8

POLYPHEMUS MOTH

(*Antheraea polyphemus*)

Polyphemus moths were collected in Philadelphia in the nineteenth century before the advent of electric lighting. Paradoxically, light pollution in Center City may protect them.

Figure 8.1 Display box from the Titian Ramsay Peale Butterfly and Moth Collection preserved at the Academy of Natural Sciences of Drexel University. The four largest moths are polyphemus moths. Records for those in the bottom left and top right specify Philadelphia, 1833. Historical notes, possibly Peale's, are partly visible in the background. (Curated by Jason D. Weintraub, entomological collection manager at the Academy of Natural Sciences of Drexel University. Photo courtesy of the Academy of Natural Sciences of Drexel University.)

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In 1833 Titian Ramsay Peale collected a male and female polyphemus moth in Philadelphia.[1] Polyphemus moths are giant silkmoths (saturniids) with big three-dimensional-appearing eyespots on their hind wings. The species is native to most of the United States and southern Canada. Its larvae eat birch (*Betula*), willow (*Salix*), maple (*Acer*), and oak (*Quercus*). Although boldly patterned and with wingspans up to 15 cm, the moth is hard to find: it folds its wings and conceals its eyespots during the day; its larvae are cryptically colored; its cocoons usually drop and disappear into leaf litter; and the moth flies exclusively at night.[2]

Municipal lighting in Philadelphia

Conceivably, Peale collected his polyphemus moths at oil lamps. Municipal lighting in Philadelphia dates back at least to 1791, when an oil depot in Franklin Square supplied fuel to the city's streetlamps.[3] Records do not document whether Philadelphia's municipal oil lamps attracted giant silkmoths, but C. A. Frost reported that a kerosene lamp attracted polyphemus moths to a window in his house in Framingham, Massachusetts, in the beginning of the twentieth century.[4]

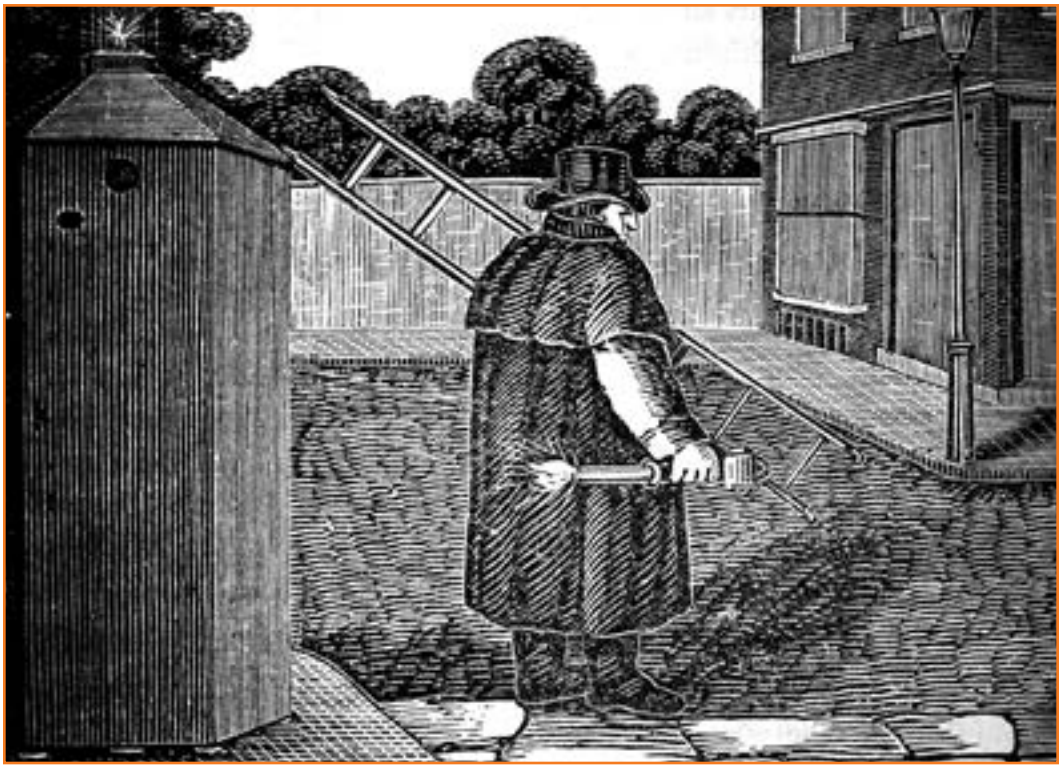

Figure 8.2 Lamplighter, Philadelphia. (Anonymous artist, from engraving in *History of Philadelphia…Containing a Correct Account of the City Improvements up to the Year 1839*[5])

