

The role and allergenic importance of storage mites in house dust and other environments

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Summary

Skin tests were performed on 210 patients with house dust allergy and bronchial asthma or perennial rhinitis using extracts of *Dermatophagoides pteronyssinus* and of four storage mites most commonly found in house dust in the United Kingdom—*Acarus siro*, *Tyrophagus putrescentiae*, *Lepidoglyphus* (formerly *Glycyphagus*) *destructor* and *Glycyphagus domesticus*. The results of the skin tests were related to certain occupations and living conditions of the patients which could have exposed them to storage mites and some patients were included because their environment seemed especially likely to expose them to these species in order to assess the importance of these conditions.

D. pteronyssinus was the most potent of the mite allergens and provoked the largest number of positive tests but a proportion of the storage mite species gave skin reactions which were larger or as large as those of *D. pteronyssinus*. No significant statistical correlation was found between reactions to *D. pteronyssinus* and any storage mite but highly significant correlations were found between some storage species. The frequency and strength of reactions to these species were unexpectedly high in view of their irregular occurrence and relative scarcity in house dust.

It is suggested that sensitisation to these species occurs through exposure either to localised sources of infestation overlooked during the random collection of floor or bedding dust or to infested materials encountered at work or other activities or to infested food or bedding of certain domestic pets. It is concluded that allergy to storage mites is more important and widespread than hitherto realised and is a considerable occupational hazard in farming communities and to those in occupations handling infested materials. Storage mites may also be important allergens for those living in very damp houses where the growth of moulds may encourage the development of *Glycyphagus domesticus* or other mites.

Introduction

Although the role and allergenic importance of *Dermatophagoides pteronyssinus* in house dust was not realised until 1964, when Voorhorst, Spieksma-Boezeman & Spieksma in Holland and Oshima in Japan published their first results, mites have long been associated with allergic disorders of the respiratory tract.

In earlier accounts of suspected mite allergy the species alleged to cause respiratory symptoms had been those associated with the infestation of stored grain, hay and other farm products and the patients affected chiefly farmers, farm workers or those whose occupations involved them in handling or contact with infested materials. In 1923, Ancona attributed outbreaks of dermatitis and asthma among grain workers in southern Italy to the grain itch mite *Pyemotes (Pediculoides) ventricosus*. A year later, a case of severe asthma in a Dutch farmer was reported by Storm van Leeuwen, Brien & Varekamp to have been caused by inhalation of grain dust from oats heavily infested by *Acarus siro* and *Glycyphagus* sp. In a later study, Storm van Leeuwen (1925) wrote that the frequent and severe asthma suffered by Dutch farmers in the van Zeeland islands was caused by exposure to heavily mite infested grain. In Ceylon, Carter, Wedd & D'Abrera (1944), Soysa & Jayawardena (1945) and Carter & D'Abrera (1946) concluded that asthma in patients in two Ceylon hospitals was caused by inhalation of the mite laden dust from bulk stored foodstuffs and other products infested by *Acarus (Tyroglyphus)* spp. and other mites. They considered that the liability to infection was increased in environments such as mills, barns, stores and in ill-kept or dilapidated houses where 'Tyroglyphid' and other mites were often numerous. Taboada (1954) formed similar opinions in Spain.

These storage species, sometimes called grain mites, flour mites, forage mites etc., comprise a wide range of families and species among which members of the Acaridae (formerly Tyroglyphidae) and Glycyphagidae usually predominate. Many are important pests of stored food and vegetable products and occur frequently, sometimes in large numbers, in infested produce in warehouses, granaries, farm storages and food stores. They are also common in houses and other occupied dwellings (Solomon, 1961) where domestic infestations may occur through the storage of infested foodstuffs, e.g. cheese, flour, dried fruit etc., or where damp conditions have caused the growth of moulds on which some species, notably *Glycyphagus domesticus* and a number of Tyrophagus species, are able to feed and develop. Dampness in houses is a common cause of infestations by these species (Evans & Browning, 1955; Solomon, 1961; Rack, 1971).

In the work reported here, 210 patients with house dust allergy and asthma or rhinitis were skin tested with extracts of *D. pteronyssinus* and of the four storage mites commonly found in house dust in the United Kingdom, in order to assess the relative importance of the latter species as sources of allergen and of the conditions and circumstances under which they occur.

