INTRODUCTION

The order Hymenoptera includes the bees, ants, and a diverse array of groups we commonly think of as "wasps." As most people were aware, many Hymenoptera can and do sting. In this chapter I will address the question of the hymenopteran sting. What is it? Which Hymenoptera sting? How does it cause pain? Is it dangerous? How can we avoid stings and treat those we do receive? Particularly important considerations are these human factors: how people relate to stinging Hymenoptera and envenomation (venom injection), and how the problem of envenomation can be approached in a rational and optimal fashion.

Traditionally, stinging insects have been considered primarily a rural problem and not especially important in the urban environment. However, since suburban lifestyles complete with lawns, greenery and gardens are becoming a norm of American living, this is no longer true. Many stinging insects thrive among trees, shrubs, lawns and gardens and nest on, in, and near human dwellings surrounded by these environments. Moreover, outdoor parks and recreational areas frequently abound in stinging Hymenoptera. The purpose of this chapter is to place the urban problem of stinging Hymenoptera in perspective and to describe how entomology and recent developments in medical knowledge can help reduce the dangers from these insects.

TAXONOMY OF STINGING INSECTS

Part of the problem in dealing with stinging Hymenoptera is a lack of appreciation of their biology, behavior, and taxonomy. If for no other
reasons than for proper medical treatment and prophylactic measures to avoid them, a knowledge of their names and classification is of paramount importance. These insects usually have one or more common names which can be useful for species identification in the absence of proper scientific names. Unfortunately, scientific and common nomenclature to describe stinging hymenopterans is in veritable disarray, mainly because these species not only sting but are also large, common, and attractive. Thus, entomologists and numerous amateurs and medical personnel have become interested in these insects and have given them their own labels. A brief explanation here will clarify the situation. The term "bee" is generally used for the honey bee, *Apis mellifera* L., though in actual fact it also refers to any of the Apoidea including sweat bees (Halictidae), carpenter bees (Anthophoridae), bumble bees (Apidae), and others. "Ant" refers to any species in the Formicidae, though a few antlike wasps are often called velvet ants (Mutillidae). Social wasps in the family Vespidae are frequently called wasps, yellowjackets or hornets. Technically, they are all wasps, a designation they share with numerous families of solitary Hymenoptera; unfortunately, such a designation is of little help in identifying a particular species or genus. Figure 9.1 is a phylogeny in which the major stinging social wasps of North America are associated with their common and scientific names.

A few comments concerning common names other than those in Figure 9.1 are appropriate. In the medical literature, yellowjackets of the genus *Dolichovespula* are frequently (and inappropriately) called aerial hornets: *D. arenaria* (Fab.) is improperly called the yellow hornet, and *D. maculata* (L.) the white faced hornet (e.g., Hunt et al., 1978b). In the past, *D. maculata* has been identified by numerous other common names including the bald hornet, the black hornet, the white tailed hornet, and so forth. Yellowish species of *Polistes* have (unfortunately) sometimes been called yellowjackets in the southwest. For an excellent discussion of social wasp common names and the associated problems with these names, the reader is referred to Greene and Caron (1980).

The designation of generic names among the Vespinae has been subject to numerous revisions (see Edwards, 1980 for discussions) and remains uncertain today (Yamane et al., 1980). For this reason, the author has adopted the simplified system of designating the *Vespula "vulgaris"* group (Bequaert, 1931) of yellowjackets as the genus *Paravespula*, and Bequaert's (1930) subgenus *Vespula* including *Vespula "rufa"* group (Bequaert, 1931) as the genus *Vespula*. (This genus also appears to be divided into two groups, but a discussion of this topic is not appropriate here.) This system may not represent a natural phylogeny, but until more detailed information is available, it is probably the most simple and straightforward system to use. For further information concerning the taxonomy of the Vespinae, see Akre et al. (1981), Edwards (1980), Yamane et al. (1980), Jacobson et al. (1978); and for taxonomy of the Polistinae, see Richards (1978). The Polistinae are
FIGURE 9.1: Social Wasps North of Mexico Known to be a Stinging Problem.

Family | Subfamily | Genus | Correct Common Names | Species | Approved Common Name
--- | --- | --- | --- | --- | ---
Vespidae (Social Wasps) | Vespinae | Vespa | hornets | V. crabro | European hornet
| Dolichovespula | yellowjackets and the baldfaced hornet | D. maculata | baldfaced hornet
| | | D. arenaria | aerial yellowjacket
| Paravespula | yellowjackets | P. vulgaris | common yellowjacket
| | | P. maculifrons | eastern yellowjacket
| | | P. pensylvanica | western yellowjacket
| | | P. germanica | German yellowjacket
| | | P. flavopilosa | no reasonable common name
| Vespidae | Vespula | yellowjackets | V. squamosa | southern yellowjacket
| | | V. atropilosa | prairie yellowjacket
| Polistinae | Polistes | paper wasps | P. exclamans |
| | | P. annularis |
| | | P. fuscatus |
| | | P. apachus |
| | | + = 15 Other species |
| | Mischocyturus | no common name | 2 Unobtrusive species |
much more poorly defined than the Vespinae and, hence, many designations for North American *Polistes* are best considered as tentative.

**STINGING BEHAVIOR OF HYMENOPTERA: GENERAL CONSIDERATIONS**

One basic difference between Hymenoptera and most other insects is the ability of Hymenoptera to sting. This ability appears to be the result of evolution of the sting apparatus—a modified ovipositor—through roles of egg laying and paralysis of prey (via venom, a modified accessory gland secretion) to roles of defense against predators. Better defense against large predators appears to have been essential in the evolution of sociality, in which many individuals and their helpless, usually immobile, progeny live together (Starr, 1981). Without effective defenses such as the sting, a group of more or less defenseless social Hymenoptera would prove to be an enormous food source for any large predator. Thus, the primary role of the sting in the majority of social Hymenoptera is defense. Is it any wonder then that social Hymenoptera can inflict painful stings?

**Behavior and Biology of Stinging Hymenoptera**

An incredible diversity of behaviors and biologies is displayed among the species of stinging Hymenoptera. Excellent in-depth discussions of the different groups including honey bees and other bees (Krombein, 1967; Michener, 1974), social wasps (Spradbery, 1973; Davis, 1978; Akre and Davis, 1978; Edwards, 1980), ants (Wheeler, 1910; Wilson, 1971), and solitary wasps (Fabre, 1921; Evans, 1966a, b; Evans and Eberhard, 1970) are available and should be consulted for detail.

Hymenoptera known to envenomate humans include mutillid, tiphid, and bethylid wasps, spider wasps, solitary bees (including sweat bees and carpenter bees), bumble bees, honey bees, yellowjackets and hornets, paper wasps, and ants. Others, such as large ichneumonid and scoliid wasps, though perhaps capable of stinging humans, almost never do except in rare cases involving entomologists who work with particular species. Other insects (Schmidt, 1982) plus a variety of spiders, scorpions, and centipedes (Bettini, 1978) as well as various vertebrates ( Bücherl and Buckley, 1971) can also envenomate humans, though they are not discussed here.

Mutillid, bethylid, and tiphid wasps are solitary, often wingless wasps that may superficially resemble ants. Females in these families run rapidly, are heavily sclerotized, and can deliver painful stings. Fortunately, because these wasps are solitary and only infrequently encountered, humans are only rarely envenomated. However, when stung the resulting pain is inordinately severe for their small size. In fact, the pain following envenomation by
mutillid wasps is so great that they have been given the common names "cow killers," "velvet ants," and so forth. In general, members of all three families are most prevalent in drier, more open areas and are usually active only when temperatures exceed 20° C. Excluding pain, swelling, and hysterical reactions in some emotionally labile people, no adverse results of envenomation have been reported. Indeed, envenomations are so rare that the repeated episodes necessary to induce allergic reactions are highly improbable. Moreover, the venom of at least mutillid wasps, though algogenic (exceedingly painful), is not particularly toxic to mammals (Schmidt et al., 1980).

