THE EVOLVING GLOBAL EPIDEMIOLOGY, SYNDROMIC CLASSIFICATION, MANAGEMENT, AND PREVENTION OF CATERPILLAR ENVENOMING

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Abstract. Caterpillars are the wormlike, larval forms of butterflies and moths of the insect order Lepidoptera. Next to flies, lepidopterans are the most abundant arthropods with more than 165,000 species worldwide, and with most species posing no human threats. However, caterpillar species from approximately 12 families of moths or butterflies worldwide can inflict serious human injuries ranging from urticarial dermatitis and atopic asthma to osteochondritis, consumption coagulopathy, renal failure, and intracerebral hemorrhage. Unlike bees and wasps, envenoming or stinging caterpillars do not possess stingers or modified ovipositors attached to venom glands, but instead bear highly specialized external nettling or urticating hairs and breakaway spines or setae to defend against attacks by predators and enemies. Since the 1970s, there have been increasing reports of mass dermatolgic, pulmonary, and systemic reactions following caterpillar encounters throughout the world.

INTRODUCTION

Most caterpillars are herbivores and are among the most common insects found grazing on plants worldwide. Although there are more than 165,000 species of caterpillars worldwide from more than 80 families with more than 11,000 species of caterpillars in the United States alone, most caterpillars are dangerous-looking and often brightly colored, but pose very little threat to humans. However, unlike solitary caterpillar feeders, communal caterpillar feeders can pose potentially devastating threats to agricultural crops and forests, such as gypsy moth caterpillars in the United States and processionary caterpillars in Europe.

Caterpillars from about 12 families worldwide can inflict serious human injuries ranging from urticarial dermatitis and atopic asthma to osteochondritis, renal failure, and intracerebral hemorrhage. Unlike bees and wasps, envenoming or "stinging" caterpillars do not possess modified ovipositors or stingers attached to venom glands, but instead bear highly specialized external nettling or urticating hairs and spines or setae to resist attacks by predators and enemies. Since the 1970s, there have been increasing reports of mass allergic and systemic reactions, including asthmatic bronchitis, osteochondritis, consumption coagulopathy, renal failure, and fatal intracerebral hemorrhage, following caterpillar envenomings throughout the world, particularly in North America, South America, Australia, China, and Europe.

MATERIALS AND METHODS

A Medline search, 1966–2004, an Ovid Old Medline search, 1951–1965, and a library search for historical articles published prior to 1951 of the world's salient scientific literature of case reports, case series, laboratory investigations, epidemiologic investigations, and reviews were conducted to determine the evolving global epidemiology and outcomes of venomous caterpillar exposures. In addition, the pathophysiologic manifestations of venomous caterpillar exposures were classified into five distinct clinical syndromes to guide clinicians in making earlier, more species-specific diagnoses to direct therapies including: 1) erucism, 2) lepidopterism, 3) dendrolimiasis, 4) ophthalmia nodosa, and 5) consumptive coagulopathy with secondary fibrinolysis. The management and prevention of specific caterpillar envenomings were discussed.

RESULTS

The mechanisms of caterpillar envenoming. Caterpillars have evolved unique systems of protection from predation including protective mimicry, foul scent-producing glands, and proteolytic and histaminergic venoms. Caterpillar venoms are produced by hypodermal, glandular epithelial cells, circulated in hemolymph, and stored in external tegument, tubercles or scoli, urticating hairs, and spines. Although caterpillars frequently store toxins throughout their bodies, caterpillars possessing only venomous spines or setae are often described as phanerotoxic; while caterpillars circulating toxins only in hemolymph and not in hairs or spines are often described as cryptotoxic.[1]

During the 1920s, Dr. P. M. Gilmer carefully studied the hairs and spines of many North American caterpillars under light microscopy and developed a classification system for the urticating hairs and spines (setae) of caterpillars that remains in use today.[2] With the advent of electron microscopy, the morphology of caterpillar envenoming structures and their classification has been further refined by Eaton[3] and Veiga and others.[4] Gilmer initially defined a caterpillar hair as a single seta derived from a single hypodermal cell (Gilmer's urticating hair), and a caterpillar spine as an evagination of the body wall lined by hypodermis (Gilmer's urticating spine).[2] Later investigations by Steher identified larger branched spines or scoli, with easily breakable, spiny branches that released toxic venoms from subapical pores or proximal bases.[5] Scanning electron microscopic investigations by Eaton[3] and later by Veiga and others[4] have now established a new classification of caterpillar urticating spines or setae including 1) a simple seta with a single glandular poison cell at its base (the original Gilmer's urticating hair); 2) a branched seta or scolus with a single glandular poison cell at its base; 3) a seta formed by cuticular evagination with venom-secreting cells in the lumen at the spine base (the original Gilmer's urticating spine); and 4) a seta formed by cuticular evagination without a basilar poison-secreting cell or cells. Caterpillar toxins have not been as well studied as caterpillar morphology and taxonomy, with the exception of *Euproctis* or browntail moth caterpillar toxins, the European

Thaumetopoea or processionary tree caterpillar toxins, and the South American saturniid moth or *Lonomia* caterpillar (*L. achelous* and *L. obliqua*) toxins.

Processionary tree caterpillars are communal deforesters of acacia, eucalyptus, oak, pine, fruit, and ornamental tree forests worldwide, and are aptly named because they queue and meander single file, head to tail, often following a trailing silk thread, and moving in concert like freight trains. Processionary caterpillars frequently cause outbreaks of caterpillar dermatitis, conjunctivitis, and allergic reactions following exposures to their urticating hairs and spines or aerosols containing hairs, especially in Australia, China, Europe, and Japan.

Venom extracts from the hairs, spines, and hemolymph of the South American saturniid moth or *Lonomia* caterpillars (*L. achelous* and *L. obliqua*) contain fibrinolytic proteases and clotting activators that can cause consumptive coagulopathies, intracerebral hemorrhage, and acute renal failure following caterpillar contact.[4] Since *Lonomia* caterpillars are communal and not solitary feeders, caterpillar contacts often result in multiple venom exposures with high case fatality rates.[4,6] Envenoming by *Lonomia* caterpillars is now a serious public health problem in Brazil and Venezuela, with case fatality rates 3–6 times higher than for venomous snakebites.[4,6] As more Amazonian rain forests are converted into grazing and croplands, and non-native settlers move onto new farmlands, South American public health authorities predict increasing contacts between humans and *Lonomia* caterpillars.[4,6]

