spotlight in the 1830s. Intricate miniature replicas of chariots, carriages, even a Man of War ship, all pulled by "trained" fleas, combined with the convincing salesmanship of Bertolotto, made the theatrics quite the attraction, at only one shilling for admission.

The Human Flea, *Pulex irritans*, was the species of choice in these enterprises, perhaps because they fed readily on the blood of their captors. Bertolotto liked to profess that his charges were fed on "ladies of distinction," and indeed, Human Fleas are attracted disproportionately to women, somehow sensing ovarian hormones.

As hygiene and sanitation practices grew more effective, fleas became scarce, and so did flea circuses. They persist today, but irregularly. In the late 1980s, the century-old Munich Flea Circus, by then run by Hans Mathes, was still alive in Germany. His fleas were



purported to dance, juggle, pull carriages, and spin a Ferris wheel.

Predictably, fake flea circuses arose to compete with, or replace, actual insect-driven acts. These faux flea endeavors capitalized on the fact that it is difficult for spectators to discern fleas in the first place. Whether any young flea ever ran away to join a flea circus remains a mystery.

Florissant Fossil Beds

Amber gets all the glory when it comes to insect fossilization, but some of the most spectacular examples of paleoentomology come from rocks and stones. One of the most prolific sites for insect fossils is Florissant Fossil Beds National Monument in Florissant, Colorado.

The monument was established in 1969, but it represents a far more ancient time, roughly 34 million years ago, preserved in shale. The Florissant Formation covers part of the Eocene epoch, in the Paleogene period of the Cenozoic era. The park is named for ancient Lake Florissant, and preserves about one-third of that now extinct body of water. A volcanic mudflow created the lake by damming streams and building up sediments on the lake bottom. Subsequent eruptions of surrounding volcanoes rained ash and pumice and added more mudflows and stream-deposited sediments. The ash also triggered a proliferation of diatoms in the lake. The result was a series of thin layers of material, diatoms included, that trapped plants, insects, and other organisms between them.

Among the more unexpected fossils is a tsetse fly, *Glossina oligocena*, larger than its modern descendants, which today occur only in Africa. It is one of about 1,500 species of insects and spiders discovered from Lake Florissant. All the specimens represent either compression fossils, impression fossils, or a combination of both. A compression is the actual insect, with a mineralized exoskeleton. An impression fossil is like a footprint: the organism is long gone, but its impression remains.

Fossil collecting within the monument is understandably prohibited, but a private family enterprise does allow digging. They have supplied many fossils to museums and the National Park Service, too.

See also Amber; Tsetse Flies.

Fluorescence

Not to be confused with insects and other arthropods that produce their own light through bioluminescence, other organisms fluoresce when exposed to ultraviolet (UV) light. Many scientists exploit this phenomenon in order to locate and collect specimens. Fluorescence is produced when light of a short wavelength (high energy) is absorbed, then rebroadcast as a longer wavelength (of lower energy).

The best-known example of arthropod fluorescence is in scorpions. It has been determined that the outer layer of a scorpion's exoskeleton, the epicuticle, is where the fluorescence originates. Among the compounds in this scorpion armor is a type of coumarin. This chemical is also found in plants, helping prevent sunburn in vulnerable seedlings. It stands to reason that scorpions, which thrive in arid habitats, would need sunscreen, even if they are mostly nocturnal. In insects, it is more complicated.

As early as 1924, fluorescent pigments were known in butterflies, with scientific papers on the subject by the 1950s. There has been a resurgence in interest since 2001, yet it remains a neglected field of study. As of today, fluorescence is also known in caterpillars, beetles, ants, many butterflies, at least one grasshopper, and one dragonfly. This is likely the tip of the iceberg; and we know only a handful of the compounds linked to insect fluorescence.

Not all insects have fluorescent pigments uniformly distributed over their bodies; and there may be sex differences, whereby males fluoresce and females do not, or vice versa. Complicating matters, UV *reflectance* is different from fluorescence. Sulphur butterflies in the genus *Colias*, for example, are known to use differences in UV reflectance as one mate recognition signal.

See also Bioluminescence.

Frass

Insects, especially in their immature stages, consume great quantities of food and consequently excrete an inordinate amount of waste. The solid feces of insects are called "frass." The term is usually reserved for the fibrous or powdery excretions of wood-boring insects like beetle larvae and termites. Occasionally, frass is broadened to include material discarded by an insect, regardless of whether it has passed through the digestive tract.

Ironically, "frass" is German for "animal feed," so its use as a term for animal droppings is rather inappropriate. Nevertheless, the English definition of frass as insect fecal matter has been in use since at least the mid-1800s.

Insect excretion must conserve water yet lubricate the passage of solid waste. The rectum is so efficient at this that little water is lost and the resulting wastes dry quickly. This is important in circumstances where the insect cannot distance itself from its waste, such as in the tunnels of wood-boring larvae. Wet excrement attracts bacteria, fungi, and other organisms that could threaten infection of the living insect.

Not all waste goes to . . . waste. Some caterpillars, like the Octagonal Casemaker, *Coleophora octagonella*, build portable shelters using their dried feces. Leaf beetles exhibit the most ingenious examples of frass recycling. The larvae of many chrysomelids fashion their excreta into protective accessories. Case-bearing leaf beetles create capsules of hardened feces around their soft bodies. Tortoise beetles and their kin pile their feces onto tail-like spines to form umbrella-like structures that protect them from solar radiation, camouflage them from enemies, or actively deter predators.

Adult warty leaf beetles take a different tack. They are near perfect mimics of the frass of caterpillars, even feigning death should they be discovered by a potential adversary.

Galls

Those strange swellings, bizarre “fruits,” and other anomalies on plants are called galls, growths initiated by other organisms, including insects, mites, fungi, and bacteria. The technical term for a plant gall is a cecidium, an innocuous object rarely detrimental to the health of the host.

Among insects that induce galls, gall wasps in the family Cynipidae are most familiar and among the most diverse. Gall midges, family Cecidomyiidae, also account for many galls, though they tend to be less conspicuous. Several families of other flies, plus moths, aphids and their kin, beetles, sawflies, and thrips also include gall-forming species.

How galls are created varies with each gall-former, but they all target plant tissues that are still growing. In cynipids, the initial feeding activities of the larva stimulates growth of the gall. In some sawflies (Tenthredinidae), the adult female wasp applies chemicals at the time she lays her egg, and those substances start the process. Every gall-maker generates unique galls, but how and why is an enduring mystery.

Galls are composed of undifferentiated parenchyma tissues, though in some cases a few cells are specialized to produce structures of the gall. Galls are richer in amino acids, minerals, and other nutrients than surrounding tissue. Many are dense, like a nutshell, or spiny, or otherwise architected to protect the tender occupant(s). Galls are thus food and shelter for the creator.

Cecidia are ecosystems unto themselves. The immature stages of gall-makers are beset by parasitoid wasps, eaten by beetles, birds, mice, and other predators, or share their gall with uninvited guests called inquilines that also feed on the gall tissue.

Humans have used galls for centuries. Oak galls, rich in tannins, have been used since at least the fifth century as a major ingredient of inks.

See also Kinsey, Alfred C.