Materials and methods

Mite culture

Cultures of *Acarus siro*, *Tyrophagus putrescentiae*, *Lepidoglyphus (Glycyphagus) destructor* and *Glycyphagus domesticus* were reared on a mixture of ground wheat germ or wholemeal flour and dried yeast powder in small glass flasks tightly plugged with non-absorbent cotton wool at 15°C and 75% r.h. The cultures were left undisturbed

until most of the food had been consumed and large numbers of mites had developed. Then both mites and substrate were transferred to freshly plugged clean culture flasks which were kept at 25°C and 90% r.h. in order to hasten mite development and rapid exhaustion of the remaining food supply. Thereafter, each flask was examined twice daily and the mites brushed from the sides of the flasks, using clean sterilised squirrel-hair paint brushes, into petri dishes in which they were killed by exposure to dry heat (55°C) for several hours. The dead mites were then collected in separate labelled specimen jars until sufficient material was available for extract. The *D. pteronyssinus* extracts were supplied by Messrs Bencard Ltd., from cultures of this species reared in their own laboratories.

Preparation of mite extracts

Dead mites (500 mg) were mixed with 10 ml of Evans buffer solution (isotonic saline) and left overnight at 4°C. The solution was then centrifuged and the super-natant filtered through a milipore pre-filter and dialysed against distilled water with four changes over 4 days. A final dialysis was carried out against 0.01 molar ammonium bicarbonate, after which each extract was filtered through a 0.22 milipore filter and made up into normal glycerol extract media to give mite concentrations of 1, 0.1 and 0.01%. The *D. pteronyssinus* extracts were prepared in the same way from purified culture material obtained by air-flotation and elutriation techniques.

Skin tests

Skin prick tests were carried out on the first seventy-two patients (Group A) using 1%, 0.1% and 0.01% extracts of each of the five species. The extracts were coded and the tests were read blind. On the remaining 138 patients (Group B) 1% extracts only were used. A few patients in Group A who gave relatively large reactions to *D. pteronyssinus*, *G. domesticus* and *T. putrescentiae* at the 0.01% level were later tested with 0.001% extracts of these species. The tests were read after 15–20 min when tracings of the weals were made and the mean diameter in mm recorded. Reactions were regarded as positive if the mean diameter was 3 mm or larger after deducting the size of any positive reactions to the glycerol saline solution used as control. Antihistamines were discontinued prior to the tests.

Subjects

All 210 patients suffered from bronchial asthma or allergic rhinitis with perennial symptoms and positive skin test reactions to *D. pteronyssinus* or to storage mites and had been referred to allergy or chest clinics in South East London. The seventy-two patients in Group A included many chosen because it was thought from a knowledge of their environments that storage mites might be playing a part in their allergy. The group comprised forty-two males and thirty females (age range 8–62 years, mean age 32.1 years). Twelve (nine boys, three girls) were under the age of 16 years. The 138 patients in Group B were selected consecutively from those with positive reactions on skin testing to one or more mite extracts. Patients who had undergone hyposensitization or who were receiving corticosteroid treatments were excluded. The group comprised ninety-nine males and thirty-nine females (age range 3–68 years, mean age 24.7 years). Fifty (thirty-six boys, fourteen girls) were under the age of 16 years.

Patients were asked if their homes were damp and if so to assess the degree of dampness present. For about a third of them, the premises were visited and this

information confirmed or supplemented. Patients' occupations, both past and present, were also recorded and particular note made of those likely to have involved patients in a risk of exposure to storage mites.

Results

Group A

For a majority of patients *D. pteronyssinus* was the most potent of the mite allergens and provoked the greatest number of positive skin reactions (Table 1). Only one of the seventy-two patients did not react positively to a 1% extract of this species whereas between 15 and 21 subjects failed to react to the various 1% extracts of the storage mites (Table 1). Indeed, more subjects reacted positively to a 0.1% extract of *D. pteronyssinus* than to any 1% extract of a storage mite. However, the one subject not reacting to *D. pteronyssinus* extract, reacted positively to the 1% extracts of all four storage species producing weals from 5 to 8 mm in diameter and to the 0.1% extract of three of them, producing weals of from 3 to 5 mm diameter. *L. destructor* and *G. domesticus* were the most potent of the storage mites, provoking a greater number of positive skin reactions and larger weals than the other storage species.

Seven patients were allergic only to *D. pteronyssinus*. Four of these gave positive reactions to the 0.01% extract and the rest to the 0.1% extract. Multiple reactions were observed in the remaining sixty-five patients, thirty-five of whom reacted positively to all five species and twenty to four of them. Altogether, thirty-seven patients (51.4%) reacted more strongly (i.e. produced a larger weal) to the 1% extract of *D. pteronyssinus* than to any storage mite extract and thirty-five (48.6%) did not. The latter included twenty (27.8%) who reacted more strongly and fifteen (20.8%) who reacted equally as strongly to at least one and usually to more than one of the storage species extracts than to *D. pteronyssinus* extract. Taken by species (Table 2), six subjects (8.3%) were more sensitive to *A. siro*, eight (11.1%) to *T. putrescentiae*, fifteen (20.3%) to *L. destructor* and eighteen (25%) to *G. domesticus*. With the exception of *G. domesticus*, the mean diameter of weals for each dilution of extract was always larger for *D. pteronyssinus*. *G.*