History of caterpillar envenoming. The ancient Greeks were the first to report skin diseases following contact with caterpillars.[7] The first relevant scientific publications on cutaneous reactions following caterpillar hair and spine contacts date from 1848.[8] In 1868–1869, the gypsy moth caterpillar (*Lymantria dispar*) was intentionally introduced into the Boston area from Europe to start a failed American silk industry, even though gypsy moth caterpillars produced insufficient, poor quality silk for their cocoons.[7] In 1901, White reported several cases of contact dermatitis in the United States following exposures to browntail moth caterpillars (*Euproctis chrysorrhoea*).[9] In 1914, von Ihering was the first to report a bleeding diathesis following contact with South American caterpillars, probably *Lonomia* saturniid moth caterpillars.[10] In 1918, Caffrey reported watery eyes, sneezing, and asthmatic bronchitis in an entomologist raising New Mexico buck moth caterpillars [*Hemileuca nevadensis* (*oliviae*)].[11] During the 1920s, Gilmer conducted his classic microscopic descriptions of the envenoming structures of several caterpillars in the United States and differentiated urticating hairs from spines.[2] In 1967, Arocha-Piñango first described hemorrhagic diathesis following contact with *Lonomia achelous* caterpillars in Venezuela,[12] and later collaborated in isolating lonomin V, the major thrombolytic toxin in the hairs and hemolymph of *Lonomia achelous*.[13,14]

Taxonomy and global distribution of envenoming caterpillars. The majority of envenoming caterpillars belong to approximately 12 families of lepidopterans, mostly moths, but also butterflies, and ranging from "A to Z" or from the family Arctiidae to the family Zygaenidae. Table 1 lists some representatives of commonly envenoming caterpillars and their taxonomic classifications and distributions.

Evolving global epidemiology of caterpillar envenoming. Entomologists and other scientists working in agricultural research stations have long recognized the allergic manifestations associated with raising insects in tightly confined

TABLE 1
Taxonomy and distribution of some commonly envenoming caterpillars of moths and butterflies

Lepidopteran family or subfamily (moth or butterfly as adults)	Representative genera/species (spp.)	Global distribution
Arctiidae (moth)	*Arctia* spp.	Worldwide
	Hyphantria spp.	United States, Europe, Japan
Eucliedae (moth)	*Euclea delphinii*	North America
Hemileucidae (moth)	*Hemileuca* spp.	New World
Lasciocampidae (moth)	*Malacosoma* spp.	United States, southern Canada
	Dendrolimus pini	Central Asia, north Africa
Limacodidae (moth)	*Sibene stimulea*	Eastern and southern United States
	Phobetron pithecium	North America
Lymantriidae (moth)	*Euproctis chrysorrhoea*	United States, United Kingdom, Europe, North Africa
	E. pseudoconspersa	Japan
	E. edwardsii	Australia
	E. flava	Asia
	E. similis	Worldwide
	Lymantria dispar	Eastern United States, Europe
	Orgyia spp.	North Africa, Europe, Asia, North America
	O. leucostigma	North America
	O. pseudotsuga	United States and Canadian Pacific Northwest
Megalopygidae (moth)	*Megalopyge* spp.	United States, Latin America
Notodontidae (moth)	*Lochmaeus* spp.	New World
Nymphalidae (butterfly)	*Nymphalis* spp.	North America, Europe, Asia
Saturniidae (moth)	*Atomeris io*	Southern Canada, United States, Mexico
	Lonomia achelous, Lonomia obliqua	South America (Brazil, Venezuela, Argentina)
Subfamily Thaumetopoeidae, family Notodontidae (processionary caterpillars) (moth)	*Thaumetopoea pityocampa*	Asia, North Africa, Europe
	T. processionea	Europe
	T. wilkinsonii	United States, Asia, Africa, Europe
	Orchrogaster contraria	Australia
Zygaenidae (moth)	*Neoprocris* spp.	New World
	Zygaena spp.	Central and southern Europe

spaces.[11] As noted, Caffrey first reported a case of occupational asthma in an entomologist raising New Mexico range caterpillars, *Hemileuca nevadensis (oliviae)*, in an agricultural research facility in 1918.[11] Caffrey attributed the patient's watery eyes, sneezing, and bronchospasm to mucosal contact with and inhalation of larval urticating spines.[11] In 1982, Etkind and others reported another workplace outbreak of gypsy moth caterpillar-associated dermatitis and occupational asthma in agricultural research workers exposed to the juvenile (first) larval instars of gypsy moth caterpillars.[15]

Massive outbreaks of puss caterpillar (*Megalopyge opercularis)* stings in school age children resulted in several days of springtime public school closings in San Antonio, Texas in 1923, and later in Galveston, Texas in 1951.[16,17] The puss caterpillars were apparently dropping from their preferred food trees, mainly elm, hackberry, oak, pecan, and sycamore, common throughout the southern United States. Typical sting sites included exposed arms, face, head, and, especially the neck behind the shirt collar.[17] Puss caterpillar stings continue to follow this seasonal pattern and distribution of sting sites in the southern United States and Central America.

By the 1980s, multiple epidemics of pruritic rash and occasional urticaria, rarely associated with fever, chills, nausea, vomiting, and diarrhea, were reported from Massachusetts and Rhode Island in 1981, Pennsylvania in 1982, and several other northeastern states in 1983–1984.[7,18–21] These epidemics of gypsy moth dermatitis and urticaria all occurred during the spring of years supporting large populations of first larval instars of gypsy moth caterpillars (*Lymantria dispar*) and were caused by the aerosolization of the urticating hairs and hemolymph of the caterpillars with subsequent human skin and mucosal contact.[7,18–21]

Considered extremely rare in South America until the 1980s, envenoming by the *Lonomia* caterpillars (*L. obliqua* and *L. achelous*) are now creating serious public health threats, especially in southern Brazil.[6,22,23] As noted, multiple envenomings by *Lonomia* caterpillars are common and may be associated with high case fatality rates from acute renal failure and intracerebral hemorrhage. *Lonomia* envenomings are also increasing in frequency in Venezuela and in northern Argentina. As a result of increasing morbidity and mortality following *Lonomia* contacts in South America, scientists in Brazil (*Instituto Butantan*, Sao Paulo) and in Venezuela (*Instituto Venezolano de Investigaciones Cientificas*, Caracas) are rapidly developing and testing antivenoms for *L. obliqua* toxins that have now effectively neutralized *Lonomia* toxins and reversed incoagulability in experimental animal models.[24–26]

In a one-year prospective epidemiologic analysis of 112 caterpillar envenomings in Louisiana, Everson and others reported expert identification of caterpillars in 68% of the cases, localized pain in 96%, erythema in 89%, edema in 72%, and systemic responses in 26%, including paresthesias, muscle spasms, and pain radiating toward proximal lymph node groups.[17] Six caterpillar species were responsible for the majority of stings, the main four of which included *Hemileuca maia*, *Automeris io*, *Megalopyge opercularis*, and *Sibene stimulea*.[17] Although 16% of the patients had a history of atopic allergy, no patients in the allergy subgroup exhibited urticarial or anaphylactic responses to caterpillar stings.[17] Mild to moderate local reactions persisted in most cases, with 61% of the patients experiencing such reactions for at least 24 hours post-exposures.[17]