By the time Peale collected these two moths, the city was planning municipal lighting powered by gas made from coal at the Philadelphia Gas Works, which was built in 1835 on the east bank of the Schuylkill River just north of Market Street.[6] Four years after its construction, the Philadelphia Gas Works was delivering gas through 23 miles of pipe to 11,802 burners, including 434 streetlamps.[7] Although Philadelphia's municipal gas lamps may have attracted polyphemus moths, conditions around the lamps may have deterred moth collectors. In a guide published in 1839, Daniel Bowen attempts to dispel fears about public safety downtown after dark:

> The City is well guarded at NIGHT by able bodied men of good character…Each of the Four Divisions has about 35 Watch-men whose duty it is to trim, light and extinguish the public lamps and gas-lights, to walk their rounds, and cry the hours while on duty and to secure the peace and quiet of the city.
>
> In addition to the Watch-men attached to particular stations, each Division has allotted to it 8 silent Watch-men whose duty it is to see that the stationed Watch-men attend to their prescribed duties and maintain watchfulness during the hours allotted them and to walk quietly through the Division, and to see that thieves &c. are not making inroads between the regular Watch-mens' rounds: they usually pursue their rounds, two in company.[8]

In 1881, four years before Peale died, the Brush Electric Company installed the city's first electric streetlights on Chestnut Street, where it erected Brush lamps, carbon arc lamps so bright that two of them in a hotel dining room replaced 144 gas burners.[9]

Moths once abundant at electric lights

In 1892 the Smithsonian Institution published *Directions for Collecting and Preserving Insects,* by Charles Valentine Riley, who advised where to search for moths:

> Collecting by the aid of strong light is a favorite means for moths as well as other insects, and nowadays the electric lights in all large cities furnish the best collecting places, and hundreds of species may be taken in almost any desired quantity.[10]

In 1900 Sherman F. Denton, author of a two-volume introduction to the butterflies and moths of the eastern United States, reported the rewards of collecting downtown at electric light:

> While employed in Washington, D.C., I made a splendid collection of the moths of that region simply by going the rounds of a number of electric lights every evening. The lamps about the Treasury Building were sometimes very productive of fine specimens and the broad stone steps and pillars were frequently littered with moths, May flies, beetles, etc., where one could stand and pick out his desiderata with little difficulty. I captured several of the Regal Walnut moths (Citheronia regalis) and a number of our largest and handsomest sphinxes. Besides making the acquaintance of a number of insects new to me, I met several entomologists who, like myself, had been attracted to the lights by the abundance of specimens.[11]

Light pollution

By 1988 Philadelphia had 100,000 high-pressure sodium streetlamps at an average density of almost 200 lamps per square kilometer. The radiant energy they emitted equaled more than 10 kilowatts per square kilometer, an order of magnitude greater than the energy of moonlight at full moon. Over the preceding four decades, the output (lumens) per lamp had increased sevenfold, while the number of lamps had tripled.[12] High-pressure sodium lamps emit minimal ultraviolet energy,[13] the spectral region most attractive to moths; but the energy they emit in the blue and green part of the spectrum does attract moths.[14]

Today light pollution in Center City is so diffuse that practically no outdoor locations are free of it, whether reflected from the sky or buildings, or transmitted directly from lamps. Even places that appear dark may be dark only relative to their artificially illuminated surroundings. Views of stars are washed out by electric light bouncing off the atmosphere. On clear nights that minimize atmospheric reflec-

tions, the Milky Way is visible, but its appearance is faint compared to that viewed in rural locations far from urban skyglow. Lamps in downtown Philadelphia attract few if any moths.

Harmful effects of light pollution on moths

Gerhard Eisenbeis, who monitored insects attracted to streetlamps in rural Germany, concluded that streetlamps deplete populations of nocturnal insects. He called the phenomenon a "vacuum cleaner effect."[15] Electric lamps can disrupt virtually every life function of moths that fly to them. These functions include feeding, mating, egg laying, dispersal, and migration. Electric lamps temporarily blind moths that approach them. The light probably resets their internal clocks. Predators such as birds and bats hunt insects attracted to light sources. By disturbing where moths land, the lamps spoil crypsis—the visual match between a moth and its background. Electric lamps desiccate or incinerate moths trapped inside their housings.[16] Based on Eisenbeis's conclusion, one might suspect that light pollution has depleted or extirpated Center City's populations of moths, such as the polyphemus moth.