Table 1. Frequency of positive skin reactions and mean and maximum weal sizes of positive reactions on prick testing with extracts of five mite species. (Group A; all patients (seventy-two) tested to all concentrations)

Species	Test extract								
	1%			0.1%			0.01%		
	No. of patients positive	Weal diameter (mm)		No. of patients positive	Weal diameter (mm)		No. of patients positive	Weal diameter (mm)	
		Mean	Max.		Mean	Max.		Mean	Max.
<i>D. pteronyssinus</i>	71 (98.6%)	8.96	15	64 (88.9%)	6.16	12	42 (58.3%)	4.52	8
<i>A. siro</i>	52 (72.2%)	5.98	12	33 (45.8%)	4.24	8	7 (9.7%)	3.29	4
<i>T. putrescentiae</i>	51 (70.8%)	6.24	12	28 (38.9%)	4.68	10	7 (9.7%)	4.0	6
<i>L. destructor</i>	57 (79.2%)	7.25	16	30 (41.7%)	5.70	12	14 (19.4%)	3.86	5
<i>G. domesticus</i>	55 (76.4%)	7.57	18	29 (40.3%)	6.28	14	18 (25%)	4.83	11

Table 2. Number of patients giving larger prick test skin reactions to storage mites than to *D. pteronyssinus*; (i) Group A, (ii) Group B. (Extract strength 1%)

Species	<i>A. siro</i>	<i>D. pt.</i>	<i>T. putrescentiae</i>	<i>D. pt.</i>	<i>L. destructor</i>	<i>D. pt.</i>	<i>G. domesticus</i>	<i>D. pt.</i>
Group A								
No. of patients	6		8		15			18
% of total numbers (72)	8.3		11.1		20.8			25.0
Mean weal diameter (mm)	8.33	3.83	6.75	3.50	11.93	6.20	12.39	7.39
Group B								
No. of patients	4		8		16			18
% of total number (138)	2.9		5.8		11.6			13.0
Mean weal diameter (mm)	8.75	6.0	8.88	5.0	9.94	6.75	10.39	6.56

domesticus, however, provoked slightly larger mean weals than *D. pteronyssinus* at the 0.1 and 0.01% dilutions of extract and the largest individual weals at all three dilutions (Table 1). It also provoked the largest mean weals of all five species among those patients who gave larger skin reactions to storage mites than to *D. pteronyssinus* (Table 2).

For the seventy-two patients in Group A, for each set of mite extracts, the correlation coefficients for the weal diameter provoked by the three concentrations were calculated. These were consistently high ($P < 0.001$) for all five mite species so that it was felt unnecessary to use more than the 1% extracts for further patients.

Group B

As in Group A, for the majority of patients *D. pteronyssinus* was again the most potent of the mite allergens and provoked the largest number of positive reactions (Table 3). Only five patients did not react positively to the 1% extract of this species compared with between fifty-six and seventy-nine patients who did not react positively to similar extracts of one or other of the storage mites. The five non-reactors, however, all gave positive reactions to the extracts of one or more storage species. Thirty-three patients were sensitive only to *D. pteronyssinus*, one only to *G. domesticus* and one only to *T. putrescentiae*. The remaining 103 patients all gave multiple reactions, twenty-nine to all five species and twenty-five to four of them. Altogether ninety-six patients (69.6%) reacted more strongly to *D. pteronyssinus* extract than to any storage mite extract and forty-two (30.4%) did not. Of the latter group, twenty-five (18.1%) reacted more strongly and seventeen (12.3%) equally as strongly to one or more storage mite extracts than to *D. pteronyssinus* extract. Taken by species (Table 2), four subjects (2.9%) were more sensitive to *A. siro*, eight (5.8%) to *T. putrescentiae*, sixteen (11.6%) to *L. destructor* and eighteen (13.0%) to *G. domesticus*. As in Group A, the mean diameter of weals for the 1% extracts was always largest for *D. pteronyssinus*. *G. domesticus* again proved to be the most potent of the storage mites producing both larger mean weals than any other storage species and also the largest individual weals (Table 3).

Comparison of the results of the skin tests with the 1% extracts showed that although the two groups of patients differed in the degree of their response to the different extracts, those in Group A showing a higher frequency of reactions and a greater sensitivity than those in Group B, the overall pattern of results was the same for both groups. In each, the same order of ranking of species was observed when the frequencies of reactions and potencies of the extracts (measured by the mean sizes of weals produced) were arranged within the group, thus indicating that both groups of patients were responding in a similar manner to the different extracts. The two sets of data were therefore combined and mean values for all 210 patients given in Table 3.

