Avoidance of bee and wasp stings: an entomological perspective
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Purpose of review
Clinicians and researchers in allergy and immunology are often unaware of aspects of stinging insect biology that would be of practical interest to their patients. This review discusses entomological literature pertaining to avoidance of bee and wasp stings, with emphasis on risk factors associated with provoking individual foragers versus disturbing colonies and preventive measures for both circumstances.

Recent findings
Recent work pertaining to sting avoidance has mostly been concerned with the development and testing of attractants, insecticides and delivery systems for toxic baiting programs to control vespine wasps.

Summary
Sting risks and avoidance measures associated with bee and wasp foragers are different from those posed by disturbing colonies. Despite widespread advice to the contrary, no evidence currently exists that wearing perfume or bright, floral-colored clothing elevates sting risk. Foragers usually have to be firmly touched before they will sting; therefore, personal protection largely involves guarding against accidental direct contact. Although still under development, the most effective means for reducing local populations of foraging vespine wasps are toxic baiting programs. Preventing stings from colonies is more problematic and depends mostly on personal awareness when disturbing vegetation. The most effective measure in mitigating the severity of a mass attack is probably the wearing of white or light-colored clothing.

Keywords
bees, colony control, social insect defense, sting avoidance, toxic baiting, wasps

Introduction
Although instruction on prophylactic measures is clearly appropriate for patients suffering from Hymenoptera sting anaphylaxis, surveys suggest this critical information is not being routinely delivered, particularly in acute care settings [1–3]. Much of the primary entomological literature pertaining to realistic avoidance of bee and wasp stings, however, is not consulted by allergists and clinical immunologists, and several misconceptions have become widespread throughout the medical community.

Stings from individual workers
Bee and wasp stings occur under two distinct sets of circumstances. The first involves encounters with individual workers away from their nest that are foraging for food, water or building materials.

Wardrobe and cosmetics
Public information literature distributed by the allergy/immunology community often contains advice concerning wardrobe and cosmetic selection to minimize the chances of being stung. A representative example of this guidance states ‘Many stinging insects are foraging for food, so don’t look or smell like a flower – avoid brightly colored clothing and perfume when outdoors’ [4].

In fact, no empirical evidence exists that perfume or bright, floral-colored clothing significantly increases a person’s attractiveness to foraging Hymenoptera, much less the risk of getting stung by them. Orientation to flowers by honey bees is governed by a complex suite of integrated factors that include floral colors, patterns and shapes, specific floral odors supplemented by multiple olfactory cues provided by the local environment, and the recent foraging history of individual workers [5–7]. Unlike humans, bees are most sensitive to the short-wavelength end of the spectrum, particularly ultraviolet light, followed by blue–violet and green. They are least sensitive to orange and cannot perceive red [5,6]. As a result, flowers that depend on bees for pollination typically have evolved distinctive ultraviolet patterns that are highly visible to the insects but are often not perceived by humans [5,8]. The bottom line for the public is that the search image of foraging bees is unlikely to be triggered by a large patch of colored cloth that appears bright to humans but has limited or no biological significance to Hymenoptera.

In contrast to apparel, it would seem more likely that some cosmetic fragrances might attract the attention of...
chemicals elicits defensive behavior by this species. Whether or not any specific product incorporating these products that includes alcohols and esters used in food flavorings can be stimulated to attack in defense of their nest, the Vespula mandarinia, which has an alarm pheromone that includes alcohols and esters used in food flavorings and cosmetic fragrances [13]. It is unknown, however, whether or not any specific product incorporating these chemicals elicits defensive behavior by this species.

Risk factors and sting prevention
Due to the ease with which some bee or wasp colonies can be stimulated to attack in defense of their nest, the public often mistakenly thinks of these insects as inherently aggressive under any circumstances. In reality, the ‘rules of engagement’ for social Hymenoptera are rigidly constrained, and stings by individual foragers away from the nest are almost always provoked by firm, accidental contact such as stepping on one, taking it into the mouth with food or drink, or pressing/striking it with the hand. Risk of getting stung is therefore highly elevated in locations where large numbers of bees or wasps have congregated to feed, particularly where humans are doing the same [14–17].

