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What's Bugging You?

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My wife and I spent a week in Mexico this spring and stayed at a small bed-and-breakfast. While packing to leave, I lifted a shirt from the dresser, and a cockroach dropped out of the shirt onto the floor. I was horrified, but I reacted quickly enough to squash the interloper flat.

Needless to say, when we arrived home, our luggage did not enter the house without careful scrutiny of the contents first!

It's not only small hotels in foreign countries that are being plagued by pests. Last year, the Helmsley Park Hotel in New York City had to settle with a Mexican businessman who suffered numerous bedbug bites in the hotel.

He further alleged that the infestation followed him home in his luggage to Mexico. (Tit for tat, I suppose.)

Unlike cockroaches, which have been a persistent problem in urban apartments, bedbugs were virtually unseen for decades. They are currently making a comeback, which theorists attribute to reductions in pesticide use. Bedbugs feed on their hosts – sleeping human beings – at night. A bedbug harborage is usually located conveniently near the food source – in mattress crevices, bed frames or floorboard gaps near the bed or behind wall hangings. About a quarter to three-eighths of an inch long, bedbugs are attracted to the heat, moisture and exhaled carbon dioxide; they suck blood out of the host and then lumber off engorged, leaving behind them itchy bites that swell.

Bugs, whether visible or microscopic, are not welcome guests – with the possible exception of spiders, which some people believe are signs of good luck. (Of course, I disagree, but I'll say more about this later.) Mosquitoes, sucking head and pubic lice, and chiggers and scabies have plagued mankind for millennia. Their bites can itch and cause rashes and other skin problems. In addition, we can unsuspectingly inhale allergen-containing fragments of body parts and excretions of any type of insect. The fecal material of non-biting bugs like mites and cockroaches often contains digestive enzymes such as proteases, many of which are potent allergens. Protease-activated receptors are on the surfaces of many cells, and activation of these is responsible for some of the cellular responses and,

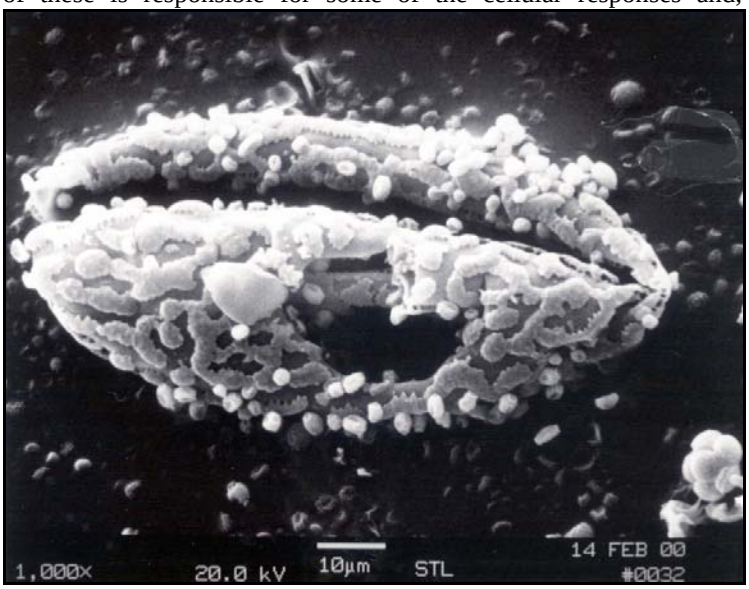


Photo courtesy of May Indoor Air Investigations
This mite egg case, surrounded and coated with *Aspergillus* spores, was collected via a tape sample on a basement floor.

ultimately, the physiological symptoms resulting from allergen exposure.

Excretions

For barely visible organisms – such as mites, which range from 100 to 350 microns in size – the fecal pellets are microscopic. For larger visible bugs like roaches and wool moth larvae, the pellets are visible. Some excreted matter is mushy; other excretions are virtually solid. Bugs with high-protein diets (e.g., house dust mites, which eat skin scales; wool moths and carpet beetles, which eat keratin from hair; or spiders, which imbibe proteinaceous fluids) cannot excrete excess nitrogen in soluble form (such as animal urine, which has dissolved urea containing two nitrogen atoms per molecule) because the organisms cannot afford the relatively huge water losses required to solubilize the urea. Whether solid or mushy, fecal excretions are often coated or filled with guanine (a highly water-insoluble organic compound, containing five nitrogen atoms per molecule).

