

Occupational Inhalant Allergy to Arthropods

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INTRODUCTION

The first report of an occupational disease attributed to an arthropod was that of Ramazzini, who noted in 1713 that the "terrible cough and serious difficulty of respiration" among silk carders was caused by "the small fragments of dead silkworms that are scattered all through the silk rolls" (1). It was more than 200 years later that the next report appeared (2). Since then, evidence has accumulated that insects and other arthropods are a source of inhalant allergens and not only can they be the cause of occupational allergies but they also give rise to allergic conditions in the general population (3).

Arthropods possess unique characteristics that contribute to the release of large amounts of allergens that readily become airborne in dry environments. This review will concentrate on the sources of inhalant allergens derived from arthropods to which people are exposed in the course of their work.

ARTHROPODS

The diverse animals known collectively as arthropods are classified in the phylum Arthropoda. They are characterized by

an exoskeleton, a body showing segmentation and bilateral symmetry, and jointed appendages. The possession of an exoskeleton that gives the animal its form and that can be hardened or armored to provide protection requires that the animals grow by molting. The old exoskeleton is discarded as an *exuviae*, allowing the newly emerged animal to enlarge before the new exoskeleton hardens. The phylum is divided into several classes of which the 3 largest concern us here; the Insecta, the Arachnida, and the Crustacea.

Insects have a body divided into head, thorax, and abdomen. In the adult, the thorax possesses 3 pairs of legs, and may have 1 or 2 pairs of wings or be wingless. In some groups, such as moths and beetles, the larval forms (caterpillars and grubs, respectively) undergo a complete metamorphosis before emerging as the adult or *imago*. In others, e.g., cockroaches, silverfish, each larval stage becomes progressively more like the adult so that there is no abrupt change in form. Insects live in terrestrial and aquatic habitats and exploit a huge variety of foods both of plant and animal origins.

The arachnids include spiders, scorpions, and mites and ticks. They all possess 4 pairs of walking legs, are always wingless, and all exhibit gradual metamorphosis. Spiders and scorpions feed on small animals. Mites are mainly phytophagous but many are predatory or parasitic.

Crustaceans are predominantly aquatic and include large forms such as crabs and lobsters as well as smaller types like brine shrimps and water fleas (*Daphnia*). They are equipped with gills and several to many pairs of legs and other appendages.

Most areas where people live and work are occupied by several to many of the incredible variety of species in this phylum. Some species may be present in enormous numbers and have major effects on other forms of life.

Source of Allergens

For an arthropod to become the cause of inhalant allergies, the allergens must be capable of becoming part of some respirable dust or aerosol. Proteinaceous products of terrestrial arthropods that can provide allergens in this form are the hairs, setae, and

scales that cover many insects and that are shed more or less readily, the dried exuviae, the fragmented bodies of the dead animals, and metabolic products; feces, secretions such as venoms, and silks that are produced by spiders, many insects, and some mites.

The hairs of caterpillars of some families of Lepidoptera possess urticating properties. Contact of the skin or other tissues with these produces an immediate irritation that can be severe. Continued exposure can lead to sensitization and allergic conditions (2). Studies have shown that the initial injuries are more than merely mechanical and that toxins are present in many cases (4). In some moths the scales (*flechettes*) that cover the body can also produce irritation and injury to the skin (4). The larvae of carpet beetles possess special hairs that are strongly irritating and also allergenic (5). American members of the spider family Theraphosidae have bodies that are covered with urticating hairs (6). The hairs on many other species of insects are intrinsically innocuous in that they do not possess any toxic effect but they still have allergenic capabilities.

The scales that are so readily discarded by many species of moths are an obvious source of potential allergens, but many insects such as locusts, cockroaches, crickets, and silkworms, which do not possess hairs or scales, are also highly allergenic. The movement of caged active insects such as moths, grasshoppers, or flies results in the spread of dusts beyond the cage (7).

Exuviae have been shown to be a major source of allergens for mayflies (8), cockroaches (9), carpet beetle larvae (10), and wasps (11), and it may be expected that the dried and fragmented *exuviae* of many other kinds of arthropods will prove to be similarly allergenic.

The role of feces has been emphasized for dust mites (12), locusts (13), fleas (14), and mentioned for other species. If the feces were merely the waste products after digestion of food it would be difficult to explain any specific activities. Edge and Burge (15), employed an immunofluorescence technique to study the site of production of allergen in the locust *Schistocerca gregaria*. Their results showed that allergen was present on the cuticle but the main sites of production of the allergen were found to be the epidermal cells of the midgut and the associated gastric caeca.

