

CHAPTER 1



SILENT SPARKS

*And above all, watch with glittering eyes the whole world around you
because the greatest secrets are always hidden in the most unlikely
places. Those who don't believe in magic will never find it.*

- Roald Dahl -

A WORLD OF WONDER

Fireflies are surely among the most wondrous creatures that share our planet. Living fireworks, these summertime icons fill the night with their spectacular, yet soundless, light shows. For centuries, fireflies' graceful, luminous dances have inspired wonder from poets, artists, and children of all ages. What makes these silent sparks so appealing?

Many of us feel a deep nostalgic connection to fireflies. They evoke childhood memories of summer evenings spent chasing through fields, gathering fireflies in our hands, our nets, and our jars. Peering closely, we marveled at these tiny radiant beings. Sometimes we even squished a few to decorate our bodies and faces with their still-glowing lanterns.

Fireflies create a magic that transcends time and space. Their resplendent displays change ordinary landscapes into places ethereal and otherworldly. Fireflies can transform a mountainside into a living cascade of light, a suburban lawn into a shimmering portal to another universe, a serene mangrove-lined river into a hypnotically pulsating disco.



FIGURE 1.1 Fireflies spark childhood memories, transform ordinary landscapes, and rekindle our sense of wonder (photo by Tsuneaki Hiramatsu).

All around the world, fireflies elicit a nearly mystical reverence. Surely even the earliest hominids stared awestruck at these silent sparks! Maybe this is what attracts tourists in growing numbers to venture into the night to commune with fireflies. In Malaysia dazzling displays of congregating fireflies draw more than 80,000 tourists each year. In Taiwan almost 90,000 people sign up for firefly-viewing tours during the season. And each June 30,000 tourists visit the Great Smoky Mountains just to admire the Light Show put on by synchronous fireflies. Once I met a woman in the Smokies who'd driven hundreds of miles to see the fireflies there—a yearly pilgrimage she'd been making with her entire family for more than a decade. When I asked what kept them coming back, she pondered a moment and then drawled, "Well, I guess it's just for the awe of it." We all stand in wonder before the silent mystery of fireflies—they move us to joy and thanksgiving.

Fireflies are intricately woven into the fabric of many cultures. But perhaps nowhere on Earth do they shine out through the cultural cloth more brilliantly

than in Japan. As described later in this book, the Japanese people have enjoyed a profound love affair with fireflies for more than a thousand years. The still-popular pastime of firefly viewing is deeply rooted in the ancient Shinto belief that sacred spirits, or *kami*, are manifest throughout the natural world. Fireflies became a metaphor for silent, passionate love following the eleventh-century publication of *The Tale of Genji*, a popular novel written by a Japanese noblewoman. Without contradiction, fireflies also came to represent the ghosts of the dead, as powerfully depicted in the 1998 anime classic, *Grave of the Fireflies*. For centuries, fireflies have been celebrated in Japanese art and poetry. These insects feature prominently in many haiku where, like a temporal GPS, fireflies anchor the poem in early summer. Nonetheless, these beloved insects were nearly extinguished from the Japanese countryside during the twentieth century. Yet a remarkable comeback turned fireflies into a symbol of national pride and environmentalism. In Japanese culture, fireflies are like glowing pearls, steadily accreting value with each new layer of symbolic meaning.

FIREFLY BASICS: WHAT, WHERE, HOW MANY?

Over the past two centuries fireflies have also ignited the spark of scientific inquiry, yielding new insights into their biochemistry, behavior, and evolution. This research really took off in just the past few decades, leading to many exciting discoveries. Beneath their gentle facade, fireflies' lives are surprisingly dramatic—they're full of spurned advances, expensive nuptial gifts, chemical weapons, elaborate subterfuge, and death by exsanguination! This hidden world of fireflies will be revealed in intimate detail within the next chapters of this book.

But first: what exactly *are* fireflies?

These insects go by many different names, including lightningbugs, candle flies, glow-worms, fire bobs, and firebugs. Yet they're neither flies nor bugs—instead, fireflies are beetles. Beetles (also known as Coleoptera) are a famously diverse and successful insect clan. When beetles first evolved 300 million years ago plenty of other insects were already around. But beetles made it big, exploding into a multitude of species. Today 400,000 beetle species live somewhere on Earth, accounting for 25% of all known animals. What gives fireflies their ticket into beetledom? They are all “sheath-winged” insects, their front wings modified into hardened coverings to protect the delicate flight wings.



FIGURE 1.2 Fireflies are really beetles; their front wings are modified into sturdy covers that protect the delicate hindwings, which they use for flying (*Photinus pyralis* photo by Terry Priest).