Spider wasps (Pompilidae) are solitary active wasps frequently seen in midsummer flying near ground level or in vegetation. They are readily recognized by their often blue, metallic, or reddish sheen, and by characteristic flicking or jerking movements of their wings. Conspicuous coloration and wing flicking behavior are aposematic warnings to potential predators. Their sting is exceedingly painful (in my experience greater than any other temperate North American hymenopteran) but is of relatively short duration and induces only minimal redness or swelling. The venom is not especially toxic to mammals; the LD₅₀ to mice of venom of the tarantula hawk (Pepsis c. chrysothemis Lucas) is greater than 60 mg/kg (0 of 4 died), and the envenomed mice exhibited no life-threatening symptoms. When injected intraperitoneally, this venom dose per mouse is greater than that available in the entire venom reservoir of one P. chrysothemis (Schmidt, unpublished data). Other than by intentionally capturing these insects, the risk of human envenomation is almost nonexistent because spider wasps have no colonies to defend and make efforts only to escape.

Solitary bees are a large and diversified group of Hymenoptera which range from a few mm to over 3 cm in length and occur in a variety of shapes and colors. Most are pollen and nectar feeders and hence are frequently found near or on flowers. They are generally diurnally active during all seasons except winter. Most will sting when captured or trapped and stings usually produce a sharp pain. Most human envenomations result from "sweat bees" of the subfamily Halictinae, especially Dialictus, having been pinched between folds of skin, or between skin and clothing, while they are collecting human sweat. The large black carpenter bees (Xylocopa) can sting painfully but will not attack humans. Their nest sites are often located in wooden timbers of houses and structures, and their mating territories are often around large bushes or flowering shrubs near nesting areas. In spite of the impressive flight and buzzing of competing males around mating territories and the activity of females around nest sites, these bees are not a threat and will sting only if captured and held.

In the desert areas of the U.S. Southwest and in California, huge aggregations of solitary anthophorid bees (Anthophora, Diadasia, Centris) numbering as great as 80,000 for Diadasia r. rinconis Cockerell are sometimes observed (S. L. Buchmann and J. O. Schmidt, unpublished). Nevertheless,
these impressive insects are harmless. Of the solitary bees, the sweat bees pose the main threat to human health; this threat is undoubtedly far greater in terms of potential for allergic reaction than is indicated by the limited data (13 confirmed cases over several years; H. L. Pence, personal communication).

Bumble bees are easily recognized and identified. They have an annual life cycle, live in small colonies often located in old rodent nests under logs, boards, rocks, porches, and so forth and number from 20 to several hundred individuals. Since a solitary queen founds each colony, bumble bees become numerous only in the mid and late summer. Human envenomations occur when a nest is disturbed or a bee becomes entangled in clothing.

The vast majority of human envenomations are a result of honey bees, yellowjackets, bald faced hornets, paper wasps, and ants. Honey bees live in large colonies numbering from 10,000 to 60,000 individuals and are found in man-made hives, hollow trees, between walls of buildings, and in warmer climates inside rock crevices and sometimes hanging freely in protected trees or shrubs. Large clusters of bees often seen hanging from branches or parts of buildings are reproductive swarms and usually are unaggressive.

Since honey bees need nectar, pollen and water for survival, they frequently make contact with humans. Stings usually occur when people inadvertently disturb colonies but also occur when bees foraging on flowers or at water sources are stepped or sat upon, when they become entangled in hair or clothing, or when people strike at them. This last cause is very important and is an unnecessary cause of stinging; scout bees often investigate new objects such as people. However, solitary foraging bees (or yellowjackets) rarely sting—they generally try to escape if confronted. The best solution is to "freeze" and to wait for the bee to leave. If numerous bees are flying about the person, or if he is near a colony, a slow calm retreat is in order.

Yellowjackets and the bald faced hornet are a much greater stinging threat in many areas than are honey bees. These areas include the cooler areas of the Northeast and Northwest as well as the Appalachian area of the East and Southeast. Yellowjackets build nests that may be subterranean, at ground level, in trees and shrubs, on buildings, or inside walls of buildings and houses. *Paravespula germanica* (Fab.) is especially known for building inside walls (Morse et al., 1977).)

Yellowjackets have a life cycle strikingly different from that of honey bees. The annual cycle starts in the spring with a solitary queen that constructs a small nest made of chewed wood fibers formed into a grey or brownish, paper-like material called carton. The queen forages for food and rears the first generation of workers, which emerge in late spring or early summer. Thereafter, colony growth increases rapidly to produce a maximum population in late summer to early fall. By this time the reproductives, males and young queens, are being reared. Depending on species, the cycle ends
from late summer to late fall at which time mated queens leave the colony to seek hibernation sites and the rest of the colony dies (for details see Spradbery, 1973; Edwards, 1980; Akre et al., 1981). It is during the time of maximum colony population and production of reproductives that yellowjackets are the greatest problem in terms of both nuisance and threat to human health.

Yellowjackets collect protein materials and sweet substances such as nectar, honey dew, fruits, juices and soft drinks, jams or jellies, candy, and so forth. Proteins collected include captured insects and arachnids and, in the case of Paravespula and Vespuia squamosa (Drury), carrion and protein waste. Overall, as a result of their general predatory activities, this group is almost certainly beneficial. Nevertheless, the scavenging habits of Paravespula are encouraged by food scraps that become available in trash receptacles. Yellowjackets often exploit these newly available food reserves to build up massive late summer and fall populations. This poses several problems: more yellowjackets are present around humans and, equally important, they become accustomed to foraging on sandwiches, beverages, meats, etc. around outdoor eating facilities and, at least in the case of P. germanica, inside homes when windows are open. Yellowjackets on and around food can become inadvertently consumed, pinched or grasped, or entangled in clothing or hair. In attempting to escape they often sting.

Yellowjackets (and the bald faced hornet) of the genus Dolichovespula pose virtually no threat around food because they eat only live insects and arachnids. Their habit of frequently nesting under eaves of houses, above doors, in barns, and so forth, does, however, cause many people great concern. In such situations, the inhabitants of the nest will sting only in defense and generally cause no problems unless disturbed.

Paper wasps (Polistes) and paper-making wasps of the genus Mischocyttarus constitute the last group of wasps responsible for numerous human envenomations. Members of both genera are strictly predaceous, feeding their larvae predominantly caterpillars. They are therefore highly beneficial. They come into conflict with humans mainly by virtue of their propensity for nesting under eaves of houses, above doors and windows, in attics and related sheltered places, and in heavy vegetation such as dead palm fronds. Some species such as Polistes annularis (L.) and Polistes exclamans arizonensis Snelling are quick to attack when their nests are disturbed. Thus, unsuspecting victims are often stung as a result of slamming a door or brushing against vegetation which disturbs wasps on a nest.

The final group of stinging Hymenoptera of medical importance are the ants. Numerous species exist, many of which can sting, but only two genera present major problems. These include imported and native fire ants (genus Solenopsis), the former of which almost ubiquitously infest lawns, fields and open areas in the Southeast from North Carolina into Texas, and harvester ants (genus Pogonomyrmex), which inhabit coastal plain areas of the Southeast and most of the West. Imported fire ants are small, blackish or
deep reddish ants about 2-5mm long. They often make hundreds of colonies per hectare, each with a hundred thousand or more individuals. They can be easily distinguished from virtually all other ant species in those areas by their habit of erupting almost immediately from the nest and obscuring the soil surface when the nest is kicked or otherwise disturbed. Their name comes from their propensity for inflicting tens to hundreds of stings which produce a burning sensation. At present the red imported fire ant, *Solenopsis invicta* Buren, has not moved west of east central Texas (presumably because of desert conditions) or north of Tennessee (presumably because of cold temperatures). There is, however, no obvious reason that this species could not survive in West Coast urban parks, lawns, etc. or in other irrigated areas. Hence, there is a constant threat of further territorial expansion.

Harvester ants are large, 5-9 mm long, reddish to blackish ants which generally build mounds and/or clear vegetation away from their nest entrances. Cleared areas of 0.5-4 m radius around nests are good indicators of the presence of these ants. Some species are extremely aggressive when activity occurs near their nests or foraging trails, and they can inflict extremely painful throbbing stings that frequently endure 4 to 24 hours.

**VENOMS: SELECTION PRESSURES AND EVOLUTIONARY CONSIDERATIONS**

Central to the hymenopteran sting is the venom. Without it the sting apparatus would be merely a piercing lance. Venom is the reason for the effectiveness of the sting apparatus, and venom properties have been molded through selection pressure to maximize its value. For example, venom of the wasp, *Tachytes*, which paralyzes preying mantids, must act very rapidly and induce long-term paralysis if the attacking individual is to be successful (Fabre, 1921). Likewise, if venom is used predominantly for defense against large predators, it must be highly painful, toxic or both. Painfulness is especially important, for it provides potential predators immediate negative feedback. Toxicity might be of less value in many cases because the feedback is delayed.