These cells are also the site of production for the peritrophic membrane, which travels through the gut and is expelled with the feces. These authors suggested that it is the peritrophic membrane that is the source of the specific allergens associated with the feces of this species. A similar study on *Dermatophagoides pteronyssinus* showed that in this animal, too, the gut was the major site of production of antigens (16). Peritrophic membranes are produced by most species of insects (17). Wharton and Brody (18) showed that a similar membrane is present in dust mites, and raised the question of its allergenic capabilities in humans.

INSECTS

The occupations in which allergies to insects occur are varied. One group of occupations involves people who work directly with insects. The insects are reared for study, for release in biological control programs, as animal feed, or for other commercial reasons. Another group of occupations involves persons who encounter insects in their work environment. Many of these work areas are adjacent to waterways, from which large numbers of insects emerge at certain times of the year. In a third group of occupations, the exposures are to insects that are present in or that have contaminated the material being worked with. In some cases, the presence of insects may not be obvious or even suspected.

It is among workers with insects that the majority of work-related allergies have been diagnosed. For this review, the definition of entomologist shall be made broad. It will include those persons who study insects as insects; *taxonomists*, *behaviorists*, *ecologists*, and so on; those persons studying insects for the purposes of pest control; *toxicologists*, *developers* and *practitioners* of biological control programs with insects as the agent or the target; and those persons who find insects convenient small animals in which to study life processes; *physiologists*, *geneticists*, *biochemists*, *biologists*, *zoologists*.

Much of the available information comes from three surveys conducted among entomologists; two conducted in North America and one in Australia. The first American survey (19), and the

Australian survey (20), that followed it, were based on returns of questionnaires distributed through the respective national entomological Societies. The second American survey was conducted by the National Institute of Occupational Safety and Health (NIOSH) in laboratories of the US Department of Agriculture (USDA) where insects were reared (21). In these three surveys, insects from 9 orders as well as mites and spiders were named as the sources of allergic responses. More than 110 species were identified, and although not all of these were the cause of inhalant allergies, about three-quarters of the respondents attributed the cause of their problems to airborne material.

In the two North American surveys, various moths were named in almost two thirds of the reports. Most of these allergies developed in persons whose job it was to rear the moths or who otherwise experienced intimate contact with the adults. Allergies to moths were also recorded in the Australian survey (20), although not to the same extent, and some have been reported from France (22), Canada (23), and the USSR (24).

Various species of grasshoppers and locusts have proven troublesome in several laboratories around the world. Frankland reported on workers from four institutions where locusts were studied and recorded several persons with rhinitis and asthma (13). A followup study in one of these institutions 27 years later found that, of the staff who worked with locusts, 26% had occupational asthma and one third had rhinitis and/or urticaria (25). An even higher sensitization rate was recorded in a research team in Germany, where, within 1–2 y, all nine persons manifested symptoms affecting the eyes and the respiratory tract (26). In one person, positive skin tests were obtained even at a dilution of 10^{-10} . Other reports of occupational allergies to locusts have come from Holland (27), France (28,29), the US (19), and Australia (20). Allergy has also been reported in an entomologist whose exposures were to locusts in the field (30).

Several species of Diptera (flies) have been implicated; screw-worm in the US (19), blowflies in Australia (7), vinegar flies in Holland and Australia (31,32), mosquitoes and houseflies in the UK (33,34), black fungus gnats in Australia (32), and nonbiting midges in Germany (35). In this last example, biochemists studying the hemoglobins from the larvae were affected.

Granary weevils, *Sitophilus granarius* (36), a grain borer, *Rhyzopertha dominica* (32), dermestid beetles (37,38), and parasitic wasps (24,39), have also been recorded as sources of inhalant allergies in entomologists.

In the NIOSH survey, the incidence of allergic conditions among persons who were directly exposed to insects was 33%. Similar figures were recorded for workers with locusts (25), and with *Drosophila* (31), and although lower and higher sensitization rates have been recorded, a figure of 30% seems to be fairly typical among those people who experience direct exposures to insects.

Honeybees can produce inhalant allergies in beekeepers through their exposure to "bee dust" (40-42). Similar allergies have been observed in persons associated with a honey treatment plant (43,44), and in workers extracting bee venom, who, in addition were affected by the dried venom (45).