Patients were divided into three groups according to the degree of dampness present in their homes and the skin test reactions of the separate groups related to the conditions under which each was living (Table 4). Homes were classified as follows, (1) as 'excessively damp', if moulds or moisture were observed on the walls, floors or ceilings of the home, (2) as 'damp' if, in the subjective judgement of the patient, doctor or health visitor, the home was considered to feel damp, and (3) as 'apparently dry', if neither of these conditions was evident. Patients' occupations, both past and present, were classified under two headings, (1) those likely to have involved patients in the risk of exposure to storage mites, e.g. farming, flour milling, etc., and (2) those not known

Table 3. Frequency of positive skin reactions and mean and maximum diameters of weals of positive reactions in two groups of patients prick tested with 1% extracts of five mite species

	<i>D. pteronyssinus</i>				<i>A. siro</i>				<i>T. putrescentiae</i>				<i>L. destructor</i>				<i>G. domesticus</i>			
	Weal diam. (mm)				Weal diam. (mm)				Weal diam. (mm)				Weal diam. No. (mm)				Weal diam. No. (mm)			
	No. of patients positive	Mean	Max.		No. of patients positive	Mean	Max.		No. of patients positive	Mean	Max.		No. of patients positive	Mean	Max.		No. of patients positive	Mean	Max.	
Group A (72 patients)	71 (98.6%)	8.96	15		52 (72.2%)	5.98	12		51 (70.8%)	6.24	12		57 (79.2%)	7.25	16		55 (76.4%)	7.57	18	
Group B (138 patients)	133 (96.4%)	9.49	18		59 (42.8%)	4.88	14		67 (48.6%)	5.31	14		82 (59.4%)	6.82	14		71 (51.4%)	6.89	16	
Groups A & B combined (210 patients)	204 (97.1%)	9.25	18		111 (52.9%)	5.36	14		118 (56.2%)	5.73	14		139 (66.2%)	7.01	16		127 (60.5%)	7.18	18	

Table 4. Dampness in homes and its influence on sensitivity to storage and house dust mites in patients with house dust allergy and asthma or rhinitis

Classification of homes	No. of patients in each category	Number and percentage of patients in each category with positive skin reactions:					
		Larger to storage mites than to <i>D. pt.</i>		Larger to <i>D. pt.</i> than to storage mites		Equal reactions to both storage mites and to <i>D. pt.</i>	
		No.	%	No.	%	No.	%
I. 'Excessively damp'	23	10	43.5	8	34.8	5	21.7
II. 'Damp'	68	15	22.0	42	61.8	11	16.2
III. 'Apparently dry'	119	20	16.8	85	71.4	14	11.8

Table 5. Skin reactions of forty-two patients currently or previously employed in occupations likely at some stage to have exposed them to storage mites

Skin reactions	Farmers, farm workers or associated with farming			Other 'at risk' occupations, e.g. flour milling, baking grain storage etc			Percentage of 'at risk' patients
	Current	Past	Total	Current	Past	Total	Grand total
Larger to storage mites	8	7	15	4	6	10	25
Equal to both storage mites and to <i>D. pteronyssinus</i>	—	4	4	2	2	4	8
Larger to <i>D. pteronyssinus</i>	4	2	6	2	1	3	9
Total	12	13	25	8	9	17	42
							59.5
							19.1
							21.4
							100

to be at risk through occupational hazard. The data were then related to the skin test reactions of patients in these employments (Tables 5 & 6).

The correlation coefficients for weal diameter caused by the 1% extracts to all five mites were calculated. None of those between *D. pteronyssinus* and any storage mite was significant (Table 7). After deleting the forty patients who reacted only to *D. pteronyssinus* (seven in Group A and thirty-three in Group B) these coefficients were recalculated for the storage mites (Table 8). That for *G. domesticus* and *L. destructor* was highly significant as was that for *A. siro* and *T. putrescentiae*. *A. siro* was clearly uncorrelated with the two Glycyphagid species but the values for *T. putrescentiae* would be reached in about 2% of experiments by chance so their significance is uncertain (Table 8). It seems reasonable to conclude, therefore, that the reactions to extracts of storage mites and *D. pteronyssinus* are distinct and that the two groups possess different allergens.

Table 6. Skin reactions of 168 patients not known to be at risk through occupational hazard

Skin reactions	No. of patients	Percentage of patients in non-risk occupations
Larger to storage mites	25	14.9
Equal or similar reactions to both storage and house dust species	19	11.3
Larger to <i>D. pteronyssinus</i>	124	73.8

Table 7. Correlation coefficients between weal diameters caused by 1% extracts of *D. pteronyssinus* and the four storage species *A. siro*, *T. putrescentiae*, *G. domesticus* and *L. destructor* to 210 patients with house dust allergy and bronchial asthma or allergic rhinitis

Species	Coefficient of correlation (<i>r</i>)
<i>A. siro</i>	0.113
<i>T. putrescentiae</i>	0.000
<i>G. domesticus</i>	0.099
<i>L. destructor</i>	0.183