Some of the more unusual outbreaks of caterpillar-associated illnesses have included an epidemic of 600 cases of caterpillar dermatitis among 6,000 Israeli soldiers in 1959[27] and 10 cases of pediatric caterpillar ingestion in the United States in 1998.[28] In the Israeli experience, soldiers were bivouacking on desert maneuvers during peak larval instar seasons of lymantriid species caterpillars.[27] In the 10 cases of caterpillar ingestion, adverse effects ranged from drooling and dysphagia to diffuse urticaria.[28] Six children were admitted for observation, and five children underwent direct laryngoscopy and bronchoscopy under general anesthesia.[28] None of the 10 patients experienced any chronic adverse outcomes.[28] Although experts did not identify the ingested caterpillars, increased browntail tussock moth caterpillar activity was reported in the vicinities of many ingestions.[28] Like gypsy moth caterpillars, both tussock moth (*Orygia* spp.) and browntail tussock moth (*Euproctis* spp.) caterpillars belong to the family Lymantriidae, and are frequently associated with outbreaks of caterpillar dermatitis, conjunctivitis, and urticaria following contact exposures.

In 2001, Balit and others reported an outbreak of caterpillar dermatitis and conjunctivitis in indoor office workers exposed to aerosolized urticating hairs from Australian browntail moth caterpillars (*E. edwardsii*) feeding communally in a nearby eucalyptus tree.[29] Although several outdoor and indoor agricultural laboratory outbreaks of caterpillar dermatitis have now been reported in association with lymantriid caterpillar exposures (gypsy moth, tussock moth, and browntail moth caterpillars), this was the first documented case of airborne caterpillar hairs causing dermatitis in a non-laboratory, indoor office environment.[29]

In 2003, Maier and others reported an epidemic of airborne caterpillar-associated illnesses in Vienna during regional tree infestations with the third through sixth larval instars of European oak processionary caterpillars (*Thaumetopoea processionea*).[30] Of 1,025 people living within 500 meters of infested oak trees and surveyed by telephone, 96% reported pruritus, 95% dermatitis, 14% conjunctivitis, 14% pharyngitis, and 4% (n = 2) severe respiratory distress.[30] The investigators concluded that such outbreaks of airborne caterpillar-associated illnesses were occurring more frequently in Austria, and that lepidopterism was a more precise description of systemic caterpillar-induced illnesses characterized by not only pruritic dermatitis, but also by mucosal inflammation and upper respiratory distress.[30]

Although not described until 1976, the first outbreak of dendrolimiasis, a migratory polyarthritis following contact with pine caterpillars (*Dendrolimus pini*) probably occurred in Hangzhou, China in 1955 in farmers picking cocoons out of pine firewood.[31] Since then, several outbreaks have been described in several prefectures in central and southern China, including Guangdong, Hubei, Jiangxi, and Zhejiang, with epidemics peaking seasonally, and often annually, in April–May, July–August, and October–November.[32] The mean incubation period for dendrolimiasis following exposure to live or dead caterpillars, their cocoons, or caterpillar-infested firewood is 1–3 days, with a mean patient age of 27 years, and no sex preference.[32]

Syndromic classification of caterpillar-associated illnesses. The syndromic classification of caterpillar envenoming includes the following clinical presentations, some of which may often overlap or combine: 1) erucism, 2) lepidopterism,

3) dendrolimiasis, 4) ophthalmia nodosa, and 5) consumptive coagulopathy with secondary fibrinolysis. Erucism is the preferred term for caterpillar dermatitis characterized by localized, pruritic macupopapular to bullous contact dermatitis and urticaria caused by contact with or airborne exposure to caterpillar urticating hairs, spines, or toxic hemolymph.[33] Conversely, lepidopterism is a systemic illness caused by a constellation of adverse effects resulting from direct or aerosol contact with caterpillar, cocoon, or moth urticating hairs, spines, or body fluids, and is characterized by generalized urticaria, headache, conjunctivitis, pharyngitis, nausea, vomiting, bronchospasm, wheezing, and, rarely, dyspnea.[34] Some caterpillars more commonly cause erucism, such as io moth (*Automeris io*) and saddleback (*Sibene stimulea*) caterpillars, whereas others more commonly cause lepidopterism, principally gypsy (*Lymantria dispar*) and browntail (*Euproctis* spp.) moth caterpillars and a variety of processionary tree caterpillars.

Dendrolimiasis is a chronic form of lepidopterism caused by direct contact with urticating hairs, spines, or hemolymph of living or dead central Asian pine-tree lappet moth caterpillars (*Dendrolimus pini*) or their cocoons.[32] Dendrolimiasis is characterized by urticating maculopapular dermatitis, migratory inflammatory polyarthritis, migratory inflammatory polychondritis, chronic osteoarthritis, and, rarely, acute scleritis.[32,35,36] The pathophysiology of dendrolimiasis is incompletely understood, but the acute phase may result from IgE-mediated allergy and hypersensitivity to foreign proteins, and the chronic bone and joint disease may be autoimmune-mediated.[32,35]

Ophthalmia nodosa is a chronic ocular condition characterized by initial conjunctivitis with subsequent pan-uveitis caused by corneal penetration and subsequent intraocular migration of urticating hairs from lymantriid caterpillars and moths, and therapsid spiders (tarantulas).[37,38] Although intraocular spider hairs in tarantula pet owners cause most current cases of ophthalmia nodosa, Cadera and others initially described ophthalmia nodosa in association with intraocular lymantriid caterpillar hairs.[37]

SPECIFIC CATERPILLAR ENVENOMINGS

Family Lasciocampidae. *Dendrolimus pini (Chinese pine-tree lappet moth caterpillar).* This caterpillar is a hairy, brown to gray-brown, tree-dwelling, communally feeding caterpillar, 2.5–3.5 cm in length, with bands of white scale-like hairs hiding hollow spines along its back or dorsal surface. Although the distribution of pine caterpillars ranges from eastern Europe and northern Africa across central and northern Asia, the caterpillar feeds preferentially on pine needles in the temperate, mountainous (greater than 200 meters above sea level) pine forests of central and southern China. The caterpillars also feed communally within other types of coniferous forests in China, including spruce and fir forests.