Within the Coleoptera, all fireflies belong to the family Lampyridae. The beetles in this family are distinguished by several shared features. Bioluminescence (from Greek *bios* for “living” + Latin *lumen* for “light”) is certainly one of their signature traits, although many fireflies exhibit this talent only during their juvenile stages. Lampyrid beetles are also distinguished by their relatively soft bodies. If you’ve ever held a firefly, you might have noticed they’re a bit squishy, in contrast with the rigid, shell-like bodies typical of many other beetles. Finally, every firefly prominently carries a flattened shield that covers the back of its head.

All living fireflies not only look alike, but they also trace their genetic roots back to a single common ancestor. This protofirefly probably lived about 150 million years ago, back in the dinosaur-dominated Jurassic period. At that time, insects were spreading out and diversifying to fill new ecological niches (including a cockroach that specialized in eating dinosaur dung!). While we don’t know what ancient fireflies might have eaten, we do know that as far back as 26 million years ago, fireflies already resembled the ones we see today. We know this because some fireflies got tangled up in sticky tree resin that later hardened into amber, trapping the creatures inside and preserving them in exquisite detail. One piece, dating from 19 million years ago, contains two fireflies caught in the act of mating, now forever sealed together in love (Figure 1.3).

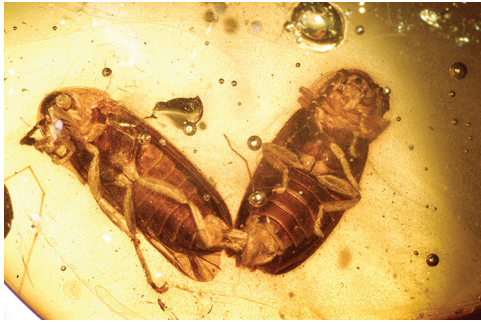


FIGURE 1.3 Long ago, these two fireflies were caught in flagrante delicto when they became trapped in tree resin (photo used with permission of Marc Branham).

People are often surprised to learn there are many different kinds of firefly, not just one. In fact, there are nearly 2,000 firefly species sprinkled across the globe. Collectively, fireflies stretch from Tierra del Fuego at 55° south latitude to Sweden at 55° north latitude, gracing every continent save Antarctica. As is true for most living things, firefly diversity rises in the tropics, peaking in tropical Asia and South America: Brazil alone hosts 350 different firefly species. There are more than 120 recognized firefly species in North America; here the greatest diversity occurs in the southeastern United States, particularly Georgia and Florida. These states are each home to about fifty different firefly species, while in all of Alaska there's only one. For many years, the scientific study of fireflies was largely focused on cataloging new species; that is, finding, naming, and formally describing their anatomical differences. Even today, new firefly species are still being discovered.

LOOKING FOR LOVE WITH FLASHES, GLOWS, AND PERFUMES

As fireflies blossomed over evolutionary time, they hit upon remarkably diverse ways to find and attract mates. Present-day fireflies can be conveniently grouped according to their courtship styles: some species use quick, bright flashes of light to locate mates, while others use slow glows, and still others use invisible wind-borne perfumes.

Lightningbugs earn their name from their talent for flashing—both sexes speak their love in the language of light. Justifiably famous for their brilliant nocturnal displays, these are the fireflies most familiar across North America. Their precise on-off flash control allows lightningbugs to carry on elaborate conversations with



FIGURE 1.4 A typical North American lightningbug; males of the American Big Dipper firefly court their females with quick, bright, J-shaped flashes (*Photinus pyralis* photo by Alex Wild).

prospective mates. Typically, flying males broadcast distinctive flash patterns, while sedentary females flash back in response. This courtship style has evolved in several different firefly lineages. Lightningbug fireflies are ubiquitous east of the Rocky Mountains, yet for reasons unknown they're found only in scattered pockets across the western states and provinces.

Photinus pyralis, commonly known as the Big Dipper firefly, could easily be the poster child for all lightningbug fireflies. Its common name reflects this beetle's large size (up to 15 mm long) as well as its flash gesture: while flashing, males dip down then sharply rise up, skywriting the letter J with their lights. Big Dipper fireflies are found all across the eastern United States from Iowa to Texas, and from Kansas to New Jersey. Active just at dusk, they fly close to the ground—even young children can easily capture them. And these lightningbug fireflies are not too picky about habitats; they're often seen flying over suburban lawns, golf courses, roadsides, parks, and college campuses.



FIGURE 1.5 A European glow-worm firefly; clinging to her perch, the female dangles her lantern to attract flying males (*Lampyris noctiluca* photo by Kip Loades).

Northern Europe has mainly *glow-worm fireflies*, whose plump and wingless females give off long-lasting glows. Flightless and earthbound, every night these females clamber up onto low perches and glow for hours to attract flying, but typically unlit, males. Some glow-worm females also add chemical scents to their love potion. Released into the air, such perfumes flow unobstructed around trees and other vegetation, attracting males from afar.