**Venom Biochemistry**

A great diversity of biochemical components is present in hymenopterous venoms; to date, over 50 have been identified from various species. These represent mainly those exhibiting strong properties or activities which lend themselves to easy detection; the number of other venom components with more subtle activities cannot even be estimated.

Biochemical components of hymenopterous venoms generally fall into three categories: small non-proteinaceous molecules of molecular weights less
than 300, peptides of molecular weights 1500–4000, and enzymes and a few other proteins of molecular weight over 10,000. Carbohydrates are sometimes attached to peptides and enzymes (Shipolini et al., 1971; Yoshida et al., 1976), and lipids and phospholipids are reportedly present in some venomous blends (O'Connor et al., 1967), but for the most part these components and the small quantities of amino acids and inorganic ions present have little overall importance.

Components of the first two categories (Table 9.1) are mainly responsible for the immediate painfulness of venoms. The first category includes histamine, 5-hydroxytryptamine (serotonin), acetylcholine, and various catecholamines (dopamine, norepinephrine = noradrenaline, epinephrine = adrenaline), which induce itch, pain, redness, and changes in vascular integrity. Except for acetylcholine, which is present only in hornet venoms, these components are found in the venoms of yellowjackets, hornets, paper wasps and the honey bee. Ant venoms generally have not been analyzed for these components. Small peptides are probably responsible for most of the immediate pain following envenomation, for much of the local swelling, redness and tenderness, and for most of the hemolytic, neurotoxic and probably lethal properties of venoms (except for fire ants). The peptide components in Table 9.1 include hemolysins, which actively destroy red blood cells and probably cause pain in most cases; neurotoxins, which may contribute to potential toxicity (and probably do not cause pain); kinins, which are extremely active on the vascular system and induce intense pain; and mast cell degranulating peptides which cause mast cells to release histamine and other components. Unlike the smaller components previously mentioned, each peptide appears to be present in only one venom or group of venoms from phylogenetically related species. The fact that many venoms in Table 9.1 possess different peptides with similar activities indicates that these activities are important in defense and that they have evolved independently several times (see Schmidt, 1982 for structures of individual peptides).

Large molecules and enzymes in venoms (Table 9.2) appear to play different roles than smaller molecules. In general, large molecules exhibit little or no toxicity or known pharmacological activities and do not appear to produce pain. Instead, by hydrolyzing a variety of substrates in the sting area they aid in the spreading and activity of other venom components. Some exceptions are phospholipases that are toxic (Habermann, 1971) and indirectly responsible for hemolysis (Mollay and Kreil, 1974) and release of pain-inducing agents; and polistin (which may or may not be an enzyme such as phospholipase) which actively lyse red blood cells (Bernheimer et al., 1982). Enzymes, in general, are important because they strongly synergize the activity of other venom components (Vogt et al., 1970; Mollay and Kreil, 1974).

Fire ants (Solenopsis) contain only about .1% protein in their venom (Baer et al., 1979); the rest is piperidine alkaloids and water. The alkaloids are
### TABLE 9.1: Small and Medium-sized Molecules Present in Venoms of Stinging Hymenoptera

<table>
<thead>
<tr>
<th>Venom</th>
<th>Vasoactive amines&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Catecholamines&lt;sup&gt;2&lt;/sup&gt;</th>
<th>Hemolysins</th>
<th>Neurotoxins</th>
<th>Kinins</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>His, 5-HT, ACh</td>
<td>Dop, Norepi, Epi</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Small Molecules</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Honey bee (Apis)</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>Melittin</td>
<td>Apamin</td>
</tr>
<tr>
<td>Yellowjackets (Paravespula)</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-Vespulakinins</td>
</tr>
<tr>
<td>Yellowjackets (Dolichovespula)</td>
<td>+</td>
<td>++</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Hornets (Vespa)</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>Mastoparans</td>
<td>Mandaratoxin</td>
</tr>
<tr>
<td>Paper wasps (Polistes)</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>Polistin&lt;sup&gt;4&lt;/sup&gt;</td>
<td>-</td>
</tr>
<tr>
<td>Harvester ants (Pogonomyrmex)</td>
<td>+</td>
<td>-</td>
<td>?</td>
<td>?</td>
<td>Barbatolysin</td>
<td>+</td>
</tr>
<tr>
<td><strong>Medium-sized Molecules (Peptides)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

<sup>1</sup>For data sources see Schmidt 1982.

<sup>2</sup>Abbreviations: His = histamine, 5-HT = 5-hydroxytryptamine, ACh = acetylcholine, Dop = dopamine, Norepi = norepinephrine, Epi = epinephrine.

<sup>3</sup>Symbols for relative quantities present: ++ = very large, + = present to large, - = not detectable.

<sup>4</sup>Molecular weight approximately 26,000.
TABLE 9.2: Large Molecules and Enzymes Present in Venoms of Stinging Hymenoptera

<table>
<thead>
<tr>
<th>Venom</th>
<th>PLA</th>
<th>PLB</th>
<th>H yal</th>
<th>AP</th>
<th>EST</th>
<th>LIP</th>
<th>OTHERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honey bee (Apis)</td>
<td>+3</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>Many enzymes</td>
</tr>
<tr>
<td>Yellowjackets</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>(Paravespula)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellowjackets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Dolichovespula)</td>
<td>+</td>
<td>+</td>
<td>±</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Hornets (Vespa)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Paper wasps (Polistes)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>Polistin</td>
</tr>
<tr>
<td>Harvester ants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Pogonomyrmex)</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Fire ants (Solenopsis)</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

1 For data sources see Schmidt 1982.
2 Abbreviations: PLA = Phospholipase A, PLB = phospholipase B, H yal = Hyaluronidase, AP = Acid phosphatase, EST = Esterase, LIP = Lipase.
3 Quantities present: + = present, − = absent, ± = detectable.
4 Unpublished results: Schmidt et al., and Donald R. Hoffman.

For data sources see Schmidt 1982.
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3 Quantities present: + = present, − = absent, ± = detectable.
4 Unpublished results: Schmidt et al., and Donald R. Hoffman.

responsible for the pain, swelling, redness, itching, etc. (Brand et al., 1972)—
symptoms not unlike those caused by other hymenopterous venoms which are
biochemically entirely different.

From an anthropocentric point of view, enzymes are perhaps the most
crucial of venom components. This is because they are the strongly allergenic
materials that cause most of the severe medical problems. The small active
molecules and peptides, which induce pain, local reaction and toxicity,
contribute little, if anything, to venom allergy.

THREATS TO HUMAN HEALTH BY STINGING HYMENOPTERA

Stinging Hymenoptera may constitute a serious threat to human health.
Unlike disease organisms which are undoubtedly a greater threat, stinging
insects are usually highly visible. This constitutes a serious psychological
factor that is strengthened by the insects themselves—they are brightly
colored, make loud buzzing sounds, rapid movements and threats. Human
beings naturally react to direct assaults, especially painful assaults upon their
bodies, through avoidance behavior. Significantly, these are innate responses
to pain and are not based on actual physical threat, i.e., potential life-
threatening or debilitating toxicity. Properties of hymenopterous venoms are
perfectly tuned to this factor—their painfulness is inordinately greater than
their actual toxicity. Compare this with the bites of some snakes such as the
banded krait and spiders such as the black widow that produce almost pain-
free yet often very serious or lethal bites (Campbell, 1979; Maretic, 1978).
Human fear of stinging Hymenoptera is genuine and almost universal. Humans often fear these and many other insects and want them removed even if they know they are not dangerous and pose no threat (Olkowski and Olkowski, 1976; E. Thoms, personal communication). This fear, which is exacerbated by reports of human deaths following envenomations, usually stems from belief that the individual is deathly allergic to stinging insects and will die from another sting. It is usually based on pain and normal local reactions from envenomation and is often extremely difficult to dispel. Unfortunately, individuals appear to be their own worst judges of real sensitivity to hymenopterous venoms. For example, parents of Boy Scouts were correct in their diagnosis of hay fever 94% of the time and of asthma 84% of the time, but were correct less than 20% of the time in their diagnosis of sting allergy (Settipane et al., 1972). If this survey is representative, at least four of five persons who feel they are allergic are in fact not allergic!