Protective effects of light pollution on moths

A contrary view is that urban light pollution protects moths. By reducing background darkness, it suppresses the attraction of insects to lamps. Such attraction is the primary means by which artificial lighting harms moths. In 1997 José Luis Yela and Marcel Holyoak in Spain showed that moonlight reduced collections of insects attracted into light traps but not bait traps. Moonlight behaved like light pollution in the sense that it reduced background darkness and suppressed attraction of moths to artificial sources of light. Yela and Holyoak's findings showed that moonlight suppressed pathological behavior around artificial light, but allowed normal attraction to bait.[17]

Figure 8.3 Skyglow over Center City on a cloudy night. Background light from light pollution decreases attraction of moths to lamps. Cloud cover amplifies urban light pollution, which paradoxically protects moths from harm due to attraction to lamps.

Light pollution from one source of artificial light can protect moths from attraction to other sources. In 1950 H. S. Robinson and P. J. M. Robinson demonstrated how one lamp could reduce another's attractiveness to moths. If the two lamps are spaced so that they reduce the surrounding darkness that each requires for attracting moths, the two together will attract fewer moths in total than they would if operated separately.[18] Their experiments demonstrate how, in a densely illuminated area downtown, interactions among light sources clustered together suppress attraction of moths to lamps.

Cloud cover at night ordinarily screens out moonlight and starlight and increases darkness, boosting the attractiveness of lamps to moths. For example, Yela and Holyoak showed that cloud cover increased collections of moths in light traps.[19] Combined with light pollution, however, cloud cover may have the opposite effect: it reflects light pollution downward, magnifying it[20] and disrupting the darkness that flight-to-light behavior requires.

As a kid, I collected polyphemus moths at light in the George Washington National Forest in Virginia. Like any collector of moths, I soon discovered that the full moon was the worst time for collecting, and the new moon (i.e., no moon) with a cloud cover was the best. To maximize the attractiveness of my lamp, I took care to turn off all others nearby.

In Center City, light pollution may have contributed to the absence of polyphemus moths around city lights, but for reasons opposite to common wisdom. It's not that light pollution downtown harms moths; on the contrary, light pollution here protects them by suppressing flight to light. Light pollution may be construed as a double-edged sword, increasing or decreasing attraction to artificial light depending on circumstances.

Moths that fly to light in Center City

During the summer and fall of 2010, thirty-four species of moths flew to light in our backyard, which is shielded from streetlights. The number of individuals per night was small—usually none—and the moths were tiny compared to polyphemus moths. To attract them, I operated a 13-watt fluorescent blacklight (ultraviolet lamp) that illuminated a white pillowcase. The most common moth attracted to this light was the ailanthus webworm moth (*Atteva aurea*). Sometimes several of these colorful moths would arrive on a single night in the early fall; a mature ailanthus tree towers above the roof of a row house on our block. Larvae of most of the species that came to my blacklight are polyphagous: they feed on many kinds of local plants, both cultivated and wild. Figures 8.4–8.12 show some of the moths I photographed after they settled on the pillowcase or other surfaces near the lamp.

Figure 8.4 Green cloverworm moth (*Hypena scabra*). Its larvae feed on many kinds of plants, including clover *(Trifolium sp.)*.[21]

Figure 8.5 Corn earworm moth (*Helicoverpa zea*). Larvae feed on corn and other crops.[22]

Figure 8.6 Boxwood leaftier moth (*Galasa nigrinodis*). Larvae feed on boxwood (*Buxus* sp.).[23]

Figure 8.7 Common looper moth (*Autographa precationis*). Larvae feed on many kinds of plants.[24]

Figure 8.8 Implicit arches moth (*Lacinipolia implicata*) on stucco wall of our house. Larvae feed on common dandelion (*Taraxacum officinale*) and many other plants.[25]

Figure 8.9 Suzuki's promalactis moth (*Promalactis suzukiella*). Larvae are found under bark of rotting logs.[26]

Figure 8.10 Morning glory plume moth (*Emmelina monodactyla*). Larvae feed on common morning glory (*Convolvulus sp.*), lambsquarters (*Chenopodium album*), and others.[27]

Figure 8.11 Little underwing moth (*Catocala minuta*). Larvae feed on honey locust (*Gleditsia triacanthos*),[28] a common street tree on our block.