Table 8. Correlation coefficients between weal diameters caused by the 1% extracts for the 170 patients reacting to storage mites. Upper quadrant: correlation coefficient (*r*) Lower quadrant: probability (*P*)

	<i>A. siro</i>	<i>T. putrescentiae</i>	<i>G. domesticus</i>	<i>L. destructor</i>
<i>L. destructor</i>	0.024	0.168	0.562	
<i>G. domesticus</i>	0.026	0.182		<0.001
<i>T. putrescentiae</i>	0.414		0.017	0.023
<i>A. siro</i>		<0.001	0.74	0.76

Discussion

Ecological factors affecting the growth of house dust and storage mite populations

Studies in Holland (Spieksma & Spieksma-Boezeman, 1967), Japan (Oshima, 1967; 1970), the United Kingdom (Cunnington, 1967; Maunsell, Wraith & Cunnington, 1968) and elsewhere have shown that pyroglyphid mites, usually the cosmopolitan species *D. pteronyssinus*, dominate the mite fauna of house dust in most situations. Storage mites, although common, are found much less frequently and abundantly than the pyroglyphid species.

In our original survey (Maunsell *et al.*, 1968) we found that storage mites, among which *G. domesticus* predominated, occurred in only 40% of samples and accounted for less than 10% of the total mite population. In contrast, we found that *D. pteronyssinus* and the closely related *Euroglyphus maynei* occurred in 82% of samples and constituted nearly 83% of total mite numbers.

Spieksma & Spieksma-Boezeman (1967) recorded an appreciably higher proportion of storage mites in Dutch house dust but it still accounted for only 24%. A particularly interesting feature of their work was a correlation established between mite abundance and dampness in houses. The largest number of mites, both of house dust and storage species, occurred in the dampest houses but in the very dampest houses the storage mites increased more rapidly and so eventually constituted a higher proportion of the total mite population than did the Pyroglyphid species.

These population changes reflect differences in the ecology of the different species. Storage mites require a moister environment and are extremely vulnerable to dry conditions. On suitable foodstuffs and at favourable temperatures they increase most rapidly at high relative humidities or in materials of high moisture content (Solomon, 1962; Cunnington, 1965; 1967). At temperatures and humidities close to the optimum for the species, i.e. about 25°C and 90% r.h., their rates of self multiplication reach four to ten-fold per week, depending on the species (Cunnington, 1976).

Very high relative humidities appear to be less suitable for the development of *D. pteronyssinus* and probably also of other pyroglyphid species. According to Spieksma (1967) optimum conditions for the laboratory culture of *D. pteronyssinus* are 25°C and 80% r.h. At 85% r.h. mould growth inhibits further mite development. Van Bronswijk *et al.* (1971) reported a failure of oviposition at 85% r.h. and above at 25°C and considered that high humidities are detrimental to the development of this species. In very damp houses, therefore, as the results of Spieksma & Spieksma-Boezeman (1967) indicated, storage mites may well occur more frequently and abundantly than *D. pteronyssinus* or other Pyroglyphidae.

Domestic factors and their influence on storage mite allergy

Dampness in homes. The homes of sixty-eight patients were classified as 'damp' and a further twenty-three as 'excessively damp', i.e. for moisture or fungi to be visible on the walls, floors or ceilings of the home. Significantly, we found that whereas nearly 44% of patients living in 'excessively damp' homes suffered from a predominantly storage mite allergy, only 22% of those living in 'damp' homes did so (Table 4). For a majority of the latter *D. pteronyssinus* was the most important house dust allergen. Moderately damp conditions in houses and other dwellings were found by Spieksma (1967) and by Maunsell, Hughes & Wraith (1970) to be especially favourable for the development of *D. pteronyssinus*, Maunsell *et al.* recording that the average number of

mites found in samples of surface bedding dust from old, damp buildings was a thousand times greater than in those from modern, centrally heated flats.

Patients living in very damp houses or those in certain occupations, e.g. farming, flour milling etc., are more likely than others to become exposed to storage mites or to mite infested materials. It was expected, therefore, that some patients would show a greater sensitivity to these species than might be expected from their irregular occurrence and relatively low numbers in house dust reported by most United Kingdom workers (Maunsell *et al.*, 1968; Sesay & Dobson, 1972; Blythe, Williams & Morrison Smith, 1974; Rao *et al.*, 1975). The frequency of positive skin reactions to these species (Tables 1 & 3) and the number of patients reacting to storage mite extracts more or equally as strongly as to those of *D. pteronyssinus* (Table 2 & figure 1) is, however,