Hymenopteran envenomation can threaten human life in two basic ways: outright poisoning through direct toxic effects, and allergic or hypersensitive reactions to injected venom components. The first is dose-dependent in that the greater the number of stings, the greater the threat. The second is also dose-dependent, but the quantities are many orders of magnitude lower and usually one sting provides enough venom to elicit a reaction. Dose-dependency of hypersensitive reactions is what allows harmless, albeit extremely tiny, quantities of venom to be injected during immunotherapy programs to treat allergic individuals. It is this dose-dependency that sometimes causes minor systemic reactions to occur during immunotherapy and is the basis of rare cases in which one sting does not provide enough venom to cause a reaction, yet several stings do.

To provide a perspective on the threat of human death occurring by outright mass envenomation, the number of theoretical stings necessary by different species to provide a human LD₅₀ venom dosage is shown in Table 9.3. To determine this limit, several assumptions were made: (1) humans and laboratory mice are about equally sensitive by weight; (2) venoms are equally efficacious whether injected intraperitoneally, intravenously, or intradermally (actually occurs during envenomation); (3) the insect injects all its venom during stinging (clearly an overestimation); and (4) the human is in normal health and reacts in the usual fashion to venom poisoning (e.g., is not hypersensitive). Death as a result of mass envenomation should be exceedingly rare (Table 9.3), and actual data suggests this is true. For example, there have been only a few reports of death as a result of numerous stings (James and Walker, 1952; Parrish, 1963; Scragg and Szent-Ivany, 1965; Hoh et al., 1966; Gadeke et al., 1977), and these have usually involved hundreds of insects. Worldwide, the number of deaths resulting from mass envenomation by Hymenoptera other than the Africanized bee is very low, probably less than 1 / 100 million / year.
TABLE 9.3: Number of Stings for a Human Lethal Dose

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>LD$_{50}$ (mg/kg) for Mice$^2$</th>
<th>mg Venom/Insect$^2$</th>
<th>Number Stings/ Human LD$_{50}$ Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Vespa mandarina</em></td>
<td>Giant hornet</td>
<td>4.6</td>
<td>.14</td>
<td>164</td>
</tr>
<tr>
<td><em>Pogonomyrmex rugosus</em></td>
<td>Rough harvester ant</td>
<td>.47</td>
<td>.029</td>
<td>810</td>
</tr>
<tr>
<td><em>Polistes comanche navajo</em></td>
<td>Paper wasp</td>
<td>5.0</td>
<td>.20</td>
<td>1250</td>
</tr>
<tr>
<td><em>Vespula squamosa</em></td>
<td>Southern yellowjacket</td>
<td>3.5</td>
<td>.10</td>
<td>1750</td>
</tr>
<tr>
<td><em>Apis mellifera</em></td>
<td>Honey bee</td>
<td>3.5</td>
<td>.05</td>
<td>3500</td>
</tr>
<tr>
<td><em>Bombus impatiens</em></td>
<td>Bumble bee</td>
<td>7.2</td>
<td>.08</td>
<td>4500</td>
</tr>
<tr>
<td><em>Dolichovespula maculata</em></td>
<td>Baldfaced hornet</td>
<td>50.</td>
<td>.38</td>
<td>6600</td>
</tr>
<tr>
<td><em>Paravespula maculifrons</em></td>
<td>Eastern yellowjacket</td>
<td>9.</td>
<td>.06</td>
<td>7500</td>
</tr>
<tr>
<td><em>Dasymutilla klugii</em></td>
<td>Velvet ant</td>
<td>71.</td>
<td>.42</td>
<td>8500</td>
</tr>
</tbody>
</table>

$^1$LD$_{50}$ dose for 50 kg person.

$^2$Data derived from Schmidt et al., 1980 and Schmidt, unpublished for values for venom quantities/insect and for LD$_{50}$ values for toxicity to mice; all venom is assumed injected and the assumption is made that the stings do not cause respiratory blockage (i.e., stings inside nose, throat, etc.) or hypersensitive reactions.

$^3$World's largest and most venomous hymenopteran.
The Africanized bee, *Apis mellifera adansonii* (Latreille), as exists in South and Central America, has an inordinate propensity to attack victims en masse with little warning. Data relating to deaths by mass envenomation are very difficult to document; however, in Venezuela from 1978 to mid-1981 over 70 deaths were reported (O. R. Taylor, personal communication). Most resulted from several hundred to 2,000 or more stings with bees often being found inside the mouth, stomach and lungs. Obviously, when dealing with stings to tissues eminently capable of profound swelling such as those of the respiratory and digestive systems, death could occur as a result of asphyxiation more rapidly than via sheer poisoning. Hence, in the case of Africanized bees, asphyxiation resulting from edema is a very real problem.

In recent years, Africanized bees have been moving northward through northeastern South America at a rate of up to several hundred kilometers per year. They are now in Panama City, will probably be in Costa Rica in 1983, and will likely reach the U.S. border between 1988 and 1992 (O. R. Taylor, personal communication; Taylor, 1977). Unless they change genetically during their advance or the cooler climate of most of the U.S. changes their behavior, these Africanized bees will undoubtedly affect the hymenopteran envenomation problem in the U.S.

At present, allergy, not mass envenomation, is the cause of the vast majority of Hymenopteran-related deaths in the U.S. The confirmed death rate is about .14 per million population per year, or less than 1 person in seven million (Parrish, 1963). No accurate figures are possible for actual death rate from stings because such deaths may be confused with those of heart attacks or strokes. The rate is probably several times that reported.

In geographical terms, deaths in the U.S. from Hymenoptera exhibit only weak regionality (Table 9.4). The highest incidences are found in the South, Texas, the Pacific Northwest and New England (Parrish, 1963). Even in the area of highest incidence, the South from West Virginia to Texas (excluding South Carolina, Florida, and Louisiana which have the lowest southern incidences), the death rate is only double the national average. In contrast, the combined death rate from snakes and spiders, though less, exhibits strong regionality (Table 9.4). The Southern area from South Carolina to Texas has a rate almost four times the national average (calculated from Parrish, 1963). The peak months for deaths caused by Hymenoptera as well as snakes and spiders is August with July and September following closely (Parrish, 1963).

U.S. information concerning ages of individuals killed by Hymenoptera, the speed at which death occurs, and its primary causes, are recorded in Tables 9.5, 9.6, and 9.7. In Tables 9.5 and 9.6, statistics for deaths from snake and spider bites are also included for comparison. Note that Hymenoptera kill relatively few people under age 40 and extremely few under 20 (Table 9.5). This is in contrast to snakes and spiders which cause a five-fold higher percentage of deaths for the under 20 age group and about two times the
TABLE 9.4: Geographical Distribution of Victims Killed by Venomous Animals

<table>
<thead>
<tr>
<th>Region</th>
<th>Hymenoptera</th>
<th>Snakes and Spiders</th>
</tr>
</thead>
<tbody>
<tr>
<td>New England</td>
<td>.156</td>
<td>.000</td>
</tr>
<tr>
<td>Mid Atlantic</td>
<td>.072</td>
<td>.003</td>
</tr>
<tr>
<td>East North Central</td>
<td>.079</td>
<td>.015</td>
</tr>
<tr>
<td>West North Central</td>
<td>.110</td>
<td>.096</td>
</tr>
<tr>
<td>South Atlantic</td>
<td>.185</td>
<td>.303</td>
</tr>
<tr>
<td>East South Central</td>
<td>.287</td>
<td>.429</td>
</tr>
<tr>
<td>West South Central</td>
<td>.260</td>
<td>.349</td>
</tr>
<tr>
<td>Mountain</td>
<td>.139</td>
<td>.191</td>
</tr>
<tr>
<td>Pacific</td>
<td>.149</td>
<td>.080</td>
</tr>
<tr>
<td>U.S. Total</td>
<td>.140</td>
<td>.124</td>
</tr>
</tbody>
</table>

1 Data based on Parrish (1963) and U.S. Population Reports.

Relative percentage of deaths for the under 40 age group as Hymenoptera. These data indicate that, in spite of children having greater outdoor exposure to stinging Hymenoptera, they are relatively free from lethal reactions to Hymenoptera but not to snakes and spiders. This is because hymenopterous envenomations primarily cause allergic, not toxic, manifestations, whereas snake and spider envenomations cause toxic reactions. These data also suggest that grandparents and parents should be more concerned about their own health vis-à-vis Hymenoptera than that of their children.