Figure 8.12 Common tan wave (*Pleuroprucha insularia*). Larvae feed on many species, including goldenrod (*Solidago sp.*), bittersweet (*Celastrus scandens*), and oak (*Quercus sp.*).[29]

Why polyphemus moths did not come to my light

If so many kinds of moth in Center City flew to my lamp, why didn't the polyphemus moth? Giant silkmoths naturally live at low population densities, which protect them from parasitoids, microbes, and other enemies.[30] Polyphemus moths can find mates far away because males can detect minute concentrations of female sex pheromone[31] and efficiently home in on the source.[32] In one instance, a trap baited with pheromone captured a marked polyphemus male released the same evening

at a distance of 7.5 kilometers.[33] Even if polyphemus moths did, like other moths, occasionally fly to lamps downtown, the large numbers of lamps and small number of moths would make the chance of finding a polyphemus moth at any particular lamp low.

A more compelling reason for the rarity of polyphemus moths at lamps in Center City is destruction of habitat. Daniel Janzen observed that declines of moths flying to electric light in Costa Rica coincided with agricultural destruction of their habitat.[34] From 1970 to 1990, urban sprawl in the 100 largest metropolitan areas in the United States increased by 37,671 square kilometers; Philadelphia's per capita increase in sprawl was 48 percent, the most of any metropolitan area.[35]

Unlike cocoons of giant silkmoths such as *C. promethea* and *H. cecropia,* cocoons of polyphemus moths usually fall to the ground rather than remaining suspended from tree branches.[36] In Center City, a cocoon on the ground is likely to be treated as litter, and trashed. In the suburbs, it is likely to be raked up with leaves, sent to a recycling center, and converted to mulch. Gray squirrels prey on polyphemus cocoons.[37]

A polyphemus moth shows up downtown

On the morning of July 24, 2011, looking out our third story window on Pine Street, I noticed a female polyphemus moth resting on a branch of a willow oak (*Quercus phellos*). This moth was just beyond arm's reach, and about 20 meters away from a high-pressure sodium streetlamp. Willow oak is a host plant of larvae of *Antheraea polyphemus.*[38] I contacted Jason Weintraub, a neighbor and lepidopterist at the Academy of Natural Sciences, who came over and, leaning out the window, used a long-handled net to capture the moth. She laid fertile eggs, and Jason reared her offspring.

Figure 8.13 Gravid female polyphemus moth on her host plant, willow oak (*Quercus phellos*), July 24, 2011, outside a third-story window of our home on Pine Street, a few doors down from a sodium streetlamp. Her wingspan when spread open was about 15 centimeters (6 inches).

In February several years later I found a polyphemus cocoon dangling from a low branch of a cultivated river birch tree (*Betula nigra*), another host plant of polyphemus caterpillars. It caught my attention after it cast a distinctive silhouette against a fresh layer of snow. This cocoon's failure to drop to the ground saved it from being trampled.

Figure 8.14 Cocoon of polyphemus moth highlighted against a fresh layer of snow in February. It is dangling from a cultivated river birch (*Betula nigra*) along the Schuylkill River Trail in Center City.

David L. Wagner recently reviewed the decline in abundance of moths in the northeastern United States, particularly in Connecticut. Among Connecticut's fifteen species of giant silkmoths (saturniids), he found an increase in abundance of only one: the polyphemus moth, which is now common. Most species of giant silkmoth in the state were either declining in numbers or extirpated. Why populations of polyphemus increased in Connecticut in the last ten years is a mystery.[39]

Whether populations of polyphemus moths are increasing in Center City is unknown. Declines in populations of house sparrows (*Passer domesticus*) could reduce predation on them. Common nighthawks (*Chordeiles minor*), nocturnal insectivores once common in Center City, are now rare. An epidemic fungal disease, white nose syndrome, is destroying local populations of little brown bats (*Myotis lucifugus*). The use of bug zappers outdoors to kill mosquitoes carrying West Nile virus may have helped polyphemus moths; in suburban Newark, Delaware, bug zappers killed fewer moths than parasites and predators of insects.[40]

Conceivably populations of polyphemus moths, like clothes moths, evolved resistance to attraction to artificial light; or they may have evolved increased fitness in some other way. Jason Weintraub has curated Titian Ramsey Peale's historic collection of moths preserved at the Academy of Natural Sciences of Drexel University. He has posted online images of nearly 100 boxes of specimens, including the two polyphemus moths Peale collected in Philadelphia in 1833. If polyphemus moths evolved traits that increased their fitness, changes in their DNA compared to that in specimens dating back to the nineteenth century might offer clues to the evolutionary steps.

Figure 8.15 Clothes moth (*Tineola bisselliella*) indoors in Center City. It is not attracted to light.