Pine caterpillars possess spines or setae that range from 1.0 to 1.6 mm long and cluster dorsally on the second and third thoracic segments, hidden by whitish bands of urticating hairs. Poison glands or, more likely, clusters of toxin-producing epithelial cells occur at the bases of breakaway spines and can release toxic hemolymph from live or even dead caterpillars or their cocoons.[32] Dead caterpillars will actually release more toxic hemolymph than live caterpillars, which release

toxins only from broken spines, or even cocoons, which are lightly armed with spines to frustrate predators.[32] Although live pine caterpillar encounters usually cause transient dermatitis with small joint pain and swelling, dead caterpillar encounters are more often associated with moderate to severe envenoming with chronic bone, joint, and cartilage sequelae possible.[32]

The tegument-produced venom contains formaldehyde and several uncharacterized histamine analogs with a tropism for receptors in bone, joints, and cartilage.[32] Direct contact with urticating hairs and spines of living or dead pine caterpillars or their cocoons may result in dendrolimiasis, a severe form of lepidopterism, characterized by urticating maculopapular dermatitis, migratory inflammatory polyarthritis, migratory inflammatory polychondritis, chronic osteoarthritis, and, rarely, acute scleritis.[32,35,36] Since the1970s, Chinese investigators have reported several outbreaks of dendrolimiasis in central and southern China.[32,35,36]

In 1991, Dezhou described the clinical and radiographic outcomes of 58 patients with dendrolimiasis from an outbreak in the village of Jiashichong, Hubei Province, China.[32] In October 1975, 58 villagers exposed to pine caterpillars while cutting or gathering firewood in the mountains contracted dendrolimiasis, with an attack rate of 9.5%, an age range of 1–67 years, a mean age of 27 years, and no sex preference.[32] The mean incubation period was 1–3 days, and clinical manifestations included urticating, maculopapular dermatitis with small-to-intermediate joint swelling and pain in all patients; fever and chills in 29%; migratory inflammatory polyarthritis in 26%, mostly in the hands (19%), but also in the knees, ankles, and feet; chronic osteoarthritis in 29%, and migratory inflammatory polychondritis in 7%.[32] Although unusual, the polychondritis showed an ordered predilection for articular, costal, auricular, and thyroid cartilages, and was characterized by prolonged pain and swelling in the cartilages involved and in the surrounding soft tissues.[32] The white blood cell count was elevated in all cases with a preponderance of neutrophils.[32]

A summary of key radiographic features in dendrolimiasis included initial solitary swelling of small and intermediate joints and their surrounding soft tissues, epiphyseal separation, osteoporosis near articulating cartilages and tendon insertions, and osteosclerosis with joint ankyloses and soft tissue ossifications possible.[32] In the wake of the outbreak, 29% of the patients recovered within a week without treatment, 59% required treatment with antihistamines and anti-inflammatory agents, and 7% suffered permanent defects including ankyloses of finger joints or deformed auricles.[32]

Treatment of dendrolimiasis remains entirely supportive with early surgical intervention recommended to excise draining sinus tracts and infected cartilage and to prevent permanent bone and joint deformities.[32] Dendrolimiasis remains an increasing public health problem in China, and further morphologic and toxicologic investigations of *Dendrolimus pini* are indicated.[32,35,36]

Family Limacodidae (slug caterpillars). *Sibene stimulea (saddleback caterpillar).* Saddlebacks are the most venomous of the slug caterpillars, and are among the most common stinging caterpillars in North America. The adult caterpillar is brown-red, 2.0–2.5 cm in length, and characterized by several distinctive features including two prominent fleshy horns or filaments studded with spines on each end, shorter armed

horns along both sides, and a bright green dorsal midsection or "blanket" trimmed in white, with a dorsal brown-to-purple central spot or "saddle", also trimmed in white (Figure 1C). Saddlebacks are solitary feeders on many trees and shrubs including apple, basswood, cherry, chestnut, dogwood, elm, maple, oak, plum, and even corn. Caterpillars are most active in the late summer and early fall and are widely distributed throughout North America.

The saddleback sting is immediately painful with proximal radiation to local lymphatic groups, and subsequent localized erythema, edema, and, possibly, later blistering, especially if the urticating spines are not stripped from the sting site. Rings and watches and any constricting jewelry or clothing should be immediately removed in the event of extensive swelling. Without blistering, the localized chemical contact dermatitis will subside within 2–8 hours. Treatment is entirely supportive with immediate washing of the site to remove toxic hemolymph; stripping of the bite site with cellophane or, preferably, adhesive duct tape; application of ice packs with cooling enhanced by topical alcohol or ammonia; topical and oral antihistamines; topical corticosteroids; and oral or intramuscular corticosteroids for prolonged reactions. Recently recommended alternatives to adhesive stripping following the soap and water washing of sting sites include topical applications of rapidly drying clear fingernail polish or lacquer, rubber cement, or commercial facial peel solutions. These solutions should be then be allowed to dry thoroughly, and then carefully peeled off sting sites, carrying embedded urticating hairs or spines. Anaphylactic reactions are rare.

Phobetron pithecium (hag moth caterpillar). The hag moth caterpillar, or monkey slug, is brown to red-brown, 1.5–2.5 cm in length, and covered in hairs, which hide urticating setae (Figure 1G). There are nine pairs of variable-length, fleshy lateral processes or lobes, all armed with setae, along both sides of the caterpillar's body. The third, fifth, and seventh pairs of processes are often elongated and twisted together, resembling the dirty, disheveled locks of an old hag; thus, the colorful, common name for *Phobetron pithecium*. This cater-

FIGURE 1. Some commonly envenoming caterpillar species. **A**, Io moth caterpillar (*Automeris io*); B, puss caterpillar (*Megalopyge opercularis*); **C**, saddleback caterpillar (*Sibine stimulea*); **D**, gypsy moth caterpillar (*Lymantria dispar*); **E**, browntail moth caterpillar (*Euproctis chrysorrhoea*); **F**, South American Saturniid moth caterpillar (*Lonomia obliqua*). **G**, hag moth caterpillar (*Phobetron pithecium*).

pillar is another solitary feeder on the leaf undersurfaces of a variety of trees including apple, ash, birch, chestnut, dogwood, hickory, oak, sassafras, and willow. The caterpillar is widely distributed throughout the eastern and southern United States and is most active in August and September.

Although hag moth caterpillar stings are immediately painful and pruritic, the chemical contact dermatitis resolves rapidly, and prolonged sequelae and anaphylaxis are rare. Treatment is supportive and follows the generally recommended management strategies of stripping off embedded urticating spines and applying cooling icepacks and topical antihistamines and corticosteroids. Although an untested remedy, coating the sting site with a generous application of a paste or plaster made of cold water and powdered baking soda may offer more symptomatic relief than topical antipruritics for hag moth caterpillar stings.