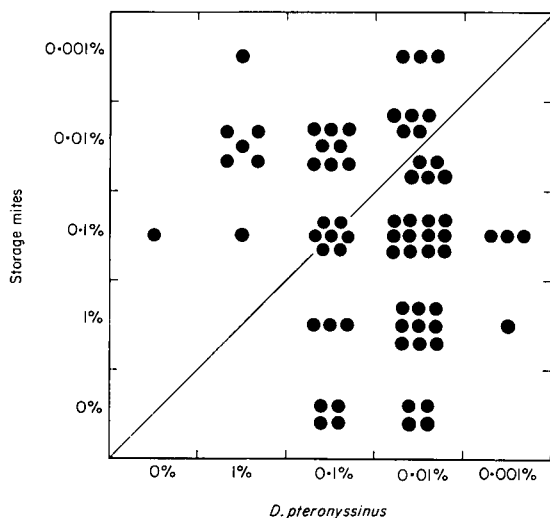


Fig. 1. Group A patients: comparative skin tests of storage mites and *D. pteronyssinus*. The highest dilution of any storage mite to give a positive prick test (3 mm or more) is compared with the highest dilution of *D. pteronyssinus* to give a positive reaction.

unexpectedly high. The examination of dusts from the bedding or floors of several of the patients considered here revealed mite populations similar to those recorded during earlier surveys. (Maunsell *et al.*, 1968; Wraith & Cunningham, 1974) so we had to examine the possibility that patients had become sensitised to these mites elsewhere at home or at work, school or during leisure activities.

Since it has been convincingly demonstrated that the surface dust of mattresses (Cunnington, 1967; Maunsell *et al.*, 1968) and bedding, especially blankets (Sesay & Dobson, 1972) and the interiors of old pillows and eiderdowns (Wraith & Cunningham 1975) are the main foci of infestation by *D. pteronyssinus* and other pyroglyphid species, other investigators have concentrated almost exclusively on these sources and have largely ignored other habitats. Some domestic localised infestations, however, have been found in sites which had little or no influence on the house dust fauna of mattresses or bedding. Blythe *et al.* (1974), reported a heavy infestation of *G. domesticus* in an animal skin hanging on a bedroom wall although samples of mattress and floor dust from the same room yielded only the normal mixed fauna of *D. pteronyssinus*

and *E. maynei*. One of us (AMC) examining an old and very damp house recorded a heavy infestation of *G. domesticus* on the damp and mildewed walls and ceiling of a bedroom in which carpet and mattress dust yielded *D. pteronyssinus* but few other mites. *G. domesticus*, commonly called the house mite in the United Kingdom, is particularly associated with dampness in houses, the mites feeding and developing on the moulds growing on the surfaces of damp wallpaper or other materials (Solomon, 1961). Hughes (1976) reports that large numbers of this species have been found on dried plant and animal remains in houses and stables and that enormous numbers have occurred on furniture covered with rush or sea grass fibre or upholstered with green Algerian fibre. All these could cause sensitization to this species.

Occupational exposure to storage mites. Patients' occupations may have an even more important bearing on their allergies than their housing conditions. Storage mites are widespread and important pests of stored food and vegetable products. Farmers and some others who encounter these materials during processing or manufacture are likely to be exposed to mites and can be more at risk than most other people. Of the 210 patients tested, forty-two (20%) were working or had worked in occupations, e.g. farming, flour milling, baking, grain storage etc., in which they could have been exposed to mite infested materials. Of these forty-two patients, twenty-five (nearly 60%) reacted more strongly to storage mites than to *D. pteronyssinus* and only nine (21%) gave stronger reactions to *D. pteronyssinus* than to any storage mite (Table 5). The latter included several who also gave strong positive reactions to one or more storage species. Thus, over 80% of the patients considered to be at risk through occupational exposure suffered from storage mite allergy. Clinical confirmation of this allergy to storage mites was shown both by the improvement in eight of those who changed their occupation and by the worsening of symptoms in eight others when in contact with products known to be infested by these mites. The following brief case histories are given as examples:

Case No. 1. Male aged 16; schoolboy, hobby, horse-riding—Asthma. Positive reactions to all five mite species but negative to extracts of horse dander, grass pollens and moulds: Reactions to storage mites larger than to *D. pteronyssinus*. Maximum weal size, *G. domesticus* 11 mm., minimum, *D. pteronyssinus* 4 mm. Symptoms worse when in stables.

Case No. 2. Male aged 31; baker—Asthma. Positive reactions to all five mite species but negative to flour; reactions to storage mites larger than to *D. pteronyssinus*. Maximum weal size, *G. domesticus* 12 mm., minimum, *D. pteronyssinus* 4 mm. Symptoms worse at work.

Case No. 3. Female aged 26; housewife, previously farm worker—Asthma. Strongly positive to all five species. Maximum weal size, *L. destructor* and *G. domesticus* 14 mm., minimum, (*D. pteronyssinus* 12 mm) *A. siro* 10 mm. Condition improved since leaving farm.