Preventive measures in these circumstances, such as at picnic areas and concession stands, can be grouped into two categories. The first pertains to modifying personal behavior to minimize accidental contact with foragers, with emphasis on maintaining a high level of vigilance as to the presence of bees and wasps in the immediate vicinity, not walking with exposed feet and exercising extreme care with beverages [14,18]. Drinking directly out of cans or bottles presents the greatest risk, as these containers are readily entered by inquisitive foragers which are subsequently concealed from view. Tightly lidded cups with inserted straws are often recommended as safer than open cups, but do not totally exclude entry by the smaller species. Despite advertising claims to the contrary, there are currently no effective repellent products for foraging bees or wasps, although observations that orange peels [12], a Meliaceae extract [19] and a bitter chemical from watermelons [20] repel foraging Vespa suggest promising avenues for research. Depending upon the extent of a patient’s concern, the most appropriate advice might be simply to not eat or drink outdoors during the warm months.

The other approach to preventing stings associated with foraging bees and wasps involves implementing measures to reduce the number of foragers. One method is to minimize local sources of attraction, such as tightly covering food and waste receptacles, frequent cleaning of food residues, frequent removal of refuse, fallen fruit and dog or other animal feces (as the attendant flies are hunted by some wasp species), and elimination of landscape plantings that attract large numbers of carbohydrate-seeking Hymenoptera [14,17,18].

Another tactic is to attempt to reduce forager populations with the use of baits, either by luring the insects into traps or as a means to deliver a pesticide. Numerous models of wasp traps are on the market [21,22], but unless very large numbers are deployed and continually serviced, they tend to be swamped by the constantly replenishing colonies within foraging range and are therefore of dubious value in most circumstances [21,23,24]. Toxic baiting programs hold the greatest promise for success but their methodology is still under development to solve the challenges of affordability, insecticide efficacy, exclusion of non-target species and sustainability of bait attractiveness [11,25–27]. The quest to discover durable, highly effective artificial attractants with efficient dispensing systems is currently one of the most active fields of applied vespine research [11,28–33].

Stings from colonies
In contrast to the pressure of direct contact needed to provoke stinging from most individual foragers, group defensive behavior by a social wasp or bee colony may be elicited by considerably more subtle stimuli – typically some abrupt movement of the nest (often due to vibration of its immediate surroundings) but, in some cases, just nearby motion, the approach of a dark object or mammalian breath [17,34–36]. Consequences for the human or animal source of the disturbance are usually far more severe than those from an encounter with an individual forager. Mature colonies of some species are potentially capable of delivering hundreds or even thousands of stings almost instantaneously [35].

Arousal thresholds and intensity of aggressive response varies widely among social Hymenoptera and are dependent on species (or subspecies and even finer degrees of genetic lineage in the case of honey bees) and a colony’s age, size and past history of disturbance [17,34,36,37*]. The major problem universally posed by these insects is the cryptic nature of their nests, many of which are concealed in cavities above or below ground. Even large nests in vegetation or attached to structures are typically obscured by foliage, overhangs or shadow and can escape detection even at close range [36].

Common sources of stings
Three common sources of bee and wasp stings prevail in the United States. Polistine wasps, commonly called
paper wasps, have small colonies of usually no more than a few dozen workers, but their nests can be extremely abundant around human habitations. The most pestiferous species is the recently arrived Polistes dominulus – an invasive Old World wasp that nests in both exposed and protected locations, including readily disturbed structural cavities such as hollow fencing, light fixtures and playground equipment [38–42].

Vespine wasps, commonly called yellowjackets or hornets, are generally considered to be the most common source of stings, due to their abundance, aggressiveness and relatively large colony size (up to several thousand workers) of some species [17,43]. Colonies typically have a single queen and last for one season only. In areas with mild winters, including Florida, California and Hawaii, however, multiple queens may inhabit the same nest and produce enormous perennial colonies with a high potential for mass stinging [44–46].

Although honey bees are often invoked as a sting hazard, accidental disturbance of feral colonies in the United States was rare until relatively recently, because nests were typically located within tree cavities or structural voids [47,48]. The arrival of Africanized bees (Apis mellifera scutellata) in 1990 markedly increased the stinging risk for people and domestic animals in several southwestern states, as this subspecies has an extremely low defensive response threshold, is capable of some of the most severe attacks known for any social insect, and establishes nests in a wide variety of locations that are subject to human disturbance [37,49–51].