Family Lymantriidae (tussock moth caterpillars). *Lymantria dispar (gypsy moth caterpillar).* The lymantriid or tussock moth caterpillars are all hairy and brightly colored with long urticating hairs on both ends that often form distinctive toothbrush-like tufts or tussocks (Figure 1D). In humans, the urticating hairs of most lymantriid caterpillars may cause severe urticarial dermatitis and conjunctivitis on contact, or wheezing and bronchospasm if inhaled, especially in subjects with prior histories of asthma or atopic allergies.[7,15,20,21] Although gypsy tussock moth and *Euproctis* lymantriid caterpillars cause most cases of caterpillar-associated dermatitis and conjunctivitis each year in the United States, Australia, and Europe, several other tussock moth caterpillars can also cause regional outbreaks of dermatitis and conjunctivitis, including the white-marked tussock or toothbrush caterpillar (*Orygia leucostigma*) in the northeastern United States, and *Orygia pseudotsuga* in the United States and Canadian Pacific Northwest.[7,15,20,21,29,34]

The gypsy moth tussock caterpillar is blue-gray, covered with hairs, 3–5 cm in length, with round, raised bumps or tubercles on each segment (Figure 1D). The dorsal tubercles on the first five segments behind the head are blue, and the dorsal tubercles on the remaining seven segments are red. The side tubercles are yellow, and the mature caterpillars have a dorsal yellow stripe and two white side stripes. Although native to Europe, North Africa, and temperate Asia, gypsy moth caterpillars were intentionally introduced into the New England states in 1868–1869 to initiate a failed silk industry, and have become much more serious agricultural pests in the United States than in their native regions, often defoliating huge tracks of temperate, deciduous forests.[7] Although demonstrating a preference for oak trees, gypsy moth caterpillars will feed communally on most trees and shrubs, including apple, cherry, and willow. Gypsy moth caterpillars will often drop from trees spider-like on long silk threads and then balloon on the wind to adjacent trees.

Allen and others have described gypsy moth caterpillar dermatitis as an acute pruritic, papular, urticarial eruption on exposed skin that occurs most commonly after contact with first larval instars of gypsy moth caterpillars.[39] Systemic manifestations of gypsy moth caterpillar envenoming may include conjunctivitis, allergic rhinitis, sneezing, upper airway hyperreactivity, wheezing and bronchospasm, especially in victims with histories of asthma or atopic allergies.[15] In 1982, Etkind and others reported an outbreak of gypsy moth-associated dermatitis and pulmonary reaction in 17 workers in an agri-
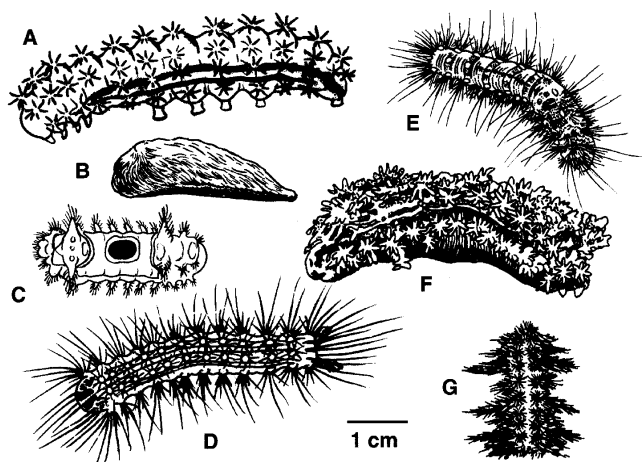
cultural research station studying gypsy moth tree infestations.[15] Of the study subjects, 70% gave histories of occupational asthma or atopic allergy.[15] Unlike limited workplace outbreaks, massive outbreaks of gypsy moth dermatitis with pulmonary reactions have now been reported in the northeast United States in the 1980s, and risk factors have included pre-existing asthma and hay fever histories and hanging washed clothing outside to dry.[15,20,21] Although the pathogenesis of gypsy moth erucism and lepidopterism has not been clearly elucidated, the mechanism probably involves local and pulmonary histamine release and delayed hypersensitivity reactions in susceptible victims. Treatment is supportive with topical and parenteral antihistamines, oral or parenteral corticosteroids, and bronchodilators, as indicated, for bronchospasm.

Euproctis species caterpillars (browntail moth caterpillars). The hairy browntail moth caterpillars of the genus *Euproctis* are distributed worldwide, and possess highly allergenic, barbed urticating hairs, that can cause erucism on contact or lepidopterism via inhalation of aerosolized hairs. *Euproctis chrysorrhoea* was introduced into the eastern United States from Europe and is widespread throughout Europe, including the United Kingdom, extending south into north Africa and the Canary Islands. It is a hairy brown caterpillar, 2–3 cm in length, with distinctive dorsal red spots, and white scale-like hairs on its sides (Figure 1E). *Euproctis chrysorrhoea* lives in communal silken nests feeding on blackthorn and hawthorn ornamental shrubs and on most fruit and ornamental trees. The Australian mistletoe browntail moth caterpillar (*E. edwardsii*) is found from Queensland and New South Wales to Victoria and southern Australia. It is a hairy, red-brown caterpillar, 2–3 cm in length, with a distinctive white stripe down its back. Like all *Euproctis* species, *E. edwardsii* caterpillars live in silken nests and feed communally on the leaves of mistletoe, a parasitic shrub of the tree canopy, and eucalyptus trees. In 2001, Balit and others reported an outbreak of caterpillar dermatitis in indoor office workers exposed to aerosolized urticating hairs from Australian mistletoe browntail moth caterpillars (*E. edwardsii*) feeding communally in a nearby eucalyptus tree.[29]

Euproctis caterpillars frequently cause outbreaks of dermatitis and allergic bronchitis following exposures to urticating hairs or to aerosols containing urticating hairs, especially in the eastern United States, western Europe, and Japan (*E. subflava*). In 1991, Werno and Lamy demonstrated a nighttime cycle of airborne urticating hair release in France by *E. chrysorrhoea* caterpillars by collecting the aerosolized hairs in pollen-collecting devices.[40]

Euproctis chrysorrhoea and *E. subflava*, both contain proteases and phospholipase A (PLA), but PLA activity is 50–100 times greater in *E. chrysorrhoea* venom than in *E. subflava* venom.[41] Venom extracts of *E. chrysorrhoea*, a common cause of caterpillar dermatitis and allergy in the United States and Europe, also contain arginine ester hydrolase.[40,41] In addition to reduced PLA activity compared with *E. chrysorrhoea*, venom extracts from hairs and setae of the less reactive browntail moth caterpillar (*E. subflava*) contain tyrosine ester hydrolase.[41]

The treatment of both browntail tussock moth-induced erucism and lepidopterism is entirely symptomatic and supportive with antipruritics, anti-inflammatory agents, and nebu-

lized and parenteral bronchodilators, as indicated, for asthmatic bronchitis.[29,41]

Family Megalopyridae (flannel moth caterpillars). *Megalopyge opercularis (puss caterpillar).* The flannel moth caterpillars are widely distributed throughout the New World and inflict neuropathically painful stings, often during seasonal outbreaks in the late summer or early fall in temperate regions and during both spring and fall in tropical regions that support two larval generations per year. Although there are many species of venomous *Megalopyge* caterpillars, *Megalopyge opercularis* is the most widely distributed and carefully studied species in the United States and Latin America. The puss caterpillar, or wooly slug ("*el perrito*" or "little dog" in Central and South America), is dirty white to gray-yellow or brown, 2.5–3.5 cm in length, tear or pear-shaped, and covered in fluffy hairs that taper into hairy ponytails hiding dorsal breakaway spines (Figure 1B). On contact, the breakaway, hollow spines release toxic venom with uncharacterized proteolytic components. Puss caterpillars feed communally on many trees and shrubs including apple, elm, hackberry, maple, pecan, oak, sycamore, and most citrus trees. Their stings may be multiple as caterpillars fall from trees and lodge in clothing, particularly shirt collars.