Case No. 4. Male aged 26; previously employed in flour mill—Asthma. Negative reactions to *D. pteronyssinus* and to flour; strongly positive to all four storage species. Maximum weal size, *A. siro* and *G. domesticus* 8 mm., minimum, *T. putrescentiae* 5 mm. Condition worse at flour mill; improved following change of occupation.

Case No. 5. Female aged 26; housewife, spends frequent holidays in farm cottage—Asthma. Positive reactions to all five species but with larger reactions to storage mites (three species) than to *D. pteronyssinus*. Maximum weal size, *L. destructor* and *G. domesticus* 15 mm., minimum, *A. siro* and *D. pteronyssinus* 4 mm. Nasal provocation

tests (Taylor & Shivalkar 1971) gave significantly stronger reactions to *G. domesticus* than to *D. pteronyssinus*. Symptoms always worse when staying at cottage; analysis of house dust from this source yielded large numbers of *L. destructor* and *G. domesticus* (217 mites per 100 mg dust) but only moderate numbers of *D. pteronyssinus* (37 mites per 100 mg dust).

Domestic infestations within the home—exposure to infested pet foods, human foodstuffs and other materials. Exposure to infested materials may also occur when animals are kept as pets or certain species are maintained in schools or other institutions for teaching purposes or research. Hamsters, guinea pigs and rabbits are popular children's pets and these and other rodents are widely used in medical and biological research. Hay and straw are commonly used for bedding or floor covering in cages and animal houses and cereal grains and seeds as animal feed. These materials are often infested or become infested. Mumcuoglu (1976) reported that he found only storage mites in bedding dust from the cages of hamsters and guinea pigs where hay was used as the bedding material while *D. pteronyssinus* predominated in the bedding dust of cats and dogs, the mite fauna of which closely resembled that from human bedding.

Three examples from our own records may serve to illustrate how this type of sensitization can occur. Three brothers, aged 8 to 15 years, all with pronounced storage and house dust mite allergy gave especially strong skin reactions to *G. domesticus* and *L. destructor* (mean sum of weal sizes for all three dilutions 28.3 and 24.7 mm) respectively. The house in which the children lived was old, damp and extremely dusty and the standard of housekeeping and domestic hygiene was poor. Mattress dust from the boys' bedroom yielded only *D. pteronyssinus* (137 mites per 100 mg dust). Floor dust collected from beneath a budgerigar cage in the living room yielded considerable numbers of *G. domesticus*, *L. destructor* and a related species *Goheiria fusca* (100 mites per 100 mg dust) but few *D. pteronyssinus* (3 mites per 100 mg dust). The second example is that of a ten years old boy with severe asthma. He had pronounced storage and house dust mite allergy but gave the largest reaction (12 mm weals) to 1% extracts of *L. destructor* and *G. domesticus*. The house in which he lived was extremely damp and his mother also kept a relatively large stock of flour in the house. Examination of floor and shelving dust from his bedroom yielded relatively large numbers of the two Glycyphagid species (140 mites per 100 mg dust) but few *D. pteronyssinus* (6 mites per 100 mg dust). The third example is of an Asian patient whose asthma had developed after arrival in this country. He gave strong skin reactions to 1% extracts of *L. destructor* and *A. siro* (5 and 8 mm weals respectively) but weak reactions to the 1% extract of *D. pteronyssinus* (weal diameter 3 mm). He was found to keep a relatively large stock of flour stored in the house, a practice we found to be common among some immigrant families. This proved to be fairly heavily infested with *A. siro* and *L. destructor*.

Skin reactions to storage mites reported in studies of house dust allergy. Skin reactions to storage mites were frequently recorded during earlier investigations of house-dust allergy but their allergenic significance was either largely ignored or overlooked. Voorhorst (1962) reported that skin reactions to *A. siro* (then called *Tyroglyphus farinae*), *T. putrescentiae* (then known as *T. castellani*) and *G. domesticus* were frequent among house dust sensitive patients but did not correlate with house dust allergy. Maunsell and co-workers (1968) recorded that more than 50% of their house dust-sensitive patients gave positive skin reactions to extracts of these species including four patients who reacted only to *A. siro*. They suggested that skin reactions

to storage mites were due either to common antigens or to exposure to these species. Pepys, Chan & Hargreave (1968) also noted that a high proportion of patients with house dust allergy and asthma gave positive reactions to *A. siro* and *G. domesticus* though these reactions were weaker than to *D. farinae* or *D. pteronyssinus*. Morrow-Brown & Filer (1968) recorded positive skin reactions to *L. destructor* and *G. domesticus* in many patients with suspected house-dust allergy and considered that these species might also be important allergens. Morrison-Smith *et al.* (1969) reported that 232 and 236 of 302 asthmatic children in Birmingham gave positive skin tests respectively to extracts of *A. siro* and *G. domesticus* and noted that some children showed evidence of a greater degree of sensitivity to one or other of these species than to *D. pteronyssinus* or *D. farinae*, a result they considered was related either to special conditions in the childrens' own homes or to differences in individual sensitization. Spieksma & Voorhorst (1969) on the other hand considered that storage mites made no contribution to the allergenicity of house dust which they attributed solely to *D. pteronyssinus*. More recently, however, Voorhorst (1977) has stated that Glycyphagid species may have some significance as house dust allergens and be responsible for a proportion of allergic complaints.