Deaths from allergic reactions to hymenopterous stings generally occur very rapidly, with about 80% occurring in less than one hour, and almost always under six hours (Table 9.6). Hence, both speed of preventative action and on-person possession of prophylaxis are mandatory for severely sensitive persons. In contrast, snakes and spiders kill relatively few people in under six hours. This is because more time is usually required for toxic venoms to diffuse and act (this is also true of mass envenomation by Hymenoptera). Speed of action is therefore much less critical to saving a life from snake and spider envenomation than from hymenopterous envenomations.

Table 9.7 is derived from the most thoroughly reported pathological investigation that describes the primary causes of death in cases of hymenopteran envenomations. Several points are worth noting. First, the vast majority of deaths result from respiratory problems, usually some form of asphyxiation, whereas vascular, anaphylactic, and neurological problems are much less frequent. Second, in cases of respiratory and anaphylactic complications, death occurs exceedingly rapidly, usually in under one hour. Finally, neurologic reactions, though the rarest type, almost always require
TABLE 9.5: Age of Victims Killed by Venomous Animals

<table>
<thead>
<tr>
<th>Venomous Group</th>
<th>Hymenoptera</th>
<th>Snakes and Spiders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at Death (yr.)</td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>&lt; 20</td>
<td>19</td>
<td>7.7</td>
</tr>
<tr>
<td>20-40</td>
<td>45</td>
<td>18.1</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>184</td>
<td>74.2</td>
</tr>
<tr>
<td>Total</td>
<td>248</td>
<td></td>
</tr>
</tbody>
</table>

\*Data from Parrish (1963) and Ennik (1980).

Several days to cause death. In fact, many fatal cases involving the neurologic systems do not exhibit symptoms until after six hours (Barnard, 1973).

Most reports of hymenopterous lethal envenomations, including those of Parrish (1963), Barnard (1973) and Ennik (1980), list the honey bee as the major offender with yellowjackets, (paper) wasps, hornets, and ants following in importance. In actual fact, yellowjackets are a far greater problem than honey bees in most areas of the U.S. (California and the desert Southwest are the major exceptions). The reason for the apparent discrepancy is that in most cases no specimens and names are available and, if they are, no scientific confirmations are available. Most medical practitioners and coroners cannot identify these insects and rather indiscriminately call them "bees" or "wasps." Thus, envenomating insects are frequently misidentified, and the honey bee and beekeeping industry receive blame. Yellowjackets appear to be the major cause of stings for two reasons: their nests are abundant in areas of direct human contact, and these insects occur around people and their food. Honey bees, on the other hand, are rarely feral and when so, nest mainly in inaccessible places such as hollow trees, rock cliffs, and inside building walls—places where inadvertent human contact is reduced. Honey bees are also less attracted to people and their food. The main risks of envenomation by honey bees occur around swimming pools where water-gathering bees may be undetected and sat upon or close to bee hives when they are being managed.

**Allergy to Venoms**

Hypersensitivity is an immunological process by which venom allergens react with immune factors, principally immunoglobulin E (IgE), to induce massive release of histamine, chemotactic factors, slow reacting substances of anaphylaxis (leukotrienes), etc., which in turn promote a variety of dermal, respiratory, circulatory, and anaphylactic reactions, among others. Why
TABLE 9.6: Interval Between Envenomation and Death¹

<table>
<thead>
<tr>
<th>Interval (hr.)</th>
<th>Hymenoptera</th>
<th>Snakes and Spiders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
</tr>
<tr>
<td>0–1</td>
<td>178</td>
<td>79.1</td>
</tr>
<tr>
<td>1–6</td>
<td>28</td>
<td>12.4</td>
</tr>
<tr>
<td>6–24</td>
<td>2</td>
<td>.9</td>
</tr>
<tr>
<td>&gt; 24</td>
<td>17</td>
<td>7.6</td>
</tr>
<tr>
<td>Total</td>
<td>225</td>
<td>200</td>
</tr>
</tbody>
</table>

¹Data from Parrish (1963) and Ennik (1980).

some individuals are prone to developing high levels of IgE and/or low levels of the more usual antibodies, including immunoglobulin G (IgG), is not known. Genetics do, however, appear to play a role. An individual normally becomes hypersensitive only after being stung one or more times. Estimates place the average initial sting occurrence at approximately 15 years before the first hypersensitive reaction (Brown and Bernton, 1970). For greater detail concerning the immunology and mechanisms relating to venom hypersensitivity see Fudenberg et al. (1980).

Venom hypersensitivity is clinically measured in four ways. The most definitive proof is an accurate clinical case history taken by a physician confirming a systemic allergic reaction. This, however, is an *a posteriori* measurement which helps little in predicting predisposition to systemic reactions. Various clinical tests including the skin test are used to augment case history diagnosis and predict potential for systemic reaction. The skin test involves application to skin scratches or intradermal injection of venom dilutions starting at $10^{-4}$ μg/ml and increasing in concentration by factors of 10 until either a small local reddish spot (erythema and wheal) is observed or until a dosage of 1 μg/ml venom is applied (Hunt et al., 1976). If no positive reaction is observed with 1 μg/ml of test venom, the test is negative (some physicians increase doses to 3 or 10 μg/ml, but these are inappropriately high and unreliable concentrations that will frequently elicit a normal reaction similar to a positive).

Skin testing is the simplest and cheapest of the clinical tests. A second test often used to analyze venom hypersensitivity is the radioallergosorbent test (RAST), which involves analysis of the levels of allergy producing IgE antibodies in a sample of the patient’s serum (Hoffman, 1979). The last method for studying hypersensitivity is the leukocyte histamine releasing test which measures ability of allergens in venoms to bind to membrane bound IgE on basophils and induce the release of histamine (Yocum et al., 1973; Santrach et al., 1980); it is difficult to perform and expensive. These clinical and laboratory tests are useful not only to confirm presence of venom allergy, but more importantly, to determine what species of stinging insect(s) is (are)
TABLE 9.7: Primary Cause of Death as Correlated with Time to Death for 100 Cases of Hymenopterous Envenomations

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Number of Deaths</th>
<th>Time to death (listed as % within group)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt; 1 hr.</td>
</tr>
<tr>
<td>Respiratory tract</td>
<td>69</td>
<td>69</td>
</tr>
<tr>
<td>Vascular system</td>
<td>12</td>
<td>25</td>
</tr>
<tr>
<td>Anaphylactic shock</td>
<td>12</td>
<td>81</td>
</tr>
<tr>
<td>Neurologic system</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>61</td>
</tr>
</tbody>
</table>

1 Data from Barnard (1973).
2 Expressed as % deaths during the time period based upon the total deaths of known time within the group.

the cause of the hypersensitivity. Unfortunately, none of these methods has proved to be totally reliable. Each gives false positives and, at times, false negatives, i.e., failure to detect hypersensitivity (Lichtenstein et al., 1979; Yunginger, 1979; Santrach et al., 1980).

Statistics on venom allergy are surprising to many people. The overall rate of venom allergy in the U.S. population has been recorded at between .35 and .8% (Settipane and Boyd, 1970; Abrishami et al., 1971; Settipane et al., 1972). The actual rate is probably nearer the upper figure. In contrast, the incidence of asthma and/or hay fever is 11% (Settipane et al., 1972). Many people believe the presence of allergies in an individual predisposes him to venom hypersensitivity. This is not the case—of 3,700 atopic (allergic) patients, the rate of systemic reactions to hymenopterous venoms was .38% (Chafee, 1970), virtually the same as in the general population. Settipane et al. (1972) reported virtually identical results. The lack of correlation between allergies and hypersensitivity to hymenopterous venoms appears to be a result of differences in the mode of contact of the allergens. Hay fever/asthma allergens make contact with the exterior membranous parts of the respiratory passages and do not directly enter the blood stream; venoms are injected directly into or near capillary beds and rapidly become blood borne.

For the average person, the most important diagnostic information available is an accurate description of actual symptoms of critical venom hypersensitivity as opposed to symptoms resulting purely from venom toxicity or from large, local reactions. Failure to distinguish properly between a severe hypersensitive reaction and an ordinary or non-life-threatening reaction is undoubtedly the greatest single cause of fear, anxiety, and unneeded medical treatment. Although there is not complete agreement among medical experts about what constitutes a life-threatening reaction, a good set of guidelines for defining dangerous hypersensitivity is illustrated in...
Table 9.8; also listed are those symptoms that do not indicate a serious venom reaction.