The production of silk has induced respiratory disease in persons exposed to the larvae, the pupae, and the adults (46,47), as well as among persons who wound the silk from cocoons (48).

A variety of insects have been reared for sale as food for pets and also as bait for fish. Freeze-dried bloodworms (*Chironomus* larvae), prepared as food for fish, have proved a particularly potent source of allergens (35). Breeders of insects as fish bait, blowfly larvae (49), waxmoth larvae (50), and crickets (51), have succumbed. Crickets reared as frog food produced allergies (52), and Rudolph et al. give an extensive list of pets and animals whose feed has provoked allergies among persons handling it (53).

Table 1 shows a list of occupations where the exposures to insects and mites were incidental to the work. These include persons whose workplace provides breeding sites for insects, e.g., ponds or rivers (Entries 1-3), who work where insects are stored, distributed or sold (4-8), who are exposed to insect derived materials (9-12), who work in areas where they are exposed to flights of large numbers of insects (13-16), who work with food contaminated with insects (17-22), or who work with animal or plant products infested with insects (23-26).

MITES AND SPIDERS

Dust mites (*Dermatophagoides* spp.) are a widespread cause of inhalant allergy, and it must be expected that, under some circumstances, the exposures could be associated with the work. It would be very difficult, however, to show that these occupational exposures were the only ones that provoked the allergic reactions. More clearly occupationally-derived are exposures to the various storage mites, which, as their name suggests, are found on stored vegetable and animal products. Allergic reactions in workers with mite-infested products are well known although commonly the symptoms are those of contact allergies (96). However, Wraith et al., implicated mites of the genera *Acarus*, *Tyrophagus*, and *Glycyphagus* in allergic respiratory disease and found that the skin test results were related to certain occupations or living conditions of the patients (97).

It must be remembered that mites are small animals; most of them are less than 500 micrometers in length. In a study of the mite fauna of barns in Scotland, the number of mites floating in the air over a one-h period during and after the feeding of cattle with hay reached 805 mites/1000 L and was never fewer than 48 (98). Furthermore, it has been shown that the fecal pellets of *Dermatophagoides pteronyssinus* contain more than 95% of the major allergen associated with this species (12), and the feces of other mites could be similarly allergenic.

Occupations associated with farming and poultry raising provide all of the examples of allergies to mites (Table 1). Phytophagous mites were responsible for entries 27–30, whereas mites parasitic on poultry and grain moths were responsible for entries 31,32.

Panzani recorded a surprisingly large number of people with sensitivities to the spider *Tegenaria domestica*, and, although it is not recorded whether any were occupationally induced, it does indicate the possible significance of spiders as a source of allergies (99). Spiders silks (cobwebs) as occupational allergens have been recorded among *priests*, *storemen*, and *laborers* by Mariani (84), and from an entomologist by Wirtz (19).

Table 1
List of Occupations and the Agent Responsible
for the Allergic Condition Recorded for the Occupation

Occupations	Agent	Reference
1 sewage treatment workers	<i>Psychoda</i> spp. (moth flies)	(54) (55)
2 power station workers	<i>Tanytarsus</i> sp. (nonbiting midges)	(56)
	Mayflies	(57)
3 forestry workers	<i>Orgyia pseudotsugata</i> (tussock moth larvae)	(58)
4 warehouse workers	<i>Tenebrio molitor</i> (mealworm)	(59)
5 shopkeepers	<i>Calliphora</i> sp. (blowfly larvae)	(49)
6 aquarium workers	<i>Chironomus plumosus</i> (bloodworm)	(60)
7 technician	<i>Chironomus</i> sp. (bloodworms)	(61)
8 packers dispersers pilots	<i>Cochliomyia hominivorax</i> (screw-worm)	(62)
9 silk weavers	<i>Bombyx mori</i> silk	(63)
10 process worker	<i>Dactylopius coccus</i> (cochineal insect) carmines	(64)
11 cosmetics blender	carmines	(64)
12 food factory workers	carmines	(65)
13 hospital workers	<i>Cladotanytarsus lewisi</i> (green nimitti)	(66)
14 rubber plantation worker	<i>Psychoda</i> sp. (moth flies)	(67)
15 factory workers	caddisflies	(68)
16 farmer	locusts	(69)
17 bakers and pastrycooks	<i>Ephestia kuehniella</i> (Mediterranean flour moth)	(70,71,72)
	<i>Tribolium castaneum</i> (rust-red flour beetle)	(73)
	<i>Sitophilus granarius</i> (granary weevil)	(74)
	cockroaches	(71,72)
	silverfish	(71)