As noted, outbreaks of puss caterpillar stings in school children in the United States have forced public school closings in Texas in 1923 and again in 1951.[16] In the southern United States, schoolchildren, walkers, and joggers are at greatest risk of puss caterpillar stings for several reasons including seeking cooler, tree-shaded outdoor recreation areas during warmer fall and spring months that coincide with peak larval instar seasons; not covering their heads when outdoors; and often wearing sleeveless, loose-fitting clothing that either expose bare skin, or trap tree-falling caterpillars or their urticating hairs.[16,17] In addition, rapidly growing trees, particularly elm, maple, oak, and sycamore, all puss caterpillar favorites, are often preferentially planted to landscape thoroughfares, parks, and schoolyards.

Like saddleback moth caterpillar stings, puss caterpillar stings are instantaneously painful and quickly followed by localized edema, erythema, and pain radiating proximally toward regional lymph nodes. To relieve pain, victims commonly hold affected extremities completely still in a reflex pseudoparalysis.[42] The descending order of the most common sites of puss caterpillar envenoming include the hand, foot, arm, finger, leg, and abdomen.[17] Although no deaths have been reported, systemic manifestations of puss caterpillar stings may occur and include headache, fever, nausea, vomiting, tachycardia, hypotension, seizures, and, rarely, acute abdominal pain, and myospasm mimicking acute appendicitis or latrodectism.[43,44] Following the initial sting with radiating, often allodynic, pain, the puss caterpillar sting site develops into a distinct lesion surrounded by an erythematous halo with an inner footprint or grid-like pattern reflecting each broken-spine hypodermic injection point.[43,44] The individual puncture sites often become hemorrhagic and vesicular, and may later become pustular and coalesce into large bullous lesions.[43–45] Treatment is supportive and includes adhesive stripping of retained broken spines, topical and systemic antihistamines, and parenteral corticosteroids for severe, prolonged reactions.[43–45] Subcutaneous epinephrine may be indicated for anaphylactic reactions with peripheral vasodilation and hypotension.[43] Intravenous calcium gluconate, 10

mL of a 10% solution, has provided dramatic relief of acute abdominal pain and myospasm associated with puss caterpillar stings.[16,44]

Family Saturniidae (giant silkworms). *Automeris io (io moth caterpillar).* This caterpillar is pale yellow-green, 5–6 cm in length, with red true legs and prolegs (Figure 1A). There is a broad white stripe on either side, bordered above by a similar red stripe, and below by a thinner, and often broken, red-purple line. Raised tubercles or scoli, each armed with a whorl of black-tipped green spines, occur on each dorsal segment of the back. Io moth caterpillars are widely distributed throughout North America and range from southern Canada, throughout the United States, and south to Mexico.

Although the io moth caterpillar sting is immediately painful and pruritic, the contact urticarial dermatitis resolves rapidly, and prolonged systemic sequelae and anaphylaxis are rare. Treatment is supportive and follows the generally recommended management strategies of stripping embedded urticating spines and topically applying cooling icepacks, antihistamines, and corticosteroids. Since *Automeris io* is a solitary feeder and not a serious threat to agriculture or human health, the mechanisms of production of io moth caterpillar venom and the characteristics of its toxic components have not been fully characterized.

Hemileuca maia (buck moth caterpillar). The buck moth caterpillar, so named because the moth appears in the fall during the buck or male deer-hunting season, is a large caterpillar, 5.25–6.0 cm in length, with a sting similar to that of the saddleback caterpillar. Like all *Hemileuca* caterpillars, the buck moth caterpillar bears rows of breakaway, urticating spines down its back and sides. The head is dark red-brown, and the body is gray-brown to black and sprinkled with white to yellow dots. There is a double row of tan-orange tufts of spines down the back, and rows of larger, longer, bristled red to black spines along both sides. The buck moth caterpillar is a solitary feeder with a preference for oak trees, but will also feed on cherry, willow, and other deciduous trees. It is distributed throughout the southeastern and southwestern United States and into northern Mexico.

Like the saddleback caterpillar sting, the buck moth caterpillar sting is immediately painful with proximal radiation to regional lymphatic groups, and subsequent localized erythema and edema. Welts raised on the skin may remain visible for 24–48 hours to more than a week. Therefore, rings and watches and any constricting jewelry or clothing should be immediately removed in the event of extensive, prolonged swelling. The localized chemical contact dermatitis will subside within 2–8 hours, and other than significant localized swelling, systemic reactions and anaphylaxis are rare. Treatment is entirely supportive and follows the generally recommended management strategies of stripping embedded urticating spines and applying cooling icepacks and topical antihistamines and corticosteroids.

South American Lonomia caterpillars. The South American *Lonomia* saturniid moth caterpillars (*L. achelous* and *L. obliqua*) are large, communally feeding caterpillars that range in length from 4.5 to 5.5 cm, and sport a variety of camouflage colors, primarily shades of green and brown (Figure 1F). *Lonomia* caterpillars are covered with rows of raised tubercles or scoli, all crowned with whorls of breakaway spines (Figure 1F). They range from Venezuela to northern Argentina, and now pose a serious public health threat in Brazil, due to high case fatality rates from venom-induced consumptive coagulopathy, intracerebral hemorrhage, and acute renal failure, possibly due to a combination of venom nephrotoxicity and microcirculatory fibrin deposition.[6,46]

Veiga and others have studied the structures involved in the production, secretion, and injection of *Lonomia* venom by *L. obliqua* caterpillars in Brazil.[4] Their microscopic and histochemical investigations demonstrated that 1) *L. obliqua* has a very complex tegument with several cuticular specializations; 2) there are no pores in the tegument or spines for venom to enter or exit the urticating spines; 3) all of the spines have hollow internal canals with weak articulations at their tips, which break off on light contact to release toxic venom; 4) the venom is produced by secretory epithelial cells and pumped into the hollow spines, which are actually evaginations of the epithelial tegument; and 5) the venom is stored in the subcuticular space and at the tips of the breakaway spines.[4]