The most serious symptoms of hypersensitivity are those that affect the respiratory and circulatory systems. These include impaired breathing or falling blood pressure, symptoms indicative of reduced or lack of oxygen to the brain. Such symptoms imply a life-threatening situation that must be dealt with immediately because of the likelihood of death occurring in less than one hour. Other less crucial symptoms include abnormal reactions in the digestive and dermal systems. The least critical symptoms are skin reactions involving generalized rashes or hives or the formation of large areas of swelling. These reactions do not indicate a life-threatening situation—acute skin problems cannot kill one—but they may be indicators of more severe future reactions. These dermal reactions include only systemic reactions—reactions occurring away from the sting area—and not reactions nearby. In other words, if one is stung on the arm, hives or large swelling on the facial area or on the body indicate hypersensitivity; but if one is stung on a finger, symptoms only on the back of the hand, wrist and even forearm do not indicate a systemic reaction but a large normal sting reaction.

Normal reactions to hymenopterous stings include immediate pain and/or burning at the sting site and development of a flare and wheal.

**TABLE 9.8: Reactions to Sting by Hymenoptera**

<table>
<thead>
<tr>
<th>Reactions Indicative of Severe Allergy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Respiratory system: difficulty in breathing (dyspnea), “lump” in throat (laryngeal edema) or difficulty in swallowing (dysphagia), difficulty in speaking, wheezing, cyanosis (bluish color).</td>
</tr>
<tr>
<td>2. Circulatory system: hypotension (unconsciousness, fainting or collapsing, feeling faint or dizzy).</td>
</tr>
<tr>
<td>3. Digestive system: incontinence, vomiting, diarrhea, abdominal pain, nauseous feeling.</td>
</tr>
<tr>
<td>4. Dermal: generalized urticaria (hives, rash), angioedema (large swelling, particularly around mouth, on eyelids, backs of hand and feet, etc.).</td>
</tr>
<tr>
<td>5. Others: runny nose and eyes, sneezing, anxiety, feeling of impending doom, malaise.</td>
</tr>
</tbody>
</table>

Common Reactions Which Are Not Indicative of Severe Allergy

1. Pain or burning (no matter how great) from sting site(s).
2. Redness (erythema), minor swelling (edema), short-lived white spot around sting site(s).
3. Itching at sting site(s).
4. Large, local swelling.
TABLE 9.9: Typical Characteristics of Stings by Various Hymenoptera

<table>
<thead>
<tr>
<th>Species with Unique Sting Characteristics</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Honey bee: (Apis mellifera)</td>
<td>The only species which usually leaves a dark sting apparatus at the sting site; intense short duration pain (&lt; 5 min.) followed by a burning hot feeling; erythema and edema can be great.</td>
<td></td>
</tr>
<tr>
<td>Imported fire ants: (Solenopsis invicta &amp; S. richteri)</td>
<td>Usually many stings, often around feet or legs; the only stings which develop into pimple-like pustules at sting site, 18-36 hr. after the sting; pain sharp but of short duration, much less than that of a honey bee; many stings can give an “on fire” feeling; erythema and edema less than in honey bee stings.</td>
<td></td>
</tr>
<tr>
<td>Harvester ants: (Pogonomyrmex spp.)</td>
<td>Induce the unique reactions of piloerection (the elevation of the hairs as viewed from an oblique angle) and sweating around the sting site which usually lasts 4-8 hr.; pain is unique in that it starts slowly, becoming noticeable in 10-60 sec., and increases to an intense burning, throbbing, unpleasant feeling that may last undiminished 4 to 5 hr; pain never as sharply intense as the pain of a honey bee.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species with Less Distinct Sting Characteristics</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellowjackets &amp; Paper wasps: (Paravespula, Dolichovespula, Vespula, Polistes, Mischocyttarus)</td>
<td>These stings are usually very similar to each other and to stings of honey bees; all induce immediate intense sharp burning pain which greatly decreases after 5 min.; erythema and edema similar to honey bee stings.</td>
<td></td>
</tr>
<tr>
<td>Hornet: (Vespa crabro)</td>
<td>In spite of great size of these insects the pain from their stings is similar, if not less than that from the yellow-jackets and paper wasps; symptoms similar to yellow-jackets and paper wasps.</td>
<td></td>
</tr>
<tr>
<td>Spider wasps &amp; Tarantula hawks: (Pompilidae)</td>
<td>Immediate excruciating and debilitating pain that lasts only a short time (2-3 min.); numbness often felt around sting site shortly after sting; no, or very little, erythema and edema and no, or little, after-effects detected shortly after sting; pain very much greater than that from a honey bee.</td>
<td></td>
</tr>
<tr>
<td>Velvet ants: (Mutillidae)</td>
<td>Large species can inflict incredibly painful envenomations, often described as similar to poking the area with a sharp, hot branding iron, smaller species less intense; erythema and edema can become very large.</td>
<td></td>
</tr>
<tr>
<td>Bumble bees: (Apidae)</td>
<td>Stings are very similar in all respects to honey bee stings except no stinger is left.</td>
<td></td>
</tr>
<tr>
<td>Solitary bees: (Apoidea)</td>
<td>Sharp, short duration pain; the larger the species the greater the pain.</td>
<td></td>
</tr>
<tr>
<td>Solitary wasps: (Scoliidae, Sphecidae)</td>
<td>Mild pain and effects for size, even large cicada killers (Sphecius) do not elicit comparatively much pain; no</td>
<td></td>
</tr>
</tbody>
</table>
Immediate pain, no matter how great it may seem, is a normal and harmless reaction. In no case is envenomation known to induce chronic pain. Itching later on at the site is also normal.

Local reactions to the sting are in some cases diagnostic. Table 9.9 lists typical reactions to stings by different species of Hymenoptera. Human reactions are variable; hence, Table 9.9 represents only average reactions and not the entire range.

The honey bee is the only North American species that regularly leaves the sting apparatus at the site. (Some harvester ants, e.g., *Pogonomyrmex maricopa* Wheeler, will occasionally leave a stinger, but their stingers are yellow, rather than black like a honey bee's, and are much smaller.) Unfortunately, the absence of a sting apparatus does not discount a honey bee sting since it may be lost from the site. Imported fire ants (but not the native species) are the only species that produce pimple-like pustules. Harvester ants are the only species that produce pain increasing with time and lasting from 4 to 24 hours or more. They also cause a unique local sweating and raising of the hair around the sting site (Hermann and Blum, 1967; personal observations). Effects from other species are less diagnostic and more difficult to characterize.

Large local reactions (swellings defined as greater than 10 cm in diameter) have also been observed. If these occur, it is virtually always after at least one or two previous stings. The importance of these large local swellings is uncertain, but they appear to be at least partially immunologically mediated (Reisman et al., 1975; Müller et al., 1977; Hoffman, 1978; Abrecht et al., 1980). They are not serious problems and do not indicate that more serious events will follow. For example, less than 5% of individuals with large, local reactions develop systemic reactions (Abrecht et al., 1980). A common course of events following a series of stings over time is: (1) pain with little local swelling; (2) pain with increasing area of local swelling (sometimes encompassing an area as large as the forearm, wrist and hand); and finally, (3) pain with diminishing or no local swelling. At the present time the best advice concerning these reactions is to monitor them closely by becoming aware of signs of systemic reactions and to watch for these signs after future stings. Very few, if any, sting victims experience only large, local reactions preceding a fatal reaction; they have intermediate stages in which nonlethal systemic reactions are observed.
Part of the historical confusion centering on hypersensitivity to hymenopterous venoms and its treatment is a result of the variability in reactions to subsequent stings exhibited by different individuals. Settipane and Chafee (1979) discovered that only 12.6% of restung patients experienced a worse reaction to succeeding than to preceding stings, whereas 44.5% exhibited a less severe response. Hence, a great many sensitive patients improve with time. This observation appears to explain why virtually any treatment (including whole body extract desensitization programs) may appear successful.

Most children appear to lose venom hypersensitivity over time (Chipps et al., 1980). Venom immunotherapy for treating hypersensitivity can be an expensive and protracted, perhaps lifetime, medical proposition (Lichtenstein et al., 1979). Therefore, it is not recommended that children be treated for hypersensitivity unless truly life-threatening reactions are observed (Chipps et al., 1980; refer to Table 9.5 for frequency of deaths in children resulting from stings).