If you look under a spider web, you will find sucked-dry bugs, sliced from the web by the spider's "housecleaning." You will also find many white dots, looking like paint spatters, one 16th to one eighth an inch in diameter, often with dark centers. Around a decimated carcass of a moth or bee, you may find brown rings of dust that are the frass of a carpet beetle larva. (Each pellet contains partially digested bites of the meal.) Under a rug consumed by wool moth larvae, you will find colored dust, which are the frass of these creatures. Each individual pellet contains approximately equal-sized lengths of partially digested wool fibers that still retain the color of the original fiber.

(Once, I was quite excited to discover that I was not alone in my arcane interest in bug stuff. I received a call from a New York City police lab that was trying to identify a decomposed body. Apparently, carpet beetle larvae had turned the victim's hair to frass, which, for those of you without a dictionary, is "debris or excrement produced by insects" according to Merriam-Webster). The inquiry pertained to the feasibility of determining the hair dye used by the victim. I advised them to obtain an infrared spectrum of the fecal material, as this would provide the needed information, since most of the hair, though fragmented, was intact.)

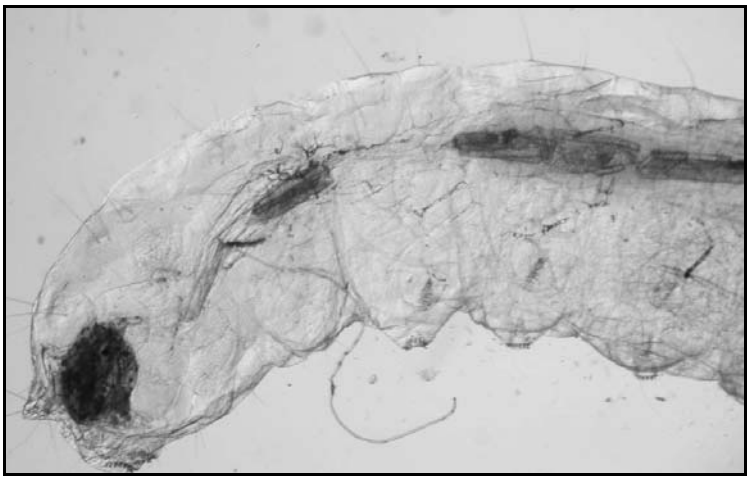
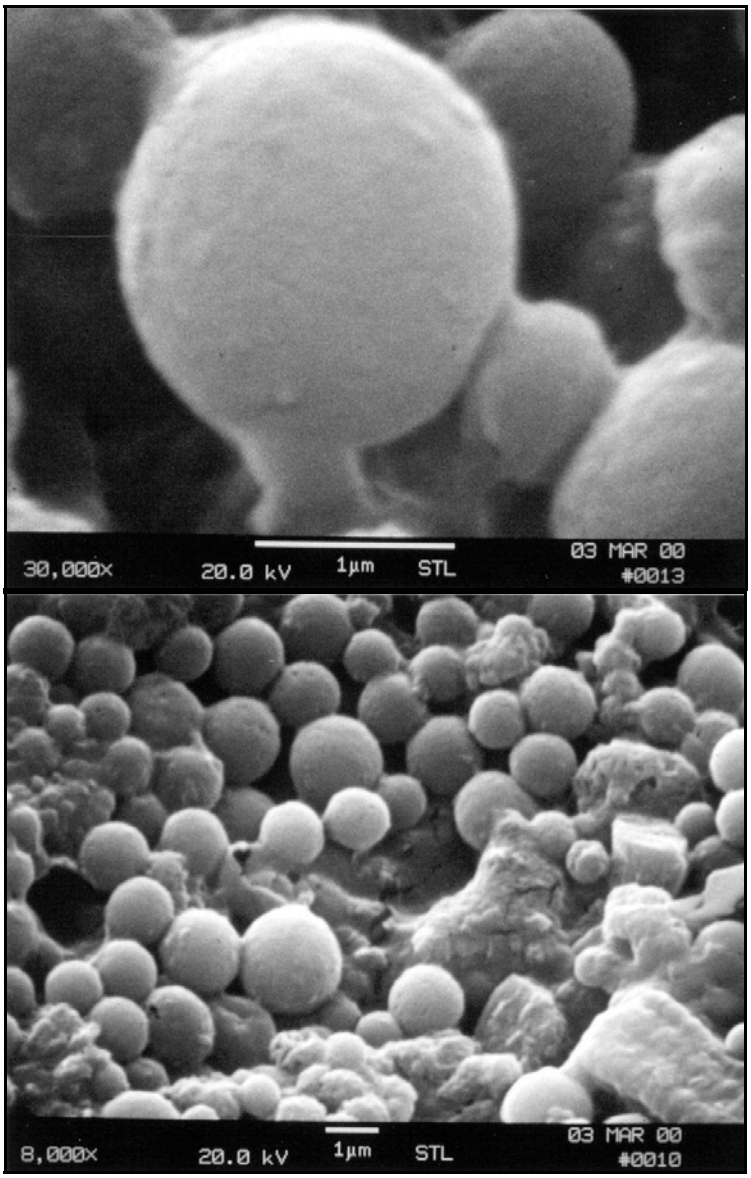