Cross reactions between species. It is possible that cross-reactivity between species is responsible for some reactions. Pepys *et al.* (1968) concluded from skin test reactions that extracts of *D. pteronyssinus* and *D. farinae* shared common or related allergens. Spieksma & Voorhorst (1969) and Voorhorst, Spieksma & Varekamp (1969) concluded that the three pyroglyphid species *D. pteronyssinus*, *D. farinae* and *E. maynei* produced the same allergen. The Dutch workers demonstrated a high correlation between skin reactions to house dust extract and those of the three pyroglyphid mites but a poor correlation between these and extracts of the three storage species, *A. siro*, *T. putrescentiae* and *L. destructor*. They also found a high correlation between reactions to storage species of the same family, i.e. between *Acarus* and *Tyrophagus* (Acaridae) and between *Glycyphagus* and *Gohieria* (Glycyphagidae) but a low correlation between species of the two different families. Dasgupta & Cunliffe (1970) examined the antigenic relationship between pyroglyphid and storage species by gel diffusion precipitin test and concluded that at least one and probably two antigens were common to *D. pteronyssinus* and *D. farinae* but that these were not present in *A. siro*, *T. putrescentiae* or the two Glycyphagid species. On the other hand, Miyamoto *et al.* (1969) using *in vitro* neutralization of antibody in P-K tests produced evidence of some cross antigenicity between *D. farinae* and a number of storage species but considered that this was incomplete and that each species possessed its own characteristic antigen. Hordle (1978) using a RAST inhibiting procedure also reported a degree of cross reaction between *D. pteronyssinus* and the four storage species, *A. siro*, *T. putrescentiae*, *G. domesticus* and *L. destructor* but stated that the reaction was not complete and that the storage mites shared common allergens not present in *D. pteronyssinus*. Statistical analysis of our own results showed that there was no correlation between *D. pteronyssinus* and the four storage mites but highly significant correlations ($P=0.001$) between *A. siro* and *T. putrescentiae* and between the two Glycyphagid species. There was no correlation between *A. siro* and *G. domesticus* or *L. destructor*. That between *T. putrescentiae* and the two Glycyphagid species was slight and of doubtful significance (Table 8).

Remarks and conclusions. Although much further work remains to be done before the antigenic relationships between species are clearly established, the evidence so far

produced suggests there is little allergenic similarity between pyroglyphid and storage species but a close allergenic identity between species of the same taxon, a view which supports the convenient working hypothesis put forward by Blythe (1976) that the allergenic similarity of mite species reflects the closeness of their phylogenetic relationships. The extent to which these species have allergens in common is of considerable practical importance because patients predominantly allergic to storage mites are unlikely to benefit from hyposensitization with *Dermatophagoides* vaccines if there is little allergenic relationship between house dust and storage species. It must also be remembered that a particular feature of the clinical condition of many patients allergic to storage mites is that sensitization to the offending species may have occurred sometime in the past when they were living or working under different environmental conditions from those of the present. Once sensitized, the presence of even small amounts of mite allergen, such as constantly occur in house dust, may be sufficient to precipitate symptoms the immediate cause of which is not readily apparent and may not be detected by skin tests using commercial extracts of house dust or *Dermatophagoides* species.

This study confirms *D. pteronyssinus* as the most potent and most important of the house dust allergens but it also demonstrates that storage mites can be important agents of allergic respiratory disease. Although we have not assessed the incidence of storage mite allergy our results lead us to believe that allergy to storage mites is more widespread and important than has hitherto been realised and that it is an important occupational hazard in the farming community (Davies, Green & Schofield, 1976; Cuthbert *et al.*, 1979) and to those in occupations where exposure to infested materials can occur. Storage mites may also be important allergens for patients living in very damp houses or dwellings where other conditions, e.g. the storage of food or keeping of pets, may favour the development of *Glycyphagus* or other storage species. An awareness of these possibilities should assist diagnosis and help towards the prevention and avoidance of this source of allergy.

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Erratum

'Blood histamine levels after exercise testing' by M. G. Harries *et al.* *Clinical Allergy*, **9**, 437-441. The first sentence of the Summary should read:

'Histamine has been measured in whole blood and in the plasma of seventeen subjects following exercise testing of eleven asthmatics and six normal controls.'

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