The Problem of Cross-Sensitivity

From the very beginning of venom treatment studies, confusion concerning the cross-sensitizing abilities of different hymenopterous venoms has existed; however, significant recent progress has been made. Insight into this phenomenon is important in terms of identifying which hymenopterous species to avoid and for designing appropriate and economical medical treatments. Venoms from bees, vespid wasps, and ants constitute the three major groups (families) inducing sensitivity. Allergy to ant (fire ant or harvester ant) venom apparently is almost never associated with allergy to the venoms of bees or vespids (James et al., 1976; Pinnas et al., 1977), but these results should be confirmed in new tests in which ant sensitive sera are tested against pure bee and vespid venoms.

Among the fire ants, extensive intrageneric cross-reactivity is observed; nevertheless, significant antigenic differences exist (James et al., 1976; Baer et al., 1979). Allergy to honey bee venom frequently is not accompanied by allergy to vespid wasp venoms (Reisman et al., 1975) and they possess different allergens (Charavejasarn et al., 1975). Yet, some degree of cross-reactivity between the venoms of honey bees and vespids is observed (Reisman et al., 1975; Jarisch et al., 1979; Hoffman et al., 1980). The yellowjacket group (Dolichovespula, Paravespula, Vespula) and the paper wasps (Polistes) possess venoms which appear to be partially cross-relative (Kern et al., 1976; King et al., 1978; Hoffman et al., 1980) even though they are biochemically different (Schmidt, 1982). Surprisingly, a high degree of cross-reactivity between yellowjackets and paper wasps, two quite different groups, appears to exist (Grant et al., 1980; Hoffman et al., 1980; Hoffman, 1981). In spite of this incidence of cross-reactivity within the vespid venoms,
these venoms appear to possess clear differences in their antigens. For example, *V. squamosa* venom behaves quite differently from those of the *Paravespula* (Wicher et al., 1980; Hoffman and McDonald, 1981, 1982a), and there even appear to be differences among the *Paravespula* (Hoffman and McDonald, 1981, 1982a). Differences between *Dolichovespula* and *Paravespula* are also evident (Kern et al., 1976; King et al., 1978; Reisman et al., 1980; Hoffman, 1981). Paper wasps as a group seem to be very closely related in terms of venom allergenicity (Hoffman and McDonald, 1982b). These studies indicate that various venoms are antigenically different, with the degree of difference being directly related to the phylogenetic distance between the taxa involved, but that a great deal of cross-reactivity is nevertheless present. Whether this phenomenon of clinical cross-reactivity indicates the existence of enough underlying antigenic similarity to cause the cross-reactivity, or whether it indicates multiple sensitization resulting from stings of several species, is not clear. The actual situation is probably caused by a combination of the two factors. Until more information is available, treatment of hypersensitive patients should be based on the assumption that hypersensitivity exists to all skin test positive venoms even if the individual has not been stung by all the species. In patients with questionable skin test results or those in life-threatening situations, RAST tests should also be performed (unfortunately, leukocyte histamine releasing tests are not commercially available). The benefit of this testing is threefold: it identifies what venom(s) should be used if treatment is desirable, it indicates what venoms should not be used, and it alerts the patient as to what particular species to avoid. In the future, a new diagnostic test, the RAST-inhibition test, will probably become available and provide the most definitive information concerning species sensitivity and cross-reactivity.

**SOLUTIONS TO ENVENOMATION PROBLEMS**

Dealing with hymenopteran envenomation requires educational, psychological, preventative and, at times, medical approaches. Since the vast majority of people have non-life-threatening reactions to stings, the first three are probably the most important. Foremost is learning how to distinguish a stinging hymenopteran from flies and other insects, and how to distinguish between honey bees, yellowjackets, bald faced hornets, and paper wasps. If one lives where fire or harvester ants are present, recognition of these should also be learned. Knowledge of such behavior as the almost universal tendency of Hymenoptera trapped in a house or car to attempt to escape by flying toward light, rather than sting, is useful. Equally useful is the understanding that Hymenoptera near a threatened nest will frequently attempt to sting in defense. Ability to distinguish between a truly hypersensitive sting reaction and a normal or large local reaction is invaluable and can spare many people
untold anxiety and time and money spent needlessly seeing physicians, and/or being unnecessarily treated.

Human mental attitudes toward stinging Hymenoptera present an enormous problem. Because people needlessly fear and hate Hymenoptera, their behavior toward them is often irrational and detrimental (Crane, 1976; Davis, 1978). They will spray toxic insecticides needlessly, stay indoors rather than enjoy outdoor recreation, and frequently strike at nearby flying insects, especially if hymenopteran-like. This can result in physical as well as psychological disaster, e.g., automobile accidents have resulted from attempts to destroy an insect. Meanwhile, the activity of attempting to destroy an insect can elicit attack behavior on the part of the insect. If one is near a colony, frantic motion can cause rapid recruitment of more nest defenders.

The solution to psychological reactions to Hymenoptera is not simple. Progress must be made both on factual and emotional fronts. Facts concerning the basic harmlessness of most stings should be stressed: the physical pain is usually quite bearable and in most cases will go away shortly. Patience in dealing with insects must be learned, especially by entomophobic people. If one attempts to accept and admire the beauty of these insects, much irrational fear can be dispelled. Most stinging insects are beautifully colored, make interesting nests and have fascinating habits and life histories. For nonsensitive people, particularly children, making a collection of different Hymenoptera (or other insects) from flowers and around the house may help them to understand and appreciate these insects (Shorthouse, 1978).

Preventive approaches to hymenopteran envenomation are especially important for those people with confirmed hypersensitivity. Most are common sense: do not go barefoot or wear sandals outdoors; wear long, smooth-finished clothes which are not loose (loose clothes can trap Hymenoptera); have short hair, tie it up, or wear a hat; avoid areas with lots of flowers or bees (because they can be stepped upon or become entangled in hair and clothing); and, if worn, perfumes should probably not be flowery; do not personally mow lawns, use garden equipment, clip hedges, or otherwise move in and about vegetation where a nest could exist; during the summer and fall avoid areas with garbage or garbage cans; do not eat outdoors; if a stinging insect gets in a car stay calm, stop the car, and open the windows to allow it to escape; and have nonsensitive people check for nests of Hymenoptera around the house and other outdoor areas and have them removed. At this time, the question of what colors of clothes to wear is unresolved. Yellow and light colors seem to attract foraging yellowjackets (Sharp and James, 1979) yet near a colony light colors, such as yellow, are the least attacked by defending insects (Maschwitz, 1964). The best compromise is probably a light to medium green.

If one is actually approached by a threatening hymenopteran, the individual should stay calm and still and wait for the insect to leave. The
insect is probably merely inspecting the person and will usually leave without causing harm. However, a calm retreat is in order when near a nest. If several Hymenoptera approach at once, it usually indicates a nearby nest, and the person is not dealing with inspecting foragers. In this case, run to the nearest safety (indoors, inside a closed vehicle, etc.) or, if no safe place is available, through shaded, wooded areas rather than open areas. An unimpeded healthy person can usually outrun bees and wasps and by running through an area with a patchwork of light and shade such as shaded woods, the pursuing Hymenoptera will have trouble following. While running, do not swat at flying insects because this helps maintain their aroused state and aids them in following. A crushing blow to a hymenopteran entangled in hair or clothing or already stinging is in order only if the motion is decisive enough to squash the insect. After running some distance from the nest one can often “hide” from the Hymenoptera by lying down in tall grass or standing within large thick bushes or trees. As a final note, take all possible action to catch or have someone catch the insect (or one from the nest) which did the stinging. Even a smashed fragment will do for identification if nothing else is available.

In the extremely unlikely situation that one is being attacked by hundreds of stinging Hymenoptera, the most important thing to remember is that hundreds of stings rarely kill, but a few inside the nose and mouth can. Thus, dismiss the stings and concentrate on protecting the nose, mouth and eyes by covering this area with a cloth or piece of clothing. Once protected, retreat. Then see a doctor immediately.

First aid for hymenopterous envenomations depends upon the situation. For a normal reaction, one should check for the presence of a small dark sting apparatus at the sting site. If present, remove it with a scraping motion of a fingernail, pocketknife blade, etc. Cooling lotions such as ammonia, vinegar, packs of sodium bicarbonate, commercial products, or other moist materials have been recommended as home remedies and might provide at least some psychological relief. If numerous stings are received, oral antihistamine tablets may be taken for partial relief from itching and burning. The usual precaution should be taken with these materials. Other than reassurance by surrounding friends and family, no other first aid is needed. Caution should be taken, however, not to scratch the sting site since this can cause secondary infection which has in rare cases been known to cause death (Barnard, 1973).