As noted, venom extracts from the hairs, spines, and hemolymph of the South American *Lonomia* caterpillars (*L. achelous* and *L. obliqua*) contain fibrinolytic proteases and clotting activators that can cause consumptive coagulopathies, intracerebral hemorrhage, and acute renal failure, following caterpillar contact.[4] The main venom component of *Lonomia* caterpillars is a proteolytic enzyme, lonomin V, which has been isolated from the hairs, spine, and hemolymph of *L. achelous*.[14] In experimental investigations in rabbits, Guerrero and colleagues demonstrated that lonomin V was a proteolytic inactivator of platelet factor XIII and a potent activator of both factor X and prothrombin.[14] These investigators recommended further study of lonomin V as a potential new human thrombolytic agent for preventing rethrombosis following coronary angioplasty and stenting.[14]

In 1998, Donato and others confirmed that crude extracts from spines of *L. obliqua* activated both factor X and prothrombin, but did not activate platelets.[47] Subsequent clinical investigations of hemorrhagic syndromes following contact with *L. obliqua* caterpillars have confirmed activation of the clotting cascade, significant reduction in platelet factor XIII activity, and secondary fibrinolysis, with normal platelet counts.[48] In their *in vitro* hemostasis investigation, Donato and others prevented clotting activation following *L. obliqua* spine extract exposures with the freshwater leech thrombolytic toxin, hirudin, and suggested that hirudin could be beneficial in emergency treatment of patients envenomed by *L. obliqua* caterpillars.[47]

Since *Lonomia* caterpillars are communal feeders, caterpillar contacts often result in multiple venom exposures with high case fatality rates. The initial clinical manifestations of *Lonomia* envenoming include immediate burning pain at the contact site, followed rapidly by localized sting-site ecchymoses and bleeding, spontaneous bleeding from the mucous membranes, epistaxis, hematemesis, melena, hematuria, and oliguria.[49] Without emergency treatment, victims may die rapidly of acute intracerebral hemorrhage or develop acute renal failure.[49] Pregnant victims may be at greater risks of consumption coagulopathy and renal failure.[49] In 1998, Fan and others reported a case of premature labor and delivery, disseminated intravascular coagulation, secondary fibrinolysis, and acute renal failure in a 37-week pregnant woman after contact with *L. obliqua* caterpillars.[49]

The treatment of *Lonomia* envenoming must be immediate and includes restoration of clotting factors with plasma, whole blood, platelet, and cryoprecipate infusions, during continuous monitoring of clotting status by thromboelastography and activated clotting times. Nevertheless, procoagulant replacement therapy for *Lonomia* envenoming is often ineffective. In addition, antifibrinolytic therapy should be instituted. Since lonomin V is an inhibitor of platelet factor XIII and an activator of intravascular clotting, aspirin-containing medications are contraindicated in potential *Lonomia* envenomings.[14]

As noted, Donato and others have demonstrated that hirudin prevented *L. obliqua* venom-initiated clot formation *in vitro*, and suggested that the leech anticoagulant might reverse the consumption coagulopathy initiated by *Lonomia* envenoming in humans.[47] Brazilian investigators have now developed an equine, experimental Fab-fragment antivenom against the venom of *L. obliqua* caterpillars that has neutralized *Lonomia* venom-induced coagulopathies in mouse and rat models.[24,25] Since clotting factor replacement therapy may exacerbate consumptive coagulopathy following *Lonomia* envenoming by supplying procoagulant substrates and not inactivating lonomin V, new treatment strategies, such as hirudin and a safe and effective *Lonomia* antivenom, are needed.

Family Notodontidae, Subfamily Thaumetopoeidae (processionary caterpillars). *Processionary tree caterpillars.* Processionary tree caterpillars, including the European *Thaumatopoea* caterpillars and the Australian *Ochrogaster lunifer*, are all dark, gray-black caterpillars with slightly raised dark red to brown tubercles and fine hairs varying from white (*T. pityocampa*) to black (*O. lunifer*). The European pine processionary caterpillar (*T. pityocampa*) is found in all Mediterranean countries, including those of north Africa. The European oak processionary caterpillar (*T. processionea*) has a wider distribution and ranges from northern Europe to north Africa. The American pine processionary caterpillar (*T. wilkinsonii*) ranges from southern Canada to Mexico, and is an unusual cause of ophthalmia nodosa and blepharoconjunctivitis in the United States.[50] The Australian processionary caterpillars include coastal ground-dwelling *Ochrogaster* species that feed on *Acacia* species shrubs, and inland canopy-nesting *Ochrogaster* species that feed on *Acacia* and *Eucalyptus* trees.

Processionary caterpillars frequently cause outbreaks of caterpillar dermatitis, ophthalmia nodosa, and allergic reactions following exposures to their urticating hairs or aerosols containing hairs, especially in Australia, Europe Japan, and the United States. Venom extracts from the hairs and spines of the European pine processionary caterpillar (*T. pityocampa*) contain a 28-kD IgE-binding protein toxin, thaumetopoein, that is a potent skin irritant and systemic histamine and kinin releaser.[51,52] Recently, Moneo and others in Madrid isolated a 15-kD IgE-binding protein in crude larval extracts from *T. pityocampa* that may be a subunit protein of thaumetopoein.[53]

Treatment of processionary caterpillar envenoming is entirely supportive and follows generally recommended management strategies of washing loose urticating hairs off the skin, stripping off skin-embedded urticating hairs, and applying cooling icepacks and topical antihistamines and corticosteroids. Nebulized and parenteral bronchodilators may be indicated for asthmatic bronchitis with bronchospasm and wheezing following exposures to aerosols containing urticating hairs from processionary caterpillars.

As noted, ophthalmia nodosa is a chronic ocular condition characterized by initial conjunctivitis with subsequent panuveitis caused by corneal penetration and subsequent intraocular migration of urticating hairs from lymantriid caterpillars and moths, processionary caterpillars, and therapsid spiders (tarantulas).[37,38,54–56] It may be complicated by chorioretinitis, corneal granulomas, cataracts, glaucoma, and reduced visual acuity, and should always be managed by an ophthalmologist.[38]

All superficially embedded urticating hairs, that can be identified by magnification of skin sting sites or slit-lamp examination of the eyes, should be removed if possible, and topical or systemic antihistamines and corticosteroids should be prescribed for pruritus from allergic response to fragmented and remaining dermal and conjunctival urticating hairs.[37,38,54–56] Prolonged topical ophthalmic corticosteroid therapy, rather than corneal excision, is often indicated for ophthalmia nodosa due to ocular-embedded caterpillar and tarantula urticating hairs.[38,56] Patients recovering from urticating hair-induced ophthalmia nodosa should be followed by an ophthalmologist with periodic slit lamp examinations and visual acuity and intraocular pressure measurements.[38,56]

General management of caterpillar envenoming. The general management of most caterpillar stings is entirely supportive and includes 1) immediate soap-and-water washing of the sting site to remove toxic hemolymph and any loose urticating hairs; 2) "no touch" drying of the sting site with a hair dryer, not a towel; 3) gentle stripping of the bite site with cellophane or, preferably, adhesive duct tape; 4) application of ice packs with cooling enhanced by initial topical swabbing with isopropyl alcohol or ammonia; 5) topical and oral antihistamines; 6) topical and oral corticosteroids; and 7) oral or intramuscular antihistamines and corticosteroids, if indicated for prolonged, allergic reactions.