Worldwide, nearly one-fourth of all firefly species are glow-worms. Best-known among them is the common European glow-worm, *Lampyris noctiluca*. Widespread, this particular glow-worm firefly occurs throughout Europe from Portugal to Scandinavia, and across much of Russia and China. The glow-worm style of courtship is also popular in many Asian fireflies. Oddly, glow-worms are rare among North American fireflies, though a few are found even west of the Rocky Mountains.

FIGURE 1.6 A North American day-flying dark firefly; instead of lights, these adults use scents to attract mates (*Lucidota atra* photo by Peter Cristofono).



Equally widespread are the *dark fireflies*, so named because these adults fly during the daytime and they don't light up. Instead these males locate mates by sniffing out wind-borne perfumes given off by their females. Evidence suggests that the very first fireflies used similar courtship styles. Such day-active dark fireflies are common across North America, even in the West.

Firefly Semantics

Although fireflies account for *most* of the world's glow-in-the-dark beetles, this bioluminescent ability is shared with beetles from other families, including the phengodid beetles (Phengodidae, or railroad worms) and a few click beetles (Elateridae; called *cucubanos* in Puerto Rico, *peenie-wallies* in Jamaica).

So what exactly do we mean by the name "firefly"? This term refers to any member of the beetle family Lampyridae, whether or not their adults light up. Fireflies can be sorted into three groups according to the different courtship styles they use to find their mates:

- *lightningbug fireflies*: adults use quick on-and-off flashes for courtship
- *glow-worm fireflies*: flightless females produce long-lasting glows to attract males; typically, the males don't light up
- *dark fireflies*: these adults don't light up; they court during the day, relying on chemical cues to find mates

ON THE MOVE

By accident or with intention, people have sometimes transplanted fireflies to places where they don't belong. Lesser glow-worms, *Phosphaenus hemipterus*—native to Europe—were discovered in Halifax, Nova Scotia, in 1947, probably traveling as stowaways in the soil of imported tree seedlings. These flightless glow-worms managed to survive and even spread out around Halifax, where several populations were still thriving in 2009. But other transplants didn't take. Around 1950, some flashing fireflies (*Photuris*) were deliberately introduced from the eastern United States, in hopes of adding some sparkle to city parks in Portland, Oregon, and Seattle, Washington. They flickered for a few weeks, then disappeared. Another transplant attempt during the 1950s introduced Japanese fireflies to control snails in Hawai'i; these transplants likewise failed to survive. No one knows why some firefly transplants failed while others thrived. Maybe the destination address had the wrong temperature, moisture, or soil conditions, maybe some favorite prey was lacking, or maybe some new predator was lurking.

We now recognize it's generally a bad idea to intentionally relocate creatures—even beautiful, apparently harmless ones like fireflies. Many gorgeous plants—like purple loosestrife, water hyacinth, and Japanese knotweed—were originally imported to the United States as ornamentals. But these exotics quickly turned invasive, weedily crowding out native species and wreaking ecological havoc. Every living species is embedded in an elaborate, yet often obscure, network of biological interactions. When we disrupt this network by plucking creatures from one place and plunking them down somewhere else, there's really no telling what will happen.

WHAT'S UP NEXT

This book offers a guided tour of fireflies' luminous lives. We'll hear behind-the-scenes stories about their courtship rituals, their potent poisons, some seductive mimics, and their present plight. Of course, these remarkable tales would remain untold if a few inquisitive scientists hadn't invested their days and nights to deciphering these firefly mysteries. Beginning with my own seduction into firefly biology in the 1980s, I've been privileged to know and work with many leading researchers. As the fireflies' stories unfold, we'll meet some of the people whose

lives are so intimately entwined with these creatures. They're not merely scientists. They include Lynn Faust: horsewoman, mom, and self-taught naturalist whose firefly-spangled childhood inspired her to become the leading expert on the Light Show of the Great Smoky Mountains. Another is Raphaël De Cock, a traveling troubadour who leads a double life, because he is also an expert on glow-worms. We'll head out into the night with James Lloyd, the solitary field biologist who has devoted a lifetime of summer nights to observing how fireflies behave in the wild. And we'll hear about the late John Buck, a dedicated sailor and physiologist whose careful laboratory studies uncovered the mechanisms that fireflies use to control their flashing. Together with others from around the world, these scientists' collective efforts have divulged some of fireflies' most deeply held secrets.

Before we enter this mysterious world, here's a quick peek at what's coming up next:

In chapter 2, "Lifestyles of the Stars," we'll see that all fireflies rise up from humble beginnings. Fireflies enjoy a remarkable childhood. They spend most of their lives—up to two years—as grub-like juveniles that live underground. Baby fireflies turn out to be fearsome predators, indulging themselves in gluttony and growth. We'll follow a firefly through its different life stages, starting from a faintly glowing egg through the curious magic of metamorphosis. Once fireflies reach adulthood, they become single-mindedly focused on sex. Traveling to Tennessee, we'll walk into a forest to find waves of light created by the synchronous pulsations of a thousand fireflies washing over us.