Photo courtesy of May Indoor Air Investigations

Taken from the far end of a larva, this light photomicrograph is of a wool moth. Fragments of wool fibers are visible in the digestive tract. At the left end is a fecal pellet full of partially digested fibers.



Photos courtesy of May Indoor Air Investigations

These scanning-electron micrographs of larval fecal pellets at low (8,000×) and high (30,000×) power illustrate spherules of guanine on pellet surfaces, which become aerosolized.

The fecal pellets of a house dust mite, or HDM, are typically 10 to 25 microns, which makes them small enough to become aerosolized but big enough that they settle out of the air within seconds to minutes. Since the intact fecal pellets are not found in air unless surfaces are disturbed, dust rather than air is sampled for mite allergens. (However, A. Woodcock and others in 1999 determined that about 20 percent of aerosolized mite allergens are carried on particles with sizes between one and four microns; in addition, mites

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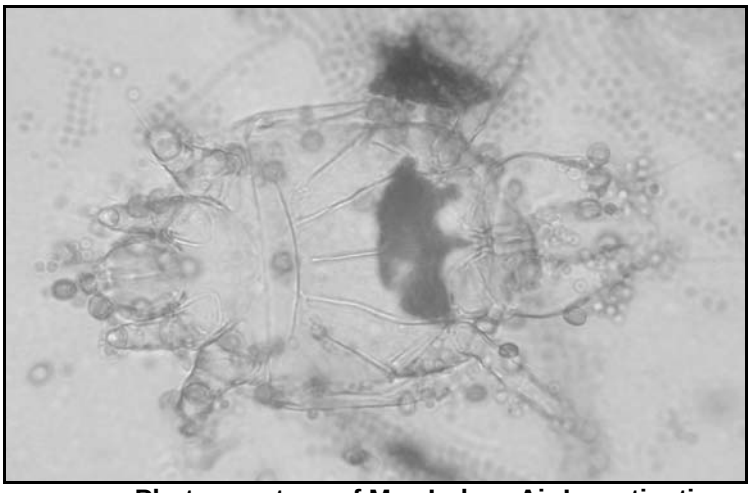

Photo courtesy of May Indoor Air Investigations

This mold-eating mite was collected in a mildew sample.

are allegedly coprophagous, so it is possible that their fecal pellets are reduced in size because the mites gnaw on them.)

Other insect droppings are far too large to be aerosolized whole, but allergens can nonetheless become airborne and be inhaled. For example, the surface of a larval wool-moth dropping is coated with a layer of spherules (probably containing guanine). About a micron in size, these spherules (cemented together by a "mucilage," visible in scanning-electron microscopy) are readily dislodged when disturbed. Spider droppings consist of almost pure guanine crystals (1–3 microns in size), also stuck together by a mucilage. I believe in both these cases, the mucilage contains allergenic proteins.

So, why are spiders not good luck? Since they eat only live insects, having lots of spiders means having lots of other bugs too. If you can't see dried-up insects on the web or under it, the spider is preying on tiny booklice and mites that proliferate in conditions of high humidity and, while alive, leave behind microscopic, allergenic droppings. Thus, extensive networks of spider webs under fiberglass ceiling insulation in a basement or crawl space are often a sign of excess moisture, invisible (extensive) growth of *Aspergillus*, *Cladosporium* or *Penicillium* mold in the insulation and sometimes equally invisible, massive infestations of mold-eating mites.

Are You There?

Since allergens from dust mites and cockroaches are significant causes of asthma, determining (and eliminating) exposures is of utmost importance. (The amount of allergen in a single HDM fecal pellet is enough, during a prick-test, to provoke a weal on the skin of a highly sensitized, mite-allergic individual.) There are readily available tests for HDM and cockroach allergens. Dust is accumulated, usually by a vacuum collection device, and sent to a lab for analysis that uses monoclonal antibodies.