Risk factors and sting prevention
Preventive measures if a social wasp or bee nest has been detected in an undesirable location normally involves killing the workers. Although insecticide products labeled for stinging insects are readily available to the general public, we strongly feel this activity should never be attempted by anyone who has not received specialized training and is not equipped with protective clothing [14,15]. Precise methodology of nest control operations is highly variable, depending on species and circumstances. The process often requires extensive experience to protect the safety of bystanders, and, in some cases, a vacuum is recommended to reduce the number of workers prior to applying insecticide. Despite wide interest in chemical-free methods of pest control, total replacement of pesticides with vacuums is not feasible in many situations. In general, rapid-knockdown aerosols are the most efficient formulations for exposed nests, while dusts are considered best for nests in cavities. It is not unusual for the initial treatment of a large colony to be only partially successful [52,53].

As it is the undiscovered colony that is the most hazardous, and as a concealed bee or wasp nest may be encountered virtually anywhere, the single greatest risk factor for multiple stinging by a disturbed colony is simply being outdoors in a spot where other humans do not frequently go. This typically implies somewhere with vegetation, so the more time spent in natural areas – particularly off well-established paths – the higher the risk. For people who live and work in developed locations, activities in parks, yards or gardens are most likely to bring them into accidental contact with a nest. Those activities producing vibration and disturbance to vegetation, such as walking or playing with a dog or mowing, pruning and string-trimming are most likely to result in stinging [17,35]. In particular, gasoline-powered lawn mowers have the distinction of being perhaps the most efficient means for stimulating wasp or bee colonies to attack. Producing noise, vibration, odors and heat, these machines have been termed ‘the perfect predator’ from the insects’ point of view [35].

Personal rescue actions
Outdoor activities are either difficult to avoid or highly pleasurable for many people; therefore, the most useful advice often involves a few common-sense guidelines for personal behavior once a nest is disturbed [35,54]:

1. If only a few bees or wasps are flying around you, slowly walk away from the area without flailing the arms. Sudden motion often exacerbates attack behavior and increases the chance of accidental contact.
2. If many insects suddenly start to fly around you, or if you are being stung, run from the area without delay and cover your mouth and nose while running. Stinging insects tend to target the facial area, which can quickly produce panic and disorientation in the victim.
3. If possible, seek shelter in a building or enclosed vehicle.

Mitigating the severity of attacks
Few readily deployed measures that might mitigate the intensity of colony defense behavior are available. Attacking bees and wasps are strongly attracted to dark colors (one reason why eyes, mouth and nostrils are selectively targeted), so white or very light-colored clothing that covers most of the body should confer some advantage [54,55]. Although it has been suggested that an aerosol spray of the common insect repellent N,N-diethyl-m-toluamide (DEET) is effective at decreasing the magnitude of mass honey bee attacks [56], other research has not shown any meaningful effect [57]. In fact, one repellent product (Repel X, Farnam Companies, Phoenix, AZ) actually stimulated a more severe attack response [57]. On the other hand, an intriguing report of...
human sweat-mediated protection against colony defense by a tropical wasp species [58] merits further investigation. Smoke has been shown to reduce defensive behavior in both honey bees and yellowjackets [55], although this would seem to have limited practical value in an unexpected confrontation. Persons with outdoor occupations that present an elevated risk for disturbing colonies have the option of carrying at least minimal protective equipment with them (e.g. a compact mesh veil to cover the head), and firefighters in natural areas are urged to take refuge in a personal fire shelter (a standard protective item made from aluminum foil, fiberglass and woven silica) in the case of severe stinging insect attack [54].

Conclusion
Despite progress in refining toxic baiting programs for area-wide abatement of foraging wasps, it is likely that these and other stinging insects will remain a common part of the outdoor experience for most people. In view of the current lack of effective methods to repel bees or wasps that are either attracted to food or defending their nest, personal awareness and avoidance of situations presenting a high sting risk remain the most important preventive measures.

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References and recommended reading
Papers of particular interest, published within the annual period of review, have been highlighted as:
• of special interest
•• of outstanding interest
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