Table 1 (continued)

Occupations	Agent	Reference
18 millers	<i>Ephestia kuehniella</i>	(70)
	<i>Sitophilus granarius</i>	(74,75)
19 transporters and packers	<i>Ephestia kuehniella</i>	(71,76)
20 growers and farmworkers	<i>Ephestia kuehniella</i>	(70,77,78)
	<i>Sitophilus granarius</i>	(79)
21 grain bin cleaners	<i>Liposcelis bostrychophilus</i> (psocid)	(80)
22 seed sorters	<i>Zabrotes subfasciatus</i> (bean weevil)	(81)
23 hairworkers	"small insects"	(82)
24 featherworkers	moths	(82)
25 waterside workers	<i>Dermestes frischii</i> (dermestid beetle)	(83)
26 antiquarians restaurateurs interior decorators	woodworm	(84)
27 farmers dairy farmers	storage mites	(85-89)
28 farmers grain handler mill workers	grain mites	(78,90,91)
29 greenhouse workers researcher	<i>Tetranychus urticae</i> (spider mite)	(20,92)
30 fruit pickers	<i>Panonychus ulmi</i> (red mite)	(93)
31 poultry workers	<i>Ornithonyssus sylviarum</i> (fowl mite)	(94)
32 farmer	<i>Pyemotes tritici</i> (hay itch mite)	(95)

It is not surprising that examples of such allergies have been reported from the food processing area. In the processing of the Norwegian lobster, *Nephrops norvegicus*, an air jet was employed to separate flesh from the exoskeleton. This process generated an aerosol. The various symptoms of allergy among workers in the factory were attributed to the breathing in of allergens contained in this aerosol. When a water jet was substituted for the air jet the concentration of airborne meat fragments was reduced ten-fold and the symptoms disappeared in 15 of the 18 workers affected (100).

Respiratory problems have been reported from crab-processing factories in the US and Canada. In Alaska, an outbreak of dyspnea and wheezing was observed among workers during the crab-processing season. The exposure to crab allergens followed the inhalation of steam from the crab-cooking vats (101). A study into respiratory problems of the workers in Canada failed to identify the causative factor, but it was shown that it was a "volatile" component of the crabs (102).

Water fleas (*Daphnia* sp.) were the cause of asthma in two workers in a fish food store. The two sieved, mixed and filled packages with fishfood that contained dried waterfleas (103). Sensitivities to *Daphnia* have been reported in users of such fishfood (104).

CONTROL AND PREVENTION

In attempting to control exposures to arthropod derived allergens, particularly when people are working with insects, consideration must be given to some special features of these animals. Flying or jumping insects can release many scales and hairs, and, since insects are often reared in large numbers, considerable amounts of allergens are generated. The growing larva produces 4 or more exuviae and large amounts of feces containing specific proteins. When dry, these exuviae and feces can be broken readily into small fragments. The feeding activity of insects in dry foods, like grains, produces a fine "flour" that is contaminated with insect metabolic products. Some insects are capable of releasing reactive chemical compounds like ammonia,

phenols, and quinones. Many mites are so small that the living animals can become airborne, and, thus, inhaled. All of these aspects must be addressed in designing techniques to reduce exposures to insect and mite allergens.

Successful control strategies have 4 elements; changes in work practices, installation of engineering controls, the provision of personal protection devices, and education of workers and supervisors.

Work practices should be designed to minimize the production and release of dusts and to eliminate hazardous procedures. Cleaning methods are often a major cause of exposures. One particularly hazardous entomological technique is that of mouth aspiration or "pooting," which can deliver allergens deep into the lungs (33).

The various engineering controls employed include exhaust hoods and capturing nozzles to remove dust as it is created, enclosures to separate the sources of dust from the workers, and filters to remove dust from contaminated air before it is returned to the room (105).

The efficacy of air purifying helmets in protecting persons working with small mammals has received a favorable report (106), and in this author's organization, these devices have allowed persons sensitized to blowflies and grain borers to work without eliciting symptoms of allergy.

For more detailed discussions on the various techniques employed to control exposures of workers with insects to inhalant allergens, the reader is referred to the reports by Wirtz (19) and Bauer and Patnode (21), and to the two reviews by Wolf (105, 107).

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