There are also two home tests for HDM allergens in dust. The first (Fisons' "Acarex") detects guanine in the dust, on the assumption that any guanine present in a bed or couch originated from the mite fecal pellets. In the test, methanolic potassium hydroxide (caustic!) and potassium nitrite are used to diazotize the amine nitrogens on the guanine in the suspended dust; a dipstick with reactant is inserted into the suspension, resulting in the formation of a dye in the dipstick, the intensity of which can be compared to a color card that is included.

In my experience, the Acarex test provided too many false positives (though the test may prove more useful as a measure of overall insect activity in dust). Recently, Indoor Biotechnologies has started selling a more precise, rapid "Mitest" that reacts only with specific HDM antigens from *Dermatophagoides pteronyssinus* and *D. farinae*. Droplets of a buffered suspension of collected dust are placed in a well above a nitrocellulose sheet imbedded with reactants. The antigens diffuse down the sheet and combine with the reactants. In a window of the kit, the darkness of an indicator strip is compared to the color of three control strips to determine the presence of low, medium or high levels of antigens.

Determining the presence of HDM and roach allergens is essential, but there are hoards of other bugs, such as booklice, spiders, silverfish, wool moths and about a dozen other species of mites that cohabit in buildings. (Most of these creatures do little more than masticate, fornicate, and defecate.) Exposure to these unwelcome denizens can cause sensitization and exacerbate allergy and asthma symptoms, and yet, there are no readily available tests kits for their allergens (nor do allergists have antigens for prick testing to determine sensitization). So although qualitative and quantitative dust sampling for allergens is important, I believe that indoor samples should also observed by microscopy.

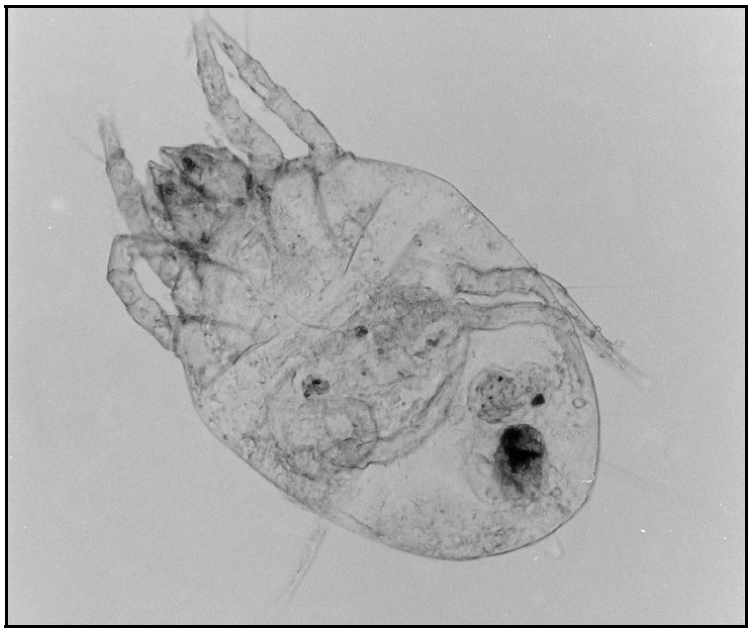

Photo courtesy of May Indoor Air Investigations

This house dust mite was found in the carpet of a residence.

More Forensic Scatology

One of my very first IAQ investigations was in a single-story, slab-on-grade music building in a wooded area at an independent school. Teachers and students would get hoarse during classes and rehearsals. Two teachers who spent the most time in the building were experiencing asthma and allergy symptoms. There was a mildew odor in the building, and a dehumidifier ran constantly.

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I took two vacuum dust samples from the carpet; I sent one to a lab for HDM-allergen analysis, and I observed the other sample with a microscope. The dust contained many, many mite fecal pellets. I reported back verbally to the school that there was a huge mite problem in the carpeting, only to be horrified when the lab test results came back negative for HDM allergens. I was so embarrassed that I never billed the school for the testing.

In hindsight, this proved to be a mistake on my part because, at the time, I did not realize the incredible specificity of the lab testing, which detected antigens only from the two species of HDM. The fecal pellets I had observed in the sample came from mold-eating mites, which did not contain cross-reacting antigens. Thus, building occupants were probably sensitized to mite allergens (and/or sensitized to the mildew growing in the carpet dust) that could not be detected with the analytical test.

In another example of how useful sampling and microscopy can be, several years ago, I purchased an expensive wool sport coat. The jacket never bothered me in the store, but when I wore it at home, I began to cough and wheeze. I placed the jacket in a large garbage bag, held the mouth of the bag tightly around an inverted personal air sampler, and kicked the jacket a few times with the sampler operating. I then stained and observed the trapped dust sample with a microscope. I was shocked to find several HDM fecal pellets.