Recently recommended alternatives to adhesive stripping of urticating hairs and spines following soap and water washing of sting sites include topical applications of rapidly drying clear fingernail polish or lacquer, rubber cement, or commercial facial peel solutions or impregnated tapes. These solutions should then be allowed to dry thoroughly under a hair dryer, and then carefully peeled off sting sites, effectively excavating embedded urticating hairs or spines. Rings and all constricting bands from watches and jewelry or clothing with elastic bands must be removed immediately following caterpillar contact in anticipation of potentially extreme swelling and lymphedema, especially with hag moth and puss caterpillar stings of distal extremities. Tetanus prophylaxis should be administered if indicated.

The treatment of lepidopterism is also entirely symptomatic and supportive with oral and intramuscular antipruritics and anti-inflammatory agents, including antihistamines and corticosteroids. Nebulized and parenteral bronchodilators may be indicated for asthmatic bronchitis with bronchospasm and wheezing following exposures to aerosols containing urticating hairs from gypsy moth and processionary caterpillars. As noted, treatment of *Lonomia* envenoming must be immediate and includes antifibrinolytic therapy and restoration of clotting factors with plasma, whole blood, platelet, and cryoprecipate infusions. Experimental treatments of *Lonomia* envenoming with hirudin and with new equine vaccines have not been tested in controlled trials in humans.[14,47]

Ophthalmia nodosa with subsequent pan-uveitis caused by corneal penetration and subsequent intraocular migration of urticating hairs from lymantriid and processionary caterpillars should be managed exclusively by ophthalmologists for initial assessment and all follow-up care, both of which may include surgical management.[37,38,56]

Management of unknown caterpillar envenoming. The management of unknown caterpillar envenoming should include all general management strategies, as well as a careful search for the distinctive syndromic features of certain stings, which could identify envenoming species, direct specific treatments, and offer reliable prognoses. Such distinctive features include 1) the reflex pseudoparalysis, grid-like spine marks, and abdominal pain and myospasms from puss caterpillar stings; 2) the migratory polyarthritis and polychondritis of dendrolimiasis; 3) the allergic conjunctival and upper airway manifestations of lepidopterism from gypsy moth, browntail moth, and processionary tree caterpillar exposures; 4) the persistent raised welts from buck moth caterpillar stings; and 5) the local and mucosal ecchymoses and bleeding following *Lonomia* encounters.

Prevention of caterpillar envenoming. As individuals spend more leisure time outdoors, there will be more opportunities for human-caterpillar contacts and envenomings. Most venomous caterpillars are brightly colored and formidable in appearance, reflecting clear warnings to potential predators. Many harmless caterpillars, however, also effectively use colorful protective mimicry to hide from or confuse predators. If one sees or encounters brightly colored, hairy or tufted caterpillars feeding on the leaves of trees or shrubs, one should avoid unnecessary contact, including attempting to touch, slap, or squash caterpillars. If one finds an un-welcomed caterpillar on oneself, do not flick, brush, slap, or squash the caterpillar with either a bare or gloved hand, or even a rolled newspaper. Such violent maneuvers could easily trap urticating hairs, spines, or hemolymph in clothing, hair, or skin, for later envenoming, or disseminate them as aerosols, to be inhaled or lodged in the eyes. Never rub or massage a potential caterpillar sting site, which could serve to further embed urticating hairs and spines into the skin or clothes or spread hemolymph over the skin, increasing venom exposures. Always use a stick or pencil or other long, thin object to gently lift the caterpillar off your skin or clothing.

During peak larval instar seasons of tree canopy-dwelling, communally-feeding caterpillars, such as gypsy moth and processionary caterpillars, close all exterior windows and doors, and do not hang wet clothes outside to dry and to trap aerosols of urticating hairs and spines. While indoors, rely on central air-conditioning, heating, and circulation systems with adequate filtration of fresh air intake, and increased air exchanges per minute per cubic meter of interior space to avoid potential inside air re-circulation of outside aerosols. Such aerosols may contain the urticating hairs, spines, or hemolymph of allergenic and venomous caterpillars, feeding in the natural environment, or on common outdoor ornamental trees, including eucalyptus, oak, maple, and pine trees.

When pruning all shrubs and trees, individuals should wear long sleeves and pants with pant cuffs tucked into socks or boots and shirt sleeves tucked into gloves, especially during peak larval instar seasons of late spring through early fall. Since many caterpillars will become butterflies (not moths) and important agricultural and ornamental plant pollinators, do not attempt to use pesticides for caterpillar control without consulting local entomologists and plant pathologists. For significant agricultural pests, such as communally-feeding gypsy moth and processionary tree caterpillars, tree pruning and biologic insect control with products containing larvicidal *Bacillus thuringiensis* or larvicidal viruses are preferred to mass pesticide spraying. If mass pesticide-spraying operations are indicated to protect commercial forests and orchards, local insect control authorities should direct and conduct such mass operations. Caterpillars appear to be more sensitive to safer carbamate, organophosphate insecticides than to non-carbamate organophosphates, and non-biodegradable organochlorines. Since caterpillars are exclusive plant feeders, they are relatively resistant to chrysanthemum-derived pyrethrin and synthetic pyrethroid pesticides.

Finally, consider all caterpillars venomous and avoid unnecessary contact with living or dead caterpillars, or even their squashed external or internal contents and their cocoons. Many brightly colored caterpillars will mature into butterflies and not moths, and even expert entomologists and plant pathologists may have difficulty in differentiating stinging from harmless caterpillars.

CONCLUSIONS

Caterpillar species from about 12 families of moths and, rarely, butterflies worldwide can inflict serious human injuries ranging from urticarial dermatitis and atopic asthma to osteochondritis, consumption coagulopathy, renal failure, and intracerebral hemorrhage. Unlike bees and wasps, the envenoming or "stinging" caterpillars do not possess "stingers" or modified ovipositors attached to venom glands, but instead secrete toxic hemolymph from their teguments, and bear highly specialized external nettling or urticating hairs and breakaway spines or setae to defend against attacks by predators and enemies. Since the 1970s, there have been an increasing number of reports of mass dermatolgic, pulmonary, and systemic reactions following direct caterpillar encounters and indirect exposures to aerosols containing toxic caterpillar hairs, spines, or hemolymph throughout the world. Most caterpillar exposures can be prevented by simple personal protective and domestic measures taken during peak larval instar seasons.

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