The spectacular displays we so admire are actually the silent love songs of male fireflies. In chapter 3, "Splendors in the Grass," we'll visit a New England meadow at dusk to experience some lightningbug courtship. For nearly three decades my students and I have studied fireflies in the wild to gain insight into sexual selection, a subtle yet powerful evolutionary process. We'll follow some males as they lift off on their nightly search missions. As these flying, flashing males earnestly broadcast their availability, coy females only flash back if they spot an especially attractive male. What exactly does a firefly female consider sexy? We'll find out. And we'll see how steeply the odds are stacked against firefly males. Only a select few will end up embracing an amorous female, while many others will embrace only death.

But what happens after the lights go out? Firefly sex is enigmatic, and not just because it happens under cover of darkness. As we'll learn in chapter 4, "With

This Bling, IThee Wed,” the drama now continues deep within the hidden recesses of females’ reproductive system. My own microscopic explorations of fireflies’ interior landscapes led to a thrilling discovery that transformed our view of firefly sex lives. In this chapter we’ll hear about nuptial gifts, and see what these amorous bundles mean both to the gift givers and to the recipients.

Because glow-worm females are flightless, their lifestyle contrasts sharply with that of other fireflies. In chapter 5, “Dreams of Flying,” we’ll meet a rare American glow-worm, the blue ghost firefly. We’ll tag along on a field expedition to the southern Appalachian Mountains to study the courtship habits of these mysterious blue ghosts. Flying ankle-high above the forest floor, males give off eerie, long-lasting glows as they search for females. Meanwhile, the blue ghost females, tiny and wingless, crawl slowly through the leaf litter. Trying to glimpse the world as they see it, we’ll enter the Umwelt of these flightless females, shrinking down to assume their vantage point.

How do these creatures *make* light? Firefly glows appear magical, but in chapter 6, “The Making of a Flasher,” we’ll learn how bioluminescence arises from carefully orchestrated chemical reactions. Inside the firefly’s lantern we’ll discover the main star, luciferase, an enzyme that’s also been put to work protecting human health. Some fireflies can quickly switch their lights on and off, a talent that allows them to blink out precise, Morse-code-like signals. How do these insects achieve such high-tech flash control? We’ll also accompany some early firefly biologists on a quest to Southeast Asia to discover how some fireflies manage to flash together all night long in marvelous synchrony.

But fireflies aren’t all sweetness and light. Chapter 7 (“Poisonous Attractions”) divulges the dark side of fireflies. Some fireflies manufacture potent poisons, and these nasty-tasting chemicals keep birds, lizards, mice, and other insectivores at bay. These chemical weapons also hold the key to understanding why fireflies’ bright lights evolved in the first place. Yet fireflies are considered quite a delicacy by certain creatures, including some flashy and alluring femmes fatales.

The world of fireflies holds many tantalizing tales, and we still have lots to learn. But meanwhile, firefly populations around the world are blinking out. In chapter 8 (“Lights Out for Fireflies?”), we’ll explore the complicated, often destructive, relationship between humans and fireflies. We’ll take a look at some likely culprits behind recent firefly declines, including habitat destruction and light pollution. We’ll also learn how people have overexploited fireflies, sometimes to extract their light-producing chemicals, other times to enjoy their numi-

nous beauty. Fortunately, there's still hope that future generations will be able to enjoy these living sparks. This chapter wraps up with some practical ways to make your yard more firefly friendly.

At the end of the book, we'll gather our gear and step out into the night to get personally acquainted with some local fireflies. A field guide will help you identify some common North American fireflies and learn how to decode their courtship conversations. The final section offers pointers on useful field gear and charts some adventures that will let you peer even more deeply into the many wondrous worlds of fireflies.

In this book I've decided to forgo the usual scientific displays, like graphs and tables. But if you're so inclined, you'll find an annotated bibliography for each chapter that points to the relevant information. When scientific articles are available online without charge, I've provided links to these resources. (In the e-book version, you can click directly through; if you're reading the print version, you'll find all the chapter notes, including these links, on the *Silent Sparks* blog or at <http://press.princeton.edu/titles/10667.html>.) I've also provided a glossary to help explain some specialized terms. And should you want even more, you'll find a carefully selected list of web and print resources to guide further explorations.

So let's begin our journey into the hidden world of fireflies. We'll be traveling behind the scenes to explore the nightly drama that unfolds in your own backyard, in your neighborhood park, and in the fields and forests nearby. Let's open the door and step lightly through . . .