When dust mites are foraging on skin scales in carpeting, they pick up accumulations like rust and soil particles; when they are foraging in beds, their diet is only skin, and their excreta contain only partially digested skin scales. The HDM pellets from this jacket were quite homogeneous, suggesting a bedroom origin (rather than the retail store). I realized that the jacket must have been purchased and then returned by a customer who had a serious HDM infestation. Dry-cleaning and heat both denature HDM allergens, so eliminating the problem was easy.

Bug BBQ: Steam Vapor

Although there are chemical treatments for carpeting (tannic acid sprays, benzyl benzoate and borate dusts), the safest way to eliminate many bug infestations is with the use of superheated steam, otherwise known as steam vapor treatment. This is very different from either steam-cleaning and washing, both of which use just hot water. When hot water hits a surface, the material is heated as the water cools. The net result is a temperature far below the boiling point of water. When steam vapor hits a surface, the vapor condenses to water at 212 degrees Fahrenheit, after delivering a punch of 540 calories per gram of steam (the heat of vaporization). This temperature is high enough to cook any bug in the path of the steam (and even denature some of the proteins and thus destroy some of the allergens present). Since steam is a gas, unlike water (which is repelled by hydrophobic surfaces), the vapor almost instantly penetrates fabric, carpeting, and even thin cushions. And since very little water is used, surfaces dry within hours rather than days, thus minimizing the chances of ensuing mildew growth.

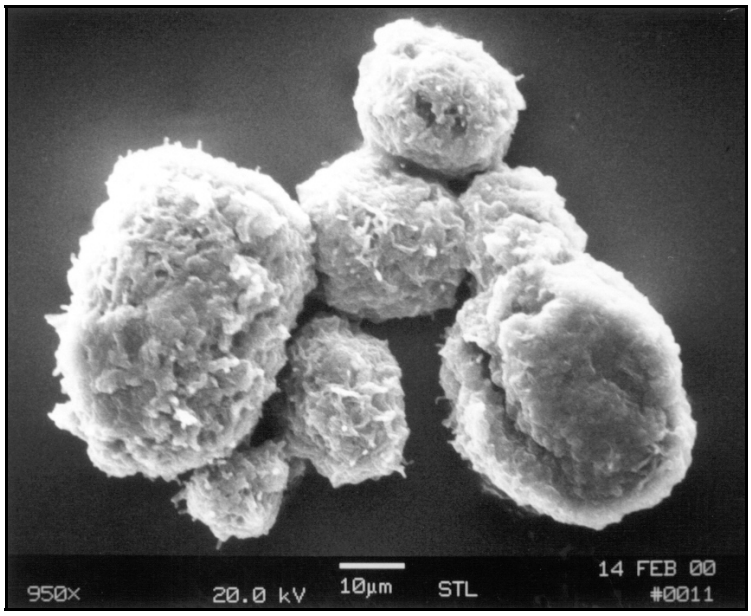

Photo courtesy of May Indoor Air Investigations

The scanning-electron micrograph shows mite feces magnified at 950×.

Conclusions

As you can imagine, my searches for bug fecal material have taken me (donned in a durable protective suit and a respirator) into odd places: an attic filled with thousands of empty moth larval cases and hundreds of thousands of spider droppings, as well as an indescribable crawlspace beneath the leaky kitchen grease trap in a college dorm, where dead roaches and droppings littered the floor, and booklice turned the glue traps solid white. I won't go on, but suffice it to say that some of the sacrifices I have made have been for naught. My precious spider droppings were lost by the lab I sent them to (before they could be tested for antigenicity against a pool of patient serum). And the roach droppings I collected in a plastic sandwich bag vanished from my desk. I had hoped to obtain a scanning-electron micrograph of the sample because with light microscopy, I had seen that the droppings were littered with mite eggs and crawling with mites fornicating under groves of *Aspergillus* conidiophores. The insignificant plastic bag must have fallen from my desk and been scooped into a waste paper basket.

Opportunities like these come up only once in a lifetime!

Jeffrey May is co-author of "The Mold Survival Guide: For Your Home and for Your Health," and author of "My House is Killing Me! The Home Guide for Families with Allergies and Asthma," both published by Johns Hopkins University Press. Currently at the press is his next book, "My Office is Killing Me," which will deal with IAQ problems in offices, schools and businesses. May's company, May Indoor Air Investigations LLC, investigates IAQ problems throughout the United States. He can be reached by e-mail at Jeff@mayindoorair.com or by phone at (800) 686-1055.

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