First aid for mildly hypersensitive individuals who are stung is the same as for normal individuals except antihistamines are indicated. One should be prepared to see a physician if the reaction becomes more severe and affects breathing and/or blood pressure. When stung, individuals who are severely hypersensitive (reactions affecting breathing and/or blood pressure) require immediate first aid. If the person has a sting kit, the epinephrine injection should be administered immediately. Any delay could allow an irreversible reaction to take place (Gottlieb, 1979; Fudenberg et al., 1980) which could
prove fatal (Barnard, 1973). The individual should then be transported to a hospital emergency room for further treatment. These individuals should wear medical tags indicating their condition.

For individuals who are mildly or severely hypersensitive, “sting kits” are often prescribed. These are inexpensive and valuable first aid against respiratory and circulatory complications following a sting. There are various kinds, two of which are illustrated in Figure 9.2. Each contains a syringe and a stabilized solution of epinephrine (1:1000) in saline.* Other minor components such as antihistamines and a constriction band may also be included. The epinephrine is the life-saving material; in many cases only immediate injection of the solution (.3 to .5ml) can prevent or arrest the life-threatening symptoms. The kits vary mainly in how the epinephrine is packaged. A preloaded-automatic, spring-activated syringe is recommended because it is the easiest to operate.

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* Mention of a trademark, proprietary product, or vendor in this manuscript does not constitute a guarantee or warranty by the U.S.D.A. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.
THE DESENSITIZATION SOLUTION FOR HYMENOPTERAN ENVENOMATION: IS IT FOR EVERYONE?

The final weapon to control envenomation problems of hypersensitive individuals is venom desensitization, called immunotherapy. Basically, this procedure involves injection of minute quantities of pure venom into the sensitive person. This results in the buildup of blocking antibodies (IgG) (Lessof et al., 1978; Hoffman et al., 1981) and/or decrease in reaginic antibodies (IgE).

The question of who and when to treat is not simple (Lichtenstein et al., 1979). There are many problems and disadvantages with venom desensitization. First, it requires a minimum of eight (and usually 18) visits to the doctor’s office in the first 20 weeks, followed by monthly visits to receive venom injections (Golden et al., 1980). This is not only a nuisance but a major expense. Lockey (1980) estimates the actual cost to the physician to be $607 per year to treat a patient with wasp, mixed vespid, and honey bee venoms. Actual costs to the patient would be approximately $900-1000 per year (R. F. Lockey, personal communication). Since treatments appear to be a continual procedure which could last years, or a lifetime (Lichtenstein et al., 1979), the cost and inconvenience could continue indefinitely. Physicians who are not thoroughly familiar with recent developments also may have a tendency to treat individuals who do not have severe enough reactions to merit treatment. Worse, many physicians are still using antiquated and useless desensitizing programs (i.e., whole body preparations). Whole body extracts consist of extracts of homogenate of the entire insect—legs, gut etc., which appear to be totally ineffective (Hunt et al., 1978b; Lichtenstein et al., 1979). Their ineffectiveness can allow fatalities to occur (Torsney, 1973), and their use can cause serum sickness, a result of the injection of a foreign protein into the human body (Hunt et al., 1978a).

Fortunately, many earlier disadvantages of desensitizing treatments have now either been eliminated or research to provide methods for their elimination has been reported. The biggest problems are centered on whom to treat, how to design the treatment protocol, and how to evaluate if the treatments are successful. Research has established that only those individuals who have severe systemic reactions (involvement of air passages or hypotension) and positive skin tests should have immunotherapy. Those with non-life-threatening systemic reactions and positive skin tests are optional candidates, and those with other symptoms should have their conditions watched but probably not treated (Lichtenstein et al., 1979). Large local swelling should be noted but not treated.

The most promising approach in treatment design consists of a rapid immunotherapy program (Rush program) involving only eight visits before attaining the 100 μg/visit maintenance dose which is administered every six weeks (Golden et al., 1980, 1981a, 1981b). This procedure is a vast improvement over many previous protocols. Nevertheless, basic questions remain: how long is the maximum safe interval between maintenance doses,
can more economical and readily available venoms replace those currently used, and can treatments ever be stopped? Progress on all these fronts will probably be forthcoming in the near future.

It has been extremely difficult to assess when an immunotherapy procedure is successful. All tests—skin tests, RAST tests, and leukocyte histamine releasing tests—are imperfect. That leaves only the actual sting challenge as a reliable test. Using a combination of tests, prediction of treatment success for immunotherapy of honey bee sensitive patients appears to be at least 90% (Hoffman et al., 1981). Perhaps, after the antigens are characterized, similar successes will be possible for immunotherapy of vespid and ant venom sensitive patients.

BRIDGING THE GAP BETWEEN ENTOMOLOGIST AND PHYSICIAN

Until recently, physicians and entomologists have not cooperated intensively. The basic problem is one of communication and information access. Doctors need to know how to identify stinging insects, how to get insect identities verified, and how to preserve insects for identification. They also need to learn the biology of various stinging Hymenoptera and how to use this knowledge to advise patients on prevention of future stings. Entomologists need to learn the physiology of venom reactions, how to recognize potentially dangerous situations, and what to do in cases of reaction to insect stings. They should also be able to refer sensitive people for diagnosis and/or treatment to the proper authorities.

The source of the insect identification problem lies in the basic training and literature in the medical profession. In general, medical schools provide only the most superficial discussions concerning stinging insects, and medical textbooks provide either no pictures or very poor ones. Other medical literature including brochures and journal advertisements from venom producing pharmaceutical companies provide equally poor and confusing pictures and information. The solutions to these problems are obvious: medical textbook writers and pharmaceutical companies should contact entomologists to obtain accurate, realistic photographs and descriptions. If these writers and firms do not know how to obtain information, they can contact the Entomological Society of America (4603 Calvert Road, College Park, Maryland 20740).

The machinery necessary to get insect specimens identified or verified is well in place; the medical profession needs only to learn whom to contact and how to get verification. Basically, the place for a physician to start is his local county extension agent, poison control center or health department. Such personnel should know local insects, their habits, and identities and can refer the physician to further help if necessary. Or, the physician may contact an
entomology department of the nearest land grant or other large university, or
a natural history museum. If these are unavailable, as a last resort, physicians
can contact the Smithsonian Institution (Department of Entomology, USDA,
ARS, BARC-WEST, Room 1, Building 003, Beltsville, Maryland 20705). Of
course, information can be obtained fastest at the local level.

The best way for a physician or individual to preserve a specimen is to
simply place it, or fragment thereof, into a vial of alcohol (rubbing,
denatured, high proof liquor, antifreeze, etc.). Then write on paper in pencil
the date of capture, place captured (city, etc.), location of insect when
captured (on person, from underground, under eaves, around garbage, etc.)
and the captor's name, and place this label in or taped to the vial. After initial
contact, these should then be sent to the nearest suitable entomology
department, museum, or the Smithsonian Institute; physicians should be
willing to pay verification charges, if necessary.

CONCLUSIONS

Stinging Hymenoptera are frequent inhabitants in and around urban
environments. Because they can sting, their interesting life habits and
behavior, as well as their general beneficial characteristics, are commonly
overlooked. Instead, attention is focused more on their potential harmfulness.
The stinging problem is actually more imagined than real; fear and loathing
override attempts to evaluate realistically the total benefit and actual threat
from these insects. Threats to life and well-being from stings themselves are
trivial in all but a very low percentage of the population who are exceedingly
hypersensitive. Nevertheless, thoughts about the pain and swelling of
envenomations conjure fears and anxiety in many individuals, the result of
which is often an unfounded belief that the next sting can be fatal. These
psychological reactions, unfortunately appear to be the norm and must be
recognized as such. Only with this realization can progress be made on the
human front to alleviate fear and apprehension about stinging Hymenoptera.
Medical progress in treatment of venom hypersensitivity has been impressive.
Today, with proper care and concern on the part of the individual and his
physician, virtually no one needs to live in fear of Hymenoptera. Perhaps
soon urban inhabitants can concentrate more on the biology and beauty of
these stinging insects, insects which are an integral and valuable part of the
urban environment.

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